


## Review Article

# Research Hotspots and Evolution of Energy Prosumer: A Literature Review and Bibliometric Analysis

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Energy prosumer participates in the balance of the energy system actively through their production and consumption of energy and will become a major participant in the open energy market increasingly in the future. This paper used the bibliometric method to sort out 1251 literature data related to energy prosumer in the “Web of Science Core Collection” and used the software named CiteSpace to perform statistics and cooccurrence analysis. The research found the following: (a) journals in the field of prosumer have their emphasis on theory, application, policy, and modeling; (b) the United States and European institutions have published the articles most, and the academic influence of Chinese scholars needs to be further improved; (c) the focus of the prosumers’ research in the past decade has turned the energy system designing to the market transaction research; (d) P2P, P2G, and prosumer community are three market models that have attracted attention for scholars; besides, self-consumption, market matching, district heating, aggregators, and household energy management systems are also the current research hotspots; (e) digital technologies such as big data, the Internet of Things, and blockchain have a significant impact on the prosumer participating in energy market transactions, which will change the existing energy supply chain model profoundly. In the context of the energy Internet, energy trading platforms, digital ecosystems, cross-border innovation, and other fields will become the hotspots in future research on prosumer.

## 1. Introduction

The term “prosumer” was coined by American’s futurist named Alvin Toffler in 1980. It refers to those consumers who participate in production activities. They are both consumers and producers (Figure 1) [1]. In the energy sector, distributed energy sources (DERs) such as rooftop solar panels, battery storage, and control equipment continue to integrate and their prices fall, as well as the advancement of information and communication technology (ICT) equipment, some energy consumers are turning into prosumers, whom produce and consume energy, and they can share the excess energy with other users or feed it back into the energy network [2]. Most of the current prosumers refer to the electricity prosumer in the power grid [3], and there are also heat prosumers in the district heating network

[4] and multienergy prosumers with cooling, heating, and electricity [5]. The emergence of prosumers will change the top-down value chain in traditional power grids or heating networks. Prosumers will become active participants in the smart grid/heating grid, promoting energy sharing and contributing to the digital energy ecosystem [6].

After nearly 10 years of development, some scholars have summarized the research on prosumers in different perspectives. Zafar et al. [7] outlined the energy management and sharing of the prosumer in the smart grid environment, analyzed related ICT technologies and optimization technologies, and detailed the mechanisms of energy sharing, management, and trading based on prosumer. Espe et al. [3] analyzed the latest research results of the prosumer community in the smart grid from the two perspectives of “prosumer community” and “prosumer relationship” and

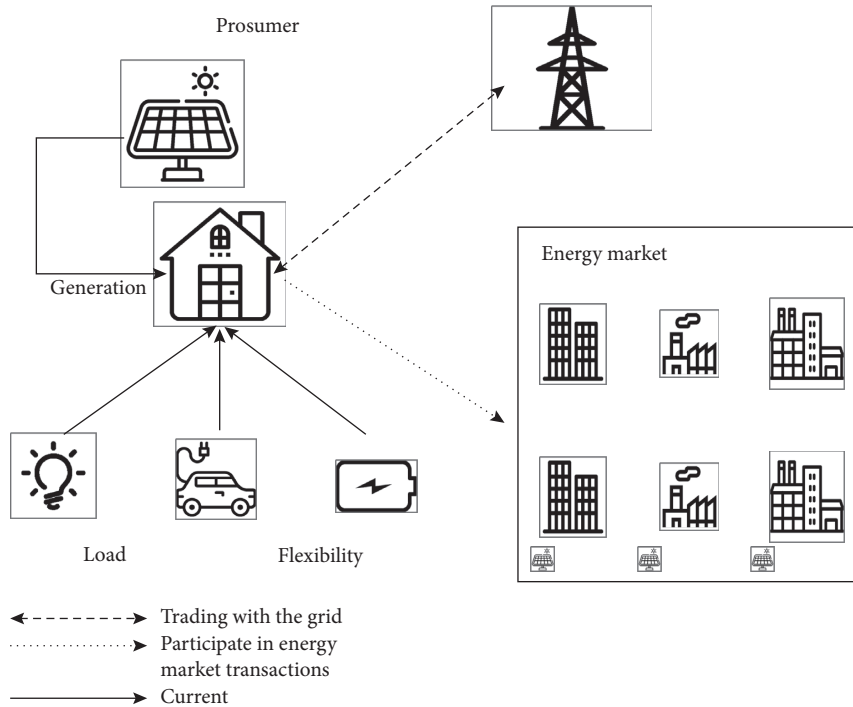


FIGURE 1: The concept of prosumer.

outlined the future research directions in these two aspects. Sousa et al. [8] summarized the three structures of the P2P market: a complete P2P market, a community-based market, and a mixed P2P market. They analyze the opportunities and challenges of the future development of the P2P market. Huang et al. [9] regarded the data center as a large energy prosumer in the regional energy system, considering the integration of upstream green energy supply and the reuse of downstream waste heat. Also, the related researches include energy blockchain [10], electric vehicles in the smart grid [11], etc.

Up to now, most of researches focused on a certain research branch (such as the community prosumers community) only. Gough et al. [12] used a bibliometric method to analyze the flexibility of prosumers and study the relationship between the five high-frequency keywords (prosumers, smart grids, microgrids, renewable energy, and demand response) and the flexibility of prosumers. Different from the former, this article will make a systematic evaluation of the internal relevance of the research content and the evolutionary trend of the period from the entire field of prosumers. Given this, this article sorts out the development history of energy prosumer based on the perspective of bibliometrics. Using CiteSpace bibliometric analysis software [13], this article systematically analyzed 1251 literatures data related to energy prosumer in the “Web of Science Core Collection.” Through the analysis of core journals, key authors, and key regions, we have sorted out the literature characteristics of the research on prosumers. Through keyword cooccurrence analysis, research hotspot analysis in

the past 180 days, and literature cocitation knowledge graph analysis, we have unearthed the research foundation of the prosumer and the research hotspots in different periods. From a broader longitudinal perspective, it systematically expounds the knowledge evolution and development frontiers of the prosumer in the international field, hoping to provide reference for future-related studies of prosumer.

## 2. Research Design

*2.1. Research Methods and Tools.* This article adopts the research method that combines bibliometrics analysis and literature review. First of all, based on CiteSpace software and Web of Science’s literature analysis tools, this paper realizes the basic statistical analysis of the major journals, core authors, and key countries and regions in the field of prosumer research and presents the basic situation of international research on prosumers. After that, this article conducts a keywords cooccurrence network analysis on the research literature to study the research hotspots and evolution process of the prosumers in the field. Finally, based on the literature cocitation knowledge graph, this article shows the mainstream subdivision areas of the field of the prosumer. Cocitation analysis means that if two documents appear together in the reference list of the third citing document, the two documents will form a cocitation relationship [14]. Mapping knowledge domains is an important bibliometric method. It visualizes the structure, rules, and distribution of scientific knowledge in the research field of the pros and cons and explores the development of the

subject knowledge field and its research hotspots, frontiers, and trend [14].

