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Barriers for Prosumers' Open Business Models: A Resource-Based View on Assets and Data-Sharing in Electricity Markets †

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Abstract: This article explores the barriers for open business models in support of sustainability in electricity markets. It puts forward privacy and data protection concerns about sharing prosumers' physical assets as well as data due to to their critical role in decentralized modes of electricity/flexibility trading. In particular, it uses a multiple case study approach to identify actors' resources, examine other interested actors in each resource, define their objectives, and consider privacy and data protection concerns of sharing prosumers' physical assets and data. The findings yield new insights into sharing opportunities beyond electricity/flexibility trading. In doing so, our study contributes to theories of the firm by applying the resource-based view in a new context and to the business model literature by shedding light on barriers in applying open business models.

Keywords: circular business model; open business model; sharing economy; circular economy; peer-to-peer; electricity trading

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1. Introduction

Adverse results of climate change which are increasingly manifesting around the globe [1] have made combating climate change an international mission [2]. The European Green Deal [3] and Paris Agreement [4] are two examples of international efforts to fight climate change. Energy transition as a path from "status quo to the envisioned future" [5] is said to be one of the most effective preventive acts against climate change [6].

While a considerable share of the extracted energy (from any source), before consumption, is transformed into electricity [7], the electricity industry is experiencing a rapid change toward more digital and decentralized forms of commercial interactions [8]. The electricity market is a highly regulated market that has been dominantly controlled by governments, with a clear division of labor and established roles [9]. In this situation, innovations do not frequently happen at the level of firms [10]. Nevertheless, digital and decentralized forms of commercial interactions are said to transform the industry from the bottom up [11]. Technological breakthroughs in the production of high-capacity batteries and solar panels at low prices, and the prevalence of smart devices, have facilitated the emergence of new market models (e.g., peer-to-peer, community self-consumption, and transactive energy models) [12]. Accordingly, electricity markets are witnessing the emergence of new types of multipolar innovation ecosystems around these models [13,14]. Not only do they innovate the paradigms of value generation and capturing, they also transcend firms' boundaries and transform a wide range of established organizations [15].

The wave of the 5D global energy megatrends, namely, decarbonization, decentralization, digital transformation, democratization, and disruption-as-usual, is said to have accelerated the shift from the conventional electricity paradigm to a new era of decentralized, distributed, clean, and smart energy systems [16]. The interactions between the urgent need to tackle climate change, advances in information and communication technologies (ICTs), and the proliferation of distributed energy resources, batteries, and home energy management systems, are, to a large extent, the main antecedents for this change [17]. New market models are said to have the capacity to generate a wide range of economic, social, and environmental values [14,18].

New market models in the electricity market have attracted scholars' and practitioners' attention over the past years [19,20]. Technical challenges of these models, such as their impacts on the power grid [21], different market and pricing mechanisms [22], security and data protection aspects [23], and (other) legal requirements [24] have been extensively studied, generating important insights toward understanding decentralized electricity/flexibility trading.

However, despite their potential value, other opportunities for sharing in the electricity market, beyond electricity and/or flexibility trading, have been overlooked in the literature [25]. Alongside the emergence of new market models, which are based on electricity/flexibility trading [26], the concept of sharing can potentially be applied beyond trading electricity or flexibility between peers [27]. This gap in the literature gains importance because some of these opportunities can already be exploited, whereas market models require several co-innovations and adoptions for emergence [28].

The purpose of this article is to explore the barriers for open business models [29] in support of sustainability in electricity markets. To do so, we narrow our focus to sharing phenomenon as a means for manifestation of open business models [30] in the electricity market and conduct a multiple case study [31] on the P2P, CSC, and TE models. The study builds upon [32]'s perspective on framing prosumers as rational market actors (i.e., firms) and therefore utilizes theories of the firm [33], resource-based theory [34] in particular, to explore opportunities for sharing physical assets as well as data. We winnow our discussions down to prosumers as one of the main emerging actors [35] in electricity markets due to their pivotal role in decentralized models. We investigate drawbacks in implementing prosumers' open business models from the perspective of privacy and data protection [36].

The findings yield insights into sharing opportunities beyond electricity/flexibility trading that have been overlooked so far. In doing so, our study contributes to theories of the firm by applying the resource-based view [37] in a new context (i.e., the electricity market) and to the business model literature by shedding light on prosumers' business models [38] through identifying barriers in applying open business models (i.e., by examining privacy and data protection concerns on sharing prosumers' physical assets and data).

This article extends previous research [39] (the preliminary results of this study were presented at the 16th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS 2020)) by conducting an extensive literature review on the theoretical and conceptual groundings of the study, improving the methodology by introducing detailed steps for data gathering and data analysis, providing a privacy discussion on the opportunities for sharing around prosumers' physical assets as well as their data, and providing discussions on prosumers' open business models [40]. This article adds two new contributions to our previous research [39] (see the second and third contributions in the next paragraph).

The novel contributions of this article are three-fold:

- First, it contributes to theory by applying resource-based theory to a relatively new context—electricity markets—to identify resources with sharing potential held by different existing and emerging actors. To our knowledge, resource-based theory has not been used before in the context of the electricity trading to discover sharing opportunities [41].

- Second, it introduces new insights on prosumers' business models [42] based on possibilities for sharing beyond trading surplus electricity from distributed resources, or prosumers' flexibility in future electricity markets [43].
- Third, it analyzes the differences between privacy [44] aspects of sharing physical objects versus data protection [45] issues related to sharing prosumers' data in electricity markets. We contend that physical privacy aspects are too often overlooked, though they can present critical barriers to prosumer sharing.

The rest of this manuscript is organized as follows. Section 2 provides a literature review on new market models for electricity and/or flexibility trading, open business models for circularity, and theories of the firm. This is followed by the methodology section, which introduces boundary conditions, case study selection, data gathering, and data analysis (Section 3). Section 4 presents the traditional electricity trading paradigm and introduces three cases: P2P, CSC, and TE. Section 5 presents the findings of the study. Valuable resources of the different actors in the electricity market with a potential for sharing, interested actors, and the benefits they can gain by accessing each resource, are presented in this section. Consequently, opportunities for sharing in the electricity market are introduced. Section 6 analyzes the findings. First, the current status of sharing is compared with future opportunities. Secony, privacy and data protection aspects of prosumers' sharing opportunities are analyzed. Section 7 critically discusses the findings and compares the results with others. Furthermore, we outline how our study contributes to theory. Section 8 discusses the limitations of this study and opportunities for future research. Section 9 concludes the paper.

2. Literature Review

2.1. New Market Models for Electricity or Flexibility Trading

When it comes to new market models for electricity trading, many initiatives can be detected, including peer-to-peer (P2P) electricity trading, community self-consumption (CSC), and transactive energy (TE) models [38]. There is not yet a clear distinction between the three market models, but they promise similar benefits. Although the three models have their own merits, there is no common understanding about them. Knowing that they may be self-contradictory in some situations, it becomes important to highlight the alignments and contradictions between them [22].

There is a rich literature on various market models for electricity transactions. The most cited models are the P2P, the CSC, the TE, or a combination of them [22]. A common element of these models is the encouragement of and incentives for prosumers (and consumers) to take up an active role in electricity markets. This element is usually achieved by allowing prosumers to trade electricity/flexibility with other market participants, such as other prosumers and grid operators, in return for some (financial) incentives. However, the models also have their own specific objectives [32].

2.2. Open Business Models for Circularity

Companies are increasingly exploring and exploiting external resources and knowledge by increasing their openness to innovating their business models, in order to gain a competitive advantage [46–48]. Yet, research on open business models remains scarce [49]. In our study, we define open business models as "a subclass of business models in which collaboration of the focal firm with its ecosystem is a decisive or novel element of value creation and capturing" [49] (p. 175). Through open business models, a company becomes part of a larger innovation ecosystem consisting of individuals, communities, and other organizations, which entails simultaneous competition and cooperation between ecosystem actors [50,51]. Thus, open business models enable an organization to be more effective in both creating and capturing value [52] by leveraging more ideas through inclusion of a variety of external concepts. At the same time, open business models allow greater value capture by utilizing a firm's key asset, resource, or position, not only in that organization's own operations, but also in other companies' businesses [40,52]. This resonates very well with the ideas of the circular and sharing economy and circular business models. In understanding why companies engage in open business models, ref. [49] identified five main antecedents that lead companies to open up their business models: (1) business model inconsistency, (2) a need to create and capture new value, (3) previous experience with collaboration, (4) open business model patterns, and (5) industry convergence. Thus, sharing opportunities for new circular business to create and capture new value are at the core of open business models for circularity.

