IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received 19 February 2024, accepted 4 March 2024, date of publication 11 March 2024, date of current version 15 March 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3375525

TOPICAL REVIEW

Peer-to-Peer Local Energy Market: Opportunities, Barriers, Security, and Implementation Options

OLAMIDE JOGUNOLA[1], (Member, IEEE), ABIMBOLA S. AJAGUN[2], WAYES TUSHAR[3], (Senior Member, IEEE), FEMI O. OLATUNJI[4], CHAU YUEN[5], (Fellow, IEEE), CRAIG MORLEY[6], BAMIDELE ADEBISI[4], (Senior Member, IEEE), AND THOKOZANI SHONGWE[7], (Senior Member, IEEE)

[1]Department of Computing and Mathematics, Manchester Metropolitan University, M1 5GD Manchester, U.K.
[2]College of Energy and Electrical Engineering, Hohai University, Nanjing 211100, China
[3]School of Electrical Engineering and Computer Science, The University of Queensland, Brisbane, QLD 4072, Australia
[4]Department of Engineering, Manchester Metropolitan University, M1 5GD Manchester, U.K.
[5]School of Electrical and Electronics Engineering, Nanyang Technological University (NTU), Singapore 639798
[6]Bruntwood Ltd., M2 6LW Manchester, U.K.
[7]Department of Electrical and Electronic Engineering Technology, University of Johannesburg, Johannesburg 2028, South Africa

Corresponding author: Olamide Jogunola (o.jogunola@mmu.ac.uk)

This work was supported in part by the Peer-to-Peer Energy Market: State of the Art Analysis and Future Potentials Project funded by Bruntwood Ltd., Manchester, U.K.; and in part by Supergen Flex Fund Round under Grant 2-2021-7752.

ABSTRACT The concept of the peer-to-peer local energy market (P2P LEM) is no longer novel to the energy community. Yet, its large-scale implementation within the current electricity network remains a complex challenge. One key reason is the lack of understanding of the supplier licensing models in different countries. For instance, in the UK, up to year 2023, a consumer is only allowed to have a single supplier at a time under its single licence supplier model. This directly contradicts the existing P2P trading models that allow a consumer to purchase electricity from multiple sellers within the local market. Given this context, this article conducts a review of recent literature and government policies in different countries on the P2P LEM and identifies the barriers behind the lack of large-scale P2P trading implementation in today's electricity markets. We explain how these barriers can be overcome by engaging prosumers in traditional and private distribution networks through either licensed or license-exempt suppliers. Particularly, we discuss six P2P LEM frameworks that can be utilised to address the supplier licensing issue. Finally, this review presents a summary of risks, and recommendations to aid the regulatory framework to implement P2P LEM.

INDEX TERMS Peer-to-peer local energy market, barriers, distribution networks, large scale implementation, policy, security.

I. INTRODUCTION

Buildings consume 30 − 45% of global energy, which is predicted to increase by more than 40% in the next 20 years [1]. It is inevitable that this predicted growth could tip the energy demand-supply balance. In the UK, 24.2% of the CO_2 emissions in 2020 were from energy generation and supply [2]. Therefore, innovative ways for managing energy generation and utilisation has become more of a necessity than a choice. There is sufficient research coverage on the role of renewables in decarbonising the energy system with seemingly equal coverage around its integration into existing power systems [3]. The European Union (EU) aims to be climate-neutral by 2050, China has a target of peak-emissions reduction by 2030, and more governments worldwide are adopting different strategies, including price on carbon to accelerate carbon reduction goals [4]. The UK has committed to adopt a consumer-centric strategy as it formulates enabling policies and strategies [5] on powering net zero future. These approaches

The associate editor coordinating the review of this manuscript and approving it for publication was Ahmed Aboushady.

toward enabling sustainable power generation and carbon-reduction would in turn create business opportunities for energy consumers as they evolve in their market roles from consumers to prosumers (producers and consumers of energy). A sustainable energy system can be created by synchronising decentralised local energy production and consumption, connecting key stakeholders, and creating new energy trading models including peer-to-peer (P2P) local energy market (P2P LEM) [6].

P2P LEM creates value and enables the integration of distributed energy resources (DERs) through the establishment of consumer-based electricity markets [7]. It enables prosumers to create and/or join a community or trading platform where energy is generated, consumed and traded by individual or consortium of users [8], [9]. In LEM, multiple energy demands are met at minimal cost through collaboration between multiple decentralised energy systems connected using local networks. Several technical research to solve some of the prevailing issues in P2P LEM have been conducted. Some of these are, trading platforms [10], [11], enabling technologies and storage systems [12], flexibility provisions [13], optimisation and algorithms for profit maximisation [14], [15], and network losses reduction [16], among others.

However, as power systems are transitioning and more consumer-centric trends are emerging, multiple LEM structures and designs for the facilitation of local energy transactions are been discussed. These are centralised/community-based [14], [17], [18], [19], decentralised [20], [21], and hybrid LEMs [19], [22]. While the structures are theoretically proven to be efficient, the implications of policies, including regulatory frameworks and licensing models in several countries, are not well-covered in the literature. Thus, large-scale implementation within the current electricity network regulatory framework is a challenge [6], [23].

In perspective, the current regulatory framework across countries, for instance, in the UK, only allows one licensed energy supplier to supply electricity to a house [24], [25]. In Austria, participants in energy communities are required to be connected by the same main line and be in the same concession area of the distribution grid operator [26]. Similar restrictions applies in other countries like Japan, Germany, South Korea and Ireland [23], [26]. These barriers are limiting any P2P LEM among multiple prosumers as depicted in the literature. Additionally, pilot studies and trials are being constructed on private distribution networks, such as the Brooklyn Microgrid [27]. These private distribution networks are seen as the feasible way to implement full P2P LEM, the major implication is that constructing private distribution networks between existing houses would be a complex and costly solution, as well as make the current transmission/distribution infrastructure network redundant. This will result in a need to invest in new infrastructure to accommodate several millions of private distribution connections. A key question to answer is "How do the distribution and transmission network co-habit with community P2P LEM beyond just balancing purposes?" or "How can the distribution and transmission network be repurposed for full P2P LEM among licensing and regulatory constraints?" Thus, in this study, we review implementation barriers of P2P LEM considering extant literature and a number of Government policies. We then discuss implementation frameworks to overcome the barriers for prosumers on both traditional and private distribution networks. While the scope covers instances from a variety of countries, the majority of the examples are focused on the UK electricity system and policies. This is to bridge the gap between the literature and the actual large-scale implementation of P2P LEM within the current electricity distribution network in the UK.

In the remainder of the work, Section II discusses the methodology and contributions. Section III provides a comprehensive review of opportunities and barriers to LEM. Section IV provides a summary of P2P LEM projects around the world. Section V discusses P2P LEM implementation options for traditional and private distribution networks. Section VI provides an outlook on risks and recommendations. Finally, Section VII concludes the work.

II. METHODOLOGY AND CONTRIBUTION

The paradigm of P2P network has received an unprecedented attention in power network, where, in theory, prosumers trade their flexibility with other prosumers or consumers in a P2P arrangement. Theoretical proofs, pilot studies, and P2P start-up companies are emerging to reinforce the P2P LEM concept [19], [28]. To address the identified gap in the literature, the focus of this article is on policy, licensing and technological barriers to the deployment and implementation of P2P LEM. In particular, the regulatory and policy framework constitutes a much less explored aspect of LEMs by the research community. However, interested readers are encouraged to refer to [12], [28], [29], [30], and [31], for an up to date coverage of the key aspect of P2P LEM, including market design, trading platforms, enabling infrastructure, and social perspective.

A. LITERATURE SEARCH

A systematic search is conducted to identify the relevant set of literature, utilising three academic databases; Scopus, Web of Science, and IEEE Xplore, as well as Government policies spanning through the last decade. The search term was ("peer-to-peer" OR "peer to peer" OR "P2P") AND ("energy trading" OR "local energy market"). The topic field was searched in Web of Science, the title field was searched in IEEE Xplore. The title, abstract and keywords fields were searched in Scopus. For relevance and to stay within the focus of this article, an inclusive search is conducted to include ((policy OR policies) AND (regulation OR regulatory) AND security AND barriers AND implementation) in the metadata of the three databases. Scopus returned 41 articles, Web of Science returned 73 articles, IEEE Xplore returned 76 articles. The readers are to note by including ''AND barriers'' in Scopus returned just 10 articles, thus, for Scopus, we changed the search term to ''OR barriers'', which then returned the 41 articles instead of 10. The total articles returned by the three databases were 190 articles.

