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Energy Sector Evolution: Perspectives on Energy Platforms and Energy Transition

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Abstract: Digital platforms are becoming more important in transforming the energy industry and altering the way we produce, distribute, and use energy. This paper explores the role of energy platforms in the transition towards renewable energy. We highlight, through real-life examples, that these platforms foster a participatory approach, convert consumers into proactive participants, democratize energy production, and encourage innovation in areas such as storage, electric mobility, and renewable project investments. Through a comprehensive review of the current literature, technological advancements, and emerging business models, we identify the possible key contributions of digital platforms to the energy sector. These platforms offer personalized user experiences, mutual benefits for users and companies, adaptability to market changes, support for peer-to-peer trade, and a reduction in bureaucracy. We then present a pioneering conceptual model by Liu et al. (2022), which integrates the energy cloud, digital platform, and transaction platform and we explore the business model of energy platforms. This business model is characterized by connectivity, innovative pricing, and revenue strategies independent of physical asset ownership. Advanced technologies like artificial intelligence and blockchain facilitate peer-to-peer energy trading, dynamic pricing, and a focus on transaction and access fees over traditional cost structures. Drawing on the business model and previous analysis we update the conceptual model for energy platforms to present a practical vision through a holistic approach.

Keywords: energy platforms; platforms; energy transition; renewable energy; digitalization

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1. Introduction

Historically, the energy sector took the lead towards innovation and digital technologies. The energy industry has been at the forefront of adopting information technology (IT) infrastructures. For instance, during the 1970s, power utilities emerged as early innovators in the digital waves, using IT solutions for grid management and operations [1]. This historical path is stressed by recent concerns. The Paris Agreement calls for a technology framework that aims to support the development and transfer of technology to improve greenhouse gas reductions. The framework encourages collaboration and the sharing of knowledge and technology, which can accelerate the adoption of sustainable energy solutions [2–4].

Furthermore, analysis by Accenture and the World Economic Forum [5] estimates that digital technologies could potentially reduce global emissions by 20% by 2050 across the three highest-emitting sectors: energy, materials, and mobility. Additionally, academic research, including refs. [6–9], highlights this significant impact of digitalization on the energy transition. Authors reveal the substantial contribution of digitalization to the energy transition and the vital role of digitalization in moderating CO_2 emissions. These technologies enhance energy efficiency and contribute to emission reductions.

Through platforms, digitalization emerges as a strong force in transforming various sectors, notably including the energy sector. Important transformations, influenced by digitalization trends in the energy sector, are taking place towards decentralized energy systems and greater consumer involvement. These changes are fostering the creation of digital platforms to address the unique challenges and opportunities within the energy sector [10]. In the last few years, this kind of platform-based approach in the energy sector has attracted attention and the idea of energy platforms has been implemented in different regions such as through, for example, the EU Energy Platform [11]. These platforms demonstrate how technology can lead the charge in reshaping the production, distribution, and consumption of energy. They are turning consumers into 'prosumers'—participants who not only consume but also produce and store energy [10].

The literature on energy platforms acknowledges the critical importance of digital technologies and platforms in enhancing productivity and expanding the renewable energy market. Such platforms are not only instrumental in managing energy consumption efficiently but also play a significant role in integrating renewable energy sources into the power grid, thereby promoting sustainability [12]. The literature also emphasizes collaborative energy management [13]. Moreover, researchers like refs. [14–16] address the emergence of different types of energy platforms, categorizing them as noteworthy advancements facilitating the direct exchange of energy between users. These platforms represent a significant shift in the energy market, where individuals can engage in the direct trading of energy.

Although the research underscores the significant technological advancements in integrating renewable sources into energy platforms, there remains a notable gap beyond specific technologies. Although there is a consensus on the benefits of these platforms, a comprehensive understanding of their functionality and the full range of benefits they offer users is still lacking. Additionally, there is a challenge in identifying both business and conceptual models that integrate all technical aspects to ensure the successful implementation of energy platforms.

This paper will try to fill the gap in the literature by identifying business and conceptual models for energy platforms and key elements that could drive a transition to sustainable consumption through energy platforms.

This paper aims to enhance the understanding of energy platforms by examining current initiatives and exploring how these platforms synergize with the production, distribution, and consumption of renewable energy sources. We aim to highlight the key attributes of energy platforms that could provide a unique experience for users and motivate their usage. We seek to present a business model for energy platforms and explore a conceptual model.

The paper is structured as follows: Section 2 gives a review of the literature with further detection of gaps in the existing literature. Section 3 identifies key drivers for platform success that foster the large-scale adoption of energy platforms. In Section 4, we explore initiatives that connect the energy transition to energy platforms and foster sustainable practices. Section 5 introduces a conceptual model, presents the business model, and concludes with an updated conceptual model for energy platforms. Finally, Section 6 summarizes the key findings and explores their wider implications.

2. Literature Review

Definitions are crucial because they create a shared framework for understanding and using language consistently across different sectors. They are important as they influence how policies and regulations view and handle assets or methods. Clear definitions help everyone understand key concepts the same way, which is essential for effective communication and cooperation. They also play a significant role in shaping policies and regulatory measures, affecting the management and regulation of various approaches and assets in and between sectors [17]. Interestingly, the term "platform" comes from the French "plate-form", which means a flat surface or a raised piece of land. It later started to be used to refer to a raised area for speeches and the places where passengers board or leave trains at train stations [18]. Energy platforms are digital frameworks that enable the connection between minor energy producers and consumers, supporting the exchange of transactions among them [19]. These platforms are essentially online marketplaces or networks that leverage technology to streamline the process of buying and selling energy.

