



# Prosumer flexibility as an enabler for ecosystem value co-creation: A resource integration approach from the Finnish electricity markets

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## HIGHLIGHTS

- tEffective resource orchestration across emerging and incumbent actors accelerates novel technology adoption and prosumer flexibility (PF) scaling.
- Frameworks that balance innovation with incumbent welfare can ease resistance and promote ecosystem-wide synergy.
- DSO business competencies must improve to enable commercial flexibility.
- Retailer-led energy literacy programs can boost consumer engagement in PF initiatives.
- Policy support for rural grid upgrades and prosumer incentives can accelerate PF deployment.

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## ABSTRACT

Energy ecosystems increasingly embrace prosumer flexibility to integrate intermittent renewable sources into the energy mix. However, our understanding of actor roles, interactions, and market dynamics related to prosumer flexibility integration remains limited. We address this gap by exploring how prosumer flexibility can facilitate value co-creation among ecosystem actors and the resources necessary for effective integration within the Finnish electricity ecosystem. To this end, we conducted an exploratory single case study in Finland, involving 24 semi-structured interviews, 18 with key stakeholders and six with flexibility platform operators active in various European markets. Our results reveal several challenges in implementing prosumer flexibility, including barriers to integrating novel actors such as aggregators in the value chain, limitations of rural distribution networks in supporting large-scale flexibility operations, and gaps in energy literacy programs. Despite these challenges, there is a generally optimistic outlook toward prosumer flexibility adoption. We further contribute to the energy prosumption literature by incorporating the Service-Dominant Logic concept into prosumer driven value co-creation. We identify a critical phase of ‘resource harmonization,’ where emerging and incumbent actors align their resources to adopt novel energy technologies and provide a comprehensive framework for facilitating value co-creation through integrating these technologies.

## 1. Introduction

With households directly or indirectly causing 70 % of global greenhouse gas (GHG) emissions, addressing this segment is among the most important avenues for energy transition [1]. Accordingly, we

observe a noticeable emphasis on novel technological interventions to incentivize optimal consumer habits, develop smart home energy systems, and prepare the grid infrastructure for flexible interactions [2–4]. Prosumer flexibility (PF), which enables household prosumers to actively manage and adjust electricity consumption in response to grid

*Abbreviations:* BR, Balance Responsible Party; *Capex*, Capital Expenses; *CEP*, Clean Energy Package; *DER*, Distributed Energy Resources; *DSM*, Demand Side Management; *DSO*, Distribution System Operator; *DR*, Demand Response; *EU*, European Union; *EV*, Electric Vehicles; *ESS*, Energy Storage System; *GHG*, Greenhouse Gas; *HEMS*, Home Energy Management System; *ICT*, Information & Communication Technology; *IoT*, Internet of Things; *OpEx*, Operating Expense; *PF*, Prosumer Flexibility; *PV*, Photovoltaic; *RI*, Resource Integration; *SDL*, Service Dominant Logic; *SDG*, Sustainable Development Goals; *TSO*, Transmission System Operator; *UN*, United Nations; *V2G*, Vehicle to Grid.

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requirements, has emerged as a critical solution inhabiting these characteristics [5]. Such flexibility is paramount for the energy transition, as it strengthens the foundation for increasing the share of intermittent renewable sources, namely wind and solar, into the energy mix [4]. Consequently, it is integral to realizing the Sustainable Development Goals related to energy efficiency (SDG 7) [6].

Enabled by demand-side management (DSM) or demand response (DR), PF provides tools that can transform traditionally passive consumers—who primarily consume electricity without actively influencing grid dynamics—into prosumers actively managing and contributing energy back to the grid [7,8]. DSM or DR occurs through smart appliances, electric vehicle (EV) charging, heat pumps, and behind-the-meter or solar PV-battery systems, allowing flexible consumption timing [5,9]. These measures are considered among the least costly and most environmentally friendly means of adding flexibility to the power system, particularly when compared to supply-side interventions [10,11].

However, as energy consumption has historically been associated with a passive role for consumers, the literature on prosumption-oriented flexibility is relatively recent [12]. Gough et al. [9] conducted an exhaustive literature review and identified electrification of end-use sectors, digitalization challenges and opportunities, and community energy systems among core PF research streams. Moreover, there are burgeoning studies on prosumer business models [13–15], participation [7,16], [17,18], and collective self-consumption in smart grids [19–21]. These studies examine how prosumers can be organized and connected to the grid, their impact on grid stability and efficiency, and the optimizing role of demand-side flexibility in prosumer-grid interactions. Consequently, studies on prosumer communities are relevant, touching on areas such as prosumer values [22–24], community success factors [8,25], and the diffusion of novel energy technologies [26–28].

While grid independence is an important goal for many prosumers (c.f., [24]), they remain part of a complex and interconnected ecosystem [29,30]. For instance, a European household with solar panels will likely hold a contract with a power retailer, which, in turn, operates in a pan-European electricity network and markets [31]. Therefore, whether individually or collectively in energy communities, prosumers are integral to this ecosystem [29,32]. Interconnectedness opens up promising opportunities to explore the dynamic between actors, elements, and innovations within the electricity ecosystem. An untapped opportunity here is the question of value co-creation between the prosumers and the ecosystem they are part of. This opportunity is relevant as [5] established that participating in demand-side flexibility (i.e., DR or DSM) is inherently co-creating. Yet, the PF literature has largely overlooked how prosumers interact with the broader ecosystem they are embedded in [10,33].

Moreover, future energy systems often place prosumers at their center, and a lack of engagement risks system-wide transition [33]. This shift in the electricity sector resonates with a classical understanding of value co-creation, especially that of Service-Dominant logic (SDL), a theoretical perspective that conceptualizes value creation as a collaborative process between actors rather than a unidirectional transfer from producers to consumers [34,35]. DSM-driven PF provides a compelling example in this context by facilitating household engagement in energy markets through technologies like smart appliances, EVs, and battery storage systems (c.f., [7]). These technologies can transform passive consumption patterns into **flexibility contributions** in line with grid requirements, often requiring minimal intervention from the user [4]. However, research exploring the blurring lines between energy suppliers and end consumers is still developing [34,36]. As such, a crucial aspect of this value co-creation is resource integration (RI), which is necessary for successfully integrating innovations into the ecosystem [37,38]. Investigating RI is further needed as PF is enabled by a novel technology that may not naturally align with the existing ecosystem [39].

Against this backdrop, this paper aims to address the above gap by

exploring the link between DSM-driven PF and its ecosystem by investigating the RI process. In doing so, we seek to answer the following research question: how does prosumer flexibility facilitate value co-creation in the Finnish electricity ecosystem, and what resources are needed by the ecosystem actors to enable this integration? To this end, we employed qualitative methodologies and conducted an exploratory single case study to examine the Finnish electricity sector's PF development and integration process. Exploratory case studies are ideal for studying 'how' questions and can shed light on complex causal links that may be difficult to investigate using surveys or experimentation [40]. Moreover, since the research field on PF is still emerging, a standardized quantitative approach may not be the appropriate choice. Using a single case also allows context-sensitive examination of the factors (e.g., people, policies, technology) forming the ecosystem and their interrelationships as we attempt to understand the possibilities and challenges associated with RI vis-à-vis PF interrelationships [41,42].

The contribution of our study is threefold. First, it introduces SDL to energy prosumption literature, conceptually strengthening and broadening the discussion on ecosystem-wide value co-creation through RI. In particular, we recognize 'resource harmonization' among the ecosystem actors as a key driver of value co-creation in novel technology adoption. Second, our findings hold comprehensive insights on PF development for practitioners in the EU electricity sector and utilize the resource harmonization framework to pinpoint specific resources necessary for shared value creation. Third, this study offers valuable insights for policymakers in the Finnish electricity sector. It identifies several areas requiring further refinement, particularly concerning energy literacy, the development of system operator capabilities, and the impact of recent amendments to electricity market regulations.

Thus, our study contributes to aligning novel technologies with the prosumers who could eventually adopt them. By comprehensively studying the actor roles, interactions, and market dynamics related to PF, we respond to [34] critique of the existing prosumer literature, which often overlooks the significance of corporate roles and the necessity of adapting business models in the market. Furthermore, while the need for and benefits of PF are clear regarding the energy transition [43], its ability to succeed in that goal is far from guaranteed [32]. Therefore, this study adds to the effort to increase the impact of PF.

The rest of the paper is structured as follows: Section 2 reviews the literature on PF, electricity ecosystem, value co-creation, and RI, culminating in a preliminary theoretical framework. Section 3 outlines the methodological approach. Section 4 presents the findings, while Section 5 discusses the ecosystem-wide implications of PF adoption and its associated challenges. It then develops propositions and introduces a refined theoretical framework. Finally, Section 6 concludes by discussing the study limitations and directions for future research.

## 2. Theoretical framework

### 2.1. Drivers for prosumer flexibility during rapid market evolution

The traditional role of customers as passive electricity consumers is changing due to new possibilities, such as selling excess energy and offering demand flexibility to the grid [11]. Moreover, the complementarity between distributed generation (e.g., solar PV) and variable demand-based prosumption (e.g., DSM) nurtures a symbiotic relationship in promoting prosumption [44]. Although, between the two, variable demand offers a more accessible and cost-effective route toward prosumption, requiring only access to smart appliances or devices capable of enabling flexible consumption [5]. This idea aligns with Gough et al.'s [11] definition of prosumer flexibility as *an instrument enabling DSM programs*. However, the seeming accessibility of variable demand does not guarantee a smooth adoption, as it still calls for a modification in prosumer behavior [45].

On the topic of PF adoption, organizing prosumers into communities is a recommended approach. For instance, [46] observed that social

interactions significantly affect prosumers' decision to adopt smart grid technologies. Prosumer communities also address the unpredictability of individual prosumers due to climatic conditions or resource gaps [36,47]. Therefore, prosumers might be better off aggregating their resources and joining the grid as a competitive unit. This approach also helps with energy literacy and addresses the issue of forecasting accuracy, which is difficult to achieve in an individual setting [11,48].