B. INCLUSION AND EXCLUSION CRITERIA

An initial review of the abstracts and titles of the 190 articles for relevance was conducted, using an exclusion criteria such as the title or the topic satisfying the inclusion criteria. This exercise together with removing duplicates reduced the articles to 114. The full text of the remaining 114 articles were reviewed following the same process to ensure the inclusion criteria were discussed. This further reduced the articles to 72. This clearly shows that while there are enormous coverage of the technicality of P2P LEM, no much attention has been paid to the policies and regulations that serve as barriers to its actual large scale implementation. The reader should note for conciseness and to eliminate redundant information, not all the 72 articles were cited.

C. COMPARISON AND CONTRIBUTIONS

The literature has established P2P LEM's economic benefits, its key aspects but with little focus on policies, barriers and risks. Thus, a comparative analysis of this work to recent existing surveys on P2P LEM that discussed at least two of the highlighted components are summarised in Table 1. Table 1 highlights the year of the article and the main focus of each article.

Thus, the contributions of this work are summarised as follows:

- a discussion on the developing opportunities and barriers to LEM focusing on Government incentives, local benefits and policies that could serve as opportunity as well as deterrent to the actual large-scale implementation of P2P LEM;
- a discussion of six different frameworks to implement P2P LEM in both traditional and private distribution networks. These proposals highlight how the existing buildings and infrastructures could participate in P2P LEM;
- a summary of risks and recommendations to implement the proposed frameworks considering both the traditional and private distribution networks P2P LEM structures.

III. OPPORTUNITIES AND BARRIERS TO LEM

Efforts to combat global warming by reducing carbon emissions are rapidly gaining momentum, bringing power generation under scrutiny now more than ever. As the proliferation of smart technologies and decarbonisation efforts continues, the pathway to power generation, supply, and utilisation are also changing. In 2020, the UK Government published a white paper detailing a 10 points action plan towards achieving its net zero carbon target. This includes development of alternative (green) energy and innovation in the built environment, making buildings more energy efficient (greener buildings). EU is committed to its European Green Deal to achieve its carbon-neutrality. Similar efforts are reported in China and other governments worldwide [4]. The diverse global decarbonisation agenda can be described as the 'green industrial revolution' as new industries are created and the face of the energy market is transformed, placing consumers at the fore. This section focuses on the developing opportunities and barriers of this new market, with a particular focus on its integration within the traditional distribution network, drawing examples from the UK and EU economy.

A. DEVELOPING OPPORTUNITIES

As Government policies and regulations are increasingly tailored towards making power generation and utilisation greener, the role of consumers are changing to prosumers trading their excess, flexibility, as well as their right to buy energy, known as negawatt trading [38]. Various factors are considered to be drivers for this shift.

1) GOVERNMENT INCENTIVES AND SUPPORT

Government policies and subsidies have been instrumental in accelerating the development of DERs such as rooftop solar photovoltaic (PV) and complementary technologies like energy storage systems including in electric vehicles, and intelligent software thereby making them more affordable [6] and in effect, mainstream. Government initiatives and policies have seen the emergence of grassroot initiatives in Europe, such as Community Energy Cooperatives (CECs) from the early 1990s and through them local renewable energy systems are being set up. Four hundred (400) out of the approximately 3000 CECs across Europe are found in the UK. These groups, have seen their generation capacity grow by nearly 500% between late 2000s and 2017, generating 80% of their energy from solar, 18% from wind and less than 1% from hydro-electric within England, Wales, and Northern Ireland [39], mirroring the UK renewable capacity connected to the grid which increased by 500% from 2009 to 2020 [5], [40]. As more consumers take advantage of these opportunities and transition to prosumers, the availability of electricity for trading is increased and equally the prospects of P2P LEM.

Besides, the revised EU Renewable Energy Directive (RED) 2018/2001, provided a definition for P2P trading of renewable energy [41]. This is defined as the sale of renewable energy between market participants and third parties such as an aggregator without any prejudice to the parties involved, such as final customers. Article 21 of the same directive stipulates that member states shall ensure that Renewable Energy Consumers are able to generate, store

TABLE 1. Comparative study of existing surveys on peer-to-peer energy trading with this Study.

Ref.	Year	Objective	Market design	Policies	Barriers	Risks	Security
[32]	2019	An overview of P2P trading in mini/microgrids considering a case of Nepal	√	√	-	-	√
[33]	2020	An overview of the existing architectures and transactive energy concepts, potentials and challenges of P2P LEM	√	-	-	-	√
[34]	2020	A survey of joint integration of blockchain and artificial intelligence in energy market	√	-	-	-	√
[22]	2020	An overview of P2P trading, its benefits, and challenges in both the physical and virtual layers	√	√	-	-	√
[6]	2021	A multi-case study and expert interviews on transition value of P2P energy communities	-	√	√	-	-
[28]	2021	A background study to P2P sharing, its advancement in various domains, pilot projects, and challenges to scaling up	√	-	-	-	√
[35]	2021	An analysis of the theoretical and practical background to LEM, challenges and future research directions	√	√	-	-	-
[23]	2022	An analysis of the drivers and challenges of implementing P2P energy trading in Thailand from the perspectives of pilot projects developers	-	√	√	-	-
[31]	2022	A summary of the recent development of P2P energy trading, social sciences, pilot projects and policy	√	√	-	-	-
[36]	2023	A summary of the recent development of P2P energy trading, methodologies and demonstration projects	√	√	-	-	√
[37]	2023	A summary of the recent development of P2P energy trading, social sciences, pilot projects and policy	√	√	-	-	-
This study	2024	A focus on regulatory and policy barriers to large scale implementation of P2P LEM	√	√	√	√	√

and trade excess renewable electricity without being subject to discriminatory or disproportionate charges or network charges that are not cost-reflective. This directive also ensures the rights and obligations of RECs as final consumers, while receiving a fair and proportionate remuneration and support for renewable electricity fed into the grid [41] in form of Feed-in-Tariff (FiT). The regulatory framework in Austria for members of the RECs to only pay the grid charges for the grid levels used and not the green electricity flat rate serves as a major incentive [26]. Other countries like the US and India considered incentives, quotas, and obligations [23]. These directives clearly indicate the support for the generation and sale of renewable energy by consumers.

2) LOCAL BENEFITS

There is a growing interest in local approaches to electricity supply with a focus on local benefits. Trials are ongoing that uses virtual aggregation or local tariff to match local generation to demand. On the regulation side in the UK, Ofgem, the UK energy regulator has welcomed this development to increase customers' engagement and choice, providing appropriate customers' protections. Similarly, Ofgem is reviewing the network costs associated with geographical location and time of use of energy in its Access and Forward Looking Charging Significant Code Review (SCR) [42]. The policies in Netherlands, Germany and South Korea supports prosumers which is seen as an enabler for P2P LEM. Here, prosumers are allowed to sell their generated energy in Netherlands and Germany, with prosumer promotion being offered in South Korea [23]. This development will favour local energy supply and aggregation backed by the Government's ambitious policies for a smart, flexible energy system [42].

3) HALF-HOURLY (HH) SETTLEMENT

The continuous roll-out of half-hourly smart meters to domestic users in Europe and the UK, provides an opportunity for domestic consumers to participate in the balancing scheme in a half-hourly (HH) settlement for all customers. HH-settlement would better equip the supplier to offer demand-side response schemes like time of use tariff to the customers, providing the opportunity for flexibility pooling and real-time demand prediction analysis and responding to real-time fluctuations [42]. Smart meters have been used as one of the main technology for P2P trial projects i.e., Piclo project in the UK, Neighbour trading project in South Korea, Latrobe Valley Microgrid in Australia, and in the Sandbox project in Malaysia [23]. In the UK, the new Market-wide

Half Hourly Settlement reform for all buildings is set to be complete by October 2025 [42], and in Japan by 2024 [43].

