Emerging business models in local energy markets: A systematic review of Peer-to-Peer, Community Self-Consumption, and Transactive Energy models

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Abstract

The emergence of Peer-to-Peer, Collective or Community Self-Consumption, and Transactive Energy concepts gives rise to new configurations of business models for local energy trading among a variety of actors. While much attention is paid in the academic literature to the transition of the underlying energy system with its macroeconomic market framework, fewer contributions focus on the microeconomic aspects of the broad set of involved actors. Even though specific case studies highlight single business models, a comprehensive analysis of emerging business models for the entire set of actors is missing. Following this research gap, the presented paper conducts a systematic literature review of 135 peer-reviewed journal articles to examine business models of actors operating in these energy markets. From 221 businesses in the reviewed literature, nine macro-actor categories are identified. For each type of market actor, a business model archetype is determined and characterized using the business model canvas framework. The key elements of each business

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model archetype are discussed, and areas are highlighted where further research is needed. Finally, this paper outlines the differences of business models for their presence in the three local energy market models. With a particular focus on the identified customers and partner relationships, the study highlights the key actors per market model and the character of the interactions between market participants.

Keywords: peer-to-peer, self-consumption, transactive energy, local energy market, business model canvas, electricity trading, flexibility provision, prosumer, consumer, aggregator

List of Abbreviations

BM	Business Model
BMC	Business Model Canvas
CAPEX	Capital Expenditures
CSC	Community (or Collective) Self-Consumption
DER	Distributed Energy Resource
DR	Demand Response
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
EV	Electric Vehicle
HRM	Harmonized Electricity Market Role Model
ICT	Information and Communications Technology
IEA	International Energy Agency
IoT	Internet of Things
LEM	Local Energy Market
OPEX	Operational Expenditures
O&M	Operation & Maintenance
P2P	Peer-to-Peer
PV	Photovoltaic
REDII	European Renewable Energy Directive 2018/2001
TE	Transactive Energy
ToU	Time-of-Use
VPP	Virtual Power Plant

1. Introduction

The electricity industry is experiencing an unprecedented and rapid change driven by the interactions between the urgent need to tackle climate change, the proliferation of Distributed Energy Resources (DERs), and advances in Information and Communication Technologies (ICTs). The wave of the 5D global energy megatrends, namely Decarbonization, Decentralization, Digitalization, Democratization, and Disruption-as-usual, has accelerated the shift from the conventional electricity paradigm to the next era of the decentralized, distributed, clean, and smart energy system [1–3]. Viewed from the power industry perspective, the ongoing transformation takes place at both sector and actor levels.

At the sector level, the transformation is largely influenced by the interplay between digitalization and the prevalence of DERs, providing power from smaller assets at lower investment costs [4]. This fosters the proliferation of potentially new Local Energy Market (LEM) models for the power sector [5]. Amid this quest for innovation, the most widely discussed models in industry and academic literature are Peer-to-Peer (P2P), Community (or Collective) Self-Consumption (CSC), and Transactive Energy (TE) [6–8].

At the actor (i.e., the energy market participant) level, these new models have agitated a similar urge for transformation, allowing a number of new digital technology businesses to enter the energy markets. The emergence of, and the competition threat from, such new Business Models (BMs) forces the current market incumbents to re-evaluate their place in the market and to readjust their business practices [4, 9].

Despite the lively and ongoing research on the topics of P2P, CSC, and TE models, to date, there has been no consolidation in the knowledge of the current structure of the BMs populating such markets, nor of the key actors that drive these models. The present paper addresses this research gap by tackling the following research question: *How are the new P2P, CSC, and TE energy trading businesses structured and what key actors drive them?*

A comprehensive structured literature review based on academic literature published at peer reviewed journals is undertaken here. The review analyses the structure of BMs ascribed to P2P, CSC, and TE market models by using the Business Model Canvas (BMC) framework [10]. The BMC is commonly used by both academics and practitioners in the energy sector to analyze, describe, and compare existing BMs [9, 11–13]. The key contributions of the present work can be summarized as follows, it:

1. Identifies the key actors that drive P2P, CSC, and TE models;
2. Undertakes a systematic literature review that aggregates and systematizes the types of P2P, CSC, and TE BMs envisioned and/or trialled by the academics into common archetypes;
3. Details the structure of each of these BM archetypes as reflected by the BMC framework;
4. Considers the specificities and peculiarities of the identified BM archetypes.

The rest of this paper is structured as follows: Section 2 outlines the relevant background work and elucidates the terms P2P, TE, and CSC. Section 3 details the systematic methodology used in this study. Section 4 presents the analysis results from the study of 135 reviewed papers and defines BM archetypes. Section 5 discusses the common aspects relevant to all of the identified BM archetypes and how they differ for the three market models. Finally, Section 6 concludes the paper.

2. Background and Related Work

To lay the groundwork for the following BM analyses, this section first introduces the concepts of emerging P2P, CSC, and TE market models as well as the main features of the BMC as an analysis tool. Next, related literature reviews are outlined and compared to the presented work.

2.1. Emerging market models: P2P, CSC, and TE

The concepts of P2P, CSC, and TE have been discussed with various meanings in extant literature. While all three concepts share common characteristics, they differ in terms of size, operational scale, and the primary purpose of their market activities [14].

P2P refers thereby to a concept of direct electricity exchange among market participants without the need of a middleman [6]. The main driver behind this market model is to empower energy end-users and to provide them with an incentive to actively engage with the energy market [15, 16]. While academic descriptions of the P2P concept usually focus on the interaction of end-users [9, 11], practical implementations instead, such as through the European Renewable Energy Directive 2018/2001 (REDII), can also have a broader set of market participants such as suppliers and aggregators [17].

The concept of the TE market model is somewhat fuzzier [7]. It emerged from decentral co-ordination methodologies of supply and demand, especially for power systems with an increasing presence of DERs and smart devices [18]. The main scope is thereby often to enhance power system reliability through dynamic market mechanisms instead of passive and expensive grid reinforcements [19]. One of the most used definitions of TE, proposed by the GridWise Architecture Council, broadly defines TE as a "set of economic and control mechanisms that allow the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key indicator" [20].

Finally, the term CSC originates in the REDII and is based on "jointly acting renewable self-consumers" [21]. A renewable self-consumer is defined in the REDII as an energy end-user "who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that [...] those activities do not constitute its primary commercial or professional activity" [17]. A CSC market is therefore specified as a group of jointly acting renewables self-consumers who are located in physical proximity with the primary purpose to "provide environmental, economic or social community benefits [...] rather than financial profits" [17, 22].

2.2. Business Model Canvas

The BMC is used as a tool to analyze, describe, and design BMs [10]. It consists of a visual template composed of nine elements that constitute the so-called building blocks for each business model. These elements are defined and presented in Table 1.

The BMC is used as an analytical framework for this paper to differentiate BM archetypes identified from the literature. Other academics too have previously used BMC for BM analysis in the energy sector e.g. [9, 11, 12], though none have undertaken a comprehensive review of LEM businesses using this framework. By applying the BMC to the analysis, the roles and business components of different actors in the emerging LEM models are scrutinized in a structured way, which reveals common and divergent features that shape the current energy sector.

Table 1: Conceptualization of the Business Model Canvas. Elaboration based on the nine business model elements [23]

BM element	Description
Value Proposition	Value that is created by the company's products and services for customers
Customer Segments	Groups of individuals or organizations to which a company wants to deliver value
Customer Relationships	Connections a company develops and maintains with customers
Channels	Modes whereby Value Propositions are communicated and delivered to customers
Key Activities	The prime activities a company needs to execute its BM
Key Resources	Key assets necessary for a company to execute its BM
Key Partner	Cooperative agreements with other actors to make the BM work
Cost Structure	Costs incurred as a result of operating a BM
Revenue Streams	Income obtained from Value Propositions provided to customers

2.3. Related Work

Several reviews and survey articles discuss LEMs from different perspectives. Khorasany et al. [24], for instance, studied the market frameworks for local energy trading concerning scalability, overheads, and grid constraints resolution approaches. The challenges that LEMs address are reviewed by Bjarghov et al. [25], and taxonomy of constructs and optimization mechanisms (e.g., meta-heuristics, convex optimization, etc.) for energy trading in smart grids is suggested by Aggarwal et al. [26]. More specifically, the challenges and opportunities of blockchain in the energy sector are researched by Andoni et al. [27]. On a similar note, Siano et al. [28] explore the different consensus mechanisms within distributed ledgers. Mengelkamp et al. [29] review LEM structures in literature and provide a high-level overview of market participants that might be present in such, namely aggregators, consumers, distribution companies, energy utilities, local governance, microgrid agents, market operators, local producers, prosumers, storage devices, and system operators. While these reviews discuss general frameworks of LEMs and their stakeholders, actual business models with their key elements within such markets are not analyzed.

Another set of reviews focuses on specific aspects of individual LEM types, such as Tushar et al. [30] outlining challenges on virtual and physical layers of P2P mechanisms or Ahl et al. [31] describing the challenges in scaling P2P mechanisms. An overview of the current research and practice landscape of P2P trading is provided by Zhou et al. [6] and Soto et al. [32], while Zhang et al. [33] provide a list of commercial P2P projects. Along the same lines, Hu et al. [34] provide a list of TE demonstration projects, and Chen and Liu [18] describe the state-of-the-art of TE trading.

There are also a few reviews that reach across different LEM types. Sousa et al. [35] provide a comprehensive review of P2P and community-based markets, Siano et al. [28] on P2P and TE markets or Zia et al. [36], which present a structured 7-layer framework that potentially covers P2P, CSC, and TE models. They define a user layer as the foundation of their model architecture, followed by a network layer, a system operator layer, a market layer, a distributed ledger layer, a communication layer, and finally, a regulation layer on top.

Survey papers that address BMs of LEM participants address, for the most part, aspects of single participants such as Brown et al. [37] on emerging prosumer BMs, Müller and Welpe [8] on storage operators, Zhou et al. [38] on sharing coordinators and retailers, Montakhabi et al. [39] on Broker and Representatives or Pang et al. [40] on investment and consulting entities. With regard to the joint analysis of multiple BMs, Burger and Luke [41] represent an exception by reviewing the sum of emerging BMs for DERs based on empirical data.

The present review differs from previous publications by focusing on reviewing the BMs that operate in the LEM and outlining their specific composition mapped against the BMC. It details how each aspect of the BMC is fulfilled and where the models lack clarity. Furthermore, it does not limit its analysis to a single LEM type but compares BM appearances comprehensively across the three models of P2P, TE, and CSC. Reproducibility and benchmarking for future research on LEMs are encouraged by following a structured review methodology and making the extracted BM raw data available (see Data Availability section for more information). To the best of the authors' knowledge, the only structured literature review on LEMs so far is provided by Mengelkamp et al. [29], which focused on the market framework with underlying trading design.

Along the line of presented reviews, additional analyses have recently been published under the umbrella of the International Energy Agency's (IEA) Global Observatory on Peer-to-Peer, Community Self-Consumption, and Transactive Energy Models, to which also this work belongs. Adams et al. [42] critically reviewing the social and economic value that these models provide. Dudjak et al. [43] analyze the impact of LEM integration on power systems, and O'regan et al. [44] describe the implications on the ICT layer concerning hardware, software, and data requirements. Finally, De Almeida et al. [45] outline the descriptive and normative legal aspects of LEM implementations in Europe and frame the regulatory challenges that lie ahead.

3. Methodology

The present study follows the systematic literature review methodology [46], which is composed of three key elements: search strategy and selection criteria (Section 3.1), data extraction (Section 3.2), and data analysis (Section 3.3). The analysis of the reviewed BMs is guided by the nine elements of the BMC [10], as described in Section 2.2. The threats to the study validity were considered and mitigated, as discussed in Appendix B. Figure 1 presents an overview of the methodology structure, with individual steps described in the following section.

3.1. Data search and selection

The adopted search strategy aims to cover the variety of terms that can refer to the notion of LEMs. Given that the terms "peer to peer", "community/collective self-consumption", and "transactive electricity" are poorly differentiated, yet all refer to the LEM, this work relies on the judgment of the paper's authors in categorizing as to which of the three market subtypes a paper pertains. Therefore, the search string used for paper selection in this work is:

("peer to peer" OR "peer-to-peer" OR P2P) OR ("self consumption" OR "self-consumption" OR CSC) OR (transactive OR TE) AND electricity .

Only journal articles indexed in Scopus and Web of Science have been of interest for this review as they include the most widely referenced and indexed peer-reviewed publications on energy and market design topics.

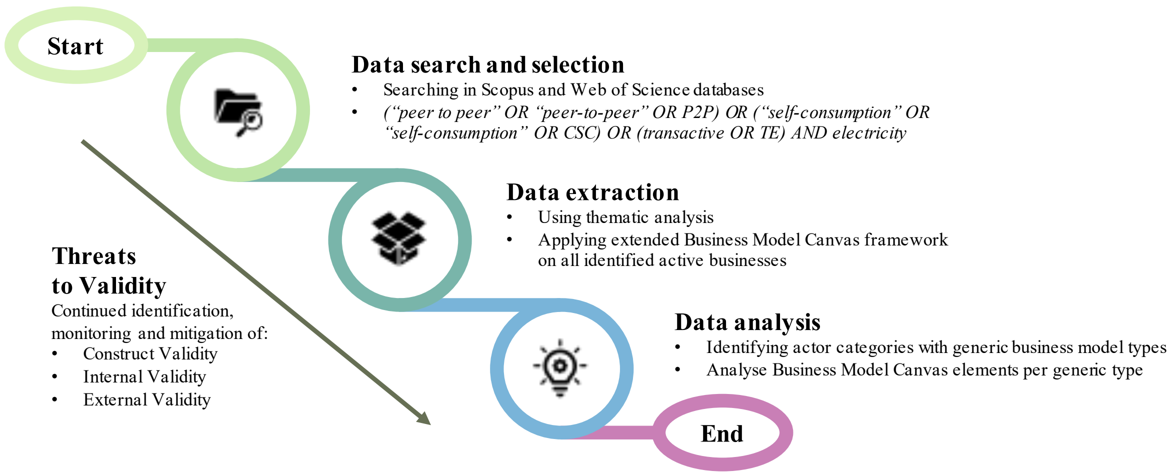

Figure 1: Flowchart of the applied methodology structure for the systematic literature review on emerging business models in P2P, TE, and CSC market models.

Further, the following inclusion criteria were used:

- Publication Year: All papers published up till and including 25 March 2020;
- Publication Type: All peer-reviewed journal papers;
- Content: Papers that discuss BMs used for electricity trading over P2P, TE or CSC markets.
- Publication Language: Only English language papers.

In the first instance, the term-based search returned 1,346 papers from the two digital libraries. Out of these, 454 results were excluded due to duplicated selection. The remaining papers were checked for relevance under the inclusion criteria, and thereby another 747 papers got removed. The remaining 145 were reviewed in detail using the methodology described in sections 3.2 and 3.3. However, a further 10 papers, which were initially considered relevant, were found to lack sufficient focus on P2P/TE/CSC following a more detailed review and were therefore excluded. The evidence discussed below is thus based on the corpus of 135 papers reviewed in detail.

3.2. Data extraction

Data extraction and analysis have been carried out using thematic analysis [47], where the deductive approach to theme and code development was used. The study draws on the detective standpoint of thematic analysis because this research was structured around the elicitation of the variety of BMs from the outset, and the BMC framework provides a detailed breakdown of elements from which a BM is constructed. Thus, as a starting set of categories, each of the nine BMC element headings was utilized, as depicted in Table 1. To create a better understanding of the distinctions between individual BMs, additional subcategories were introduced as follows:

- Business channels were subdivided into channels for evaluating, purchasing, and delivering the value proposition-

- Resources were further subdivided into tangible, non-tangible, and human resources.
- Revenue streams were distinguished between those based on static or dynamic variables.
- Cost structures were differentiated between Capital Expenditures (CAPEX) and Operational Expenditures (OPEX).

The full codebook is provided in Appendix A. For the following data extraction, the 135 papers were randomly distributed across 14 researchers. Each researcher performed data extraction independently, accompanied by weekly meetings with validity checks of extraction samples. In case a paper discussed multiple active businesses, each business was represented separately through the data extraction process. The term "active business" implies here that the named actor (e.g., organization, company, etc.) actively engages with the market addressed in the reviewed paper, and the BMC elements for its activities are sufficiently described.

For better data consistency, a cross-review process was instigated upon completion of the individual data extraction. Here the data extraction categories were assigned to independent researchers who validated the extracted data under their categories for:

1. Completeness (i.e, no missing information);
2. Information type consistency with the codebook;
3. Relevance (i.e., the provided data informs the set category).

Where inconsistencies were found, the initial data extraction researcher addressed the issue to complete the data extraction.

3.3. Data analysis methodology

Data analysis was undertaken in two major stages: first, the analyzed BMs were categorized into generic types; then, the nine BMC elements for each generic type were examined in detail for each of the three market sub-categories: P2P, CSC, and TE.

3.3.1. Generic Business Model Type Identification

While undertaking data extraction, the businesses discussed in the reviewed literature were mapped to the ENTSO-E Harmonized electricity market Role Model (HRM) [48], whereby:

1. The set of extracted businesses were reviewed to *identify synonymous businesses* referred through different terms (such as consumer, user household, etc.).
2. The detailed techno-economic HRM roles (see Appendix C) were combined to *form business-focused macro-actors* based on an established and harmonized terminology (see Appendix D). For example, a Prosumer actor in this paper combines the HRM roles of a Producer, Consumer and Party Connected to the Grid. The prosumer could also actively manage its resources, hence taking the HRM role of a resource provider or delegate this task to a third party, such as an aggregator. This approach led to the definition of the possible roles for each market actor as a min-max set of HRM techno-economic roles.
3. Having developed the set of macro-actors, the extracted *BMs from the literature were mapped to these macro-actors* comprising generic BM types, and their respective papers were categorized as describing the said BM type.

3.3.2. Analysis of Business Model Canvas Elements per Generic Type

Each set of papers per BM category was randomly assigned to two researchers. The researchers first analyzed the BMC elements for the assigned categories independently, then discussed, elaborated, and harmonized their findings pairwise.

4. Analysis of Business Model Categories

As per previously discussed methodology, the BM analysis has identified a set of actor categories. These categories and their distribution across the three investigated LEM models are discussed below, followed by a detailed analysis of the BM archetypes.

4.1. Identified actors' types

Based on the descriptions of 221 businesses elicited from the reviewed literature and the integrated techno-economic roles of the HRM, nine actor categories were identified. These can be organized into to the following three sets:

1. A set of actors that are *asset owners* and are *connected to the grid*:
   - Prosumers;
   - Pure Consumers;
   - Pure Generators;
   - Storage Operators.
2. A set of facilitators which can either act as *platform providers* for direct business transactions among actors, or as *intermediaries* for (groups of) actors to enable interactions with a wider market:
   - Platform Operators;
   - Aggregators;
   - Representatives.
3. A set of actors that act as *service providers* and potential customers of asset owning actors:
   - Retailers;
   - Grid Operators.

A short description of each actor's main characteristics is presented in Table 2. More detailed descriptions, a definition of each actor's category in terms of the set of HRM role combinations, as well as a selection of synonyms used in literature, are presented in Appendix D.

With Prosumers being the by far the most common actors in the reviewed literature, the amount of retrieved information gave the opportunity to study them in more detail (see section 4.3.1). While all Prosumers share fundamental key characteristics, four distinct types of Prosumer BMs have been identified, depending on their interactions with other actors in their ecosystem. These four types of Prosumer are: Prosumers that interact directly with other Prosumers *(peer-peer)*, Prosumers that interact with a group of other Prosumers *(peer-group)*, Prosumers that interact with one or multiple markets *(peer-market)*, or Prosumers that interact through or with the support of a dedicated individual Energy Management System (EMS) *(peer-EMS)*. More detailed characteristics of these four Prosumer subcategories are described in Section 4.3.1.

It should be noted that businesses can also cover multiple actor roles simultaneously. For example, a microgrid operating business might act as a Platform Operator for a set of microgrid participants to facilitate the energy exchange among them. Simultaneously, the same business might act as an Aggregator to coordinate the ancillary service provision to a higher-level Grid Operator. Whether or not such combined roles might pose any legal and regulatory challenges is discussed in Section 5. However, regulatory compliance has not been judged in the below analysis of the BMs.

4.2. Presence of individual actors in different market models

Figure 2 shows how the 221 identified active businesses from the reviewed literature are distributed among the nine actor categories. The majority (about 60%) of businesses belong to a group with grid connected assets, i.e., Prosumers, Pure Consumers, Pure Generators, and Storage Operators (see group 1, Section 4.1). Among these, Prosumers clearly prevail as, overall, the mostly

Table 2: Description of identified actor categories in P2P, CSC, and TE market models

Actor	**Description**
Prosumer	An entity which is connected to the grid and that injects and withdraws energy at the same grid connection point. It is characterized by a bidirectional electricity flow based on generating, consuming, and storing assets at its grid connection point.
Pure Consumer	An entity connected to the grid which possesses and potentially operates its own assets to consume electricity. Among such assets can be also storage assets, although they will only be utilized to shift consumption, and not for reinjecting electricity into the grid. A Pure Consumers is therefore characterized by a unidirectional, withdrawing electricity flow at its grid connection point.
Pure Generator	An entity connected to the grid which possesses and potentially operates its own assets to generate electricity. It is thereby characterized by a predominately unidirectional, injecting electricity flow at its grid connection point.
Storage Operator	An entity connected to the grid which possesses and operates its own assets to store electricity. Although it neither generates nor consumes energy (except minor process losses), it does however buy, keep for a time, and then sell energy to the local market at different instances of time. It is thereby characterized by a bidirectional electricity flow at its grid connection point.
Platform Operator	An entity which operates a platform for energy trading or sharing. It is not connected to the grid and does not own any relevant generation or consumption assets, yet it facilitates the exchange among its customers.
Aggregator	A virtual entity, not physically connected to the grid, which acts on behalf of a variable group of parties connected to the grid (or their Representatives). Aggregators manage the combination of their clients' individual assets as one virtually aggregated asset, with various levels of activity on a potential plurality of markets.
Representative	A virtual entity, not physically connected to the grid, which acts on behalf of a single party connected to the grid. Representatives manage the combination of their client's individual assets toward a potential plurality of trading agents or market platforms. Other than Aggregators, Representatives always represent only one single client.
Retailer	Usually a virtual entity, not physically connected to the grid, which does not own any physical assets. Retailers hence neither generate nor consume energy, yet they buy and sell energy on Platform Operators to then exchange it with individual clients.
Grid Operator	An entity that manages, develops, and maintains the electricity or gas network for a specific territory.

described businesses with the two subcategories peer-peer and peer-market making up the largest shares. The facilitators group also contains reasonably widespread actors, with Aggregators and Platform Operators accounting for 13% and 12% of the active businesses, respectively. The group of service providing actors, on the other hand, is comparatively least represented, with Grid Operators and Retailers accounting for 7% and 5%, respectively. However, this only applies to their presence as businesses actively participating in the LEMs. Their presence as passive customers and supporting partners to other businesses is clearly more pronounced, as shown in Section 5. Figure 3 reports the presence of actors in absolute numbers broken down by market model.

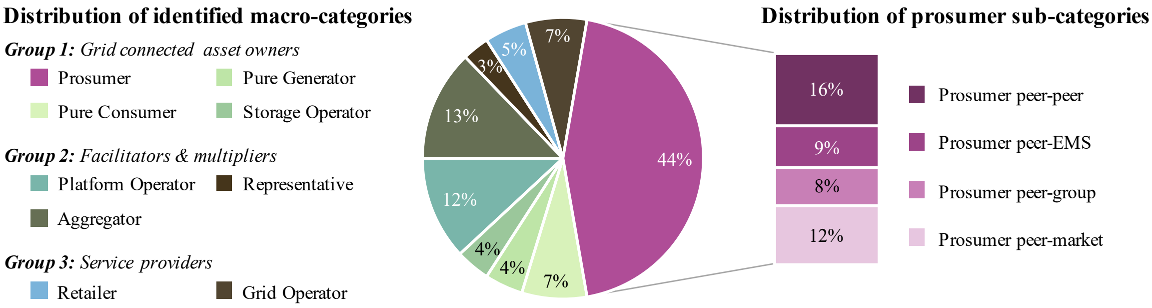

Figure 2: The presence of identified actors in the reviewed literature

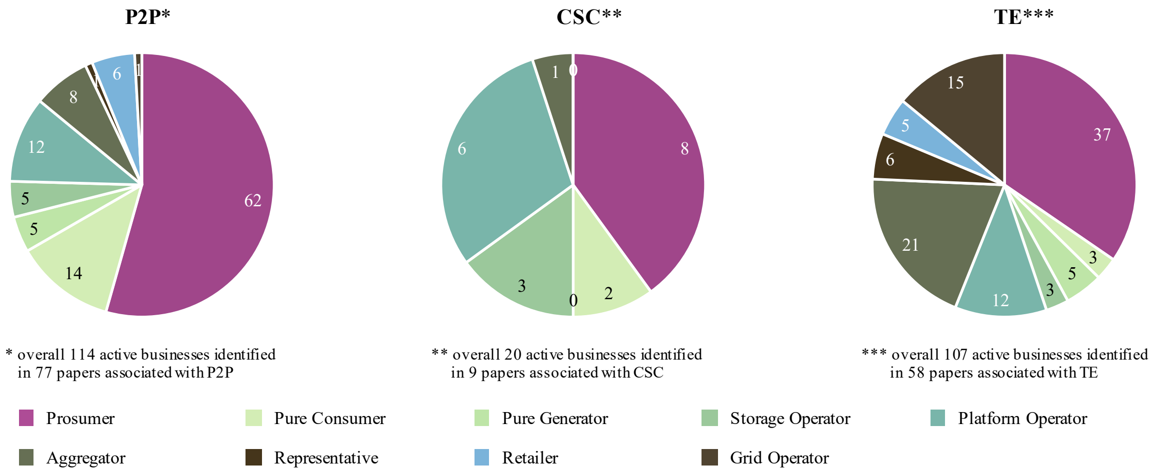

Figure 3: The presence of identified actors in reviewed literature associated with P2P, CSC and TE models

Table 3 provides the actors' presence in the associated literature references. A single paper can contain multiple actors and some papers contain more than one energy model.

4.3. Individual actors' business model analysis

The following section presents the synthesized BMs of each actor of interest as reported in the reviewed literature. First, it outlines how the individual BM is structured, how it operates, and

Table 3: Presence of identified macro actors in the reviewed literature.