Gough et al. [11] suggest that the technological requirements for PF have matured, but regulatory and market barriers remain. Moreover, it gets trickier as prosumer markets tend to be more complex than existing electricity markets due to the inclusion of heterogeneous and emerging actors [49]. As a result, challenges arise in areas such as incentive and tariff design, information dissemination, business models, and fairness and privacy policies [11,34]. Notably, distributed flexibility varies across prosumption domains. Kubli et al. [5] found that onboarding heat pump users is more challenging than EV or storage-integrated PV system users due to its direct impact on personal comfort.

Similarly, in their survey of Finnish households, Sridhar et al. [50] found that prosumers require comparable compensation levels to participate in distributed flexibility initiatives involving heating (through electric heating or heat pumps) and other electric loads, such as household appliances and EVs. Differences also exist between early and late-stage prosumers, as early-market adopters are found to be more intrinsically motivated than their late-market peers [17]. Market designers must also consider the matching of different technological components and their effect on PF adoption. For instance, pairing energy storage and DSM increases the prosumption rate [51], whereas energy storage systems (ESS) alone are deemed uneconomical for households or in a community setting [52].

The emerging smart grid differs fundamentally from the traditional utility grid in its ability to intelligently integrate prosumers by accommodating their behaviors and actions [53]. In transitioning to smart grids, smart meters play a fundamental role [17], allowing real-time interaction with the grid and facilitating the participation of novel energy technologies such as HEMS, ESS, and V2Gs [11]. Moreover, the Internet of Things (IoT) facilitates the 'Internet of Energy', supplying real-time data to various stakeholders and easing the prosumption journey [54]. However, despite the benefits, the transition to a smart prosumer grid also presents challenges around managing increased complexity arising from numerous connected devices and handling large amounts of prosumer data [11]. Good engagement strategies focusing on prosumer acceptance drivers [36] and employing digital communication channels such as mobile applications have been prescribed to address these challenges [55]. The rollout tempo of smart grid technology is also essential, especially given our experience with solar PVs, with its rapid diffusion creating operability issues in many markets [8]. Fig. 1 presents the summary of this discussion.

2.2. Actor interdependencies and emerging value propositions in the electricity ecosystem

The impact and effectiveness of prosumer flexibility can only be fully appreciated within the broader context of the electricity ecosystem. Accordingly, successfully adopting PF requires high levels of interaction

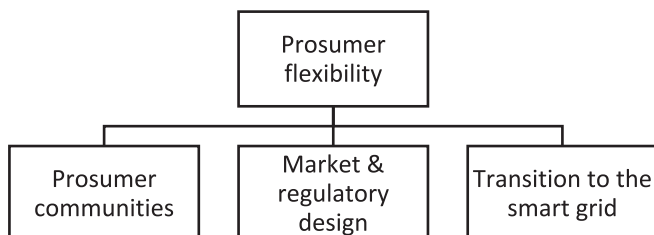


Fig. 1. Drivers of prosumer flexibility.

and interdependence among ecosystem actors [56,57]. It is not just an emerging technology; it involves an emerging network of actors, business models, and governance regimes [57]. The actors in this ecosystem are individuals or organizations who can make decisions and exchange information with other participants [58]. The successful integration of PF thus depends on the independent and aggregate roles these actors play, where the role is the intended external behavior of an actor [58]. It is important to stress that the evolution of roles for many actors has been ongoing since the liberalization of the Finnish electricity markets began in the late 1990s [59]. This shift meant developing a service-based operation for the newly decoupled companies, which was not an easy role to assume for an industry that historically viewed customers as 'loads' [59]. Indeed, for certain actors (e.g., retailers), this new role was relatively easier to grow into [60]. However, it is still problematic for actors not directly contacting customers (e.g., DSOs) [61]. This role ambiguity challenges PF since the contract models needed to facilitate its adoption call for multilateralism among the actors [62]. Moreover, the ongoing energy transition is increasingly blurring the line between end consumers and suppliers, making customers uncertain [34]. This, coupled with the cynicism many consumers harbor toward the liberalized energy markets [63], underscores the importance of clarifying and solidifying the roles of various actors within the ecosystem.

Moreover, emerging actors, such as prosumers or aggregators, challenge the traditional top-down value chain of the electricity market [34]. Gough et al. [11] suggest that this transformation should consider the ecosystem actors' welfare as it will ultimately determine the value it offers to society. This conclusion aligns with Adner's [64] idea that discrete actions are necessary for value propositions to emerge in an ecosystem. For example, Brown et al. [14] identified a mutually beneficial relationship between prosumer business models that promote real-time local consumption and the willingness to reduce the need for peak charging and expensive network updates. Besides, with intermittent DERs rising, the value pools for flexibility services are expected to double by 2030, and when DSOs can procure flexibility to manage grid constraints, it will further increase the value of prosumption [14]. However, since this value relies on the ecosystem's PF adoption, nurturing trust and credibility among the actors is crucial for developing value propositions [65].

Lastly, interaction has been identified as a critical driver for ecosystem value creation [66]. For PF, interactions can occur at the ecosystem level through contracts, profit, or risk sharing [36] or at a platform level through the collaboration of flexibility aggregation systems, DER suppliers, customers, and prosumers [67]. However, new entrants offering PF may not align with incumbents, leading to conflicts over time due to power shifts, as seen with emerging solar PV providers' interaction with incumbent power utilities in Sweden [2]. Moreover, interactions also take place between government interventions, such as energy policies and participatory regulations [68]. We can summarize the discussions on the electricity ecosystem as expressed in Fig. 2.

2.3. Facilitating value co-creation through prosumer flexibility integration in electricity ecosystems

Value co-creation is a collaborative process involving customers and

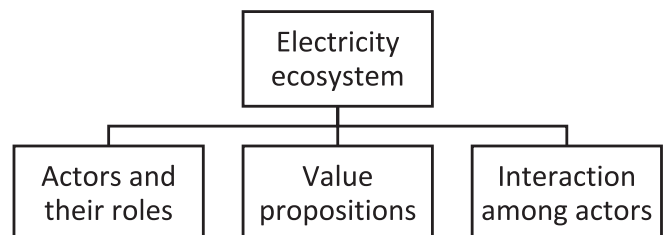


Fig. 2. Evolving electricity ecosystem in the context of prosumer flexibility.

suppliers to produce mutually beneficial outcomes. Customers actively participate in this process by designing and developing products, services, or experiences and contributing their insights, ideas, and efforts [69,70]. Initially observed in sectors with high customer engagement, like financial services and healthcare, Prahalad and Ramaswamy [69,70] note that customer dissatisfaction often leads to novel solutions. As technology became more accessible and customer awareness grew, value co-creation expanded into sectors with traditionally lower levels of user involvement, including electricity consumption [69,71]. DSM emerges as a prominent example in this regard, where the low involvement nature of electricity consumption and the strong momentum of routines and inertia kept the cost to switch to dynamic consumption traditionally high [5,72]. However, as technological advancements and consumer awareness increased, there was a noticeable shift among prosumers to engage in the co-creation of flexibility in their consumption patterns [5].

As value co-creation gained attention from marketing scholars, it branched out in multiple directions, with different conceptions of the process [73]. According to the SDL perspective, value co-creation occurs at various levels and is impacted by the social contexts, networks, and systems in which the co-creation occurs [35]. Moreover, SDL states that products are merely a means to convey a service, making service the fundamental unit of exchange, regardless of the traded object [35,74]. Therefore, customer-supplier collaboration is necessary for value creation across product categories. Notably, with the blurring of division between consumers and suppliers, this collaboration is becoming increasingly relevant for the electricity ecosystem [34]. For instance, in the utility sector, companies are transforming from mere energy suppliers to providers of peace of mind by investing in digital technologies [55]. Consequently, it motivates customers to change their electricity consumption behavior, resulting in long-ranging influences on the ecosystem [75].

However, despite progress in understanding the co-creation process, research on collaboration is lacking in some areas, particularly in how companies organize themselves and the resources required at the actor level to facilitate co-creation [71]. This gap exists, although resource integration is a fundamental proposition from the SDL perspective [76]. Additionally, Mele et al. [77] suggested that a firm’s ability to match its resources to those available in its ecosystem enhances co-creation possibilities and contributes to the evolution and success of the ecosystem. This integration drive is further supplemented by market forces that compel firms to act as resource integrators in any ecosystem as they seek to co-create value [66]. Multiple drivers influence the RI process, which

can be divided into two streams based on the setting (c.f., [78,79]) and the orientation (c.f., [37,39]) of the RI process. Our paper examines both streams and sheds light on three core drivers of this process: complementarity, redundancy, and asymmetry.

Gummeson and Mele [66] define resource complementarity as resources that supplement each other and must be incorporated collectively to form a whole. Achieving resource complementarity is often challenging in highly regulated sectors such as electricity, and this attribute can affect the value co-creation possibilities of the ecosystem [79]. Resource redundancy refers to resources similar in a category and possessed by multiple actors [66]. These resources should be combined to promote a shared understanding and facilitate the transfer of tacit knowledge. However, its challenges must also be highlighted to depict the RI process accurately. As such, asymmetry in the resources represents the prohibiting factor of unequal access to resources (e.g., finances, knowledge, network, or competencies) among the actors, hindering value co-creation [39]. It applies aptly to the transitioning energy landscape [36].

Our literature review proposes a dynamic framework for RI that considers the relationship between complementarity, redundancy, and asymmetry in enabling PF in the electricity ecosystem. The framework draws on insights from previous research by Mele et al. [77] and Dehling et al. [39] and is illustrated in Fig. 3.