The concept of the circular economy has gained attention in the literature by transforming the way resources are applied: by shifting from existing open production systems to closed production systems, where resources are reused and kept in a loop of production and consumption [53]. Thus, the circular economy provides large potential for sustainability transformation [54]. Yet, very little is known about the realization of the political goals and scientific principles attached to a circular economy in business practice [55]. Researchers have recognized that in order to facilitate a circular economy, fundamental transitions of established business strategies, value chains, and eventually business models are needed [56]. Hence, the circular economy may be described as a cyclic system that aims to eliminate waste by turning goods that are at the end of their life cycle into resources for new goods [57]. Closing material loops in industrial ecosystems can create a continual use of resources, which is achieved through long-lasting design, proactive maintenance, recycling, repairing, refurbishment, and re-manufacturing [58].

The concept of circular business models has gained increasing focus (e.g., [59–61]) and may be defined as creating, delivering, and capturing value, while implementing circular strategies that can prolong the useful life of products and parts and close material loops [62], p. 187. A circular business should be built on distributed marketplaces or decentralized networks that create a sense of belonging, collective accountability, and mutual benefit through the community they build [63]. The market relations between the circular businesses differ between peer-to-peer (P2P), business-to-consumer (B2C), and business-to-business (B2B), where ref. [64] emphasizes sharing among peers as the most innovative and most interesting variant of the sharing economy. Increasingly, the sharing of products (as a service), specifically through digital sharing platforms, is seen as an enabler for a circular economy (e.g., [65]). Unlocking the potential of the circular economy depends on innovative large and complex dynamic data collection and analysis [66]. Thus, sharing data and opportunities with stakeholders is a critical dimension [67] as the circular economy depends on developing new business models.

2.3. Theories of the Firm

Theories of the firm are applied to state why firms exist and how they make decisions to maximize profits, compete, etc. In other words, they are applied to predict behaviors of firms. For more than four decades, economists, sociologists, and organizational scholars have extensively examined the theory of the firm's central question: What determines the boundaries of the firm? Many alternative theories have emerged and are frequently positioned as competing explanations, often with no shortage of critique for one another [68]. By building our study on [32]'s perspective, which considered prosumers as firms, we take the liberty of applying theories of the firm to discuss prosumers' open business models. In the following we provide an overview of three (out of many) theories of the firm—industrial organization theory, resource-based, and dynamic capabilities—that are mostly applied to tackle the increasing importance of transcending organizational boundaries through open business models in the literature [29]. Furthermore, we argue for choosing resource-based theory for this research.

Industrial organization theory considers the strategies that an organization would devise as a means to relate the firm to its environment. In this view, an organization selects a position that provides the best competitive conditions. An organization may decide to maintain this position or, if required, impact rivalry for its own benefit. As an example, we can mention strategies that hinder any new entry into the market in which the organization is competing. In this view, external events dictate a firm's strategies [69].

By contrast, the resource-based view takes an internal approach and considers strategies of organizations beyond responses to the actions of market forces. It prioritizes the resource base of an organization. Opportunities and threats (which are out of the control of organizations) are not the only identifiers of organizations' strategies [70]. Whether an organization continues to exist or maintain its superiority depends on whether it builds idiosyncratic capabilities: capabilities that distinguish it from competitors in changing markets [71]. In [70]'s view, industrial organization theory and resource-based theory complement each other, and can therefore be combined in the theory of industrial organization and resources.

Everything that a firm uses to achieve its planned goals is considered to be part of the firm's "resource base" [72]. Resources thus are "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness" [73], p. 101. Resource-based theory considers specific types of firms' resources (i.e., VRIN resources) as potential basis for building competitive advantages.

Firms in competition possess various types of resources, which are mostly immobile. The immobility of firms' resources intensifies the variety of their competitive positions in the long run [74,75]. Value, rarity, inimitability, and non-substitutability are the characteristics of special resources of organizations, which impact their market selection and increase their success rate [76]. The possession of special resources is required for the success of a firm. Furthermore, possession of distinguishing capabilities enables a firm to effectively exploit its resources [75].

Resource-based theory has been criticized for being too static and for ignoring the dynamism of markets in recent decades, when competition was fiercer and markets were more turbulent [77]. Resource-based theory assumes that (a) resources are heterogeneously persistent, and (b) benefits originating in a lack of competition in gaining complementary resources are long lasting [74]. Both assumptions lead to a failure of resource-based theory in explaining the effects of turbulent markets and the evolution of firms. Despite the effective influence of resource-based theory on strategic management, its validity is disputed as it cannot answer questions about turbulent market situations, nor transformational mechanisms that use resources to create market advantages for a firm in competition [78]. For instance, ref. [79] calls resource-based theory into question because it fails to identify the mechanisms which allow firms to evolve their resources and capabilities, and transform their resources into competitive advantages.

Subsequently, the concept of "dynamic capabilities" can complement resource-based theory by considering resources' developing characteristics as well as developing capabilities of firms [80]. Dynamic capabilities are defined as the ability to build, develop, or amend the resource base of a firm. They are capabilities that are simultaneously part of the resource base of a firm. Dynamic capabilities can amend and develop themselves; they have the capacity to self-modify [72]. The concept of dynamic capabilities also completes the shortcomings of resource-based theory by justifying the effects of market dynamism [81]. Therefore, the relationship between the concept of dynamic capabilities and resource-based theory is complementary.

The concept of dynamic capabilities has been effectively used as a theoretical framework in abundant empirical research over the past two decades. It has been continually improved and now completes resource-based theory by filling its gaps, specifically to address the natural evolution of organizations' resources and capabilities under conditions of market turbulence. The concept of dynamic capabilities makes it possible to identify processes that are necessary for the evolution of the resources of firms, whether they are industry- or firm-specific [78].

Considering the purpose of this research, which is to identify sharing opportunities and consequently to identify barriers to apply prosumers' open business models, we opt for the resource-based view [37] for two main reasons. First, the sharing concept is tied with resources of others that can be deployed by the firm or resources of a firm that could be deployed by others [82]. Among the three discussed theories, the resource-based view is a better fit with the sharing concept. Second, the electricity market is, arguably, not a really turbulent market [83]. Therefore, between resource-based and dynamic capabilities, the former is a simpler theory to apply in this context.

3. Methodology

To carry out our study, an exploratory approach [84] was deployed. The overarching method for data gathering is multiple case study [31]. In the following subsections, boundary conditions, case study selection, data collection, and analysis are explained in detail.

3.1. Boundary Conditions

In this study, we apply the resource-based view [37]. Hence, each actor is considered as a bundle of resources under a common governance [85]. The resource base of a firm can have various components. Among the common categories of resources are:

1. Physical assets: grid infrastructure, smart meters, batteries, electric vehicles, etc.
2. Digital resources (data): smart meter information, flexibility-related information, supply and demand information, etc.

The resource base of a firm is not limited to these two categories. Other categories of resources have also been mentioned in literature, such as human resources, financial resources, downstream and upstream knowledge, governance-related (administrative) knowledge, and reputation-related resources, to name a few [85].

The sharing economy is concerned with non-VRIN resources [86]. Therefore, we use the two categories mentioned above, physical assets and data, to categorize the non-VRIN resources of different actors in the electricity market to which the sharing concept would apply.

3.2. Case Study Selection

As there is a flurry of initiatives centered on decentralized production and digitally enabled forms of transactions, we decided on a two-step process to narrow the focus. First, the empirical study was set to three cases in order to investigate actors and their resources as well as their motivations. Second, three controversial cases were selected yet with considerable similarities, that is, based on a decentralized nature, and with a diverse range of capacities in value generation [32] that affect electricity trading in similar ways, but at different capacities. The selected cases, arguably, are said to alternate the traditional electricity trading [87].

In doing so, setting market models as cases—thus, P2P, CSC, and TE models—they are not required to be limited to a specific project, pilot test, geographic region, or study [88], allowing a broad range of data for each case. While these are three different decentralized forms of electricity/flexibility trading changing electricity trading in different ways, the conclusions drawn are comparable.

3.3. Data Collection

In the first step of our study, extensive desk research [89] yielded insights into the identification of different existing and emerging actors in the electricity market. In particular, actors' resources, the objectives they pursue in the market, and other interested actors and their motivations are identified. This resulted in an overview of several actors in different market models (traditional, P2P, CSC, and TE models).

Subsequently, semi-structured interviews [90] were planned to validate the findings from the literature review (Appendix A shows the guideline questions for semi-structured interviews). For this purpose, the interviewees represent several stakeholder groups (e.g., existing actors, prosumers, policy makers, and academics) to provide a comprehensive view of the electricity market. Interview questions covered a wide range of aspects related to the current and future electricity markets (actors in the market, their responsibilities, resources, objectives, etc.). Top levels in management hierarchies were chosen for interviews to have a broad view on their companies' business models as well as a good understanding of the electricity market. To identify and select the interviewees, a snowball technique was deployed [13,91]. This helps to approach relevant people that otherwise tend to remain "under the radar"; this continues until data saturation is reached. A total of 26 interviews were conducted between October 2019 and March 2020. Interviews were conducted face-to-face and via Skype. Each interview took forty-five minutes on average.

