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RESEARCH ARTICLE

Empowering Energy: Legal and Regulatory Perspectives on Blockchain-Enabled Trading in Malaysia and Australia

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Abstract

Leveraging blockchain technology in the energy sector holds immense potential, particularly in facilitating decentralised energy systems. However, the legal and regulatory landscapes of several countries, including Malaysia and Australia, pose significant obstacles to its effective implementation. This article examines the specific legal and regulatory hurdles hindering the incorporation of P2P energy trading systems in these two jurisdictions: Malaysia and Australia. Through a comparative analysis, the authors aim to provide valuable insights for policymakers and regulators seeking to develop comprehensive frameworks that encourage blockchain adoption in the energy sector. The article highlights the need to address the under-inclusiveness of laws, legal uncertainty around novel blockchain-based concepts like smart contracts, and the obsolescence of legal frameworks designed for traditional centralised energy systems. By examining Malaysia's and Australia's unique challenges, the article seeks to contribute to a broader understanding of the complexities of adapting legal and regulatory frameworks to accommodate this transformative technology.

Keywords: Blockchain; energy trading; decentralised energy system; technology; regulation

1. Introduction

Decentralised energy systems (DESs) have become a focal point post-COP28. DESs can play a crucial role in meeting the objectives outlined in the Paris Agreement and attaining sustainable energy targets. Emphasising the importance of decentralisation, not only as a technological shift but as a fundamental rethinking of energy systems, may indeed be critical in advancing the global commitment to sustainable and resilient energy infrastructures post-COP28. However, despite the existence and exponential development of technology supporting DESs, the institutional and legal frameworks still need to evolve.

The locked-in effect in centralised energy systems stems from substantial, capital-intensive infrastructural investments. This entrenchment creates a long-term commitment, reinforcing the systems' inclination to maintain the status quo rather than embracing alternative and sustainable approaches. Hence, while blockchain technology catalyses DESs, a successful transition necessitates substantial regulatory reform. This transformative process can only unfold gradually, underscoring the urgency for swift policy adjustments and interventions at various levels of the energy supply chain.

Blockchain-based peer-to-peer (P2P) energy trading systems are beginning to emerge as a promising architecture needed for the renewable energy transition. Integrating DESs can ensure bidirectional power flow and improve overall performance of the energy system. Blockchain-based P2P energy trading empowers prosumers to leverage renewable energy generation and facilitate trading environments smoothly. With the presence of interoperability, security, and transparency features that are core elements of blockchain-based power trading, centralised ledgers cannot compete with the opportunities of blockchain as decentralised ledgers (Nguyen et al., 2020, p. 2, Marthews and Tucker, 2023, pp. 49–50). The potential of decentralised blockchain-based energy trading systems is immense, allowing automated bid and offer matching, enabling real-time processing of energy demand and supply, and broadcasting information to blockchain participants for energy transactions. Effectively undertaking this task is impossible with a centralised database due to the high costs of maintaining centralised registries and managing energy data. The diversity in types, attributes, portfolios, and ownerships of blockchain-based P2P energy trading makes centralised management unfeasible and costly. Automated billing and settlement procedures, in addition to demand and supply matching, reduce overall administrative costs and accommodate various energy trading systems (Esmat et al., 2021, p. 2, Andoni et al., 2019).

Blockchain, therefore, addresses deficiencies in existing energy structures by accelerating the viability and efficiency of the energy sector through the development of key use cases. Prosumers and consumers using blockchain can trade energy without exposure to a single point of failure and high intermediary costs. Blockchain-enabled transactive energy systems offer functionalities that incrementally facilitate dynamic value creation and provide new opportunities for introducing business models securely (Tushar et al., 2020b). In addition, blockchain-based energy trading may be necessary to support the transition to renewable energy in both developed and developing countries. Solar energy has become a popular form of distributed energy resource (DER) throughout the world and is currently the most common source of energy in P2P trading. There are other forms of energy generation (such as wind and hydrogen) but these are far less common at the residential level. Hence, widespread solar energy generation at a residential level has made P2P trading possible with many consumers evolving to become prosumers.

Specific limits, barriers, and technological and legal challenges plague blockchain-based energy trading applications. The imminent technological development calls for change considering the under-inclusiveness of laws, legal uncertainty, and obsolescence of legal frameworks stemming from the new blockchain paradigm. As a result, this paper systematically addresses the industry-specific challenges as the change in norms and regulations can only manifest if we clearly and pragmatically delineate the foundational challenges that inhibit the far-reaching implementation of blockchain in transactive energy domains in two very different countries, Malaysia and Australia. These countries represent nations that have unique challenges in mobilising P2P energy trading as a part of the energy system and therefore provide excellent case studies for this paper. As a developing country, Malaysia is in the early stages of embracing renewable energy, while Australia, a developed country, has a more advanced and established renewable energy sector. Malaysia's energy sector, once a monopoly, has made substantial strides in energy democratisation and liberalisation, transitioning towards a horizontally-centric, bottom-up sector through the involvement of independent power producers. In the 2023 Energy Transition Index by the World Economic Forum, Malaysia is a top-ranked country in Southeast Asia for its progress in energy transition (Ministry of Economy, 2023). In comparison, Australia is at the forefront of liberalising the energy market and privatisation, fostering intense competition and lowering energy prices with greater efficiency (Godden and Kallies, 2021). This contrast provides a rich ground for a comprehensive analysis of how regulatory landscapes influence consumer participation in energy markets. The differences between Malaysia and Australia create unique and complex regulatory challenges for each country. In Malaysia, challenges include building adequate infrastructure, formulating robust, flexible, and cost-reflective pricing structures, creating incentives for prosumers, and developing supportive policies for renewable energy (Ministry of Economy, 2023). In contrast, Australia faces challenges integrating more prosumers into an already mature market, maintaining grid stability, and dealing with network impacts, such as thermal overloading and safety concerns (Australian Energy Market Commission, 2017). These differences necessitate tailored and intricate regulatory strategies to address each country's circumstances effectively.

The absence of judicial cases in our analysis is attributable to the novel nature of the subject, which is still in the pilot stage in Malaysia. As a pioneering area, it has not generated legal disputes or judicial trials. While the initiative has gained more traction in Australia, it remains relatively new and has no reported judicial cases. Consequently, our paper focuses on legal norms and theoretical implications while developing practical applications and judicial precedents are underway. Our approach underscores the innovative aspects and the field's emerging nature. Therefore, while we acknowledge the importance of incorporating judicial pronouncements and administrative cases to fully present the regulatory challenges posed by new blockchain pathways in energy trading systems, the lack of precedents in the judicial or arbitral fora does not negate the utility of our present discussion.

2. The pathway for blockchain-enabled energy trading

There are many obstacles associated with adopting P2P energy trading at scale. Within this paper, we identify several industry-specific challenges with significant implications in adopting blockchain-enabled energy trading in Malaysia and Australia. The challenge involves recognising the lack of prosumers' access to the grid due to the centralisation of generation, transmission, and distribution networks. This position poses far-reaching implications that inherently shape the energy structure and acceptability of P2P energy trading. At the same time, the need for more unmediated access perpetuates the need for centralisation. Second is a lack of fit-for-purpose network tariff designs adaptive to prosumer-centric and decentralised trading. Conventional tariffs are not adaptive towards DERs, integral to blockchain-enabled P2P energy trading (Karisma and Tehrani, 2024).