### 3. Methods and research setting

#### 3.1. Research strategy

Using a qualitative research strategy, we conducted an exploratory single-case study to investigate the integration of prosumer flexibility (PF) in the Finnish electricity ecosystem. This method is apt for addressing ‘how’ and ‘why’ questions and aligns with our research objectives [40]. This approach offers several advantages for this study. First, the field of PF is still nascent, with limited prior research providing a foundational understanding of the topic. A qualitative, exploratory approach allows us to capture the nuanced nature of the environment surrounding PF integration, including stakeholder roles, technological implementations, and policy implications, thereby addressing the foundational gap [80]. Second, exploratory case studies allow for a context-sensitive analysis of the ecosystem’s interrelationships between the constituent components (e.g., people, policies, technology). This permits studying complex causal links and emergent patterns in PF-enabled value co-creation, which may be difficult to identify through

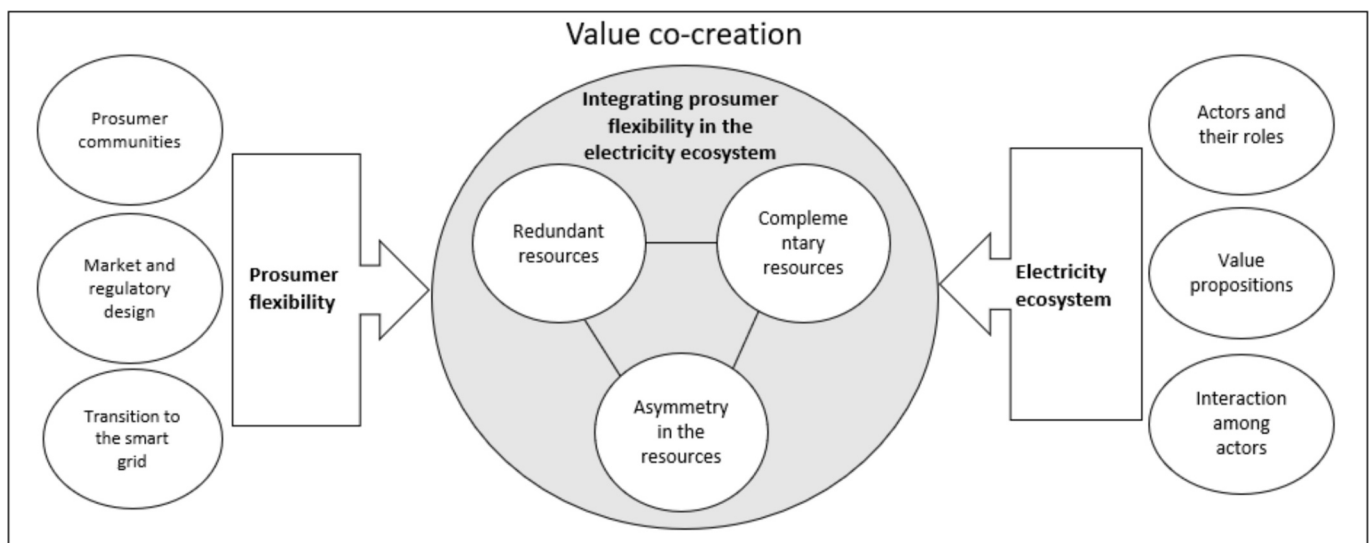


Fig. 3. The conceptual framework for prosumer flexibility integration in the electricity ecosystem.

quantitative surveys or experimental methods [41].

Moreover, a single-case study is justified when the case is unique and provides a revelatory opportunity for researchers to investigate previously inaccessible phenomena [40]. Accordingly, the Finnish electricity ecosystem presents an exemplary case with a highly developed smart grid, a system-wide approach to demand-side flexibility development, and renewable energy integration [81]. Studying the juncture of these developments from a PF-driven resource integration (RI) and value co-creation perspective could yield nuanced insights that might be obscured in a broader, multiple-case study setting.

### 3.2. Case context and data collection

We employed the ecosystem architecture development method that Ma [58] proposed to conceptualize the Finnish electricity ecosystem. It blends theories from system engineering, business ecosystems, and ecology and has been previously applied in electricity sector conceptualizations (cf., [82,83]). Following [83], the ecosystem boundary in the current setting can be set by the geographic/cultural frontier of Finland and the target domain of the country's electricity sector. According to [67], the main incumbent actors in this ecosystem are energy producers, market operators, transmission and distribution system operators, power retailers, industrial and domestic consumers, and various independent service providers (e.g., technology and balance responsibility providers).

With the boundary set, we employed a purposeful sampling method to select the organizations in this ecosystem. Yin [40] defines purposeful sampling as selecting cases based on information richness and offering practical manifestations of the phenomenon of interest. In addition, it aims to gain insight into the phenomenon that goes beyond statistical generalization. Given its centrality to flexibility operations, the TSO appeared as a primary actor with which to consult. In Finland, a single TSO oversees nationwide electricity transmission. We opted for an in-depth perspective from this organization and settled with a Senior Corporate Director with a birds-eye view of the electricity ecosystem and a Specialist with competencies in PF. In the next step, we picked a mid-sized DSO with electricity retail operations in eastern Finland. We then opted for a DSO of a similar size from the western part of the country. Lastly, we interviewed a large electricity retailer from the capital region of Helsinki. This way, we registered a diverse perspective regarding geography, organizational size, and operational roles. For these interviews, we sought senior experts with a background in flexibility projects and familiarity with customer affairs.

Moreover, to get a sense of the industrial actors on PF, we chose two firms with a long history in operations in the electricity sector, one from the manufacturing side, while the other provides industry services. The former is a major forestry company with operations in the balancing markets, and the latter is a prominent energy consulting firm with expertise in developing flexibility services. Experienced managers were interviewed in both cases, with the ranks of a Vice-President and a Director.

[84] identified regulators, policymakers, and interest groups as integral to the energy ecosystems. Consequently, we interviewed two Senior Experts from the local electricity industry interest group and a Deputy Director General from the Finnish energy regulator, overseeing the system operators. Moreover, [14] identified novel entrants such as platform providers, aggregators, community groups, and non-endemic technology firms eager to access the increasing value pool as relevant actors. Consequently, we included the sole commercial aggregator in the Finnish electricity sector in this discussion. To get the perspective of prosumers and community groups, we sought a diverse perspective regarding geographical spread, community development, and technological orientation. We interviewed a CEO and a Project Manager from a community renewable energy development company based in a north-eastern Finnish city. Next, we interviewed the Head of Co-Innovation of an energy consulting firm specializing in smart prosumer

communities and active in multiple locations within the country. Lastly, we identified two community energy groups active in the Finnish countryside, one run by the local municipal body and the other a citizen initiative, and interviewed the lead organizer in both instances.

February 2022 saw the beginning of a global energy crisis with the Russian invasion of Ukraine. This compelled us to initiate an additional data collection round to discern this significant event's repercussions on PF and the broader electricity ecosystem. This phase materialized in three interviews where we first interviewed a Development Director from an energy services company with operations in electricity retail, solar PV, and EV charging. Then, we moved on to a mid-sized electricity retailer with nationwide operations. Here, we interviewed the firm's Development Manager. We also interviewed the senior vice president of customer services from an energy services company based in south-eastern Finland, which operates in electricity retail, distribution, and comprehensive solar PV packages. In total, 17 semi-structured interviews were conducted between September 2019 and May 2022. These were conducted on a rolling basis, with each round of interviews transcribed, coded, and analyzed before returning to the field for further data collection. This iterative process allowed for continuous data validation until saturation was reached. Data saturation is reached when no new information or themes are observed, ensuring the collected data is comprehensive and sufficient to substantiate the study's findings [85]. Seven interviews were conducted in person, while the rest were through Zoom.

To further ensure the robustness of our findings, we conducted an additional interview in June 2024 with a Market Analyst from a Helsinki-based energy consulting company. The firm is involved in various flexibility market initiatives across the EU, and the interviewee is a veteran flexibility regulations expert. Although this interview provided a more recent perspective, it did not reveal any new patterns in our data, reinforcing our conclusion that data saturation had been achieved.

The extended timeline reflects the study's aim to capture significant and evolving developments in the Finnish energy landscape. Strategies such as revisiting earlier themes during later interviews ensured temporal consistency across the dataset [86]. Key contextual factors included temporary disruptions to energy community engagement during the COVID-19 pandemic, the Ukraine War's impact on Finland's energy policies, and the anticipated challenges stemming from the 2023 expansion of nuclear power. These developments were subsequently incorporated into the analysis. By addressing pre-existing and evolving factors, the dataset offers a nuanced understanding of the country's electricity sector during a period of noteworthy transition.

Furthermore, a semi-structured interview method was chosen for its ability to integrate thematic questionnaires while allowing the possibility for modifications during conversations [87]. The interview guide was developed through a combination of theory-driven and data-driven approaches. Thematically, the guide was informed by prior flexibility literature and industry reports. Simultaneously, its iterative design allowed emergent themes to shape subsequent rounds of interviews. The interview guide was divided into three sections. The first section probed general sector overview and flexibility services suitability, using literature and industry reports to prompt discussion and establish a baseline. The second section had thematic prompts tailored to the interviewee's organizational role and expertise. This phase involved discussing specific organizational practices, with company reports and personal professional profiles (via LinkedIn and public web sources) consulted beforehand to inform the questioning. The third and final section was open for a free-flow discussion to pursue emergent insights that came up during the interview. Appendix 1 presents the interview questions, while Table 1 provides an overview of the Finnish ecosystem interviews.

Several interview facilitation strategies were applied to ensure a smooth flow of conversation and comprehensive data collection, guided by [86,87]. Open-ended questions were used as a foundation, with the interviewer frequently employing prompting and probing techniques to

**Table 1**  
Interviews from the Finnish electricity ecosystem.

Interviewee code	Duration (min)	Organization role	Job title
E1	69	TSO	Specialist
E2	67	TSO	Corporate Advisor
E3	101	Industrial actor/Energy services	Development Director
E4	57	Retailer/BRP	Head of Unit, Risk Management
E5	70 + 81	Retailer/DSO	Business Director
E6	61	DSO	Head of Sales
E7	58	Industrial actor/ BRP	VP, Energy Markets
E8	55	Energy Regulator	Deputy Director-General Experts
E9	61	Energy Industry Interest Group	Operations Manager
E10	54	Aggregator	CEO/Project Manager
E11	63	Renewable Energy/Community Management	Head of Co-Innovation
E12	80	Energy Services/Community Development	Municipal Chairman
E13	61	Municipality/Energy Community	Energy Community Leader
E14	58	Energy community	Development Director
E15	48	Energy Services	Development Manager
E16	150	Retailer	SVP, Customer Services (B2C)
E17	60	Energy Services	Market Analyst
E18	37	Energy Services	

encourage deeper reflection. Active listening was integral, with the interviewer summarizing key points and asking clarifying questions to understand participant perspectives accurately. Flexibility in the sequencing and phrasing of questions allowed conversations to adapt organically to participants' responses. Additionally, storytelling was encouraged, with participants invited to share personal experiences and concrete examples rather than limiting responses to abstract concepts.