The literature on energy platforms and links with the energy transition are relatively recent. We distinguish a collective narrative that underscores a shift from traditional, centralized energy systems to more distributed, digital, and platform-based models. This shift reflects broader technological and societal trends and is rooted in the conceptual foundations and evolution of energy platforms, as discussed by refs. [11,19]. These studies lay the groundwork for understanding the shift towards digitalization and decentralization, drawing parallels with developments in other industries like telecommunications, and suggesting a holistic approach that integrates hardware, software, and digital tools for efficient energy management.

A critical theme across the literature is societal engagement and consumer dynamics. For example, ref. [13] looks into how energy platforms can foster energy citizenship, enabling households to participate in virtual energy collectives, despite challenges related to agency, responsibility, and the definition of energy citizenship within digital contexts. Ref. [20] further explores the incentives and challenges of adopting peer-to-peer energy models, touching on participatory benefits, equitable distribution, and the management of decentralized renewable sources of energy.

Lastly, the technological, regulatory, and innovative frameworks constitute a cornerstone in facilitating the transition to digital energy platforms. Ref. [21] focuses on integrating IoT technologies to enhance user applications, while refs. [22,23] critically examine the regulatory and value frameworks necessary for balancing traditional values with those emerging from digitalization. Innovation within the sector is also addressed, with ref. [24] presenting a conceptual framework for green energy platforms and ref. [25] discussing the importance of digital privacy and security in fostering trust and facilitating flexible energy services.

The literature underscores the multifaceted nature of transitioning towards digital and platform-based energy systems. However, the current literature focuses largely on the technological, regulatory, and societal aspects of digital energy platforms, with less emphasis on the economic and business model innovations that underpin these platforms' sustainability and scalability. There is a need for research that delves into innovative business models tailored to digital energy platforms, especially models that can accommodate the complexities of energy systems, encourage stakeholder participation, ensure financial viability, and promote the integration of renewable energy sources.

3. Factors Driving Platformization

In the current digital environment, users form the heart of a unified network of interactive channels. The organizations that will succeed are those able to use these channels to engage with users and influence their actions. Moreover, digital platforms are evolving into personal assistants that serve as both an extension of the user and a sophisticated data processing tool. These platforms offer a technological foundation that enables social participants to create and access networks on a global scale, reflecting the diverse ways in which users or groups of users mix and match various online services based on their preferences [26,27].

Actually, the behavior, choices, and feedback of users are essential to creating a customized experience within a framework centered on the user. User behavior includes the ways in which individuals engage with content, their viewing patterns, the devices they employ, and the circumstances under which they access content. Preferences are related to the particular genres, themes, or kinds of content that a user finds appealing, whereas feedback offers valuable insights into their satisfaction and wishes. Through the examination of these aspects, platforms can develop user profiles and implement algorithms that adjust content recommendations, streaming quality, and viewing resolutions dynamically. This approach allows platforms to predict user preferences and provide a more customized and engaging experience that meets individual expectations [28]. To support this customization of experience, interfaces that are intuitive allow systems to adjust to the user and their preferences. Wearable devices are gathering information on users for health networks, and social media platforms like Facebook and Twitter are compiling data on everything from social events to individual preferences and actions. GPS technology is being incorporated into public and private transport, generating vast amounts of location data [27].

The personalized experience that platforms can provide could emphasize a user centricity in energy platform experiences tailored to individual preferences, consumption and behaviors. This approach supports the use of user data to create customized interfaces and recommendations, aiming to enhance engagement and satisfaction. The success of energy platforms lies in their ability to adapt to and predict user needs, which makes user centricity central for the development and success of energy platforms.

Moreover, the feedback and data generated from user interactions offer platform owners invaluable insights for continuous improvement and innovation, fostering a cycle of mutual growth and benefit. Interdependence drives both user satisfaction and economic success. Research conducted by scholars such as refs. [29–31] has examined, through various examples and contexts, customer attitudes to and acceptance of platforms. The outcomes of these studies indicate that users view these platforms as effective tools for promptly meeting their requirements for services or products. Specifically, they agree that platforms enhance efficiency and offer advantages, such as saving time and providing convenience. Consequently, there is a willingness among users to persist in using the digital platforms. Furthermore, the expectation of effort was also identified as having a positive and substantial influence on users' intentions to behave in certain ways.

On the other side, ref. [32] demonstrated in their research that digital platforms can derive profit from various innovative models, surpassing traditional theories of profitability. A comparative study of the 43 largest digital platform companies, publicly listed from 1995 to 2015, with a control group of 100 non-platform businesses in similar industries, revealed that both groups generated approximately $4.5 billion in annual revenue. Platform-based companies reached these sales figures with only half the workforce [33]. This indicates that digital platforms are not only redefining revenue generation strategies but also significantly outperforming conventional profit paradigms.

The literature collectively illuminates how digital platforms serve as catalysts for mutual benefits across the board. For users, they offer enhanced efficiency, convenience, and a tailored approach to accessing services and products. For platform companies, especially those that have established dominance in their markets, the ability to generate substantial revenues with a leaner workforce signifies a revolutionary approach to business operations.