	P2P	CSC	TE
Prosumer	[37, 38, 49–102] [28, 103–107]*	[37, 108–110] [103–105, 107]*	[111–145] [28, 106]*
Prosumer peer-peer	[37, 49, 52, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 79, 81, 83–86, 93, 94] [28, 106]*	-	[112, 113, 115, 125] [28, 106]*
Prosumer peer-group	[53, 61, 65, 67, 73] [103, 105, 107]*	[37, 108–110] [103, 105, 107]*	[118, 119, 129, 134]
Prosumer peer-EMS	[55, 57, 67, 68, 72, 75, 97–100]	-	[116, 121, 130, 132, 139–141]
Prosumer peer-market	[37, 38, 51, 54, 69, 70, 78, 80, 87, 88, 90–92, 95, 102] [104]*	[104]*	[114, 117, 120, 122, 126, 127, 136, 137]
Pure Consumer	[60, 75, 78, 82, 92, 93, 131, 146–150] [103, 107]*	[103, 107]*	[151–153]
Pure Generator	[77, 146, 149, 154, 155]	-	[131, 153, 156–158]
Storage Operator	[50, 54, 90] [103, 104]*	[159] [103, 104]*	[157, 158, 160]
Platform Operator	[37, 53, 69, 84, 89, 161–164] [103, 104, 107]*	[37, 108, 109] [103, 104, 107]*	[118, 128, 129, 131, 133, 135, 140, 152, 153, 165–167]
Aggregator	[37, 79, 80, 100, 168, 169] [103, 107]*	[103, 107]*	[118, 119, 122–126, 128, 131, 139, 144, 151, 153, 157, 165, 166, 170–174]
Representative	[89]	-	[140, 144, 145, 156, 175, 176]
Retailer	[37, 58, 77, 91, 147, 150]	-	[129, 166, 167, 170, 177]
Grid Operator	[54]	-	[111, 118, 119, 123, 124, 128, 144, 153, 160, 165, 167, 173, 178–180]

[ ]* entry refers to a paper that contains more than one energy market model

what its main characteristics are. This is accompanied by a detailed BMC-based analysis of the BM across all three LEMs of interest. Finally, a brief discussion of peculiarities, missing elements, and contradictions is provided.

4.3.1. Prosumer

As previously noted, four subcategories of Prosumer have been identified. Table 4 provides an overview of the subset of overarching BM elements that characterize all subcategories. The table cites the source research papers, while the brightness of each cell's color denotes the frequency with which the relevant feature was referenced. Further detail on the BM elements for each subcategory is provided in Appendixes E.9, E.10, E.11, and E.12.

The basis of Prosumers *Value Proposition* is consistent for all four subcategories and is dominated by the generation and delivery of electric energy at convenient prices. More than 75% of the Prosumer businesses provide this value to their customers. The second most common value proposition consists of flexibility provision through demand response or dispatchable generation. However, the occurrence of this value proposition varies considerably between model subcategories: from only 10% for the peer-peer Prosumers subcategory to over than 50% for the peer-EMS subcategory. Concerning *Customer Segments*, Prosumers serve as the most cited customer to other Prosumers across all subcategories. The only other customer segment reported for all four Prosumer subcategories is the Pure Consumer.

Platform Operators are the only *Key Partner* that is equally relevant to all Prosumer subcategories (cited around 25-35%). Aggregators, Retailers, and Grid Operators also serve as partners across all Prosumer types, but with varying importance. Peer-EMS Prosumers rely most significantly on Aggregators, whereas the other three Prosumer types rather interact with Retailers and Grid Operators. Beyond these key elements, the four Prosumer sub-types each develop their own distinct BM features, as discussed below.

Prosumer category I: peer-peer

This Prosumer subcategory represents individual actors who produce and trade their surplus electricity and/or flexibility directly to other individual peers, mostly via platforms. Individual actors and peers herewith refer to household Prosumers, Pure Consumers, and juristic persons, e.g., microgrids, residential buildings, and small commercial entities.

The fundamental *value proposition* of this Prosumer version is to provide electricity to other peers at prices cheaper than those from the retail market. The *customer segments* are formed exclusively by other Prosumers and Pure Consumers. Irrespective of market models, *relationships with customers* are maintained through automated services, i.e., processes without human involvement. Peer-peer Prosumers rely on the following key activities, resources and partners:

- *Key activities* are generally producing electricity, managing loads and generation, deciding selling prices, and trading their electricity on the online platform.

- *Key resources* consist of tangible assets, such as PVs for electricity generation, BESSs for temporary storage and balancing, and to a lesser extent, ICT infrastructure. Intangible assets are modestly present and consist of software for supply and demand forecasts, active market interaction through bidding, and the ability to interact with data stores (e.g., blockchain).

- *Key partners* include Platform Operators as central facilitators, Grid Operators as infrastructure and balancing providers, and Retailers as the suppliers of last resort.

Table 4: Comparison of selected business model elements for different Prosumer types

	Prosumer peer-peer	**Prosumer peer-group**	**Prosumer peer-EMS**	**Prosumer peer-market**
Value Proposition				
Provide electricity	[28, 37, 49, 52, 53, 58–60, 62, 64, 66, 73, 74, 76, 77, 79, 81, 83–86, 93, 94, 106, 112, 115, 125]	[37, 53, 61, 67, 73, 103, 105, 107–109, 118, 129, 134]	[55, 68, 72, 75, 97–99, 112, 121, 130, 139–141]	[37, 38, 51, 54, 69, 78, 80, 87, 88, 90–92, 95, 102, 104, 114, 117, 120, 126, 127, 136]
Provide flexibility	[63, 71, 113]	[61, 65, 108, 118, 119, 129]	[55, 67, 97, 98, 100, 116, 121, 132, 139]	[70, 78, 95, 122, 136, 137]
Customer Segments				
other Prosumer	[28, 37, 49, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 81, 83–85, 94, 106, 112, 113, 115, 125]	[37, 53, 61, 65, 73, 103, 105, 108, 109, 129, 134]	[55, 67, 68, 72, 75, 97–100, 112, 121, 130, 139, 141]	[38, 54, 54, 69, 70, 78, 80, 87, 88, 91, 92, 95, 102, 104, 114, 120, 127, 136]
Pure Consumer	[52, 79, 83, 84, 86, 93, 94]	[67, 103, 105]	[75, 112, 139]	[78, 90, 92, 117, 120]
Pure Generator			[139]	
Storage Operator				[54, 104]
Platform Operator		[109]	[132, 139, 140]	[38, 51, 69, 78, 104, 126]
Aggregator		[118, 119]		[117, 122, 126]
Representative				
Retailer		[129]		[37, 122]
Grid Operator			[116, 139, 141]	[137]
Key Partners				
other Prosumer		[53]		
Pure Consumer				
Pure Generator				
Storage Operator				
Platform Operator	[28, 53, 59, 60, 64, 71, 84, 86, 106]	[65, 103, 109, 129]	[72, 99, 130, 132, 140]	[38, 69, 78, 90, 104, 114, 120, 126, 127]
Aggregator	[79]	[134]	[100, 112, 132, 134]	[80, 87]
Representative			[132]	[70]
Retailer	[52, 58, 77, 84, 85, 94, 112]	[37, 67, 108]	[121]	[91, 95, 102]
Grid Operator	[63, 64, 74, 83, 85, 86, 106, 112]	[67, 105, 118, 129, 134]	[67, 72, 121]	[37, 51, 54, 54, 70, 80, 90, 102, 114, 122, 136]

Online marketplaces or platforms are the main *channels* used by customers to purchase electricity from Prosumers. The most important factor customers use to evaluate the value proposition and thus justify their purchase decision is its price. Delivery of electricity is done through a distribution network.

DERs installations entail the only mentioned *CAPEX* for peer-peer Prosumer, whereas *OPEX* comprises costs such as maintenance of generation units, and transaction and grid charges. Their primary *revenue streams* come from the sale of surplus electricity. Figure 4 provides an overview of the peer-peer Prosumer subcategory's BMC (see details and references in Appendix E.9).

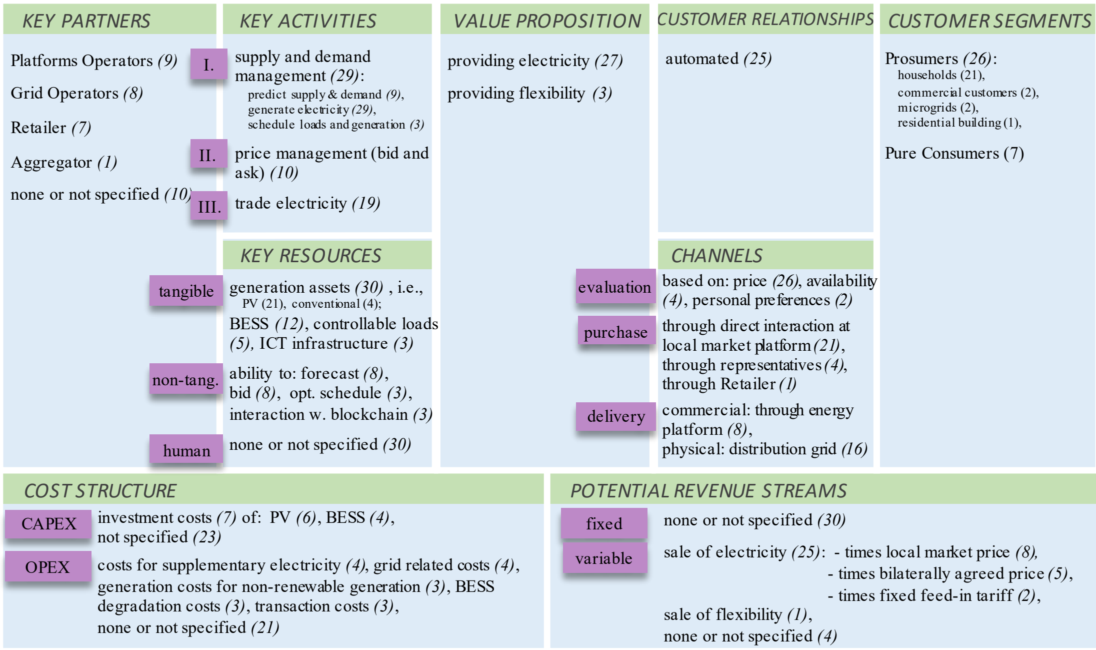

Figure 4: The Business Model Canvas of Prosumers in the peer-peer version as reviewed in literature. A total of 30 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.9.

Observations of note on Peer-Peer BMs relate to the fact that many papers under-specify the relevant resources and costs for business viability. For instance, since most of the peer-peer Prosumers trade their electricity and/or flexibility on automated online platforms, the ICT and software that enables trading are vital parts of the peer-peer BM. However, only a minority of the reviewed papers identify ICT infrastructure as a tangible key resource [79, 86, 93] or the ability to actively interact with other peers or the market as a non-tangible key resource [58, 59, 73, 85, 106, 112, 113, 115, 125].

Similarly, although most reviewed papers name PV as a key resource for Prosumers [28, 52, 53, 58–60, 62, 63, 66, 71, 76, 77, 79, 83–86, 94, 113, 115, 125], the investment cost of PV is noted in only one-fifth of the reviewed papers [52, 62, 63, 84, 85, 113].

Finally, discussion of OPEX, such as the maintenance costs of DERs, transaction costs, and grid fees for electricity export, is also limited to only a third of the reviewed papers [52, 58, 64, 66, 71, 72, 74, 83, 84, 112, 115].

Prosumer category II: peer-group

The second Prosumer category considers the actors for which supply and demand is submitted to a group or a cooperative Platform Operator. Unlike category I, the Platform Operator optimizes solutions for the group as a whole.

Figure 5 presents the BMC for the peer-group Prosumer category. *Value proposition, Customer Segments*, and *Relationships* are mainly in line with other Prosumer categories' BMs. Differences occur concerning *Channels* where community-based preferences appear as an evaluation criterion. Furthermore, instead of an active bidding process, a uniform passive assignment to all trade participants dominates with a respective commercial delivery through a specific community scheme. In *Revenue Streams*, reduced costs for consumed electricity are noted as the additional revenue stream from leveraging Demand Response (DR) at community level.

Key Activities comprise fewer forecasts of own consumption and more exchange of information with other actors, and controllable resources are operated mainly based on centralized objectives and less for self-optimization. Significantly, group-based Prosumer BMs have BESS as tangible assets compared to *Key Resources* of other Prosumer BM types. Non-tangible resources are, on the contrary, less present. *Key Partners* are dominated by Grid Operators, Platform Operators, and to a certain extent, Retailers, whereas Aggregators are generally less present. The reported *Cost Structure* consists mainly of the consumption costs for supplemental (i.e., not self-generated) electricity, and in very few cases, transaction costs (see further details and references in Appendix E.10).

Observations on Peer-Group BMs include the Value Proposition, which involves mainly DR used to shift individual consumption to times of surplus generation within the local community. This, in turn, leads to reduced consumption costs rather than direct payments for flexibility provision [53, 65, 119, 129, 134]. It is also interesting that less than half of the covered businesses have a central facilitator such as a Platform Operator or Aggregator among their Key Partners [65, 103, 109, 129, 134]. This might be interpreted as an indication of a prevalence of decentralized group management schemes. On the other hand, the cost structure does not mention payment for the Platform Operators or Aggregators, which flags an existent gap in the published models. Similarly, no opportunity costs for the provision of individual assets such as BESS for utilization at community level are reported [119, 129, 134].

Prosumer category III: peer-EMS

The third Prosumer category includes the actors whose energy market interaction is ruled via an EMS. The EMS optimizes Prosumers' generation and consumption, then submits supply or demand bids to a Platform Operator to buy and sell from other Prosumers. The Platform Operator optimizes per peers' multi-device preferences first, then carries out peer-to-peer trading (as for Prosumer category I).

As shown in Figure 6, the *Value Proposition* of peer-EMS Prosumers includes both trading of electricity and flexibility at convenient rates, albeit with a more pronounced flexibility offering than other Prosumer categories. This is complemented by the offering of additional ancillary services such as reactive power and spinning reserve. In value proposition evaluation, the main criterion of price is complemented by individual preferences such as comfort parameters or risk aversion. Besides Prosumers and Pure Consumers, *Customer Segments* also notably contain Grid Operators and Platform Operators. Considering *Channels*, the purchase of the value proposition mainly

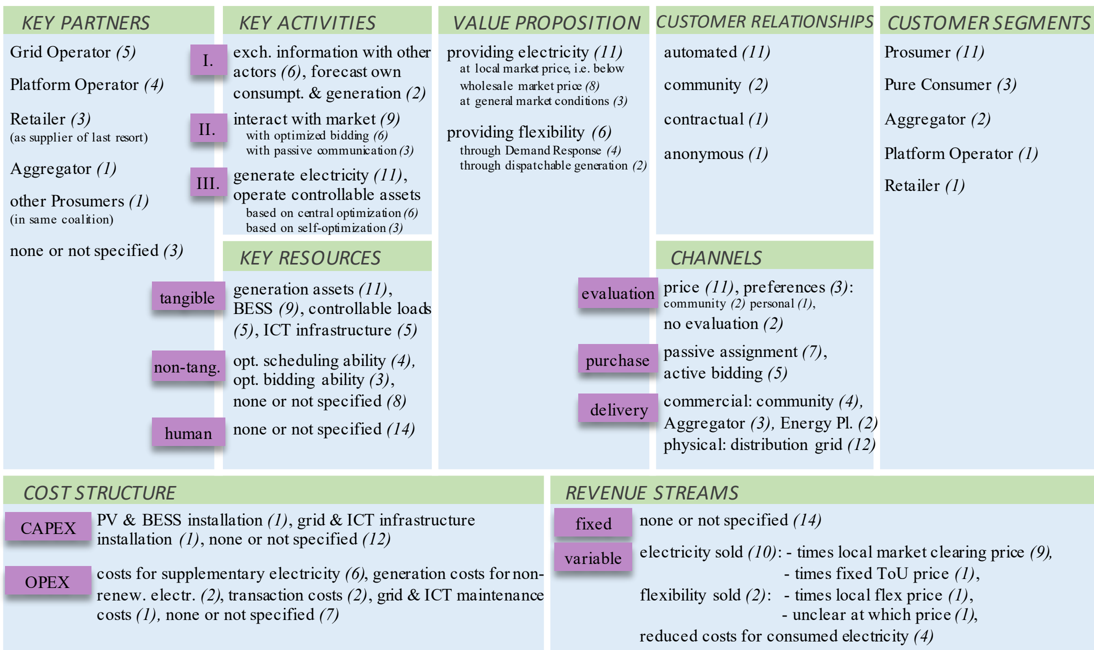

Figure 5: The Business Model Canvas of Prosumers in the peer-group version as reviewed in literature. A total of 14 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.10.

happens for this subcategory increasingly through active interaction and specifically by using the EMS. *Revenue Streams* are based more often on both sold electricity or on cost reductions for consumed electricity from flexibility activation. Additionally, direct revenue streams from ancillary services are reported.

The *Key Resources* include a significant number of BESS, controllable loads, and ICT infrastructures. The non-tangible resources include a wide range of abilities associated with the EMS (e.g., load and generation forecasting, optimal scheduling, optimal bidding, and resources control). No *Key Partner* gains significance. Considering the *Cost Structure*, CAPEX and fixed OPEX are absent, as for most Prosumer types. The variable OPEX is specified for electricity consumption, generation costs for non-renewable resources, and opportunity costs for providing flexibility (i.e., demand response and curtailed generation, see Appendix E.11 for further detail and references).

Observations on Peer-EMS BMs note that the Value Proposition of this category relies on flexibility service provision, predominantly delivered implicitly through price signal response [55, 68, 75, 99, 116, 121, 130, 132, 139]. Overall, the EMS appears to support Prosumers at the individual bidding process by i) forecasting [75, 97, 100, 116, 121, 132, 139, 141], ii) executing the actual sales of the value proposition through active market interaction [55, 68, 97, 116, 121, 132, 139], and iii) optimizing self-dispatch in case of rather passive market interactions [67, 100, 140, 141]. In all cases, however, no costs are associated with EMSs, neither CAPEX nor OPEX, representing thus a significant gap in the reviewed literature models.

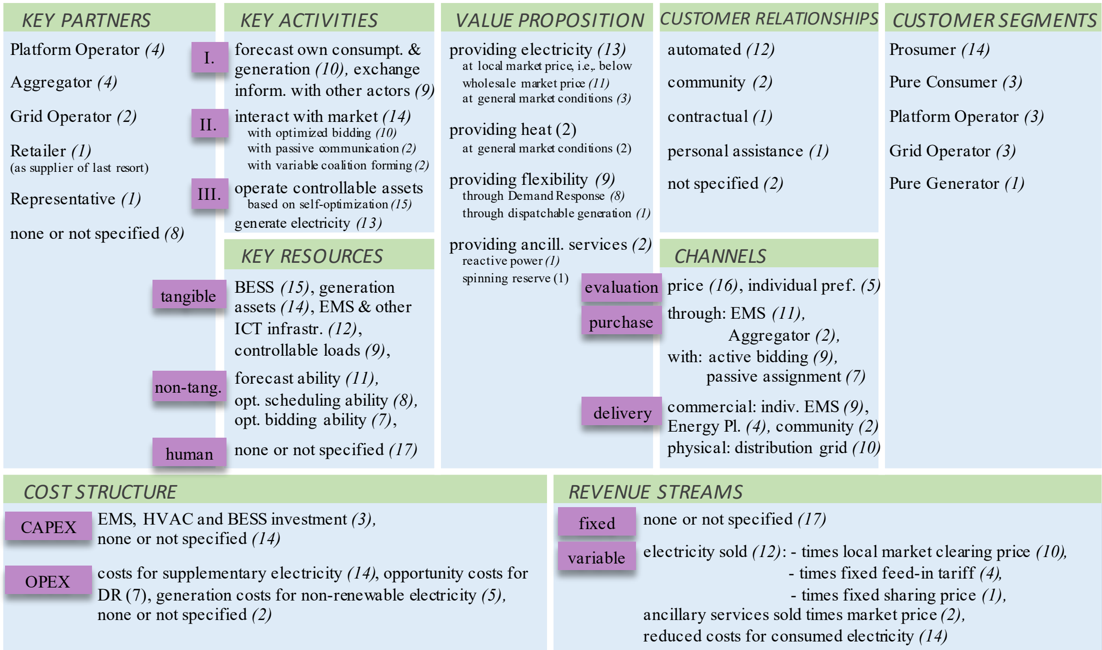

Figure 6: The Business Model Canvas of Prosumers in the peer-EMS version as reviewed in literature. A total of 17 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.11

Prosumer category IV: peer-market

The fourth Prosumer category is defined by actors primarily interacting with a market and, unlike the previous three categories of Prosumers, not directly interacting with other peers. Actors' activities are driven by a personal preference optimization under the constraints and goals of the market, whereas the market platform itself might integrate additional processing such as setting a fixed price, aggregating requests, or integrating central storage availability constraints.

The *Value proposition* of peer-market Prosumers is fully in line with that of other Prosumers' in terms of cheaper electricity and flexibility provision. However, the *Customers* of this subcategory are the most diverse, including all actor categories except Pure Generators and Representatives. In general, customers are not captively acquired but can freely choose the provider in the market. *Key Partners* are wide-ranging (as for other Prosumers), though clearly dominated by Grid Operators. Last but not least, the reported *Revenue Streams* are mainly based on sold electricity times the local market-clearing price and the underlying *Cost Structure* concerns quasi exclusively variable OPEX, with purchase costs for supplementary electricity being the most referenced feature.

The resulting BMC for peer-market Prosumers is presented in Figure 7 (see Appendix E.12 for further detail and references).

Observations on Peer-Market BMs include that here, while still being mentioned for only 17 out of 24 reviewed papers, variable OPEX is reported for a comparably broad spectrum. This links to more detailed market costs, including imbalance costs [126], transaction costs [114], or associated network constraints [90]. Note that CAPEX and fixed OPEX are absent, as for most

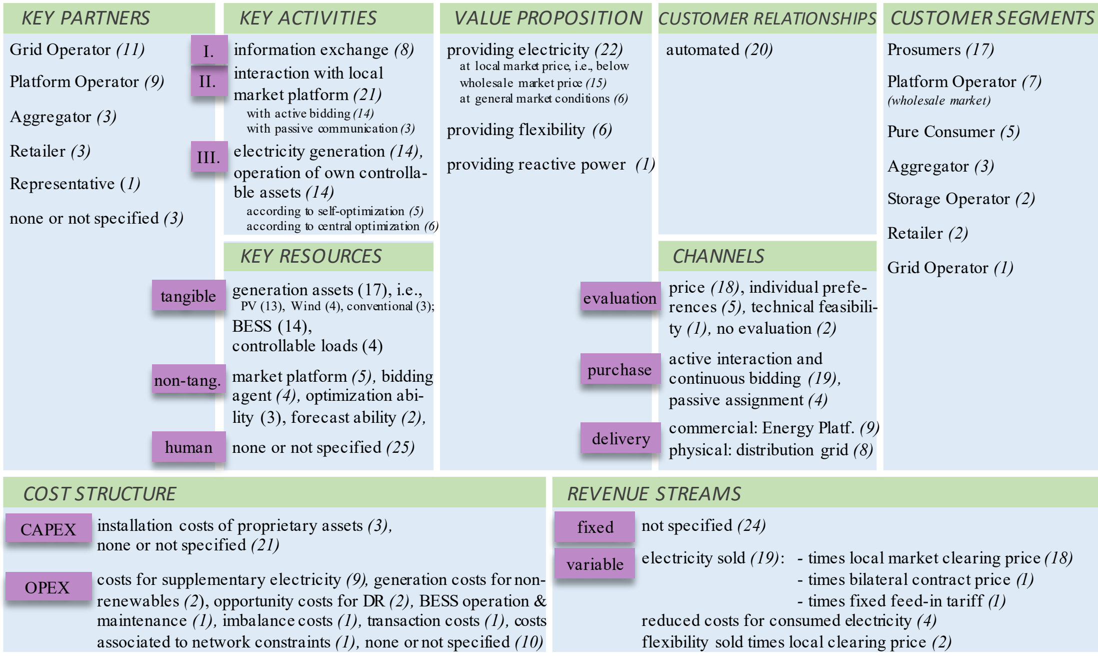

Figure 7: The Business Model Canvas of Prosumers in the peer-market version as reviewed in literature. A total of 24 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.12.

other Prosumer types.

It is also worth mentioning that a reasonable number of these Prosumers do not rely on an external institution for the market platform provision. Instead, many integrate a decentralized market platform as part of their intangible resources [69, 70, 80, 87], often with a blockchain implementation. Other members of the peer-market Prosumers subcategory have a dedicated bidding agent [38, 78, 91, 92, 136], and do not outsource the bidding process to third-party Representatives or Aggregators.

4.3.2. Pure Consumer

Figure 8 presents the BMC elements of the Pure Consumers BMs for P2P, TE, and CSC markets. Pure Consumers offer two major *Value Propositions*. On the one hand, there is flexibility from DR, and on the other hand, there is electricity demand, which remunerates generating parties in the LEM. This remuneration is usually at higher than from other (off-market) sources, such as the feed-in tariff. The latter value proposition aims at the principal *Customer Segment* of Prosumers, from which the Pure Consumers purchase electricity. Platform Operators or Retailers also appear in some cases as customers concerning the DR flexibility from Pure Consumers. The number one *Key Partners* for the Pure Consumer are Platform Operators. All Pure Consumers have loads as their *Key Resource*, most of which are controllable to a considerable extent. BESSs constitute the second controllable asset and are fundamental for their flexibility offering. On the financial side, their *Cost Structure* is dominated by the costs for consumed electricity. The *Revenue Streams* that this BM generates are mainly of an indirect nature, manifesting as reduced costs for the consumed electricity (see further details in Appendix E.13).