The third challenge we highlight is licensing requirements. In Australia and Malaysia there are multiple industry codes, standards, and provisions that can disproportionately hinder P2P energy trading. While licences resemble the gatekeepers of energy security, we must come face-to-face with the potential of P2P energy trading and the hindrances that licensing requirements generate. As such, regulating licensing requirements in the blockchain-enabled P2P energy trading landscape facilitates fairness and equitability, considering that prosumers are not on a level playing field with energy suppliers regarding financial and economic resources.

This article aims to provide an understanding of the legal framework in Australia and Malaysia that by and large hinder decentralised blockchain-enabled energy trading systems adoption. Discussing these frameworks and identifying the challenges provides important pathways for developing appropriate policy solutions to address the primary impediments of blockchain-enabled P2P energy trading. We recognise that most countries are locked-in to the confines of centralised energy systems, requiring intermediary control. Here, countries would benefit from a gradual and non-radical change given the current regime and technical complexities of adapting and responding to market liberalisation.

The findings from this article are derived from a larger study considering blockchain-based energy trading. The larger study employed a mixed methodology approach consisting of a systematic literature review and semi-structured qualitative interviews. This article makes an important contribution to the literature and identifies the importance of future research in achieving a low-carbon economy and implementing bottom-up energy models that entail flexibility, ownership, and accountability in energy systems.

3. Connecting renewable energy with digital P2P trading

Transitioning to renewable energy is necessary for international climate change mitigation targets limiting warming to 1.5–2 degrees. Australia has a target of net zero by 2050, which will require phasing out coal-fired electricity well before 2040 (Skarbek, Malos and Li, 2023). Although this is not an impossible goal, there is a significant amount of infrastructure needed to support this transition (An et al., 2020). Renewable energy generation at scale is not likely to occur in the same places as the existing power generation, hence, new transmission lines will be needed. These infrastructure challenges are not entirely overcome with P2P energy trading, although if trading of energy is done within a particular proximity, it may limit the development needed. However, there will be several economic concerns that follow. For instance, it will be necessary to consider who will own the transmission lines that are built to facilitate trade. There will be questions about who will finance them and how benefits and costs will be distributed fairly. These are questions that will need answers if P2P energy trading is a desirable aspect of any energy system.

In adopting a progressive approach, Malaysia has developed the National Energy Transition Roadmap (NETR) to facilitate the transition from fossil fuels to a renewable energy (RE) economy to achieve net zero targets. NETR is a crucial tool for charting the course towards a low-carbon future and guiding the implementation of policies and strategies (Ministry of Economy, 2023). While it enables cross-border RE trading with our neighbouring countries, the concept of P2P energy trading is still on the horizon. The main roadblock is overcoming grid limitations to fully embrace higher levels of RE integration. A major hurdle developing nations, such as Malaysia, face is the need for more funding strategies to support grid investments and strengthen their infrastructure to accommodate RE. Investing in a platform that serves as a price discovery mechanism for willing buyers and sellers is pertinent. While Malaysia has expressed its commitment towards becoming a carbon-neutral nation by 2050, many challenges persist, including the need for more funding traction towards decarbonisation and limited return on investments to meet RE targets (Ministry of Economy, 2023). Apart from robust and resilient infrastructure not readily available in many regions in Malaysia and the initial set-up costs that diminish investment capacities, the lack of awareness and resistance from residents and local communities may impede adoption efforts. A major challenge highlighted in the NETR is that while the owner is responsible for investing in energy-efficient improvements, the tenant reaps the benefits of cost savings (Ministry of Economy, 2023). It is of utmost importance for Malaysia to dedicate efforts consistently and collaboratively towards raising awareness about the advantages and functions of P2P energy trading systems. Moreover, it is crucial to relinquish the control and power currently held by monopolised and centralised systems.

The concept of P2P energy trading is reinforced in academic literature, connected to the growing emphasis on integrating DERs within energy systems (Andoni et al., 2019). It is rooted in harnessing prosumer's flexibility via active demand-side management and participation (Xia et al., 2023). Prosumers are individuals or other entities who both consume and produce electricity. Prosumers usually produce energy through rooftop solar or other forms of renewable energy. Prosumers have become more common through the tendency for households with rooftop solar to produce more energy than they consume, which means they have excess energy to export to other users (An et al., 2020). Presently, these prosumers transmit energy back to the grid, which can result in inefficiency of electricity through transmission loss.

There are benefits for those households that transition from being a passive consumer to an active prosumer within the energy system. These benefits include those to the energy system as a whole. For instance, with their unique ability to participate in energy systems fully and democratically, prosumers are key drivers in ensuring successful transitions to RE. Indeed, prosumers generally exhibit intrinsic and extrinsic motivations fuelling individual and collective prosumerism. Social, financial, and environmental motivations facilitate and catalyse significant governance and structural shifts towards RE, orchestrating top-down and bottom-up transitions. We explore some of these motivations below.

Social motivation factors influencing the transition from consumers to prosumers include social normative frameworks, social identity, and trust (Tushar et al., 2020a, p. 2). These social norms, deeply ingrained in societal values, shape cooperative energy-related behaviour and influence prosumers' decision-making in energy landscapes (Ajzen, 2005). By playing the prosumer role, individuals contribute to creating robust and reliable local energy markets (LEMs) by pooling, sharing, and trading energy resources for social good. Prosumers thus facilitate virtual electricity transfer through DERs guided by these norms.

Social identity drives energy communities and residential prosumers regarding demand reduction, energy efficiency, and flexibility (Bögel et al., 2021, p. 10, Georgarakis et al., 2021, p. 3, Mäkivierikko et al., 2019, p. 791). Energy communities can be defined as the collaborative production, consumption, storage, and sale of electricity generated, manifesting diverse decision-making and organisational and governance arrangements. Energy communities promote prosumerism by integrating prosumers, consumers, and other stakeholders, including local authorities, small and medium enterprises, and municipalities, to pursue a common goal or objective (Boulanger et al., 2021, p. 2, Bukovszki et al., 2020, p. 2).

Prosumers' roles ensure affiliation with a community that prioritises energy democratisation. Trust in market actors, institutions, and infrastructures is not just crucial but a cornerstone of prosumerism, enabling cooperative motives and mutual benefits (Tushar et al., 2020a). Blockchain is a decentralised technology that plays a significant role in enhancing trust through data transparency and immutability, which in turn provides a secure platform for prosumer participation. The use of this technology can, therefore, enhance prosumer's participation through building trusted energy systems.

