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Evolution of photovoltaic business models: Overcoming the main barriers of distributed energy deployment

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ABSTRACT

The use of renewable energy resources is rapidly growing around the world. However, several barriers may hinder the diffusion of distributed energy solutions. This paper aims to identify the main inhibiting factors using a literature review methodology. To overcome these barriers and adapt to changing environmental conditions, companies operating in the distributed energy market need to develop innovative business model solutions. We therefore investigated the evolution of photovoltaic business models using the Business Model Canvas to determine how the obstacles to distributed energy deployment can be addressed. Finally, we applied the Lean Canvas to show the main differences between the models analysed and describe the benefits of the community-shared model compared with the alternatives, host-owned and third-party-owned solutions.

1. Introduction

The global solar photovoltaic (PV) industry has undergone a major transformation in recent years, with significant growth as a result of strong demand and the continual emergence of new markets [1]. However, according to estimates from GTM Research, global PV demand growth is expected to slow down in the next year and will reach 86 GW in 2018 [2]. This deceleration in major markets can be traced back to policy shifts and regulatory vagueness [3]. This paper therefore aims to examine the main barriers—including policy and regulatory aspects—that may influence the diffusion of renewable energy solutions.

Considerable changes have been seen in photovoltaic business models, as well as significant market growth. Changing contextual conditions have led to innovative concepts designed to tackle the increased complexity. Addressing the high upfront costs of solar systems and other emerging barriers, third-party-owned (TPO) and community-shared (CS) models have an increasingly important role. The TPO model offers Power Purchase Agreement and lease solutions, while CS models allow consumers to subscribe to a defined number of panels or a portion of the generated energy in solar parks through virtual net-metering. These solutions show that innovation is important in the PV market. Managers have a decisive role in successful business model adaptation and operation. They are advised to behave like entrepreneurs, be opportunity-driven and develop inventive products and services to address unmet customer needs and emerging inhibiting factors [4].

The United States is one of the leading countries for PV business model development, and several of its states continue to develop new renewable energy solutions. A good example is California, where the three biggest utilities (Pacific & Gas Electric, Southern California Edison, and San Diego Gas & Electric) were required to secure 600 MW of new community solar capacity by 2019 [5]. These attempts and business models could inspire countries that struggle with distributed energy (DE) deployment but are committed to renewables.

This paper uses a literature review methodology to evaluate the major barriers that may hinder the diffusion of distributed energy. We also identify and analyse the main PV business models using the Business Model Canvas (BMC), to give a full picture of the concepts and compare the identifiable models. Along the nine building blocks of the BMC, we highlight the value proposition and other core elements that distinguish each model and address consumers' problems, drawing on Osterwalder and Pigneur's [6] definition of business models.

TPO and CS models offer a possible solution for regions with a less developed residential solar market, so this review, and the detailed presentation of the core elements of the models, may help with adoption. We also use the Lean Canvas to identify significant consumer problems and possible solutions offered by the community-shared model, and provide examples of how and to what extent business models can provide solutions to the identified barriers. Finally, we give

Abbreviations: BMC, Business Model Canvas; CS, Community-shared; DE, Distributed energy; FiT, Feed-in tariff; kW_p, Kilowatt peak; LC, Lean Canvas; PPA, Power Purchase Agreement; PV, Photovoltaic(s); ROI, Return on Investment; RPS, Renewable Portfolio Standard; TPO, Third-party-owned

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a brief summary highlighting the value proposition of each model and some important implications for policy-makers, then note some future research issues. The paper's aim is to help policy-makers and business leaders to understand the problems that customers face in using renewables, and the main barriers to the spread of certain models, helping them to develop a proper political, regulatory and corporate background that will allow the widest possible dissemination of renewable energy resources.

The paper is organized as follows. Section 2 describes the theoretical background. Section 3 introduces the methodology and Section 4 the main barrier groups, while Section 5 sets out the business models. In Section 6, we synthesize the business models and in Section 7 we describe how the different business models can help overcome the identified barriers. The paper finishes with a summary and conclusions (Section 8) and some directions for future research in Section 9.

2. Theory

2.1. Business models

There is no commonly accepted definition of business model, and there are many approaches in the literature. The term itself was first introduced in economics in the 1950s, with an upswing in its use in the mid-1990s, with the emergence of Internet businesses. According to Zott, Amit and Massa [7], despite a significant increase in the number of publications on business model research, many researchers disagree on the meaning of the term.

Christensen and Johnson [8] described four compulsory elements of business models: *key resources*, including people, technology, products, tools and brand, *key processes* such as design, manufacturing and R&D, *value proposition for customers,* for instance, price and payment and finally the *profit form*, which includes the cost structure and the revenue model. Magretta [9], however, described the business model as nothing more than a story of how a company works. Overall, success depends on finding a good story. This referred back to Peter Drucker [10], who said that a good business model answers the questions “Who are the customers?”, “What is valuable to them?” and “How can this value be provided at an appropriate cost level?”.

Casadesus-Masanell and Ricard [11] stated that a business model is made up of decisions and consequences and defined three common features along which successful business models can be captured. Firstly, the business model must be in line with the company's goals. Secondly, the decisions made in the design of the model must complement each other: internal consistency is essential. Thirdly, a good business model should be able to overcome threats over time. Chesbrough and Rosenbloom [12] defined the functions of business models as articulation of value proposition, market segment identification, definition of the structure of the value chain, estimation of cost structure and profit potential, description of the position of the firm within the value network and formulation of a competitive strategy. Teece [13] emphasized that a business model includes identifying customer needs and payment capability, responding to these needs, and creating value for them. It also encourages customers to pay for the value provided, and converts these payments into profit by properly designing and operating the various elements of the value chain.

Chatterjee [14] suggested that the business model is about more than just making a profit by selling products and services. In his view, every business model starts with the value proposition, which is constantly evolving and so provides a competitive advantage for the organization. According to Osterwalder and Pigneur [6], *“a business model describes the rationale of how an organization creates, delivers and captures value”*. In this paper, we have used this definition as a starting point, because it fits well with renewable energy business models.

Business model innovation is also an important issue, because it enables companies to renew their value proposition, enhance their uniqueness, acquire new markets and customers, and gain long-term sustainable competitive advantage [15–20]. Bashir and Verma [19] suggested that business model innovation can serve as a sustainable competitive advantage, since imitating a whole new system is much more difficult than imitating a product or a service. Aspara et al. [21] defined business model innovation as *“initiatives to create novel value by challenging existing industry-specific business models, roles and relations in certain geographical market areas”*. Giesen et al. [22] identified three main ways to innovate business models: industry model, revenue model and enterprise model innovation. Some authors have differentiated between replication and renewal of business models. Replication refers, for example, to the exploitation of opportunities offered by an existing business model in other geographic areas [23], and renewal means introducing a new business model that goes beyond the previous one [24]. According to Amit and Zott [25], companies can implement business model innovation in a number of ways. These include the addition of new activities to business operations, the innovative linking of activities or changes in who performs the activity.