The literature underscores the enhancement of managerial flexibility and adaptability within the context of digital platforms. Platforms empower business leaders to make informed, real-time decisions, effectively addressing potential disruptions. Ref. [34] emphasizes the critical role of metrics in digital platforms, noting their indispensability in evaluating platform success and garnering insights into consumer perceptions, thereby allowing managers to finely tune their strategies to align with consumer expectations.

During times of crisis, the value of digital platforms becomes even more pronounced, as evidenced by [35], who points out the increased reliance on digital platforms during the COVID-19 pandemic. This reliance underscores their essential role in fulfilling needs unmet by traditional economic systems. It highlights their ability to make operational continuity and adaptability in the face of continuous market changes. Ref. [36] observes that digital platforms facilitate the creation and maintenance of relationships by offering ease of use and flexibility. These features proved critical during the COVID-19 lockdowns, as digital platforms became crucial in maintaining operational continuity and facing the extensive restrictions.

There is also the evolving nature of platform technologies. This is highlighted by the continuous engagement of developers in cycles of modification, reinterpretation, and refinement of their applications. This process, characterized by prototyping, testing, and incorporating feedback, is exemplified by the flexibility inherent in digital platforms. This process enables a swift adaptation to changing user needs and preferences. This dynamism allows developers to quickly identify effective strategies and implement necessary adjustments with user demands [37].

Ref. [38] expands on this concept by illustrating how digital platforms have revolutionized traditional payment systems, removing the complexities tied to the physical aspects of payment terminals. Furthermore, these platforms enable dynamic routing of payments and data across various dimensions: territories, channels, partners, and endpoints. Similarly, ref. [34] emphasizes the transformative role of digital platforms in enabling economic participation, facilitating a shift where thousands can engage not only as consumers but also as producers and sellers.

Through the literature, we find that platforms are characterized by flexibility, adaptability, and the capacity to innovate. This adaptability enhances operational efficiency and impacts economic participation and growth.

Besides the previously mentioned features, the concept of the "sharing economy" is increasingly becoming a significant facet of the modern economic landscape. Defined in a more focused manner, the "sharing economy" denotes the peer-to-peer (P2P) lending of assets through an online platform, where "sharing" emphasizes access over possession [39]. The rise of P2P commerce, enabled by these innovative platforms, is having various economic impacts. These include decreased costs for transactions within marketplaces, efficient production, the generation of more output from an identical level of inputs, and the introduction of novel production and exchange opportunities. Furthermore, these platforms are anticipated to drive innovation by fostering 'microentrepreneurship', thereby enabling individuals who were once limited to roles within traditional companies to pursue new ventures [40].

The rapid evolution of technology, particularly through the growth of digital governance and platforms, has led some experts to speculate about the potential decline of traditional bureaucratic structures [41].

Ref. [42] highlights how digital platforms are transforming traditional bureaucratic governance models. Platforms enable a shift away from bureaucratic governance towards more participatory and interactive models. These platforms facilitate collaboration between citizens and administration, promoting the co-creation of value and sustainable development by leveraging digital technologies to orchestrate collective action and pursue collective goals.

The uprising organizational model is platforms linking together a network of entities and services to create what is known as an ecosystem. This transformation signifies that the core models for both administrative and business organizations will evolve into platform-based structures. Such a shift represents a significant move away from the traditional Weberian bureaucratic system (the term Weberian bureaucracy refers to Max Weber's (1864–1920) ideal type (or model) of rational bureaucracy [43]) [44].

The literature emphasizes that digital platforms represent a step toward user-centric design and managerial flexibility which ensures crisis resilience and transformative potential. These characteristics underscore the influence platforms have on organizational strategies, economic models, and societal structures. Each key element has its unique implications. The centric design diverges from traditional approaches by prioritizing individual user preferences. In contrast, managerial flexibility focuses on the ability of platform managers to swiftly adapt operational strategies in response to dynamic market conditions or disruptions. The economic efficiency of digital platforms mainly exists in the ability to maximize output while minimizing resources. This efficiency supports structures like peer-to-peer trade and the sharing economy. Finally, the shift towards participatory governance represents a move from decision-making processes to a more inclusive and interactive governance

Digital platforms could significantly contribute to the energy transition through several key offerings. The energy sector could take advantage of user engagement based on personalized experiences, individual preferences, and behaviors. It could also benefit from increasing efficiency and convenience for users, while enabling companies to generate higher revenues with fewer resources. This would provide a solution to changing market demands by quick adaptation. Moreover, the energy sector will have an opportunity for large peer-to-peer trade practices. Finally, platforms contribute to fighting bureaucracy in the energy sector and move toward participatory governance.

4. How Platforms Are Shaping the Energy Transition: Production, Distribution, and Consumption

Established energy providers, grid managers, and independent entities are currently creating collaborative platforms for distributed energy systems. These systems often involve setting up solar panels and storage batteries in individual properties, which are then collectively managed as "virtual power plants". Moreover, platform concepts like community energy, peer-to-peer trading, virtual marketplaces, or access platforms have been tested worldwide. These trials are being conducted at different scales in countries such as France, Denmark, the USA, Korea, and Japan [1,14].

Specifically, community and access platforms are crucial conduits linking consumers to the production of renewable energy, facilitating a more distributed and participatory energy generation landscape [14].