4) BALANCING MECHANISM

Among the recent development in the UK, the department of Business, Energy and Industry Strategy (BEIS) and Ofgem have reduced the minimum threshold to participate in the balancing market from 100MW to 1MW as well as allowing independent energy aggregators to participate in the balancing mechanism. This enables small assets/consumers through an aggregator to participate, which serves as an opportunity for the LEM implementation. Likewise, the Balancing and Settlement Code, P375, seek to change the behind-the-meter measurement, thereby making all asset balancing contribution visible. Through P375, prosumers will have a better chance to participate in the balancing scheme thus supporting the implementation of P2P LEM. P375 has been approved by Ofgem and has been implemented in June, 2022.

5) SOCIAL AWARENESS

The increased social awareness of the causes and effects of climate change is increasing the shift in consumers' attitudes toward electricity generation, consumption and trading. Consumers are shifting from passive to active participants in the energy system. Prosumers who are dissatisfied with the incumbent supply and pricing models, deemed to undervalue the price of self-generated renewable electricity, are found to be very keen on P2P LEM [7] although the question about the affordability of enabling technologies and profitability without government assistance still remains [44].

6) PRODUCT DIFFERENTIATION AND DYNAMIC PRICING

The continuous uptake of dynamic pricing by customers to reduce electricity bills by adjusting consumption serves as a developing opportunity for LEM. Dynamic pricing is a demand-side management scheme that charges different electricity prices at different times based on the demand at that time. This has been shown to increase economic value compared to existing regular pricing schemes [45]. Similarly, the potential to trade different products including energy and flexibility or both, serves as developing opportunity for LEM. Flexibility is the shifting of energy consumption and/or generation pattern in response to an external signal such as change in price to create excess energy to trade or to provide a service within the energy system [46].

7) NET METERING

Net metering and net billing are utility programs aim to encourage self-consumption from local generation, mostly from solar PV, with excess generation produced by a behind-the-meter generation system being compensated with either energy credit or payment [23]. In the US, net metering is rewarded by energy credit. In the UK, net metering is in form of the Smart Export Guarantee (SEG), where solar panel owners can earn a rate per unit of electricity sent to the grid. The first annual report of SEG in the UK saw a total export of 2,567,211 kWh of low-carbon electricity to the National Grid, of which 99.98% is from Solar PV, with majority of individual capacity of less than or equal to 10kW [47]. The SEG was initiated after the phased out of FiT incentive in the UK. The phased out of FiT is further discussed under limitation and barriers.

B. LIMITATIONS AND BARRIERS

The regulatory framework in the EU for energy communities is different for member states. This lack of uniformity requires more administrative work serving as regulatory barrier from a European implementation perspective [26]. In Austria, a condition in the Electricity Act is that all participants in the energy communities are all connected to the electrical distribution network by the same main line and being in the same concession area of the distribution grid operator [26]. In Thailand, prosumers and consumers cannot apply for a supplier license, only the power producer can obtain one [23]. Similarly, in some developing countries such as Nepal and Nigeria, lack of finances amongst others have been reported as barriers to P2P LEM [32]. All these regulations and restrictions are a major barrier to P2P LEM which will be discussed in this section with a particular focus on regulations and security.

1) POLICIES AND REGULATIONS - R&D

To accelerate clean energy development, policymakers around the world have enacted progressive policies, which have facilitated clean energy integration and reduction in greenhouse gases. Due to the differences in economic structures, clean energy distributions, and development models, the scope, focus and coverage of national energy policies are known to vary between countries [48]. Research and development (R&D) costs are known to have had an impact on private sector investments in renewable energy technologies (RETs). Therefore, Government intervention through environmental policies is necessary to help entrepreneurs and investors overcome the R&D costs and other obstacles and encourage the development and improvement of RETs. To stimulate R&D growth in the renewable sector, Governments have designed and made innovative policy interventions such as the FiT [6], [49] which was designed to track and encourage technological improvement in renewable energy. This FiT support has been implemented in a number of countries, including, Europe, the UK, Germany, Nepal and Japan, etc. [23], [32]. As FiT served as incentive to renewable uptake by consumers, the tariff digression as implemented in the FiT policy has had a negative effect on renewables' R&D, such as high costs for inventors and uncertainties in returns on investment. Thus, as at April 2019, the UK Government has closed FiT to new entrants. Similarly to the UK, other countries, like Spain and Japan have discontinued FiT. The withdrawal of FiT and other incentives have hindered the profitability and growth of community energy cooperatives [40]. In the same token, this policy shift has halted investments in RET required for microgeneration and consequently stifled LEMs which are reliant on renewable generation for their own growth. In addition to FiT, countries like Malaysia have other incentive programs like Self-consumption Scheme, Large Solar Scale, and Supply Agreement with Renewable [50].

The green certificate scheme (GCS) is another policy scheme aimed to encourage innovation in mature RET [51], [52] as well as sourcing and consumption of electricity from renewable sources. Under the scheme, producers are issued a certificate confirming the production of a certain quantity of their electricity portfolio delivered to the grid from renewable sources. Different countries have their versions of this scheme and depending on the country, the certificates have also been known by other names such as Guarantees of Origin, Renewable Energy Certificates or Tradable Renewable Certificates (TRCs). Fundamentally, the idea is to use this instrument to provide transparency to consumers regarding the source of the energy they consume. In practice, an authorised body would issue the certificates to beneficiaries (producers) for each unit of verified energy produced from renewable sources. Although TRECs existed in various forms in different countries, Guarantees of Origin were introduced in Europe by the RED 2009 for accountability purposes and as evidence to consumers that their procured energy was produced from renewable energy sources [53].

2) POLICIES AND REGULATIONS - LEGISLATIVE

Authors in [54] identified oligopolistic electricity generation and monopolistic grid management as a barrier to LEM in China. In the UK, local authorities powers over energy systems are limited, although some local authorities have converted their sustainable energy plans and projects into more strategic local programmes. The UK governance system centralises power through the legislative sovereignty of the Parliament in Westminster, and limits local discretion over energy systems [55]. In addition to the oligopolistic and monopolistic environments, it is believed that the lack of a regulatory framework for third-party services could lead to inconsistent consumer protection [56]. There is the need for a statutory power, and commensurate resources, for Local Authorities, to ensure a more comprehensive and systematic contribution to clean energy [55]. Economic feasibility and achievement of other benefits of local energy trading depends on the regulatory framework on which it is established. Besides, the current regulatory frameworks do not allow consumer to consumer electricity trading [57]. However, some countries like the Netherlands and Germany allow prosumers to trade electricity through their suppliers [23]. Other countries like UK allow LEM to be facilitated by a licenses energy supplier, while, South Korea allow prosumers to sell electricity through a broker to the wholesale market, and to suppliers and neighbours in the retail market.

3) POLICIES AND REGULATIONS - LICENSING

It is virtually impossible to discuss the effects of legislations and/or policies on the design and implementation of LEM without mentioning licencing requirements. In the UK, electricity and gas licences are underpinned by Government Acts of 1989 and 1986 (as amended) respectively [58]. Anyone intending to generate, distribute or supply electricity must apply for a licence under each of those headings through Ofgem. Similar law exists in other countries, like the Netherlands, that requires a prosumer to apply for supplier licenses to sell electricity [59]. Exemptions may be sought for an installation with a generating capacity of no more than 10MW or a maximum of 50MW for installations with declared net capacity of less than 100MW [60]. For Germany, a generation less than 2MW is exempt from supplier licenses. However, to distribute and/or supply another facility, a licence must be obtained. Energy exchange and trading in a LEM will require robust, intelligent and efficient metering and coordination. To facilitate smart meter communications in the system, a licence must also be obtained. These licensing conditions, which are designed with large companies in mind, are complex and difficult to understand for small installations who may be generating just enough to meet their need with the intention to trade any excess. Part of the licensing conditions for electricity supply is the commodity pricing. Government legislation points towards a perfect market, making P2P LEM less attractive for installations and consequently stifle entrepreneurial investments in green generating and storage capacities. Thus, achieving P2P LEM within the current licensing and single energy supplier model is very challenging. For instance, only licensed electricity suppliers are permitted to manage energy flows onto distribution networks and only one licensed supplier can supply electricity at a customer's premises [24], [25]. This directly contradicts P2P as proposed in the literature that allows one-to-many or many-to-one transactions. Unless this changes, new business models to enable local energy trading cannot be realised. A new model is required that creates a market where licence-exempt producers and consumers of electricity can trade bilaterally.