Several triggers of business model innovation have been identified, such as: (1) economic pressure [16,26,27], (2) product development-related issues [27], (3) price competition [18,19,27,28], (4) customer-related issues [27], (5) strategic circumstances [27,29], (6) underlying conditions [20], (7) situational triggers [20,30–32] and (8) increasing digitization [33–35].

2.2. The business model canvas

The Business Model Canvas provides an attractive template for visualizing new or existing business models. Osterwalder and Pigneur [6] divided the tool into four parts: customers, value proposition, infrastructure and financial aspects. The customer part covers customer relationships, customer segments and distribution channels. The value proposition includes those products and services that solve a specific problem and create value for the customers. The infrastructure section covers the architecture used for value creation, and the financial aspects highlight the connection between revenue streams and the company's cost structure.

Several articles and studies can be identified that have used the Business Model Canvas to demonstrate business models in the energy sector. Hannon et al. [36] used it to discuss the characteristics of Energy Service Companies and Energy Utility Companies. Richter [37] used its building blocks to compare utility-side and customer-side renewable energy business models. Huijben and Verbong [38] also applied the building blocks to describe the main types of PV business models in the Netherlands, as did Strupeit and Palm [39] in the United States, Japan and Germany. Meier [40] used the BMC framework to evaluate PV business models in emerging regions.

2.3. The Lean Canvas

The Lean Canvas (LC) is a business model hypothesis testing and validation tool that can be considered as a further development of the BMC [41]. It offers a more structured way to understand customer problems, and to build the value proposition and solution around them. It also highlights the main risks during the learning process. Its creator based the LC on the BMC but changed some fields to make it even more action-oriented.

One important addition was the Problem section. Many companies fail because they do not focus on real consumer demand, and waste time and money developing the wrong products and services. Another addition is the Solution, because once a firm understands the customers' problem, it is then in the best position to identify an appropriate solution. It is very important to measure the right elements of the operation, which can be recorded in the Key Metrics section. The fourth new part in the LC is a section on Unfair Advantage, which means obstacles preventing others entering the market.

The LC also removed some parts of the BMC, such as the Key

Activities that can be derived from the Solutions. Key resources are considered similar to unfair advantages, with the distinction that a key resource can be an unfair advantage, but not all unfair advantages are key resources. These parts were also merged. Customer relationships are now captured in Channels, since all products and services must start with direct customer relationships. Companies should then identify suitable paths to reach their customers. Finally, the section on Key partners was also deleted, since the LC's creator argued that it is only essential for a few type of companies to establish good partner relationships.

3. Methodology

This section describe the methodology used in this study, to ensure that it is fully understand and enable it to be reproduced in future studies. This research is based on a literature review. In line with Webster and Watson [42] and Von Brocke et al. [43], we used five successive steps: (1) scope definition, (2) conceptualisation of topic, (3) literature search, (4) literature analysis and synthesis and (5) research agenda.

1. The scope of this study is to identify the main barriers of distributed energy deployment and to synthesize possible business model solutions that may help in overcoming the emerging obstacles.
2. In the topic conceptualisation phase, we found that scholars discussing different business models generally used the Business Model Canvas. The main framework of our research is therefore the BMC in the business model presentation section. Barrier and business model discussion parts of papers are usually characterized by geographical breakdown such as developing and industrialized countries, so regional structuring became an essential unit in our research. This phase also helped to determine the main keywords for the literature search.
3. The literature review used the EBSCO database, as this includes the most important journals in the fields of business, management, and energy. In the first step, the search covered titles, abstracts and keywords of papers and contained combinations of the following keywords: “business model”, “energy”, “renewable”, “alternative”, “distributed”, “solar”, “photovoltaic”, “barrier”, “host-owned”, “third-party”, “community”. In the second step, citations were examined, to broaden the existing base and get a wider overview.
4. In the fourth phase, the collected articles were divided into different groups by topic. After closer examination, papers that were not closely related to our scope were excluded (e.g. papers about energy production modelling). Based on Palvia et al. [44] and Cardenas et al. [45], we then defined the following categories among the remaining papers: survey, interview, field study, case study, literature analysis, frameworks and conceptual model. Studies on barriers were also grouped by area: awareness and behavioural, financial and profitability, regulatory and institutional, technological and company resource barriers. Papers on existing business models were divided into three categories: host-owned, third-party-owned, and community-shared. There were possible overlaps between the categories as studies could cover two or more business models and/or barriers.
5. In the final step, the study classification was completed and the papers were categorized along with the specified criteria. We used the Business Model and Lean Canvases to visualize the benefits of the CS model compared to the alternatives and to help in the further development of the possible solutions.

4. Barriers to the diffusion of renewable energy technologies

Numerous factors and barriers can be identified that exert strong influence on the deployment of distributed energy technologies (Table 1). We identified different problem groups that contain the most important elements and factors, to develop an overall picture about the emerging obstacles in the DE market.

Table 1
Overview of the main barriers and related papers.

Main barriers	Related papers	Elements, main factors
Financial and profitability barriers	[38,39,46–53]	• Lack of financial resources • Profitability problems • High initial investment costs • Additional costs • Lack of available loan constructions
Awareness and behavioural barriers	[46,48,52,54–56]	• Lack of knowledge and information • Lack of skilled people • Misinformation about DE benefits • Behavioural barriers and concerns
Regulatory and institutional barriers	[48,50–52,54,57–62]	• Shortcomings of legal framework • Issues about feed-in-tariffs and taxation • Low electricity price • Unpredictable regulations
Technological barriers	[46,50–52,63,115]	• Grid capacity • Security of supply • System performance risks
Company resource barriers	[46,49,52,55]	• Lack of competence • Gaps in the product portfolio • Shortcomings in management and business skills

4.1. Financial and profitability barriers

Financial barriers such as high initial investment costs and lack of financial resources result in a long payback period in renewable technology investments, which in turn decreases the demand [46–48]. According to utility managers in Germany, economies of scale cannot be realised in the residential customer segment because of high upfront investment costs and size of PV projects. These managers therefore do not see much future potential in the B2C area [49]. Low profitability of small domestic projects is therefore a strong dissuasive factor in the DE market [50].