Within the category of community platforms, entities like Germany's Sonnen Community and Australia's Shinehub are significantly influencing the generation and production of energy. These platforms allow for the communal generation of renewable energy, facilitating a shared management of electricity production and distribution. The Sonnen Community, for example, empowers its users to produce, share, and store solar energy, effectively creating a decentralized network of energy producers. Shinehub in Australia operates similarly, allowing consumers to participate in community solar projects, contributing to the generation of renewable energy within the community [14]. Platforms like Germany's Sonnen Community and Australia's Shinehub exemplify the shift towards decentralized and participatory energy generation, allowing consumers to actively engage in renewable energy production.

In a broad sense, applications of behind-the-meter (BTM) platforms can be categorized into three main sectors: distributed storage, electric mobility, and peer-to-peer energy transactions. More specifically, the storage domain predominantly consists of companies that manufacture batteries, such as Tesla and Sonnen, along with a growing number of new entrants. These companies, along with their counterparts, are in the midst of developing platforms that consolidate the capacities of various distributed batteries to form a virtual power plant. This plant can then supply services as needed to the system operator, local power networks, and utility companies. The goal for these firms seems to be the expansion of their platforms to include a broader array of third-party residential batteries, electric vehicle (EV) batteries, and batteries for the Internet of Things (IoT)—and possibly other devices or assets. With the decreasing costs of information and communication technology (ICT) and the increased ability to monitor and control BTM devices remotely, there is potential to broaden the business model to encompass smaller business clients and, eventually, residential consumers as well [15].

Within the access platforms, initiatives such as the Netherlands' ZonnepanelenDelen and the USA's SunShare are reshaping the way energy production is invested in and owned. These platforms enable individuals to financially contribute to renewable energy projects, such as solar or wind farms, without requiring them to have the physical infrastructure on their property. Through these investments, participants are directly supporting the production of renewable energy, which not only supplies the grid with cleaner power but also provides them with a return on investment, linking their contributions to tangible energy production outcomes [14].

Additionally, the peer-to-peer (P2P) framework, inspired by the concept of the sharing economy, proposes a paradigm similar to that of Airbnb and Uber for the electrical grid. This model employs a P2P platform to enable direct exchanges of electricity and related services between producers and consumers. In this arrangement, the distribution grid is compensated with a management fee and a tariff for its role in distribution, with the rates varying based on the type of service, the volume of electricity, and the distance between the involved parties. These markets may encompass a variety of contractual agreements, ranging from long-term commitments to short-term associations, among entities involved in the production, storage, and sale of electricity. Numerous peer-to-peer energy trading projects have emerged in recent years. Some initiatives rely on algorithms, like Powerpeers in the Netherlands and Open Utility (now known as Piclo Flex) in the UK, while others use distributed ledger technologies (DLTs), including blockchain [15,16,45]. The practice of peer-to-peer trading emerges as a forward-thinking strategy for energy management, providing economic advantages to proactive consumers who trade their energy as commodities and services. It is anticipated that peer-to-peer energy trading will contribute to the electricity grid's efficiency by diminishing peak demands, reducing the necessity for reserves, and minimizing network losses [46].

Access platforms and the peer-to-peer model are redefining investment and ownership in energy production, enabling broader consumer participation without the need for physical infrastructure.

Business models based on platforms are becoming increasingly significant in the electric mobility sector. For example, Motionwerk's Share & Charge, using Ethereum's open-source blockchain technology, allows individuals to locate parking and smart charging stations. It simplifies transactions by facilitating billing and settlements across various service providers in the ecosystem. The advantage of a service that enables electric vehicle (EV) drivers to access multiple charging providers across vast regions is set to become more pronounced as the shift towards EVs accelerates in the coming years. Toyota is in the process of creating a mobility services platform aimed at leveraging versatile, specifically designed autonomous vehicles. Initial collaborators include notable companies such as Amazon, DiDi, Mazda, Pizza Hut, and UBER, working together on vehicle design, application development, and validation activities. In parallel, battery expert Blue Solutions has introduced the largest all-electric car-sharing service in America, further diminishing the boundaries between public and private transportation methods. The anticipated surge in EV adoption indicates that there will initially be space for a variety of platforms and participants in the market. This phase is expected to last until certain business models prove to be superior and begin to dominate the industry [15].

Moreover, the concept of a localized virtual marketplace is becoming increasingly central to the evolution of business models aimed at the efficient financing and management of microgrid operations. These operations go beyond just producing and providing power; they include a variety of services related to electricity. By expanding offerings, project developers can significantly reduce investment risks. Key to this development is the growing adoption of the pay-as-you-go model, enhanced by smart meters and online platforms. These platforms are set to further develop, streamlining access and payments for services provided by microgrid operators and thus cementing the foundation of a virtual marketplace at the local level [47–49]

This evolution towards platform-based models is streamlining the integration of the production, consumption, and distribution of energy, thereby starting a new era of platformization in the energy sector.

5. Energy Platform Business and Conceptual Models

Although scientists acknowledge the importance of platforms in advancing a sustainable energy transition and the existence of successful energy platform models, it is still rare to find a conceptual model for energy transition and a general business model that aligns with previous experiences to provide a clear, practical framework for energy platforms. Ref. [11] presents one of these important contributions with their conceptual model for energy platforms (Figure 1).