4) RELIABILITY AND SECURITY

As cyber attacks become mainstream affecting every systems, energy transaction is not an exception. Several researchers and pilot projects have proposed distributed ledger technology, specifically, blockchain to secure energy trading transactions [34], [57], [61]. In the energy market, third parties like brokers, trading agents are usually used as intermediaries for transaction management creating a complex system, increased cost, delayed transaction processing and communications [57]. Thus, blockchain allows direct interaction between distributed prosumers, giving consumers more choice and flexibility over its asset. Transactions are securely recorded in the blockchain and payments are processed based on a smart contract [57]. While this development has resulted in increase in trust, and security, blockchain poses several risks such as possibility of failure due to lack of large scale trial [57]. Ethereum, which is the most deployed blockchain platform, has been the target of serious attacks in the past and resilience to such attacks is important, especially when used in critical national infrastructure. Since blockchain is heavily reliant on software development, which process can be compromised by bugs in the smart contract, ultimately resulting in cyber attacks. Example of such vulnerabilities include, submission of fake contracts, modification of transactions, double spending of energy or money, possible denial of service attacks, etc. [32], [57]. The necessity for research on new algorithms to increase the security and speed of blockchain platforms has been suggested in [29]. Furthermore, the use of blockchain has resulted in concern as to responsibility and ownership. Thus, the author in [62] discussed the policy implications and legal challenges of blockchain-based transactions in the EU electricity law. She concludes that further research is imminent to determine ownership and responsibilities, establishing incentives and protection of consumers. Thus, while blockchain is an enabling technology, resilience, security and responsibility implications of blockchain is still a major limitation.

5) NETWORK VISIBILITY AND DATA AVAILABILITY

The distribution network is characterised by limited operational network visibility and data availability, which is a critical regulatory barrier around LEMs. Such as, DSOs having minimal information regarding the topology/constraints of the low voltage (LV) network. As LEM is sometimes used in the literature with respect to the trading of different products, including energy, flexibility or both, Ofgem has identified that transparency over platform operations including the underlying data they produce is important for a well-functioning flexibility platforms [46]. Thus, it is the role of the regulator to ensure this data transparency to build user's trust on such platforms. Energy Data Task Force (EDTF) also highlight the essential role that data will play in the growth of flexibility platforms, from enabling smarter electricity networks, to creating new revenue streams and addressing consumer's engagement barriers [46]. While the benefit of data visibility has been assessed, developing this data standards for LEM platforms require some degree of planning from all involved stakeholders.

Table 2 summarises the regulatory limitations and barriers to P2P LEM across the analysed countries in this article. The authors recognised that other countries could have similar restrictions in place, but our focus is the UK with examples drawn from the mentioned countries.

TABLE 2. Limitations and barriers to P2P LEM across analysed countries in this article - FiT: Feed-in-Tarrif;

Barriers	Countr(y)ies	Description
Supplier licensing	UK, Thailand	Single-supplier license model in the UK, and single-buyer model in Thailand. Only one licensed supplier can supply electricity to a customer
License procurement	UK, Thailand, Netherlands, Germany	A license is required to sell electricity. Some exemption exist discussed in Section III-B-3
LEM via energy supplier	UK, Netherlands, Germany, South Korea	Energy trading through virtual balancing can only be achieved through an energy supplier or a broker
Withdrawal of FiT	UK, Spain, Japan	Feed-in-Tariff has been discontinued to new entrants but there are other incentive programs in the UK, Netherlands, Germany and South Korea. This is discussed in Section III-A and summarised in Table 6
Oligopolistic and monopolistic grid management	UK, China	Centralisation of power where the Local Government have limited power over energy systems
Lack of Finance	Nigeria, Nepal	Lack of finance to support LEM initiative and implementation
Trading based on geographical location	Austria	Participants in energy communities to be connected by the smae main line, in the same distribution area

IV. P2P LEM PILOT PROJECTS

This section presents a comprehensive overview of R&D of P2P pilot projects according to their start year from the year 2010. The countries in which the projects were conducted, focus, network size, objectives, and outcomes are highlighted in Tables 3 and 4. The highlight shows that most P2P pilot projects are being conducted in Europe and Asia. However, Table 4 shows existing projects conducted by Power Ledger for different countries. This is included because of the scale projects being conducted by Power Ledger offers interesting insights from different countries in Europe, Asia, North America, South America, Australia, and Africa. Power Ledger is a software development company and a major deployer of energy trading platforms that use cutting-edge technology to make it easier for grid users to track, trace, and exchange energy in real time, which helps to create a more adaptable and durable power system. While the authors recognised other LEM projects by recent startups, Power Ledger has received global recognition for its unique solutions towards sustainability including managing renewable energy targets, P2P energy trading, EV solutions, solar swap, etc [63].

Several projects on P2P have been researched and implemented to demonstrate the practicality of P2P LEM. In 2017, a review of existing P2P trading projects was given by the authors of [64]. The review highlighted each of the projects from 2011 to 2016. A comparison between these

TABLE 3. P2P LEM projects including research and pilot projects.

Start year	Project name	Country	Network size	Focus area	Objective	Outcome
2020	Share and Charge [67]	Germany	Local	National	Energy Market	A blockchain-based market for EV charging, transactions, and data sharing
2019	ProjectTrader [68]	UK	Local	Energy market, Business, ICT	Local energy marketplace for RES	A trading platform operated by a neutral market facilitators
2018	EnerPort [69]	Ireland	National	Energy Market, ICT	P2P energy trading model	Developed a new software tool for P2P energy trading
2017	Electrify [70]	Singapore	National	Energy market, Business, ICT	Energy Trading Platform	Energy Trading Platform
2017	Energy Collective [71]	Denamrk	Community, National	Energy market design, ICT, Control, Policy	Energy trading platform centred on consumers	Developed a community-based Energy market
2017	Brooklyn microgrid [27]	USA	Microgrid	Energy market, ICT, Policy	Energy trading platform on a private network	Community energy marketplace
2016	Power Ledger [63]	Several countries	Regional	Energy market, Business, ICT	Energy trading platform	Power ledger application fuse box
2016	Power Ledger Xgrid [72]	USA	Local	Energy market, Business	Solar energy trading platform	LEM
2016	TEMIX [73]	USA	National / Local	Energy market, Business, Control	Energy trading platform	Developed Retail Automated Transactive Energy System (RATES)
2016	P2P-3M [74]	UK, South Korea	Regional	Energy market	P2P trading platform	Investigated market and industrial structure for low cost, low carbon energy
2015	Sonnen Community [75]	Germany	National	Energy market, Business	P2P energy trading with storage system	An online P2P energy trading platform
2015	EMPOWER [76]	Several countries	Local	Energy market, Business, ICT	Local energy trading platform	Local energy development for local community
2015	P2PSmarTest [77]	Finland, UK, Spain, Belgium	Regional	Energy market, Business, ICT	P2P approach in ensuring renewable integration	Developed energy trading platform
2014	Piclo [78]	UK	National	Business, trading platform	Retail supplier P2P trading platform	P2P energy trading platform
2014	Vandebron [79]	Netherlands	National	Business, trading platform	Retail supplier P2P trading platform	P2P energy trading platform
2012	Peer Energy Cloud (32)	Germany	Microgrid	Energy Network, ICT	Cloud-based P2P energy trading platform for Smart home	Cloud-based P2P energy trading platform for Smart home
2010	Lichtblick Swarm Energy [80]	Germany	National	Energy Network, ICT	IT platform for energy markets and customers	Many services was provided by energy supplier

projects in terms of their objectives, network sizes, P2P layers, outcomes, and limitations was highlighted. The result also showed that most of the projects were carried out in Germany, and while some are focused on the type of control and ICT technologies used, others emphasised the business models and platforms for energy markets. Some research such as [22], [65], [66] have highlighted the use of blockchain technology in P2P pilots.