As well as the high level of initial investments, extra cost items e.g. increased operation and maintenance costs, transaction costs associated with grid interconnection and cost of batteries also act as inhibiting financial factors [50–52]. In several countries, it is not possible to alleviate these expenses, since large parts of society are excluded from government support, and in other countries, there are no solar loan options for residential customers [38,39].

To overcome the lack of financial resources, companies operating in the DE market should develop innovative financing schemes that are adapted to customer needs and allow them to invest in renewable technologies. One possible solution could be community-shared and third-party-owned business models, as these aim to reduce or eliminate up-front costs and therefore encourage the use of renewable energy solutions for the residential market [38,39,53].

4.2. Awareness and behavioural barriers

Customer awareness and acceptance are considered essential elements in the renewable energy market, and can strongly affect demand. In developing countries in particular, the potential customer segments are unskilled because of a shortage of information about renewables [46,52,54]. A poor knowledge base and misinformation about the benefits of renewable technologies, however, are not only issues in developing countries but influence the deployment of DE technologies

Table 2
Overview of the analysed business models and related papers.

Business model	Related papers
Host-owned/Customer-owned/Host-owned feed-in/Customer-sited/End-user owner	[38,39,51,59,64,65,71–73,115]
Third-party-owned/Third-party/Third-parties/Third-party owner/Third-party ownership/Third party PV/Solar City model/Third-party financing/Solar services model/Solar energy management service model (solar EMS model)	[2,38,39,47,51,53,64,74–87,90,93]
Community-shared/Shared solar/Community solar/Community-owned model	[38,51,61,94–102,105,107]

more generally [48]. Behavioural barriers and concerns related to personal values and norms also strongly affect attitudes toward DE investments. People are usually risk-averse and do not recognize the exploitable benefits offered by renewable energy technologies alone [52,55,56].

We therefore conclude that market actors should take on an active role in the dissemination of information and the education of consumers. The widespread availability of information may result in higher awareness and acceptance.

4.3. Regulatory and institutional barriers

Most of these barriers are related to shortcomings of the legal framework, or government actions as well as energy and environmental policy [48,52,54,57,58]. Reductions in feed-in tariffs and the low price of electricity set by the government result in a longer payback period and increased liquidity risks for green technologies. When paired with the high initial investment costs, these form a serious barrier to the deployment of renewable technologies [48,59,60]. Taxation also has an inhibiting influence, as it is usually imposed on the basis of installed system capacity [50,61]. Ongoing changes in feed-in tariff reductions (e.g. low buy-back rates) and high levels of taxation lead to lack of long-term planning reliability [50,51,61]. Governments need to define appropriate purchase prices, eligibility period and type of incentives that fit local needs and endowments, to increase the appetite for DE investments. Dependable state activity would not only result in increased consumer investment but also attract attention from public and private investors [62]. It can be concluded that stable political factors are essential to cost-effective system operation, and governments therefore play an important role in the deployment of DE technologies.

4.4. Technological barriers

Grid reliability, stability and efficiency are all critical technological issues [63]. Increasing numbers of newly built DE facilities result in a higher network load, so grid capacity must be developed to ensure reliability. Capacity constraints that were initially designed to protect the grid from collapse and overload have therefore become a substantial barrier to further investment [50–52]. In developing regions such as South America or Asia, problems in security of supply are a significant challenge for local companies [49]. The risk of poor system performance can exert a strong negative influence on investment activity, because residential consumers are not able to realize their initial energy targets with inefficient systems [46,51].

Technology development is key in the DE market. These obstacles are not insurmountable, however, because development of unique local specialized solutions could overcome supply problems [52].

4.5. Company resource barriers

Lack of company competencies are seen in both industrialized and developing countries [49,52,55]. In recent years, utilities have faced significant changes in their business models and managers of these companies have identified competence shortage as a key barrier in the residential customer segment. Decades of experience in contracting with corporate customers does not really transfer to private customer segments [49]. Utilities also have to develop their product and service portfolio to create value for the residential segment and be competitive in the B2C market. Shortcomings in management and business skills make the situation worse in developing countries, where managers face lack of technical support, although these factors should be the keys to value creation and daily corporate operations [46,52,55].

5. Identifying basic PV business models

The papers on business models identified a new PV business model as well as the two better-known models (host-owned and third-party-owned): the spread of community-shared constructions. We examined the main characteristics of these models using the Business Model Canvas, assessing them from the perspective of the operating companies. The aim of this review is to provide an overall picture of the models and contribute to understanding of the concepts. The descriptions were divided into two, customer and infrastructure sides of the Business Model Canvas. The customer side includes value propositions, customer relationships, customer segments, channels and revenue streams, and the infrastructure side includes key partners, key activities, key resources and cost structure [6]. A summary of the business models examined, together with details of source papers, is in Table 2.

5.1. Host-owned business model canvas

The most widespread PV business model is host-owned, which is given a variety of names in the studies analysed. These include customer-owned [38,59], host-owned [51], host-owned feed-in [39], customer-sited [38], and end-user owner [64]. We use the term 'host-owned' for consistency. In the host-owned model, the owner of the building where the PV system is installed is the main user of the energy produced. An overview of the host-owned concept is shown in Table 3.

5.1.1. Customer side of the canvas

5.1.1.1. Value propositions. This section describes how companies create value for their target segments using the products and services offered. Firstly, these firms offer both pre-fixed, complex packages that contain specified elements (e.g. inverter, PV panels, cables) that cannot be modified by the customer, and non-pre-fixed packages. Non pre-set packages allow the customer to customize the system to fit their needs [38,51,59]. Installation is usually provided by the solar firms but some of them allow customers to arrange the installation of the system. Secondly, independence from utilities also appears in this part as customers become "prosumers" who produce their own energy and so reduce their energy bills [65].

Customers can also benefit from feed-in tariffs (FiTs), which can be a significant factor in investment decisions. The rates of FiTs provide a level of return of investment (ROI) that is competitive with other investment opportunities [66–68]. These tariffs can therefore greatly reduce investment risks and significantly promote the spread of renewables, so policy makers should carefully design and implement them [39,66]. Depending on the national regulations, residential customers may also enjoy tax benefits, get initial investment support or benefit from other special financial support programmes [51,64,69].

5.1.1.2. Customer Segments. This block defines the most important

Table 3
Host-owned Business Model Canvas.