Prosumers serve as drivers of smart grid energy trading, a crucial aspect of the evolving energy landscape, and are instrumental in shaping the future of the energy sector. Academic scholars have augmented the prosumer concept beyond self-generation and consumption to include innovative business models and technological initiatives. Rodríguez-Molina's definition of prosumers as "economically active" and "motivated entities" that self-generate, consume, and store electricity, participate in "economic and technological optimisation" in energy consumption, and actively engage in value creation for energy services, highlights the empowerment of prosumers in the energy sector (Rodríguez-Molina et al., 2014, p. 6161). Similarly, Rahi et al. define prosumers as active energy sector participants capable of generating and storing energy (El Rahi et al., 2017). Parag and Sovacool highlight the potential societal benefits of prosumer involvement. They argue that regulators should prepare themselves for a more decentralised energy grid, which could bring significant societal benefits and a more sustainable energy future. This offers a hopeful outlook for the energy sector (Parag and Sovacool, 2016, p. 4). Botelho et al. highlight that prosumer business models are no longer confined to electricity. They can now include various electricity-related services such as energy storage, response demands, and grid management (Botelho et al., 2021). As such, the literature promotes prosumers in a saviour role, that may be essential to a clean and just transition in energy generation leading to widespread social benefits within a given energy system. The social benefits of P2P energy trading reinforce individual and collective prosumerism. It fosters social engagement through energy-related behaviours and leverages DERs to engage in energy sharing and trading activities, all to achieve cooperative motives and mutual socio-economic and environmental benefits. It is pivotal to adopt a streamlined regulatory framework that considers and accommodates social features and motivation.

In addition, there is a universal acceptance of innovative prosumer-side business models surpassing conventionally accepted ones for financial reasons. Prosumers can optimise financial benefits for their households and each other by participating in P2P energy trading platforms, enabling them to buy and sell excess energy with one another directly. This represents an intrinsic motivation of certain prosumers as they are able to prioritise personal gains and individualistic ideals, strengthen innovative business models that facilitate prosumer-centric activities, and offer services to inspire the shift from centralised to decentralised systems (Last, 2022).

Motivations for P2P energy trading includes the need to achieve greater independence from conventional energy providers and systems (Hackbarth and Löbbe, 2020). Financial gain is not necessarily the main reason to actively partake in P2P energy trading (Hackbarth and Löbbe, 2020). Indeed, Mengelkamp et al. argue that the primary motivator for residential prosumers to participate in LEMs is the sense of belonging in a community through involvement in sustainable energy initiatives (Mengelkamp et al., 2018, p. 3). This involvement creates a feeling of connection and shared purpose, making individuals feel part of a larger cause and fostering a sense of community. Moreover, the empowering interactions with technology applications are significant drivers of active participation in LEMs, equipping individuals with the means to contribute to a sustainable future (Mengelkamp et al., 2018). The environmental benefits and a sustainable lifestyle stem from the self-generation and consumption of renewable energy, surpassing the need for financial incentives and reimbursements. As per a survey by Wilkinson et al., participants in live P2P trials were motivated by the potential shifts in the electrical matrix to enable "socially equitable and clean" energy landscapes (Wilkinson et al., 2020, p. 8). The energy flexibility and efficiency enhancements prompted other participants to eliminate third-party intermediaries from the energy value chain. It follows that environmental and social motivations are pivotal in individual and collective prosumerism, inspiring a sense of empowerment and purpose.

As explored above, prosumers are key actors in the renewable energy revolution and low-carbon economy, contributing to overall energy efficiency and flexibility by enabling energy production and consumption through diverse energy installations and infrastructures. Prosumers can trade surplus electricity through P2P energy trading systems, adopting a bottom-up transition of the energy market. The models for P2P energy trading derive from the economic rationale of bilateral transactions between prosumers and consumers. Prosumers who generate more electricity than they consume can store their excess energy in energy storage infrastructure (Poulose, Kumar and Torell, 2022). They also have the potential to sell this surplus to other individuals or even export it back to the grid (Ziras, Calearo and Marinelli, 2021, Parag and Sovacool, 2016). Therefore, P2P energy trading in LEMs is direct, decentralised, flexible, and horizontal energy trading between peers. Therefore, P2P trading involves transporting power from a source of energy to the destination (Abdella and Shuaib, 2018). P2P energy trading is facilitated by DERs. These are resources that are connected to the distribution network but generate energy in different locations rather than in one central place.

Peer-to-peer energy trading has emerged as a remarkable and game-changing way to address energy supply and demand effectively. This transformative paradigm is revolutionising the energy sector by using advanced technologies like smart meters, IoT devices, sensors, and other digital appliances (Hua et al., 2022). It enables seamless energy transactions in real time while promoting the rapid adoption of renewable energy sources, optimising resources, and ensuring the security and efficiency of DERs, all without central coordinators or intermediaries. Market participants in P2P energy trading models independently determine the volume and price of bilateral energy transactions (Guerrero et al., 2021).

Using a P2P model enhances the resilience of energy systems by eliminating single points of failure often present in centralised energy systems, while offering market participants increased choice and autonomy. For instance, there is direct communication with energy peers and complete control in deciding energy transactions. There are additional benefits to enabling blockchain-enabled P2P energy sharing and trading projects. Blockchain can handle high volumes of energy generation, consumption, and trading data in an automated and tamper-proof manner at lower costs and increased flexibility, thus encouraging reliable P2P integration at local and regional levels. This is explored in more detail in the next section of this paper.

Peer-to-peer energy trading usually allows prosumers to sell electricity at a higher price than exporting it to the grid through feed-in tariffs (Xia et al., 2023, p. 1). Consumers can also benefit from the lower prices offered by prosumers who sell their excess electricity, thereby decreasing energy consumption costs. In P2P energy trading models, considerable interest is attached to consumers' and prosumers' economic welfare, working collaboratively to achieve a common interest. P2P energy trading is more viable when conducted on existing distribution networks rather than on microgrids. Constructing microgrids can be seen as impractical due to their higher investment costs. However, it is still important to consider practical considerations, specific use cases, and cost-benefit analysis when making decisions regarding microgrid energy installations.

Implementing P2P energy trading within existing distribution grid systems can bring about various challenges related to power losses during transmission, voltage fluctuations, and the overall stability of distribution networks (Xia et al., 2023, p. 5). These issues might prove to be insurmountable obstacles in ensuring the effective delivery of energy. Additionally, P2P energy trading could lead to power flows in electricity lines or voltages at nodes on the electricity grid exceeding acceptable limits, placing excessive strain on distribution network infrastructures beyond predefined thresholds and capacities. These challenges may escalate the need to engage in grid investments and reinforcements. Rising grid peaks and network congestion can decrease revenue as capital and operational expenses increase accordingly.

Although the promise of P2P energy trading offers an attractive solution to increasing renewable energy resources, there are many challenges associated with its widespread adoption in both developed and developing countries. The question arises whether legal and regulatory frameworks warrant prosumers' ability to engage in P2P energy trading and whether there are limits to such engagements. Within this article we consider the circumstances in both Australia and Malaysia to highlight differences between the different energy markets. Within this analysis, we aim to identify the existing stakeholders within these two different energy markets, and show that P2P trading will only be facilitated where it is desired within a given economy and regulation is revised accordingly.

4. Intrinsic value of blockchain in transforming the landscape of decentralised P2P energy trading markets

Peer-to-peer electricity trading incorporates a virtual connection along with a physical one. The physical network is a complex matter that differs between jurisdictions. Although this article has a focus on blockchain to facilitate a virtual connection, a physical network is needed to facilitate the transfer of electricity from sellers to buyers (Tushar et al., 2021, p. 2). This physical connection may be in the form of a "traditional distributed-grid network provided and maintained by the independent system operator or an additional, separate physical microgrid distribution grid, in conjunction with the traditional grid"(Tushar et al., 2020b, p. 3186). So long as the infrastructure exists for prosumers to be feeding electricity to a storage system, there will be a means for decentralisation at least in a physical sense. The challenges with regulation and trading of data are significant, however, and within this article we consider how blockchain can enable the effective trade between prosumers and consumers in Malaysia and Australia.