**2.2. Data Source and Processing.** This article focuses on the evolution and structure of research on prosumers, and all the research literatures come from the Web of Science Core Collection. At first, search according to the subject search formula “TS = (“prosumer\*”) AND TS = (“electricity” OR “energy” OR “electric” OR “power”)”. Through screening, irrelevant documents were eliminated, and 1251 English literatures were retrieved. The actual literature data year is 2009–2020, and the data search time is May 26, 2020. This paper uses these data to establish the original database for the study and then import the original data into the software of CiteSpace 5.6.R5, the time parameter is set to 2009–2020, year per slice is set to 1, and G-index  $K = 25$ .

### 3. Basic Statistical Analysis of Research on Energy Prosumer

**3.1. Posting Trend.** As shown in Figure 2, from 2009 to 2020, the number of publications in the field of prosumers has increased year by year, and the upward trend is obvious. This shows that the field of prosumer has received great attention by scholars in the world. According to data retrieved by the Web of Science, the first paper referring to energy prosumer by Mauri (2009) “Energy conservation and smart grids: new challenge for multimetering infrastructures.” In this paper, the author believes that the future power system will be a combination of centralized and distributed, and power prosumer will become a part of the grid [15]. Besides, scholars have not yet formed a unified academic concept for the term “prosumer,” and some articles may still use consumer to express it. With the popularization of the term prosumer, relevant literature will become more and more concentrated.

**3.2. Distribution of Journals.** Table 1 lists the major journals published in the field of prosumer from 2009 to 2020. The topics and contents of different journals have their focuses. Among them, “IEEE Transactions on Smart Grid” focuses on research related to energy generation, transmission, distribution, and delivery in the field of smart grids. “Applied Energy” focuses on energy conversion and conservation, optimal utilization of energy resources, and energy process analysis and optimization. “Renewable and Sustainable Energy Reviews” publishes review papers, original research, case studies, and new technology analysis related to renewable and sustainable energy. “Energy Policy” focuses on energy politics, economics, planning, environmental, and social research. “Energy” focuses on energy analysis, energy modeling and forecasting, integrated energy systems, energy planning, and energy management. The scope of transactions of “IEEE Transactions on Power Systems” includes the planning, analysis, reliability, operation, and economics of power generation, transmission, and distribution systems.

**3.3. Author.** Table 2 lists the top ten high-published authors and highly cited authors in the field of prosumers. Among them, the high number of publications indicates that there is more output in the field of research on the prosumer, and high citation is an important indicator to measure the academic level and academic influence. According to the ranking of high-published authors in Table 2, the four scholars named Menniti Daniele, Pinnarelli Anna, Sorrentino Nicola, and Burgio Alessandro from the University of Calabria in Italy published the most, followed by Liu from North China Electric Power University with 13 articles and Morstyn from Oxford University with 11 articles. The highly cited authors Zhang and Long in Table 2 are both from Wu’s team at Cardiff University, UK. It can be found that the number of articles published is not necessarily related to the frequency of citations. The top ten scholars in the number of publications did not stand out in the evaluation of the citation frequency index.

Highly cited authors are generally one of the important indicators to measure the important influence of a research field. According to the ranking of the highly cited authors in Table 2, the highly cited authors have put forward important opinions on the research of the various subdivisions of the prosumer. Mengelkamp et al. [16] proposed the concept of a microgrid energy market based on blockchain and summarized the seven components of an efficient microgrid energy market. Parag et al. [17] designed three power markets in the era of prosumers: P2P mode, P2G mode, and prosumer community mode. Zhang et al. [18] established a four-layer P2P energy trading system architecture model and, for the first time, proposed a P2P energy trading bidding system between consumers and prosumers in the grid-connected microgrid. The main contribution of Liu et al. lies in the management of energy sharing within the microgrid, including the Stackelberg game between microgrid operators (MGO) and prosumer [19], P2P energy sharing based on dynamic pricing of supply-demand ratio (SDR) [20], and energy sharing providers with energy storage coordinate multiple producers and consumers to form an energy sharing network [21]. Tushar et al. [22] studied P2P energy trading from the perspective of the prosumer alliance.

**3.4. Country/Region and Organization.** Table 3 lists the top ten countries or regions and top ten organizations with the largest number of postings. The number of papers published can reflect the research level and contribution degree of different countries or regions and scientific research institutions to a certain extent. First of all, except for the United States, China, and Australia, the top ten countries are concentrated in Europe, such as Italy, Germany, the United Kingdom, Spain, and the Netherlands. Secondly, judging from the top ten scientific research institutions, the amount of publications is not much different. Except for a Chinese institution, the others are from Europe. Also, countries such as the United States and the United Kingdom with a large number of publications have not appeared in the top ten high-publishing institutions. It can be seen that the current

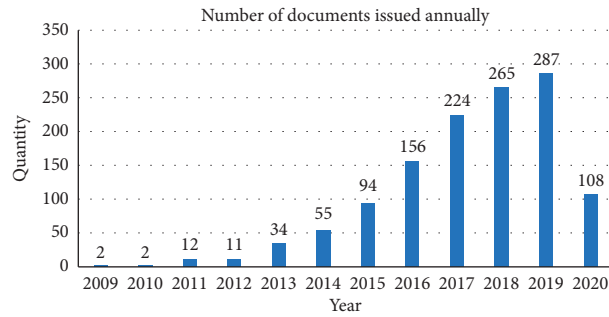


FIGURE 2: Annual number of papers published.

TABLE 1: Distribution of the top ten journals published in the field of prosumer.

Number	Number of articles	Source journal	2018 impact factor
1	77	Energies	2.707
2	53	Applied Energy	8.426
3	32	IEEE Transactions on Smart Grid	10.486
4	29	Renewable & Sustainable Energy Reviews	10.556
5	26	Energy	5.537
6	25	IEEE Access	4.098
7	22	Energy Policy	4.88
8	22	IEEE Transactions on Power Systems	6.807
9	17	Sustainability	2.592
10	12	Energy Research & Social Science	5.525

TABLE 2: The top 20 high-volume authors and highly cited authors in the field of prosumers.

Number	Number of articles	High-published authors		Highly cited	Highly cited author	
		Author	Organization		Cited author	Organization
1	16	D. Menniti		81	E. Mengelkamp	Karlsruhe Institute of Technology
2	16	A. Pinnarelli	University of Calabria	80	Y. Parag	Interdisciplinary Center Herzliya
3	16	N. Sorrentino		78	C. H. Zhang	Cardiff University
4	14	A. Burgio		77	N. Liu	North China Electric Power University
5	13	N. Liu	North China Electric Power University	57	W. Tushar	The University of Queensland
6	12	T. Morstyn	Oxford University	54	C. Long	Cardiff University
7	11	S. Grijalva	Georgia Institute of Technology	53	T. Morstyn	Oxford University
8	11	G. C. Christoforidis	University of Western Macedonia	52	A. J. D. Rathnayaka	Curtin University of Technology
9	11	M. Sanduleac	Politehnica University of Bucharest	49	H. Lund	Aalborg University
10	11	B. Adebisi	Manchester Metropolitan University	48	W. Saad	Virginia Tech

research is still at a preliminary stage and research cooperation is relatively scattered. Based on the high-published authors and highly cited authors mentioned above, the research results of Liu's team at North China Electric Power University are relatively outstanding [19–21]. Also worthy of attention are Wu's team from Cardiff University [23, 24] and Morstyn's team from Oxford University [25].