Customer side	
Value propositions	• Pre-fixed packages • Non pre-fixed packages • Possibility of installing the system individually • Independence from utilities • Reduced energy bills • Benefit from feed-in tariffs • Reduced investment risk and competitive investment opportunity • Tax benefits • Initial investment support possibilities • Benefit from special financial support programmes
Customer relationships	• Direct interactions, personal relationships • Word of mouth • Online contact forms
Customer segments	• Homeowners • Farmers • Small and medium-sized enterprises
Channels	• Sales representatives • Different personal channels e.g. solar walks, multi-level marketing (MLM) • Company website
Revenue streams	• PV system installation • Maintenance • Reparation • Energy consulting • Sales of PV panels
Infrastructure side	
Key partners	• Producers of system components • Wholesalers of system components • Utilities • Banks
Key activities	• Turn-key solutions • Sales of PV panels • After-sales services • Customer support services • PV insurance service • Price bargaining • Supplier selection • Marketing activities
Key resources	• Technical knowledge • Human capital (e.g. expert staff) • Close knowledge of consumers • Close knowledge of local markets • Visibility of the company • Brand image
Cost structure	• Sales costs • Wages • Stock costs • Inventory holding and warehousing costs

customer groups that solar PV companies aim to reach and serve via the host-owned model. The studies analysed provide only a few umbrella terms about the target groups, and no detailed sub-segments are specified. One of the main groups is households with a suitable roof and enough money to invest in DE technologies [38,39]. The capacity of the installed system in the residential segment is up to approximately 10 kW_p [70]. Members of this group can be characterized as early adopters who are motivated by energy independence and environmental benefits [64]. This segment usually includes pioneer customers like solar PV engineers and committed environmentalists [51], but no other information is available about their lifestyles, social and family status, attitudes and further characteristics. Other customer segments for this model are farmers and small and medium-sized enterprises [39,71].

5.1.1.3. Customer relationships. Customer acceptance and behavioural barriers to renewable energy technologies mean a significant challenge for DE companies. Customer relationships therefore play an essential role in building trust and long-term relationships. Many firms interact directly with customers by using personal channels [38]. For instance, before creating a sales quote, a sales representative visits the customer's house to assess the roof space, sunshine potential, and customer preferences [38,59]. This section also covers online contact forms like corporate websites [39].

5.1.1.4. Channels. The identified channels are strongly related to customer relationships. The use of personal channels is a key area in trust-building and consumer engagement. Company sales representatives are the most essential channel elements as they make the first contact with customers [38,59]. This initial interaction can determine the whole relationship with the firm and the choice of quotation. A good example of use of personal channels is Hartmann Energietechnik GmbH's (HET) solar walks, which are held every month. During the walks, potential customers visit a number of reference houses with PV systems installed by HET [59]. Another useful practice that could be followed by companies operating in the DE market, and which is an excellent pattern for multilevel marketing, is SolarCity's Ambassador Program, where consumers can refer SolarCity to other people. If the recommended person purchases a PV system, the recommender can earn some money. Word-of-mouth communication also has a significant impact on consumers' investment decisions [72]. The use of company websites and special PV magazines are also essential channels, allowing the firm to inform potential customers about their product and service portfolio [39].

5.1.1.5. Revenue streams. In the host-owned model, the major source of revenues comes from PV system installation. Smaller amounts of income are also available through complementary services such as maintenance and repairs [39,59,73]. Companies can sometimes use their unique know-how through customized non-material value-added services such as energy consulting [39]. Finally, on rare occasions, PV panels may be sold directly to end customers without any supplementary services [64].

5.1.2. Infrastructure side of the Canvas

5.1.2.1. Key partners. The most important key partners of solar PV companies are producers and wholesalers of system components such as inverters and solar panels. These partners usually support firms with technical, marketing and project-specific knowledge [39]. It is essential to establish a stable relationship with them to ensure constant product supply and strengthen the bargaining position. Utilities also have a determinative role between the key partners as they provide permission to connect to the electrical grid. Many companies also liaise with banks offering financing services such as loans to their customers [39,64].

5.1.2.2. Key activities. In line with the full-service approach, most of the companies operating in the DE market offer turn-key product solutions. This means that they design the system, arrange the permits, order the components, install the system, monitor its performance and if necessary, carry out repairs and maintenance [39,59,73]. Some companies also sell PV panels or offer separate after-sales services such as system performance monitoring and repairs. These firms also generally provide advice on financing, support and incentive systems, taxation, and renewable energy solutions. Customer support services have also been identified between the key activities [38,39,64]. Some market actors offer PV insurance services, reducing the investment risk and increasing customers' sense of security [38]. Price bargaining and selection of suppliers are also included in this section, as PV companies procure solar system components from several producers and wholesalers [38,39]. Finally, firms often use different marketing activities to increase the company's reputation and strengthen customer relationships [64].

5.1.2.3. Key resources. Technical knowledge, expert staff and personal know-how are indispensable for DE companies [38,39]. Firms' human

capital therefore plays an important role in competitiveness and future prospects. Secondly, close knowledge of consumers and local markets, usually based on geographical proximity, is an essential resource, particularly for local companies who are in daily contact with customers and have a deeper insight into their lifestyles and preferences [39,59]. Company visibility, achieved through marketing and social activities, may have a strong influence on consumer interest [59]. These factors significantly contribute to brand-image building [64].

5.1.2.4. Cost structure. The papers analysed did not generally provide company-side costs, but certain conclusions can be drawn based on the other parts of the Business Model Canvas. Firstly, sales representatives play an important role in customer relationships and expert staff are indispensable for efficient operations. Sales costs and wages are therefore likely to be substantial elements of general expenses. Secondly, marketing expenditure related to partnership and brand image building could also constitute a significant proportion. Stock costs such as PV system components (e.g. inverters, panels, and holding devices.), inventory-holding and warehousing costs are also likely to be significant.

5.2. Third-party-owned Business Model Canvas

This type of business model was given several names in the literature, including Third-party [74], Third-parties [75], Third-party owner [64], Third-party ownership [39,51,74,76–84], Third-party-owned [53,85], Third party PV [38], Solar City model [51], Third-party financing [51,86,87], Solar services model [88], and Solar energy management service model (solar EMS model) [51]. For consistency, we use third-party-owned.

Third-party-owned business models first emerged in the United States in 2005 [89], and a variety of TPO models can now be observed in many countries e.g. in the Netherlands, Denmark, China, Germany [38,39,51,75]. In the United States, Sun Edison and MMA Renewable Ventures were among the first companies to apply this model, followed by many other developers [80]. These solar service firms usually offer Power Purchase Agreement (PPA) or lease constructions. The history of PPAs goes back much further than the TPO model, because it was originally used by utilities to buy energy from each other. The Public Utility Regulatory Policies Act (PURPA) of 1978 obliged utilities to purchase all their power from qualifying facilities. Utilities and independent generators (qualifying facilities) used PPAs for these transactions [74,80].