Blockchain, a groundbreaking technology, builds trust by employing cryptographically verifiable systems, distributed networks, and integrated incentive mechanisms within open-source software. These distinctive features collectively foster consensus regarding the ledger's current state, eliminating the need for dependence on centralised intermediaries (Davidson, De Filippi and Potts, 2018). The unique technical features of blockchain interact coherently and add value to the architecture of trust which in turn radically transforms business models, processes, and transactions, achieving the end goal of transparency, validity, and reliability of the blockchain ledger. These include, (a) decentralisation, (b) autonomy, (c) real-time processing, (d) permanency, immutability, anonymity, and (e) transparency and auditability. For these reasons, this technology will be essential to support decentralised P2P energy trading.

The objective in supporting P2P energy trading aligns with shifting power from a centralised grid to decentralised suppliers and consumers (Thomas, Abraham and Arya, 2021). Although blockchain is not the only way to facilitate P2P trading, without it P2P trading would require an intermediary (or a centralised ledger). With the numerous participants and entities involved in energy trading platforms, a blockchain-driven energy framework presents a more fitting structure. Further, centralised ledgers can only record several energy transactions in real-time, preventing reliable and efficient energy trading records (Gawusu et al., 2022, pp. 8–10). Intermediary institutions and entities come with a high cost, as they rely on centralised mechanisms for "legitimacy" and "accuracy," leading to the imposition of significant fees (Davidson, De Filippi and Potts, 2018, p. 6). Participants on energy trading platforms are burdened with fees, discouraging their active involvement in energy trading systems. In terms of achieving representational bottom-up practices to narrate the success of Sustainable Development Goals, escalating costs when engaging in direct and bidirectional energy transfers can impede affordability and acceptability, negating energy security.

Blockchain is an incredibly robust, secure, and effective system for operation and management, capable of overcoming cost barriers. Additionally, due to the growing number of DERs, sensors, smart meters, and other installations, centralised ledgers can no longer control, manage, and record data. Another critical feature of blockchain is its ability to permanently record energy transaction data on the ledger, ensuring that it cannot be changed, tampered with, or deleted. This feature provides a highly secure and trustworthy record, significantly reducing the potential for data falsification and manipulation (Viriyasitavat and Hoonsopon, 2019). Accurate and immutable records are vital in enhancing grid management and optimising energy resources for energy transactions.

However, the existing legal and regulatory regimes do not provide a conducive or favourable environment for blockchain technology to thrive. There is a noticeable lack of practical understanding regarding the challenges faced by countries. This adds costs and potentially reduces some of the benefits associated with P2P energy trading (which we suggest needs to be encouraged to meet renewable energy targets). As such, in the next section we underscore the challenges to blockchain-enabled P2P energy trading and by extension to DESs.

5. Legal and regulatory challenges of P2P energy trading in Malaysia and Australia

Three key stumbling blocks impede blockchain-enabled P2P energy trading and, by extension, DESs. These involve the lack of prosumer access to the grid, absence of fit-for-purpose network tariff designs, hindrances to licensing requirements, and imposing financial, technical, and legal barriers on energy supply licensees. Even though Malaysia and Australia have distinct energy market structures and tariff methodologies, the commonalities lie in the push towards a bottom-up electricity trade and the emphasis on promoting efficient operations and enhancing consumer welfare in electricity services. These priorities encompass price, quality, security, and reliability, all in alignment with national targets for achieving carbon neutrality by 2050.

This section identifies the formidable industry-specific challenges in Malaysia and Australia through an explorative approach. The main challenges are the need for more network access for the transmission of electricity. The monopolisation of energy markets has led to the pernicious foreclosure of new entrants with generation units, hindering innovative business models from flourishing and forming a restrictive effect on market liberalisation. Currently, the legal framework of many countries is stringent, impeding access to the public grid and preventing the implementation of P2P energy trading and open competition in retail electricity markets (Hojckova et al., 2020).

This pattern applies to Malaysia, Australia, and most developed and developing nations, where potential driving factors include bureaucratic considerations and economic interests associated with centralised systems. Consequently, despite the widespread adoption of blockchain as a decentralised technology to enhance coordination across diverse entities, political and economic factors hinder grassroots initiatives to empower end-users by redistributing authority.

5.1. Position in Malaysia

Malaysia has a diverse array of energy-related legislation and policies that guide efforts towards achieving a resilient energy future, emphasising energy availability, reliability, and sustainability. This regulatory framework includes vital legislation such as the Electricity Supply Act 1990 (ESA 1990), the Energy Commission Act 2001, the Renewable Energy Act 2011, and the Sustainable Energy Development Authority Act 2011(Economic Planning Unit, 2022). Policies complement these legislations and empower stakeholders to address energy poverty and climate-related issues, including the National Energy Policy 2022–2040, National Renewable Energy Policy and Action Plan 2010, and National Energy Efficiency Action Plan 2015 (Economic Planning Unit, 2022).

The enactment of a new energy policy aligns existing soft-law and hard-law instruments with future orientations and energy targets. Additionally, it involves formulating unified action plans to address the energy trilemma through the development of integrated energy legislation and policies. Cross-sector collaboration is crucial for future-proofing Malaysia's energy structures and driving transformative changes aligned with the global energy transition. While actively facilitating the distribution of solar energy through the ongoing development of P2P, the recent policy also recognises the importance of ensuring more accessible access to capital and funding.

The Malaysia Energy Commission, a statutory body under the Energy Commission Act 2001, oversees the energy markets. The EC ensures efficiency and fair and effective market conduct in electricity generation, production, transmission, distribution, and supply. This responsibility encompasses promoting renewable energy, including necessary research and development activities (*Energy Commission Act 2001*).

The Ministry of Natural Resources, Environment and Climate Change (NRECC) regulates electricity tariffs through the Energy Commission under an Incentive Base Regulation (IBR) framework. IBR facilitates the development of electricity tariff setting (Kumar, Poudineh and Shamsuddin, 2021). The Commission, empowered by Section 26 ESA 1990, determines charges to ensure a reliable supply with tariffs that are reasonable and cost-reflective (*Energy Commission Act 2001*).

Further, Malaysia Energy Supply Industry (MESI) operates in a single-buyer market, where an independent single-buyer entity is responsible for buying electricity from Independent Power Producers and Tenaga Nasional Berhad to meet the demand in Peninsular Malaysia (Aziz, 2023). The single-buyer entity manages the day-to-day scheduling of generating units using the Least Cost Dispatch Scheduling Methodology (Energy Commission of Malaysia, 2018). However, the centralised nature of this single-buyer model may hinder P2P energy trading systems. Because the single-buyer entity acts as a central authority overseeing electricity procurement and demand fulfilment, the entity may not facilitate direct transactions or trading between individual energy producers and consumers (Energy Commission of Malaysia, 2018). This poses a challenge for implementing P2P energy trading despite its untapped potential. Energy settlement involves reconciling energy procured by energy suppliers from generators and producers with energy allocated or dispensed to consumers. This process ensures an equilibrium between generator procurement through term contracts and consumption, generating costs that consumers bear.