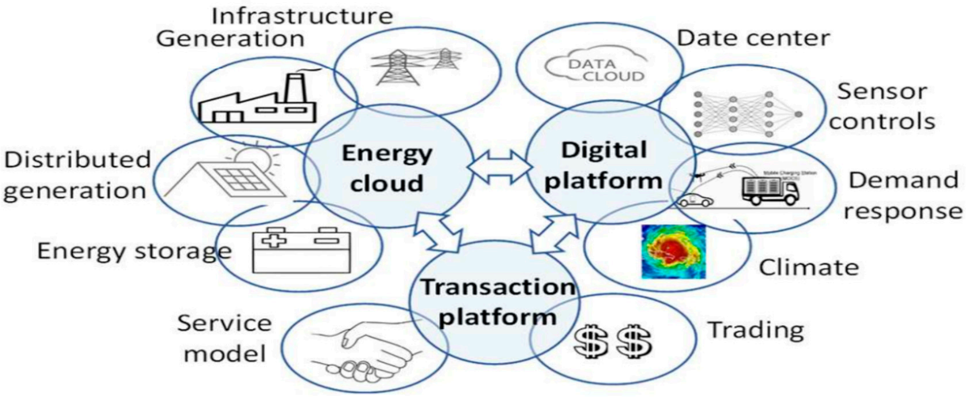

Figure 1. Energy platform conceptual model (Source: [11]).

The conceptual model of a smart energy system, as outlined by [11], offers a comprehensive framework for an advanced energy network. The first component is the "energy cloud", which involves hardware and software for generating, storing, controlling, and transmitting electricity and data. This includes physical infrastructure (energy production facilities, transmission systems, energy storage units, and electric vehicle charging stations) and digital assets like energy consumption data and cloud services. The second component is the "digital platform", which makes an interconnected network to facilitate the efficient flow of energy and information among various stakeholders. Stakeholders include energy producers, utilities, and consumers. This platform leverages controls and algorithms to manage physical and digital assets. The third component, the "transaction mechanism", includes innovative approach models and allows standard and new energy players to improve efficiency and create economic benefits. It also encourages the use of renewable energy and helps reduce carbon emissions by offering various incentives.

Although the business model proposed by [11] is one of the few models that provide a general and comprehensive conceptual framework for energy platforms, it still omits some elements. This model was based on the telecommunications industry's history and models, which may lead to the assumption that it did not consider certain aspects that could be specific and important for energy platforms. To identify these elements, we will proceed to study the business model for energy platforms. Drawing from that business model and the previous conceptual model, we aim to formulate a clearer picture of a potential conceptual framework.

As explained by [50], the concept of a business has been the subject of extensive research over the past few decades. Numerous scholars link the idea of a business model to four key inquiries:

- Who? Identifying the target audience for whom the company generates value;
- What? Defining the products or services the company provides to its customers;
- How? Describing the process through which the company's offerings are produced;
- What's in it? Considering the financial implications for the company.

Platforms are revolutionizing the business world by offering a highly effective and profitable model. These platforms, including Uber, Airbnb, Instacart, and Google, act as thin layers connecting a wide range of providers and customers. They eliminate the need to own physical assets or manage goods and services directly, functioning instead as dynamic online marketplaces. According to the network externalities theory, this model's success partly derives from the fact that the value of these platforms increases as more users join, creating a virtuous cycle of growth. This approach has led to rapid growth, making such companies some of the fastest-growing in history. By leveraging extensive supply networks and reaching large audiences, these platforms generate significant revenue without the traditional overheads. This shift in business operations has also changed how we interact with service providers. For instance, instead of relying on traditional mobile operators, services like WhatsApp have become more valuable to us by offering essential functionalities and monetizing our engagement. The widespread adoption of such platforms is influenced by their performance expectancy, ease of use, and the social influence of other users, reinforcing the network externalities effect. Moreover, in the context of the sharing economy, the idea of virtual ownership is becoming increasingly important. It allows users to access and influence goods and services without owning them physically. This model promotes a significant shift in how individuals use and perceive ownership, empowering them to make meaningful choices about their lifestyles and environments. (Figure 2) [15,51–54].

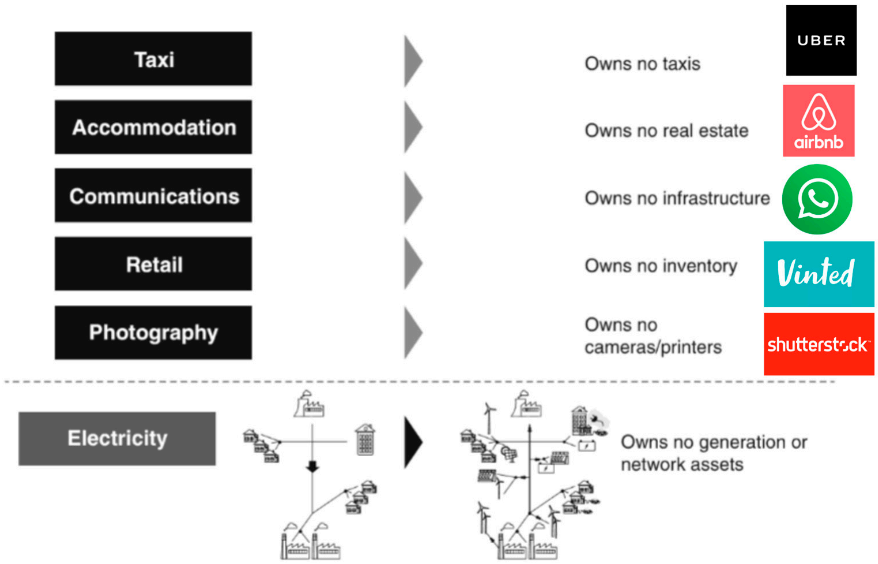

Figure 2. Platform ownership model across industries (Source: Adapted from [15]).