To analyze the differences in the research directions and focus of different institutions, we further analyzed and compared the 5 subject terms most concerned by the top 8 institutions. The results are shown in Table 4.

In addition to the topics of common concern of various institutions, such as demand-side management and systems, INESC TEC focuses on flexibility [26] and aggregators

TABLE 3: High-published countries or regions and organizations.

Number	High-published countries/regions		High-published organizations	
	Number of articles	Country/region	Number of articles	Organizations
1	142	USA	26	INESC TEC
2	138	Italy	24	North China Electric Power University
3	99	Germany	23	Aalto University
4	93	Peoples R China	23	Polytechnic University of Bucharest
5	81	England	19	University of Calabria
6	79	Spain	18	Aalborg University
7	75	Netherlands	17	Polytechnic University of Turin
8	75	Australia	17	The University of Lisbon
9	67	Poland	16	Eindhoven University of Technology
10	65	Portugal	16	Helmholtz Association of German Research Centres

TABLE 4: Comparative analysis of research topics of the top eight institutions.

Organization	Top 5 topics that have received the most attention (in order of frequency)
INESC	Prosumer (14), flexibility (8), aggregators (8), electricity market (8), energy storage (5)
North China Electric Power University	Demand response (10), prosumer (10), optimization (9), system (6), microgrid (6)
Aalto University	Prosumer (12), systems (7), district heating (5), impact (4), demand-side management (3)
Polytechnic University of Bucharest	Prosumer (8), smart grid (7), renewable energy (4), power distribution system (4), microgrid (3)
University of Calabria	Prosumer (10), demand response (7), system (6), home automation system (4), management (3)
Aalborg University	System (6), prosumer (5), microgrid (5), demand response (3), blockchain (2)
Polytechnic University of Turin	Smart grid (5), energy management (4), prosumer (4), system (4), demand-side management (2)
Universidade de Lisboa	Self-consumption (5), prosumer (5), demand response (4), demand (3), influence (3)

[27–30], North China Electric Power University mainly studies issues such as microgrid optimization [31, 32], Aalto University focuses on district heating [33, 34], the Polytechnic University of Bucharest noticed the power distribution system [35, 36], the University of Calabria focuses on home automation system [37, 38], Aalborg University researches blockchain [39], the Polytechnic University of Turin considers energy management [40, 41], and the University of Lisbon focuses more on self-consumption [42, 43].

#### 4. Analysis of the Evolution of Research Hotspots for Energy Prosumer

*4.1. Identification and Evolution of Research Hotspots Based on Keyword Cooccurrence.* Table 5 lists the top 20 keywords in the field of prosumers according to the frequency of keyword cooccurrence. Keywords represent knowledge points and research hotspots in a certain research field. The year in the table represents the time when the keyword-containing article first cooccurs with high frequency and not necessarily the time when the keyword first appeared mainly including prosumer, smart grid, demand response, microgrid, optimization, energy storage, distributed power generation, and electric vehicles.

In Table 5, keyword frequency ranking shows the hotspots in the research field of prosumer from 2009 to 2020 at a certain level. The “prosumer” is the keyword with the highest frequency of cooccurrence in the field of energy prosumer, reflecting the research theme in this field. The “smart grid” and “microgrid” indicate the network background studied by prosumer. “System,” “optimization,” “management,”

“energy management,” and “model” reflect different levels and scales of energy system management and optimization issues based on prosumer. “Distributed generation,” “storage,” and “electric vehicle” reflects the flexibility of prosumer fully. Also worthy of attention are “demand-side management” to improve energy efficiency, and “blockchain” promotes decentralized P2P energy transactions.

To better understand the evolution law of research hotspots in the field of the prosumer and identify research frontiers, this article lists keywords with relatively high frequency or high centrality in each year, aiming to analyze the development trend of research hotspots in the field of prosumer. “Centrality” means “betweenness centrality,” which is one of the important indicators for measuring nodes in the network. It is usually a hub connecting two different fields. The higher the centrality value, the more important the node. As shown in Table 6, in 2014, hot keywords were more numerous and scattered, reflecting that the concept of “prosumer” has attracted more scholars’ attention this year. The research in these subdivisions has laid the foundation for the subsequent research and development of prosumers. Besides, it can be seen in the research roughly that it were focused more on the scientific and technological research of various energy managements and energy system elements before 2015; and in 2015 and later, it were focused more on the soft science research of market transactions.

*4.2. Analysis of Research Hotspots of Prosumer in the past 180 Days.* To further analyze the research hotspots of the prosumer in the past 180 days, that is, to identify cutting-edge

TABLE 5: The ranking of the cooccurrence frequency of the top 20 keywords.

Number	Frequency	year	Keyword
1	354	2010	Prosumer
2	226	2010	Smart grid
3	184	2011	System
4	142	2013	Demand response
5	135	2011	Microgrid
6	115	2014	Optimization
7	114	2014	Renewable energy
8	106	2014	Management
9	93	2014	Storage
10	78	2016	Power
11	77	2014	Energy
12	75	2010	Distributed generation
13	72	2016	Model
14	69	2014	Generation
15	68	2012	Energy management
16	64	2009	Demand-side management
17	58	2016	Network
18	54	2010	Electric vehicle
19	54	2017	Blockchain
20	54	2014	Electricity

TABLE 6: Hot keywords in the field of prosumer.

Number	Keyword
2009	Demand-side management (64)
2010	Prosumer (354), smart grid (226), distributed generation (75), electric vehicle (54), distributed energy resource (39), load (23)
2011	System (184), microgrid (135), renewable energy source (34), virtual power plant (21), ancillary service (12)
2012	Energy management (68), operation (47), energy management system (30), multiagent system (20), energy efficiency (18)
2013	Demand response (142), energy storage (52), electricity market (50), aggregator (28)
2014	Optimization (115), renewable energy (114), management (106), storage (93), energy (77), generation (69), electricity (54), battery (42), algorithm (32), building (27), distribution system (26), district heating (23), business model (18), battery storage (17)
2015	Game theory (34), photovoltaics (21), energy market (16), price (14), net metering (14)
2016	Power (78), model (72), network (58), self-consumption (37), technology (35), integration (33), flexibility (32), policy (30)
2017	Blockchain (54), market (38), energy trading (32), transactive energy (22)
2018	Challenge (17), household (14), sustainability (13), IoT (8)
2019	Peer-to-peer energy trading (10), optimal operation (7), peer to peer (7), local energy market (6), big data analytics (2)
2020	Game (6), home energy management system (3), energy community (2)

research within the 180 days before May 26, 2020, scholars focus on this article. This article uses the function of “Usage180” in CiteSpace, according to the number of visits to the full text in the past 180 days, or the number of times the record is saved, which counts recent high-frequency keywords in the field of prosumer [14]. Table 7 reflects the high-frequency keywords that appeared in the field of prosumer within the 180 days before May 26, 2020, which can identify the latest research hotspots. Among them, battery energy storage (battery and battery storage) has the highest frequency of occurrence, with a total frequency of 43 times. Battery energy storage is a recent focus of research by prosumer, which can improve the self-consumption of prosumers and the flexibility of energy exchange. Besides, it also includes aggregator, algorithm, ancillary services, auction, and architecture.