3.4. Data Analysis

We transcribed interviews, coded the data, synthesized, built narratives, and applied storytelling techniques [92] to present the findings. Furthermore, in order to identify opportunities for sharing in the electricity market, a matrix was built on the findings of the study, which has actors in the electricity markets on its axes. For this study, we consider an opportunity to be a situation in which new services, products, raw materials, markets, and in general business models emerge through the formation of new means-ends combinations [93]. In this article, a sharing opportunity is a combination of a valuable resource of an actor and another actor interested in gaining access to that resource. The interested actor pursues one of several benefits by accessing the resource. In other words, the resource may be utilized for value generation or capturing by the interested actor.

The results of the matrix analysis were validated (i.e., face validity) by two expert members of the Global Observatory on Peer-to-Peer, Community Self-Consumption and Transactive Energy Models. We made a database of expert members in different five sub-tasks of Global Observatory: (i) power systems integration, (ii) hardware, software and data, (iii) transactions and markets, (iv) economic and social value, and (v) policy and regulation. Considering our research design, for the purpose of face validity, we opted for experts from sub-tasks ii and iii.

The next step in our analysis was to focus on the sharing opportunities of prosumers, and examine aspects of privacy and data protection related to the prosumer resources. To this end, we disambiguated concerns over privacy from concerns over personal data, based on a seminal study providing a comprehensive overview of different privacy typologies [94]. Applying these different types of privacy conceptions to the listed prosumer resources serves to clarify that sharing of physical assets can raise other privacy concerns (and merit a different type of protection) than merely concerns related to sharing data. Addressing these concerns will be instrumental to promoting prosumer sharing in electricity markets. Figure 1 shows a summary of our applied methods.

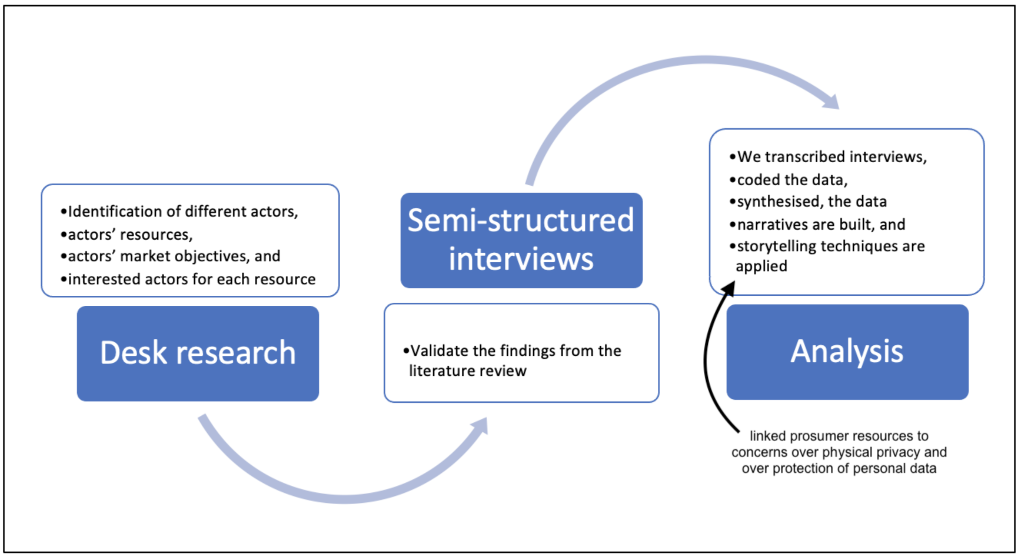

Figure 1. An overview of the applied methods.

4. Three Cases

The traditional electricity trading model refers to central electricity production from non-renewable (fossil-fuel, nuclear, gas, etc.) and renewable (wind, hydroelectric, etc.) resources in power plants. Electricity, in a one-directional flow, passes through the transmission grid, is transformed from high to low voltage, and is delivered to consumers through distribution grids [95]. Figure 2 shows the evolution of power systems during the time. In the following subsections, three cases (P2P, CSC, and TE) are introduced.

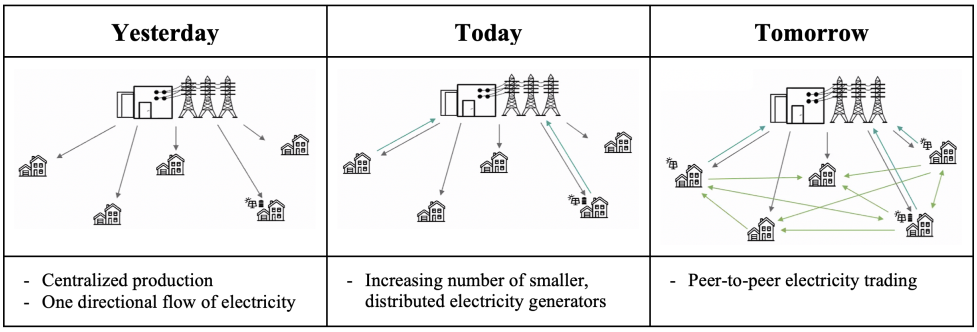

Figure 2. Evolution of power systems [14].

4.1. Case 1: Peer-to-Peer Electricity Trading

P2P market models support trading of electricity between prosumers (directly or through an intermediary) [39]. A possible future scenario of P2P energy trading is shown in Figure 3. Apart from prosumers, the scenario also envisions the presence of representatives who can trade electricity on behalf of citizens and a broker who facilitates and clears the market [35].

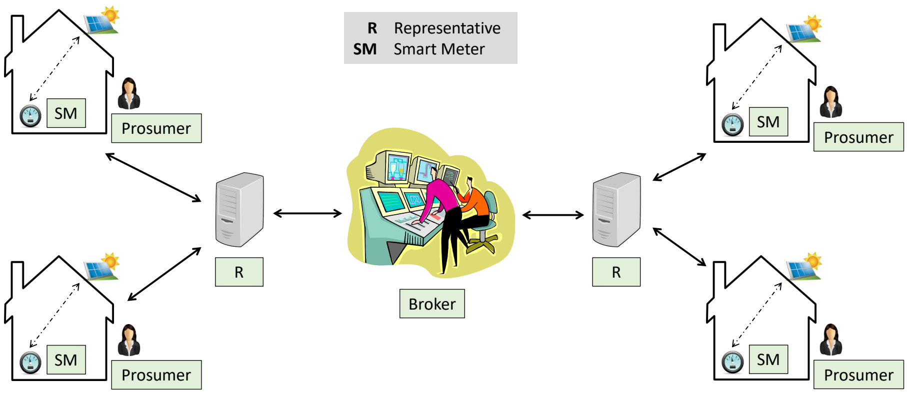

Figure 3. Peer-to-Peer electricity trading [13].

P2P models enable mutual transactions among different entities to trade electricity [96,97]. Energy traders in the P2P market may be of different sizes, i.e., residential houses, neighborhoods, microgrids, or local distribution networks [96,98]. These models are described as ways to allow the grid to take advantage of demand-side, flexible resources, operationally as well as economically [99]. In P2P models, the objective of the market mechanism is to incentivize transactions that prioritize maximizing the benefits of individual prosumers [100]. Such models could involve intermediate parties that facilitate the trades among prosumers, or support fully decentralized trades among them. The market mechanisms used in P2P models are usually set to optimize the trading based on algorithms with objectives of matching the excess supply of prosumers with the demand of consumers.

P2P electricity trading schemes enable consumers and prosumers in the same region to trade electricity they have produced with their own renewable energy resources among each other [101]. The type of sharing that occurs in these schemes is similar to what happens in most other sharing concepts that are based on P2P interaction [102–104], such as Airbnb and Uber.

4.2. Case 2: Community Self-Consumption

Community Self-Consumption (CSC) market models support communities in reducing their dependence from the electricity grid [105] through collectively utilizing their members' available resources [106]. Apart from aiming at grid independence, they could also provide flexibility services to other communities or to grid operators. Typically, a community manager orchestrates the market and assists members to collectively decides how to utilize their resources [107]. The assistance could range from having full responsibility for making decisions on behalf of the community members to only playing the role of a facilitator and strictly following the instructions given by the community's members. The community manager, the rights and privileges he or she holds, the scope of operation he or she has, and the length of his or her term are chosen by the community members via consensus mechanisms. Once these choices are made, the community manager's responsibility is to ensure that every community member receives a fair share of the rewards received according to their contribution to the service provided. The distribution of rewards is typically done via transactions between community members, between the community manager and community members, and the community manager and other communities/grid operators.

In CSC models, the overarching goal is independence from centralized electricity generation through unification of dispersed resources in communities [105]. Community members operate in a collaborative manner to optimize usage of resources [14,107]. CSC incentivizes transactions that prioritize maximizing the benefits of the community. CSC models usually involve a community manager [107] who coordinates transactions within the community as well as the transactions with other communities or the main grid. The market mechanisms used in CSC models are set to optimize the trading based on algorithms with objectives such as minimizing the electricity import by the community from the main grid and maximizing the revenue for the community. They usually involve sharing the individual prosumers' assets among each other or aggregating all the assets within the community in order to maximize the benefits for the entire community.