The TPO model eliminates several financial barriers such as high upfront costs for residential customers. Thanks to the many benefits provided by the model, the concept started to spread rapidly. In 2014, 72% of the residential solar systems in the United States were sold under PPA or lease constructions. However, by 2015, this rate began to decline and GTM Research predicts that by 2020, direct ownership will surpass third-party ownership in the US residential PV market [90]. This downturn can be traced back to three reasons: (1) availability of many types of loan facilities, (2) lack of suppliers for the TPO model, and (3) SolarCity's move away from this model [2].

This section describes the most important features common to TPO models. The Business Model Canvas can be seen in Table 4.

Table 4
Third party-owned Business Model Canvas.

Customer side	
Value propositions	• No up-front costs • Immediate energy savings (reduced energy bills) • Green energy at a very competitive price • Predictable cost of electricity • High transaction cost of handling, linked to complex regulatory and policy systems • Removal of operation and maintenance tasks • Reduced technology risks • Possibility of installing the system individually
Customer relationships	• Long-term relationships • Personal contacts • Online contact forms
Customer segments	• Households • Farmers • Companies • Public organizations • Institutional and private investors
Channels	• Sales representatives • Conferences and events • Online and printed marketing tools • Active media relations • Company website
Revenue streams	• Power Purchase Agreements • Solar lease • Subsidies, incentives from the government • State and federal incentives • Incentives offered by municipalities and local utilities • Federal tax benefits incl. renewable energy investment tax credit, and accelerated depreciation • Revenue from the sale of Renewable Energy Certificates • Development, monitoring and other service fees
Infrastructure side	
Key partners	• Banks, large corporations • Utilities • Producers and wholesalers of PV components • Consultants • Law firms • Insurance companies • Installation and maintenance companies
Key activities	• Provide lease or PPA • Fund management • Providing turn-key solutions • Taking permits, arranging interconnections with utilities and completing documentation for incentives and tax breaks • Sale of Renewable Energy Certificates • System operation, maintenance • Active marketing activities
Key resources	• Existing customer base • Project management software • Well-trained employees
Cost structure	• PPA and lease management costs (labour and IT) • Acquiring investors • Sales costs • Marketing costs • Stock and warehousing costs

5.2.1. Customer side of the Canvas

5.2.1.1. Value propositions. The financial and profitability barriers identified that high initial costs of PV systems can strongly influence demand. The biggest benefit of the TPO model is therefore that customers can use green energy without paying the upfront costs [51]. Electricity bill savings can be expected from the first month and customers do not have to worry about the long pay-back period [84]. In the third-party-owned model, host customers receive a green energy supply at a very competitive price, much lower than the normal electricity price [47,51]. The cost of electricity becomes predictable for the duration of the contract (up to 25 years), and the financing construction allows customers to avoid unpredictable price fluctuations from utility rates [39,91]. Strupeit and Palm [39] also emphasized that solar service firms can provide additional benefits to consumers as they are able to handle the high transaction cost linked with the complex regulatory and policy systems.

PPA contracts place the operation and maintenance responsibility on the solar service firm and not the customer [79,81,86,88]. For lease agreements, the host is responsible for the upkeep but solar lease companies usually offer maintenance packages and performance guarantees, reducing the number of tasks and the risks for the customer [74]. Customers may also be able to install the system themselves [38].

5.2.1.2. Customer relationships. In the third-party-owned business model, solar service firms build long-term relationships with their customers through PPA and lease contracts. It is therefore essential to build personal contacts and strengthen relationships with the hosts through multiple channels e.g. social activities, sales representatives, customer exhibitions, and enhanced customer service [39]. Use of online contact forms is also common [38].

5.2.1.3. Customer segments. In the TPO model, the most important customer segment is households who cannot afford to pay the high up-front costs but would like to reduce their electricity bills and protect the environment [38,39,51]. According to Drury et al. [47], third-party-owned constructions are attractive to younger, unqualified people who are less prosperous. Other customer segments are farmers, public organizations and companies [38,39,47]. Solar service firms also target public and private investors who become the technical owners of the PV systems and also benefit from PPA payments and government subsidies [64].

5.2.1.4. Channels. Like the host-owned model, company sales representatives are the most important channel components in TPO business models. Solar service firms use sales representatives to inform potential customers about the benefits of third-party solutions and strengthen relationships. Solar service firms often attend conferences and events (e.g. energy industry conferences, and exhibitions for consumers), and they can broaden their network by doing so. A variety of marketing tools (both printed and online) and active media relations are usually common across channels [64]. Company websites are also used to highlight attributes of products or services and to present forms of financing [38].

5.2.1.5. Revenue streams. The majority of the revenue is derived from PPA or solar lease solutions. Under a PPA contract, the host customer pays a bill calculated on the basis of generation per kWh (e.g. $/kWh) [51,53,87,88]. The duration of PPAs can vary from company to company, but they are generally valid for a 10–25 year period [64,74,87]. After the expiry date, the customer can choose from three options: buying the PV system, renewing the agreement or letting the PPA provider remove the system [74,82]. With a solar lease, the customer does not pay for the energy produced but leases the equipment and uses the energy generated by the PV system. This means monthly rental payments (e.g. $/month) [38,39,53]. The leasing solution is usually predominant in states in the US where PPAs are not permitted [81].

Solar service firms' other sources of income may include subsidies from the government, state and federal incentives, and incentives offered by municipalities and local utilities [84,85,92]. System owners can benefit from federal tax incentives—which tax-exempt units cannot—such as investment tax credit (ITC) and accelerated depreciation [77,78,83]. The ITC allows 30% of the total investment amount of PV systems to appear as a tax credit, while accelerated depreciation allows a complete depreciation during the first five years of the operation of the projects by offsetting income tax [82,83]. In those states in the US where the Renewable Portfolio Standard (RPS) is in force, which requires increased production of energy from renewable energy sources, solar service firms can generate additional revenue from the sale of Renewable Energy Certificates [93]. Last but not least, depending on the range of activities, development, monitoring and other service fees may also form part of revenue streams [38,51].

5.2.2. Infrastructure side of the canvas

5.2.2.1. Key partners. Banks and other large corporations may contribute to financing project funds, by subsidizing the solar service providers' PPA and lease business models. They play a decisive role between the key partners [51,64]. Like the host-owned model, relations with utilities, producers and wholesalers of PV components are also important under TPO models. Additional partners may include consultants, law firms, insurers, installers and maintenance companies [39,76].