4.3. *Research on Prosumer Based on the Knowledge Graph of Article Cocitation.* Article cocitation represents the knowledge base in the field. Through citation cluster analysis of document cocitation relationships, it is possible to understand the migration of research hotspots and research trends. This article uses the timeline diagram in CiteSpace, which describes clustering along the horizontal timeline. As shown in Figure 2, colored lines indicate the correlation between different clusters. Under each timeline, the three most cited references in a particular year will be displayed. According to the number of articles contained in the clusters, numbering starts from 0, and the 10 largest clusters are obtained from 73 clusters. Large nodes or nodes with red tree lines are particularly interesting because they are either highly cited, or have citation bursts, or both [44]. Table 8 shows the specific characteristics of each cluster in Figure 3,

TABLE 7: Keyword ranking in the past 180 days.

Number	Frequency	Centrality	Year	Keywords
1	33	0.04	2014	Battery
2	32	0.06	2014	Algorithm
3	29	0.18	2013	Aggregator
4	14	0.09	2017	Barrier
5	14	0.08	2009	Ancillary service
6	13	0.1	2017	Adoption
7	12	0.01	2015	Auction
8	10	0.02	2014	Battery storage
9	10	0.1	2010	Smart grid
10	8	0	2013	Architecture

TABLE 8: Overview of clustering of cocited documents.

Cluster	Quantity	Average year	Label words	Research focus
0	84	2017	Energy trading	Energy trading, peer-to-peer, automated negotiation, energy prosumer, local electricity markets, blockchain
1	68	2013	Self-consumption	Self-consumption, net metering, battery storage, distributed generation, photovoltaic (PV), vehicle-to-grid
2	63	2012	Smart grid	Smart grid, energy efficiency, virtual power plant (VPP), genetic algorithm (GA)
3	57	2014	Matching markets	Matching markets, game theory, microgrid, transactive energy, demand response
4	35	2015	District heating	District heating, mathematical modeling, district heating system
5	30	2010	Variable grid prices	Variable grid prices, complex network, network evolution, automated demand-side management, smart household appliance
6	26	2009	Information management	Information management, web services, power system economics
7	25	2012	Local electricity market	Local electricity market, multiagent system, intelligent agents
8	24	2015	Aggregators	Aggregators, flexibility, electricity markets, distribution network
9	19	2011	Profiling	Profiling, energy demand estimation, prosumers behavior, peer-to-peer communication

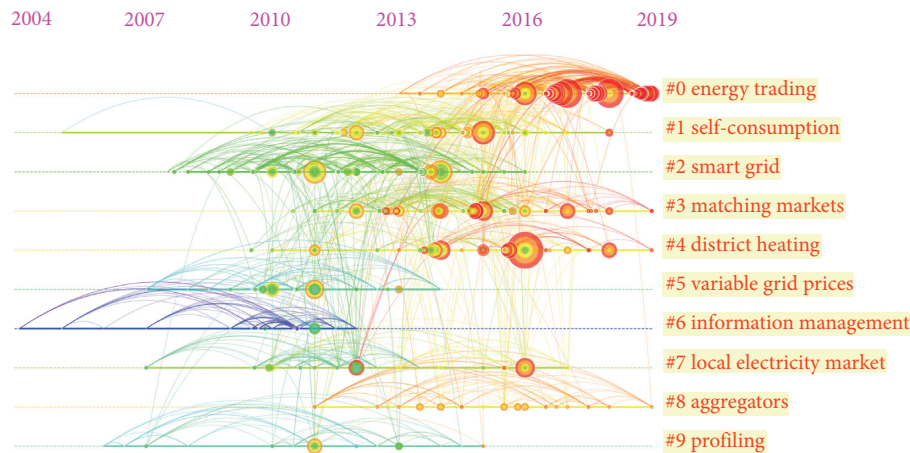


FIGURE 3: Time line diagram of the largest 10 clusters.

including the cluster number, the number of cluster members, the average publication years of the cluster literature, the main tags of the cluster, and the research focus. In this paper, the clustering tags are extracted from keywords, and the LLR (log-likelihood ratio) algorithm is used to generate the clustering tag words.

According to the research focus of the categories in Table 8, we can summarize several main research paths in the field of energy prosumer at the present stage. (1) Types of the prosumer, including electricity prosumer and thermal prosumer. Cluster 4 is concentrated in the district heating system, and the remaining clusters are concentrated in the

field of smart grid and microgrid. (2) Prosumer application scenarios: the research of clusters 1, 5, 6, and 9 is closely related to the distributed energy system. It can be seen that the prosumer model is beginning to be applied in the distributed energy system, which improves the flexibility of end-user's energy demand. (3) Prosumer transactions: clusters 0, 1, 2, 3, 5, 7, and 8 are all concentrated on prosumer transactions. Prosumer use distributed photovoltaics, batteries, and electric vehicles to meet and regulate loads, increase self-sufficiency, and reduce power purchase costs. Excess or insufficient energy is traded in local power markets such as communities through P2P mode, or through the P2G mode, transactions are based on grid electricity prices such as grid-connected electricity prices.

Among the above clusters, cluster 0 "energy trading" is particularly noteworthy. It has the largest number of documents, with an average age of 2017, and is closely related to the research content of other clusters. It is the cutting-edge content of research on prosumers. In recent years, many scholars have devoted themselves to research in this field, including trading market and trading platform design, operation models of different trading entities, and multi-agent trading pricing mechanism. This article will conduct a further cocitation analysis on the cross-references of the three market models (P2P mode, P2G mode, and community model of the prosumer) to find the cutting-edge research results and trends of prosumer.

This article retrieved articles related to the three market models of prosumers and consumers in the "Web of Science Core Collection." As of July 19, 2020, the search results are shown in Table 9. It can be seen that some literature studies involve two or more themes. Using highly cited literature on three themes as the research samples, the following research trends can be summarized.