4.3. Case 3: Transactive Energy Models

Transactive Energy (TE) market models support grid operators in balancing the grid at all times [108]. They achieve this by facilitating demand response services provided by prosumers based on market-based incentives [109]. The key difference between the TE and P2P/CSC market models is that in TE models there is typically a single buyer—the grid operator or aggregator—who demands a certain amount of flexibility, thus offering financial incentives to prosumers to engage and provide flexibility. Prosumers are competing with each other on who would be selected for the service provision. Typically, the flexibility demanded is substantially larger than the flexibility an individual prosumer could provide [110]. Hence, typically, a number of prosumers is selected such that their aggregated flexibility satisfies the needs of the aggregator/grid operator. Similarly to CSC market models, all selected prosumers are rewarded in proportion to their contributed flexibility.

TE models are based on demand response, where end-user loads are automated and engaged through market-based interactions [108,110]. They provide market access to flexibility providers, and a support tool for the grid operators to manage technical complications [111]. It is a distributed control strategy that uses market mechanisms to engage self-interested responsive loads to provide services to the grid [112]. The objective of the market mechanism is to incentive transactions that prioritize and support the stability and reliability of the grid [108]. As the grid operators are the main actors who are responsible for maintaining the stability of the grid, they are usually the primary participants in the market buying electricity/flexibility directly from prosumers or via aggregators [113]. The market mechanisms used in TE models are set to optimize trading based on algorithms with different objectives, such as keeping the grid in balance, reducing grid congestion, and maintaining the voltage and frequency stability.

5. Findings

5.1. Actors' Resources and Interested Parties

In this section, actors (existing and emerging) and their market objectives in the electricity market are briefly introduced. Resources of each of the actors are identified. For the list of actors in the future electricity market, the study considers the future scenarios introduced in [114] and actors introduced based on the future scenarios in [35]. Resources of each actor are categorized under physical and digital groups. An overview of these resources is given in Table 1.

Table 1. Valuable resources of each actor in the future electricity markets and interested actors in each resource.

	Physical Resources ← Interested Parties	Digital Resources (Data)—Interested Parties
Prosumer (Pro)	RES ← Pro, Rep Home Battery ← Pro, Rep EV ← Pro, Rep EV charging station ← Pro, Rep, DSO EV battery ← Pro, Rep HEMS ← Pro, Rep Smart Appliance ←	Smart Meters ← Rep, Ret, DSO, TSO Demand ← Rep, Br, Ret, DSO, TSO Supply ← Rep, Br, Ret, DSO, TSO Flexibility ← Rep, DSO, TSO
Representative (Rep)	Clients' RES ← Pro, Rep Clients' Batteries ← Pro, Rep Clients' EVs ← Pro, Rep Clients' EV Charging Stations ← Pro, Rep, DSO Clients' Batteries of EVs ← Pro, Rep Clients' HMS ← Pro, Rep	Clients' Smart Meters ← Ret, DSO, TSO Clients Demand ← Br, Ret, DSO, TSO Clients' Supply ← Br, Ret, DSO, TSO Clients' Flexibility ← DSO, TSO
Broker (Br)		Sellers'supply information ← Ret, DSO, TSO Sellers'offered price ← Ret Buyers'demand information ← Ret, DSO, TSO Buyers offered price ← Ret Clearance price ← Ret Total traded volume ← Ret, DSO, TSO, Gen
Aggregator (Agg)		Clients'supply capacity ← TSO Clients'demand capacity ← TSO Clients'balancing capacity ← TSO
Retailer (Ret)		Customers'demand information ← DSO, TSO Customers'supply information ← DSO, TSO
DSO	Distribution grid infrastructure ← Pro, Rep, Ret	Smart meters' inflow information ← Rep, Ret Smart meters' outflow information ← Rep, Ret Congestion information ← Rep, Ret
TSO	Transmission grid Infrastructure ← TSO, Gen, Pro	Balancing information ← Agg, Ret, TSO, Gen Congestion information ← Agg, TSO, Gen Demand/supply pred. ← Agg, Ret, DSO, TSO, Gen
Generator (Gen)		Power plants (coal, gas, nuclear, etc.) ← Ret

Note: If the interested actor in a resource is the same as the owner, it indicates other peer actors are interested in that resource.

5.1.1. Prosumers

Prosumers are consumers who can also act as producers. In the electricity market, this means that they can generate electricity and inject it into the grid. To this end, they are in possession of renewable energy sources (e.g., solar panels) and storage devices (e.g., batteries). They will most likely also own smart meters, home energy management systems, and various other smart appliances. Prosumers' main objectives will be to *minimize cost* (specifically, their electricity bills), *maximize profit*, and *mitigate their dependency on the electricity grid*, by maximizing how they use their resources. To summarize, prosumers have the following valuable resources:

- A **renewable energy source (RES)** is a mini-generator located on a prosumer's premises (e.g., a solar panel). Typically, most of the electricity generated by a RES is consumed by its owner, who may inject surplus electricity into the grid.
- **Home batteries** are storage appliances that allow for intentional latency between the provision and the consumption of electricity generated or purchased by prosumers.
- A **smart meter** is an advanced measuring and recording device that keeps track of the electricity flowing in both directions (from the home to the grid, and vice versa) and that can perform two-way communications with other actors or appliances.
- A **home energy management system (HMS)** is a platform that consists of hardware and software to monitor electricity consumption and production. It allows prosumers to manually control and/or automate their household energy consumption.
- **Demand information** is information about the electricity requirements of prosumers, as well as their energy consumption patterns.
- **Supply information** is information about the volume of electricity produced by prosumers' RES, as well as production patterns.
- **Flexibility information** is information about the extent to which prosumers can modify their electricity production or consumption in response to variability, expected or otherwise.
- **Smart appliances** are Internet-connected appliances that connect to each other and/or other intelligent devices in the home. They can often be accessed and controlled remotely.
- An **electric vehicle (EV)** is a vehicle that has an electric motor for propulsion (or two such motors). EV owners typically also possess EV batteries and charging stations.
- An **EV battery** is a battery installed in an EV, which stores (and transports) electricity.
- An **EV charging station** is an appliance that can connect EVs to the grid to (dis)charge electricity.

5.1.2. Representatives (A New Role in Future Electricity Markets)

Representatives are a new type of actor in the peer-to-peer electricity market. Their role is to manage their clients' information and physical assets (RES, home battery, smart appliances, etc.) and to represent them in the peer-to-peer sharing market [35,114]. In doing so, they transform consumers' passive roles into active market participation. The presence of representatives can therefore increase consumer involvement in peer-to-peer electricity markets.

Representatives are expected to facilitate sharing opportunities between prosumers and other, already established market players.

Their main objectives will be to *minimize costs* and *increase profits* for their clients (prosumers). As representatives do not own their clients' assets, their resources mostly fall into categories other than physical and digital resources. Instead, representatives may for instance possess upstream knowledge (sourcing knowledge, and knowledge about product/service- or process-related technologies), downstream knowledge (which is critical to customer interfaces and is related to marketing, sales, distribution, and after-sales services), administrative (governance-related) resources, and reputable resources (brand names, a good reputation for honest business dealings, etc.).

5.1.3. Brokers (A New Role in Future Electricity Markets)

Like representatives, brokers take up a new role in future electricity markets [35]. They are intermediate, (neutral) actors facilitating the trade between peers. Due to their position, they have access to information about all parties participating in peer-to-peer electricity trading, as well as all transactions. Their objectives are to *clear the peer-to-peer market* while *respecting the grid's constraints*, as well as the *prosumers' preferences*.

As for representatives, brokers' special market position is not derived from their own physical or digital resources. Nor do they have upstream or downstream knowledge, or brand and other common resources. Brokers' positions mostly result from legal monopolies or first-mover advantages, which can provide actors with an important share of the market. Essentially, they will have access to all the information contained in a prosumer bid, such as the amount of electricity offered, the price requested, the demand and supply bids, buyer preferences (specific type of energy source, location, etc.), grid access points (location), and electricity source (solar, wind, biomass, etc.).

5.1.4. Aggregators

Aggregators are actors that exist already in current markets. They provide ancillary services to grid operators. They play an important role in balancing the electricity market by aggregating prosumers' flexibility and trading. Their main objective is to *maximize profit* by offering ancillary services to grid operators. To achieve this, they have access to the following information:

- **Clients' supply capacity:** Information about the capacity of their clients' electricity supply to the grid, including supply patterns.
- **Clients' demand capacity:** Information about the capacity of their clients' electricity demand from the grid, including demand patterns.
- **Clients' balancing capacity:** Information about the flexibility of their clients, which can be served to the grid.