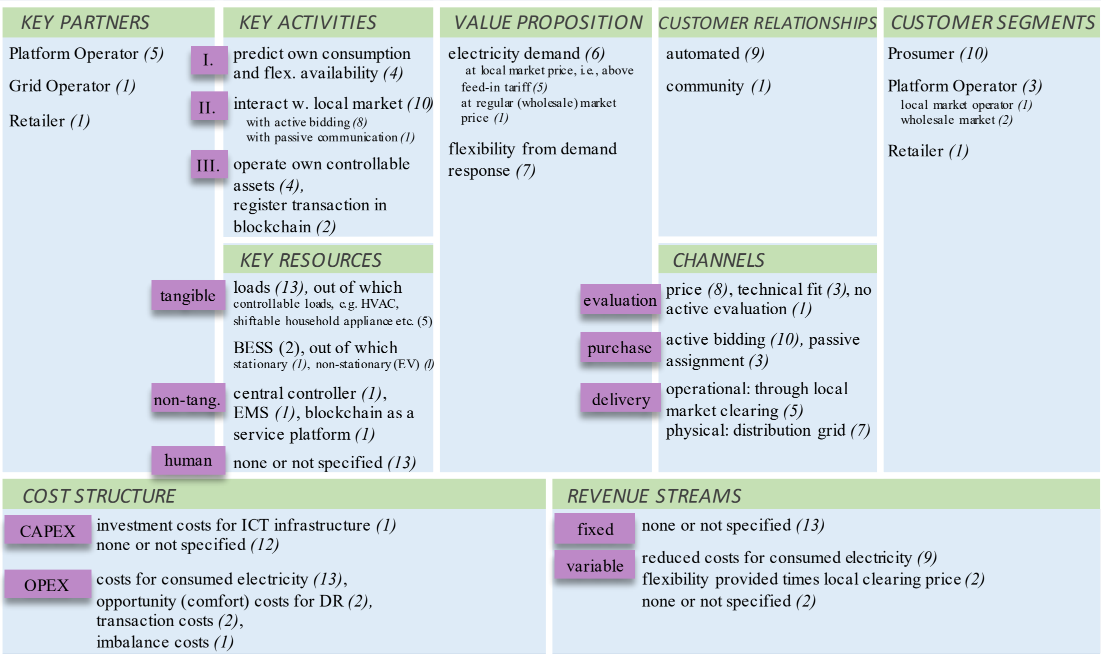

Figure 8: The Business Model Canvas of Pure Consumers as reviewed in literature. A total of 13 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.13

Observations on Pure Consumer BM: A notable peculiarity here are the very limited customer segments. Besides the Prosumers, only four out of thirteen papers mention Platform Operators [103, 147, 153] or Retailer [152] as customers. Compared to other small-scale participants, Pure Consumers also appear to have comparably little forecasting ability (only four out of thirteen papers mentioning this activity [60, 149, 153, 162]). Further non-tangible resources such as EMS or other abilities for optimized bidding are barely present. Pure Consumers appear, therefore, to be a somewhat more passive business.

Another peculiarity concerns the evaluation of the Pure Consumers value proposition. Customers are reported to use both price and 'technical fit' [103, 150, 162]. In these cases, the value proposition comprises flexibility used to balance local imbalances from PV uncertainty [162] or to align with other local DR offers in terms of timely availability and capacity for aggregated flexibility offers to the Grid Operator [103]. Overall, flexibility offers are noted in seven papers, but only in two of them, the offer is explicitly remunerated [103, 153]. In the remaining five cases, its utilization is remunerated via reduced costs for electricity consumption [147, 149, 150, 152, 162].

Limited information was provided on the cost structure, noting only the cost for electricity provision and, in a few cases, opportunity costs for the DR provision [147, 150], transaction costs [148, 149], or potential imbalance costs [148]. As for other BMs, another missing element for this group is information on ICT infrastructure and how Pure Consumers interact with their customers or the other market participants.

4.3.3. Pure Generator

The BCM elements of the Pure Generator BMs for the P2P, TE, and CSC markets are summarized in Figure 9 (see more detail and references in Appendix E.14)

Pure Generators are electricity sellers who have generation capability, are able to sell electricity at lower prices than the market (retail) price, and can actively respond to the market demand by adjusting their generation rate. These capabilities can not only be used to maximize the generator's profits but also to serve local communities. value which Generators provide is delivered to various *customer segments*. Pure Consumers and Prosumers buy electricity from Pure Generator at a price below the retail price, whereas Retailers or other Pure Generators rely on them to balance their portfolios for supply.

Pure Generators' customers purchase partly through active bidding or simply by signing up to a local scheme. The *channels* for value delivery include local market platforms (to support bid submission), with the physical delivery occurring through the local distribution grid. Necessary *activities* for value delivery include, amongst others, electricity generation, surplus supply prediction, offer pricing, evaluation and selection of offer propositions, and transactions recording. Their *key partners* are Platform Operators to operate and clear the local markets and Aggregators that run Virtual Power Plants (VPPs). The primary tangible *resources* they possess are generation assets (such as wind turbines, PVs, diesel generators, and gas-fired micro-turbines). Intangible assets instead include software for generation and demand forecasting for a given timeslot, as well as price setting. Pure Generator models mention no specific human resources. In this model, the *revenue streams* are generally based on variable rather than fixed components, which change based on market conditions. The generated revenue is calculated as the energy sold times the respective transaction or clearing prices. The BM is cost-driven, and variable *cost structure* elements include: i) fuel costs for non-renewable electricity generation, ii) imbalance costs, and iii) transaction costs.

Observations on Pure Generator BM: The BM is strongly asset-based, with the presence of tangible resources in this BM being significantly increased compared to other BMs. This is because the generation assets are fundamental for the actor's value proposition.

Furthermore, this BM serves a wide range of customers, from Pure Consumers [146, 149, 154–157] and Prosumers [155] to Platform Operators [146, 149, 149, 154, 156] and Aggregators [157]). Here the customer relationships are almost exclusively automated [77, 146, 154–157] and anonymous [146, 154, 156]. However, the details on the ICT infrastructure to enable such automated communication with customers are missing. Also, this BM's cost structure reports neither related investment costs (CAPEX) nor fixed operating costs (OPEX) such as maintenance or repairs, resulting in a second gap of information from the literature.

4.3.4. Storage Operator

Figure 10 presents the derived Storage Operator's BMCs for the P2P [50, 90], CSC [103, 104], and TE [157] models. The *Value Proposition* of Storage Operators' BM is based on energy trading with price arbitrage and the provision of flexibility services. In general, the Storage Operator acts as the entity that offers the capability of absorbing and injecting power into the grid depending on price signals or technical requirements (see more details and references in Appendix E.15).

Here the *Key Resources* are storage devices (e.g., stationary or non-stationary BESS) that can provide multiple (simultaneous) services. With these, Storage Operators exploit price differentials either directly by active trading or indirectly by providing energy flexibility to balance the local

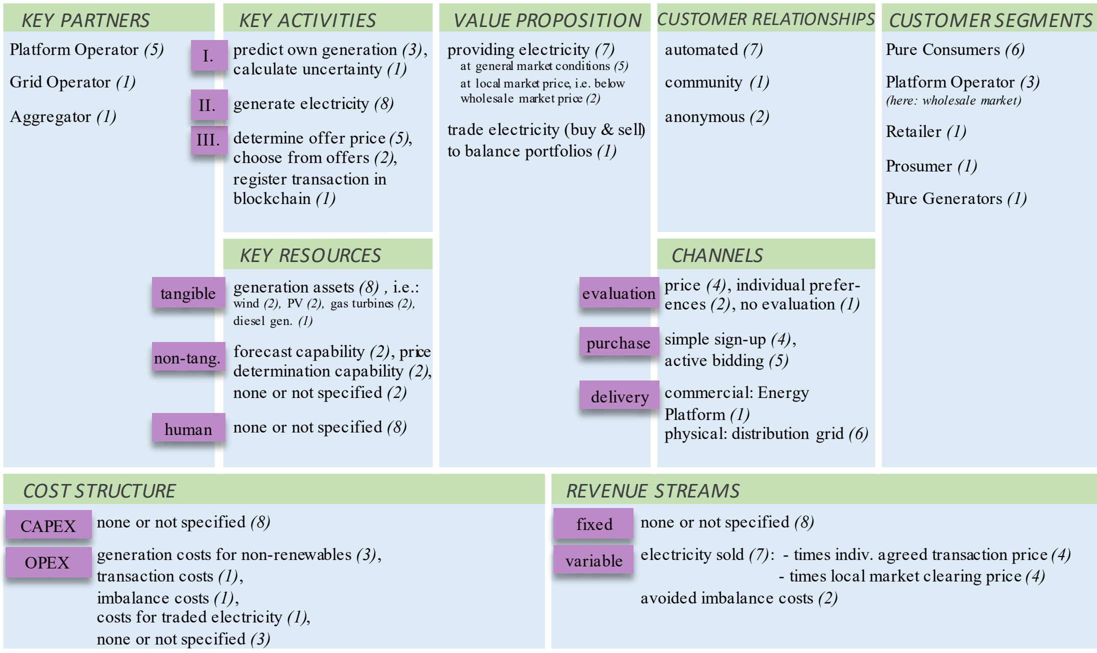

Figure 9: The Business Model Canvas of Pure Generators as reviewed in literature. A total of 8 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.14

market. Therefore, price differentials on the local or wholesale market constitute the fundamental basis of their BMs financial structure. Additional *revenue streams* from system service provision related to frequency and voltage control (power flexibility) are marginal. In P2P and TE markets, the Storage Operator aims at maximizing its profits. Storage Operators who participate in the CSC markets provide a service to the community allowing the achievement of community goals and own profit maximization.

Observations on Storage Operator BM: Discussion on CAPEX sensitivity and possible economies of scale would be a crucial element here but is missing in the models of the reviewed literature. Only one paper reports CAPEX and fixed OPEX (maintenance costs). Moreover, the ICT infrastructure and software requirements for local market interactions are poorly defined. A particular Storage Operator case is provided by Basnet and Zhong [50], with a BM built around hydrogen storage with electrolyzer and fuel cell as Key Resources, instead of the otherwise prevailing BESSs.

4.3.5. Platform Operator

Platform Operators are agents who run a platform for energy trading, sharing, or dispatch at a local level. Moreover, the platform may also deal with ancillary services and congestion management. *Value Proposition* of Platform Operators relies on local market clearing, and customers evaluate it based on price, partially ex-ante on a subscription basis or continuously during operation. Purchase options for customers are either single sign-up with automatic execution or continuous though manual interaction through active bidding. *Customer Segments* consist of a va-

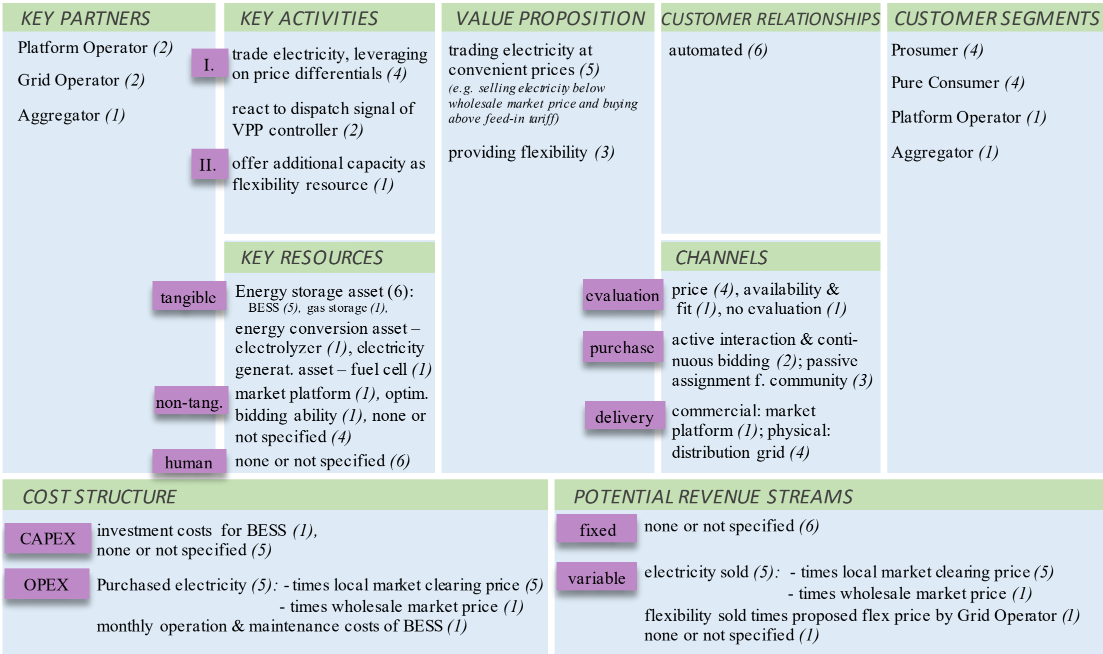

Figure 10: The Business Model Canvas of Storage Operators as reviewed in literature. A total of 6 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.15.

riety of actors with a single point of delivery to the grid, as well as Aggregators and Grid Operators. *Customer relationships* are either automated or community-based.*Revenue Streams* for Platform Operators consist of registration fees and transaction fees or profit margin on the total trading amount. Moreover, Platform Operators can generate cash flows from arbitrage between wholesale and local markets. *Key Resources* are the non-tangible market platform and related market algorithms. Tangible resources are the distribution- or micro-grid, and smart meters and other ICT infrastructure. Grid Operators, Retailers, and other Platform Operators act as high-level *Partners* to make the BM work. The reported *Cost Structure* is based on the purchase of electricity from different markets in case the BM comprises also retailing to local consumers. Further detail can be found in Figure 11 or with references in Appendix E.16.

Observations on Platform Operator BM: The reviewed papers identify the pivotal role of the Platform Operator, which is the only actor that (in one way or another) interacts with all the other actors. In most of the reviewed papers, the Platform Operators are also the market operators. Nevertheless, some Platform Operators can also be community managers, or energy sharing coordinators. In most cases, this actor connects passive market participants that are optimizing their electricity use. The mere platform provision is thereby topped up by complementary services such as central optimization [37, 69, 84, 104, 107–109, 129, 162, 164, 166, 167], forecasting [129, 166, 167] or the connection to higher-level markets [37, 69]. Centralized optimization is prevalent in platforms for fair energy sharing (rather than energy trading). Some authors describe such sharing with central optimization as an additional value above the direct P2P trading [107]. Yet there

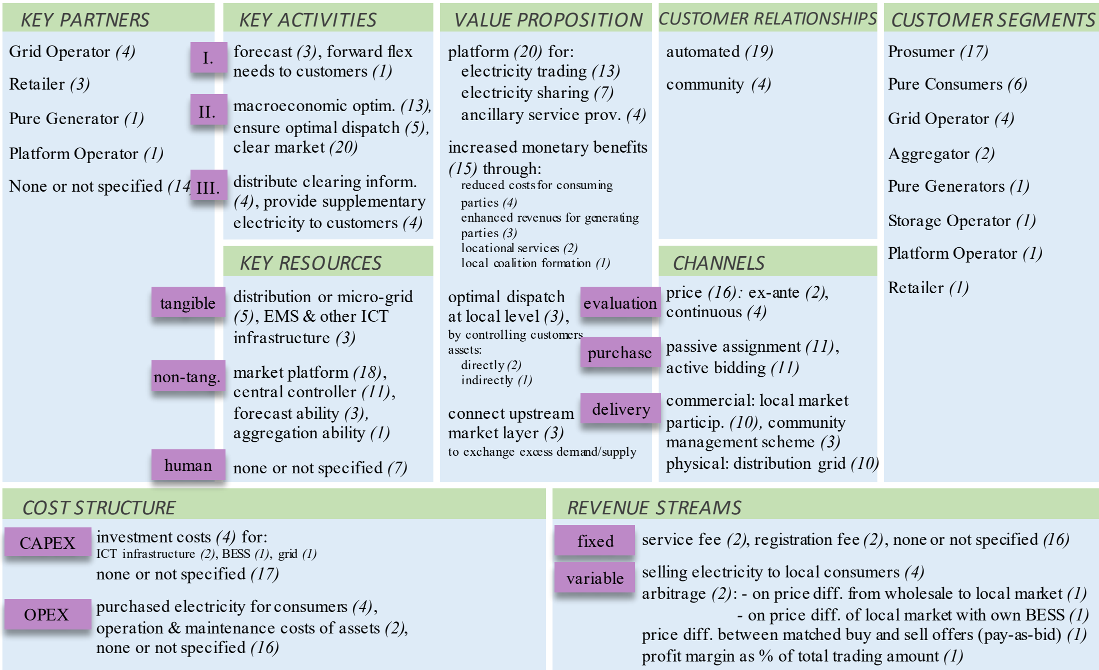

Figure 11: The Business Model Canvas of Platform Operators as reviewed in literature. A total of 20 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.16.

seem to be no common understanding in the literature of sharing and trading. While solutions that exchange power from participants without their active interaction are usually referred to as sharing platforms (e.g., [104, 107]), in some examples, they are also referred to as trading (e.g., [108]). In most cases, Platform Operators connect market participants who optimize their electricity use. However, in a few cases, this is also extended to direct control of customers' assets for optimal dispatch [107, 162, 164, 166].

Despite this diverse field of activities, no revenue streams connected to the core activity of platform provision are reported in the reviewed literature, except one paper noting fixed registration fee [161] and another a fixed transaction cost [109]. Neither is there detail on the costs of the required ICT infrastructure, except in [166].

4.3.6. Aggregator

Aggregators act as entities on behalf of bundled customers. They aggregate small-scale downstream customer assets to form a sizable capacity and then engage in a market on their behalf. There are various types of Aggregators operating in different segments of the electricity system, such as load aggregators, DR aggregators, microgrid aggregators, and aggregators as VPPs. Figure 12 shows the BMC of an Aggregator archetype.

Customer Segments of Aggregators comprise essentially the full set of LEM actors, divided into downstream and upstream customers. Downstream customers are mainly Prosumers and Pure

Consumers, or also DER Generators and Storage Operators. Upstream customers, on the other hand, can be Grid Operators and Platform Operators, or also large-scale Generators and Retailers. Essential *Value Propositions* of Aggregators circle around virtual aggregation and central dispatch. For downstream customers Aggregators optimize thereby asset operation, generating additional revenue from electricity trading or flexibility provision and cost minimizations in terms of scheduling cost or imbalance costs. For upstream customers, Aggregators untap new flexibility sources, either with a locational component to react to network constraints or without such to balance portfolios or network areas.

Aggregators rely for their value propositions mainly on non-tangible *Key Resources*, especially ICT, to communicate with connected units as well as software such as algorithms for forecasting and central optimization. The *Key Activities* in which these resources are then applied are designed to bundle and manage customers' DERs, interact with markets and upstream actors on behalf of downstream customers, and facilitate electricity exchange among local customers. Similar to their customer portfolio, Aggregators interact thereby with a large *Partner* network (by and large the full set of LEM actors) to provide their value proposition.

The majority of reviewed papers describe the Aggregator business with little detail on the *Cost Structure*. Most noted costs are variable OPEX related to the purchase or generation of electricity for downstream customers, imbalance costs for their portfolio of controlled assets, and opportunity costs for flexibility activation. The main *Revenue Streams* of Aggregators come from payments or revenue sharing from electricity sales, flexibility capacity, or ancillary services (see Appendix E.17 for further details).

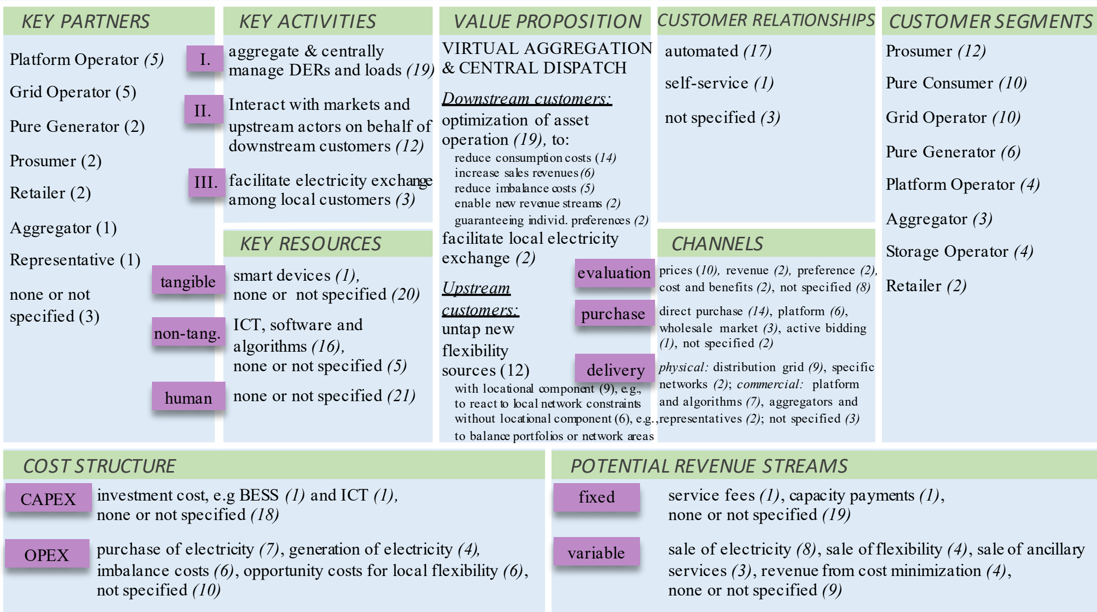

Figure 12: The Business Model Canvas of Aggregators as reviewed in literature. A total of 21 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.17.

Observations on Aggregator BM: While ICT resources are identified as key enablers for the Aggregator's BM, the related conditions of such are inadequately discussed in the reviewed literature. Only one paper mentions associated investment costs [166] and likewise only one other paper describes the underlying tangible resources such as computers or other relevant hardware [79].

Another noteworthy aspect concerns the revenue streams. Especially for their downstream customers, Aggregators create a variety of benefits: from enabling new revenue streams of additional market access' (e.g., [37, 166]) to reduced imbalance costs (e.g., [157, 172]) or reduced consumption costs from shifting load to off-peak times (e.g., [165, 168]). However, it remains unclear for the most part how these benefits are shared between customers and the Aggregator. Essentially all mentioned Aggregators' revenue streams are based on variable components, only one paper mentions a fixed service fee [166]. This appears reasonable for the commodity-based activities around the provision of electricity given their cost-driven character. Yet, the value-driven activity of flexibility services might require different forms of remuneration, such as capacity payments for flexibility provision. The ownership of the electricity that Aggregators buy or sell on behalf of their customers also remains unspecified.

4.3.7. Representative

Similar to Aggregators, Representatives are agents that represent an aggregate of client's resources and that act on the client's behalf in a market or in interaction with other agents. However, unlike Aggregators, Representatives always represent only the portfolio of a single client (see actor descriptions in Table 2 and Appendix D).

As shown in Figure 13, the Representative's *Value Proposition* is to increase the monetary benefits while balancing the individual customer's preferences. *Customer Segment* for this BM includes Prosumers and Pure Consumers. Representatives impersonate the active market role of their customer's EMS processing information from appliances, forecasts, and markets. Their *Key Activity* is to represent and optimize the customers' interaction with other peers and agents. The Representative schedules and controls customers' appliances either directly [144, 145] or through subordinate agents [89]. Overall, this BM is comparably asset-light, with *Key Resources* being primarily non-tangible such as the abilities to forecast, aggregate and control appliances, as well as to optimize biddings (see more detail in Appendix E.18).

Observations on Representative BM: Representatives are facilitators of the interactions between two levels of actors. On the lower level are energy end-users (e.g., Prosumer [140, 144, 175, 176] or Pure Consumer [89, 140, 145, 156]), whereas the upper level may includes Aggregators or Grid Operators [144], Platform Operator with any generic market [145, 176], or a group of peers in P2P models [89, 140]. Representatives generate financial benefits for their downstream customers by delivering a "secondary" value proposition to upsream actors. For instance, a localized flexibility service is delivered to a Retailer using a Pure Consumer's assets, and, in return, financial gain is delivered to the asset owner. However, all reviewed papers lack a description of the financial structure of Representatives.

4.3.8. Retailer

Retailers are usually virtual entities within the local market that trade with local participants, buying electricity from generators and selling to consumers.

The *Value Proposition* of Retailers is centered around cost reductions using load shifting or innovative pricing strategies (e.g., time of use) and guaranteeing the security of supply in case the local market fails. *Customer Segments* of Retailers generally comprise both Pure Consumers and

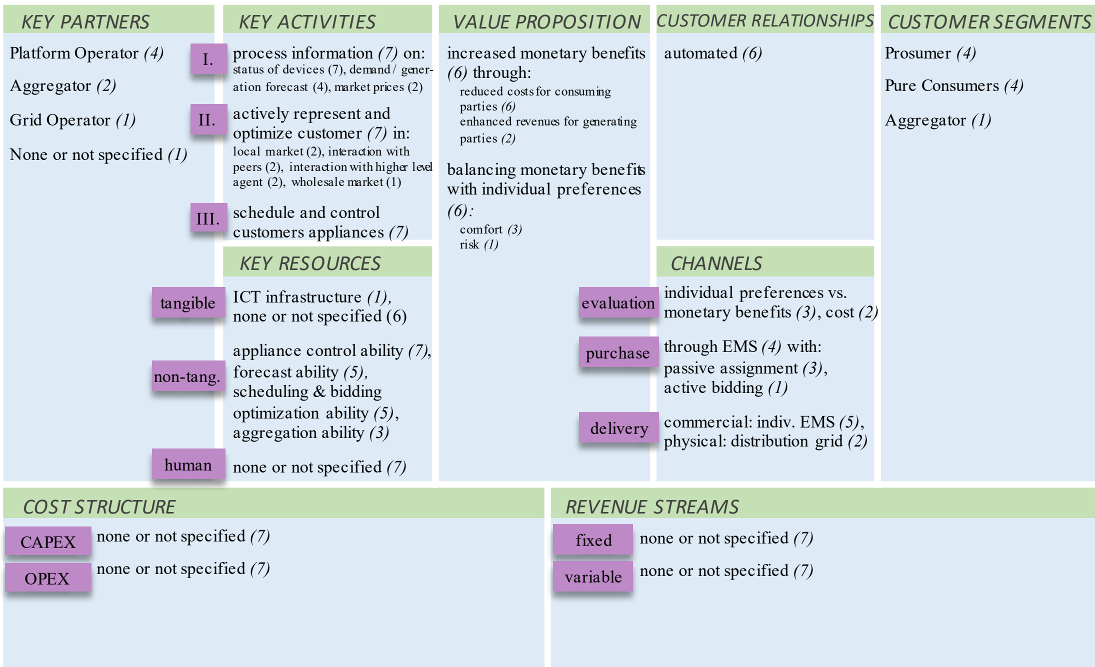

Figure 13: The Business Model Canvas of Representatives as reviewed in literature. A total of 7 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.18.