The P2P model refers to direct negotiation and transaction between prosumers, mainly in complete P2P energy transaction. Mengelkamp et al. [16] proposed the concept of a blockchain-based microgrid energy market; besides, they designed and simulated the application of blockchain in the local energy market [45]. Zhang et al. [18] designed a P2P energy trading platform and bidding mechanism. Liu et al. [20] designed a shared pricing model between prosumers within the microgrid. Zhang et al. [46] analyzed the characteristics of existing P2P projects comparatively. Morstyn et al. suggested that prosumer jointly forms a virtual power plant [47]; also, to coordinate prosumer of different sizes, they proposed bilateral contracts for real-time and forward markets [48]. The P2P market may also involve prosumer agents, and P2P market transactions with smart agents seem to be more able to get the lowest electricity price [49]. Luo et al. [50] proposed to promote electricity trading by forming alliances between prosumer through agents. Etukudor et al. [51] used an autonomous agency model to establish an automatic P2P power transaction negotiation framework between consumers and prosumers. P2P energy trading can produce obvious benefits, but there are also a series of severe challenges at the technical, institutional, economic, and social levels. How to achieve key technological breakthroughs at the physical level of trading? How to reform the

existing power market system and mechanism to adapt to distributed power trading? How to improve the economics of participating in transactions by prosumers? How to increase the willingness of the prosumer to participate and ensure fairness and privacy? These issues are still worthy of further exploration.

In the P2G mode, the prosumer can connect to the microgrid, and the MGO determines the transaction price and balances the power of the microgrid. Through the Stackelberg game, MGO maximizes profits, and prosumer maximizes utility [19, 52]. In addition to PV inside the microgrid, cogeneration [53] and battery energy storage [32] are also considered. Prosumers can also directly trade with the main grid. Generally, the state adopts preferential electricity tariff policies when encouraging PV popularization, such as feed-in tariffs and net metering. In recent years, compared with the FIT, net metering has received more attention in coordinating the power generation and consumption of prosumer [54]. Yamamoto et al. [55] compared the possible differences in social welfare and retail electricity prices among the three mechanisms of the feed-in tariff, net metering, and net purchase and sale. Gautier et al. [56] pointed out two drawbacks of the net metering policy: while reducing the cost of the prosumer, it will increase the cost of traditional consumer; it is not conducive to promoting local consumption of electricity. Eid et al. [57] designed cross-subsidies to coordinate policy objectives and the cost recovery balance of utility companies to change the unfairness of net measurement to non-PV owners. It is worth noting that the economic motivation for prosumer to install photovoltaic battery energy storage systems is more dependent on the self-consumption of photovoltaic power generation rather than trading with the grid [58]. Luthander et al. [59] reviewed two technologies for improving self-consumption: energy storage and demand-side management. According to the existing literature, they believe that the combination of the two can maximize the self-consumption rate. Weniger et al. [60] analyzed the proper configuration of residential photovoltaics and batteries and selected the most cost-optimized configuration for various cost scenarios. Noor et al. [61] introduced blockchain into demand-side management and implemented decentralized energy supply and demand management in practice. The P2G model is relatively easier to implement, but the two-way power flow will involve the issue of electricity prices and grid management pressure. Also, aggregators' participation in demand-side management and power market transactions can play an intermediary coordination role.

The prosumer community model, which is somewhere in between the former two, aims to promote local energy trading. Compared with the traditional P2G model, community P2P energy sharing can save energy costs. Rathnayaka et al. [62] and Yan [63] put forward the issues of community formation, common goals, and distribution of prosumers; Koirala et al. [64] reviewed the technical, socioeconomic, environmental, and institutional issues of the development of integrated community energy systems. Moret et al. [65] introduced a community-based collective energy market structure and evaluated it through fairness



TABLE 9: Number of documents in the three topic search formulas.

Number	Search	Quantity
1	TS = “prosumer*” AND TS = (“P2P” OR “peer-to-peer”)	168
2	TS = “prosumer*” AND TS = (“P2G” OR “peer to grid” OR “feed-in” OR “sold to the grid” OR “prosumer* to grid”)	75
3	TS = “prosumer*” AND TS = “community*”	292
4	#1 AND #2 AND #3	440

indicators. In terms of community energy transactions, Paudel et al. [66] pointed out that, in P2P transactions, in addition to the game between the buyer and the seller, there is also price competition within the buyer and the seller. Wang et al. [67] proposed a P2P energy transaction method using double auctions, which can improve system stability and protect the privacy of prosumer. The community also provides new ideas for energy storage sharing. Luth et al. [68] studied the benefits of decentralized and centralized energy storage in P2P energy transactions in the community. Van et al. [69] compared household energy storage and community energy storage methods and believed that the current two types of energy storage are not economical. Rodrigues et al. [70] considering that, in the case of producers and consumers participating in community P2P, community energy storage can reduce the investment costs of the prosumer. The prosumer community is a regulated P2P model, and future research hotspots are mainly the fairness of internal P2P transactions and the greatest overall benefits.

## 5. Research Conclusions and Prospects

**5.1. Main Research Conclusions.** This article uses qualitative literature review and quantitative bibliometric methods to systematically review the research in the field of prosumers. In this paper, CiteSpace software is used to analyze 1251 articles in the field of consumer and producer from 2009 to 2020 as follows: annual publishing trend, core journals, important authors, key countries/regions and organizations, keyword cooccurrence, hot keywords in recent 180 days, and the literatures cooccurrence. The main research conclusions of this paper are as follows.

Firstly, the trend of publishing articles in the field of the prosumer is increasing year by year. With the popularization of distributed photovoltaic, battery energy storage, and electric vehicles, this field is bound to gain more attention.

Secondly, authoritative journals in the field of prosumer focus on theoretical foundations, energy applications, energy policies, and energy modeling. Among them, “Renewable & Sustainable Energy Reviews” focuses on analysis and review of academic viewpoints, “Applied Energy” focuses on energy conversion applications, “Energy Policy” emphasizes energy policy, and “Energy” focuses on energy modeling and forecasting.

Thirdly, the main countries and regions in the field of prosumers are distributed in Europe, North America, Asia, and Australia. Among them, the United States ranked first with 138 articles. After that, except for China and Australia, the remaining seven were all European countries. Among the high-published organizations in the field of the

prosumers, INESC TEC, located at the University of Porto in Portugal, topped the list with 26 articles, followed by North China Electric Power University, and the remaining eight institutions are also in Europe. It is worth noting that institutions in the United Kingdom, Spain, Australia, and Poland are not among the top ten high-published institutions, but there are institutions from Finland, Romania, and Denmark. It can be seen that Europe is still an important research area for prosumers, which benefits from Europe’s pursuit of carbon neutrality in recent years and the promotion of the popularization of distributed power generation and energy storage by policies. Also, this shows that research on prosumer is still in its infancy, and various research institutions are exploring from different angles, and no institution has formed a strong academic influence.

Fourth, the results of the cooccurrence of keywords in the research on prosumer show that, in the context of smart grids, research on prosumer focuses on energy system management on the microgrid side, flexible resources on the prosumer side, and flexible response on the demand side and energy trading between the three. Besides, the research found that since 2015, the research focus has shifted from scientific and technological research on energy systems to soft scientific research on market transactions.