5.2.2.2. Key activities. There is considerable variation in key activities in the TPO model category, but several are usually common for solar service companies. The most essential key activities are lease and PPA provision [39,51,53]. Companies that offer solar leases usually arrange financing by collecting several PV projects into a fund and selling this to investors. This requires fund management functions from the service firm to manage these processes [84]. Secondly, many companies offer turn-key solutions in the TPO model as well as the host-owned model. This implies that under the full-service concept, solar service firms install the PV systems, take the necessary permits, contact utilities to arrange interconnections and complete any applications for tax breaks and incentives [79,91]. In the US, these companies also usually sell Renewable Energy Certificates in several states [93].

Companies often offer additional services such as performance monitoring, maintenance, and repairs [38,47,51]. Active marketing activities are also observed, because many companies use a variety of media and other complementary channels [64].

5.2.2.3. Key resources. In the third-party-owned business model, the existing customer base plays a crucial role as a key resource that allows the companies to become even better known, broadening their network. The TPO model is associated with complex project management tasks, so it is essential for solar service firms to possess software for sales, project management, and system monitoring [39]. Well-trained employees with appropriate financial and technological expertise to operate this complex business model are also essential [38,64].

5.2.2.4. Cost structure. Like the host-owned model, few papers listed the main costs of this model, but we can draw some inferences from other parts of the Business Model Canvas. Firstly, the majority of the expenses are likely to be related to PPA and lease construction management, including the acquisition of public and private investors through labour and IT costs. There are significant differences between the TPO and host-owned models, but some expenditure is likely to be the same, including sales, marketing, stock (components of PV systems e.g. panels, inverters) and warehousing costs.

5.3. Community-shared Business Model Canvas

There were a number of terms used for this category in the papers, including Shared solar [94], Community solar [38,95–100], Community-shared [51,101,102], and Community-owned model [61]. We use the term 'community-shared'.

Community-shared business models are still in the early stages of development, and there were few dedicated studies. The information about this category was therefore scattered through the related literature. We have tried to provide an overall picture of the model, in the hope that this will contribute to understanding the differences between this and the host-owned and third-party-owned models.

In the United States, the first community-shared projects were completed in 2006, to enable consumers to access energy produced by the systems in solar parks or solar gardens, without installing their own photovoltaic panels [99]. The business model can be operated and administered by several different organizations, including utilities, non-profit organizations, and solar project developers [94,100,102]. Customers can subscribe to these projects and own PV panels in solar farms or gardens. For community members, the CS model therefore provides a cost-effective alternative enabling them to use renewable energy through virtual net-metering. The development of information and communication technologies allows the idea to spread, and knowledge mechanisms within the operator companies can strongly determine their ability to renew the firms' value proposition and collaborate with

Table 5
Community-shared Business Model Canvas.

Customer side	
Value propositions	• Use of green energy without hosting the PV system • Reduced electricity bill • Decreased financial barriers and costs • Flexibility
Customer relationships	• Personal relationships • Online contact forms
Customer segments	• Residential customers • Businesses • Commercial companies who lease their buildings • Non-profit organizations • Institutional consumers (e.g. universities, military)
Channels	• Conferences, meetings • Educational programmes • House parties, community events • Websites • Sales representatives
Revenue streams	• Sale of solar bonds • Upfront payments • State incentives • Tax incentives incl. renewable energy investment tax credit and accelerated depreciation
Infrastructure side	
Key partners	• Utilities • Subcontractors (e.g. construction company) • Producers and wholesalers
Key activities	• Subscriber management • Program management incl. customer protection, data reporting, regulatory compliance • Installation • System purchase • System operation and maintenance
Key resources	• Existing customer base • IT infrastructure • Workforce (incl. sales representatives)
Cost structure	• Initial infrastructure development • Operation and maintenance • Labour and IT costs

others [103].

The community-shared business model is an attractive opportunity for utilities, enabling them to realize economies of scale through larger projects [94]. This type of project therefore allows utilities to innovate their business models and could also mean the introduction of a new sales channel through which they can sell additional services [97]. Utilities may also be able to increase customer engagement and satisfaction [102]. Augustine [101] emphasized these possibilities and drew attention to potential challenges such as poor project economics. In regions where the electricity rates are low, a CS project may not be sufficiently profitable. Before starting a new CS program, utilities therefore have to make detailed returns calculations.

An overview of the CS concept is in Table 5.

5.3.1. Customer side of the Business Model Canvas

5.3.1.1. Value propositions. Many residents are not able to host a PV system on their own roof because of three main obstacles. They may not be the owners of the building (e.g. tenants), they may live in a condominium or there may be insufficient roof space or no suitable space (e.g. shaded or old roof) to install a system. Many people worry about system performance and efficiency, or simply do not want to install a PV system on their own roof [94,98]. In the United States, there may be other barriers to buying or leasing a private solar system, for example, that residential customers do not have a creditworthy FICO score and/or live in a state without a net energy metering policy. GTM Research therefore estimates that 77% of US households cannot install their own solar system, so could be potential customers for CS projects [104].

The community-shared model enables customers to use green energy without hosting the system through virtual net-metering, reducing their electricity bills [105]. CS model subscribers receive a credit on their energy bills corresponding to their interest in the PV system's power generation [102]. CS also decreases the financial barriers and reduces PV system costs for customers because of group purchasing [51]. The contract subscriptions usually last from five to 20 years. This model therefore offers an attractive long-term saving option with low risk. Flexibility is also an essential part of the model. If consumers sell their house, they have two optional opportunities. They could sell the subscription, either with the property or separately [61]. If they do not want to sell their bonds, and they move within the service territory, the solar credits can follow them [106]. This business model also contributes to customer commitment to renewable energy sources.

5.3.1.2. Customer relationships. As with host-owned and third-party owned models, forming and maintaining personal relationships are essential to the successful operation of this business model. Solar service providers make long-term contracts with customers (up to 20 years), so need to make contact in various ways, such as customer exhibitions, community events and meetings as well as online channels to increase confidence and commitment [38,96]. Research about community-shared business models is rare, but it seems likely that firms will expand their client network by employing sales representatives.

5.3.1.3. Customer segments. Depending on the regulatory framework, several consumer groups may be included in the customer segments for this model. One of the main groups is residential customers facing the obstacles described in the value propositions section (e.g. renters). Businesses, commercial companies who lease their buildings, and non-profit organizations e.g. religious organizations, are also targeted by solar owners and developers [51,61,95]. Additional subscriber groups include institutional consumers such as local governments, universities and the military [51,61,94].

5.3.1.4. Channels. Community-shared business models are in an early phase of development, so continuous learning and sharing of information play an essential function in determining the deployment of these constructions. Project operators may arrange conferences, meetings, educational programmes, house parties, and community events and also use websites to share their knowledge among consumers and potential investors [38,96]. Sales representatives of solar service providers may also provide much of the foundation for corporate success [96].