Prosumers. Aggregators, Grid Operators, and even autonomous trades with the IoT entities, such as EVs are also included in the TE model. In deciding whether the Retailer's value proposition is agreeable, the prospective customers evaluate the expected cost-saving and the perceived discomfort (e.g., due to shifting energy use in time). There are various value delivery *Channels* observed in the reviewed literature, although, in some cases, the Retailer is a monopolistic supplier. Retailers can also participate in upstream markets (e.g., the wholesale market), optimizing bidding strategies. In downstream markets, Retailers may also be the local market operator and aggregator. To deliver their services, the Retailers rely on several *Key Resources* and *Key Partners* as shown in Figure 14.

The provided *Cost Structure* of Retailer BMs in P2P and TE literature consists almost exclusively of variable OPEX. The reported costs concern the purchase of electricity on multiple markets or through bilateral negotiations, own generation costs, or transaction costs. The shape of the defined cost functions can vary from linear (e.g., for transaction costs) to quadratic. Finally, the studied literature lacks detail on economies of scope and scale. Only one paper considers decreasing marginal costs for P2P through economies of scope (with and without storage). See Appendix E.19 for further detail.

Observations on Retailer BM: Retailers are versatile actors, undertaking various vital activities and responsibilities from delivering the overall balancing to acting as a supplier of last resort [58, 166, 167]. In parallel, Retailers often take somewhat hybrid roles, e.g., additionally acting as a Grid Operator [58, 150, 166, 167], Aggregator [77, 147, 166, 167], or Platform Operator [166, 167, 177].

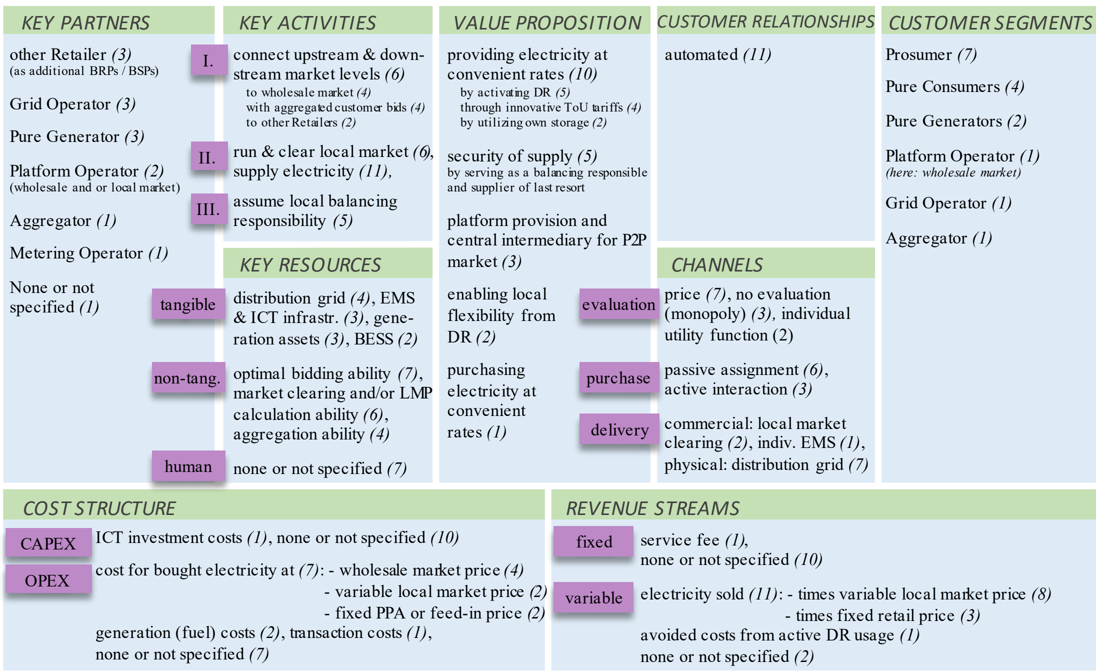

Figure 14: The Business Model Canvas of Retailers as reviewed in literature. A total of 11 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.19.

. The regulatory compatibility of such a "super-actor" would require further analysis, especially for regulated activities or in a monopoly context. This, however, is not covered in the reviewed literature. All reviewed Retailers supply electricity and therefore run a commodity-based BM, both with regards to costs and revenues. However, the purchase or generation costs are often not described, resulting in cost and revenue stream composition inconsistencies [129, 150]. Where described, the revenues are often equal to the costs and the reported BM would therefore represent a non-profit business case. Only one paper explicitly states that retailers will make a margin by selling at higher than purchase prices [77].

4.3.9. Grid Operator

Unlike the other electricity market actors, a Grid Operator is typically a regulated body whose role is to own and operate the power system to guarantee a reliable electricity supply and universal network access [181, 182].This is a relatively passive business that mostly partners or customers to other actors. However, in some literature, the Grid Operator also takes an active role in LEMs to operate the electric network [111, 118, 119, 160, 165, 167, 173, 178–180], to act as the local market operator [119, 160, 167, 173, 178, 180], or as a retailer [54, 111, 167]. The *Value Proposition* of Grid Operators in LEMs includes ensuring the continuity of electricity supply and (where relevant) the provision of a platform and clearing of the LEM. Its *Key Activities* often bring increased monetary benefits for its customers, such as, for example, reduced costs for consuming parties, increased revenues for generating parties, or additional revenue streams for local flexibility providers.

Given the service role (of access and continuity), Grid Operators serve a particularly extensive portfolio of *Customer Segments*. *Key Partners* are local Platform Operators if the Grid Operators themselves do not incorporate this role (see Figure 15 and Appendix E.20 for further detail).

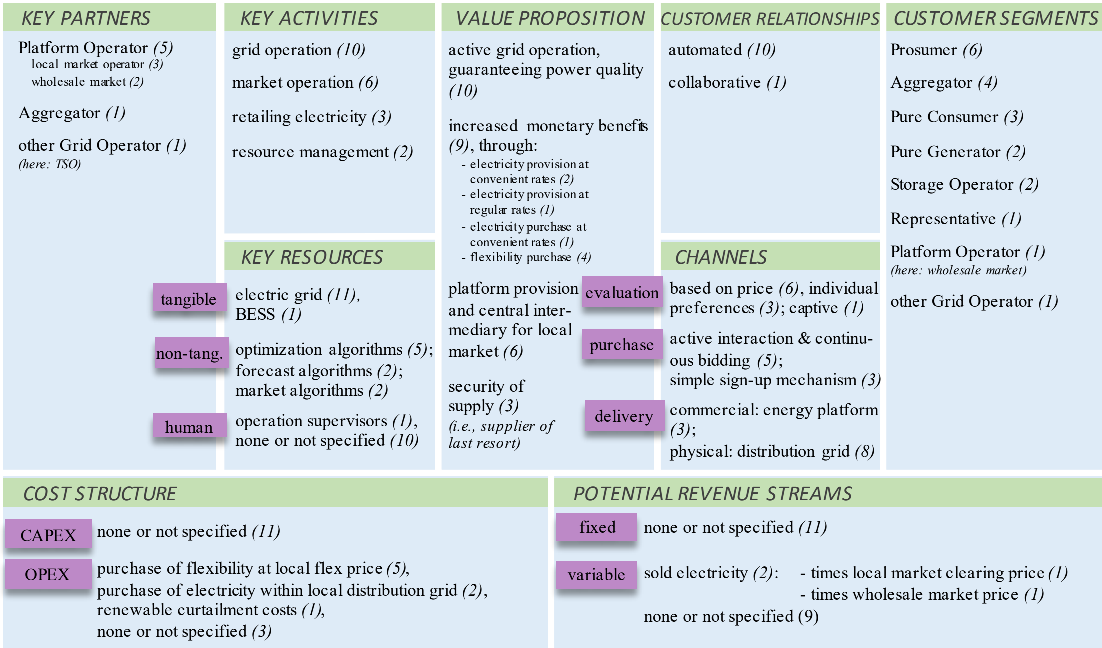

Figure 15: The Business Model Canvas of Grid Operators as reviewed in literature. A total of 11 associated papers were analyzed for this actor. Numbers in parentheses behind individual features represent the number of references, more details in Table E.20.

Observations on Grid Operator BM: Most of the reviewed papers study the Grid Operator BM in the TE market; only one paper focuses on P2P. Moreover, the Grid Operator undertakes the role of a natural monopoly, where it owns and operates the electricity network [54, 111, 119, 160, 165, 167, 173, 178–180]. Only Hu et al. [118] differentiate the owner and operator as distinct actors.

As previously noted, some papers combine additional services (e.g., local market operation, retailing with price arbitrage, etc.) with this BM. However, this is likely to cause regulatory challenges. For example, the unbundling and liberalization of the electricity sector does not allow price arbitrage for Grid Operators in the European Union. Given that all customers are captively connected to the Grid Operator's network, such regulatory challenges must be carefully considered, being a gap in the present literature. Additionally, the cost and revenue analysis related to the actual grid operation (e.g., cost of key resources, such as ICT infrastructure) are also insufficiently detailed.

5. Discussion

Having discussed each individual BM in the above sections, this section discusses some overarching observations, relevant to all of the presented BMs.

5.1. Central Role of Prosumers

Prosumers are by far the most pronounced and present players in the LEM literature reviewed in this work; they are the lead players in around 100 papers from the reviewed set of 135. As shown in Table 4, there is a clear gradual increase in the complexity of various prosumer-led BMs: from simple (e.g., directly maximizing one's use of own generation and trading with peers) to more complex arrangements (e.g., using an Aggregator to coordinate the peer's trading at several markets). Accordingly, four distinct subcategories of Prosumers BMs were identified. The more complex models are all structured around integrating additional value streams into the base BMs and collaborating with increasingly more actors as the business grows in the scope of engagement: from ultra-local self-consumption to transacting at the national level. Thus, the *Prosumer is the key and most innovative actor*, bringing about many new value creation opportunities at different scoping levels.

Compared to the Prosumers, the other actors often play a more auxiliary role in the reviewed papers. Nevertheless, these auxiliary roles (e.g., Aggregators, Retailers, etc.) are critical in enabling access to the decentralized energy market for most smaller players (e.g., Prosumers, Pure Consumers, and Generators). For instance, Retailers often serve as the suppliers "of the last resort", assuring energy service availability, even when the parties of the decentralized energy trading infrastructure are unavailable.

It is interesting to note that the intermediary/facilitating actors could have a BM that sometimes fulfills a "super-actor" function (i.e., takes on several actor roles at once, for example, acting as an Aggregator, Retailer, and Platform Operator at the same time). Some models even include the Grid Operator into their generic BM setup. Clearly, the regulatory compliance of such super-actors is, at the very least, questionable, especially if an actor exerts a monopoly. However, these issues have not been considered in the reviewed literature.

5.2. Differentiating P2P, CSC, and TE Market Models

While the individual BMCs show the customers and partners of each business type, this section considers the integrated perspective of for whom each company is a customer and partner to (note that this is not a reciprocal relationship). Figures 16, 17 and 18 therefore provide a visual representation of actor interactions in the different market models. Both the thickness of, and the numbers on the depicted arrows indicate the number of mentions a business has in the reviewed literature as a customer or a partner to the linked business.

5.2.1. Parties to the CSC Market Model

Overall, the CSC model is the least studied and also has the least number of roles associated with it. Here the roles of Pure Generator, Retailer, Representative, and Grid Operator are not mentioned as active businesses in the reviewed literature, although they can be present as either passive or supporting parties (thus, their grey outlines in Figure 16).

This model tends to operate with a reduced variety of actors. The main actors are Prosumers who interact with each other in peer groups. Thus, the CSC model is designed to support the "many-support-many" context, i.e., many Prosumers supporting each other with their excess generation

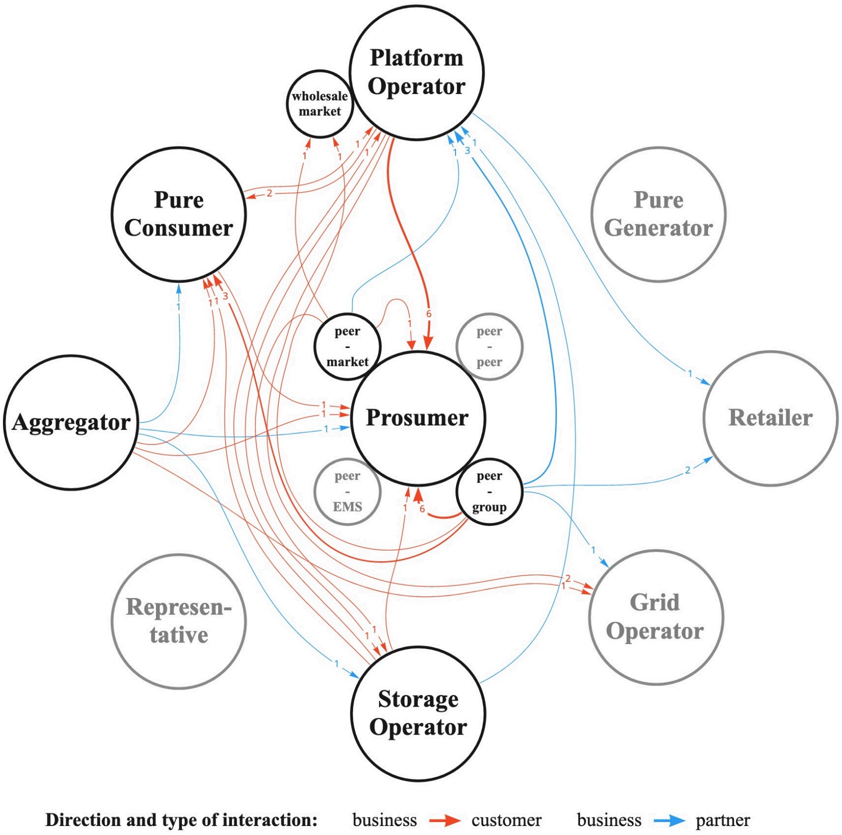

Figure 16: Actor relationships in reviewed CSC models

and consumption. Platform Operators often act as facilitators in these cases, especially for those markets that adopt an effectively passive energy sharing approach (instead of active energy trading). On the one hand, this is not surprising, as CSC is set up for the self-consumption of its members. On the other hand, it indicates that, to remain in a "pure" CSC form, such organisations must generate and consume all of their energy, as any shortage or surplus will require the broadening of the set of participating actor roles.

Looking at the figure for the total number of customer and partner relationships extracted from the presented analysis (and depicted in Figure 16), one notes that this model is characterized by the interaction between three main kinds of actors:

- Prosumers (15 mentions) who serve as customers mainly to their peer-group Prosumers;
- Pure Consumers (7 mentions) who are also customers to their peer-group Prosumers;
- Platform Operators (7 mentions) who partner mainly with Prosumers and Storage Operators.

5.2.2. Parties to the P2P Market Model

P2P has a clear focus on the end-user businesses of Pure Consumers and Prosumers, with other roles such as Aggregators only used sparsely.

Given that P2P models are characterized by many individual Customers or Prosumers that interact (in the majority) directly with each other, it appears that the "pure" P2P model is best suited for a "one-supports-one" trading context.

Figure 17 also reveals that, within the P2P context, the Pure Consumer is not a very active business by itself (i.e., it does not have many customers of its own); however, it is a key customer for many other businesses.

Finally, while Platform Operators are also seen as an active business on their own, they are actually the most frequently referenced key partner for P2P businesses. This clearly demonstrates their crucial facilitation role in such models.

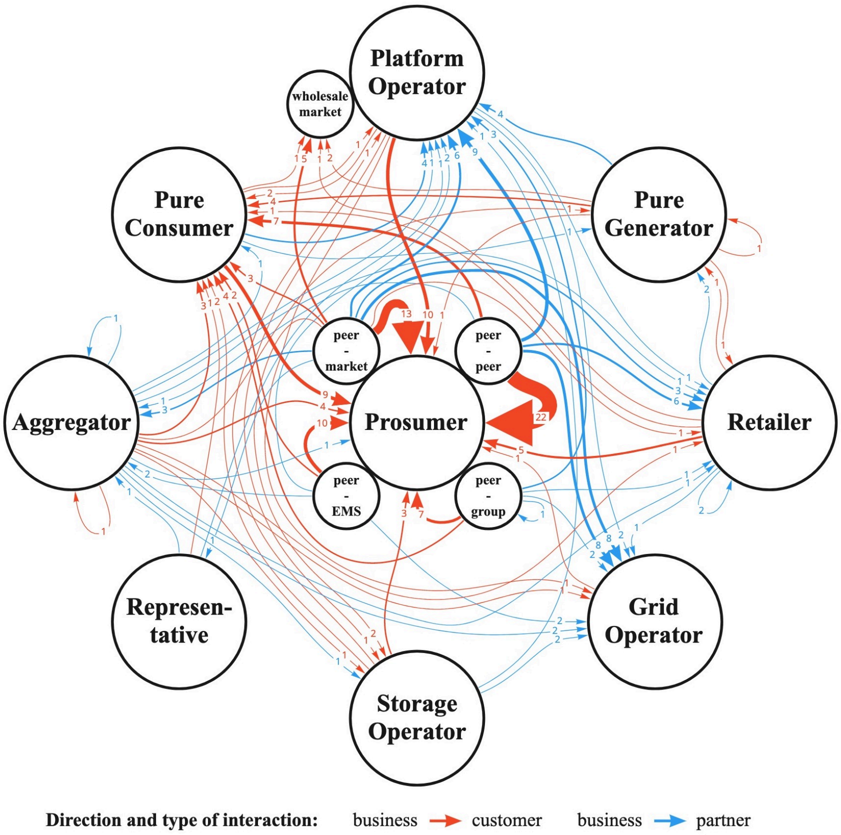

Figure 17: Actor Relationships in reviewed P2P models

The figure for the total number of customer and partner relationships extracted from this analysis (and depicted in Figure 17) shows that the P2P model is characterized by the interaction between five main kinds of actors (with other actors taking more minor roles):

- Prosumers (87 mentions) acting as customers mainly to their peer Prosumers;
- Pure Consumers (30 mentions), who serve as customers to the whole set of other market actors;
- Platform Operators (33 mentions), who are close partners with Prosumers as well as with all other market actors.
- Grid Operators (28 mentions), who have a strong partnership with Prosumers and also collaborate with the wider market participants.
- Retailers (18 mentions), who, again, have strong partnerships with Prosumers and have a broader market engagement.

5.2.3. Parties to the TE Market Model

The TE model finally has the greatest variety of actors engaged with the most diverse interactions, as shown in Figure 18. The diversity is higher than for P2P models, even though there were fewer TE papers (and therefore BMs) reviewed.

TE also has the highest presence of all the facilitator roles. The focus on Prosumer is reduced here and the three actors that play a more important role are: Aggregators, Grid Operators, and Retailers. Aggregators are key partners to many businesses and have many customers of their own. This indicates that the TE model is best suited for a "many-support-one" context, e.g., when many distributed energy market actors support a single customer or service for each trading period.

Grid Operators and Platform Operators are the other key facilitators of the TE models.

The figure for the total number of customer and partner relationships extracted from the analysis (and depicted in Figure 18) shows that the TE model is characterized by interactions between six main kinds of actors (with other actors taking more minor roles):

- Prosumers (42 mentions) acting as customers to their peer Prosumers, Aggregators, Grid Operators and other market actors;
- Pure Consumers (27 mentions) who serve as customers to all market actors and specifically as major customers to Aggregators;
- Pure Generators (14 mentions) who are a major customers to the Aggregators and also purchase from other market actors.
- Grid Operators (16 mentions as a customer, 20 as a business partner) and Aggregators (17 customer and 8 business partner mentions) who are mutually major customers and major business partners to each other, and also serve the broader market.
- Platform Operators (31 mentions), with partnerships across all of the market actors.

To summarize, 5 provides a comparative overview of the identified actor relations in the three market models. Despite the absence of a formal delimitation between P2P, CSC, and TE models, aggregated findings from the literature converge on the characterizations that:

- CSC models operate (groups of) peer Prosumers and Pure Consumers acting as costumers to each other and in partnership with a Platform Operator.

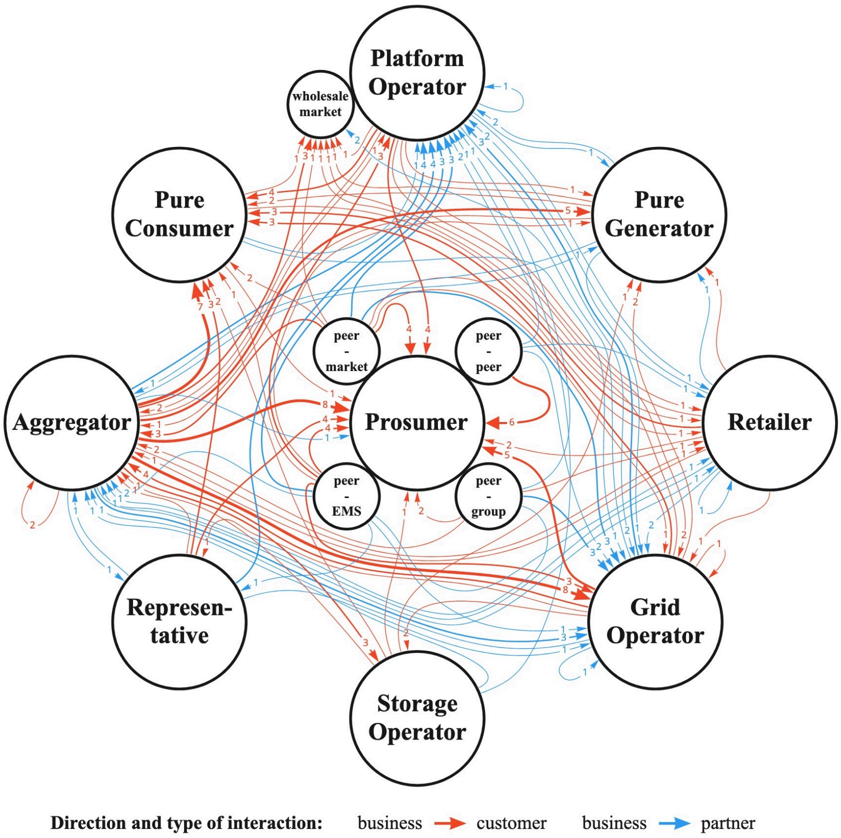

Figure 18: Actor relationships in reviewed TE models

- P2P models operate as (groups of) peer Prosumers and Pure Consumers acting as costumers to each other and in partnership with Platform Operators, Grid Operators, and Retailers.
- TE models operate as (groups of) Prosumers, Pure Consumers, and Pure Generators acting as costumers to the Aggregators and Grid Operators, and in partnership with Platform Operators, Grid Operators, and Aggregators.

5.3. Underspecified Business Model Elements

Another general observation from this study is that various models have different levels of detail in describing key elements of their business, but hardly any of them are complete.

5.3.1. Tangible and Intangible Assets

For instance, the tangible assets (e.g., PVs, consumption loads, etc.) are generally quite well described, especially for asset-based actors such as Pure Generators or Prosumers.

Table 5: Identified actor relations across the three LEM models

Actor category	P2P			CSC			TE		
	Actor presence	Customer mentions	Partner mentions	Actor presence	Customer mentions	Partner mentions	Actor presence	Customer mentions	Partner mentions
Prosumer	62	85	2	8	14	1	37	41	1
Pure Consumer	14	29	1	2	6	1	3	27	0
Pure Generator	5	3	3	0	0	0	5	11	3
Storage Operator	5	4	1	3	2	1	3	5	0
Platform Operator	12	2	31	6	2	5	12	4	27
Aggregator	8	1	7	2	0	0	21	17	8
Representative	1	0	0	0	0	0	6	1	2
Retailer	6	3	15	0	0	3	5	5	5
Grid Operator	1	2	27	0	3	1	15	16	20

The non-tangible assets, in contrast, are often lacking in detail if they are mentioned at all. For instance, the ICT services and infrastructure are essential for the communication and interaction with partners and customers. Most BMs also noted automated communication channels for interaction with their customers, which implies the use of ICT solutions. However, many models do not account for ICT resources, or even human resources, required for the BM operation. In short, the models reviewed in the present study appear to be incomplete concerning their resource requirements.

5.3.2. Financial Aspects

Another poorly described section of the BMs concerns the financial aspects. Both revenue streams and cost structures are often described in a rudimentary way, or not at all. In general, fixed operational costs (OPEX) are the least considered and only mentioned in sporadic cases. Investment costs (CAPEX) are noticed more, although still rarely. If any cost structure is given, it is usually about the variable OPEX such as fuel costs or electricity purchase costs. Specific costs for transactions, trading, or supporting services remain mostly unspecified.

Similarly, the revenue side remains, for the most part, rudimentary. For this, the most common cash flows in the reviewed models stem from the sale of electricity or flexibility services. More specific or detailed revenue streams that are not based on the direct sale of the commodity, such as potential community services, are not specified. There is also a lack of fixed component revenues (e.g., fees for subscription to ICT platform services, etc.). Therefore, from a financial point of view, some actors do not have any evidence for a viable business case. For instance, it seems that most of the Platform Operator providers would operate on a pro-bono basis.

In short, while the literature review undertaken in this study allows to define the *types and key components of the BMs* reported upon in the literature, the lack, or poor quality, of reported information prevents an ascertainment of their their *financial viability* and *suitability for practical operation*.

6. Conclusions

Local energy markets receive an increasing interest in academic literature as they are considered to be a fundamental building block of the ongoing energy transition. While much attention focuses on the transition of the overall system with its respective market perspective, considerably little attention focuses on the individual actor with its business model perspective.

The systematic literature review presented in this paper identifies market actors and outlines their business models in Peer-to-Peer, Community Self-Consumption, and Transactive Energy market models. The review identified 221 active businesses out of a total of 135 peer-reviewed journal papers and analyzed them by utilizing the business model canvas framework. Nine macro actor business categories were identified across the three local energy market types.

While Prosumers appear to be by far the most mentioned actors across all reviewed market models, Pure Consumers, Pure Generators, and Storage Operators are identified as additional grid-connected actors with varying presence. Platform Operators, Aggregators, and Representatives constitute the three macro-categories of facilitating actors, complemented by Retailers and Grid Operators.

Based on the reviewed literature, this paper outlines the emerging business models of the identified key actors. For each of the nine actors, a synthetic business model is derived, and key elements, peculiarities, and gaps are discussed. In general, the reviewed papers focus on such activities as information exchange, optimization of the generating or consuming resources, and coordination of the actors' behavior. The presented review points out the need for enhanced discussion on underlying resources such as information and communication technologies to enable the main business activities. Furthermore, it highlights the lack of a deep analysis of the financial aspects of the business activities, leaving the financial viability of the reported business models under a question mark.