Hack et al., [82] concluded that the 'digitalization drive' in the European energy sector is not a regional standalone, and due to the interconnectedness of the electricity systems, a cross-border perspective is preferable. We addressed this point by including six European flexibility platforms in the interview process operating in relatively similar regulatory landscapes, market conditions, and technological benchmarks. Furthermore, the necessity of a platform perspective in PF development is well documented (c.f., [14,67]). These interviews addressed this critical gap since no operational demand-side flexibility platform exists in the Finnish market. Four selected platforms have commercial ambitions, while the remaining two are research-oriented. The experts from these interviews have all been part of the platform development process, making them suitable candidates to highlight the integrational issues within the ecosystem. Similar to the Finnish interviews, we used a semi-structured format, and further triangulation was achieved through a detailed benchmarking exercise. In the benchmarking process, we investigated issues such as the value propositions of these platforms for the ecosystem and their potential to enable flexible prosumer interaction with the grid. The interviews were conducted online between February 2020 and May 2024. Cross-validating the Finnish ecosystem findings with insights from this interview round increases our results' applicability across a broader European context. Table 2 provides an overview of these interviews.

### 3.3. Data analysis, validity, and reliability

The data analysis was conducted in three stages, with some iteration. Following [86], it began with a content analysis where raw data from

**Table 2**  
Interviews from flexibility platform providers.

Interviewee code	Duration (min)	Operation location	Job title
P1	52	Netherlands	Business Consultant, Smart Energy
P2	36	UK	Project Manager
P3	30	Norway	Senior Consultant
P4	31	Germany	Analyst
P5	68	Croatia	R&D Project Manager
P6	55	Portugal	Innovation Manager

transcripts, interview notes, and additional materials were assembled. An initial coding phase applied descriptive labels directly to the data, capturing patterns emerging from participant statements without theoretical imposition. In the second stage, several case records were constructed by grouping the coded data into emerging patterns identified across the dataset. A pattern analysis followed, in which recurring themes across the case records were identified and further condensed to reveal overarching patterns within the dataset [86].

To further refine the analysis, the third stage employed the Gioia methodology [88] to construct a data structure visually representing the progression from raw data to higher-order theoretical themes (Fig. 4). The first-order concepts emerged directly from the interview data. These concepts were then grouped into nine theoretical second-order themes in Fig. 3. Finally, they were aggregated into the three central pillars of this study: prosumer flexibility drivers, electricity ecosystem, resource integration, and value co-creation in the PF context. Appendix 2 presents an example of the coding process, including representative raw data, content codes, and the progression to theoretical themes.

The principal author primarily conducted the coding process to ensure the consistency of criteria; however, the co-authors validated the coding throughout this process. Moreover, following [89], extensive data triangulation was used to maximize the study's internal validity. As such, we reviewed numerous materials from the selected organizations (e.g., publicly available financial and technical data, industry reports, press releases, etc.). In addition, three of the authors of this paper had been involved in a national project to conduct a feasibility study of a demand-side flexibility market in Finland. The project involved significant research and industrial actors from the country's energy sector. Notes and memos from the project workshops, seminars, and meetings were used to validate the interview data.

## 4. Findings

This section presents the main findings from the interviews, organized according to the data structure detailed in Fig. 4. In line with [86], selected participant quotes are included in the text to illustrate central themes and represent participants' views directly. Additional supporting evidence in the form of illustrative quotes is provided in the Annex.

### 4.1. The drivers of prosumer flexibility

#### 4.1.1. Prosumption pathways through prosumer communities

The interviews revealed a general willingness among prosumers to engage in community-based frameworks, particularly when incentives align with their interests. Prosumers were perceived as more open to sharing data, modifying consumption schedules according to price signals, and participating in energy-sharing schemes with their neighbors. However, several participants emphasized the challenge of engaging "ordinary consumers" (non-prosumers) in such initiatives due to limited domain awareness of DR mechanisms and widespread distrust toward energy companies' motives. A business director for a power retailer observed:

"It is very difficult to explain to ordinary people, domestic customers, how the market works, what flexibility is, and what benefit they might

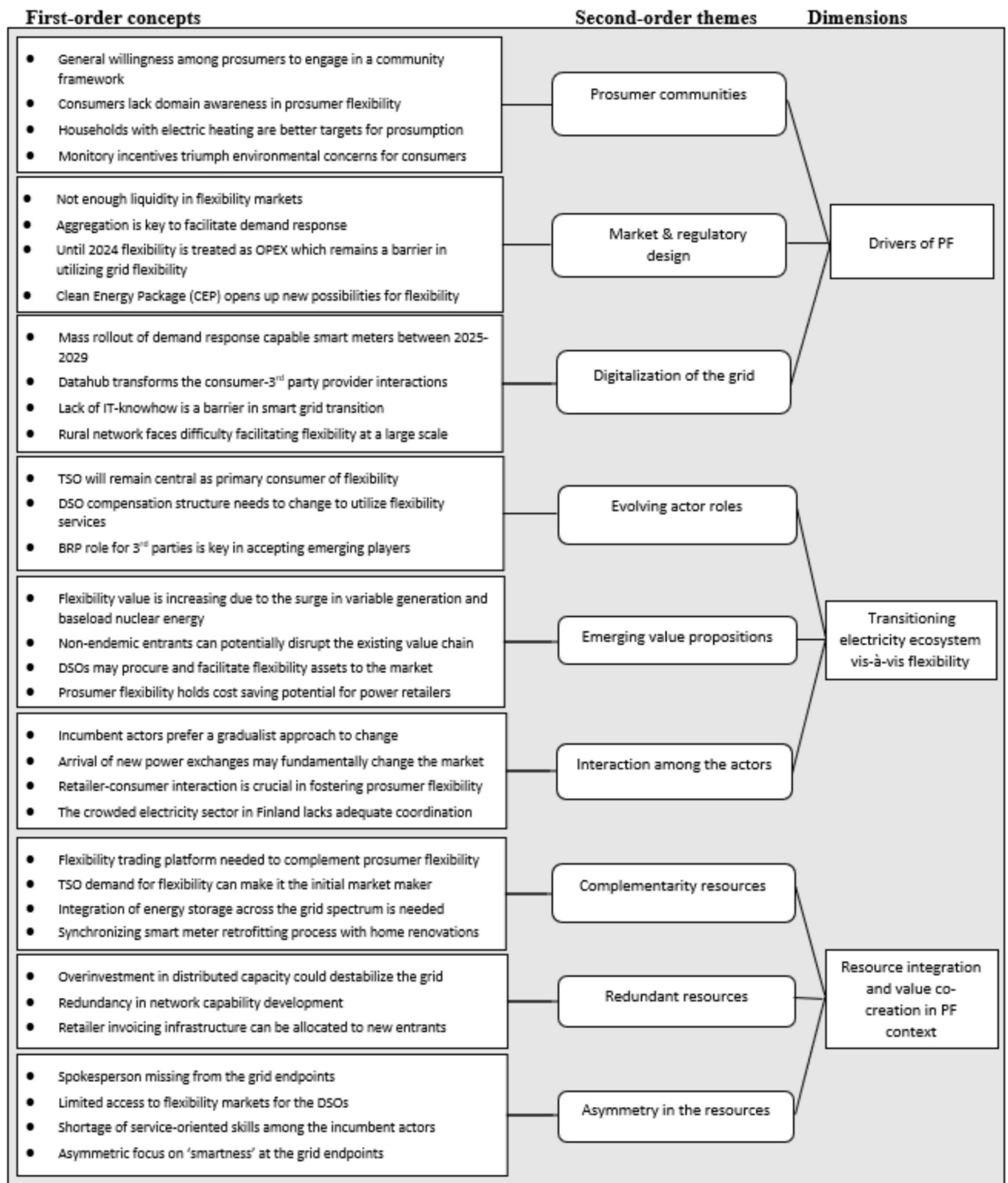


Fig. 4. Data structure.

gain from it. Customers are, how would I say, healthy-minded people, which means they are somewhat suspicious, what scheme the utility is up to now.”

Given these reservations, several interviewees identified households with electric heating as promising candidates for greater flexibility

participation. Such households offer the potential for flexible load control due to the high energy density of electric heating systems. Furthermore, technologies like heat pumps and smart cooling systems were frequently mentioned as critical enablers of prosumption, especially as their adoption grows.

When examining the underlying drivers for prosumption, most interviewees consistently pointed to monetary incentives being more compelling than concerns over sustainability. This perspective was consistent across both industry and community sectors. One community leader argued that a pragmatic approach emphasizing comfort and habitability, particularly for remote energy communities, would be more effective than promoting sustainability alone. Similar concerns were found in another energy community representative, who described the “sustainability-driven waste” phenomenon, where functional household appliances are prematurely discarded in favor of newer, smart technologies.

#### 4.1.2. Market and regulatory design shaping prosumer flexibility

Ensuring liquidity in flexibility markets emerged as a recurring concern among interviewees regarding the influence of PF on the development of PF. Several actors contended that high liquidity would enable efficient price formation, resulting in better utilization of flexibility. A dominant suggestion to counteract market fragmentation was to allow flexibility to be bid across multiple markets, ensuring that it is directed toward areas with the highest demand. Additionally, aggregation was frequently highlighted as a critical strategy to enhance market liquidity and automate the consumer end of the process. It also helps bypass barriers stemming from entrenched consumer habits and the appeal of convenience.

Interviewees also reflected on the appropriate bid size for household flexibility participation. There was a general preference for maintaining a low threshold for market entry, mainly when third-party intermediaries are not involved. This approach was crucial for smoothly incorporating prosumer-grade flexibility into market operations. Moreover, regarding the pricing mechanism for flexibility, the consensus strongly favored market-derived over subsidy-based approaches. This preference extends to PF-enabling devices such as EVs or home battery systems.