5.1.5. Retailers

Retailers provide consumers with electricity. (In the case of prosumers, they also fulfill this role when prosumers' RES do not generate sufficient volumes of electricity). Retailers buy electricity in bulk from generators in the wholesale market and sell it to prosumers in the retail market. In current market settings, retailers are also obliged to buy any of the clients' electricity that is not traded in the P2P electricity market and still injected back to the grid. Their main objective is to *maximize profit*, while ensuring that their clients' demand for electricity is met. Retailers have access to the following information:

- **Customers' demand information:** This indicates how much electricity is consumed by retailers' clients over a specific period of time. This information is valuable to make any estimates about the future demand of the market.
- **Customers' supply information:** This indicates how much electricity is injected into the grid by retailers' clients over a specific period of time. Similarly, this information is valuable to make any estimates about the future demand/supply of the market.

5.1.6. Distribution System Operators (DSO)

DSOs are the operating managers (and sometimes owners) of energy distribution networks [115], operating at low and medium voltage levels. Their main objective is to *avoid congestion*.

- **Distribution grid infrastructure:** Distribution grid refers to the final stage of the electrical grid in which electricity is distributed to homes, industry, and other end-use products. Distribution is the process of reducing power to safe customer-usable levels, and delivering the electric power to the grid.
- **Smart meters' inflow information:** This includes the information regarding the amount and pattern of consumption at any smart meter. The more real-time this

information, the more valuable it is. Modern smart meters make it possible to read the smart meters' information in a real-time pattern. DSO is the sole actor who has access to this information through the smart meters installed at clients' premises.
- **Smart meters' outflow information:** Similar to the smart meters' inflow, this includes the information regarding the amount and pattern of electricity provisioned at any smart meter. The more real-time this information, the more valuable it is.
- **Congestion information:** Congestion can be defined as violations of network constraints (voltage and frequency) due to high electricity demand or excess electricity generation.

5.1.7. Transmission System Operators (TSOs)

A TSO is responsible for maintaining the transmission network, balancing the grid, and charging suppliers transmission network fees based on the electricity consumption/provision data of the suppliers' customers in the grid. A TSO's main objective is to *balance the grid*. A TSO has the following valuable resources:

- **Transmission grid infrastructure:** Electricity transmission is the bulk movement of electricity from a generating site, such as a power plant, to an electrical substation. The interconnected lines that facilitate this movement are known as a transmission grid.
- **Balancing information:** Electricity balancing encompasses all actions and processes, on all timelines, through which TSOs ensure, in a continuous way, the system frequency remains within a predefined stability range, as set forth in the Network Code on System Operation. It complies with the amount of reserves needed with respect to the required quality. This includes deficit, surplus, and reserves for any time period.
- **Congestion information:** Transmission congestion happens when scheduled market transactions (generation and load) result in power flow over a transmission element that exceeds the available capacity for that element.
- **Demand/supply prediction:** This includes all the estimates that TSOs can have based on the comprehensive information they receive for the balancing purposes.

5.1.8. Generators

Generators are the entities who generate electricity to meet the demand for electricity by consumers/prosumers. Their main objective is to *maximize profit* by trading electricity in the wholesale and/or balancing market. They have the following valuable resource:

- **Power plant:** An industrial facility for the generation of electric power. Power plants are connected to electricity grids. Their energy sources vary widely. Most of them burn fossil fuels (e.g., coal, oil, and natural gas). Cleaner energy sources of power plants include nuclear power and, increasingly, renewables (e.g., solar, wind, wave, and hydroelectric).

5.2. Opportunities for Sharing

In this section, the existing (or new) market players who would be interested in utilizing (some of the) resources of other actors, identified in the previous section, and the attainable benefit by accessing the resource are discussed. This part answers two questions: *who is interested in the resource?* and *what benefit can the interested actor gain?*

5.2.1. Prosumers

- **Renewable Electricity Sources (RES):** Other *prosumers/consumers* (or *representatives* on behalf of them), by accessing prosumers' RES, can produce renewable electricity. The owner of the produced electricity is the party with which it is shared. In a sense, rather than trading the electricity generated by the RES, prosumers can lend/rent their RES for a specific time period.
- **Batteries:** Other *prosumers/consumers* (or *representatives* on their behalf) can store electricity by accessing prosumers' batteries. The owner of the stored electricity is the party

with which the battery is shared. Renting out the RES and the battery in combination should be the most beneficial for both—the owner and the renter.

- **Electric vehicles (EV):** Electric vehicles can be used by other *prosumers* in idle time. Car sharing initiatives in a peer-to-peer manner are imaginable for this type of sharing. *Representatives* can represent underutilized capacity of electricity vehicles in a more efficient way on behalf of owners of EVs.
- **EV battery:** Other *prosumers* are interested in EV batteries as portable storage devices. People can, for instance, sell 2kw to users living close to their work place. Rather than feeding this energy to the grid at their home location, they can transport it with their EV and inject it to the grid at their work locations, potentially saving on grid use fees. *Representatives* can represent their clients' EV batteries in a more efficient way.
- **EV charging station:** EV charging stations can be used by other *prosumers* in idle times. This requires bringing the cars to the location of the station to charge them. Other prosumers can be interested in using the EV charging stations for charging their EVs. *Representatives* are also interested in expanding their service basket and in sharing charging stations more efficiently on behalf of the owners. *DSOs* would be interested as a means to help the congestion problem without occupying the distribution grid's capacity.
- **Smart meters:** People cannot share the smart meter, but it generates valuable data to be shared. Considering the frequency of access to the smart meter data, it reveals information that is highly valued by several actors. *DSOs* value this information for billing and solving congestion problems, *TSOs* for balancing, and *retailers* for customer consumption/production estimation purposes. *Representatives* can represent this information on behalf of their clients.
- **Home energy management system (HMS):** As is the case for the smart meter, the data generated by these systems are probably their most valuable output. *Representatives* can use these data for participating in various markets. It is unclear how one can benefit from sharing the system, unless a neighbor (*other prosumer*) could use the system's functionality as well. In a sense, the neighbor (or any user) could send the data of their assets and let the home management system of another user make intelligent decisions for them. It is yet to be seen how practical this solution is. It might well work in apartment buildings, where several flats use only one home management system.
- **Demand information:** *Representatives* are interested to have this information because it enables them to better represent their clients' demand and decide on the way to supply (purchasing from other prosumers, purchasing from grid, using the battery capacity, etc.). *Retailers* can plan their electricity provision based on forecasts based mainly on their clients demand/supply information. *DSOs* can use these data to better handle the distribution grid congestion problem. *TSOs* can better balance the grid by having this information. *Brokers* are interested in the part of this information which would be traded in peer-to-peer electricity markets through their channel.
- **Supply Information:** *Representatives* are interested in this information because it enables them to better represent their clients' supply and decide how to sell/share (selling to other prosumers, selling to the grid, using the battery capacity to store the produced electricity, etc.). *Retailers* can plan their electricity provision based on forecasts based mainly on their clients' demand/supply information. *DSOs* can use these data to better handle the distribution grid congestion problem. *TSOs* can better balance the grid by having this information. *Brokers* are interested in the part of this information which would be traded in peer-to-peer electricity markets through their channel.
- **Flexibility:** *DSOs* are interested in flexibility capacity to overcome the congestion problem. *TSOs* can use this capacity as a means to balance the electricity grid. *Representatives* can represent this capacity on behalf of clients to other interested parties.

Aggregators do the same type of representation for their clients in the current electricity market.

5.2.2. Representatives

As discussed in the presentation of representatives in the previous section, the type of resources representatives own is mostly not relevant to sharing. However, representatives (on behalf of prosumers) have access to the same valuable resources as prosumers and facilitate sharing. What differentiates representatives' role in sharing from prosumers is that representatives have the aggregate capacity of their clients to share. The aggregation of clients' resources in the hands of a representative gives it a service basket and leverages its position to negotiate and enter to markets that is not possible for a single prosumer to access.

- **Sellers' supply information:** This information is about the capacity for supply, and not necessarily all the supply capacity is traded in peer-to-peer markets. The information is useful for planning purposes. *DSOs* are interested in the supply information to have a better congestion management in the distribution grid. *TSOs* can enhance balancing planning by access to this information. *Retailers* can have plan better for their electricity demand from generators, which later they will supply in the retail market.
- **Sellers' offered price:** Access to this information helps *retailers* in their pricing. Retailers' pricing is in direct competition with the supply price in peer-to-peer trading market.
- **Buyers' demand information:** This information is about the capacity for demand, and not necessarily all the demanded amount is traded in the peer-to-peer market. The information is useful for planning purposes. *DSOs* are interested in the demand information to have a better congestion management in the distribution grid. *TSOs* can plan better for balance through access to this information. *Retailers* can plan better for their electricity demand from generators, which they will later supply in the retail market.
- **Buyers' offered price:** Access to this information helps *retailers* in electricity pricing. It indicates potential customers' willingness to pay. It is also worth mentioning that this willingness is for the peer-to-peer market. Considering that retailers nowadays are also offering green electricity to their customers, it would help retailers to tailor their offering in that product segment.
- **Clearance price:** This is the price for complementary/substitute service of *retailers*. It is expected that retailers' pricing is directly impacted by this information.
- **Total traded volume:** *Retailers* and *generators* can adjust their pricing and supply by knowing the actual traded amount of electricity in the peer-to-peer trading market. *DSOs* can better manage the congestion problem in the distribution grid. *TSOs* can better balance the grid by knowing this information.