In 2019, research projects and companies related to P2P markets increased and this was evident in [19], as more projects were added to the list created by [64], detailing a comparison based on starting year, P2P layers, network size and outcomes. However, the status of each project and their focus level was included without specified objectives and project limitations. Also, [12] analysed the existing P2P projects by classifying it into research and industrial projects. Compared to the previous studies mentioned above, recent projects were added to the list while some of the pasts ones have been omitted. The study showed that most of the projects were conducted in European countries and the focus were not only on market design and trading platform or ICT technologies but also on policy issues and social science perspective. Most recently, an overview of pilot projects in four continents, Asia, Australia, North America and Europe

TABLE 4. P2P LEM pilots conducted by Powerledger in different countries.

Project name	Country	Network size	Focus area	Outcome
Nicheliving [81]	Australia	Local	Energy market, business	Energy trading platform for apartments
Silicon Valley Power [82]	USA	National	Energy market, business, ICT, storage	Energy trading platform and digitising EV charging transactions
East Village [83]	Australia	Local	Energy market, business	Solar energy trading platform for 36 homes
ReNeW Nexus [84]	Australia	Local	Energy market, business	Blockchain-based P2P and virtual power plant trading
OP properties [85]	Australia	Local	Energy market, business	Solar energy trading platform for high-rise apartment
Gen Y [86]	Australia	Local	Energy market, business, ICT	Blockchain-enabled energy trading platform for housing project
Wongan-Ballidu [87]	Australia	Local	Business	Solar energy trading platform for commercial sites
EPC Solar [88]	Australia	Local	Energy market, business	Energy trading platform
DeHavilland Apartments [89]	Australia	Local	Energy market, business	Solar energy trading platform
Kansai Electric Power Co [90]	Japan	Local	Energy market, business, ICT	Blockchain-enabled energy trading platform
TATA Power [91]	India	National	Energy market, business, storage	Blockchain-enabled energy trading platform
Uttar Pradesh [92]	India	National	Energy market, business, ICT, policy	Blockchain-based solar energy trading platform
BSES Rajdhani [93]	India	Local	Energy market, business	Cross tarrif solar energy trading platform
TDED [94]	Thailand	National	Energy market, business, ICT, policy	Blockchain-enabled energy trading platform
T77-BCPG [95]	Thailand	Local	Energy market, business, ICT	Blockchain-enabled energy trading platform
Solar Swap [96]	Australia	Local	Energy market, business	Trade energy in exchange for goods and services
America PowerNet [97]	USA	National	Energy market, business, ICT	Energy trading platform
SEDA [98]	Malaysia	National	Energy market, business	Energy trading platform

was presented in [28]. The authors provided full details of one of the projects in each continent while the remaining projects were summarised. The study also showed the leading countries in each continent. It is worth mentioning that while most of these pilot projects are constructed on private distribution networks, others are made possible through virtual balancing.

V. LEM STRUCTURES AND IMPLEMENTATION OPTIONS

In light of the barriers to P2P implementation discussed in Section III-B, this Section focuses on the practical integration within the current policies and regulations, addressing the identified gaps. First, a brief discussion of the current market structures proposed in the literature are discussed, while assessing their viability for real-world deployement. Then, the different frameworks to integrate P2P LEM in both traditional and private distribution networks are discussed. These frameworks allow consumers on both traditional and private distribution networks to engage with the wider energy system either through a licensed supplier or without. This will involve both domestic and commercial prosumers and include electric vehicle charging/discharging, and existing building to show how these various elements can interact in a local energy marketplace.

A. PEER-TO-PEER LOCAL ENERGY MARKET STRUCTURES

Full P2P LEM is still a futuristic concept due to the scale of ICT and regulatory clarity that is required. However, as power systems are transitioning and more consumer-centric trends are emerging, multiple LEM designs and platforms for the facilitation of local energy transactions are been proposed in the literature. These are centralised/coordinated, decentralised, and hybrid markets. In a centralised coordinated LEM, Fig. 1-1, communication and energy trading occur in a centralised fashion through an independent entity that could be a licensed energy supplier or a trading platform.

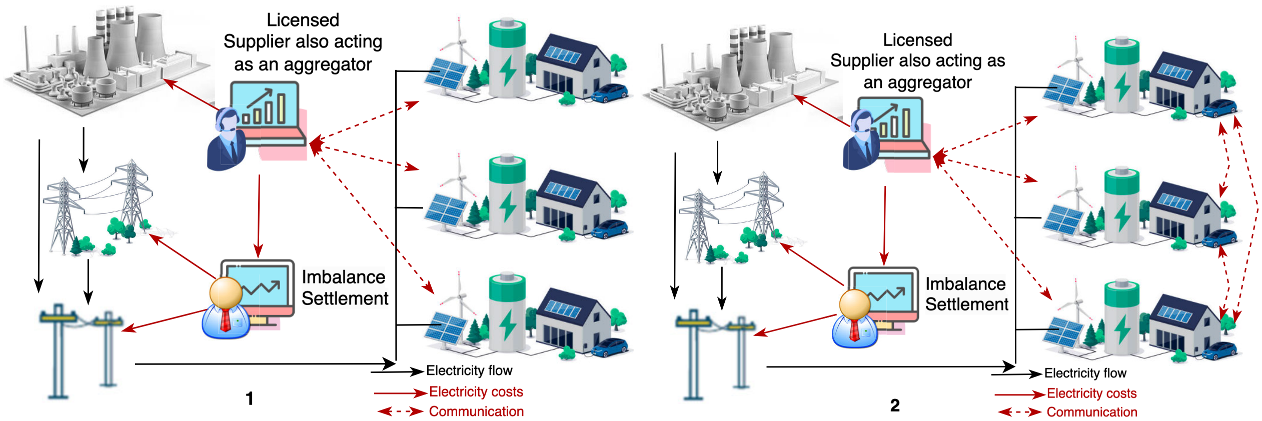

FIGURE 1. This figure shows the P2P local energy market describing the power flow, communication flow and the payment for electricity. The power flows from the generators to the transmission, distribution and then the final consumers. Electricity payment is from the consumers to the suppliers, imbalance settlement and the respective transmission parties. For the flow of communication, in the centralised market (Fig. 1-1), the prosumers can only communicate with their suppliers, while in the decentralised market (Fig. 1-2), communication is decentralised among the prosumers, and they can also communicate with their suppliers. In both market structures, electricity is supplied through the distribution network.

This market structure is the most adaptable to the existing market design, where an energy supplier could act like the central entity overseeing the market. Some examples of this structure are found in [14] and [17]. A centralised coordinated LEM is typically associated with community-based structure, that incentivise participation in LEM, where, a community manager or a licensed supplier coordinates the P2P LEM among the prosumers [18], [19]. Community-based market have started gaining momentum in trial projects. An example can be found in Cornwall local energy marketplace in the UK [99]. In a fully decentralised market, Fig. 1-2, prosumers interact directly to decide the trading terms and parameters [20], [21]. However, the current electricity market do not fully cater for a decentralised LEM because of its complex implementation relating to network constraints, network visibility, data availability, regulatory barriers and infrastructure readiness to maintain the reliability of the grid. Finally, hybrid or composite market is the combination of the decentralised and coordinated market [19], [22]. This type of market serves as an approach to scale up local energy trading as well as a means to create inter-community interactions.

These market structures lacks discussion on the deployment and implementation barriers in P2P LEM relating to licensing, policies and building structures. While the distribution and transmission networks will play key roles in electricity sharing, their current role is virtual balancing of power between prosumers and not providing the full flavour of P2P LEM. Licensing is another barrier, where a consumer can only accept electricity from one supplier at a time, limiting the chances of achieving P2P LEM from multiple suppliers or prosumers as depicted in the literature. Also, existing buildings including multi-tenant or high-rise apartments having a different electricity suppliers or old buildings that are not "smart buildings" are isolated in energy transitions and trading. Thus, in Section V, we proposed some implementation frameworks for P2P LEM, discussing how the identified gaps can be addressed. While these are implementation frameworks, the authors would consider theoretical proofs as a future work.