Significant **regulatory barriers** were also identified, particularly by participants representing DSOs and TSOs. One of the most cited challenges was classifying flexibility-related costs as operating expenses (OpEx) rather than capital investments (CapEx). This regulatory treatment discourages grid operators from opting for flexibility solutions over traditional grid reinforcements. A DSO sales manager explains:

“The regulatory environment does not incentivize grids to use flexibility as the profit comes from investments. That is a very important reason for forgetting flexibility... (since) DSOs do not profit from making savings. Also, if you avoid investments, you have higher operational costs, which is punished.”

#### 4.1.3. Digitalization of the Finnish electricity grid

The ongoing digitalization of the Finnish electricity grid was generally well-received by the stakeholders. Enhancing the “smartness” embedded within electricity meters at the consumer level emerged as a cornerstone of this effort. According to the participants, the next-generation smart meters are poised to streamline the bi-directional flow of energy and data and are compatible with the imminent transition to 15-min balance settlement intervals. However, participants acknowledged that full implementation will take time, with many meters operational only by 2029.

Several stakeholders indicated that data management is a significant aspect of modernizing the electricity grid. The introduction of Datahub – a centralized information exchange operated by the TSO – heralds a transformative era for the Finnish electricity sector, revolutionizing consumer-service provider interactions. However, despite these advancements, the inadequate ICT capabilities among DSOs were noted as a significant barrier to the grid digitalization effort. It was particularly apparent in these parties’ failure to join the Datahub exchange on time, resulting in several delays. Concerns about the rural grid’s ability to handle large-scale flexibility were raised. A senior DSO executive described the infrastructural limitations:

“...if all the customers were taking their high peak demand at the same time, the truth is that the distribution network in the rural areas cannot pass that electricity. Whether it goes that direction or comes back from the customers, the network is not strong enough... so when we talk about rural networks, the DSO will face problems if the new world is such that you have a low spot price for one hour and everybody consumes electricity or fills their storage exactly at the same time.”

### 4.2. A transitioning electricity ecosystem

#### 4.2.1. Evolving actor roles and responsibilities

The roles and responsibilities within the Finnish electricity ecosystem have continued to evolve since market liberalization [59]. Nevertheless, despite these shifts, interviewees indicated that the central responsibility of the TSO in maintaining system balance would remain constant, positioning it as the principal user of flexibility services while keeping most other market participants on the supply side.

Simultaneously, several participants noted the expanding role of the DSOs due to the anticipated rise in demand for flexibility at local levels. However, it was mentioned that their current compensation structure largely relies on grid investments and distribution fees and is not aligned with the emerging flexibility needs. Further complicating matters, the potential role conflicts between DSOs and third-party operators were mentioned as adding to the challenge of encouraging flexibility at the distribution level. Interviewees also noted the historical emphasis of DSOs in enhancing the security of supplies as an obstacle to the development of flexibility services. The regulatory frameworks that once were designed to ensure stability and security are now seen to be a double-edged sword, impeding the adaptability required in this fast-evolving landscape. A participant from a DSO noted:

“In this industry, people think very traditionally, with a historical burden where everything new is always a threat.”

Electricity retailers, meanwhile, are grappling with the implications of rising third-party players (e.g., independent aggregators) attempting to adopt flexibility-enabling roles. Several interviewees suggested that these third-parties need to assume a balance-responsible role to gain acceptance from retailers. Resolving this issue is central because of retailers’ proximity to customers and the necessity of aggregators in DSM. However, the situation is not as straightforward for the third-parties. Stepping into the BRP role is considered burdensome for smaller entities due to the costs of maintaining a round-the-clock operational presence. Furthermore, the economics of sharing profits from unconsumed energy was mentioned as introducing specific challenges. If aggregators are compelled to buy and sell flexibility in the day-ahead price, their financial viability is undermined.

#### 4.2.2. Emerging value propositions in the ecosystem

Interviewees highlighted that the Finnish electricity ecosystem is undergoing a significant restructuring, driven by shifts in generation capacity and market demands. A notable surge in variable renewable generation, particularly wind energy, contributes to greater system unpredictability. Simultaneously, the rising share of nuclear power in the baseload supply has made the market less flexible [90]. Compounding this structural shift, some interviewees indicated that the need to reduce the reliance on natural gas, necessitated by the ongoing energy crisis, further increases the value of flexibility services.

This situation is placing new demands on distribution networks. With the increasing trend of prosumption and the growth of small-scale flexibility assets, several interviewees suggested that DSOs might soon find themselves procuring and facilitating these assets in the market in addition to their regular distribution duties. Moreover, the accelerated adoption of EVs further complicates this transition. Interviewees identified EV growth as a source of load pressure on the grid and a valuable flexibility asset. Technologies such as vehicle-to-grid (V2G) systems, where EV batteries feed energy back into the grid, were mentioned as promising flexibility solutions. Some participants expressed optimism

that PF could assist DSOs in managing EV-related load growth and balancing consumption and generation more effectively.

Retailers in the electricity sector view PF with growing interest as they recognize its promise in managing energy imbalances and navigating expensive peak hours. Several pilot programs focusing on such services are currently being developed. The ongoing energy crisis catalyzes this arena, incentivizing retailers to develop flexibility-driven business models. Notably, interviewees indicated that PF allows retailers to innovate beyond pricing to appeal to a broader customer base.

#### 4.2.3. Collaboration and competitive interactions among the actors

Participants repeatedly emphasized the highly interconnected nature of the electricity network, which complicates the implementation of radical innovations. Due to the system's delicate balance, even minor alterations can lead to substantial ramifications throughout the network; consequently, established players favor a gradual approach to change. They further note that any major disruption in the existing value chain could trigger significant resistance from entrenched stakeholders. In the words of a veteran utility manager:

“This is a chain of values...If the chain of value is created so that somebody gets hurt, this somebody will do everything to prevent flexibility from happening. And if this somebody is an electricity sales company, he does have a relatively strong grip on the customer... So it would be a lot better that nobody gets hurt, so everybody works in the same direction.”

Despite this interconnectedness, interviewees also pointed to transformative shifts within the ecosystem. For instance, emerging non-traditional players introduce unpredictability and challenges to established roles. These new entrants often bypass traditional constraints utilities face, leveraging their technological infrastructure and existing customer bases.

Furthermore, several interviewees highlighted the impact of political decisions in setting the course for business model development. A case in point is the EU's policy of an open market, which welcomes competition between power exchanges. The Nordics has traditionally relied on Nord Pool for hourly electricity prices; however, the entry of new exchanges could pave the way for a diversified pricing mechanism. Additionally, participants stressed how the historical certainty of uninterrupted power supply is under increasing pressure, necessitating a pivot in retailers' business models. They noted that retailers must recalibrate their communication strategies, moving from the traditional narrative of constant supply assurance to a more nuanced service offering emphasizing grid flexibility.

Lastly, the Finnish electricity ecosystem is rather crowded, with 53 electricity retailers and 77 DSOs (excluding high-voltage ones) [90]. Feedback from interviewees highlighted a prevailing lack of coordination within this saturated market. Further complicating matters, many retail entities have instigated aggressive price competition to solidify their market positions. Such competition affects market development, resulting in a lack of priority for offering innovative products or services.

### 4.3. Resource integration and value co-creation in the context of prosumer flexibility

#### 4.3.1. Resource complementarity for prosumer flexibility adoption

The adoption of PF depends heavily on resource complementarity, where different assets and capabilities collectively enhance value creation. Actors require various complementary resources to effectively engage in value co-creation, as resources are more impactful when they work together to achieve system-wide benefits [77]. Accordingly, several interviewees indicated that integrating a flexible trading platform into the Finnish electricity market would simplify the flexibility-sharing process and increase customer domain awareness.

A recurring theme among interviewees was the need for a marketplace capable of handling small-scale flexibility loads. This need arises from a market barrier commonly described in the literature as the

“chicken and egg” dilemma, where supply and demand for a novel service struggle to develop concurrently [91]. However, several participants noted that the TSO's high demand for system flexibility positions it as a potential initial market maker.

Energy storage was also identified as a critical complementary resource for PF. From individual households to community energy setups (e.g., EV and behind-the-meter batteries) and the broader grid infrastructure (e.g., utility-scale), battery systems are expected to bolster self-reliance, harmonize grid operations, and usher favorable flexibility trading opportunities.

However, the current smart meter infrastructure presents a significant barrier to effective PF integration. While the next-generation smart meters are crucial for DSM, full deployment in Finland is not expected until 2029. Until then, households interested in participating in flexibility programs would face significant retrofit costs, including expensive equipment upgrades and installation fees. An innovative proposal emerged from the interviews to address this, suggesting that meter upgrades could be synchronized with other home construction or renovation activities.

#### 4.3.2. Resource redundancies and its implications

Resource redundancy is noticed when multiple actors possess resources that are similar in category [66]. Accordingly, the interviewees indicated that the current trend of investing in distributed capacity (e.g., wind or solar PV) is not always optimal from the systemic perspective. Such overdevelopment of capacity – and the associated capabilities – might contribute to a grid imbalance and create resource scarcity in other areas of the system. Furthermore, several participants highlighted a redundancy in network capability development, especially within the zoned areas in distribution networks. An overinvestment here implies that the physical infrastructure (e.g., cables, substations, transformers, etc.) in the urban areas will be enhanced more than is required, slowing down the adoption of more efficient or sustainable technologies in power distribution.

Beyond physical assets, operational redundancies were also identified, particularly concerning billing mechanisms. Retailers, by their long-standing presence in the market, possess sophisticated billing systems, and through a partnership with them, novel entrants could utilize this resource. A senior manager from a power retailer explains:

“When discussing one domestic customer, you know billing is big. If you enter a (flexibility) market where hundreds of thousands of households can enter, you must have a billing system for hundreds of thousands of households. And in the end, you may compensate or invoice a few euros per month. Then, the billing system itself more or less doubles the cost. Whereas we (retailers) have a billing system already, and we have to invoice those customers anyhow.”

#### 4.3.3. Resource asymmetry among the actors

Interviewees highlighted significant resource disparities, particularly for DSOs, when compared to TSOs, in accessing flexibility markets. This imbalance has resulted in limited flexibility service growth at the distribution level, emphasizing the need to cultivate DSO-driven flexibility. Another critical resource gap identified during the interviews was the shortage of service-oriented skills within the electricity industry. Some participants point to a prevailing “engineer mindset” as a cultural barrier, suppressing the emergence of a more customer-centric approach. One industry professional candidly described this challenge:

“I am an engineer; I have a master's degree in engineering and am very proud of it. However, one problem is that too many engineers are in this field. We like machines; we believe in generators and not in the forward market.”