5.3.1.5. Revenue streams. The CS model provides two basic forms of revenue from consumers. Firstly, customers can purchase a portion of the power produced by the solar parks or gardens, so most of the owners' revenue is derived from the sale of solar bonds [61]. The price of the shares is generally adjusted to fit government-imposed tax rates [38]. Secondly, customers can pay an upfront fee to defray all the costs of the project. Some projects use a combination of the two payment options [99].

Depending on the regulatory framework, solar project operators in the US can also benefit from federal tax benefits and state incentives. Federal tax incentives are available for individually-owned residential system installations or for commercially-owned projects. However, community-owned systems do not fit into either of these two categories, which generates challenges in designing these projects [106]. Augustine [101] also noted this when examining the possibilities of CS projects for public utilities and pointed out that municipalities and regulated utilities tend not to have a tax liability. When a utility wants to take advantage of tax incentives, therefore, including the renewable energy investment tax credit and accelerated depreciation, it usually has to contract with a third party entitled to receive the tax benefits [101]. To use federal tax reliefs in full, the entity that owns and

operates the infrastructure needs to have an adequate number of community subscribers [106].

5.3.2. Infrastructure side of the Business Model Canvas

5.3.2.1. Key partners. Firstly, the subscribers must be customers of the local utility in which the solar farm is located. Secondly, by applying virtual net-metering in CS projects, the amount of generated electricity must be synchronized with utilities' billing systems to adjust the customers' accounts suitably [106]. Solar project operators therefore need to develop close relationship with utilities. If the service providers also arrange the construction of the infrastructure, they must collaborate with additional partners such as subcontractors, producers and wholesalers [96].

5.3.2.2. Key activities. Solar farm or solar garden owners offer different subscription options (purchasing or leasing panels, investing in systems, buying energy or capacity), so their main activity is subscriber management [51,101,102] This process involves signing up customers and liaising with them. Further tasks will include consumer protection, data reporting and regulatory compliance [107].

The infrastructure is usually installed by these companies, but in some cases they just take over the finished PV systems. This model places operational and maintenance responsibility on the service provider [61].

5.3.2.3. Key resources. Like the third-party-owned model, the existing customer base is an essential key resource in CS models, as it enables companies to gain more clients and may lead to further investments. To manage community projects successfully, and synchronize data with utilities' systems, service providers must possess adequate IT infrastructure [106], including suitable software solutions to monitor energy generated in real-time and manage subscriber contracts [101]. Another indispensable element is the workforce, including sales representatives, who contribute to network expansion and the management of complexity [96].

5.3.2.4. Cost structure. The papers included no detailed information about the CS model's cost structure, but we can draw some conclusions from the other sections, as with the previous models.

Firstly, if the initial installation investments are not funded by the community, the development of the infrastructure will have considerable costs. There are a number of examples where future subscribers pay the up-front costs, such as Briston Energy Solar (BES). BES sold shares (between £250 and £20,000) to individuals to raise money for the project. The initiative was so successful that the required amount was collected within three weeks, with 103 non-corporate contributors [61]. Secondly, a significant part of the costs are probably related to PV system operation and maintenance tasks. Subscriber management costs such as labour and IT costs are also likely to feature, because this is an essential activity of service providers. IT costs therefore play an essential role because of the management tasks, but also because of the complex software needed to harmonise the utilities' billing system with the amount of energy produced.

6. Synthesizing business models by applying the Lean Canvas

We used the Lean Canvas framework to identify the major differences between the three models, highlight the main reasons behind the appearance of the community-shared business model, describe its benefits in comparison with the other models and identify the problems it addresses (Table 6).

The LC is filled in a particular order: 1. Customer segments, 2. Problem, 3. Unique Value Proposition, 4. Solution, 5. Channels, 6. Revenue Streams, 7. Cost structure, 8. Key metrics, and 9. Unfair advantage. We used yellow for the host-owned model, green for the third-party-owned model and blue for both. Contributions from the CS model are shown in orange.

Firstly, customer segments must be determined for each model to assess which groups may be attracted by the community-shared model. The main segment in the host-owned solution is the so-called "green mass market", containing early adopters with a high level of income. In the TPO model, younger, unqualified and less affluent people are the major target groups. The community-shared model may also be attractive to early adopters and less prosperous people, since the former are usually the first users of new, innovative solutions and the latter cannot afford to pay the high initial investment costs.

Secondly, identifying the main problems of the host-owned and third-party models creates the initial phase of the analysis and can lead to appropriate solutions. The high upfront cost of the investments and a degree of technological risk are the major barriers for potential consumers of the host-owned model. Consumers also need to own a building with sufficient roof space for both the host-owned and third-party-owned models. However, many clients of solar providers do not own a property or have a suitable roof, because they are renters or live in a multi-unit house. Concerns about aesthetic issues may also be a problem.

The unique value proposition's function is to capture customers' attention. In the CS model, the most compelling factors are flexibility, subscription opportunities and reduced costs. As consumers do not have to pay the high upfront costs, and agreements are easily terminable or modifiable, the value is organized around these aspects.

The fourth step is to outline responses to the problems highlighted that are provided by the community-owned model. Through virtual net-metering, the CS model allows consumers to subscribe to a specified number of panels or a portion of the energy generated in solar parks. Clients receive credits on their utility bills. The solution therefore significantly reduces the barriers and provides several concessions to customers.

The fifth step is to examine the channels specified in the BMC. A solar ambassador program (from the host-owned model) could also be used successfully in community-shared business model solutions, attracting more consumers. The revenue streams and cost structures are not described here, because they were fully covered in previous sections.

Key metrics require companies to define actionable metrics, which should be organized around the value. In the initial stages, less complex indicators such as market coverage, or number of consumers, may be sufficient to lead to the fundamental engines of growth.

Finally, unfair advantage, also known as competitive advantage, describes barriers to entry for others. Unlike the host-owned and third-party-owned models, CS model customers are not required to make a firm commitment, because the model offers significant flexibility via transferable solar bonds.

7. Overcoming the identified barriers

This section provides some examples from the papers reviewed of how and to what extent the different PV business models help to overcome the barriers identified. In Table 7, one star is shown if the business model can partially help, and two if it can provide significant help in overcoming the barrier group. Where no star is shown, the model cannot help to overcome that barrier group.

None of the models help to address company resource barriers, because they do not affect management skills. Instead, specific management tools and business model solutions are needed. However, the alternative models address several of the issues and barriers in the other groups.