Nevertheless, in Malaysia, intertwined electricity generation strategies with economic development, social welfare, and political decision-making complicates policymaking to reflect the actual energy cost. Adopting DESs and DERs hinge upon network tariffs. The collective integration of decentralised and distributed generation must have the support of an enabling framework to dismantle barriers deep-rooted in energy monopolisation. An inadequate network tariff structure would inequitably distribute fixed system costs to active participants, disincentivising them from investing in DERs (Brown et al., 2020).

Traditionally, utility companies have been in charge of the complete energy supply chain, overseeing energy generation, transmission, and distribution to end-users. The potential for restructuring from centralised to DESs lies in its ability to transform traditional business models and redefine the roles and responsibilities of market facilitators. The ESA 1990 must undergo significant wholesale changes to integrate new market participants and decentralise energy resources effectively. Although the ultimate objective is to guarantee a dependable, secure, and accessible energy supply, the current situation of restricted authorised energy suppliers contradicts the goal of market deregulation.

The National Energy Policy centres on three key aspects: Firstly, "macroeconomic resilience and energy security" are pivotal for driving robust economic growth and ensuring financial well-being, heavily reliant on sustained energy security (Economic Planning Unit, 2022). Secondly, "social equitability and affordability" is directed towards achieving the goal of energy justice, which involves restoring equality and upholding due process and transparency through fair and just procedures (Economic Planning Unit, 2022). Thirdly, "environmental sustainability" is emphasised per Malaysia's commitment to the Paris Agreement, which ensures a harmonious and resilient socio-economic development that balances environmental considerations (Economic Planning Unit, 2022). These pillars serve as a foundation for fostering economic growth and achieving energy justice, steering Malaysia towards a sustainable future.

5.2. Position in Australia

The electricity system and the markets in the majority of Australian states and territories is subject to legislation under the National Electricity Law (NEL) and the National Electricity Rules (NER). Only Western Australia is subject to different legislative requirements, however it remains similar to other Australian states and territories (Australian Energy Market Operator, no date -a). The operation of the market in Australia does not support widespread trade of electricity, as settlement on the market is required (Battery Storage and Grid Integration Program, 2022). This is because of the gross pool approach of the market. The gross pool of energy is not a physical pool. But a virtual one, that supports the optimum level of electricity generation at five-minute intervals (Australian Energy Market Operator, no date -c). Up until 2021 the gross pool was subject to a 30-minute averaging, which meant bidding still took place in 5-minute intervals, however there was an average across a 30-minute period. This led to gaming of the system in some instances (Nikitopoulos and Mwampashi, 2023).

The Australian Energy Market (AEM) is managed by the Australian Energy Market Operator (AEMO). The AEMO was established by the Council of Australian Governments (COAG) in 2009 to manage the eastern and southeastern states' electricity market. Members include federal and state politicians and representatives from various businesses engaged in the National Electricity Market (NEM) (Australian Energy Market Operator, no date -b). The role of AEMO is to monitor supply and demand, voltage and frequency, and manage outages. The role of AEMO is not to regulate retail energy prices, rather the retail price is set by individual retail companies (Australian Energy Market Operator, no date -b).

There are many other collectives involved in the operation of the AEM in Australia. The Australian Energy Regulator (AER) regulates the markets and networks to ensure they are "secure, reliable and affordable" (Australian Energy Regulator, no date -b). The AER is charged with monitoring the compliance with the NER by retailers and other AEM participants. The NER are made by the Australian Energy Market Commission (AEMC). The role of the AEMC is to both make and amend the laws. The AEMC is consumer-focused with a mandate to advise on the "design of regulatory and energy market arrangements to benefit consumers in accordance with the national energy objectives (Energy Security Board, no date)."

The Energy Security Board (ESB) is relatively new to the NEM, as it was established in August of 2017. The purpose of the ESB was to provide "whole of system oversight for energy security and 'to drive better outcomes for consumers' (Energy Security Board, no date). The National Electricity Objective is contained within the National Electricity Law.

The objective aims to *promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:*

a. *price, quality, safety, reliability and security of supply of electricity; and*
b. *the reliability, safety and security of the national electricity system; and*
c. *the achievement of targets set by a participating jurisdiction—*
   i. *for reducing Australia's greenhouse gas emissions; or*
   ii. *that are likely to contribute to reducing Australia's greenhouse gas emissions.*" (*National Electricity (South Australia) Act 1996*)

Various institutional and governance bodies in Malaysia and Australia play distinct and pivotal roles in shaping their energy landscapes. Actively engaging in energy justice discussions, these entities prioritise crucial aspects, including energy affordability, availability, security, and reliability.

5.3. Challenge one: Access to the grid

The grid is a complex network through which electricity is delivered from power plants to the homes of consumers. It is a complex system of transmission towers and power lines. There is a significant cost to both establish and maintain this system (An et al., 2020, p. 2). It is physical in the sense that connections are required, however there is also a market that underpins the supply and demand of electricity in different parts of the world. These markets differ slightly and can impact who can participate in supplying energy to a broader consumer base.

To a large degree (unless consumers are connected through a microgrid), the trade of energy in P2P markets will be digital rather than physical. "Electricity is not a tangible good" and "consumption of electricity is functionally equivalent." However, the virtual nature of this trade is no different from the election for "green energy" that consumers in some jurisdictions opt for (Australian Energy Market Commission, 2017). If consumers were able to opt for this type of trading in a given area, it would send a price signal to retailers. Without access to the public grid to support prosumer–consumer trading, prosumers who wish to sell surplus energy can only pursue such activity via a private grid (Henni, Staudt and Weinhardt, 2021). Private distribution (including sharing and trading) is only allowed in specific energy communities in Netherlands, under the supervision of energy regulators, who oversee the energy flow (Olivadese et al., 2021, p. 5). Further, the replication and scaling of private grids are economically ineffective (Herrera Anchustegui, 2018).

In Malaysia and Australia, challenges in accessing the grid impede the operationalisation of P2P energy trading. With a single connection point for most consumers, the prevailing setup is structured around centralised systems, impeding bidirectional energy flows. Moreover, establishing separate connection points to facilitate trade demands additional investments, as existing network capacities must enhance efficiency and be suitably equipped to manage increased loads. When designing bidirectional energy mechanisms, addressing challenges such as voltage stability, thermal overloading, and other safety concerns is crucial.

5.3.1. Access to the grid: Malaysia

In Malaysia, for P2P energy trading systems to thrive, ensuring accessibility to the electricity grid is crucial. The primary obstacle involves securing the necessary grid access. Significant resistance persists in allowing prosumers to connect to the primary grid, especially in an energy market with a vertically integrated monopoly system. The imminent release of the third-party access (TPA) framework, expected in the coming months, marks a crucial step towards harnessing the benefits of prosumer activities in achieving renewable energy targets and implementing climate policies (Zainul, 2023). This regulatory mechanism ensures energy liberalisation and inclusivity through third-party access.

Further, due to Malaysia's current market structure, consumers and private enterprises face numerous obstacles in trading electricity using the public grid. Excessive wheeling charges may discourage prosumers from engaging in energy trading. Tenaga Nasional Berhad, a utility company in Malaysia, has made significant investments to strengthen the grid and ensure the reliability of RE systems (The Malaysian Reserve, 2022). However, Minister of Economy Rafizi Ramli proposes revising our targets to incorporate essential factors such as wheeling charge, capital expenditures, and operational costs (Zainul, 2023). The proposed revisions would greatly facilitate grid development and ultimately drive the stability and reliability of our energy infrastructure.