Consideration: What defines the brokers' position in the market is the type of information that they have access to. It seems some of this information (sellers' supply and price information, and buyers' demand information and offered price) are VRIN resources that, despite the existence of other interested parties, brokers are not supposed to share.

5.2.3. Aggregators

- **Clients' supply capacity:** *TSOs* are interested in this information for prevention of congestion in the transmission grid.
- **Clients' demand capacity:** *TSOs* are interested in this information for prevention of congestion in the transmission grid.
- **Clients' balancing capacity:** *TSOs* are interested because of the use of this capacity in balancing of the grid.

5.2.4. Retailers

- **Customers' demand information:** *DSOs* are interested in this information for distribution grid congestion prevention. *TSOs* are interested because of balancing purposes.

- **Customers' supply information:** As above.

5.2.5. Distribution System Operators (DSOs)

- **Distribution grid infrastructure:** *Prosumers* are interested in the distribution grid to receive their electricity (purchased in the retail or peer-to-peer market) through it. Connectivity to the grid is also necessary for receiving the balancing services which translates into the stability of the electricity stream. *Representatives* have the same dependency/interest as prosumers regarding the distribution grid. The distribution grid makes the existence of *retailers'* services meaningful. This means that they can only deliver what they sell if the client is connected to the grid.
- **Smart meters' inflow information:** *Retailers* are interested in this information because it reveals their customers' consumption behavior. It is valuable for pricing and planning purposes. *Representatives* are also interested in this information because they are the sellers in the peer-to-peer market. Electricity sold in the peer-to-peer market is in competition with retailers' offers. So it has a similar value for representatives. Considering the level of expertise of prosumers, the required expertise to process this information is absent in individual prosumers.
- **Smart meters' outflow information:** As above.
- **Congestion information:** *Representatives* are interested in this information because it shows where the situation is more prone to peer-to-peer trading (considering that peer-to-peer trading of electricity may cause congestion problems in the distribution grid). *Retailers* have similar interests as representatives in this information.

5.2.6. TSOs

- **Transmission grid infrastructure:** *Generators* and *prosumers* are already making use of this infrastructure by using it as a transposition means for their traded electricity.
- **Balancing information:** Active players in the balancing market are the interested parties. This includes *retailers*, *aggregators*, and *generators*. Other *TSOs* (neighboring countries) are interested in these data because of the balancing purposes.
- **Congestion information:** *Aggregators*, other *TSOs*, and *generators* are interested actors in this information. As a source of balancing solutions, this information is meaningful for the interested actors to find where there is a good node to offer their balancing services.
- **Demand/supply prediction:** Active players in the balancing market are the interested parties. This includes *retailers*, *aggregators*, and *generators*. Other *TSOs*, (neighboring) countries, are interested in these data because for balancing purposes. *DSOs* are also interested in these data because of the implications that it could have on the congestion in the distribution grid.

5.2.7. Generators

- **Power plants:** *Retailers* are interested in the production capacity of power plants rather than buying the electricity they produce. Retailers can keep it as a reserve for balancing purposes. This scenario makes sense if sharing the capacity is more beneficial for generators than selling the output electricity.

6. Analysis

6.1. Current vs. Future Opportunities for Sharing

This study was initially designed to explore sharing opportunities in future electricity markets. Interestingly, the findings revealed several opportunities already available in the present, which have been overlooked despite their potential for value creation and capturing for several actors. It goes without saying that these are missed opportunities that can be sources of value. This also resonates with the concept of increasing the exploitation of existing resources, which is one of the cornerstones of circularity [116]. To clarify this argument, by following the boundary conditions set for the study (i.e., a "sharing opportunity" is a situation in which at least one actor other than the owner is interested in a resource), we built a matrix based on a combination of actors to highlight sharing opportunities between every two types of actors. We also highlight the presently missed opportunities and future opportunities for sharing. As shown in Table 2, matrix cells present a combination of actors that make up the two axes of the matrix. Each cell lists resources of the actor in the left column that are of interest to the actor in the top row. We underline the items that are currently shared. The remaining items in the list are opportunities for sharing in the future.

One of the implications of the identified sharing opportunities is that we can expect new entrants [35] (e.g., providers of sharing platforms or other supporting services) in electricity markets. Attractive sharing opportunities may attract these actors, which will also lead to facilitation of trading. Among the newly introduced actors, representatives are credible candidates to extend their activities and seize these opportunities [115]. However, privacy concerns may stand in the way of full-fledged, active participation of all prosumers [39]. As a consequence of privacy concerns, which go beyond issues of data protection, prosumers may apply a privacy/sharing calculus, weighing sharing risks against benefits [117]. In that calculus, the compounded physical privacy and data protection concerns may weigh more heavily against the benefits of sharing than data protection concerns alone would do. Those promoting sharing opportunities in electricity markets would do well to consider not only security and data protection measures but also to address the physical privacy concerns that may impede (some) prosumers from reaping the benefits.

Among the existing players in the electricity market, aggregators currently more or less undertake the combined activities of brokers and representatives [13]. A future opportunity imaginable for aggregators is to diversify their activities to offer representative and broker services. An interesting question that remains open is whether a single actor will play representative, broker, and aggregators' roles [115]. It is yet to be seen if specialization and a division of labor, meaning distinct actors undertaking separate roles [13], is the path forward, or if diversification would generate enough return for aggregators.

Table 2. Opportunities for sharing between different actors.

	Pro	Rep	Bro	Agg	Ret	DSO	TSO	Gen
Pro	**Physical assets:** - RES - Batteries - EV - EV charging station - Battery of EV - HMS	**Physical assets:** - RES - Batteries - EV - EV charging station - Battery of EV - HMS **Data:** - SM info - Demand info - Supply info - Flexibility	**Data:** - Demand info - Supply info		**Data:** - SM info - Demand info - Supply info	**Data:** - SM info - Demand info - Supply info - Flexibility	**Data:** - SM info - Demand info - Supply info - Flexibility	
Rep	**Physical assets:** - Clients' RES - Clients' Batteries - Clients' EV - Clients' EV charging station - Clients' Battery of EV - Clients' HMS	**Physical assets:** - Clients' RES - Clients' Batteries - Clients' EV - Clients' EV charging station - Clients' Battery of EV - Clients' HMS	**Data:** - Clients' Demand info - Clients' Supply info		**Data:** - Clients' SM info - Clients' Demand info - Clients' Supply info	**Data:** - Clients' SM info - Clients' Demand info - Clients' Supply info - Clients' Flexibility	**Data:** - Clients' SM info - Clients' Demand info - Clients' Supply info - Clients' Flexibility	
Bro					**Data:** - Sellers'supply info - Sellers'offered price - Buyers'demand info - Buyers offered price - Clearance price - Total traded volume	**Data:** - Sellers'supply info - Buyers'demand info - Total traded volume	**Data:** - Sellers'supply info - Buyers'demand info - Total traded volume	**Data:** - Total traded volume
Agg							**Data:** - Clients' supply capacity - Clients' demand capacity - Clients' balancing capacity	
Ret						**Data:** - Customers' demand info - Customers' supply info	**Data:** - Customers' demand info - Customers' supply info	
DSO	**Physical assets:** - Distribution grid infrastructure	**Physical assets:** - Distribution grid infrastructure **Data:** - SM inflow info - SM outflow info - Congestion info			**Physical assets:** - Distribution grid infrastructure **Data:** - SM inflow info - SM outflow info - Congestion info			
TSO				**Data:** - Balancing info - Congestion info - Demand/supply prediction	**Data:** - Balancing info - Demand/supply prediction	**Data:** - Demand/supply prediction	**Physical assets:** - Transmission grid infrastructure **Data:** - Balancing info - Congestion info	**Data:** - Balancing info - Congestion info - Demand/supply prediction
Gen					**Physical assets:** - Power plants			

Note: Underlined items are the resources which are shared in the current market between the two involved actors.

6.2. Privacy and Data Protection Aspects of Prosumers' Sharing Opportunities

Despite opportunities to generate additional income, promote sustainable consumption, or enjoy the social activity of sharing [118], prosumers may be reluctant to share assets due to privacy concerns [114]. Such concerns may vary, from a desire to limit access to private spaces to discomfort with sharing information about daily behavioral patterns, or distrust against commercial parties whose access to sensitive data may lead to price or other market manipulation attempts. This section presents an analysis of privacy and data protection aspects of the sharing opportunities for prosumers discussed above, as well as a number of potential remedies.