Third-party-owned and community-shared models mean consumers do not have to meet high upfront costs, significantly reducing financial and profitability barriers. In the CS model, solar bonds can be transferable, offering more financial flexibility. In the United States, customers need a creditworthy FICO score to buy or lease a solar system, but

Table 6
Business model synthesis and development to overcome the inhibiting factors of distributed energy deployment (Lean Canvas).

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer Segments
High initial costs	Solar parks	Flexibility	Transferable bonds	Green mass market
Technology risk	Subscription options	Subscription	Not necessary to commit	Younger, less educated people
Need for own roof (Property)	Virtual net-metering	Reduced costs		Renters
	Key Metrics		**Channels**	
Multi-unit housing	Market coverage		Conferences, meetings	Condominium residents
Aesthetic concerns	Number of consumers		Websites	
			Sales representatives	
			Ambassadors	

Cost Structure		Revenue Streams	
Initial infrastructure development	Labour and IT	Sale of solar bonds	State incentives
Operation and maintenance		Tax benefits	Upfront payments

Colour legend: yellow: host-owned, green: third-party-owned, blue: host-owned and third-party-owned, orange: community-shared model.

Table 7
Possible barrier elimination opportunities.

Main barriers	Host-owned	Third-party-owned	Community-shared
Financial and profitability barriers		*	**
Awareness and behavioural barriers		*	**
Regulatory and institutional barriers			*
Technological barriers		*	**
Company resource barriers			

the CS model allows them to use solar energy without such a FICO score. Overall, both the TPO and CS models can significantly reduce financial barriers, but the CS model provides more opportunities to do so.

TPO and CS actors often take on an active role in education and disseminating information, reducing awareness problems. The possession of information results in a lower risk perception and allows customers to identify the potential benefits of the different business models and the use of renewable energy sources. Karakaya et al. [108], drawing on Rogers [109], also emphasized that active communication and the activities of change agents can greatly increase the adoption of new technologies including PV systems. Work by Rai et al. [110] also confirmed this for the decision-making process of residential PV customers. Members of the community, especially in the CS model, also contribute to the reduction of acceptance difficulties because they assume a key role in knowledge transfer. The strength of the community can be exploited not only in the community-shared model, but also others, as shown by SolarCity's ambassador program.

Regulatory and institutional barriers can only be slightly overcome with the help of the existing business models. A variety of external factors may influence regulatory requirements. However, in states and regions without a net energy metering policy, the CS model may help consumers to use solar energy.

Table 8
Value creation, delivery and capture of PV business models.

Value	Host-owned	Third-party-owned	Community-shared
Proposition	Turn-key solutions Independence from utilities Feed-in tariffs (Negative: high up-front costs) Reduced energy bills	Lower and predictable electricity price No up-front costs No operational and maintenance responsibility[a]	Use of green energy without hosting the PV system Decreased financial barriers and costs Flexibility
Creation	Maintenance PV insurance Energy consulting PV system installation	Lease and PPA provision Fund management Performance monitoring, maintenance, and repairs	Subscriber management Program management incl. customer protection, data reporting, regulatory compliance Installation System purchase System operation and maintenance
Delivery	Solar walks Multi-level marketing Word-of-mouth marketing Sales force Websites	Online and printed marketing tools Active media relations Conferences, events, meetings	Educational programmes House parties Community events
Capture	Selling turn-key solutions (margin)	Power Purchase Agreements or solar lease solution fees (margin) Subsidies from the government, state and federal incentives, and incentives offered by municipalities and local utilities	Sale of solar bonds Upfront payments State incentives Tax incentives incl. renewable-energy investment tax credit and accelerated depreciation

[a] For the TPO model, this applies to PPAs.

In Power Purchase Agreements (the TPO model) and community-shared projects, companies take responsibility for maintenance, reducing the technological barriers for customers. In solar leasing (the TPO model), the operating company does not always assume responsibility for maintenance, so the CS model will provide a higher degree of barrier elimination potential. The transferred responsibility means that customers do not have to worry about the risk of poor system performance.

8. Summary and conclusions

We have used a literature review to highlight the most common barriers hindering the deployment of renewable energy technologies, and also identified the basic PV business models. Using Osterwalder and Pigneur's [6] business model definition, we summarized each business model's most important value propositions, value creation, delivery and capture mechanisms in Table 8. Reduced energy bills are common to all three models, but the degree of savings may be different for each. Determining whether the investment is better under the host-owned or the TPO model very much depends on the financing solution and the amount of support available.

Overall, it can be seen that the greatest benefits can be identified for the community-owned model. The biggest advantage of the CS model is the possible economies of scale. It also allows companies to use the latest technology solutions and take into account the territorial conditions to designate the most optimal solar installation areas with the highest potential efficiency and energy output (exploiting location benefits).

We also outlined how and to what extent the different business models can help eliminate the identified barriers. The literature review showed that the spread of renewables can be significantly restricted by regulatory and institutional issues, and the identified business models provide only a limited response to these problems. Policy-makers therefore need to develop comprehensive regulatory and incentive schemes that provide multiple options to foster the spread of renewable energy sources. Financing mechanisms and innovative business models that fit local or regional circumstances could significantly increase the use of renewables.

Despite this, the community-owned model is a good opportunity for utilities to innovate their business model and increase their competitiveness. They will, however, have to take into account a number of factors during the development of CS projects. Successful implementation will require utilities to review their strategic assets and key competences [111]. They will have to invest in high productivity and high absorptive capacity to gain sustainable competitive advantage [112]. To take advantage of tax incentives, they will need to build strong and lasting partnerships with third parties who are entitled to these tax benefits. Overall, however, the community-owned model can generate significant benefits in many areas, and trends such as increasing digitization and the rise of the sharing economy are also expected to support the further development of this model [113,114].

9. Future research directions

Reduction of barriers would justify the wider diffusion of TPO and CS models, but these solutions have not yet been adopted in many countries. It may therefore be worth examining the reasons for this on a national basis. There are few studies on the community-shared model, implying a lower knowledge base. Future research in this field could close this gap and help regions and countries with easier business model adoption. The Lean Canvas summary in this review may serve as a starting point for prospective studies that accentuate the differences between the three models and help to identify and create new models. To simplify the adoption process, the investor side of PV businesses could also be examined using the Business Model Canvas and the Lean Canvas.

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Appendix: List of abbreviations

BMC	**Business Model Canvas**
CS	**Community-shared**
DE	**Distributed energy**
FiT	**Feed-in tariff**
kW_p	**Kilowatt peak**
LC	**Lean Canvas**
PPA	**Power Purchase Agreement**
PV	**Photovoltaic(s)**
ROI	**Return on Investment**
RPS	**Renewable Portfolio Standard**
TPO	**Third-party-owned**

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