5.3.2. Access to the grid: Australia

Prosumers in Australia will generally have access to the grid and, as a result, are able to send excess energy to the network. However, before connecting any energy generator to the grid approval must be sought and given. Domestic generators are considered small-scale connections, and therefore different rules apply. Where a large scale connection is requested, Chapter 5 of the NER will be applicable, adding a layer of complexity to the process. To date, there has been no impediments for small-scale connections where a generation system complies with basic requirements.

For this reason, there are a large number of DERs in Australia that are connected to the distribution network. In April 2017, PV installations provided a capacity of 5.92 GW (Australian PV Institute, 2001, Australian Energy Market Commission, 2017). As of 30 September 2023, this has risen sharply with a current combined capacity of 32.9 GW (Australian PV Institute, 2001). The rapid increase of solar photovoltaic (PV) installations in the network has had an impact on some of the distribution networks, which means the distribution network is likely to be increasingly affected. "In Australia trades need to be facilitated and settled by a market operator with a retailer license to ensure that National Electricity Rules are abided by (Localvolts, 2023)." Network impacts, encompassing voltage stability, thermal overloading, and safety concerns, have led some distributors to limit solar PV installations in specific network areas (Australian Energy Market Commission, 2017). As of July 2023, most homes with rooftop solar are not able to send more than 5kW of electricity back to the grid as a means to prevent overloading the grid during the day (Williamson, 2023).

5.4. Challenge two: Network tariffs

The development of network tariff methodologies should aim to capture and respond to such signals more effectively, allowing participation in DESs with robust, flexible, and cost-reflective pricing structures. That is because, "Network tariff reform is a key enabler for the efficient deployment of distributed energy resources. All jurisdictions should allow the Distributed Network Service Providers (DNSPs) to progress the implementation of cost-reflective network tariffs including locational pricing (Australian Energy Market Commission, 2017)."

The cost of establishing, operating, and maintaining the distribution network in light of heightening utilisation to allow the exchange of surplus energy involves significant costs. While P2P energy trading is primarily digital, peers must physically transmit electricity in parallel with the transactions. The grid serves as an effective conduit in ensuring energy distribution and transmission. The prevailing argument is that increased P2P energy trading may drive investments to accommodate decentralised energy generation and bidirectional energy flows. Further, the distribution system operators (DSOs) must balance energy demand and supply within the network to address energy deficits and surpluses.

There is currently a lack of fit-for-purpose network tariff designs that are adaptive to emerging technological development in energy sectors. Conventional volumetric and fixed tariffs trigger the cross-subsidisation conundrum and raise various socio-technical debates. Existing tariffs are inapt to integrate prosumer-centric P2P and community-based energy trading (Felice et al., 2022, p. 2). Capacity-based tariffs incentivise active customers with heterogeneous energy profiles to reduce their peak demands and connection capacities (Willems and Zhou, 2020, pp. 1–2). Further, the espousal of dynamic tariffs accounts for spatial and temporal granularity, facilitating flexibility through the active participation of consumers and minimising grid congestion (Abdelmotteleb, Fumagalli and Gibescu, 2022). However, due to governance gridlocks, countries have yet to widely adopt capacity-based and dynamic tariffs (Karisma and Tehrani, 2024). In light of the deployment and proliferation of blockchain-enabled energy trading, regulators should amend existing tariff frameworks, as conventional frameworks distort price and economic signals and do not accurately reflect grid congestions. Redesigning network tariffs is no easy feat, as regulators must balance clear and competing priorities.

5.4.1. Network tariffs in Malaysia

In Malaysia, three primary tariff design structures are in place: fixed, capacity, and volumetric (Kumar, Poudineh and Shamsuddin, 2021). Domestic tariff rates are determined based on energy consumption, with a fixed monthly charge that remains unaffected by the amount of electricity consumed. For commercial and industrial consumers, fixed, capacity, and volumetric charges based on peak and non-peak periods account for the significant aspects of network pricing (Tenaga Nasional Berhad, no date). Industrial and commercial users can benefit from time-of-use, peak, and off-peak tariffs, providing flexibility and tailored pricing options. However, domestic consumers typically face fixed rates based on their tier or category (Tenaga Nasional Berhad, no date). Different categories of consumers are imposed distinct tariff rates for a more equitable cost distribution. The NRAs oversee and regulate these tariffs after obtaining input from DSOs and other relevant parties. It is important to note that the Minister of Energy, Water, and Communications formally endorses these electricity tariffs per Section 26 of the ESA 1990 (*Electricity Supply Act 1990*).

Scholars have emphasised the need to shift from volumetric consumption-based tariffs to capacity-based tariffs, as defining network tariff structures is crucial for the smooth functioning of P2P energy trading systems and effectively utilising DERs (Hoarau and Perez, 2019). Capacity-based charges, unlike volumetric tariffs, offer a more accurate representation of the actual costs involved in network usage, which can encourage consumers to adopt dynamically efficient behaviours and facilitate peak-shaving opportunities (Tomar et al., 2021). This shift aligns with the evolving energy landscape and paves the way for a more equitable and sustainable energy distribution system.

Higher costs of fossil fuels may increase P2P energy trading to mitigate energy costs. In contrast, high voltage surges at different points in the power system network can significantly raise concerns for DSOs. The reason for this is that just like network load amplification, there will be increases in expenses such as capital costs, overhead costs, system upgrade costs, and investments in the grid. These increases can impact the network, leading to inefficiencies and posing a risk to energy security.

In Malaysia, consumers are charged through volumetric tariffs, paying higher rates for greater energy consumption. Many places commonly employ this approach to cover both capital and operational costs (Kumar, Poudineh and Shamsuddin, 2021). However, the drawback is that volumetric tariffs offer little motivation for consumers to adopt dynamically efficient behaviour. While volumetric tariffs may incentivise the increase of DERs and P2P energy trading systems as tariffs are directly related to energy consumption, they may propagate network inefficiencies and result in financial instabilities for network operators (Hoarau and Perez, 2019). However, imposing fixed tariffs regardless of grid usage to recover costs and grid investments can lead to cross-subsidies and is therefore unfair to the passive consumer. To explain, affluent network users who can invest in DERs and actively engage in P2P energy trading can unfairly burden passive consumers even though the utilisation of the grid is higher amongst the more affluent users engaging in P2P energy trading schemes (Schittekatte and Meeus, 2018; Kulkarni and Kulkarni, 2020).

Decentralisation and depoliticisation are crucial concepts in energy sector reforms, particularly when considering initiatives such as increasing retail competition, unbundling, and implementing TPA frameworks. A significant barrier to effective tariff reform lies in the "politicisation" of electricity. In this context, politicisation refers to the influence of political considerations on decision-making processes related to electricity tariffs. Decentralisation, therefore, must accompany the "depoliticisation" of the electricity sector to ensure the most advantageous low-carbon economy and widespread use of RE, even as the intricate dynamics in various institutional contexts may continue to pose formidable barriers to achieving transparent and cost-reflective RE tariff rates.