Fifth, the results of high-frequency keyword analysis in the research field of the prosumer in the past 180 days show that battery energy storage has become the biggest recent hotspot in the research of prosumers; the emergence of prosumer provides an opportunity for the development of various aggregators. It has also become a recent research hotspot.

Sixth, the analysis results of the cocited knowledge map of the literatures show that the mainstream research on energy prosumer is summarized into three parts, namely, the types of the prosumer, the application scenarios of the prosumer, and the trade of prosumer. The various subfields are still relatively scattered, but their rise and development explain the new market entity “energy prosumer” from different perspectives. Among them, energy trading is the most important hot area, and further research frontier analysis has been done from the three market models of P2P, P2G, and the prosumer community. Also, self-consumption, market matching, district heating, aggregators, and household energy management systems have been researched hotspots since 2015, indicating that research in these six fields is in a rapid development stage and there is still a lot of research space.

**5.2. Outlook.** Based on the analysis of the cocited literature of research on prosumer, this article finds that the main research hotspots in recent years are energy trading, self-

consumption, and distributed energy system management. Keyword analysis found that energy storage, aggregators, buildings, and home energy management systems are currently hotspots of high attention; social issues such as policies and motivations are hotspots of continuous attention, which need to be further studied and expanded. Also, the use of digital technologies such as big data, the Internet of Things, and blockchain in this field has attracted more and more attention. In the future, digital technology will have a significant impact on the participation of prosumer in energy market transactions, including upstream distribution network operations, microgrid operations, peer interaction between prosumer, and downstream demand response. This will profoundly change the existing energy supply chain model.

With the rise of the concept of the energy Internet, combining multienergy complementary systems and information and communication technologies to achieve the integration and development of multiple energy supply networks, research on prosumer and related fields has also attracted more attention. Based on the bibliometric analysis and the actual needs of the development of prosumer, this article summarizes some related research hotspots: ① in the context of the energy Internet, prosumers as transaction entities will not be limited to electricity prosumers, and the transaction field will be the whole energy Internet not limited to the grid, and the transaction objects will be a variety of energy categories; based on this, future research on prosumer can be placed in the context of the energy Internet to explore the key technologies, behavioral characteristics, transaction decisions, and path trends of the development of prosumer groups. ② Current research mostly focuses on engineering technology and economic analysis, and the research methods adopted are mainly quantitative mathematical models and relatively few research studies involving the perspective of social science. Research perspectives are mostly system optimization and transaction design, and there is less research on various corporate roles and the adjustment of business models in the market. Based on this, in future research, the management of prosumer can be discussed from the perspective of social science, on the one hand, in combination with management, sociology, and psychology and, on the other hand, the business model innovation of various enterprises in the existing market and the design of business models for new entities such as aggregators, virtual power plants, and integrated energy services. ③ Consumers and prosumers are more involved in energy transactions. Value cocreation blurs the boundaries between users and energy suppliers. The value cocreation and effects of the two in the interactive process need to be studied in depth. Based on this, from the value chain of the activities of the prosumer, consider the cooperative relationship between various enterprises and the prosumer and ordinary prosumers and improve the value cocreation ability between elements. ④ The development of prosumer still needs policy guidance and energy market reforms to adapt. Therefore, supporting policies and market reforms have become a common concern of enterprises and scholars.

In summary, domestic research can be further expanded in combination with the above current research hotspots and

possible future hotspot issues. In the context of the energy Internet, energy trading platforms, digital ecosystems, cross-border innovation, and other fields will also become the focus of future research on the production and prosumer groups.

There are still deficiencies in the research in this paper. First of all, this research only selects data from the Web of Science Core Collection, and some research results may be omitted. Secondly, since the concept of energy prosumer has just emerged, the current research hotspots are relatively scattered. Although the overall picture of the research on energy prosumer can be presented, it is difficult to conduct an in-depth analysis of each cluster. Finally, this article only focuses on the international research results of energy prosumer, which can be compared with domestic research in the future, and provides reference suggestions for the development direction of domestic prosumer research.

### Data Availability

The data used to support the findings of the study are available within the article.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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### References

- [1] A. Toffler, *The Third Wave*, B. Williams and T. Tapscott, Eds., Bantam Books, New York, NY, USA, 1981.
- [2] R. Ford, J. Whitaker, and J. Stephenson, *Prosumer Collectives: A Review A Report for the Smart Grid Forum*, Centre for Sustainability, University of Otago, Dunedin, New Zealand, 2016.
- [3] E. Espe, V. Potdar, and E. Chang, “Prosumer communities and relationships in smart grids: a literature review, evolution and future directions,” *Energies*, vol. 11, no. 10, p. 2528, 2018.
- [4] L. Brange, J. Englund, and P. Lauenburg, “Prosumers in district heating networks - a Swedish case study,” *Applied Energy*, vol. 164, pp. 492–500, 2016.
- [5] Y. Hongming, X. Tonglin, Q. Jing, Q. Duo, and Y. D. Zhao, “Optimal operation of DES/CCHP based regional multi-energy prosumer with demand response,” *Applied Energy*, vol. 167.
- [6] K. Kotilainen, M. Sommarberg, P. Järventausta et al., “Prosumer centric digital energy ecosystem framework,” in *Proceedings of the 8th International Conference on Management of*