Understanding that the traditional profit theory does not adequately apply to the evolving digital economy, new profit mechanisms should be presented [32]. Furthermore, much attention should be paid to pricing strategies. The analysis of successful platforms and their 209 competitors revealed that failures often resulted from pricing errors, either by undercharging or overcharging on one market side, excessive subsidies to platform participants, or late market entry. These failures underscore the importance of innovative pricing strategies [33]. Innovative pricing strategies play a crucial role in differentiating services and attracting users to energy platforms. Strategies such as freemium models, pay-as-you-go with subscription fees, surge pricing during peak demand, and discounts during periods of low demand, provide flexibility and reward users. These approaches adjust prices based on real-time changes in demand, mirroring the smart pricing system utilized by Airbnb. Moreover, platforms like Alipay exemplify the transformative power of scale on pricing strategies, where competitive rates are made possible by a large user base and high payment volumes, significantly contributing to profitability. Within this ecosystem, platform providers have developed various revenue models to monetize their services. For instance, they may charge energy companies for access, akin to the fees associated with switching sites, or they may opt for a transaction-based model, taking a percentage cut from the value of each transaction. This latter approach is a common practice across various industries, where a fee is levied for each transaction performed on the platform. An additional example of the revenue stream for energy platforms emerges directly from the customers, who may choose to pay the platform a fee for the convenience of selecting the best deals and facilitating service switches. This model becomes particularly enticing when integrated with smart home/automated demand response (DR) offerings, effectively marrying two distinct business models. Through this integration, platforms can deliver a comprehensive solution that not only enables users to manage their energy consumption more efficiently but also leverages innovative pricing and revenue models to sustain and expand the platform's operations [15,55].

Ref. [15] argues that the growth of energy storage platforms is supported by the reduced expenses associated with information and communication technology, as well as improvements in the ability to monitor and control systems remotely. This suggests a potential for these services to become accessible to smaller businesses and individual household consumers in the future. This can be seen through the network externalities theory, indicating that as these platforms become more accessible and widely used, their value to each user increases, encouraging further adoption.

The concept of network externalities, alternatively known as network effects, is crucial to understand the dynamics of digital platforms within the energy transition. This concept suggests that a product's or service's value grows as the number of its users increases [54,56]. The theory is further nuanced by distinguishing between direct and indirect network externalities. Direct network externalities manifest when the value of a product or service is directly linked with an increase in its users. Conversely, indirect network externalities emerge when the growth in the user base enhances value through the growing availability or quality improvement of complementary products or services [57]. The importance of network externalities, especially with the emergence of digital platforms that link users, services, and products in new ways is shown in a number of examples: social media, online shopping, and related software, where the more people use them, the more valuable they become. This helps them grow quickly and makes it hard for new companies to compete [34]. Drawing from the network externalities theory, energy platforms can increase their value by continuously expanding their user base. In the same way as for various digital platforms, this concept suggests that energy platforms derive substantial value and profitability from network externalities, rather than solely relying on traditional revenue streams. This highlights the unique advantage of leveraging network effects, where the platform becomes more valuable to each user as more participants join, distinguishing these platforms from conventional business models that depend primarily on direct sales or service fees.

The foundational technology behind platform-based business models, particularly in sectors such as e-mobility, is both complex and vital for their operational success. Increasingly, companies are adopting blockchain technology as the base for their daily operations. Specifically, in the context of electronic mobility, platforms frequently employ sophisticated blockchain technology to facilitate secure and transparent transactions. Additionally, they use smart contracts for automated billing and settlement processes. The adoption of blockchain technology, especially Ethereum, guarantees that transactions are permanent, traceable, and reliable. This reliability is crucial for platforms managing transactions between multiple providers and users in different locations. Within the Ethereum framework, blockchain is powered by smart contracts. These are autonomous programs that offer benefits for platform-based business models [15,58–60].

In recent years, a number of peer-to-peer energy trading initiatives have emerged, with many more anticipated to follow. Among these, several leverage algorithm-based approaches and utilize distributed ledger technologies (DLTs), blockchain being a notable example. Such technologies ensure transaction records are immutable across numerous computers offering a decentralized model that eliminates the need for a central authority. However, a significant challenge with this model is its governance structure, which complicates adjustments to the system in response to changing conditions, leading to various adaptations and alternatives, known as "forks", in the blockchain domain. A prominent example in this sector is LO3 Energy, which gained attention in April 2016 by facilitating a blockchain-enabled energy transaction between neighbors in a Brooklyn micro-grid. Despite the initial excitement, concerns have been raised about whether current blockchain technologies can scale effectively and affordably enough to support widespread peer-to-peer transactions. To overcome these limitations, IOTA introduced a DLT called the Tangle, designed for high-volume Internet of Things (IoT) transactions. In the Tangle system, users validate two prior transactions through a proof of work to execute their own, without any rewards or transaction fees. Although these developments are still in their infancy, IOTA's approach, integrating peer-to-peer energy trading into a broader framework for machine-to-machine transactions, represents a potentially significant advancement in this evolving field [15]. This evolution illustrates how platforms seek to simplify user interactions and adapt to the evolving expectations of their user base.