5.4.2. Network tariffs in Australia

The operation of the market in Australia does not support widespread trade of electricity, as settlement on the market is required (Battery Storage and Grid Integration Program, 2022). This is because of the gross pool approach of the market. The gross pool of energy is not a physical pool. But a virtual one, that supports the optimum level of electricity generation at 5-minute intervals (Australian Energy Market Operator, no date -c). Up until 2021, the gross pool was subject to a 30-minute averaging, which meant bidding still took place in 5-minute intervals, however there was an average across a 30-minute period. This led to gaming of the system in some instances (Nikitopoulos and Mwampashi, 2023). The gross pool approach means that all electricity generators will receive a "spot price." In order to participate in the market, generators must fall into one of three categories. These categories are:

- Scheduled generators—with a capacity of 30 MW or more
- Non-scheduled generators with a capacity of less than 30 MW
- Semi-Scheduled Generators—have a capacity of equal to or greater than 30 MW and produce electricity intermittently" (*National Electricity Rules*, 2005)

Consumers in Australia have contractual relationships with retailers rather than generators, and the spot price paid to generators only makes up a small portion of a consumer's bill for electricity.

The Australian Energy Regulator recognises the importance of network tariff reform for the transition to a renewable energy electricity supply. Presently, consumers are offered contracts by the energy retailers where the terms and conditions of their electricity costs are determined in advance. A retailer's electricity charges include all costs for the supply of electricity to a consumer, including:

- Wholesale costs (generation of energy)
- Retail costs (the costs for the retailer in terms of market participation)
- Access costs (transmission and distribution of energy)
- Any additional costs such as those required to fund the renewable energy target.

On average, the wholesale electricity costs (network tariffs) make up only 34% of a consumer's electricity bill (Energy Facts Australia Climate Council, no date). Consumers will generally have an option to sign up for either fixed rates or variable rates over a 12-month period (depending on the services provided within their designated area).

The Australian Energy Regulator is responsible for reviewing the tariff charges by distributors to retailers, which are then passed on to their customers. The objective of the AER is, presently, to ensure that customers pay no more than is necessary to ensure the safe and secure supply of energy to all customers (Australian Energy Regulator, no date -b). This includes the requirement that the distributors make their tariffs cost-reflective. The objective of this tariff reform is to ensure that DERs are "integrated into the grid as efficiently as possible" (Australian Energy Regulator, no date -a). These reforms are gradual however, with most consumers still paying fixed tariff rates.

In summary, in Malaysia and Australia, challenges in accessing the grid hinder the effective implementation of P2P energy trading. With a single connection point for most consumers, the prevailing setup is structured around centralised systems, impeding bidirectional energy flows. Moreover, establishing separate connection points to facilitate trade demands additional investments, as existing network capacities must enhance efficiency and be suitably equipped to manage increased loads. When designing bidirectional energy mechanisms, addressing challenges such as voltage stability, thermal overloading, and other safety concerns is crucial.

5.5. Challenge three: Licensing

Licensing is crucial in the energy sector, serving multilateral objectives, particularly energy security. Licensees must comply with industry codes, standards, and provisions mandated by national legal and regulatory instruments. The lack of a comprehensive and enabling framework and imposition of onerous licensing requirements on prosumers impede their participation in energy markets and disproportionately hinder the deployment of blockchain (Karisma and Tehrani, 2024).

It is crucial to facilitate the role of prosumers in taking charge and modulating their production, consumption, and trading decisions, and precipitating the shift to prosumers as technology enablers by ensuring a level playing field considering the various financial, technical, and regulatory constraints. With the coming into force of DESs and the growth of prosumer-driven markets, ensuring adequate, proportionate, objective, transparent, simplified, and non-burdensome licensing requirements is pivotal (*Directive 2018/2001 on the Promotion of the Use of Energy from Renewable Sources*, 2018, *Directive 2019/944 on Common Rules for the Internal Market for Electricity and Amending Directive 2012/27/EU* 2019).

5.5.1. Licensing: Malaysia

According to the ESA 1990, a licence is required for any involvement in electricity supply activities. It is explicitly stipulated under Section 9 of the ESA 1990 that no person except the supply authority is allowed to utilise or provide energy from any installation under explicit authorisation through a licence or specific exemptions. In furtherance to Section 9(1) of the ESA 1990, Section 9(2) allows the Energy Commission, with the Minister's approval, to issue licences upon the payment of fees and the imposition of conditions considering the responsibilities highlighted under the ESA 1990 (*Electricity Supply Act 1990*).

The Electricity Regulations 1994, similarly, underscore various financial, technical, and administrative requirements for the issuance of licences. Further, while the Exemption Order [P.U. (B) 156)] allows the utilisation of PV systems for the purpose of generating electricity with a capacity of 5 kWh and below, trading of surplus electricity is not expressly provided (*Electricity Supply Act 1990: Electricity Supply (Exemption) Notification 1994: P.U. (B) 156*).

Stringent licensing regulations, while crucial to maintain energy security, might result in various deficiencies within blockchain-enabled trading platforms, potentially perpetuating a persistent challenge in establishing a prosumer-oriented energy market if not mitigated proactively.

Although Malaysia licenses private installations that align with the DERs, it restricts energy supply solely to the owner's premises. This position does not fully support the role of prosumers in DESs. Currently, the laws do not facilitate active participation in energy markets. Whether prosumers should acquire energy supply licences to enable multilateral transactions is still unclear. Furthermore, although individual or community-led prosumers may be interested in acquiring a licence, they will only grant it if applicants have a minimum paid-up capital equivalent to a percentage of the net capital cost of the project or connection charge (Energy Commission of Malaysia *Licensing*, no date).

This prerequisite could create barriers to entry for individual and collective prosumers, which hinders their ability to obtain licences and participate fully in energy markets due to their limited resources and funding compared to more established energy suppliers. Implementing market reform in Malaysia has the potential to create a dynamic landscape that enhances energy efficiency and promotes competition in energy supply operations. However, several hindrances are identified as follows. The ongoing reform efforts in Malaysia aim to boost competition in the generation and supply sectors through a TPA framework while promoting market liberalisation and active participation. However, the absence of a proper licensing mechanism can lead to network constraints and jeopardise the stability of distribution and transmission networks.

5.5.2. Licensing: Australia

"In Australia trades [of electricity] need to be facilitated and settled by a market operator with a retailer license to ensure that are abided by (Localvolts, 2023)."

Under the *National Energy Retail Law* in Australia, a person or a business who sells energy for the use by another person must have either a retailer authorisation or an exemption to hold a retailer authorisation (Australian Energy Regulator, 2022). The activities of energy selling under the retail law includes a wide range of activities, from the traditional retail supply of energy to landlord recovery of energy costs. These activities include where the sale of energy does not generate a profit (Australian Energy Regulator, 2022). An authorisation ensures uninterrupted supply of energy by ensuring that a retailer has the technical and organisational capacity to act as a retailer, has the necessary financial resources, and is generally suitable (Australian Energy Regulator, 2022). There are limited conditions for which a person or a business will be eligible for an exemption from this requirement, for which P2P energy trading would likely be suitable. This is particularly the case as an exemption will generally be issued where a sale of energy is incidental to a main business activity or is to a defined group of customers at a particular site. Although the likelihood of receiving an exemption for P2P energy trading is high, understanding the process and completing an application can still be onerous for individuals.