Lastly, the ongoing modernization of Finland's electricity grid has attracted criticism for its asymmetric focus on “smartness” at the endpoints (e.g., households) instead of smart infrastructure across the distribution network. This approach, critics argue, could lead to an overdependence on the endpoint resources (e.g., DERs, HEMS) when

similar outcomes might have been achievable through smart control mechanisms within the grid. Moreover, another prominent concern is the absence of a spokesperson for the endpoints. It is crucial for PF because both consumers and prosumers are located at grid endpoints and do not have the means to collaborate effectively within the ecosystem, hindering value co-creation.

## 5. Discussion

The Finnish electricity ecosystem is experiencing prominent structural changes, revealing tensions that challenge and shape the path toward PF adoption. These challenges manifest across market competition, evolving actor roles, consumer engagement, regulatory frameworks, and resource integration. This section explores the frictions and outlines pathways to balance these tensions, emphasizing strategies for achieving ecosystem-wide value co-creation.

### 5.1. Ecosystem modifications and market competition: Navigating resistance

The Finnish electricity ecosystem is undergoing significant structural changes driven by market saturation and evolving business models. The saturated market has led to intense price competition, leaving little room for innovation or investment in flexible solutions. These challenges echo observations by [59], who noted shifting roles in the Finnish electricity sector following market unbundling. A central feature of this evolution is companies transitioning from energy suppliers to energy services, a shift corroborated by [55]. However, this shift mainly introduces tensions for actors distanced from direct consumer interactions, also emphasized by [61].

Adding to this complexity is the entry of non-traditional actors, such as power cooperatives and aggregators, which complicates the current value chain and increases the chances of conflict between novel and incumbent players [49]. Retailers, historically the primary touchpoints for consumers within the electricity grid [7,59], are increasingly challenged by the rise of third-party intermediaries and the expansion of smart metering systems. This shift reshapes traditional ecosystem dynamics and could potentially spark friction. Evidence also points to a growing convergence among consumer and retailer aspirations for an interactive, bi-directional grid engagement. This inference is backed by a marked 63 % annual increase in partial self-generation contracts in Finland [90]. The energy crisis stemming from the Russia-Ukraine conflict acts as a catalyst, increasing consumer involvement in their energy consumption patterns and prompting retailers to enhance their service offerings centered around energy efficiency.

Despite these advancements, established players often resist disruptive innovations due to concerns over losing market shares or compromising existing value chains [64]. This resistance underscores the need to balance innovation with incumbents' welfare, as Gough et al. [11] echoed. Cultivating symbiotic relationships among ecosystem actors through innovative business models and operational frameworks offers a pathway to mitigate this resistance (c.f., [13]). For instance, adaptable energy schedules and decentralized energy storage [36] provide opportunities for prosumer value co-creation with distributed flexibility. Moreover, entrepreneurial initiatives, such as heat pump-based DR solutions (e.g., Kapacity.io), illustrate the potential synergies between prosumers and the ecosystem actors.

Thus, we propose the following:

**Proposition 1.** Collaborative frameworks that balance innovation with incumbent welfare can minimize resistance and nurture synergies among ecosystem actors.

**Proposition 2.** Streamlined market coordination and reduced fragmentation can enable the prioritization of innovative flexibility solutions, particularly in competitive environments.

### 5.2. Actor roles and responsibilities: Tensions in evolving ecosystem dynamics

The emergence of novel actors within the Finnish electricity ecosystem has intensified tensions related to evolving roles and responsibilities. This is concerning because Effective adoption of PF relies on high interaction and interdependence among actors, as highlighted by [57]. These interactions are necessary at the ecosystem level and within platform-specific engagements [36,56]. However, challenges arise in defining and allocating balancing responsibilities for new entrants, such as independent aggregators. Resonating with the conclusion by [67], we recognize the need for third party operators to assume balancing responsibility in order to be seamlessly integrated into the value chain by the retailers. Additionally, we extend the literature by incorporating profitability challenges for aggregators—such as the high costs of maintaining 24/7 operations and difficulties establishing fair price differentials when compensating suppliers at day-ahead market rates.

Thus, we propose the following:

**Proposition 3.** Addressing operational bottlenecks and establishing fair pricing mechanisms for third-party actors are critical in enabling their participation in balancing responsibilities and enhancing prosumer flexibility adoption.

### 5.3. Consumer engagement and energy literacy: Bridging knowledge gaps

Consumer engagement remains a significant challenge in transitioning to a flexibility-driven electricity ecosystem. Prior research has established a positive relationship between energy literacy and consumer participation in energy efficiency behaviors, as demonstrated in the Finnish context by [48]. Our findings further align with this, indicating that higher energy literacy increases the likelihood of consumer participation in DSM flexibility programs. However, our analysis suggests that current energy literacy programs are insufficiently adapted to meet the demands of a rapidly evolving electricity ecosystem. A critical limitation in existing programs is the prevailing narrative, which emphasizes thrifty energy consumption while neglecting the operational realities of a flexible grid. This outdated messaging fails to communicate the present reality, where intermittent renewable generation necessitates periodic consumption spikes. Accordingly, there is an urgent need to update the energy literacy initiatives provided by educational institutions such as schools, energy communities, and cooperatives.

Compounding this issue is widespread consumer skepticism toward corporate-driven energy efficiency campaigns, a sentiment also noted by [63]. Our analysis suggests that the roots of this skepticism partly lie in the consumer knowledge gap concerning the changing status quo of the electricity sector. Consumers have internalized the ecosystem's historical assurance of uninterrupted power supply, whereas the current reality calls for the grid to take on a more active role in shaping consumption patterns. The ecosystem is aware of this shift; however, the messaging to end consumers is yet to be adequately adjusted.

This gap is critically essential because PF may not achieve its intended impact if consumers are not informed about concepts such as 'flexibility' and 'congestion' and do not understand their changing roles in the ecosystem. Retailers, as the primary contact points for electricity consumers, are ideally positioned to bridge this gap. They can educate consumers on flexibility's mechanics and tangible benefits by delivering updated energy literacy programs. This approach aligns with recommendations by [60], who emphasize the importance of retailer involvement in promoting flexibility initiatives. Tailored energy literacy campaigns that address the "how" and "why" of energy consumption patterns can demystify key concepts, reduce skepticism, and encourage greater consumer engagement in PF initiatives.

Thus, we propose the following:

**Proposition 4.** Retailer-led energy literacy programs that explain

flexibility concepts and their tangible benefits can enhance consumer engagement in prosumer flexibility initiatives.

#### 5.4. Policy and regulatory interventions: Addressing structural barriers

Policy and regulatory misalignments remain significant obstacles to the widespread adoption of PF in the Finnish electricity landscape. Our findings emphasize the cost-saving potential of flexibility services in the Finnish distribution network, supporting prior conclusions from [14]. However, despite their potential value, capacity constraints in rural networks pose a substantial barrier to scaling PF solutions. In particular, recent amendments to The Electricity Market Act in Finland have complicated matters by extending the deadlines for DSOs operating outside zoned areas (i.e., rural networks) to meet their network development and investment obligations. Initially set for 2028, this deadline has been pushed back to 2036 [90]. This exacerbates infrastructural delays, creating prolonged hurdles for implementing flexibility services. Moreover, our analysis aligns with [43] observation that low spot prices could lead to grid congestion in such areas and conflicting signals from retailers and the DSOs to prosumers regarding electricity consumption.

Our findings suggest that without targeted improvements to the non-zoned rural grid and more proactive support for flexibility initiatives, such inefficiencies could escalate, potentially involving emerging actors (e.g., aggregators, VPPs). This scenario mirrors broader trends in smart grid technology diffusion, where rapid technology adoption has resulted in operational inefficiencies and grid instability [8].

To address these structural barriers, DSOs must transition from their traditional focus on supply reliability toward more proactive roles in localized flexibility service development. However, our findings reveal a persistent innovation-averse culture among DSOs. This reluctance is evidenced by only a minority of DSOs exploring or piloting flexibility projects despite regulatory incentives such as R&D support and requirements to include flexibility in network development plans [90]. One approach to address this could be to mandate system operators to develop collaborative projects with service-oriented partners. An example of this can be found in Germany, where the SINTEG initiative by the federal government fosters partnerships among various stakeholders, including DSOs, technology, and service providers, to co-create solutions [92].

Thus, we propose the following:

**Proposition 5.** Targeted capacity-building initiatives, including ICT proficiency and service-oriented skills, can enhance DSOs' ability to integrate prosumer flexibility services effectively.

**Proposition 6.** Policy frameworks prioritizing grid upgrades and incentivizing prosumer participation can accelerate the adoption of flexibility services, particularly in underserved rural areas.

#### 5.5. Resource integration challenges: Balancing complementarity, redundancy, and asymmetry

Effective RI is crucial for successfully adopting PF within the electricity ecosystem. Our findings reveal key tensions surrounding resource complementarity, redundancy, and asymmetry, which must be addressed to optimize resource utilization. Collaboration across multiple levels—micro (e.g., prosumer-to-prosumer), meso (e.g., prosumer-to-retailers), and macro (system-wide) is necessary to facilitate a resource matching process [35,71].

A key challenge arises from resource asymmetry based on actor incumbency in such circumstances. Incumbent actors like system operators, retailers, and energy companies frequently overinvest in conventional capacities like network infrastructure while underperforming in critical areas such as ICT capabilities. Conversely, emerging actors might lack financial resources or established market relationships despite excelling in technological innovation, exemplified by V2G or cloud-based DR services. Resource redundancy further

complicates this landscape. For instance, overlapping investments in specific urban infrastructure components may create inefficiencies, while rural areas remain under-resourced and underdeveloped for flexibility integration. However, resource complementarity offers opportunities for collaborative advancement. For instance, while some emerging actors lack invoicing capabilities critical for flexibility service delivery, established retailers possess underutilized infrastructure, such as billing systems, that could be leveraged for PF expansion.