B. P2P LEM IMPLEMENTATION - TRADITIONAL DISTRIBUTION NETWORK

The key parties involved in the electricity market are summarised in Fig. 2-1. In Fig. 2-1, electricity flows from the generator through the transmission lines and the distribution lines to the end customers. In some cases, the energy can bypass the transmission lines directly to the distribution lines to the customers, e.g., in cases of self-consumption or local generation. In general, the energy operators connects active customers to their networks, and a connection contract describes the tariffs, terms, and conditions for access to the distribution grid. Also, because of the current laws in countries like the Netherlands, and UK, that allow only licensed electricity suppliers to manage energy flows onto distribution networks [24], [25], [59], a licensed supplier is connected between the plant and the imbalance settlement.

Here, we discuss some implementation frameworks for P2P LEM in the traditional distribution network. These models consider various ways to implement P2P trading in different energy consumer's building structures. The type of building such as a multi-tenant apartments, high-rise apartments or a detached house will impact the consumer's participation in the P2P LEM. Thus, P2P LEM in these models can be effected via a trading platform or a virtual pool, where suppliers either purchase electricity from prosumers and redistribute or sell to another consumer.

1) EXISTING BUILDING, MULTI-TENANT APARTMENT

We know that around 50% of our current building stock will still be standing in the year 2050 [100]. This model demonstrates how retrofitting can deliver energy savings,

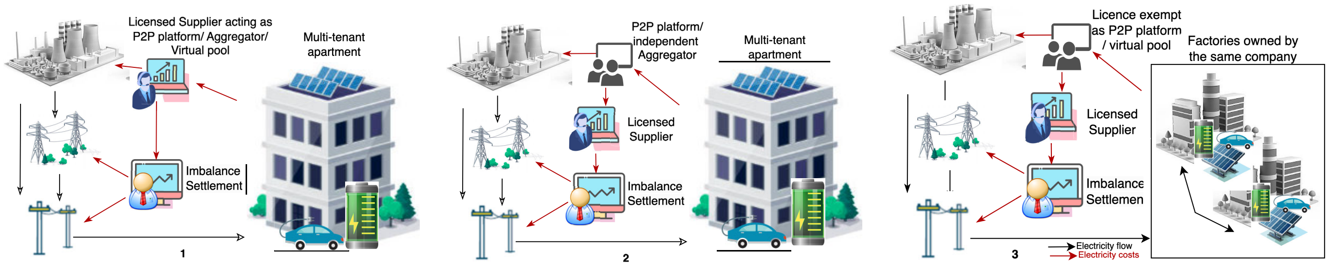

FIGURE 2. This figure demonstrates P2P transaction frameworks over the traditional distribution network with the different parties and buildings involved. Fig. 2-1 is a multi-tenant apartment with a joint supplier acting as the platform provider or an aggregator. Fig. 2-2 is a multi-tenant apartment with an independent platform provider or an aggregator that still requires a licensed supplier to access the imbalance market. Fig. 2-3 is a sleeving arrangement where energy generated at a company can be utilised by the same company in another location.

support the local electricity system (for both the producers and consumers of energy) and help to make our city regions more resilient to climate change. Thus, considering different building types, Fig. 2-1 illustrates a P2P transaction within a building, multi-tenant apartment or a flat aggregated by an energy supplier and connected to the grid for energy transfer and balancing. The P2P transaction is carried out on a platform provided by a licensed supplier. The transaction could also be aggregated or virtually pooled to serve the participants. This model is similar to the centralised market structure, where a licensed supplier serves as the aggregator. Although network charges still apply, this model can be implemented under the current legal framework by pooling flexibility from customers supplied by the same licensed supplier.

2) MULTI-TENANT APARTMENT WITH AN AGGREGATOR

Fig. 2-2 illustrates a P2P transaction within a building, multi-tenant apartment or a flat with an independent aggregator but is connected to the grid through a licensed supplier for balancing. In contrast to the licensed supplier providing the trading platform as shown in Fig 2-1, here, an independent entity called an aggregator provides the P2P platform for the energy transaction while balancing is achieved via a supplier with the grid. Aggregator pools flexibility from multiple flexible prosumers or customers to provide useful volume to flexibility users like DSO, TSO, and other parties. These flexibility services include demand response, storage, and switching on and off of generation. While the value of aggregators in LEM is assessed in [101], their role in energy communities is currently being assessed in Ireland [26].

3) SLEEVING ARRANGEMENT

Sleeving is a clause in a flexible supply contract that allows a customer to approach a third party for a better price than their supplier's when looking to buy or sell energy. Sleeving arrangement also requires a licensed energy supplier to use the traditional distribution grid. Fig. 2-3 illustrates a P2P transaction within buildings or factories owned by the same company which could be at different locations. A sleeving arrangement could be sorted out with a third party for the company to utilise its generated energy at a different location. In the UK, sleeving arrangements could work here with a license-exempt supplier or P2P platform when the electricity generated is less than 2.5MW. This is considered self-consumption since the electricity is generated by the same company but used at a different location. However, network charges still apply.

C. P2P LEM IMPLEMENTATION - PRIVATE DISTRIBUTION NETWORK

Utilising private distribution networks is the current way (demonstrated in pilot projects) to implement a P2P LEM, but not a sustainable solution for existing distribution networks and buildings. In private distribution networks, energy transactions take place within a microgrid without interfacing with the traditional distribution network. Here, we discuss some implementation frameworks for P2P LEM in a private distribution connection mode. These models also consider various ways to implement P2P trading in different building types. In this instance, energy can be transacted through a trading platform or a virtual pool, where suppliers either purchase electricity from prosumers and redistribute it or sell it to another consumer.

1) NEW BUILT MULTI-TENANT APARTMENT

Fig. 3-4 illustrates a P2P transaction within a building, multi-tenant apartment, or a flat with the same energy supplier to accommodate the current regulatory barriers of one electricity supplier to a customer at a time. The model is similar to the traditional distribution network model, but, the P2P platform can be provided by an aggregator, a supplier, or a license-exempt supplier. However, the connection here is private and it is only connected to the grid for balancing purposes if there is a demand-supply mismatch.

2) MULTI-TENANT APARTMENT WITH EV

Fig. 3-5 illustrates a P2P transaction within a building, an apartment, or a flat with the charging and discharging of an electric vehicle. Also, with the same energy supplier. The EV charging is flexible as it can be charged at a residence and discharged to another facility. The P2P platform is

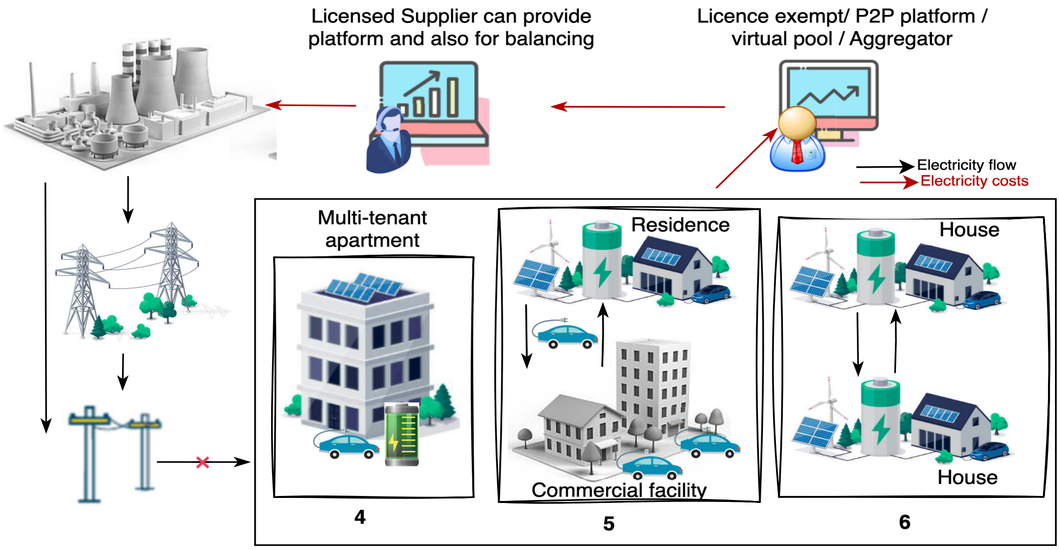

FIGURE 3. This figure demonstrates P2P transaction frameworks over a private distribution network. The grid connection is only for balancing purposes and can be disconnected. In the 3 scenarios, they are connected through an independent aggregator who pulls flexibility from the prosumers. Fig 3-4 is a new built multi-tenant apartment. Fig. 3-5 is a multi-tenant apartment with electric vehicles interacting with another residence. Fig. 3-6 illustrates houses and neighbours transacting energy.