Furthermore, the three market models are differentiated in accordance with their business actor interactions. Prosumers appear to be both the most cited actor as well as the central actor for all three market models. The presence of and interactions with the other actors vary for the three market models. Peer-to-Peer models appear to be constructed around the interaction of Prosumers with other Prosumers and Pure Consumers in particular. Community Self-Consumption models add to these Platform Operators as key facilitators and partners. Finally, Transactive Energy market models appear even further diversified with both Platform Operators and especially Aggregators becoming key facilitators, and Grid Operators acting as active businesses.

In summary, this review provides an overview of the emerging key actors in local energy markets, how they interact and how their business models are expected to operate. While many opportunities for further research remain (some of which were already noted in the previous sections), we would like to point out two of them:

- As previously noted, publications post March 2020 are outside of the scope of this review. However, due to the high speed of content generation around local energy markets, the data set that matches the initial search terms has almost doubled since the research cut-off date. This will remain an issue for all literature review papers. Thus, building a dashboard based on this research that would automate data extraction and categorization from literature could help keep a more up-to-date overview of the published models and data.

- The research published on local energy markets is almost entirely theoretical. There is a severe lack of empirical evidence and reports on such market trials to demonstrate the profitability of the proposed models. Therefore, addressing this gap in research by reporting on the empirical results of ongoing or recently completed pilot projects is an immediate priority for future work.

Data Availability

The completed data extraction table which formed the basis of the analysis presented in this paper is available at https://doi.org/10.48420/16930768

Credit Author Statement

Jan Marc Schwidtal: Conceptualization, Formal Analysis, Investigation, Methodology, Project Administration, Validation, Visualization, Writing - original draft, Writing - review & editing, **Proadpran Piccini:** Formal Analysis, Investigation, Validation, Visualization, Writing - original draft, Writing - review & editing, **Matteo Troncia:** Formal Analysis, Investigation, Validation, Visualization, Writing - original draft, Writing - review & editing, **Ruzanna Chitchyan:** Formal Analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing, **Mehdi Montakhabi:** Formal Analysis, Investigation, Validation, Writing - original draft, **Christina Francis:** Formal Analysis, Investigation, Visualization, Writing - original draft, **Anna Gorbatcheva:** Conceptualization, Investigation, Methodology, Project Administration, Validation, Writing - review & editing, **Timothy Capper:** Conceptualization, Investigation, Methodology, Project Administration, Validation, Writing - review & editing, **Mustafa A. Mustafa:** Investigation, Validation, Writing - review & editing, **Merlinda Andoni:** Investigation, Validation, **Valentin Robu:** Investigation, Validation, Writing - review & editing, **Mohamed Bahloul:** Investigation, Validation, **Ian J. Scott:** Investigation, Validation, **Tanaka Mbavarira:** Investigation, **Juan Manuel Espana:** Investigation, **Lynne Kiesling:** Investigation.

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 A. Data Extraction Codebook

This study developed a data extraction table which was used to consistently extract data from each paper in the review. The data extraction table is based on the *Business Model Canvas* (BMC) framework [10] and defined 16 data extraction fields for the nine business model elements. For more details on the data extraction process see section 3.2. Details about how to access the full data extraction table are available in the section *Data Availability*. Table A.6 contains the codebook for the data extraction table. The codebook contains a list of all data extraction fields, the BMC element they are related to and a description of the data required.

Table A.6: Data extraction codebook

BM element	**Data extraction field**	**Description**
Value Proposition	Value Proposition	What is the value proposition of the business for each of their customer segments, i.e., what service or product does the business offer to its customers? What problem is it trying to solve? Which customer needs are satisfied?
Customer Segments	Customer Segments	Which are the groups of target customers of this business, i.e., who is the business trying to sell to?
Customer Relationships	Customer Relationships	Type of relationships a business establishes with specific customer segments, e.g. personal assistance vs. automated services vs. self-service vs. communities vs. co-creation.
Channels	Evaluation channels	How can customers evaluate the business' value proposition, i.e., how do customers choose which product or service to buy?
	Purchase channels	How can customers purchase the business' value proposition, i.e., how do customers indicate to the business that they want their product or service?
	Delivery channels	How is the business' value proposition delivered to the customers, i.e., how does the businesses' product or service reach to its customer?
Key Activities	Key Activities	The choreography of the business, i.e., what activities must the business undertake to deliver its value proposition and in what order. Production? Problem solving? Platform/network operation?
Key Resources	tangible resources	Physical assets of individual business that are key to provide its value proposition, e.g. solar panels, batteries, etc.
	non-tangible resources	Non-physical assets of individual business that are key to provide its value proposition, e.g. an ability to forecast supply and demand, algorithms, software, patents, etc.
	human resources	People with specific skills which are required by the business to provide its value proposition, e.g. does the business require a home owner to manually bid within a market.
Key Partner	Key Partner	What other business could this business not deliver its value proposition without. Key Partners? Key suppliers? And what are they doing?
Cost Structure	CAPEX	What investment costs must the business pay to provide its value proposition?
	fixed OPEX	What operating costs does the business incur to provide its value proposition which do not vary with output?
	variable OPEX	What operating costs does the business incur to provide its value proposition which do vary with output?
Revenue Streams	fixed revenues	Revenues from value proposition based on static variables, e.g. licensing or subscription fees.
	variable revenues	Revenues from value proposition based on dynamic variables, e.g. sales with changing prices based on market conditions.

Appendix B. Threats to the Study Validity

While undertaking this study, a number of potential threats to the study validity have been identified and mitigated, as discussed below:

Appendix B.0.1. Construct Validity

The notions of P2P/TE/CSC models are not clearly defined and consistently used in the current literature. There are also no mutually accepted guidelines for differentiating these market models. Consequently, our paper search and categorization included all papers where authors self-defined their work as belonging to one of these categories. The reliance on such self-categorization was not deemed to be a serious threat to the construct validity, as in this case, one of the key objectives of this study is to delineate the differentiating features of such BMs, as perceived by the publishing research community itself.

Coding BMs against the 9 elements of the BMC was arguably the most difficult judgement to make because, at times, researchers had to rely on their own interpretation of implicit implications (e.g., often trading platforms may not be explicitly mentioned as a resource, yet these are essential for undertaking any electricity trade). To enable consistent coding, an initial independent coding and subsequent discussion of a test paper was carried out by all researchers, which helped to improve the general understanding and agreement. As a subsequent validation, all coded content was second-checked per element (for each of the 9 BMC elements) for relevance by another checker. Additionally, while undertaking data analysis and report writing, another (third) researcher revisited the papers where the reported BM elements were unclear or were deemed to be missing contextual detail.

Appendix B.0.2. Internal Validity

Although the good practice guidelines for systematic literature reviews were followed [46] no explicit measure of the publication quality was constructed; instead it was opted to include only articles published in peer-reviewed journals. By making this decision, quality checks were implicitly deferred to the anonymous peers. Given that reputable journals tend to maintain good peer review practices, such an implicit quality check was considered to be acceptable. This, however, also introduced a selection constraint (e.g., by disregarding papers published at conferences), which is a threat to the external validity of our findings.

Appendix B.0.3. External Validity

As previously noted, included papers were limited to only journal publications, and the search was also limited to two databases. Neither was there any snowballing conducted. Although enhancing replicability, this limits the external validity of our findings. However, the used databases are commonly considered to be the main sources for business and energy-related publications. Consequently, although being confident to have captured a representative body of literature on energy markets, the conclusions drawn here may not be generalizable across the board.

The review period is for the publications up to March 2020. Very recent work will be missed from this report. The conclusions, however, remain valid for the reviewed period.

Appendix C. HRM role definitions

The following definitions stem from ENTSO-E, the European Network of Transmission System Operators for Electricity. They are part of a wider set of definitions from their the Harmonized electricity Market Roles (HRM) [48].

Table C.7: Definitions of the Harmonized electricity Market Roles (HRM) from ENTSO-E [48].

Harmonized role	**Definition**
Billing Agent	The party responsible for invoicing a concerned party
Consumer	A party that consumes electricity. Additional Information: This is a type of "Party connected to the grid"
Data Provider	A party that has a mandate to provide information to other parties in the energy market
Energy Supplier	An Energy Supplier supplies electricity to or takes electricity from a "Party connected to the grid" at an accounting point
Energy Trader	A party that is selling or buying energy
LFC Operator	Responsible for the Load Frequency Control (LFC) for its LFC Area or LFC Block Additional information: This role is typically performed by a TSO
Market Information Aggregator	A party that provides market related information that has been compiled from the figures supplied by different actors in the market. This information may also be published or distributed for general use. Note: The Market Information Aggregator may receive information from any market participant that is relevant for publication or distribution.
Market Operator	A market operator is a party that provides a service whereby the offers to sell electricity are matched with bids to buy electricity. Additional Information: This usually is an energy/power exchange or platform. The definition is based on the "Regulation (EU) 2019/943"
Merit Order List Responsible	Responsible for the management of the available tenders for all Acquiring LFC Operators to establish the order of the reserve capacity that can be activated
Party Connected to the Grid	A party that contracts for the right to consume or produce electricity at an Accounting Point
Producer	A party that generates electricity. Additional information: This is a type of "Party connected to the gid". The definition is based on the "Directive (EU) 2019/944"
Reserve Allocator	Informs the market of reserve requirements, receives bids against requirements and in compliance with the prequalification criteria, determines which bids meet the requirements and assigns bids
Resource Aggregator	A party that aggregates resources for usage by a service provider for energy market services. Note: In the current version, the only service provider in HRM is the Balancing Service Provider
Resource Provider	A role that manages a resource and provides production/consumption schedules for it, if required
Scheduling Area Responsible	A party responsible for the coordination of nominated volumes within a scheduling area. Additional information: This role is typically performed by a TSO
System Operator	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of transmission of electricity. Additional information: The definition is based on "Directive 2009/72/EC"

Appendix D. Identified Actor Characterization

The following table reports the macro-actor characterizations that were derived by mapping extracted BMs from reviewed literature to HRM roles. Each actor covers per definition a minimum combination of such roles and, depending on the actual BM configuration, a potentially extended set of roles.

Table D.8: Derived actor characterizations based on HRM roles

Actor	Minimum combination of HRM roles	Potential combination of HRM roles	Characterization	Associated synonyms in literature
Prosumer	Party Connected to the Grid, Producer, Consumer	Party Connected to the Grid, Producer, Consumer, Resource Provider, Energy Supplier, Energy Trader (& BRP, CRP, BSP, PRP)	A Prosumer is an entity which is connected to the grid and that injects and withdraws energy at the same grid connection point. It is characterized by a bidirectional electricity flow based on generating, consuming and storing assets at its grid connection point. The operation of its asstes can either be done by the Prosumer itself or further delegated to a third party. Prosumers exist in various dimensions from electric vehicles to residential households, over commercial buildings up to microgrids interacting with other microgrids	Residential Prosumer, Commercial Prosumer, Electric Vehicle, Energy Node, Microgrid Grid-Edge Resource
Pure Consumer	Party Connected to the Grid, Consumer	Party Connected to the Grid, Consumer, Resource Provider, Energy Supplier, Energy Trader (& BRP, BSP, CRP)	A Pure Consumer is an entity connected to the grid which possesses and potentially operates its own assets to consume electricity. Storage assets can also be among such assets, as long as they are only used to shift consumption without reinjecting electricity into the grid. A Pure Consumer is therefore characterized by a unidirectional withdrawing of electricity flow at its grid connection point	Consumer, Customer, End user, Household
Pure Generator	Party Connected to the Grid, Producer	Party Connected to the Grid, Producer, Resource Provider, Energy Supplier, Energy Trader (& BRP, BSP, PRP)	A Pure Generator is an entity connected to the grid which possesses and potentially operates its own assets to generate electricity. It is thereby characterized by a predominately unidirectional flow, which injects electricity at its grid connection point	Distributed Generators, Generators, Producer, Seller

Table D.8: Derived actor characterizations based on HRM roles

Actor	**Minimum combination of HRM roles**	**Potential combination of HRM roles**	**Characterization**	**Associated synonyms in literature**
Storage Operator	Party Connected to the Grid, Resource Provider, Energy Supplier, Energy Trader (& BRP, BSP)		A storage operator is an entity connected to the grid which possesses and operates its own assets to store electricity. It neither generates nor consumes energy (except minor process losses), yet it buys, keeps for a time, and then sells energy to the local market at different points in time. It is thereby characterized by a bidirectional electricity flow at its grid connection point	Battery Energy Storage System (BESS) owner, BESS operator, Battery storage operator, Gas energy storage system
Platform Operator	Market Information Aggregator, Data Provider	Market Information Aggregator, Data Provider, Billing Agent, Market Operator, Energy Supplier	An Platform Operator is an entity which operates a platform for energy trading or sharing. It is not connected to the grid and does not own any relevant generation or consumption assets, although it facilitates the exchange among them. This activity can encompass the mere provision of the platform, or it can also conduct more active tasks such as market clearing and the subsequent billing. In some cases, the Platform Operator will also be responsible for supplying the cleared energy to local participants, hence taking over the role of a local supplier	Local Market Operator, Community Manager, Coordinator, Crowdsourced Energy System Operator, Microgrid Operator, Transactive Energy Operator, Virtual Energy Company
Aggregator	Resource Provider, Resource Aggregator	Resource Provider, Resource Aggregator, Energy Supplier, Energy Trader (& BRP, BSP, CRP, PRP)	An Aggregator is a virtual entity, not physically connected to the grid, which acts on behalf of a variable group of parties connected to the grid (or their representatives). Aggregators manage the combination of their clients' individual assets as one virtually aggregated asset, with various levels of activity on a potentially plurality of markets. As such, and in the simplest case, they can represent one type of actor with one unidirectional offering (e.g., as a load aggregator for a number of Pure Consumers) up to a diverse number of actors with a diverse portfolio of controllable and non-controllable assets with bidirectional needs and offerings on multiple markets (commodity and services) in more advanced cases	Demand Response Aggregator, Load Aggregator, Micro Grid Energy Manager, Virtual Power Plant, Commercial Aggregator, Flexibility Service Provider

Table D.8: Derived actor characterizations based on HRM roles

Actor	**Minimum combination of HRM roles**	**Potential combination of HRM roles**	**Characterization**	**Associated synonyms in literature**
Representative	Resource Provider *or* Energy Supplier, Energy Trader	Resource Provider, Energy Supplier, Energy Trader (& BRP, BSP, CRP, PRP)	A Representative is a virtual entity, not physically connected to the grid, which acts on behalf of a single party connected to the grid. Representatives manage (the potential combination of) their clients' individual asset(s) toward a potential plurality of traders (such as Retailers or Aggregators) or market platforms with varying products or services depending on each client's preferences and asset capabilities. Other than Aggregators, they always represent only one single client. A common example of Representatives are home energy management systems	Agent, Broker, Building Energy Management System (BEMS), Home Energy Management System (HEMS), Local Intelligent Software Agent, Domotic Node
Retailer	Energy Supplier, Energy Trader	Energy Supplier, Energy Trader, Resource Provider, Producer, Party connected to the grid	A Retailer is usually a virtual entity, not physically connected to the grid, which does not own any physical assets. It buys and sells energy to the individual clients, and in exchange for Platform Operators, rather than either generating or consuming energy. Retailers often connect markets of different levels, e.g., the local market with an overarching wholesale market. In some exceptional cases, they also own generation assets and so are an actual party connected to the grid, in parallel to their virtual trader and supplier role	Local Energy Company, Load Serving Entity, Utility company, Supplier
Grid Operator	System operator	System operator, Scheduling Area Responsible, LFC operator, Merit Order List Responsible, Reserve Allocator	A grid operator is an entity that manages, develops, and maintains the electricity or gas network for a specific territory. Such management can range from the mere infrastructure provision to a rather passive management style by only flagging potential resource scheduling issues up to an active grid management with reserve provision and deployment	Distribution Network Operator, Distribution System Operator, Distribution Independent System Operator, Independent System Operator, System Operator

Appendix E. Detailed Actor's Business Models per Market Model

Table E.9: Detailed business model elements with references of reviewed Prosumers (peer-peer) in local energy markets

	Prosumer peer-peer		
	P2P	**CSC**	**TE**
Value proposition	• providing electricity [37, 49, 52, 53, 58–60, 62, 64, 66, 73, 74, 76, 77, 79, 81, 83–86, 93, 94] [28, 106]* – at more convenient rates (e.g. than wholesale market) [53, 58, 60, 85, 93, 94] – at auctioned local market price (no comparison to other markets) • providing flexibility [63, 71] – through demand response (incl. EVs & battery) – through dispatchable generation • providing reactive power [83]		• providing electricity [112, 115, 125] [28, 106]* – at more convenient rates (e.g. than wholesale market) [112, 115] – at auctioned local market price (no comparison to other markets) • providing flexibility [113] – through demand response (incl. EVs & battery) – through dispatchable generation
Customer segments	• Prosumer [37, 49, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 81, 83–85, 94] [28, 106]* • Pure Consumer [52, 79, 83, 84, 86, 93, 94]		• Prosumer [112, 113, 115, 125] [28, 106]*
Customer relationships	• automated [37, 49, 52, 58–60, 64, 66, 71, 73, 74, 76, 77, 79, 81, 83–86, 93] [28, 106]*		• automated [112, 115, 125] [28, 106]*
Channels	**Evaluation:** • price [49, 52, 53, 58, 58–60, 62, 66, 71, 73, 74, 76, 77, 79, 81, 84–86, 93] [28, 106]* • availability [60, 63, 93, 94] • personal preferences (e.g. energy source, autarky, etc.) [86, 94] **Purchase:** • through interaction with P2P marketplace [37, 49, 58, 59, 62–64, 66, 71, 73, 74, 76, 79, 81, 84, 85, 93] [106]* • through bargaining of representatives [53, 60, 77, 86] • through passive assignment from retailer [52]		**Evaluation:** • price [112, 113, 115, 125] [28, 106]* **Purchase:** • through TE platform [112, 113, 115] [106]* **Delivery:** • physically: through the distribution grid [112, 113, 115] [106]*

Table E.9: Detailed business model elements with references of reviewed Prosumers (peer-peer) in local energy markets

	Prosumer peer-peer		
	P2P	**CSC**	**TE**
Channels *(cont'd)*	**Delivery:** • physically: through the distribution grid [49, 58–60, 62–64, 71, 84–86, 93] [106]* • commercially: through P2P platform [52, 66, 74, 76, 84–86, 93]		
Revenue streams	**fixed Revenues:** • none or not specified [37, 49, 52, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 79, 81, 83–86, 93, 94] [28, 106]* **variable Revenues:** • electricity sold [49, 52, 53, 58–60, 62, 63, 66, 73, 74, 76, 79, 83–86, 93, 94] [28, 106]* – times local market price [49, 60, 66, 84–86, 94] – times auction price [53] [28]* – times bilaterally agreed price [52, 58, 63, 93] – times fixed feed-in tariff [62, 84] • flexibility sold [71]		**fixed Revenues:** • none or not specified [112, 113, 115, 125] [28, 106]* **variable Revenues:** • electricity sold [112, 113, 115, 125] [28, 106]* – times local market price [113] – times auction price [28]* – times bilaterally agreed price [112]
Key partners	• Platform Operators [53, 59, 60, 64, 71, 84, 86] [28, 106]* – blockchain platform [59, 64, 71] • Grid Operators [63, 64, 74, 83, 85, 86] [106]* • Retailer [52, 58, 77, 84, 85, 94] • Aggregator [79] • none or not specified [37, 49, 62, 66, 73, 76, 81]		• Platform Operator [28, 106]* • Grid Operators [112] [106]* • Retailer [112] • none or not specified [113, 115, 125]
Key resources	**tangible:** • Generation assets [37, 49, 52, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 79, 81, 83–86, 93, 94] [28, 106]* – PV [52, 53, 58–60, 62, 63, 66, 71, 76, 77, 79, 83–86, 94] [28]* – conventional [58, 71] • BESS [58, 62, 63, 66, 71, 76, 83–85, 94] [28]* – stationary [58, 62, 63, 76, 83–85, 94] [28]* – non-stationary (EVs) [58] [28]*		**tangible:** • Generation assets [112, 113, 115, 125] [28, 106]* – PV [113, 115, 125] [28]* – conventional [112, 115] • BESS [115] [28]* – stationary [115] [28]* – non-stationary (EVs) [28]* • Loads [112, 113, 115] [28, 106]* – controllable (e.g. HVAC, household appliances etc.) [28]* – non-controllable [113, 115] [28]*

Table E.9: Detailed business model elements with references of reviewed Prosumers (peer-peer) in local energy markets

	Prosumer peer-peer		
	P2P	**CSC**	**TE**
Key resources *(cont'd)*	**tangible:** *(cont'd)* • Loads [37, 49, 52, 53, 58, 58–60, 63, 64, 66, 71, 73, 74, 76, 77, 79, 84, 93], [28, 106]* – controllable (e.g. HVAC, household appliances etc.) [71, 74, 76, 77], [28]* – non-controllable [58, 71, 74, 77], [28]* • ICT infrastructure (e.g. sensor, smart meters etc.) [79, 86, 93] **non-tangible:** • ability to forecast own demand and or generation [49, 53, 59, 60, 62, 66, 71] • ability to actively interact with market [59, 73, 85], [106]* • ability to optimize proprietary operations [58, 71] • ability to interact with blockchain [59, 62, 64] • ability to communicate with other peers in the network [58, 59] **human:** • none or not specified [37, 49, 52, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 79, 81, 83–86, 93, 94], [28, 106]*		**non-tangible:** • ability to forecast own demand and or generation [115] • ability to actively interact with market [112, 113, 115, 125], [106]* • ability to optimize proprietary operations [112] **human:** • none or not specified [112, 113, 115, 125], [28, 106]*
Key activities	• supply and demand management [37, 49, 52, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 79, 83–86, 93, 94], [28, 106]* – forecast own demand and or generation [49, 53, 59, 60, 62, 66, 71] – produce electricity [37, 49, 52, 53, 58–60, 62–64, 66, 71, 73, 74, 76, 77, 79, 83–86, 93, 94], [28, 106]* – schedule own load and generation profile [58, 62, 71] • price management [49, 53, 62, 71, 73, 81], [28, 106]* • trade electricity [49, 52, 53, 58–60, 62, 66, 71, 73, 76, 79, 81], [28, 106]*		• supply and demand management [112, 113, 115, 125], [28, 106]* – forecast own demand and or generation [115, 125] – produce electricity [112, 113, 115, 125], [28, 106]* • price management [115, 125] • trade electricity [112, 113, 115, 125], [28, 106]*

Table E.9: Detailed business model elements with references of reviewed Prosumers (peer-peer) in local energy markets

	Prosumer peer-peer		
	P2P	**CSC**	**TE**
Cost structure	**CAPEX:** • investment costs [52, 62, 63, 84, 85, 94] – of PV [52, 62, 63, 84, 85] – of BESS [62, 63, 84, 85] • none or not specified [37, 49, 53, 58–60, 64, 66, 71, 73, 74, 76, 77, 79, 81, 83, 86, 93], [28, 106]* **fixed OPEX:** • maintenance costs [52, 66] • none or not specified [37, 49, 53, 58–60, 62–64, 71, 73, 74, 76, 77, 79, 81, 83–86, 93, 94], [28, 106]* **variable OPEX:** • generation (fuel) costs for non-renewables [58] • consumption costs for not self-generated electricity [58, 84] • operation (degradation) costs of BESS [58, 64] • transaction costs [52, 71, 84] • grid related costs [74, 83] • none or not specified [37, 49, 53, 59, 60, 62, 63, 66, 73, 76, 77, 79, 81, 85, 86, 93, 94], [28, 106]*		**CAPEX:** • investment costs of PV [113] • none or not specified [112, 115, 125], [28, 106]* **fixed OPEX:** • none or not specified [112, 113, 115, 125], [28, 106]* **variable OPEX:** • generation (fuel) costs for non-renewables [112, 115] • consumption costs for not self-generated electricity [112, 115] • operation (degradation) costs of BESS [115] • grid related costs [112, 115] • none or not specified [113, 125], [28, 106]*

[ ]* entry refers to a paper that contains more than one energy market model

Table E.10: Detailed business model elements with references of reviewed Prosumers (peer-group) in local energy markets

	Prosumer peer-group		
	P2P	**CSC**	**TE**
Value proposition	• providing electricity [53, 61, 67, 73], [103, 105, 107]* – at more convenient rates (e.g. than wholesale market) [53, 67], [103, 105, 107]* • providing flexibility [61, 65], [107]* – through Demand Response (inc. EVs & battery) [65], [107]*	• providing electricity [37, 108, 109], [103, 105, 107]* – at more convenient rates (e.g. than wholesale market) [37, 109], [103, 105, 107]* • providing flexibility [108], [107]* – through Demand Response (inc. EVs & battery) [108], [107]*	• providing electricity [118, 129, 134] – at more convenient rates (e.g. than wholesale market) [129, 134] • providing flexibility [118, 119, 129] – through Demand Response (inc. EVs & battery) [119, 129] – short time dispatch [118, 129]

Table E.10: Detailed business model elements with references of reviewed Prosumers (peer-group) in local energy markets

	Prosumer peer-group		
	P2P	**CSC**	**TE**

Customer segments	• Prosumer [53, 61, 65, 73] [103, 105, 107]*
	• Pure Consumer [67] [103, 105, 107]*
		• Prosumer [37] [108] [109] [103, 105, 107]*
		• Pure Consumer [103, 105, 107]*
		• Platform Operator (*wholesale market*) [109]
			• Prosumer [129, 134]
			• Aggregator [118, 119]
			  – selling to DSO (Grid Operator) [119]
			  – selling to TSO (Grid Operator) [118]
			• Retailer [129]

Customer relationships	• automated [61, 65, 73] [103, 105, 107]* • community [53] • contractual [67] • Anonymous [103]*	• automated [37, 109] [103, 105, 107]* • community [109] • anonymous [103]* • not discussed [108]	• automated [118, 119, 129, 134]