To resolve these tensions, we introduce the concept of resource harmonization, emphasizing the need to bridge gaps between incumbent and emerging actors. Resource harmonization focuses on balancing resource availability across the ecosystem, nurturing collaboration, and enhancing the operationalization of PF (Fig. 5). Although classifying actors by incumbency is familiar in the electricity sector (c.f., [93]), the novelty of our research lies in focusing on RI dynamics during early-stage technology adoption. Resource harmonization encourages collaborative business models and shared technological platforms by addressing redundancy and complementarity, reducing asymmetry across ecosystem actors. This approach paves the way for greater value co-creation.

We further propose the following,

**Proposition 7.** Resource harmonization through collaborative initiatives and innovative business models can enable value co-creation and enhance the operationalization of prosumer flexibility.

## 6. Conclusion

While the value of flexibility is uniformly anticipated to rise, our findings indicate varied levels of preparedness in the Finnish electricity ecosystem. This discrepancy is particularly evident when integrating flexibility services closer to grid endpoints, home to prosumers. However, PF's significance resonates throughout the ecosystem, highlighting the value chain's interconnected and often delicate nature among ecosystem actors (e.g., as discussed in [29,32,33]). Although specific studies have identified PF's potential in enabling customer engagement with the energy infrastructure (c.f., [5,17]), comprehensive exploration remains in its infancy. This literature gap becomes noticeable when examining the value co-creation potential of distributed flexibility. Addressing this, our study explored the resource integration aspect of value co-creation in the Finnish electricity ecosystem through the prism of PF. To achieve this, we conducted an exploratory single-case study and identified key actors and their resource attributes concerning this technology, leading to several important contributions.

### 6.1. Theoretical contribution

This study contributes to the energy prosumption literature by incorporating SDL as a framework to conceptualize electricity consumers as active participants in value co-creation. By emphasizing the shift from passive consumption to active engagement, this paper lays the groundwork for more dynamic and interactive energy markets, challenging traditional consumer roles and enabling innovation and adaptability in business models within the energy sector. Our paper is among the first to apply the value co-creation framework to the PF literature and, to our knowledge, the first to incorporate SDL into this domain.

Additionally, we extend SDL literature by examining resource matching within an interdependent ecosystem undergoing early-stage innovation diffusion. SDL research has predominantly focused on the interaction side of resource matching—such as dialog, learning, and resource transfer (c.f., [66]) our findings extend this perspective by examining resource alignment within an evolving ecosystem. Specifically, we align with [37], who identify resource matching as a necessary precursor to RI rather than a simultaneous process (c.f., [39]). We observe notable resource differences based on actor incumbency and term the subsequent matching process 'resource harmonization',

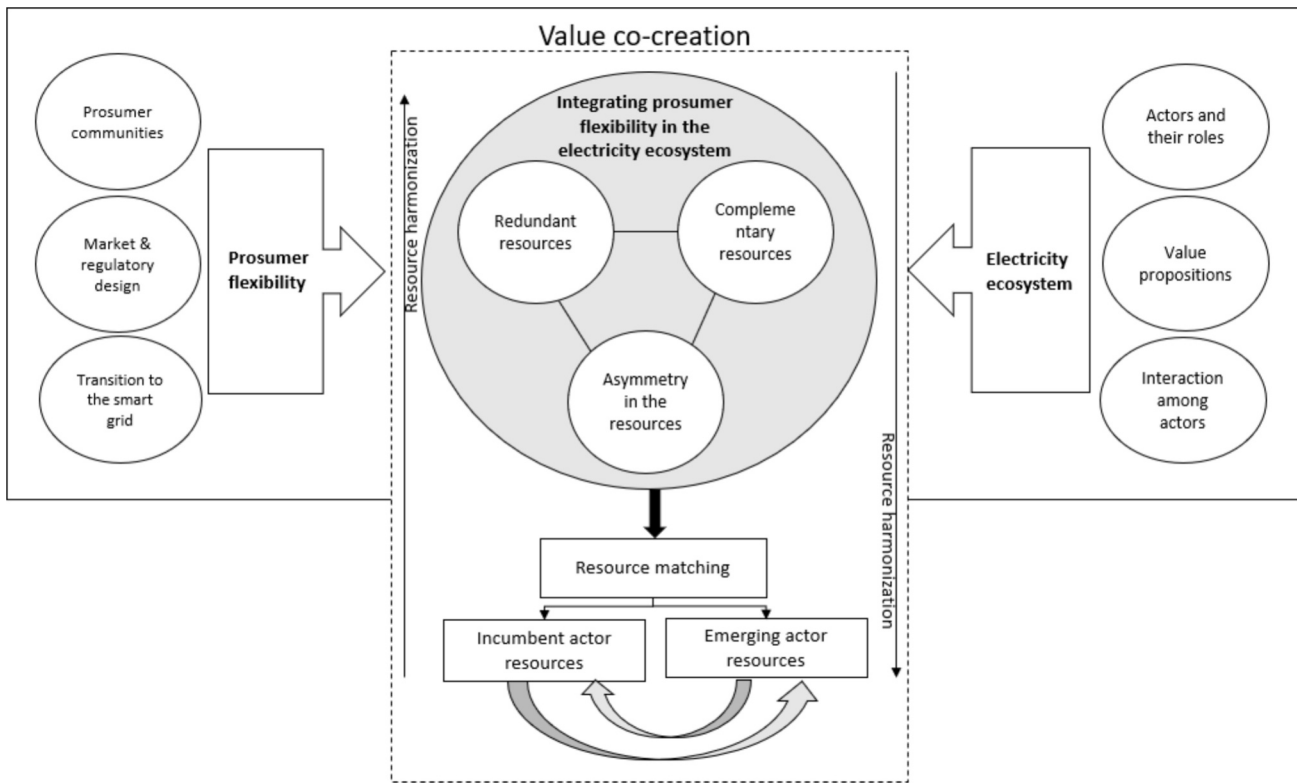


Fig. 5. Modified theoretical framework.

providing a nuanced understanding of how different actors align their resources to collectively co-create value.

Building on these insights, our study integrates multiple dimensions of PF development and ecosystem characteristics into a cohesive, actionable model, visually represented in Fig. 5. This approach addresses critiques by [34], who observed that prosumer literature often narrows on system optimization and transaction design, overlooking actor roles and the necessity for adaptive business models.

### 6.2. Practical implications

Our study offers several important insights for practitioners and policymakers within the energy sector. For practitioners, the resource harmonization framework is valuable for identifying and leveraging stakeholder synergies. For instance, our findings highlight how the lack of invoicing capabilities among new market entrants hinders PF implementation despite the availability of underutilized invoicing infrastructure within established retailers—offering a clear avenue for value co-creation. Similarly, addressing residential consumers’ lack of domain awareness presents another opportunity. Retailer-led energy literacy campaigns can play a pivotal role in bridging this gap, using digital communication tools such as mobile applications to reach a wider audience effectively. Fig. 6 visually illustrates these dynamics. We believe the application of this framework extends well beyond PF and could offer valuable insights into RI dynamics within the broader energy sector.

Moreover, for policymakers our findings emphasize the need for targeted interventions addressing several structural barriers. First, energy literacy programs must evolve to reflect the realities of a flexibility-driven energy system. Collaborative efforts among educational institutions, energy communities, and retailers should deliver updated, context-specific initiatives that explain the role of consumer behavior in grid stability and environmental outcomes while emphasizing practical benefits like EV charging optimization and storage-integrated PV systems. Second, policies should incentivize DSOs to adopt a more

proactive role in flexibility service development. Capacity-building initiatives targeting ICT proficiency and service-oriented skills are essential to enable DSOs to manage flexibility solutions effectively. Mandating DSOs to collaborate with service-oriented partners, as seen in Germany’s SINTEG initiative, could further accelerate innovation and ecosystem-wide integration. Finally, recent amendments to The Electricity Market Act in Finland explicitly extended the deadline for rural DSO infrastructure development risk, prolonging bottlenecks in non-zoned rural areas. Policies must prioritize grid upgrades in these underserved regions and incentivize DSOs to proactively integrate flexibility solutions into their network development plans.

### 6.3. Limitations and future research

As an early contribution to an emerging research area, our study has certain limitations that can pave the way for subsequent investigations in this critical domain. First, our research does not include a flexible platform from the Finnish electricity ecosystem. While flexibility platforms are crucial for advancing PF, no commercial platforms are available in the Finnish market. To address this, we have incorporated data from six European flexibility platforms. This approach assumes that reliable market conditions, including regulations and operational environments, allow us to draw informed comparisons. Future studies could fill this research gap by including insights from a local flexibility platform when it becomes available in Finland.

Second, our study focuses on prosumer communities rather than individual prosumers as the primary analysis unit. This approach might result in missing out on the nuances of individual behaviors and preferences, especially if community representatives hold biased views. Additionally, this study does not distinguish between homeowners and tenants within the prosumer category. Considering the implications of this distinction, particularly in contexts where access to flexibility solutions may vary, future research could explore these dynamics more comprehensively.