TABLE 5. Viability of each framework to the identified challenges in scaling-up P2P local energy market.

Framework	License	Building type	Customer type	Legal framework	Grid connection	Network charges	EV
Existing building, multi-tenant or high-rise apartment	Licensed supplier	Existing building	Domestic & commercial	Yes	Yes	High	Yes
Multi-tenant or high-rise apartment with an aggregator	License exempt (licensed supplier for balancing)	Existing building	Domestic and commercial	Yes	Yes	High	Yes
Sleeving arrangement	License exempt (licensed supplier for balancing)	Existing building	Commercial	Yes	Yes	High	Yes
New built, multi-tenant or high-rise apartment	License exempt	New built	Domestic & commercial	Yes	Maybe (for balancing)	Low	Yes
Multi-tenant or high-rise apartment with EV	License exempt	New built	Domestic & commercial	Yes	Maybe (for balancing)	Low	Yes
Semi-detached or detached Houses	License exempt	New built	Domestic & commercial	Yes	Maybe (for balancing)	Low	Yes

provided by an aggregator, a supplier, or a license-exempt supplier.

3) HOUSES AND NEIGHBOURS

Fig. 3-6 illustrates a P2P transaction within a community, houses, neighbours, who are connected through a private distribution network, mostly in a newly built development and with the same energy supplier. Similarly, the P2P platform is provided by an aggregator, a supplier, or a license-exempt supplier. Table 5 summarises the discussed frameworks against the identified challenges.

VI. RISKS AND RECOMMENDATIONS

As the benefits of P2P LEM towards achieveing net zero carbon cannot be over-emphasied, so is the risks and uncertainty associated with implementing P2P LEM. This section briefly discussed the risks as well as recommendations for P2P LEM.

A. RISKS AND UNCERTAINTIES

The identified risks and uncertainties are summarised below.

1) P2P LEM is designed as an enabler of the opportunity to give prosumers choice over their purchase, consumption and sale of electricity. This choice raises some

questions, for instance about who benefits the most or how can profit be maximised? There are uncertainties about whether P2P trading will be economically advantageous compared to the traditional supply model especially from the perspective of the Government, who gauges if P2P LEM really worth the hype or investment.

2) As blockchain technology is the commonly adopted technology for transaction management in distributed systems and the main implementation choice in P2P LEM pilot projects to manage decentralisation and security, there are also open questions and risks associated with it. Uncertainties around ownership, responsibilities, scalability of the platform for large-scale implementation, standardisation, development status, computational costs of the consensus mechanisms and even security of the underlying smart contracts such as against reentrancy attack, for example [34] and [57].
3) Possibility of fraud, data privacy breaches and loss associated with energy transactions, may arise through the use of smart meters or from using a P2P LEM model not operated by a licensed electricity supplier. Also, customers may be left vulnerable especially in private distribution network (off-grid connection) if the unlicensed platform provider liquidates.
4) Lack of acceptance by consumers and the need for behavioural change or adaptation. There is also the risk that participants may exit participation thereby resulting in a demand-supply imbalance and therefore an additional cost for imbalance settlement with the grid. This calls for ways to incentivise many consumers for continual participation by providing additional services to realise the full benefit of the P2P LEM model.
5) Legal and regulatory requirements delaying P2P LEM implementation and deployment. For instance, the single licence supplier mode discussed in Section III need to be re-evaluated for full adoption of P2P LEM.
6) Increased risk to electricity network operators having to cope with a continual increase in decentralised flexibility. As well as uncertainties for participants who are geographically restricted, especially in private distribution network, interested participants may not be able to participate if no such initiative in their locality.

B. RECOMMENDATIONS - TRADITIONAL AND PRIVATE DISTRIBUTION NETWORKS

The discussed P2P LEM frameworks in Section V focused on its integration within the current legislation and policy across the highlighted countries. However, the following recommendations suggest changes and ongoing deliberations on policies, regulations and behaviours to further allow implementation and uptake of P2P LEM on both the traditional and private distribution networks.

1) SUPPLIER PARTNERSHIP

Implementing a full P2P LEM within the current infrastructure would require disruption in regulations and raised questions about the worth of P2P LEM in order to propose such a radical regulation. However, to avoid infrastructure redundancy and to incorporate existing buildings and networks to participate in a P2P LEM, a partnership with a supplier or suppliers across geographical areas can be arranged for billing and settlement purposes of the P2P LEM. In this arrangement, a third party or a local council can take up a new role as a community energy aggregator in partnership with a supplier for grid access. This potential new role may disrupt the supplier's main business model, thus, a policy change that may involve an incentive mechanism is recommended to attract suppliers to facilitate local energy trading.

2) ADDITIONAL SERVICES

P2P LEM is identified as one of the ways to achieve community pool towards net-zero carbon. Integrating additional services like carbon offsetting opportunity in the P2P LEM could serve as an incentive for carbon-savvy customers to take up the P2P LEM initiative for a community pool towards net-zero carbon economy.

3) LOCAL ELECTRICITY BILL

In the UK, a petition is ongoing by a selection of cross-party members of parliament (MPs) to make a 'Local Electricity Bill' law. This Bill would allow local organisations to become energy suppliers, removing the costly, complex barrier to selling electricity and make it financially viable for electricity generators to sell directly to the local community. This should favour P2P LEM if implemented in different countries, by allowing more organisations to become suppliers offering new improved services.

4) SLEEVING ARRANGEMENT

Sleeving arrangement allows a customer to approach a third party for a better price to buy or sell energy than their current supplier's offer is currently allowed within the regulations. This arrangement means a customer with a flexible supply contract can approach another supplier when looking to buy or sell energy. Thus, this process could be modified to suit P2P LEM implementation where a prosumer can transact with one or more prosumer at a time. However, sleeving arrangement also requires a licensed energy supplier to use the traditional distribution grid, which could result to network charges.

C. RECOMMENDATIONS - TRADITIONAL DISTRIBUTION NETWORK

The following recommendations are specific for the traditional distribution network P2P LEM.

TABLE 6. A summary of the Government programs, discussed frameworks, limitations and barriers, risks, and recommendations - T: Traditional; D: Distribution; N: Network; P: Private; R: Research.

Government Programs	Framework	Limitations & Barriers	Risks	Recommendations
Community Energy Cooperatives	TDN - Existing building, multi-tenant apartment	Policies and regulations - R & Development	Economic benefits uncertainties	T & PDN - Supplier partnership
Self-consumption scheme and net metering	TDN - Multi-tenant apartment with an aggregator	Policies and regulations - legislative	Technology ownership, responsibility, scalability and standardisation	T & PDN - Additional services
Virtual aggregation or local tariff	TDN - Sleeving arrangement	Policies and regulations - licensing	Security risk - fraud, data privacy breaches and loss	T & PDN - Local electricity bill
Half-Hourly settlement	PDN - New built, multi-tenant apartment	Reliability & security	Human risk - Acceptance, sudden behavioural changes and adaptation	T & PDN - Sleeving arrangement
Balancing mechanism	PDN - Multi-tenant apartment with EV	Network visibility & data availability	Legal and regulatory requirements bottlenecks	TDN - Integrated role; Multiple suppliers
Social awareness	PDN - Houses and neighbours	-	Uncertainty about safety of electrical network operators	TDN - Location-based energy supply; Capacity increase
Product differentiation and dynamic pricing	-	-	Uncertainty about access to LEM due to geographical restriction	PDN - Subsidised asset; Consumer's protection

1) INTEGRATED ROLE
Since licensed suppliers are required to distribute electricity through the traditional distribution grid, the suppliers can take up an additional role as P2P platform operators and/or aggregators for locality-based electricity pooling.