In essence, the reforms needed to the regulatory framework in Australia do not appear, on the face of it, to be overly problematic. Indeed, legislative changes could be easily implemented (although this would require cooperation across the eastern states of the nation along with acceptance by the Federal Government). However, the problem in implementing legislative changes will be in the negotiation and consultation process because in any legislative reform there are winners and losers. One could argue that if consumers (or prosumers) are the winners, then the losers will likely be the retailers, distributors, and potentially energy wholesalers. Each of these groups include powerful interests within the Australian economy, and as a result may be unwilling to relinquish the power and market share they presently enjoy. At the same time, with the need to reach ambitious climate change mitigation targets, the Australian governments may be left with little choice but to support a different approach in energy generation. All indications at present are that the government will encourage P2P trading; however, whether this will mean it will be realised at scale is another matter entirely.

The journey towards P2P energy trading in Malaysia began with a pilot programme alongside Power Ledger, an Australian leader in blockchain-powered energy marketplaces. This initiative highlights the need for broader discussion and engagement among stakeholders across various sectors. Building a diverse, adaptable, and interconnected regulatory framework for these emerging bottom-up energy markets is crucial to guiding comprehensive policy responses. While advocates for energy equity support the adoption of affordable, sustainable, and reliable renewable energy sources, regulators must swiftly address potential inequalities impacting passive users.

6. Conclusion

The aim of this article was to outline and analyse the legal and regulatory challenges of blockchain-enabled energy trading systems in Malaysia and Australia. A cross-national understanding of these challenges allows readers to navigate overlapping realms affecting countries' readiness for digital transformation towards a low-carbon economy.

The main argument posits that while P2P energy trading can facilitate the transition from fossil fuels to RE systems, it encounters challenges. As a transformative and decentralised technology, blockchain can overcome many virtual landscape challenges by ensuring immutable record-keeping and data integrity. With their high costs and potential single points of failure, centralised ledgers are functionally less effective. Despite blockchain's potential to optimise and create a conducive environment for thriving, there are inherent industry-specific challenges. Prosumer access barriers hinder individual and collective prosumers' entry, preventing P2P energy trading. Overcoming these hurdles, including issues like single connection points, is crucial for the widespread adoption of this trading method.

Examining tariff design structures in Malaysia and Australia reveals a need for cost-reflective and fit-for-purpose network tariff designs adaptive to blockchain transformations in energy landscapes. The politicisation of electricity can disincentivise end-users from participating in low-carbon energy trading markets, making decentralised and distributed RE systems dependent on network tariffs. While capacity-based and dynamic tariffs are still in progress, a future-proof implementation requires a proper tariff framework balancing clear and competing priorities. Another significant challenge is licensing. Energy suppliers, conventionally, must obtain licences and comply with various industry codes, standards, and provisions to ensure sustainable energy supply. Despite existing licence exemptions, their limited application due to market complexity and compliance requirements hinders new actors from engaging in prosumer-centric business models.

Decentralised energy systems can strengthen national energy security in light of increasing supply shortages and excessive resource exploitation by facilitating the operability and reliability of DERs that are pivotal for energy transition. The use of blockchain catalyses the shift from centralised to decentralised systems. While the technology ushers in a bottom-up, decentralised approach, ineffective institutional and governance strategies currently shape the trajectory. Additionally, it demands redefining operational models, potentially encountering resistance from established entities, which raises barriers to entry. Many questions persist at practical and theoretical levels, yet a unique vantage point emerges concerning DESs premised on energy democratisation.

In conclusion, achieving heightened readiness levels for implementing blockchain in energy trading systems requires effectively navigating legal barriers. Prospective avenues for future research include developing regulatory indicators to assess blockchain energy trading readiness and facilitating the creation of enabling instruments to ensure digital transformation viability in critical infrastructures. The successful implementation of blockchain in the energy sector depends on addressing industry-specific legal and regulatory challenges, as evidenced by the case studies of Malaysia and Australia. Overcoming legal inclusiveness issues, addressing uncertainty, and modernising legal frameworks to accommodate blockchain's decentralised nature are crucial steps for unlocking its potential. This article calls upon policymakers and regulators worldwide to engage with stakeholders, developing comprehensive frameworks that foster innovation and expedite blockchain adoption in the energy sector for a more efficient, inclusive, and sustainable future.

7. Recommendation

One of the key factors in enabling blockchain-based P2P energy trading in Malaysia is the recognition of third-party access to the electricity grid. Such recognition is essential for the trading system's competitive segments through legal and regulatory frameworks. Prosumers must have non-discriminatory access to the distribution grid without building a private grid. Regulators can facilitate this access by mandating contractual arrangements that outline wheeling charges and tariffs to cover the escalating grid costs. These charges must be non-discriminatory, cost-reflective, proportionate, and reasonable based on the services offered by system operators and to recoup capital and operational expenditures. Enhancing the regulatory framework by developing dynamic grid-management strategies and comprehensive safety standards to handle the increasing number of solar PV installations is crucial for facilitating blockchain-enabled P2P energy trading in Australia. The optimistic future of energy trading is further bolstered by the role of technology, such as smart meters and grid sensors, in mitigating issues like voltage stability and thermal overloading. Different tariff approaches and modalities are necessary for digitalising energy systems and transforming operations and business models.

Implementing efficient tariff reforms catering to the complexities of emerging business models is vital to address the second challenge hindering effective decentralisation and digitalisation. These reforms should uphold transparency and guarantee that renewable energy tariff rates accurately reflect the costs. In Australia, the AER, with its pivotal role in ensuring consumers are billed only for what is necessary to maintain a reliable and safe energy supply, provides a reassuring oversight. Consequently, distributors must introduce essential tariff reforms to integrate DERs into the power grid seamlessly.

It is crucial to establish a dynamic landscape to fully exploit the potential of blockchain-enabled P2P energy trading. This design, which strategically boosts energy efficiency and fosters competition in energy generation and supply, is not just a goal, but a necessity. It is the key to promoting market liberalisation, a crucial step in the evolution of the energy sector. Establishing effective licensing mechanisms that empower individuals and communities to lead prosumer-centred systems, where consumers also produce and sell energy, without imposing excessive financial, technical, and administrative demands is not only essential but also inspiring. These mechanisms will put power back into the people's hands, fostering a sense of ownership and responsibility in the energy sector. Furthermore, it is crucial to consider formulating licensing mechanisms to facilitate multilateral transactions and ensure the stability and security of distribution and transmission networks.

8. Future research

This article contributes to the scholarship emerging on industry-specific challenges in blockchain-enabled energy trading. There is much more to accomplish in this area. First, let us focus the discussion on specific challenges posed by blockchain adoption, fully exploring the limits and barriers and ensuring a granular exploration of this topic to account for changes in transitioning to decentralised energy markets. Future scholarship can draw on various methodological lenses, such as by conducting empirical work to thoroughly explore the challenges at the ground level of various nation-states with heterogeneous economic, regulatory, and political landscapes. Further, a detailed and comprehensive mapping of potential policy solutions can acknowledge the institutional and governance conflicts. Pluralistic and pragmatic approaches in shaping the legal frameworks of prosumers can, in light of their commercial and behavioural renewable energy profiles, heighten blockchain-enabled prosumer-centric initiatives and business models. In the changing world with the immense potential and promise of blockchain and DESs, future work is diverse, providing opportunities for researchers to explore the dynamics of law and technology in energy systems.

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