Third, our interview data from the Finnish ecosystem seems to lean

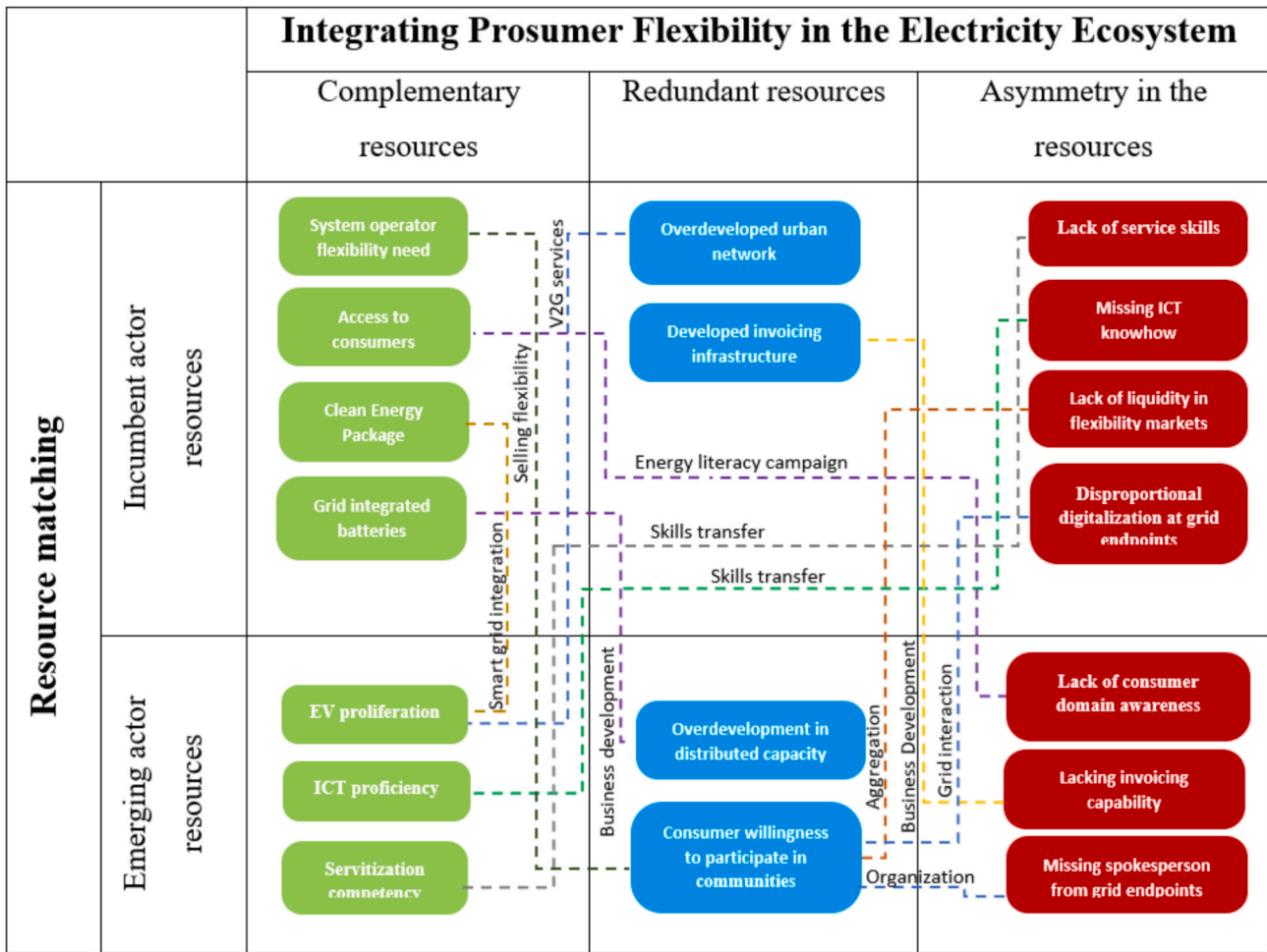


Fig. 6. Examples of value co-creation through resource harmonization.

toward incumbent actors, at least in quantity. Even though we tried to ensure that the managers interviewed from incumbents had experience in demand-side flexibility projects, this could still introduce certain biases into our analysis. Future investigations can go deeper into the perspectives of emerging actors, with particular emphasis on individual prosumers engaged in flexibility programs. Furthermore, while our study broadly conceptualizes DSM to include both operator-driven and actor-driven initiatives, comparative research focusing on these distinct dimensions of DSM-enabled PF could offer valuable insights.

Lastly, we believe conducting a multiple-case study as confirmatory research on our proposed resource harmonization framework would be worthwhile. This could ensure a detailed examination of variations across different contexts, enhance the generalizability of our findings, and offer deeper insights into effective implementation strategies in diverse regulatory and market environments.

**CRedit authorship contribution statement**

Nayeem Rahman: Writing – review & editing, Writing – original

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.apenergy.2025.125814>.

draft, Methodology, Formal analysis, Data curation, Conceptualization. **Rodrigo Rabetino**: Writing – review & editing, Supervision, Methodology. **Arto Rajala**: Supervision, Funding acquisition. **Hannu Makkonen**: Writing – review & editing, Conceptualization.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix B. Interview Guide.

### General Questions for All Actors

1. How feasible is implementing prosumer flexibility (PF) in Finnish energy sector, considering market readiness, stakeholder willingness, technical preparedness, and financial transaction mechanisms?
2. What are the three biggest barriers to implementing PF in Finland?
3. What benefits do you foresee from a local demand-side flexibility market?

### TSO-Specific Questions

1. What are the most critical features needed in a flexibility marketplace from a TSO perspective?
2. How should TSOs and DSOs collaborate to facilitate flexibility services effectively?
3. What mechanisms could ensure effective coordination of flexibility resources across multiple stakeholders?

### DSO-Specific Questions

1. How do you decide between grid reinforcement and flexibility solutions in network planning?
2. What pricing mechanisms would work best for flexibility services in your operations?
3. How should DSOs screen and select flexibility service providers to ensure reliability?

### Retailer-Specific Questions

1. How does PF influence your retail strategies and interactions with consumers?
2. How should risks and responsibilities between retailers and aggregators be distributed?
3. What role can retailers play in bridging consumer knowledge gaps about flexibility and its benefits?

### Regulator-Specific Questions

1. What regulatory changes are required to enable DER participation in ancillary services in Finland?
2. How can regulations better support smaller prosumers/consumers to overcome participation barriers, such as the 100 kW limit?
3. What steps is Finland taking to align with the EU Clean Energy Package (CEP) and Guideline on Electricity Balancing (EBGL)?
4. How can free-riding in balancing responsibilities be avoided when customers sign contracts with multiple providers?

### BRP-Specific Questions

1. How can demand-side resources improve portfolio optimization and passive balancing?
2. Should licenses be issued to third parties for trading flexibility, and what safeguards would be needed?
3. What is the impact of Finland's Datahub on BRP operations, and how could it facilitate flexibility?

### Aggregator-Specific Questions

1. What challenges do aggregators face in organizing and integrating prosumers into the current system?
2. How should aggregators manage a diverse consumer composition (e.g., households vs. industrial participants)?
3. How does Finland's Datahub impact aggregator operations, and how can it be optimized for flexibility services?

### Energy Community-Specific Questions

1. What incentives and motivations drive energy communities' members to participate in PF programs?
2. Are members willing to engage in peer-to-peer energy trading, and what tools or platforms would facilitate this?
3. Would your members be interested in trading energy with neighbors? How would they feel about real-time energy monitoring?
4. What are the key challenges for energy communities in adopting PF practices, and how can these be mitigated?
5. Are there any concerns about current energy consumption habits within your community? What potential areas for reduction do you see?

### Flexibility Platform Operator-Specific Questions

1. What flexibility products or services do you currently offer? Could you describe their adoption and reception?
2. What is your pricing model for flexibility services? How do you screen stakeholders and establish contracts?

3. How do you ensure data security and privacy for stakeholders using your platform?
4. What are the main challenges you face in the Finnish energy ecosystem? Are there specific regulatory barriers or conflicts between grid reinforcement and flexibility deployment?
5. What role do you see energy communities playing in the development of prosumer flexibility? How are they integrated into your platform?

**Appendix C. Example data analysis process.**

Illustrative participant quotes	Content analysis and the resulting codes	First-order concepts from pattern identification	Second-order themes (theoretically informed)	Theoretical aggregate dimensions (final abstractions)
<p>“We concentrated on electrical heating because the possibilities for flexibility are the best when you have electrical heating. You have a boiler where you heat your water, and then you have radiators or (roof) heating or whatever, floor heating, which you can also adjust” (E5)</p>	Electrification of heating; load control; flexibility potential			
<p>“First, you need to have something that uses electricity or produces it, like a boiler or floor heating, for example. There are service providers who offer smart boxes or something to your boiler, and they can control it. But, if you have oil-heating, then there is nothing you can do.” (E1)</p>	Electrification of heating; smart boxes; load adjustability	Households with electric heating are better targets for prosumption	Nurturing prosumer communities	Prosumer flexibility
<p>“Flexibility is part of the solution because there is a lot of discussion about sector integration. In Finland, a lot has been done to use the flexibility of heating to give more flexibility to the electrical grid. As heating gets more electrified, there will be more flexibility for the grid.” (E18)</p>	Electrification of heating; sector integration; flexibility potential			
<p>“Regarding the Finnish electricity production system, we are heading toward more nuclear in the mix because of Olkiluoto. But, the property of nuclear energy is that it is not very adjustable; you always push it with full power. So the base power runs steadily through the year, and it is everything else but flexible, and then we will have more and more wind power. And we know the problem: you get the power when the wind wants to produce it.” (E5)</p>	Nuclear baseload; Renewable variability; inflexibility of production			
<p>“If we have more electricity systems based on variable renewable generation or solar... Then, the consumption patterns typically do not match. Traditionally, we have a fixed consumption pattern, and the power generation pattern matches that consumption... If you go into the future, you will have an unpredictable production pattern, and consumption should match that. And this is then, of course, a challenge. I would say consumption has a huge role because you have the seasonality (wind), seasonality (– sun), and sometimes the not-so-windy times can take several days or weeks.” (E7)</p>	Renewable variability, consumption mismatch, seasonality	The value of flexibility is increasing due to the variable generation and baseload nuclear energy	Emerging value propositions	Electricity ecosystem
<p>“In fact, the more renewable sources in the network, the energy will be less of a problem because there will be more and more energy produced, but flexibility will be key to the market. Especially if you want to get rid of natural gas from the system, which is the primary source for flexibility now.” (P5)</p>	Renewable energy; flexibility market; reducing natural gas reliance			
<p>“At the beginning of local flexibility markets, there might not be enough demand and, then we are thinking that maybe we [the TSO] need to be the market makers and doing some buying.” (E1)</p>	TSO, as a market maker			
<p>“And this flexibility as such, of course, who needs flexibility is [the TSO]. They need to balance the Finnish power system. So, they need to purchase flexibility from others because they do not have any capacity. So there is a natural buyer of flexibility, and then everybody else is more or less seller.” (E7)</p>	TSO as market maker; system balancing; market roles	TSO’s demand for flexibility can make it the initial market maker	Complementary resources	Resource integration, Value co-creation

**Data availability**

The data that has been used is confidential.

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