First, a disambiguation between "privacy" and "(personal) data protection" is in order. A comprehensive, systematically developed typology of privacy distinguishes eight basic types: bodily, intellectual, spatial, decisional, communicational, associational, proprietary, and behavioral privacy, with informational privacy as a ninth type that overlaps, but does not coincide with, the eight basic types [94]. This non-exhaustive typology underscores the importance of protecting more than merely personal information when it comes to privacy.

The distinction between different types of privacy is also a legal one. The right to privacy was established in the Universal Declaration of Human Rights (UDHR), which states that "[n]o one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honour and reputation". The European Convention for Human Rights (ECHR) of the Council of Europe also provides protection for the right to privacy ("respect for private life, family life, home, and correspondence") in its Article 8. This right covers a wide range of issues in the rulings of the European Court of Human Rights (ECtHR): bodily integrity, wiretapping, gender identification, and unwarranted trespassing and protection against environmental nuisances, among other issues [119]. The Treaty on the Functioning of the European Union distinguishes a separate right to the protection of personal data in its Article 16. So does the European Union's Charter of Fundamental Rights, which includes both the right to respect for private and family life in Article 7 and the right to protection of personal data in Article 8. The EU's General Data Protection Regulation (GDPR) regulates this latter right, not the right to private and family life.

In the context of prosumers sharing assets in the electricity market, concerns related to physical assets are discussed here as "privacy concerns", whereas concerns related to digital assets are discussed as "data protection concerns". These labels are chosen for reasons of brevity, not to introduce a strict distinction between informational or data privacy and other privacy concerns. Our aim is to clarify that privacy concerns do not end when (personal) data are secure.

To be clear, this section does not deal with the situation in which prosumers are handling other individuals' data, i.e., the situation in which the prosumer becomes a "controller" in terms of the GDPR. What is discussed are potential personal privacy and data protection concerns of prosumers related to sharing their own assets.

6.3. Privacy Aspects of Sharing Prosumers' Physical Assets

Prosumers experience privacy concerns when they fear an infringement of personal boundaries around their bodies, intimate spaces, or personal assets. Prosumers' physical resources, as listed above, are likely to be found in or around their private homes, and possibly the homes of their families. In "collaborative consumption" schemes [118], privacy concerns about giving strangers access to zones of intimacy (which can include electric vehicles) may affect prosumers' willingness to share. Compared to data protection issues, these physical privacy concerns have been understudied, but they can weigh more heavily than concerns about the protection of personal data [117]. Among the eight basic types of privacy distinguished by [94], five are primarily related to physical aspects: bodily, spatial, behavioral, associational, and proprietary privacy. Each of these types is discussed below in relation to the sharing of physical resources of prosumers in the electricity market.

- **Bodily privacy** refers to the integrity of a person's body, from excluding others from touching one's body to having the freedom to move one's body [94]. Though prosumers may fear infringements of their bodily privacy when allowing strangers into their homes for the purpose of sharing smart appliances or home batteries, privacy would not be their primary concern in this respect, which is why we shall leave bodily privacy concerns aside in this discussion. It is, however, of no small importance to realize that related concerns may dissuade, for instance, female prosumers who live alone from actively participating in collaborative consumption schemes.
- Like bodily privacy, **spatial privacy**, particularly the privacy of the home, is a constitutionally protected right around the world [94]. In some countries, "dwellings" or (in Poland) vehicles are also protected, while the inviolability of property, of computers, or of cell phones sometimes also falls under the protection of the private sphere. Clearly, the need to protect intimate spaces is felt worldwide. This implies that sharing of all physical assets mentioned in Section 5.1—renewable electricity sources, home batteries, electric vehicles, EV charging stations, EV batteries, home energy management systems, and smart appliances—can, to some extent, and depending on circumstances, trigger spatial privacy concerns.
- **Behavioral privacy** has to do with excluding others from observing one's personal actions and behaviors [120], with systemic observation being of particular concern. Visitors to a private space (when sharing renewable electricity sources, electric vehicles, home or EV batteries, EV charging stations, or smart appliances) would undoubtedly learn something of the sharing prosumer's lifestyle, actions, and personal behavior. However, systemic observation is unlikely to occur in the physical environment, but is potentially of graver concern in relation to information-sharing, or information that could be gleaned from the sharing of a home energy management system.
- **Associational privacy** refers to an "individuals' interests in being free to choose who they want to interact with: friends, associations, groups, and communities" [94]. Assuming that prosumers would voluntarily engage in collaborative consumption schemes, associational privacy is unlikely to be affected by the choice to share in itself. In fact, social influence plays an important role in users' sharing decisions: "The more the people in the sharers' environment encourage and support their sharing, the more frequently these users will share" [117]. Collaborative consumption therefore appears to be rather a positive expression of associational privacy preferences.
- **Proprietary privacy** is about property-based interests, meaning that property can be used to shield activity or information from others. Window curtains, locked doors, or closed bags are examples of physical property protections. Naturally, if property is shared, proprietary privacy is affected, but not necessarily infringed upon. Proprietary privacy is mostly a legal issue, in that it mostly applies to situations of unreasonable search and seizure [94], not to voluntary sharing. It is therefore less likely to be a concern specific to collaborative consumption.

For some assets, mitigation of physical privacy concerns can be achieved by introducing "safe spaces", away from intimate zones. For example, lighter smart appliances can be handed over in a public space. For less mobile physical assets, it will be of utmost importance to establish trust between sharing partners, e.g., through privacy-preserving features of sharing platforms or by introducing physical security checks, setting clear boundaries in contracts, or introducing sharing policies [121,122].

For all five types of physical privacy concerns, there are related data protection concerns. Information "leaked" about bodies, spaces, behavior, property (e.g., photos or videos taken surreptitiously), or associations (e.g., contact lists) may be as much a concern, or even more worrisome, to prosumers.

6.4. Data Protection Issues of Sharing Prosumers' Digital Resources

While informational privacy is considered to be a somewhat separate type of privacy that overlaps with the eight basic types, three of those basic types are also closely related to the protection of data: communicational, intellectual, and decisional privacy. These types, and informational privacy, are discussed below in relation to the sharing of digital resources of prosumers in the electricty market.

- **Communicational privacy** is also protected in all constitutions, specifically mediated communications (or "correspondence" in the ECHR) [94] (Unmediated communication, or communication in person, is sometimes protected in the same vein, or sometimes considered as a part of physical privacy). It refers to concerns regarding conscious communication, such as sending messages on sharing platforms or online marketplaces (potential "representatives"). Communicational privacy is affected if platforms are processing communications data [122] or in case of "eavesdropping" [114].
- **Intellectual** and **decisional privacy** are two sides of the same coin: intellectual privacy can be regarded as freedom from intrusion into the functioning of the mind, and decisional privacy is seen as the freedom to exercise one's mind. Prosumers sharing smart meter data, demand and supply data, and/or flexibility information with retailers or system operators may fear that their beliefs about prices and demand may be manipulated by incorrectly presented or skewed information provision by larger players in the market, affecting their ability to make effective, rational decisions in their own best interest.
- Lastly, **informational privacy** concerns around P2P sharing in the electricity market are well documented, including such risks as impersonation, data manipulation, and individual privacy breaches leaking location or trajectory data, payment information, or behavioral patterns to third parties [114,122]. Any kind of privacy also has an informational aspect. At the same time, information always relates to certain aspects of people's physical situations, which have privacy elements beyond information.

Fortunately, there is also ample discussion regarding mitigating data protection issues, partly due to the introduction of the GDPR, which requires that organizations processing personal data take extensive "technical and organizational measures" to protect such data. Technical measures can include secure authentication of parties and messages, encryption, anonymization and pseudonymization, secure channels, prosumer data aggregation, decentralized data storage, unlinkability, multiparty computation, and zero-knowledge proofs [114]. Organizational measures can include access controls, logging, contractual clauses, staff privacy training, confidentiality agreements, and binding policies, to name but a few common approaches. Figure 4 summarizes the privacy and data security aspects of sharing prosumers' physical assets as well as their data.