Channels	**Evaluation:**
	• price [53, 65, 67, 73] [105, 107]*
	• personal preferences [61]
	• no evaluation (once subscribed) [103]*
	Purchase:
	• through active interaction and continuous bidding [53, 61, 65, 73]
	• through passive assignment from community once signed up [67, 73] [103, 105, 107]*
	Delivery:
	• physically through the grid [53, 61, 65, 67] [103, 105, 107]*
	• commercially through:
	  – community [67] [103, 105, 107]*
	  – individual EMS [67]
	  – P2P market clearing [53]
	• not discussed [73]
		Evaluation:
		• price [108, 109] [105, 107]*
		• community preferences [108, 109]
		• no evaluation [37] [103]*
		  – (once subscribed) [103]*
		  – (once physically connected) [37]
		Purchase:
		• through passive assignment from community once signed up [108, 109] [103, 105, 107]*
		• not specified [37]
		Delivery:
		• physically through the grid [37, 108, 109] [103, 105, 107]*
		• commercially through community [109] [103, 105, 107]*
			Evaluation:
			• price [118, 119, 129, 134]
			Purchase:
			• through active interaction and continuous bidding [129]
			• through passive assignment from community once signed up [134]
			• not specified [118, 119]
			Delivery:
			• physically through the grid [118, 119, 129, 134]
			• commercially through transactive market clearing:
			  – with Aggregator [118, 119, 134]
			  – with platform operator [129]

Revenue streams	**fixed Revenues:**
	• none or not specified [53, 61, 65, 67, 73] [103, 105, 107]*
	variable Revenues:
	• electricity sold times local clearing price [53, 67, 73] [103, 105, 107]*
	• reduced costs for electricity consumed [53, 65] [107]*
	• none or not specified [61]
		fixed Revenues:
		• none or not specified [37, 108, 109] [103, 105, 107]*
		variable Revenues:
		• electricity sold times local clearing price [37, 109] [103, 105, 107]*
		• reduced costs for electricity consumed [107]*
		• none or not specified [108]
			fixed Revenues:
			• electricity sold times fixed ToU price of grid [134]
			• none or not specified [118, 119, 129]
			variable Revenues:
			• flexibility sold to Aggregator [118, 119]
			  – times local flex clearing price [118]
			  – unclear at which price or how remunerated [119]

Table E.10: Detailed business model elements with references of reviewed Prosumers (peer-group) in local energy markets

	Prosumer peer-group		
	P2P	**CSC**	**TE**
Revenue streams *(cont'd)*			**variable Revenues:** *(cont'd)* • electricity sold times local clearing price [129, 134] • reduced costs for electricity consumed [129, 134]
Key partners	• other Prosumers (in same coalition) [53] • Grid Operator [67] [105]* • Retailer (as retailer of last resort) [67] • Platform Operator [65] [103, 107]* • none or not specified [61, 73]	• Grid Operator [105]* • Retailer (as retailer of last resort) [37, 108] • Platform Operator [109] [103, 107]*	• Aggregator [134] • Grid Operator (to approve local network feasibility) [118, 129, 134] • Platform Operator [129] • none or not specified [119]

Key resources	**tangible:**
	1. Generation [53, 61, 67, 73] [103, 105, 107]*
	  • PV [53, 61, 67] [103, 105, 107]*
	2. BESS [53, 61, 65] [107]*
	  • stationary [53, 61, 65] [107]*
	  • non-stationary (EVs) [65]
	3. Distribution grid [67]
	4. ICT infrastructure (e.g. controller, meter) [67] [105]*
	non-tangible:
	• ability to determine optimal bidding [73]
	• ability to optimize own consumption (EMS) [65, 67]
	• none or not specified [53, 61] [103, 105, 107]*
	human:
	• none or not specified [53, 61, 65, 67, 73] [103, 105, 107]*
		tangible:
		1. Generation [37, 108, 109] [103, 105, 107]*
		  • PV [37, 108] [103, 105, 107]*
		  • conventional generation [109]
		2. stationary BESS [108] [107]*
		3. Loads
		  • controllable [109]
		  • non-controllable [37]
		4. Distribution grid [37]
		5. ICT infrastructure (e.g. controller, meter) [37] [105]*
		non-tangible:
		• ability to perform the actions of a retailer [37]
		• none or not specified [108, 109] [103, 105, 107]*
		human:
		• none or not specified [37, 108, 109] [103, 105, 107]*
			tangible:
			1. Generation [129, 134]
			  • PV [129, 134]
			  • wind turbine [129]
			  • conventional generation [129]
			2. BESS
			  • stationary [119, 129, 134]
			  • non-stationary (EVs) [118, 119, 129, 134]
			3. Loads
			  • controllable [119, 129]
			  • non-controllable [129, 134]
			4. ICT infrastructure (e.g. controller, meter) [118, 134]
			non-tangible:
			• ability to determine optimal bidding [119, 129]
			• EMS [119, 134]
			• none or not specified [118]
			human:
			• none or not specified [118, 119, 129, 134]

Key activities	1. forecast own generation and consumption [53, 65]
	2. join local market [53] [103, 105]*
	3. exchange information with other actors [53, 65]
	4. interact with market
	  • with optimized bidding [53, 61, 65, 73]
	  • with passive communication of surplus / net-demand of electricity [67] [103]*
		1. install required infrastructure [37]
		2. join local market [103, 105]*
		3. exchange information with other actors [37, 109]
		4. interact with market
		  • with passive communication of surplus / net-demand of electricity [103]*
		  • with communication of cost function [109]
			1. join local market [118]
			2. exchange information with other actors [119, 134]
			3. interact with market
			  • with optimized bidding [119, 129]
			4. generate electricity [129, 134]
			5. operate own controllable assets
			  • according to central-optimization [118, 119, 129, 134]

Table E.10: Detailed business model elements with references of reviewed Prosumers (peer-group) in local energy markets

	Prosumer peer-group		
	P2P	**CSC**	**TE**
Key activties *(cont'd)*	5. generate electricity [53, 61, 67, 73, 103, 105, 107]* 6. operate own controllable assets [53, 61] • according to self-optimization [53, 61, 107]* • according to central optimization [107]* 7. clear local market [53] 8. buy (supplemental) electricity from other Prosumers [53, 61, 103, 105]*	5. generate electricity [37, 108, 109, 103, 105, 107]* 6. operate own controllable assets [108, 109, 107]* • according to self-optimization [108] • according to central-optimization [108, 109, 107]* 7. buy (supplemental) electricity • from other Prosumers [103, 105]* • from Retailer [37]	6. buy (supplemental) electricity from other Prosumers [134]
Cost structure	**CAPEX:** • installation costs of BESS [107]* • none or not specified [53, 61, 65, 67, 73, 103, 105]* **fixed OPEX:** • none or not specified [53, 61, 65, 67, 73, 103, 105, 107]* **variable OPEX:** • transaction costs [65] • electricity consumption costs at local clearing or retail price (upon availability) [107]* • BESS depreciation [107]* • none or not specified [53, 61, 67, 73, 103, 105]*	**CAPEX:** • installation costs [108, 107]* – of PV [108] – of BESS [108, 107]* • installation of local grid and ICT infrastructure [37] • none or not specified [109, 103, 105]* **fixed OPEX:** • maintenance of local grid and ICT infrastructure [37] • none or not specified [108, 109, 103, 105, 107]* **variable OPEX:** • generation costs based on individual cost function [109] • electricity consumption costs at local clearing or retail price (upon availability) [37, 109, 107]* • costs for transaction with community [109] • BESS depreciation [107]* • none or not specified [108, 103, 105]*	**CAPEX:** • none or not specified [118, 119, 129, 134] **fixed OPEX:** • none or not specified [118, 119, 129, 134] **variable OPEX:** • generation costs for non-renewable generation [129] • electricity consumption costs [118, 119, 129, 134] – for not self-generated electricity, paid at retail price [118] – within DR scheme, paid at local clearing price [119] • revenue sharing costs with Aggregator [134]

[ ]* entry refers to a paper that contains more than one energy market model

Table E.11: Detailed business model elements with references of reviewed Prosumers (peer-EMS) in local energy markets

	Prosumer peer-EMS		
	P2P	**CSC**	**TE**
Value proposition	• providing electricity [55, 57, 68, 72, 75, 97–99] – at more convenient rates (e.g. than wholesale market) [55, 57, 68, 72, 98, 99] – at auctioned local market price (no comparison to other markets) [75, 97] • providing flexibility [55, 67, 97, 98, 100] – through demand response (incl. EVs & battery) [55, 67, 98, 100] – through dispatchable generation [97] • Providing heat – at auctioned local market price (no comparison to other markets) [97, 98]		• providing electricity [121, 130, 139–141] – at more convenient rates (e.g. than wholesale market) [121, 130, 139–141] – at auctioned local market price (no comparison to other markets) [139] • providing flexibility [116, 121, 132, 139] – through demand response (incl. EVs & battery) [116, 121, 132, 139] • providing reactive power [139] • providing spinning reserve [141]
Customer segments	• Prosumer [55, 57, 67, 68, 72, 75, 97–100] • Pure Consumer [57, 75]		• Prosumer [121, 130, 139, 141] • Pure consumer [139] • Pure Generator [139] • Grid Operator [116, 139, 141] • Platform Operator [132, 139, 140] – Energy management agent at microgrid level [132] – market at next higher voltage level [139] – community energy management system [140]
Customer relationships	• automated [55, 68, 72, 75, 97, 99, 100] • community [57] • contractual [67] • personal assistance [72] • not specified [98]		• automated [116, 121, 130, 139, 140] • community [132] • not specified [141]
Channels	**Evaluation:** • price [55, 57, 68, 72, 75, 97–100] • individual preferences [55, 99] • technological suitability [98]		**Evaluation:** • price [116, 121, 130, 132, 139–141] • individual preferences [116, 121, 132] • resources' status [121]

Table E.11: Detailed business model elements with references of reviewed Prosumers (peer-EMS) in local energy markets

	Prosumer peer-EMS		
	P2P	**CSC**	**TE**
Channels *(cont'd)*	**Purchase:** I (a) through EMS [55, 57, 68, 72, 99, 100] (b) through aggregator [57, 100] (c) through Platform Operator [72, 99] II (a) with active interaction and continuous bidding [55, 68, 75, 99] (b) with passive assignment once signed up [57, 67, 97, 100] III not specified [98] **Delivery:** • physically: through the grid [55, 67, 68, 72, 75, 97–99] • commercially: through P2P scheme with – community [57] – individual EMS system [67, 68, 72, 75, 97, 99, 100] – central market platform [72, 99] – blockchain validation [68]		**Purchase:** I (a) through EMS [116, 121, 130, 132, 140] (b) through [132] II (a) with active interaction and continuous bidding [116, 121, 130, 132, 139] (b) with passive assignment once signed up [139–141] **Delivery:** • physically: through the grid [132, 140] • commercially: through TE scheme with – community [140] – individual EMS system [116, 140] – central market platform [121, 130] – nested system of multiple market levels [139, 140] • not specified [141]
Revenue streams	**fixed Revenues:** • none or not specified [55, 57, 67, 68, 72, 75, 97–100] **variable Revenues:** • electricity sold [57, 67, 68, 72, 75, 98, 99] – times local clearing price [57, 68, 72, 75, 99] – times fixed feed-in tariff [67, 68, 75] – times fixed local sharing price [98] • heat sold times fixed local sharing price [98] • reduced costs for electricity consumed [57, 67, 68, 72, 97, 99, 100] • reduced costs for heat consumed [97] • none or not specified [55]		**fixed Revenues:** • none or not specified [116, 121, 130, 132, 139–141] **variable Revenues:** • electricity sold [121, 130, 139–141] – times local clearing price [121, 130, 139–141] – times fixed feed-in tariff [121] • ancillary services sold times respective market price [139, 141] • reduced costs for electricity consumed [116, 121, 130, 132, 139–141] • reduced imbalance costs [132]
Key partners	• Aggregator [57, 100] • Grid operator [67, 72] • Platform Operator [72, 99] • none or not specified [55, 68, 75, 97, 98]		• Aggregator [132, 134] • Grid operator [121] • Retailer [121] • Representative [132] • Platform Operator [130, 132, 140] • none or not specified [116, 139, 141]

Table E.11: Detailed business model elements with references of reviewed Prosumers (peer-EMS) in local energy markets

	Prosumer peer-EMS		
	P2P	**CSC**	**TE**
Key resources	**tangible:** I Generation • PV [55, 57, 68, 72, 75, 97–100] • wind turbine [68, 75, 97] • conventional, fossil fuel based (e.g. CHP) [97, 98] II BESS • stationary [55, 57, 68, 72, 75, 97, 98] • non-stationary (EVs) [98, 100] III Loads • controllable (e.g. HVAC, household appliances) [55, 67, 72, 97, 98] • non-controllable [72, 97, 98] IV EMS [55, 57, 67, 68, 72, 75, 97, 99, 100] V ICT infrastructure (e.g. sensor, meter) [67, 68, 72, 99] **non-tangible:** • ability to forecast individual demand and supply [57, 68, 75, 97, 99, 100] • ability to determine optimal bidding [55, 68, 72, 75, 99] • ability to form coalitions [68] • ability to optimally schedule loads [57, 67, 68, 100] • ability for local information processing [97] • ability to verify (blockchain) transactions [68] • none or not specified [98] **human:** • none or not specified [55, 57, 67, 68, 72, 75, 97–100]		**tangible:** I Generation • PV [121, 130, 139–141] • wind turbine [139] • conventional, fossil fuel based (e.g. CHP) [141] II BESS • stationary [116, 121, 130, 132, 139–141] • non-stationary (EVs) [130, 132] III Loads • controllable (e.g. HVAC, household appliances) [116, 121, 130, 132] • non-controllable [130] IV EMS [116, 121, 140] V Reactive power sink (e.g. smart inverters) [139] **non-tangible:** • ability to forecast individual demand and supply [116, 121, 132, 139, 141] • ability to determine optimal bidding [121, 132, 139] • ability to optimally schedule loads [116, 121, 130, 141] • ability to respond to dispatch signals [132, 139, 141] • none or not specified [140] **human:** • none or not specified [116, 121, 130, 132, 139–141]
Key activities	I **In general** (a) forecast own consumption and generation [57, 99] (b) exchange information with other actors [57, 97] (c) interact with market i. deciding to trade with grid or local agents [68] ii. with optimized bidding [75, 99] iii. calculating the local market clearing price [57, 97]		I **In general** (a) exchange information with other actors [141] (b) interact with market through passive communication of surplus / demand of electricity [130] (c) generate electricity [121, 130, 139–141] (d) operate own controllable assets [130, 132, 141]

Table E.11: Detailed business model elements with references of reviewed Prosumers (peer-EMS) in local energy markets

	Prosumer peer-EMS		
	P2P	**CSC**	**TE**
Key activities *(cont'd)*	I **In general** *(cont'd)* (d) generate electricity [55, 57, 68, 72, 75, 97–99] (e) operate own controllable assets [75, 97, 98] i. according to self-optimization [75] (f) validate financial transaction in blockchain [68] II **Specifically of Prosumers themselves** (a) set individual preferences (*comfort parameters, profit expectation, risk preferences, willingness to trade with a specific counterparty*) [55, 99] III **Specifically of EMS** (a) forecasting of • own consumption and generation [75, 97, 100] • market price [75] (b) interact with market through • with optimized bidding [55, 68, 72, 97] • coalition forming [68, 98] (c) operate own controllable assets [55, 57, 67, 68, 100] (d) exchange information with other actors [68, 72, 98]		II **Specifically of Prosumers themselves** (a) set individual preferences (*comfort parameters, profit expectation, risk preferences, willingness to trade with a specific counterparty*) [121, 132] III **Specifically of EMS** (a) forecasting of own consumption and generation [116, 121, 132, 139, 141] (b) aggregate individual assets for unified bidding [139] (c) interact with local market through • optimized bidding [116, 121, 132, 139] • passive communication, e.g. of surplus / demand [140] (d) operate controllable generation and consumption assets [116, 121, 139–141] (e) illustrate relevant information for decision making to Prosumer [130] (f) exchange information with other actors [116, 130, 141]
Cost structure	**CAPEX:** • Investment costs [72, 98] • none or not specified [55, 57, 67, 68, 75, 97, 99, 100] **fixed OPEX:** • maintenance costs [72, 98] • none or not specified [55, 57, 67, 68, 75, 97, 99, 100] **variable OPEX:** • consumption costs for not self-generated electricity – paid at local clearing price [55, 57, 68, 72, 75, 98, 99] – paid at grid (retail) price [55, 72, 75, 98, 100] • generation (fuel) costs for non-renewables [68, 75, 97, 98] • operation (degradation) costs of BESS [68, 72, 100] • opportunity costs for DR [55, 68]		**CAPEX:** • Investment costs [116] • none or not specified [121, 130, 132, 139–141] **fixed OPEX:** • none or not specified [116, 121, 130, 132, 139–141] **variable OPEX:** • consumption costs for not self-generated electricity – paid at local clearing price [116, 121, 130, 132, 139, 141] – paid at grid (retail) price [121] • generation (fuel) costs for non-renewables [141] • operation (degradation) costs of BESS [132] • opportunity costs for DR [116] • greenhouse gas emission tax for non-renewables [141] • none or not specified [140]

Table E.11: Detailed business model elements with references of reviewed Prosumers (peer-EMS) in local energy markets

	Prosumer peer-EMS		
	P2P	**CSC**	**TE**
Cost structure *(cont'd)*	**variable OPEX:** *(cont'd)* • curtailment (opportunity) costs for renewables [97] • variable maintenance costs for generation assets [98] • imbalance costs [100] • none or not specified [67]		

Table E.12: Detailed business model elements with references of Prosumers (peer-market) in local energy markets

	Prosumer peer-market		
	P2P	**CSC**	**TE**
Value proposition	• providing electricity [37, 38, 51, 54, 54, 69, 78, 80, 87, 88, 90–92, 95, 102, 104]* – at more convenient rates (e.g. than wholesale market) [38, 54, 78, 88, 90–92, 95, 102, 104]* – at auctioned local market price (no comparison to other markets) [37, 38, 51, 69, 87] • providing flexibility [70, 78, 95] – through demand response (incl. EVs & battery) [78, 95] – through dispatchable generation	• providing electricity at more convenient rates (e.g. than wholesale market) [104]*	• providing electricity [114, 117, 120, 126, 127, 136] – at more convenient rates (e.g. than wholesale market) [117, 120, 126, 127, 136] – at auctioned local market price (no comparison to other markets) [114] • providing flexibility [122, 136, 137] – through demand response (incl. EVs & battery) [136] – through dispatchable generation [136, 137] • providing reactive power [114]
Customer segments	• Prosumer [38, 54, 69, 70, 78, 80, 87, 88, 91, 92, 95, 102, 104]* – EVs [80, 87] • Pure Consumer [78, 90, 92] • Storage Operator [54, 104]* • Platform Operator (*wholesale market*) [38, 51, 69, 78, 104]* • Retailer [37]	• Prosumer [104]* • Storage Operator [104]* • Platform Operator (*wholesale market*) [104]*	• Prosumer [114, 120, 127, 136] • Pure Consumer [117, 120] • Platform Operator (*wholesale market*) [126] • Aggregator [117, 122, 126] • Retailer [122] • Grid Operator [137]
Customer relationships	• automated [37, 38, 51, 54, 69, 70, 78, 80, 87, 88, 90–92, 104]*	• automated [104]*	• automated [114, 117, 120, 122, 126, 127]
Channels	**Evaluation:** • price [38, 51, 54, 69, 70, 78, 80, 87, 88, 90, 92, 104]*	**Evaluation:** • price [104]*	**Evaluation:** • price [117, 120, 122, 126, 127, 136]

Table E.12: Detailed business model elements with references of Prosumers (peer-market) in local energy markets

	Prosumer peer-market		
	P2P	**CSC**	**TE**
Channels *(cont'd)*	**Evaluation:** *(cont'd)* • personal preferences (i.e., generation resource, proximity, comfort etc.) [69, 70, 91] • technical feasibility [88] • no evaluation [37] **Purchase:** • active interaction and continuous bidding [38, 51, 54, 69, 70, 80, 87, 88, 90–92, 104]* • passive assignment [37, 78] **Delivery:** • physically: through the grid [37, 51, 54, 78, 90, 104]* • commercially: through P2P market clearing [38, 70, 80, 87, 104]*	**Purchase:** • active interaction and continuous bidding [104]* **Delivery:** • physically: through the grid [104]* • commercially: through P2P market clearing [104]*	**Evaluation:** *(cont'd)* • personal preferences (i.e., generation resource, proximity, comfort etc. [122, 127] • no evaluation (once subscribed) [114] **Purchase:** • active interaction and continuous bidding [114, 117, 120, 126, 127] • passive assignment [122, 136] **Delivery:** • physically: through the grid [114, 126] • commercially: through TE market clearing [117, 120, 122, 126]
Revenue streams	**fixed Revenues:** • none or not specified [37, 38, 51, 54, 54, 69, 70, 78, 80, 87, 88, 90–92, 95, 102, 104]* **variable Revenues:** • electricity sold [37, 38, 51, 54, 69, 78, 80, 87, 88, 90–92, 104]* – times local market clearing price [38, 51, 54, 69, 78, 80, 87, 88, 90–92, 104]* – times fixed feed-in tariff [37] • flexibility provided times local clearing price [70] • reduced costs for electricity consumed [90, 104]*	**fixed Revenues:** • none or not specified [104]* **variable Revenues:** • electricity sold times local market clearing price [104]* • reduced costs for electricity consumed [104]*	**fixed Revenues:** • none or not specified [114, 117, 120, 122, 126, 127, 136, 137] **variable Revenues:** • electricity sold [114, 117, 120, 126, 127, 136] – times local market price [114, 117, 120, 126, 127, 136] – times bilateral contract price [117] • flexibility provided times local clearing price [122] • reactive power provided times local clearing price [114] • reduced costs for electricity consumed [126, 136]
Key partners	• Platform Operator [38, 69, 78, 90, 126, 104]* • Aggregator [70, 80, 87] • Representative [70] • Retailer [91, 95, 102] • Grid Operator [37, 51, 54, 54, 70, 80, 90, 102] • none or not specified [88, 92]	• Platform Operator [104]*	• Platform Operator [114, 120, 127] • Grid Operator [114, 122, 136] • none or not specified [117]
Key resources	**tangible:** • Generation assets [37, 38, 51, 54, 69, 70, 78, 90–92, 104]* – PV [37, 38, 51, 54, 69, 78, 90–92, 104]* – Wind [78] – conventional [51]	**tangible:** • Generation assets (PV) [104]* • BESS (stationary) [104]* **non-tangible:** • ability to forecast own demand and or generation [104]*	**tangible:** • Generation assets [114, 117, 120, 126, 127, 136] – PV [114, 120, 127] – Wind [120, 126, 127] – Biomass [120] – conventional [117, 127]

Table E.12: Detailed business model elements with references of Prosumers (peer-market) in local energy markets

	Prosumer peer-market		
	P2P	**CSC**	**TE**
Key resources *(cont'd)*	**tangible:** *(cont'd)* • BESS [38, 69, 78, 80, 87, 88, 90, 92, 104]* – stationary [78, 88, 90, 92, 104]* – non-stationary (EVs) [38, 80, 87] • Loads [38, 88] – controllable (e.g. HVAC, household appliances etc.) [38, 88] – non-controllable [88] **non-tangible:** • ability to forecast own demand and or generation [54, 104]* • market platform [38, 69, 70, 80, 87] • ability to optimize proprietary operations [38, 90] • own bidding agent [38, 91, 92] • ability of blockchain interaction [87] **human:** • none or not specified [37, 38, 51, 54, 69, 70, 78, 80, 87, 88, 90–92, 104]*	**human:** • none or not specified [104]*	**tangible:** *(cont'd)* • BESS [114, 122, 126, 127, 136] – stationary [114, 126, 127, 136] – non-stationary (EVs) [122] • Controllable loads (e.g. HVAC, household appliances etc.) [127, 136] **non-tangible:** • ability to optimize proprietary operations [136] • own bidding agent [136] **human:** • none or not specified [114, 117, 120, 122, 126, 127, 136]
Key activities	• forecast own consumption and generation [38, 51, 54] • exchange information with other actors [38, 51, 87, 90] • interact with local market [37, 38, 51, 54, 69, 70, 78, 80, 87, 88, 90–92, 104]* – with active bidding [38, 51, 69, 70, 78, 80, 87, 88, 90–92] – with passive communication of surplus / net-demand of electricity [54, 78, 104]* • generate electricity [37, 38, 51, 69, 78, 90–92, 104]* • operate own controllable assets [38, 51, 70, 78, 80, 88, 90, 92, 104]* – according to self-optimization [38, 51, 90, 92] – according to central optimization [78, 104]*	• interact with local market with passive communication of surplus / net-demand of electricity [104]* • generate electricity [104]* • operate own controllable assets according to central optimization [104]*	• forecast own consumption and generation [114, 120, 126] • exchange information with other actors [114, 122, 126, 127] • interact with local market [114, 117, 120, 122, 126, 127, 136] – with active bidding [117, 120, 136] • generate electricity [117, 120, 127, 136] • operate own controllable assets [114, 122, 126, 127, 136] – according to self-optimization [136] – according to central optimization [114, 122, 126, 127]
Cost structure	**CAPEX:** • installation costs [37, 78, 104]* – of PV [37, 78] – of wind generation [78] – of BESS [78, 87, 104]*	**CAPEX:** • installation costs of BESS [104]*	**CAPEX:** • none or not specified [114, 117, 120, 122, 126, 127, 136]

Table E.12: Detailed business model elements with references of Prosumers (peer-market) in local energy markets

Prosumer peer-market			
	P2P	**CSC**	**TE**
Cost structure *(cont'd)*	**CAPEX:** *(cont'd)* • none or not specified [38, 51, 54, 69, 70, 80, 88, 90–92] **fixed OPEX:** • monthly operation & maintenance costs for BESS [104]* • none or not specified [37, 38, 51, 54, 69, 70, 78, 80, 87, 88, 90–92] **variable OPEX:** • consumption costs for not self-generated electricity [69, 87, 88, 90] [104]* • operation (degradation) costs of BESS [69] • opportunity costs for DR [88] • costs associated to network constraints [90] • none or not specified [37, 38, 51, 54, 70, 78, 80, 91, 92]	**fixed OPEX:** • monthly operation & maintenance costs for BESS [104]* **variable OPEX:** • consumption costs for not self-generated electricity [104]*	**fixed OPEX:** • none or not specified [114, 117, 120, 122, 126, 127, 136] **variable OPEX:** • consumption costs for not self-generated electricity [120, 122, 126, 127] • generation (fuel) costs for non-renewables [117, 127] • opportunity costs for DR [127] • imbalance costs [126] • transaction costs [114] • none or not specified [136]