- Digital EcoSystems*, pp. 47–51, Biarritz, France, November 2016.
- [7] R. Zafar, A. Mahmood, S. Razzaq, W. Ali, U. Naeem, and K. Shehzad, “Prosumer based energy management and sharing in smart grid,” *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1675–1684, 2018.
  - [8] T. Sousa, T. Soares, P. Pinson, F. Moret, T. Baroche, and E. Sorin, “Peer-to-peer and community-based markets: a comprehensive review,” *Renewable and Sustainable Energy Reviews*, vol. 104, pp. 367–378, 2019.
  - [9] P. Huang, B. Copertaro, X. Zhang et al., “A review of data centers as prosumers in district energy systems: renewable energy integration and waste heat reuse for district heating,” *Applied Energy*, vol. 258, Article ID 114109, 2020.
  - [10] A. Ahl, M. Yarime, K. Tanaka, and D. Sagawa, “Review of blockchain-based distributed energy: implications for institutional development,” *Renewable and Sustainable Energy Reviews*, vol. 107, pp. 200–211, 2019.
  - [11] K. Mahmud, G. E. Town, S. Morsalin, and M. J. Hossain, “Integration of electric vehicles and management in the internet of energy,” *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 4179–4203, 2018.
  - [12] M. Gough, F. S. Santos, M. Javadi, R. Castro, and P. S. Catalão, “Prosumer flexibility: a comprehensive state-of-the-art review and scientometric analysis,” *Energies*, vol. 13, no. 11, p. 2710, 2020.
  - [13] C. Yue, C. Chen, Z. Liu et al., “Methodological function of CiteSpace knowledge graph,” *Studies in Science of Science*, no. 2, pp. 242–253, 2015.
  - [14] L. Jie, *Citespace: Science and Technology Text Mining and Visualization*, Capital University of Economics and Business Press, Beijing, China, 2017.
  - [15] G. Mauri, D. Moneta, and C. Bettoni, “Energy conservation and smartgrids: new challenge for multimetering infrastructures,” in *Proceedings of the 2009 IEEE Bucharest PowerTech*, pp. 1–7, IEEE, Bucharest, Romania, October 2009.
  - [16] E. Mengelkamp, J. Gärtner, K. Rock, S. Kessler, L. Orsini, and C. Weinhardt, “Designing microgrid energy markets,” *Applied Energy*, vol. 210, pp. 870–880, 2018.
  - [17] Y. Parag and B. K. Sovacool, “Electricity market design for the prosumer era,” *Nature Energy*, vol. 1, no. 4, pp. 1–6, 2016.
  - [18] C. Zhang, J. Wu, Y. Zhou, M. Cheng, and C. Long, “Peer-to-Peer energy trading in a Microgrid,” *Applied Energy*, vol. 220, pp. 1–12, 2018.
  - [19] N. Liu, X. Yu, C. Wang, and J. Wang, “Energy sharing management for microgrids with PV prosumers: a Stackelberg game approach,” *IEEE Transactions on Industrial Informatics*, vol. 13, no. 3, pp. 1088–1098, 2017.
  - [20] N. Liu, X. Yu, C. Wang, C. Li, L. Ma, and J. Lei, “Energy-sharing model with price-based demand response for microgrids of peer-to-peer prosumers,” *IEEE Transactions on Power Systems*, vol. 32, no. 5, pp. 3569–3583, 2017.
  - [21] N. Liu, M. Cheng, X. Yu, J. Zhong, and J. Lei, “Energy-sharing provider for PV prosumer clusters: a hybrid approach using stochastic programming and Stackelberg game,” *IEEE Transactions on Industrial Electronics*, vol. 65, no. 8, pp. 6740–6750, 2018.
  - [22] W. Tushar, T. K. Saha, C. Yuen, P. Liddell, R. Bean, and H. V. Poor, “Peer-to-Peer energy trading with sustainable user participation: a game theoretic approach,” *IEEE Access*, vol. 6, pp. 62932–62943, 2018.
  - [23] C. Long, J. Wu, Y. Zhou, and N. Jenkins, “Peer-to-peer energy sharing through a two-stage aggregated battery control in a community Microgrid,” *Applied Energy*, vol. 226, pp. 261–276, 2018.
  - [24] Y. Zhou, J. Wu, and C. Long, “Evaluation of peer-to-peer energy sharing mechanisms based on a multiagent simulation framework,” *Applied Energy*, vol. 222, pp. 993–1022, 2018.
  - [25] T. Morstyn and M. D. McCulloch, “Multiclass energy management for peer-to-peer energy trading driven by prosumer preferences,” *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 4005–4014, 2018.
  - [26] J. P. Iria, F. J. Soares, and M. A. Matos, “Trading small prosumers flexibility in the energy and tertiary reserve markets,” *IEEE Transactions on Smart Grid*, vol. 10, no. 3, pp. 2371–2382, 2018.
  - [27] J. Iria, F. Soares, and M. Matos, “Optimal supply and demand bidding strategy for an aggregator of small prosumers,” *Applied Energy*, vol. 213, pp. 658–669, 2018.
  - [28] M. Yazdani-Damavandi, N. Neyestani, M. Shafie-khah et al., “Strategic behavior of multi-energy players in electricity markets as aggregators of demand side resources using a bi-level approach,” *IEEE Transactions on Power Systems*, vol. 33, no. 1, pp. 397–411, 2017.
  - [29] J. Iria, F. Soares, and M. Matos, “Optimal bidding strategy for an aggregator of prosumers in energy and secondary reserve markets,” *Applied Energy*, vol. 238, pp. 1361–1372, 2019.
  - [30] J. Iria and F. Soares, “Real-time provision of multiple electricity market products by an aggregator of prosumers,” *Applied Energy*, vol. 255, Article ID 113792, 2019.
  - [31] S. Cui, Y. W. Wang, J. W. Xiao et al., “A two-stage robust energy sharing management for prosumer microgrid,” *IEEE Transactions on Industrial Informatics*, vol. 15, no. 5, pp. 2741–2752, 2018.
  - [32] H. Huang, S. Nie, J. Lin, Y. Wang, and J. Dong, “Optimization of peer-to-peer power trading in a microgrid with distributed PV and battery energy storage systems,” *Sustainability*, vol. 12, no. 3, p. 923, 2020.
  - [33] K. Kontu, S. Rinne, and S. Junnila, “Introducing modern heat pumps to existing district heating systems-global lessons from viable decarbonizing of district heating in Finland,” *Energy*, vol. 166, pp. 862–870, 2019.
  - [34] B. M. Delgado, S. Cao, A. Hasan et al., “Thermoeconomic analysis of heat and electricity prosumers in residential zero-energy buildings in Finland,” *Energy*, vol. 130, pp. 544–559, 2017.
  - [35] M. Sanduleac, G. Lipari, A. Monti et al., “Next generation real-time smart meters for ICT based assessment of grid data inconsistencies,” *Energies*, vol. 10, no. 7, p. 857, 2017.
  - [36] M. Sanduleac, J. Martins, I. Ciornei et al., “Resilient and immune by design microgrids using solid state transformers,” *Energies*, vol. 11, no. 12, p. 3377, 2018.
  - [37] G. Brusco, A. Burgio, D. Menniti, A. Pinnarelli, N. Sorrentino, and L. Scarcello, “An energy box in a cloud-based architecture for autonomous demand response of prosumers and prosumages,” *Electronics*, vol. 6, no. 4, p. 98, 2017.
  - [38] G. Belli, A. Giordano, C. Mastroianni et al., “A unified model for the optimal management of electrical and thermal equipment of a prosumer in a DR environment,” *IEEE Transactions on Smart Grid*, vol. 10, no. 2, pp. 1791–1800, 2017.
  - [39] M. F. Zia, M. Benbouzid, E. Elbouchikhi, S. M. Mueyeen, K. Techato, and J. M. Guerrero, “Microgrid transactive energy: review, architectures, distributed ledger technologies, and market analysis,” *IEEE Access*, vol. 8, pp. 19410–19432, 2020.
  - [40] Y. Cai, T. Huang, E. Bompard et al., “Self-sustainable community of electricity prosumers in the emerging distribution