Additionally, artificial intelligence (AI) plays a pivotal role in enhancing operational efficiency, ranging from customizing user interactions to accurately forecasting demand and managing resources. Artificial intelligence (AI) serves dual purposes: firstly, it supports power enterprise applications through the provision of algorithms, models, and service frameworks; secondly, it offers extensive capabilities for processing diverse datasets, maintaining algorithm libraries, delivering intelligent services, managing models, and facilitating typical application scenarios for business personnel at various levels. The development of this platform architecture not only overcomes data silos, enhancing technology portability, but also prevents the redundancy of investments by mitigating the need for repeated infrastructure developments. This foundational work supports the establishment of a "platform + application + service" ecosystem [15,61].

The business model canvas (BMC) simplifies the understanding of business models while effectively capturing their complexities. The BMC is composed of nine essential elements: customer segments, value proposition, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure. [62]. To answer the questions of business model inquiries [49] and to simplify the previously discussed elements, we will try below to summarize them under the BMC.

Value Propositions: Energy platforms enable interactions between energy providers and consumers without the need for physical assets. These platforms use digital technology to offer a wide range of services. This includes energy consumption management, cost optimization, and facilitating energy trades. They effectively act as dynamic marketplaces for energy services. They drive better accessibility to energy services with sustainable practices by reducing physical resources, and introducing efficiency in consumption [15,54].

Key Resources: ICT infrastructure for data management, blockchain technology for secure transactions, DLTs for decentralized peer-to-peer trading, and AI for operational efficiency [15,58,60].

Customer Segments: Energy platforms target two primary customer segments: First, individual consumers looking for energy efficiency and cost reductions. Second, energy providers looking for efficient market access to a broad customer base. The consumer base includes residential users, small businesses, and larger commercial clients [15].

Channels: The main channels through which energy platforms operate are digital, user-friendly websites and sophisticated mobile applications. These digital channels make it easy for both consumers and providers to access and use a platform's services. The importance of these channels is that they facilitate real-time interactions and service delivery. This will facilitate the high responsiveness and adaptability needed for the success of energy platforms. [15].

Customer Relationships: Energy platforms use advanced automated tools and personalized communication strategies. These platforms use artificial intelligence to analyze user data and provide customized recommendations for energy savings. They provide personalized interactions that enhance customer satisfaction and customer retention and to build engagement by giving users the ability to make decisions about their energy use. Customer support mechanisms are also very important. Dedicated services to address inquiries and issues provide a mechanism to build trust and reliability [15,61].

Revenue Streams: Innovative revenue models characterize the energy platforms. They involve transaction fees that are charged to energy providers. Subscription models or premium services offer features like advanced energy analytics, priority customer support, or additional management tools for a fee. Additionally, dynamic pricing strategies are applied. They adjust service prices in real time based on demand fluctuations to maximize profitability and adapt to market conditions. For revenues, blockchain plays the role of facilitating secure and transparent peer-to-peer energy transactions [46].

Key Activities: This includes the management of the platform technology, continuous development and upgrading of the interface, marketing activities to attract new users, and the integration of new energy providers. Furthermore, AI and blockchain are critical in the activities of energy platforms. They provide the security and efficiency of the platforms [61].

Key Partnerships: Collaborations with energy providers, technology service firms, regulatory bodies, and even competitors. These partnerships are an important way to access advanced technologies and offer a broad range of energy options [15].

Cost Structure: The costs are primarily in the areas of technology development, maintenance, marketing, and customer support. As digital platforms, they benefit from lower costs compared to traditional energy companies, but they must invest significantly in technology and data security [15,59].

The business model for energy platforms introduced by the analytical framework focuses on connectivity, innovative pricing, and revenue strategies without the need for owning physical assets, and the use of cutting-edge technologies like AI and blockchain to enable peer-to-peer energy trading. This model makes a move towards virtual ownership and operational agility within the energy sector, offering the promise of transformation through decentralized and user-centric services. This general business model allows extending the conceptual model by [11] and gives further insights.

Although the conceptual model for energy platforms by [11] is one of the first, it still lacks some specifications. We attempted to identify these elements through an analysis of business model characteristics. Figure 3 presents a more advanced and detailed conceptual model for energy platforms that may better serve practical applications. It provides a visualization of the internal workings of the energy cloud, clearly including both AI and blockchain technologies within its operations. Additionally, the explicit illustration of network externalities underscores the increasing value derived from an expanding user base which makes a critical pillar for energy platform systems. The updated conceptual model offers a clear integration of different components into the overall system. The interconnections are more defined in terms of their function (energy flow, data flow, or financial transactions). Furthermore, the model delineates the bidirectional relationships between the transaction platform and the service model, illustrating the flow of services and financial transactions with clarity. This illustration outlines the system's acknowledgment of the reciprocity between service provision and revenue generation.