[ ]* entry refers to a paper that contains more than one energy market model

Table E.13: Detailed business model elements with references of reviewed Pure Consumers in local energy markets

Pure Consumer			
	P2P	**CSC**	**TE**
Value proposition	• Electricity demand at convenient prices (i.e., buying electricity for a price higher than the FIT rate or the price offered by other buyers such as retailers) [60, 75, 92, 93] [107]* • Flexibility from demand response (e.g.from battery) [147, 149, 150, 162] [103]* • Reduced transaction costs for electricity provision [148]	• Electricity demand at convenient prices (i.e., buying electricity for a price higher than the FIT rate or the price offered by other purchasers such as retailers) [107]* • Flexibility from demand response [103]*	• Electricity demand at regular market prices [153] • Flexibility from demand response [152, 153]

Customer segments	• Prosumer [60, 75, 92, 93, 148–150, 162] [107]*
	• Platform Operator [147] [103]*
	  – Local market operator [103]*
	  – Wholesale market [147]
		• Prosumer [107]*
		• Platform Operator, i.e., local market operator [103]*
			• Prosumer [152]
			• Retailer [152]
			• TSO/wholesale market [153]

Table E.13: Detailed business model elements with references of reviewed Pure Consumers in local energy markets

	Pure Consumer		
	P2P	**CSC**	**TE**
Customer relationships	• Automated [75, 92, 93, 147, 148] [103, 107]* • Communities [149]	• Automated [103, 107]*	• Automated [152, 153]

Channels	**Evaluation:**
	• Price or cost saving [75, 93, 148, 150] [107]*
	• Technical fit [150, 162] [103]*
	• No active evaluation, but passive allocation based on (1) distance, (2) volume of electricity needed per trading period (3) volume of electricity needed per day, (4) random selection and (5) price offers [60]
	Purchase:
	• active interaction and continuous bidding [75, 92, 93, 147, 148, 150, 162] [103]*
	• passive assignment [60, 149] [107]*
	Delivery:
	• commercially: through P2P market clearing and respective operational adjustments [75, 147, 148, 150]
	• Physically: through local distribution grid [60, 92, 93, 149, 162] [103, 107]*
		Evaluation:
		• Price or cost saving [107]*
		• Technical fit [103]*
		Purchase:
		• active interaction and continuous bidding [103]*
		• passive assignment [107]*
		Delivery:
		• Physically: through local distribution grid [103, 107]*
			Evaluation:
			• Price or cost savings [152, 153]
			Purchase:
			• active interaction and continuous bidding [152, 153]
			  – Bidding to coordinator [152]
			  – Participating in auctions [153]
			Delivery:
			• commercially: through communication with the TE coordinator (Platform Operator) [152]
			• Physically: through the transmission grid [153]

Revenue streams	**fixed Revenues:** • none or not specified [60, 75, 92, 93, 147–150, 162] [103, 107]* **variable Revenues:** • reduced costs for electricity consumed [60, 92, 93, 147–149, 162] [107]* • flexibility provided times local flexibility clearing price [103]* • none or not specified [75, 150]	**fixed Revenues:** • none or not specified [103, 107]* **variable Revenues:** • reduced costs for electricity consumed [107]* • flexibility provided times local flexibility clearing price [103]*	**fixed Revenues:** • none or not specified [152, 153] **variable Revenues:** • reduced costs for electricity consumed [152] • flexibility provided times local flexibility clearing price [153]
Key partners	• Local market operator [60, 148, 162] • Hierarchical load serving entities that aggregate bids [147] • Full nodes (blockchain miners) [93] • Microgrid agent [149]	• None or not specified [103, 107]*	• Platform Operator (TE coordinator) [152] • Grid Operator (TSO) [153]

Table E.13: Detailed business model elements with references of reviewed Pure Consumers in local energy markets

	Pure Consumer		
	P2P	**CSC**	**TE**
Key resources	**tangible:** • Loads [60, 75, 92, 93, 147–150, 162] [103, 107]* – controllable (e.g. HVAC, household appliances etc.) [147, 150, 162] [103]* • BESS [150, 162] – stationary [150] – non-stationary (EVs) [150, 162] • ICT infrastructure (e.g. smart sensors, smart meters etc.) [149, 150] **non-tangible:** • Central controller [148] • Automated agent / energy management system to control loads [103]* • Blockchain as a service platform [150] **human:** • None or not specified [60, 75, 92, 93, 147–150, 162] [103, 107]*	**tangible:** • Loads [103, 107]* – controllable (e.g. HVAC, household appliances etc.) [103]* **non-tangible:** • individual energy management system to control loads [103]* **human:** • None or not specified [103, 107]*	**tangible:** • Loads [152, 153] – controllable (e.g. HVAC, household appliances etc.) [152] **non-tangible:** • None or not specified [152, 153] **human:** • None or not specified [152, 153]
Key activities	• forecast [60, 149, 162] – own consumption [60] – own flexibility availability [162] • interact with local market [60, 75, 92, 93, 147, 149, 150] [103]* – with active bidding [75, 92, 93, 147, 150] [103]* – with passive communication of electricity demand or flexibility availability [60] • operate own controllable assets [148, 150, 162] • interact with blockchain to register and pay transactions [93, 149]	• interact with local market through active bidding [103]*	• forecast own consumption and flexibility availability [153] • interact with local market through active bidding [152, 153] • operate own controllable assets [152]
Cost structure	**CAPEX:** • Investment costs for ICT infrastructure (in this case: advanced smart meters) [149] • none or not specified [60, 75, 92, 93, 147, 148, 150, 162] [103, 107]* **fixed OPEX:** • none or not specified [60, 75, 92, 93, 147–150, 162] [103, 107]*	**CAPEX:** • None or not specified [103, 107]* **fixed OPEX:** • None or not specified [103, 107]* **variable OPEX:** • purchased (i.e., consumed) electricity [103, 107]*	**CAPEX:** • None or not specified [152, 153] **fixed OPEX:** • None or not specified [152, 153] **variable OPEX:** • purchased (i.e., consumed) electricity [152, 153]

Table E.13: Detailed business model elements with references of reviewed Pure Consumers in local energy markets

	Pure Consumer		
	P2P	**CSC**	**TE**

Cost structure *(cont'd)*	**variable OPEX:**
	• purchased (i.e., consumed) electricity [60, 75, 92, 93, 147–150, 162], [103, 107]*
	  – times local market price [60, 75, 92, 147, 148, 150, 162]
	  – times grid (retail) price [162]
	• opportunity costs for providing demand response (comfort costs) electricity costs [147, 150]
	• transaction costs [148, 149]
	• imbalance costs [148]		

[ ]* entry refers to a paper that contains more than one energy market model

Table E.14: Detailed business model elements with references of reviewed Pure Generators in local energy markets

	Pure Generator		
	P2P	**CSC**	**TE**
Value proposition	• selling electricity below wholesale market price [146, 154] • Selling electricity at market conditions [149, 155] • trade electricity (buy & sell) to balance portfolios [77]		• selling electricity at market conditions [153, 156, 157]
Customer segments	• Pure consumer [146, 149, 154, 155] • Prosumer (with electricity demand) [155] • Retailer [77] • Pure generator [77] • Wholesale market [146, 154]		• Pure consumer [156, 157] • Aggregator [158] • Wholesale market [153]
Customer relationships	• automated [77, 146, 154, 155] • community [149] • anonymous [146] • not fully anonymous, but with options for personal preferences [154]		• automated [153, 156, 157] • anonymous [156]

Table E.14: Detailed business model elements with references of reviewed Pure Generators in local energy markets

	Pure Generator		
	P2P	**CSC**	**TE**
Channels	**Evaluation:** • price [77, 154, 155] • personal preferences (i.e., eagerness factor) [154] • none (i.e., monopoly) [146] **Purchase:** • through active interaction and continuous bidding [77, 154, 155] • through passive assignment once signed up [146, 149] **Delivery:** • commercially: through market operator [154] • physically: through distribution grid [77, 146, 149, 154]		**Evaluation:** • price [157] **Purchase:** • through active interaction and continuous bidding [153] • through passive assignment once signed up [156, 157] **Delivery:** • physically: through distribution grid [156, 157]
Revenue streams	**fixed Revenues:** • none or not specified [77, 146, 149, 154, 155] **variable Revenues:** • sold electricity times individual (transaction) price [77, 149, 154, 155] • sold electricity times local market clearing price (based on Shapley value) [154] • avoided imbalance costs [146]		**fixed Revenues:** • none or not specified [153, 156, 157] **variable Revenues:** • sold electricity times local market clearing price [153, 156, 157] • avoided imbalance costs [157]
Key partners	• Platform Operator [146, 149, 149, 154]		• Platform Operator [156, 158] • Grid Operator [153] • Aggregator (VPP) [157]
Key resources	**tangible:** • Generation assets [77, 146, 154, 155] – PV [146, 154] – Wind [154] – Gas turbines [154] – Diesel generators [77] **non-tangible:** • demand and or generation forecast capability [146, 154] • price determination capability [146] **human:** • none or not specified [77, 146, 149, 154, 155]		**tangible:** • Generation assets [153, 156, 157] – Wind [157] – Gas turbines [157] **non-tangible:** • none or not specified [153, 156, 157] **human:** • none or not specified [153, 156, 157]
Key activities	**ex-ante:** • forecast generation [146, 149, 154] • calculate forecast uncertainty [146]		**real-time:** • generate electricity [153, 156, 157] – self-dispatched [156] – centrally dispatched [157]

Table E.14: Detailed business model elements with references of reviewed Pure Generators in local energy markets

Pure Generator			
	P2P	**CSC**	**TE**
Key activities *(cont'd)*	**ex-ante:** *(cont'd)* • determine offer price [77, 77, 146, 149, 154] • choose from customer offers [77, 155] **real-time:** • generate electricity [77, 146, 149, 154, 155] **ex-post:** • register transaction in blockchain [149]		
Cost structure	**CAPEX:** • none or not specified [77, 146, 149, 154, 155] **fixed OPEX:** • none or not specified [77, 146, 149, 154, 155] **variable OPEX:** • generation (fuel) costs [77] • imbalance costs [146] • transaction costs [149] • cost for traded electricity to balance portfolio [77] • none or not specified [154, 155]		**CAPEX:** • none or not specified [153, 156, 157] **fixed OPEX:** • none or not specified [156, 157] **variable OPEX:** • generation (fuel) costs [153, 157] • none or not specified [156]

Table E.15: Detailed business model elements with references of reviewed Storage Operators in local energy markets

Storage Operator			
	P2P	**CSC**	**TE**
Value proposition	• providing flexibility [50, 103]* – for balancing the P2P market, reducing the overall power exchange at retail market prices [50] – to compose additional DR offers from community to Grid Operator [103]* • trading electricity - electricity at prices usually bellow other market price, e.g. the wholesale market price [90, 103, 104]* • coordinating and operating the local market [104]*	• providing flexibility - to compose additional DR offers from community to Grid Operator [103]* • trading electricity - electricity at prices usually bellow other market price, e.g. the wholesale market price [103, 104]* • coordinating and operating the local market [104]*	• providing flexibility - for balancing the VPPs renewable generators [157] • trading electricity - electricity at prices usually bellow other market price, e.g. the wholesale market price [157, 158]

Table E.15: Detailed business model elements with references of reviewed Storage Operators in local energy markets

Storage Operator			
	P2P	**CSC**	**TE**
Customer segments	• Prosumer [50, 90, 104]* • Pure Consumer [90, 103]* • Platform Operator [103]*	• Prosumer [104]* • Pure Consumer [103]* • Platform Operator [103]*	• Prosumer [54] • Pure Consumer [54, 157] • Pure Generator [157] • Aggregator [158]
Customer relationships	• automated [50, 90, 103, 104]*	• automated [103, 104]*	• automated [157, 158]
Channels	**Evaluation:** • price [50, 90] • availability & fit [103]* • no evaluation [104]* **Purchase:** • through active interaction and continuous bidding [50, 90] • through passive assignment from community [104]* **Delivery:** • commercially: through P2P market clearing [103]* • physically: through the grid [90, 103, 104]*	**Evaluation:** • availability & fit [103]* • no evaluation [104]* **Purchase:** • through passive assignment from community [103, 104]* Delivery: • commercially: through P2P market clearing [103] • physically: through the grid [103, 104]*	**Evaluation:** • price [157, 158] **Purchase:** • though passive assignment from community [157] **Delivery:** • physically: through the grid [157]
Revenue streams	**fixed Revenues:** • none or not specified [50, 90, 103, 104]* **variable Revenues:** • sold electricity times local market clearing price [50, 90, 103, 104]* • sold electricity times variable wholesale market price [104]* • sold flexibility times proposed flex price by Grid Operator [103]*	**fixed Revenues:** • none or not specified [103, 104]* **variable Revenues:** • sold electricity times local market clearing price [103, 104]* • sold electricity times variable wholesale market price [104]* • sold flexibility times proposed flex price by Grid Operator [103]*	**fixed Revenues:** • none or not specified [157, 158] **variable Revenues:** • sold electricity times local market clearing price [158] • none or not specified [157]
Key partners	• Platform Operator [103]* • Grid operator [50, 90]	• Platform Operator [103]*	• Platform Operator [158] • Aggregator [157]

Key resources	**tangible:**
	• Energy storage asset [50, 90, 103, 104]*
	  – BESS [103, 104]* [90]
	  – Gas storage [50]
	• electrolyzer (power-to-gas unit) [50]
	• generation asset: fuel cell [50]
	non-tangible:
	• market platform [104]*
	• none or not specified [50, 90, 103]*
		tangible:
		• BESS [103, 104]*
		non-tangible:
		• market platform [104]*
		• none or not specified [103]*
		human:
		• none or not specified [103, 104]*
			tangible:
			• BESS [157, 158]
			non-tangible:
			• ability to determine optimal bidding [158]
			• none or not specified [157]
			human:
			• none or not specified [157, 158]

Table E.15: Detailed business model elements with references of reviewed Storage Operators in local energy markets

	Storage Operator		
	P2P	**CSC**	**TE**
Key resources *(cont'd)*	**human:** • none or not specified [50, 90] [103, 104]*		
Key activities	• trade electricity, leveraging price differential on local market [50, 90] [103, 104]* • offer additional capacity as flexibility [103]* • operate the market (sharing) platform [104]*	• trade electricity, leveraging price differential on local market [103, 104]* • operate the market (sharing) platform [104]*	• react to dispatch signals of VPP controller [157, 158]
Cost structure	**CAPEX:** • investment costs of BESS [104]* • none or not specified [50, 90] [103]* **fixed OPEX:** • monthly O&M costs for BESS [104]* • none or not specified [50, 90] [103]* **variable OPEX:** • purchased electricity times local clearing price [50, 90] [103, 104]* • purchased electricity times wholesale market price [104]*	**CAPEX:** • investment costs of BESS [104]* • none or not specified [103]* **fixed OPEX:** • monthly O&M costs for BESS [104]* • none or not specified [103]* **variable OPEX:** • purchased electricity times local clearing price [103, 104]* • purchased electricity times wholesale market price [104]*	**CAPEX:** • none or not specified [157, 158] **fixed OPEX:** • none or not specified [157, 158] **variable OPEX:** • purchased electricity times local clearing price [158] • none or not specified [157]

[ ]* entry refers to a paper that contains more than one energy market model

Table E.16: Detailed business model elements with references of reviewed Platform Operators in local energy markets

	Platform Operator		
	P2P	**CSC**	**TE**
Value proposition	I Platform provision for • electricity trading [37, 53, 69, 84, 161, 162, 164] [103, 104]* • electricity sharing [103, 107]* • ancillary service provision [103]* II Optimal dispatch through • direct control of customers assets [107]*	I Platform provision for • electricity trading [109] [103, 104]* • electricity sharing [37, 108] [103, 107]* • ancillary service provision [109] [103]* II Optimal dispatch through • direct control of customers assets [107]*	I Platform provision for • electricity trading [129, 165] • electricity sharing [140] • optimized electricity provision [120, 166, 167] • ancillary service provision [129, 152] II Optimal dispatch through • direct control of customers assets [166] • indirect control of customers assets [167]

Table E.16: Detailed business model elements with references of reviewed Platform Operators in local energy markets

	Platform Operator		
	P2P	**CSC**	**TE**
Value proposition *(cont'd)*	III Increased monetary benefits [37, 69, 161, 162, 164] [103, 104]* • through enhanced revenues for generating parties [103]* • reduced costs for consuming parties [103]* • locational services [103]* IV Facilitate self-consumption [161] V Invest in and operate central storage system [104]* VI Interaction with upstream market layer for excess demand / supply [37, 69]	III Increased monetary benefits • through enhanced revenues for generating parties [103]* • reduced costs for consuming parties [103]* • locational services [109] [103]* IV Preserving trading fariness by balancing individual and community preferences [109] V Invest in and operate central storage system [104]* VI Interaction with upstream market layer for excess demand / supply [37]	III Increased monetary benefits [120, 129, 152, 166, 167] • through enhanced revenues for generating parties [120, 167] • reduced costs for consuming parties [120, 166, 167] • local coalition formation [129]
Customer segments	• Prosumer [37, 53, 69, 84, 161, 162, 164] [103, 104, 107]* – residential [37, 84] – commercial [37] • Pure Consumer [103, 107]* • Storage Operator [103]* • Grid operator [103]*	• Prosumer [37, 108, 109] [103, 104, 107]* – residential [108, 109] [103, 104]* – within microgrid [37] • Pure Consumer [103, 107]* • Storage Operator [103]* • Grid Operator [109] [103]*	• Prosumer [120, 129, 140, 167] – residential [129] – micrograds [167] • Pure Consumer [120, 140, 152, 166] – residential [140, 152] – commercial [166] • Pure Generator [167] • Aggregator [165, 167] – EV Aggregator [165] – load Aggregator [167] – DR Aggregator [167] • Grid Operator (DSO) [165, 167] • Platform Operator (wholesale market) [167] • Retailer [129]
Customer relationships	• automated [37, 53, 69, 84, 161, 162, 164] [103, 104, 107]* • community [103]* • anonymous [104]*	• automated [108, 109] [103, 104, 107]* • community [108, 109] [103]* • anonymous [104]*	• automated [120, 129, 140, 152, 165–167] • community [166] *(while for TE it is case dependent either automated or community, for CSC it is both at the same time)*

Table E.16: Detailed business model elements with references of reviewed Platform Operators in local energy markets

	Platform Operator		
	P2P	**CSC**	**TE**

Channels	**Evaluation:**
	• price [37], [53], [69], [161], [162], [164], [103]*
	  – ex-ante price evaluation [164], [103]*
	  – continuous price evaluation [164], [103]*
	• network feasibility [103]*
	• individual preferences [69]
	• not specified [84], [104], [107]*
	Purchase:
	• automatically, once signed up [37], [84], [164], [104], [107]*
	• manually, via active bidding to platform [53], [69], [161], [162], [103]*
	• selectively, accepting or refusing individual offers from Platform Operator [103]*
	Delivery:
	• physically through the grid [69], [161], [162], [103], [104]*
	• commercially through
	  – local market participation and clearing [69], [84], [164], [103]*
	  – community management scheme [103]*
		Evaluation:
		• price [108], [109], [103]*
		  – ex-ante price evaluation [103]*
		  – continuous price evaluation [103]*
		• network feasibility [103]*
		• no evaluation (monopolistic operation) [37]
		• not specified [104], [107]*
		Purchase:
		• automatically, once signed up [108], [109], [104], [107]*
		• automatically, once being physically connected [37]
		• manually, via active bidding to platform [103]*
		• selectively, accepting or refusing individual offers from Platform Operator [103]*
		Delivery:
		• physically through the grid [37], [108], [103], [104]*
		• commercially through
		  – local market participation and clearing [108], [103]*
		  – community management scheme [109], [103]*
			Evaluation:
			• price [120], [129], [140], [152], [166], [167]
			  – continuous price evaluation [129], [167]
			• no evaluation (monopolistic operation) [167]
			Purchase:
			• automatically, once signed up [140], [166], [167]
			• manually, via active bidding to platform [120], [129], [152], [165], [167]
			Delivery:
			• physically through the grid [120], [140], [167]
			• commercially through
			  – local market participation and clearing [120], [152], [165]–[167]
			  – community management scheme [140]

Revenue streams	**fixed Revenues:** • registration fee to platform [161] • service charge for forecast and maintenance activities [161] • none or not specified [37], [53], [84], [162], [164], [103], [104], [107]* **variable Revenues:** • arbitrage on fluctuating local market prices with own BESS [104]* • arbitrage on fluctuating wholesale market prices with own BESS [104]* • profit margin as percentage of total trading amount [84] • sold electricity (from wholesale market) times local market price [69] • none or not specified [37], [53], [161], [162], [164], [103], [107]*	**fixed Revenues:** • fixed fee per transaction [109] • none or not specified [37], [108], [103], [104], [107]* **variable Revenues:** • arbitrage on fluctuating local market prices with own BESS [104]* • arbitrage on fluctuating wholesale market prices with own BESS [104]* • none or not specified [37], [108], [109], [103], [107]*	**fixed Revenues:** • service fee [166] • none or not specified [120], [129], [140], [152], [165], [167] **variable Revenues:** • arbitrage on price differences from local to wholesale market [167] • price differences between matched biy and sell offers on local market (pay-as-bid clearing) [120] • selling electricity to local consumers within distribution grid [166], [167] • none or not specified [129], [152], [165]

Table E.16: Detailed business model elements with references of reviewed Platform Operators in local energy markets

	Platform Operator		
	P2P	**CSC**	**TE**
Key partners	• Grid operator [37, 162] • Retailer [37] • none or not specified [53, 69, 84, 161, 164], [103, 104, 107]*	• Retailer [37] • none or not specified [108, 109], [103, 104, 107]*	• Grid operator [129, 166] • Retailer [166] • Pure Generator [166] • Platform Operator [167] • none or not specified [120, 140, 152, 165]
Key resources	**tangible:** • distribution or micro-grid [161, 164] • BESS [104]* • multi-channel power router [162] • none or not specified [37, 53, 84], [103, 107]* **non-tangible:** • market platform [37, 53, 69, 84, 162], [103, 104, 107]* • central controller [84, 162, 164], [104, 107]* • order monitoring software [103]* • ability to aggregate multiple (flexibility) bids [103]* • ability to clear market [37, 53, 69, 84, 161, 162, 164], [103, 104, 107]* • ability to operate and maintain grid infrastructure [161] **human:** • none or not specified [37, 53, 69, 84, 161, 162, 164], [103, 104, 107]*	**tangible:** • distribution or micro-grid [37] • BESS [104]* • ICT infrastructure (electricity meter) [37] • none or not specified [108, 109], [103, 107]* **non-tangible:** • market platform [37, 108, 109], [103, 104, 107]* • central controller [37, 108, 109], [104, 107]* • order monitoring software [103]* • ability to aggregate multiple (flexibility) bids [103]* • ability to clear market [37, 108, 109], [103, 104, 107]* **human:** • none or not specified [37, 108, 109], [103, 104, 107]*	**tangible:** • distribution or micro-grid [166, 167] • central energy assets (e.g. central heat pump, diesel generators and BESS) [166] • ICT infrastructure [166] • none or not specified [120, 129, 140, 152, 165] **non-tangible:** • market platform [120, 129, 140, 152, 165–167] • central controller [129, 166, 167] • ability to clear market [120, 129, 140, 152, 165–167] • ability to forecast and evaluate uncertainty [129, 166, 167] **human:** • none or not specified [120, 129, 140, 152, 165–167]

Key activities	**ex-ante market:**
	• forward Grid operators flex needs to customers [103]*
	continuous:
	• aggregate individual flex offers of customers [103]*
	• ensure that local trading does not inflict grid operation [161, 164]
	• macroeconomic optimization at platform level [37, 69, 84, 162, 164], [104, 107]*
	• ensure optimal dispatch through
	  – direct control of customers assets [162, 164], [107]*
	• clear the market [37, 53, 69, 84, 161, 162, 164], [103, 104, 107]*
		ex-ante market:
		• forward Grid operators flex needs to customers [103]*
		continuous:
		• aggregate individual flex offers of customers [103]*
		• macroeconomic optimization at platform level [37, 108, 109], [104, 107]*
		• ensure optimal dispatch through
		  – direct control of customers assets [107]*
		• clear the market [37, 108, 109], [103, 104, 107]*
			ex-ante market:
			• forecast and evaluate uncertainty of:
			  – non-programmable RES generation [129]
			  – load [166]
			  – other markets prices [166, 167]
			continuous:
			• enable and coordinate customers:
			  – DR [152]
			  – capacity market participation [166]
			• ensure that local trading does not inflict grid operation [129]
			• macroeconomic optimization at platform level [129, 166, 167]
			• ensure optimal dispatch through
			  – control of own assets [166]
			  – customer guidance based on local marginal prices [167]

Table E.16: Detailed business model elements with references of reviewed Platform Operators in local energy markets

	Platform Operator		
	P2P	**CSC**	**TE**
Key activities *(cont'd)*	**ex-post market:** • distribute clearing information among participants [53] • monitor the proper performance of individual flex offers [103]* • provide customers (supplemental) electricity [37] • O&M of: – grid infrastructure [161, 164] – BESS [104]*	**ex-post market:** • monitor the proper performance of individual flex offers [103]* • provide customers (supplemental) electricity [37] • O&M of: – grid infrastructure [37] – BESS [104]*	**continuous:** *(cont'd)* • clear the market [120, 129, 140, 152, 165–167] **ex-post market:** • distribute clearing information among participants [140, 152, 165] • provide customers (supplemental) electricity [140, 166]
Cost structure	**CAPEX:** • Investment costs for: – BESS [104]* • none or not specified [37, 53, 69, 84, 161, 162, 164] [103, 107]* **fixed OPEX:** • O&M costs for: – BESS [104]* • none or not specified [37, 53, 69, 84, 161, 162, 164] [103, 107]* **variable OPEX:** • bought electricity times: – local market clearing price [104]* – wholesale market price [69] [104]* • maximum demand charge for Grid Operator [104]* • sold flexibility times flex price of Grid Operator (*forwarding revenue to flex providers*) [103]* • none or not specified [37, 53, 84, 161, 162, 164] [107]*	**CAPEX:** • Investment costs for: – BESS [104]* – local grid and metering infrastructure [37] • none or not specified [108, 109] [103, 107]* **fixed OPEX:** • O&M costs for: – BESS [104]* – local grid and metering infrastructure [37] • none or not specified [108, 109] [103, 107]* **variable OPEX:** • bought electricity times: – local market clearing price [104]* – wholesale market price [104]* • maximum demand charge for Grid Operator [104]* • sold flexibility times flex price of Grid Operator (*forwarding revenue to flex providers*) [103]* • none or not specified [37, 108, 109] [107]*	**CAPEX:** • Investment costs for: – ICT infrastructure [166] • none or not specified [120, 129, 140, 152, 165, 167] **fixed OPEX:** • none or not specified [120, 129, 140, 152, 165–167] **variable OPEX:** • bought electricity times: – local market clearing price [167] – wholesale market price [166] • none or not specified [120, 129, 140, 152, 165]