- system,” *IEEE Transactions on Smart Grid*, vol. 8, no. 5, pp. 2207–2216, 2016.
- [41] X. Hou, J. Wang, T. Huang, T. Wang, and P. Wang, “Smart home energy management optimization method considering energy storage and electric vehicle,” *IEEE Access*, vol. 7, pp. 144010–144020, 2019.
- [42] C. H. Villar, D. Neves, and C. A. Silva, “Solar PV self-consumption: an analysis of influencing indicators in the Portuguese context,” *Energy Strategy Reviews*, vol. 18, pp. 224–234, 2017.
- [43] V. Reis, R. H. Almeida, J. A. Silva, and M. C. Brito, “Demand aggregation for photovoltaic self-consumption,” *Energy Reports*, vol. 5, pp. 54–61, 2019.
- [44] C. Chen, “Science mapping: a systematic review of the literature,” *Journal of Data and Information Science*, vol. 2, no. 2, pp. 1–40, 2017.
- [45] E. Mengelkamp, B. Notheisen, C. Beer et al., “A blockchain-based smart grid: towards sustainable local energy markets,” *Computer Science-Research and Development*, vol. 33, no. 1-2, pp. 207–214, 2018.
- [46] C. Zhang, J. Wu, C. Long, and M. Cheng, “Review of existing peer-to-peer energy trading projects,” *Energy Procedia*, vol. 105, pp. 2563–2568, 2017.
- [47] T. Morstyn, N. Farrell, S. J. Darby, and M. D. McCulloch, “Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants,” *Nature Energy*, vol. 3, no. 2, pp. 94–101, 2018.
- [48] T. Morstyn, A. Teytelboym, and M. D. McCulloch, “Bilateral contract networks for peer-to-peer energy trading,” *IEEE Transactions on Smart Grid*, vol. 10, no. 2, pp. 2026–2035, 2018.
- [49] E. Mengelkamp, P. Staudt, J. Gartner et al., “Trading on local energy markets: a comparison of market designs and bidding strategies,” in *Proceedings of the 2017 14th International Conference on the European Energy Market (EEM)*, pp. 1–6, IEEE, Dresden, Germany, July 2017.
- [50] F. Luo, Z. Y. Dong, G. Liang et al., “A distributed electricity trading system in active distribution networks based on multi-agent coalition and blockchain,” *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 4097–4108, 2018.
- [51] C. Etukudor, B. Couraud, V. Robu, W.-G. Früh, D. Flynn, and C. Okereke, “Automated negotiation for peer-to-peer electricity trading in local energy markets,” *Energies*, vol. 13, no. 4, p. 920, 2020.
- [52] S. Cui, Y. W. Wang, and N. Liu, “Distributed game-based pricing strategy for energy sharing in microgrid with PV prosumers,” *IET Renewable Power Generation*, vol. 12, no. 3, pp. 380–388, 2017.
- [53] L. Ma, N. Liu, J. Zhang, W. Tushar, and C. Yuen, “Energy management for joint operation of CHP and PV prosumers inside a grid-connected microgrid: a game theoretic approach,” *IEEE Transactions on Industrial Informatics*, vol. 12, no. 5, pp. 1930–1942, 2016.
- [54] G. Christoforidis, I. Panapakidis, T. Papadopoulos et al., “A model for the assessment of different net-metering policies,” *Energies*, vol. 9, no. 4, p. 262, 2016.
- [55] Y. Yamamoto, “Pricing electricity from residential photovoltaic systems: a comparison of feed-in tariffs, net metering, and net purchase and sale,” *Solar Energy*, vol. 86, no. 9, pp. 2678–2685, 2012.
- [56] A. Gautier, J. Jacqmin, and J.-C. Poudou, “The prosumers and the grid,” *Journal of Regulatory Economics*, vol. 53, no. 1, pp. 100–126, 2018.
- [57] C. Eid, J. Reneses Guillén, P. Frías Marín, and R. Hakvoort, “The economic effect of electricity net-metering with solar PV: consequences for network cost recovery, cross subsidies and policy objectives,” *Energy Policy*, vol. 75, pp. 244–254, 2014.
- [58] E. McKenna, J. Pless, and S. J. Darby, “Solar photovoltaic self-consumption in the UK residential sector: new estimates from a smart grid demonstration project,” *Energy Policy*, vol. 118, pp. 482–491, 2018.
- [59] R. Luthander, J. Widén, D. Nilsson, and J. Palm, “Photovoltaic self-consumption in buildings: a review,” *Applied Energy*, vol. 142, pp. 80–94, 2015.
- [60] J. Weniger, T. Tjaden, and V. Quaschnig, “Sizing and grid integration of residential PV battery systems,” in *Proceedings of the 8th International Renewable Energy Storage Conference and Exhibition (IRES 2013)*, Berlin, Germany, November 2013.
- [61] S. Noor, W. Yang, M. Guo, K. H. van Dam, and X. Wang, “Energy Demand Side Management within micro-grid networks enhanced by blockchain,” *Applied Energy*, vol. 228, pp. 1385–1398, 2018.
- [62] A. J. D. Rathnayaka, V. M. Potdar, T. Dillon, O. Hussain, and S. Kuruppu, “Goal-oriented prosumer community groups for the smart grid,” *IEEE Technology and Society Magazine*, vol. 33, no. 1, pp. 41–48, 2014.
- [63] Y. Yan, Z. Haoran, L. Yin et al., “A factor-based bottom-up approach for the long-term electricity consumption estimation in the Japanese residential sector,” *Journal of Environmental Management*, vol. 270, pp. 260–273, 2020.
- [64] B. P. Koirala, E. Koliou, J. Friege, R. A. Hakvoort, and P. M. Herder, “Energetic communities for community energy: a review of key issues and trends shaping integrated community energy systems,” *Renewable and Sustainable Energy Reviews*, vol. 56, pp. 722–744, 2016.
- [65] F. Moret and P. Pinson, “Energy collectives: a community and fairness based approach to future electricity markets,” *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 3994–4004, 2018.
- [66] A. Paudel, K. Chaudhari, C. Long et al., “Peer-to-peer energy trading in a prosumer-based community microgrid: a game-theoretic model,” *IEEE Transactions on Industrial Electronics*, vol. 66, no. 8, pp. 6087–6097, 2018.
- [67] Z. Wang, X. Yu, Y. Mu, and H. Jia, “A distributed Peer-to-Peer energy transaction method for diversified prosumers in Urban Community Microgrid System,” *Applied Energy*, vol. 260, Article ID 114327, 2020.
- [68] A. Lüth, J. M. Zepter, P. Crespo del Granado, and R. Egging, “Local electricity market designs for peer-to-peer trading: the role of battery flexibility,” *Applied Energy*, vol. 229, pp. 1233–1243, 2018.
- [69] S. Van Der Stelt, T. AlSkaif, and W. van Sark, “Techno-economic analysis of household and community energy storage for residential prosumers with smart appliances,” *Applied Energy*, vol. 209, pp. 266–276, 2018.
- [70] D. L. Rodrigues, X. Ye, X. Xia, and B. Zhu, “Battery energy storage sizing optimisation for different ownership structures in a peer-to-peer energy sharing community,” *Applied Energy*, vol. 262, Article ID 114498, 2020.