2) MULTIPLE SUPPLIERS
Also, in most countries, only a licensed supplier can supply electricity to a customer at a time, this policy could be reviewed to either allow; multiple suppliers at a time; supplier-to-supplier interaction and energy (virtual) balancing; or to allow prosumers to trade limited amount of energy without a licence by incorporating some form of licence-exempt trading.

3) LOCATION-BASED ENERGY SUPPLY
Regulate electricity prices across suppliers to enable a supplier to supply electricity at a localised area. i.e., a supplier to supply electricity to all houses at a particular postcode. A localised or postcode-based P2P trading could reduce fees and emissions. This suggestion might limit customers' options in terms of available energy suppliers.

4) CAPACITY INCREASE
Increase the capacity of license-exempt suppliers, for the UK, $(\geq\ 2.5MW)$, and $(\geq\ 2MW)$ for the Netherlands while applying similar increases in other countries. This would enable the integration of sleeving arrangement.

D. RECOMMENDATIONS - PRIVATE DISTRIBUTION NETWORK
The following recommendations are specific to the private distribution network P2P LEM. Although, considering the strict regulations in many countries, private distribution network for all buildings is unrealistic. However, this could be achieved in a new development area.

1) SUBSIDISED ASSET
For private distribution networks especially in the newly built environment, a subsidised asset (network installations, DERs) would incentivise the take-up of local energy consumption and sustainability by design utilising renewable energy.

2) CONSUMER'S PROTECTION
Since private distribution networks could be supplied by a licence-exempt supplier, customers protection is not guaranteed. A complete care plan or regulations for customers' protection under licence-exempt suppliers should be revised and implemented.

Table 6 summarises the main concepts of this article including the Government programs, the discussed frameworks, limitations, barriers, risks, and recommendations.

VII. CONCLUSION
This study has suggested frameworks to drive the actual implementation of P2P LEM within the existing building infrastructure and distribution network. Firstly, the study discusses the opportunities and barriers across policies, to viability of LEM. Secondly, we discussed six frameworks to implement P2P LEM within the current network infrastructure as well as private distribution networks. Finally, we specified the risks and uncertainties, while providing recommendations to the actual large-scale implementation of P2P LEM.

In summary, to achieve the carbon emission goal within the current building infrastructure through a LEM, P2P LEM will be most appropriate in new development areas with renewable energy, while a virtual balancing/ aggregation through the traditional distribution network will be more appropriate in retrofit buildings. Other enablers for P2P LEM uptake include a reliable clearing platform, availability of conducive regulatory framework, reliable grid, and digitalisation. The current regulatory framework surrounding supplier licensing to supply electricity need to change for P2P LEM to be realised. However, if customers were able to have more than one supplier this would in turn raise issues regarding the balance of power; which supplier would be responsible for balancing obligations, network charges, security obligations, environmental policy obligations, data sharing privacy, etc.

ACKNOWLEDGMENT
The authors declare no conflict of interest

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OLAMIDE JOGUNOLA (Member, IEEE) received the Ph.D. degree in electrical engineering from Manchester Metropolitan University (MMU). She is currently a Lecturer in cyber security with MMU. Her research interests include energy transitions, local energy markets, and the cyber security of critical national infrastructure, such as energy network (smart grid). She was a Research Associate on several industry and government-funded projects on energy transition, smart grid, and smart cities. She was a recipient of the MMU Department of Engineering Ph.D. Studentship. She was a PI on a SuperGen Network/EPSRC-funded project and a Co-I in a NWPST-funded project on security of interlinked computing, a case study of smart grid. She is also a Co-I on a KTP funded by Innovate U.K. with Badger Energy. She is a fellow of Higher Education Academy.

ABIMBOLA S. AJAGUN received the B.Eng. degree in electrical and computer engineering and the M.Sc. degree in electrical and electronic engineering from the Federal University of Technology, Minna, Nigeria. She is currently pursuing the Ph.D. degree in electrical engineering with the College of Energy and Electrical Engineering, Hohai University, Nanjing, China. She is also a Lecturer with the Department of Electrical and Electronic Engineering, Federal University of Technology. Her research interests include the area of clean energy and gender equality in STEM. She founded the Females in Clean Energy (FiCE) Foundation. She is involved in the artificial intelligence in clean energy project, funded by the Royal Academy of Engineering U.K. Grant under the Higher Education Partnerships in Sub-Saharan Africa (HEP-SSA).

WAYES TUSHAR (Senior Member, IEEE) received the B.Sc. degree in electrical and electronic engineering from Bangladesh University of Engineering and Technology, in 2007, and the Ph.D. degree in engineering from The Australian National University (ANU), in 2013. He is currently a Senior Lecturer with the School of Electrical Engineering and Computer Science (EECS), The University of Queensland (UQ). His research interests include energy management and energy market.

FEMI O. OLATUNJI received the bachelor's degree in industrial chemistry from the University of Ilorin, Nigeria, and the master's degree in chemistry with entrepreneurship from the University of Nottingham, U.K. He is currently a Ph.D. Researcher with interests in techno-economic pathways to decarbonize energy systems using predictive models. He is a Chartered Energy Manager, currently working as a Process and Quality Manager in a manufacturing setting, with over 18 years of cumulative professional experience across various industries, including steelmaking, glasswool insulation, FMCG, energy (power generation and retail), and the financial sector.

CHAU YUEN (Fellow, IEEE) received the B.Eng. and Ph.D. degrees from Nanyang Technological University, Singapore, in 2000 and 2004, respectively.

He was a Postdoctoral Fellow with Lucent Technologies Bell Labs, Murray Hill, in 2005. From 2006 to 2010, he was with the Institute for Infocomm Research, Singapore. From 2010 to 2023, he was with the Engineering Product Development Pillar, Singapore University of Technology and Design. Since 2023, he has been with the School of Electrical and Electronic Engineering, Nanyang Technological University. He received several awards, including the IEEE Communications Society Fred W. Ellersick Prize, in 2023, the IEEE Marconi Prize Paper Award in Wireless Communications, in 2021, the IEEE APB Outstanding Paper Award, in 2023, the IEEE ICC and ICCT Best Paper Award, in 2023, and the EURASIP Best Paper Award for *EURASIP Journal on Wireless Communications and Networking*, in 2021. He currently serves as an Editor for several journals, including in IEEE Transactions and Elsevier. He is in the Top 2% Scientists by Stanford University, and also a Highly Cited Researcher by Clarivate Web of Science. He has three U.S. patents and he has published over 400 research articles at international journals.

CRAIG MORLEY is currently an Energy Manager with Bruntwood Ltd., Manchester, U.K. He worked on several government-funded projects in smart city, smart grid, energy decarburization, electric vehicles, and Greater Manchester local energy market. Example of such projects is the 30 Million Euro Smart City project; Triangulum, with partners across the U.K. and Europe.

BAMIDELE ADEBISI (Senior Member, IEEE) received the Ph.D. degree in communication systems from Lancaster University, U.K. He is currently a Professor in intelligent infrastructure systems and the Head of the Smart Infrastructure and Industry Research Group, Department of Engineering, Manchester Metropolitan University. His research interests include embedding sensing, communication, control, and data analytic technologies in critical infrastructure. He has published over 195 peer-reviewed articles and he has been part of multi-partner, multi-country projects as a PI, a CI, and a RI. He is a fellow of IET, a fellow of Higher Education Academy, and a Chartered Engineer.

THOKOZANI SHONGWE (Senior Member, IEEE) received the B.Eng. degree in electronic engineering from the University of Swaziland, Swaziland, in 2004, the M.Eng. degree in telecommunications engineering from the University of the Witwatersrand, South Africa, in 2006, and the D.Eng. degree from the University of Johannesburg, South Africa, in 2014. He is currently an Associate Professor and the Vice-Dean of Postgraduate Studies, Research and internationalization with the University of Johannesburg. His research interests include digital communications, powerline communications, smart grid, visible light communications, and artificial intelligence. He is the Founder of a Research Group, University of Johannesburg called Artificial Intelligence for Electrical Engineering Applications (AI for EE Applications).