[ ]* entry refers to a paper that contains more than one energy market model

Table E.17: Detailed business model elements with references of reviewed Aggregators in local energy markets

	Aggregator		
	P2P	**CSC**	**TE**
Value proposition	**For upstream customers** I untapping new flexibility [37] [103]* • with locational component to react to network constraints, e.g., for congestions [103]* • without locational component to balance portfolios or network areas [37] II trading electricity [79, 169] • at convenient rates (buy above wholesale, sell below wholesale price) [169] • at regular market rates [79] **For downstream customers** I virtual aggregation and central dispatch [37, 79, 100, 168] [107]* • for supply of (deficit) electricity with reduced procurement costs [79, 100, 168] • for purchase of (surplus) electricity with enhanced revenues [79] [107]* • to reduce imbalance costs [100] • to enable additional revenues from utilization of assets' flexibility [37] II facilitate electricity exchange amongst customers [103, 107]*	**For upstream customers** I untapping new flexibility with locational component to react to network constraints, e.g., for congestions [103]* **For downstream customers** I virtual aggregation and central dispatch for purchase of (surplus) electricity with enhanced revenues [107]* II facilitate electricity exchange amongst customers [103, 107]*	**For upstream customers** I untapping new flexibility [118, 119, 122, 126, 139, 144, 153, 165, 170, 173] • with locational component to react to network constraints, e.g., for congestions [119, 122, 139, 144, 153, 165, 173] • without locational component to balance portfolios or network areas [118, 122, 126, 139, 144, 153] • for optimal electricity procurement on upstream markets[170] **For downstream customers** I virtual aggregation and central dispatch [118, 122, 126, 139, 144, 157, 165, 166, 170, 172, 173] • for supply of (deficit) electricity with reduced procurement costs [118, 122, 126, 139, 144, 157, 165, 166, 170, 172, 173] • for purchase of (surplus) electricity with enhanced revenues [126, 139, 157, 172] • to reduce imbalance costs [118, 157, 166, 172] • to enable additional revenues from capacity market participation [166] • while guaranteeing individual preferences [122, 144] II No specific value proposition to downstream customers [119, 153]
Customer segments	• Prosumer [37, 79, 100] [107]* – EVs [100] – residential prosumers [37, 79] [107]* • Pure Consumer [168, 169] [107]* – Loads [168, 169] – EVs [107]* • Pure Generator [169] • Storage Operator [169] • Aggregator [169] • Retailer [79] • Grid operator [37], [103]*	• Prosumer (residential) [107]* • Pure Consumer (EVs) [107]* • Grid operator [103]*	• Prosumer [118, 119, 122, 126, 139, 144, 165, 172] – residential prosumer [118, 119, 144] – EVs[118, 122, 165] • Pure Consumer [126, 139, 157, 166, 170, 171, 173] • Pure Generator [126, 139, 153, 157, 171] • Storage Operator [126, 157, 171] • Platform Operator [139, 144, 153, 171] – wholesale mrkt [144, 153, 171] – nested market at next higher voltage level [139]

Table E.17: Detailed business model elements with references of reviewed Aggregators in local energy markets

	Aggregator		
	P2P	**CSC**	**TE**
Customer segments *(cont'd)*			• Aggregator [126] [153] • Retailer [170] • Grid Operator [118], [119], [139], [144], [153] [165], [171], [173]
Customer relationships	• Automated [79] [100], [168] [169], [107]* • Not specified [37], [103]*	• Automated [107]* • Not specified [103]*	• Automated [118] [119] [122] [126] [139], [144] [153], [157] [165] [166], [171] [172] • self-service [166] • Not specified [173]
Channels	**Evaluation:** • Bid and ask prices [168] [169] • Price merit order (for a grid operator) [37] • Not specified [37], [79], [100], [103] [107]* **Purchase:** • P2P market/platform [79] [168] [169] • Energy Management System (EMS) [100] • Aggregator [107]* • Established balancing market (for a grid operator) [37] • Platform Operator (local market operator) [103]* **Delivery:** • Market algorithm [79] • Representative (HEMS) [100] • Distribution grid [37], [168] [169], [103]* • Balancing market [37] • Aggregator [37] • Not specified [107]*	**Evaluation:** • Not specified [103] [107]* **Purchase:** • Aggregator [107]* • Platform Operator (local market operator) [103]* **Delivery:** • Power network [103]* • Not specified [107]*	*For upstream customers:* **Evaluation:** • Price [118], [119] [126] [139], [153] [170] • Constraints of DERs [119] • Cost [171] • Not specified [165] **Purchase:** • Auction [144], [153] [170] • TE platform [126] [165] • Direct purchase through aggregators or VPP [119] [166] [172] • Wholesale market [139] [171] • Not specified [118] **Delivery:** • Distribution grid [118], [119], [126], [144] [153] • Wholesale markets [118], [171] • TE platform [166] • Not specified [170] *For downstream customers:* **Evaluation:** • Preference for charging EVs [122] • Revenue generation [166] [172] • Benefits from aggregator's services[157] • Price[173] • Types of services [166] • Not specified [126], [144] [165] **Purchase:** • Direct purchase from aggregator [118], [119], [126] [144], [157], [165], [172], [173] • TE market [122] • Microgrid [139]

Table E.17: Detailed business model elements with references of reviewed Aggregators in local energy markets

	Aggregator		
	P2P	**CSC**	**TE**
Channels *(cont'd)*			**Delivery:** • TE platform [119, 122, 126, 165, 166] • Specific systems/networks - Bus network [172] - A nested system [139] • Distribution grid [157] • Not specified [170]
Revenue streams	**fixed Revenues:** • None or not specified [37, 79, 100, 168, 169] [103, 107]* **variable Revenues:** • Sale of electricity [169] • Revenue from accepted bids and offers for flexibility [37] [103]* • Not specified [79, 100, 168] [107]*	**fixed Revenues:** • None or not specified [103, 107]* **variable Revenues:** • Revenue from accepted bids and offers for flexibility [103]* • None or not specified [107]*	*From upstream customers* **fixed Revenues:** • Capacity payments for flexibility provision [166] • None or not specified [118, 119, 126, 139, 144, 157, 165, 170, 171, 173] **variable Revenues:** • Sale of electricity [126, 139, 144, 157, 166, 171] • Sale of ancillary services [139, 171] • Sale of flexibility [118, 166] • Revenue from cost minimisation [118, 157] *From downstream customers* **fixed Revenues:** • Services fees [166] • None or not specified [119, 122, 126, 139, 144, 157, 165, 170, 172, 173] **variable Revenues:** • Sale of electricity to prosumers [126, 139, 144, 157, 166, 172] • Sale of ancillary services [139, 166] • Revenue from cost minimisation [122, 157, 172] • None or not specified [119, 165, 170, 173]

Key partners	• Grid operator [168, 169]
	• Platform Operator (microgrid operators) [168]
	• Prosumer [103]*
	• Pure Consumer [103]*
	• Storage Operator [103]*
	• Pure Generator [169]
	• Aggregator [100]
	• Retailers [37]
	• None or not specified [79] [107]*
		• Prosumer [103]*
		• Pure Consumer [103]*
		• Storage Operator [103]*
		• None or not specified [107]*
			• Grid Operator [122, 144, 166]
			  – DSO [122, 166]
			  – TSO [144, 166]
			• Platform Operator [122, 126, 165, 173]
			  – TE platform operator [165]
			  – Market operator [122, 126, 173]
			• Prosumer (DERs and EVs) [118]
			• Pure Generator [166]
			• Representative (commercial agent) [166]
			• Retailer (Utility and retailer) [166]
			• Not specified [139, 157, 172]

Table E.17: Detailed business model elements with references of reviewed Aggregators in local energy markets

	Aggregator		
	P2P	**CSC**	**TE**
Key resources	**tangible:** • Smart devices [79] • None or not specified [37, 100, 168, 169], [103, 107]* **non-tangible:** • ICT and software to manage and communicate with customers and operate relevant activities [37, 79, 100, 168, 169], [103]* • None or not specified [107]* **human:** • None or not specified [37, 79, 100, 168, 169], [103, 107]*	**tangible:** • None or not specified [103, 107]* **non-tangible:** • software to manage bids and control individual flex [103]* • None or not specified [107]* **human:** • None or not specified [103, 107]*	**tangible:** • None or not specified [118, 119, 122, 126, 139, 144, 157, 165, 166, 170–173] **non-tangible:** • ICT and software for: – Demand response forecast [170] – Aggregating and managing DERs [139, 153, 157, 165] – Optimisation [119, 122, 166] – Generation and loads forecast [139, 157] – Interaction with the market [139, 166] • None or not specified [118, 144, 171, 172] **human:** • None or not specified [118, 119, 122, 126, 157, 165, 166, 170–173]
Key activities	**For upstream customers** • Facilitate service provision through: – aggregating individual flexibility [37], [103]* – controlling the performance of individual flexibility providers [103]* • Facilitate energy trading through: – aggregation of individual consumption/generation profiles [79, 169] **For downstream customers** • Aggregate and actively manage assets of customers [37], [168], [169], [107]* – Shifting load to off-peak periods [168] – Control, schedule and reschedule DERs for optimized production [37], [169], [107]* • Operate local market and facilitate exchange amongst customers [79], [103, 107]* • Forward external flexibility needs to customers [103]* • Interact with other local market participants on behalf of customers to buy/sell supplemental/surplus electricity [100, 168, 169]	**For upstream customers** • Facilitate service provision through: – aggregating individual flexibility [103]* – controlling the performance of individual flexibility providers [103]* **For downstream customers** • Aggregate and actively manage assets of customers [107]* – Control, schedule and reschedule DERs for optimized production [107]* • Operate local market and facilitate exchange amongst customers [103, 107]* • Forward external flexibility needs to customers [103]*	**For upstream customers** • Facilitate service provision through: – Submit DR [170] – Submit requirements and bids from EVs [118, 165] – Communicate with DSO [119] • Optimisation [119] **For downstream customers** • Aggregate and and actively manage assets of customers: – Manage DR [157, 170] – Manage DERs and submit bids to the market [126, 139, 157, 166, 171–173] – Manage EVs and submit bids to DSO and TE operator [118, 122, 165] – Optimisation of DERs [119, 126, 157, 172] • Participate in the wholesale market (bidding) on behalf of aggregated customers [171, 173] • Trade electricity on behalf of prosumers [126, 172] • Communicate with DERs [119]

Table E.17: Detailed business model elements with references of reviewed Aggregators in local energy markets

	Aggregator		
	P2P	**CSC**	**TE**
Key activities *(cont'd)*	**For downstream customers** *(cont'd)* • Participate in the wholesale market (bidding) on behalf of aggregated customers [100]		
Cost structure	**CAPEX:** • Not specified [37, 79, 100, 168, 169], [103, 107]* **OPEX:** • Remuneration paid to prosumers for provided flexibility/ancillary services [37] [103]* *(Cost equals revenue received [103]*)* • Purchasing electricity from DNO and microgrid operators [168] • grid costs [168] • Not specified [79, 100, 169] [107]*	**CAPEX:** • Not specified [103, 107]* **OPEX:** • Remuneration paid to prosumers for provided flexibility/ancillary services [103]* *(Cost equals revenue received [103]*)* • Not specified [107]*	**CAPEX:** • BESS investment cost [172] • ICT [166] • Not specified [118, 119, 122, 126, 139, 144, 157, 165, 170, 171, 173] **OPEX:** • purchase costs for electricity from upstream (wholesale) market [118, 122, 139, 157, 166] • generation (fuel) costs for local electricity [126, 157, 171, 172] • opportunity costs for local flexibility (e.g., load shifting) [157, 166, 171, 172] • imbalance costs [118, 122, 126, 157, 166, 172] • Not specified [119, 144, 153, 165, 170, 173]

[ ]* entry refers to a paper that contains more than one energy market model

Table E.18: Detailed business model elements with references of reviewed Representatives in local energy markets

	Representative		
	P2P	**CSC**	**TE**
Value proposition	• increased monetary benefits through – reduced electricity procurement costs [89] • balancing monetary benefits with individual preferences – comfort [89]		• increased monetary benefits through – reduced electricity procurement costs [140, 144, 145, 156, 176] – enhanced revenues for generation [144, 176] • balancing monetary benefits with individual preferences – comfort [144, 145] – risk [176] • local flexibility to mitigate network issues or solve local imbalances [175]

Table E.18: Detailed business model elements with references of reviewed Representatives in local energy markets

	Representative		
	P2P	**CSC**	**TE**
Customer segments	• Pure Consumer [89]		• Pure Consumer [140, 145, 156] • Prosumer [140, 144, 175, 176] • Aggregator [175]
Customer relationships	• automated [89]		• automated [140, 144, 145, 175, 176] • not specified [156]
Channels	**Evaluation:** • individual comfort preferences versus financial gains [89] **Purchase:** • contracting representative [89] • through EMS – automatically, once EMS is installed [89] **Delivery:** • commercially through individual EMS [89]		**Evaluation:** • individual preferences versus financial gains [145, 176] • cost [140, 175] • none or not specified [144, 156] **Purchase:** • through EMS – automatically, once EMS is installed [140, 145] – manually, via active bidding [175] • not specified [144, 156, 176] **Delivery:** • commercially through individual EMS [140, 144, 145, 176] • physically through local distribution grid [140, 145] • not specified [156, 175]
Revenue streams	**fixed Revenues:** • none or not specified [89] **variable Revenues:** • none or not specified [89]		**fixed Revenues:** • none or not specified [140, 144, 145, 156, 175, 176] **variable Revenues:** • none or not specified [140, 144, 145, 156, 175, 176]
Key partners	• Aggregator [89] • Platform Operator (local energy market) [89]		• Aggregator [144] • Platform Operator [140, 145, 156, 176] – local energy market [140, 156, 176] – wholesale market [145] • Grid Operator (DSO) [144] • none or not specified [175]

Table E.18: Detailed business model elements with references of reviewed Representatives in local energy markets

	Representative		
	P2P	**CSC**	**TE**
Key resources	**tangible:** • none or not specified [89] **non-tangible:** • ability to process multiple forecast and input information [89] • ability to aggregate individual customer appliances in one joint bidding function [89] • optimization algorithm for optimal bidding [89] • ability to control customer appliances [89] **human:** • none or not specified [89]		**tangible:** • none or not specified [140, 145, 156, 175, 176] • ICT infrastructure [144] **non-tangible:** • ability to forecast: – individual demand [140, 145, 156] – demand elasticity [175] – individual generation [140, 145] – weather conditions [145] – market prices [145, 176] • ability to aggregate individual customer appliances in one joint bidding function [144, 176] • optimization algorithm for optimal bidding [145, 156, 176] • ability to control customer appliances [140, 144, 145, 156, 175, 176] **human:** • none or not specified [140, 144, 145, 156, 175, 176]
Key activities	**ex-ante:** • process information – on demand forecast [89] – on weather forecast [89] – on market prices [89] – on updated status of local devices [89] **real-time:** • actively represent and optimize customer's position – in interaction with other pers [89] **ex-post:** • schedule and control customer's appliances [89]		**ex-ante:** • process information – on demand and or generation forecast [145, 156, 176] – on weather forecast [145] – on market prices [145] – on updated status of local devices [140, 144, 145, 156, 175, 176] – customer preferences [176] **real-time:** • actively represent and optimize customer's position – in interaction with other pers [140] – interaction with higher level agent (Aggregator / Grid Operator) [144, 175] – in local energy market [156, 176] – in wholesale market [145] **ex-post:** • schedule and control customer's appliances [140, 144, 145, 156, 175, 176]

Table E.18: Detailed business model elements with references of reviewed Representatives in local energy markets

	Representative		
	P2P	**CSC**	**TE**
Cost structure	**CAPEX:** • none or not specified [89] **fixed OPEX:** • none or not specified [89] **variable OPEX:** • none or not specified [89]		**CAPEX:** • none or not specified [140, 144, 145, 156, 175, 176] **fixed OPEX:** • none or not specified [140, 144, 145, 156, 175, 176] **variable OPEX:** • none or not specified [140, 144, 145, 156, 175, 176]

Table E.19: Detailed business model elements with references of reviewed Retailers in local energy markets

	Retailer		
	P2P	**CSC**	**TE**
Value proposition	• increased monetary benefits through reduced costs for electricity consuming customers via – DR and load shifting services [147, 150] – innovative ToU pricing [37] • security of supply (supplier of last resort) [58, 91] • balancing responsibility provision [58] • platform provision and central intermediary for P2P market [77, 91, 147]		• increased monetary benefits through reduced costs for electricity consuming customers via – DR and load shifting services [166, 167, 170] – innovative ToU pricing [129, 166, 177] – own storage [166, 170] • local flexibility from DR [167, 177] • increased monetary benefits through enhanced revenues for generating parties [167] • security of supply (supplier of last resort and local Grid Operator) [166, 167]
Customer segments	• Pure Consumers [150] • Prosumer [37, 58, 77, 91, 147] • Platform Operator (*wholesale market*) [147] • Pure Generators [77]		• Pure Consumers [166, 170, 177] • Prosumer [129, 167] • Aggregators (*Load- & DR-Aggregators*) [167] • Grid Operators (*DSO*) [167] • Platform Operator (*wholesale market*) [167] • Pure Generators [167]
Customer relationships	• automated [37, 58, 77, 91, 147, 150]		• automated [129, 166, 167, 170, 177]

Table E.19: Detailed business model elements with references of reviewed Retailers in local energy markets

	Retailer		
	P2P	**CSC**	**TE**
Channels	**Evaluation:** • no evaluation, monopolistic operation or last resort [91] • price with financial gains vs. – individual utility functions (e.g. based on comfort level for load shifting) [147, 150] – local (P2P) market price [77] **Purchase:** • last resort whenever local (P2P) market is exhausted [58, 91] • being involved in a network contract [77] • offering a load schedule and adapting accordingly when required [150] **Delivery:** • physically through distribution grid [37, 58, 77, 147, 150] • commercially through EMS [150]		**Evaluation:** • no evaluation, monopolistic operation [167, 170] • price with financial gains [129, 166, 167, 177] **Purchase:** • automatically, once signed up [166, 167, 177] • manually, through active bidding to a platform provided by the retailer or the Platform Operator [129, 167] **Delivery:** • physically through distribution grid [129, 167] • commercially through local market participation and clearing [129, 167]
Revenue streams	**fixed Revenues:** • none or not specified [37, 58, 77, 91, 147, 150] **variable Revenues:** • sold electricity times fixed retail price [58, 91] • sold electricity times variable market price [77, 147, 150] • none or not specified [37, 91]		**fixed Revenues:** • Service fee [166] • none or not specified [129, 167, 170, 177] **variable Revenues:** • sold electricity times fixed retail price [167] • sold electricity times variable market price [129, 166, 167, 170, 177] • avoided costs from DR usage [167] • none or not specified [177]
Key partners	• other Retailers (*acting e.g. as BRPs*) [37, 147] • Grid Operators [37] • Pure Generators [37, 77] • Metering Operators [37]		• other Retailers (*acting e.g. as BRPs*) [166] • Grid Operators [129, 166] • Pure Generators [166] • Platform Operators [129, 167] • Aggregator [170] • none or not specified [152, 177]
Key resources	**tangible:** • distribution grid [58, 150] • ICt infrastructure [147, 150] • generation assets (conventional) [91] • EMS [150]		**tangible:** • distribution grid [166, 167] • ICt infrastructure [166] • generation assets (conventional) [166, 177] • BESS [166, 170] • none or not specified [129]

Table E.19: Detailed business model elements with references of reviewed Retailers in local energy markets

	Retailer		
	P2P	**CSC**	**TE**
Key resources *(cont'd)*	**non-tangible:** • ability to aggregate individual flexibility bids of customers [77, 147] • ability to clear local market with Nash equilibrium [91] **human:** • none or not specified [37, 58, 77, 91, 147, 150]		**non-tangible:** • ability to aggregate individual flexibility bids of customers [166, 167] • ability to clear local market [166, 167, 170, 177] • local market platform [167, 170, 177] • ability to determine optimal bidding [129, 166, 167, 170, 177] • none or not specified [152] **human:** • none or not specified [129, 166, 167, 170, 177]
Key activities	• supply electricity to customers [58, 147, 37, 77, 91, 150] • run and clear local market [77, 91] • assume local balancing responsibility (*for unmet demand, unmet transactions and other uncertainties*) [58, 91, 150] • connect downstream and upstream market levels [37, 147, 150] – to other Retailers [37] – to wholesale market [147] – with aggregated customer bids [147, 150] • facilitate electricity exchange amongst customers [37]		• supply electricity to customers [129, 166, 167, 170, 177] • run and clear local market [166, 167, 170, 177] • assume local balancing responsibility (*for unmet demand, unmet transactions and other uncertainties*) [129, 166] • connect downstream and upstream market levels [166, 167, 170] – to other Retailers [166] – to wholesale market [166, 167, 170] – with aggregated customer bids [166, 167]
Cost structure	**CAPEX:** • none or not specified [37, 58, 77, 91, 147, 150] **fixed OPEX:** • none or not specified [37, 58, 77, 91, 147, 150] **variable OPEX:** • bought electricity times – fixed power purchase agreement price [37] – fixed feed-in price [58] – variable wholesale market price [77] – variable local market price [147] • transaction costs [77] • generation costs [91] • none or not specified [150]		**CAPEX:** • ICT infrastructure investment [166] • none or not specified [129, 167, 170, 177] **fixed OPEX:** • none or not specified [129, 166, 167, 170, 177] **variable OPEX:** • bought electricity times – variable wholesale market price [166, 167, 170] – variable local market price [167] • generation costs [177] • none or not specified [129]

Table E.20: Detailed business model elements with references of reviewed Grid Operators in local energy markets

Grid Operator			
	P2P	**CSC**	**TE**
Value proposition	• increased monetary benefits [54], through – electricity provision at convenient rates (below regular retail rate) [54] – electricity purchase at convenient rates (above feed-in tariff) [54] • security of supply (supplier of last resort) [54]		• active grid operation, guaranteeing power quality [111, 118, 119, 160, 165, 167, 173, 178–180] – peak shaving [165] – dispatches aggregator resources to avoid congestion and voltage problems [118] – procures capacity [160] • increased monetary benefits [111, 119, 160, 165, 167, 173, 179, 180], through – electricity provision at convenient rates (below wholesale or regular retail rate) [167] – electricity provision at wholesale or regular retail rate [111] – electricity purchase at convenient rates [167] – flexibility purchase [111, 119, 160, 165] • platform provision and central intermediary for local market [119, 160, 167, 173, 178, 180] • security of supply (supplier of last resort) [111, 167]
Customer segments	• Prosumer [54]		• Prosumer [118, 165, 167, 173, 180] • Pure Consumer [119, 167, 178] • Pure Generator [167, 178] • Storage Operator [160, 178] • Aggregator [119, 165, 173, 179] • Representatives [111] • Wholesale market [167] • other Grid Operator [167]
Customer relationships	• Automated [54]		• Automated ([111, 118, 119, 160, 165, 167, 173, 178, 179]) • Collaborative ([180])

Table E.20: Detailed business model elements with references of reviewed Grid Operators in local energy markets

Grid Operator			
	P2P	**CSC**	**TE**
Channels	**Evaluation:** • None (captive) [54] **Purchase:** • Active market participation (also submitting own bids) [54] **Delivery:** • Distribution network [54]		**Evaluation:** • pure price (local market vs wholesale) [160, 173, 178–180] • "eagerness factor" [111, 119, 165] • none [118, 167] **Purchase:** • Simple (market) mechanism sign-up [119, 160, 165] • Active market participation (also submitting own bids) [111, 167, 178, 180] • not specified [118] **Delivery:** • operational (often) through market / platform operator [111, 160, 179] • physically always through distribution grid [119, 165, 167, 173, 178, 180] • not specified [118]
Revenue streams	**fixed Revenues:** • none or not specified [54] **variable Revenues:** • sale of electricity at price above P2P clearing [54]		**fixed Revenues:** • none or not specified [111, 118, 119, 160, 165, 167, 173, 178–180] **variable Revenues:** • sold electricity times wholesale market price [167] • none or not specified [111, 118, 119, 160, 165, 173, 178–180]
Key partners	• None [54]		• Platform Operator [111, 118, 165] • Wholesale market [167, 180] • Aggregator [119] • other Grid Operator (TSO) [180]
Key resources	**tangible:** • Electrical network [54] • Storage system [54] **non-tangible:** • none or not specified [54] **human:** • Supervision of the operation [54]		**tangible:** • Electrical network[111, 118, 119, 160, 165, 167, 173, 178–180] **non-tangible:** • Optimisation algorithm [111, 119, 167, 178, 180] • Forecasting algorithm [118, 167, 178] • Pricing algorithm [167, 180] **human:** • Supervision of the operation [178] • none or not specified [111, 118, 119, 160, 165, 167, 173, 179, 180]

Table E.20: Detailed business model elements with references of reviewed Grid Operators in local energy markets

	Grid Operator		
	P2P	**CSC**	**TE**
Key activities	• retailing electricity [54] • resource management [54]		• grid operation [111, 118, 119, 160, 165, 167, 173, 178–180] • market operation [119, 167, 173, 178–180] • retailing electricity [111, 167] • resource management [160]
Cost structure	**CAPEX:** • none or not specified [54] **fixed OPEX:** • none or not specified [54] **variable OPEX:** • purchase of electricity from local prosumers at price lower than P2P clearing [54]		**CAPEX:** • none or not specified [111, 118, 119, 160, 165, 167, 173, 178–180] **fixed OPEX:** • none or not specified [111, 118, 119, 160, 165, 167, 173, 178–180] **variable OPEX:** • purchase (dispatch) of electricity within local distribution area [167] • purchase of flexibility at local flex price [111, 118, 119, 160, 165] • renewable curtailment costs [180] • none or not specified [173, 178, 179]

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