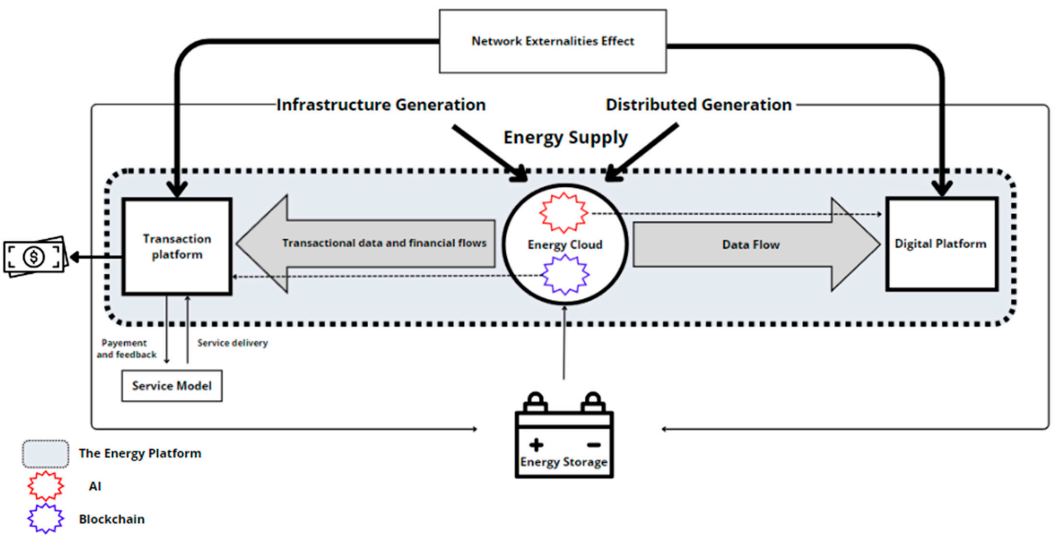

Figure 3. An updated conceptual model for energy platforms (Source: by author).

6. Conclusions

This paper underscores the transformative potential of energy platforms. These platforms not only foster the integration of renewable energy resources but also promote a participatory approach to energy management and transform consumers into proactive participants.

We highlight that the transition towards renewable energy and its distribution is increasingly being influenced by platform-based models, revolutionizing how energy is produced, consumed, and managed. Collaborative platforms, established by a range of stakeholders including traditional energy providers, new entrants, and community initiatives, are facilitating the shift. Virtual power plants, community energy projects, and peer-to-peer trading platforms exemplify this transition, enabling individuals and communities to actively participate in renewable energy production and distribution. These platforms democratize energy production and foster innovation in storage, electric mobility, and investment in renewable projects.

A critical examination of the current literature, technological trends, and emerging business models highlights the important contributions of digital platforms in shaping social and economic habits. These models offer several key elements that could shape a digital energy transition through energy platforms. First, they provide a user centric experience. The centricity of this experience provides personalized experiences, tailored to individual preferences and behaviors. Such experience is fundamental for user engagement in reducing consumption and moving to efficient and renewable energies. Second, these platforms also offer mutual benefits by fulfilling user needs while enabling companies to generate higher revenues with fewer resources. Third, the flexibility of platforms allows for quick adaptation to changing market demands, ensuring that services and products remain aligned with consumer needs. Fourth, platforms facilitate peer-to-peer trade, supporting the sharing economy and innovative energy management strategies. Finally, they contribute to reducing bureaucracy by moving away from traditional governance models towards more participatory and interactive frameworks.

The work by [11] presents a pioneering conceptual model for smart energy systems that aligns with the business models of energy platforms. It highlights the integration of three critical components: the energy cloud, the digital platform, and the transaction platform.

We find through our examination that the business model for energy platforms is characterized also by three main ideas: connectivity, innovative pricing, and revenue strategies that do not rely on owning physical assets. First, these platforms use advanced technologies such as artificial intelligence and blockchain to facilitate peer-to-peer energy trading. This approach eliminates the need for physical asset ownership and enables direct transactions between producers and consumers. Second, the value proposition offered to customers, ranging from residential to industrial sectors, focuses on secure and efficient transactions along with dynamic pricing that responds to demand fluctuations. This ensures that the service caters effectively to a diverse customer base. Third, the revenue model for these platforms is primarily built around access and transaction fees, while their cost structure is largely concentrated on investing in technological development and maintaining operational efficiency.

Drawing on insights from the business model and the previous sections we updated the conceptual model by [11] in an attempt to provide a more comprehensive framework and to include omitted elements. The heart of the conceptual model for energy platforms is the energy cloud. It is central to managing the flow of energy and information across the network (production, distribution, and storage), and integrating technologies like blockchain, AI, and machine learning to enhance efficiency and sustainability. It provides a sophisticated fusion of energy infrastructures with intangible digital assets. This is crucial for smooth generation, storage, and distribution of energy. The conceptual model of an energy platform is characterized by advanced technological and operational components. Part of it is the transaction platform that provides a nexus for service and financial exchanges. An integral digital platform serves as the conduit for data. This part of an energy platform is essential to managing the complex actions between the energy network's stakeholders and resources. Moreover, infrastructure generation and distributed generation take a proactive stance towards the expansion of energy production capacities. Energy storage within the model underlines its importance as a stabilizing element in aligning energy supply with fluctuating demands. Moreover, the conceptual model takes into consideration the network externalities effect. It underscores the incremental value garnered with each participant's addition. The model highlights the responsive and adaptive nature of energy platforms to user interactions and service refinement. The bidirectional relationships across various components of the model illustrate the reciprocity of energy, data, and financial flows.

Further research is necessary to explore the emerging trend of energy platforms. This research could expand upon both the business model and the conceptual model to investigate potential barriers to the adoption of these platforms. A study of the barriers that may limit the use of these platforms is particularly important, given our findings that these platforms rely on network externalities for their survival. This examination could be based on empirical investigations or surveys that provide a broader perspective on the unified theory of acceptance and use of technology by Venkatesh et al. [53].

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