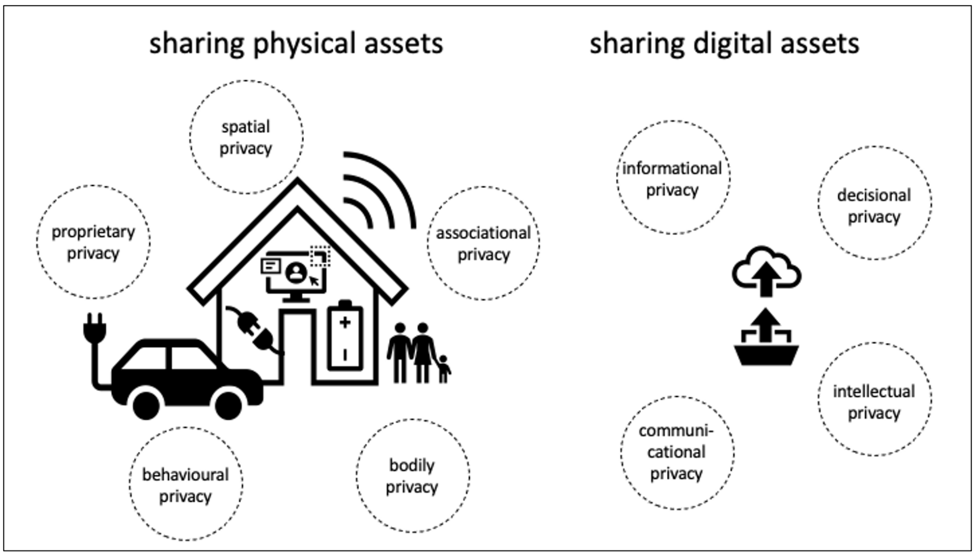

Figure 4. Privacy and data security aspects of sharing prosumers' physical assets as well as their data.

7. Discussion

The findings from this study suggest how prosumers' open business models, in decentralized market models in the electricity market, may be hindered by privacy concerns on sharing physical assets as well as data protection issues with sharing their data.

Our results showed several sharing opportunities in electricity markets exist which are already exploitable by prosumers for value creation and capturing in their business models. Furthermore, all the identified opportunities have a collaborative nature through resource sharing, which emphasizes the openness aspect of prosumers' business models. This is in line with previous studies' claims [46–48] on increasing use of open business models for exploring and exploiting external resources and knowledge. Furthermore, by identifying sharing opportunities between dual combination of actors it provides empirical evidence for [40,52]'s claim that open business models allow greater value capture by utilizing a firm's key asset, resource, or position not only in that organization's own operations, but also in other companies' businesses. Previous studies [29,49] mostly take a positive tone and focus on antecedents of open business models. Nevertheless, our analysis on prosumers' privacy and data protection concerns complements this strand of research by showing barriers for implementing open business models.

Somewhat surprisingly, most of the identified sharing opportunities are already exploitable. In other words, building open business models to make use of these opportunities is not hindered by legal constraints [24] or other structural changes in the electricity grid [123]. This sheds new light on previous studies that suggest the large-scale rollout of P2P, CSC, and TE models, as non-stand-alone innovations, requires several co-innovations and adoptions [13]. Furthermore, the results broaden the scope of sharing, which was mostly focused specific devices (charging stations, batteries, etc.) in previous studies [124], by putting prosumers as the core of discussion rather than a specific device.

Formerly, prosumers were considered passive actors in the electricity market because they could only inject their excess electricity into distribution grids and had no negotiation power on price setting nor on whom to sell [106,125]. As a result of the limited decisions they could take, having a business model for active prosumer participation in the market was deemed unnecessary. However, technology breakthroughs in the production of high-capacity batteries, distributed renewable resources (e.g., solar panels), ease of communication, and prevalence of smart devices (smart meters, home energy management systems, etc.), as shown under actors' resource base in our study, are expanding prosumer control and allowing them to play a more substantial active role in future electricity markets [126,127]. This shift in prosumers' capabilities necessitates better understanding of their options for value generation and capturing through their business models. A clear picture is necessary for prosumers as potential active participants in future electricity markets and for policy makers to better prioritize public resource allocation [32].

By following [128]'s guidelines for making theoretical contributions, we applied the resource-based theory of the firm in relatively new context—the electricity market—to identify resources with sharing potential held by different existing and emerging actors. This is a novel application for the resource-based theory to discover sharing opportunities [41]. Hence, our study contributes to theories of the firm, in particular to the resource-based theory [128]. Furthermore, by highlighting the privacy and data protection aspects on prosumers' sharing of physical assets and data, as potential barriers for open business models, the study contributes to open business models literature. Finally, by analyzing the differences between privacy [44] aspects of sharing physical objects and data protection [45] issues related to sharing prosumers' data in electricity markets, we contend that physical privacy aspects are too often overlooked, though they can present critical barriers to prosumer sharing.

8. Limitations and Opportunities for Future Research

This study has limitations that can be overcome in future research. Furthermore, this study raises important questions for follow-up research. First, it would be fruitful to pursue further research into the dynamics of prosumers' resource transformation in the short run and in the long run. The intersection of open business models [29], digital transformation [129], and dynamic capabilities [130] is another area for further research. The study is partly based on speculations derived from case studies. A follow-up, quantitative study (e.g., a survey) with a large sample size [131] can validate our findings. Among the drawbacks for implementing open business models by prosumers, we focused on privacy as well as data protection concerns. Taking other perspectives (technical, legal, etc.) to study the factors which hinder applying open business models can contribute to theory and practice. Broadening the scope to cover the business models as well as privacy and security aspects of other actors is another path to follow in future studies.

It is valuable to perform an in-depth privacy analysis of identified sharing opportunities that goes beyond concerns over sharing data or the security of IT infrastructure. While there is evidence that prosumers hesitate to participate in particular parts of the sharing economy due to concerns about the privacy of their homes, bodies, or other aspects of their private lives (e.g., in schemes such as Airbnb), there has been no empirical research into prosumers' privacy-related hesitations to participate in sharing schemes for physical assets in the electricity market [132]. This may be partly due to the lack of existing schemes. Although our data collection and validation did not allow for such empirical exploration of potential concerns related to all different types of privacy, there are certainly research strategies that do allow for exploration of future attitudes, e.g., using fictional methods [133] such as "futuristic autobiographies" [134].

Last but not least, the implicit assumption in identifying opportunities for sharing in our study, which is based on scenarios for the future [135,136], is that we can extrapolate and speculate about the future using the knowledge that we have at present. Hence, the possibility of disruption as the result of breakthrough innovations [137] is overlooked in this method. These could alter the whole market. Taking into account possible sources of disruption can be another inspiration for conducting follow-up studies.

9. Conclusions

This article explores the barriers for prosumers' open business models due to their critical role in decentralized modes of electricity/flexibility trading. In particular, it puts forward privacy and data protection concerns on sharing prosumers' physical assets and data. This is an exploratory study that utilizes a multiple case study method to identify existing and emerging actors in electricity markets. Furthermore, resource-based theory is applied to identify resources of the actors under physical assets and data categories. Objectives that different actors pursue in the electricity market are identified, and for each identified resource, interested actors and their motivation are introduced. Accordingly, a matrix is built by dual combination of actors, to identify what opportunities for sharing exist between every two actors. We built on [32]'s perspective and dealt with prosumers as firms in applying the resource-based theory and in our discussions. Identified sharing opportunities, besides participation in the new market models for electricity/flexibility trading, call for developing prosumers' open business model and highlight less attended opportunities. The study contributes to theories of the firm by applying the resource-based view in a new context and to the business model literature by shedding light on barriers in applying open business models.

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Abbreviations

The following abbreviations are used in this manuscript:

ICTs	Information and Communication Technologies
P2P	Peer-to-Peer
CSC	Community Self-Consumption
TE	Transactive Energy
B2C	Business-to-Consumer
B2B	Business-to-Business
VRIN	Valuable, Rare, Imperfectly imitable and Not substitutable
RES	Renewable Energy Sources
EV	Electric Vehicle
HMS	Home energy Management System
DSO	Distribution System Operator
Pro	Prosumer
Rep	Representative
Br	Broker
Agg	Aggregator
Ret	Retailer
Gen	Generator
TSO	Transmission System Operator
RES	Renewable Electricity Sources
EV	Electric Vehicle
HMS	Home energy Management System
UDHR	Universal Declaration of Human Rights
ECHR	European Convention for Human Rights
ECtHR	European Court of Human Rights
GDPR	General Data Protection Regulation
DCOSS	Distributed Computing in Sensor Systems

Appendix A. Guideline Questions for Semi-Structured Interviews

- Would you please introduce yourself and your organization?
- What are your organization’s roles in the electricity market?
- How do you describe the current electricity market (Who are actors and what are their roles)?
- What are the main influencers on the future of electricity market?
- How do you describe the future electricity market (Who are actors and what are their roles in next 5 to 10 years)?
- What are the constraints for P2P electricity trading?
- What are the best and worst scenarios for P2P electricity market?
- Who are the main actors and their roles in the P2P energy trading?
- Do existing trading mechanisms in electricity market need to be changed for P2P electricity trading (How should they be in order to allow for P2P trading)?
- Which non-energy-related market mechanism is applicable for P2P electricity trading?
- What roles would your company have in the future electricity market?
- What are your organization’s objectives and business model in P2P electricity market?
- What problem is peer-to-peer is trying to solve?
- Which type of actors are trustworthy to have the critical roles in P2P, CSC, and TE models for electricity/flexibility trading?

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