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Exploration of Funding Models for Residential Solar Photovoltaic Adoption in the United Kingdom: Systematic Review

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Abstract

Renewable energy is a central component of global sustainable energy development, with solar energy experiencing substantial growth over recent decades. Solar power is widely regarded as one of the most accessible routes to clean energy generation. However, high upfront costs remain a major barrier to adoption. Many potential users are reluctant to invest in solar photovoltaic (PV) systems because of the longer payback period. To address this financial constraint, a range of business models has been developed. This study used a systematic literature review to examine existing and emerging business models for promoting Solar PV solutions. The review included peer-reviewed journal articles published in English from 2020 to 2026. In total, 39 articles were critically evaluated considering their characteristics. Nine potential business models were identified, several of which are commonly used internationally and have shown positive results that could also be applied in the UK. Importantly, Community Energy Models have shown success in Europe, Sub-Saharan and Asian regions. This has been widely supported by the government due to sustainability and climate change targets. The UK has set their target to achieve net-zero in greenhouse gas emissions by 2050. Beyond financial barriers, reliance on weather conditions and the mismatch between energy demand and supply remain substantial barriers to wider solar PV deployment.

Keywords: business models; energy; financial models; funding models; renewables

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1. Introduction

The UK can be identified as one of the most ambitious nations in the world, which has aimed to achieve net-zero emissions by 2050. The Climate Change Act 2008, which was amended in 2019, has legally bound the UK government to achieve this goal [1]. To achieve this target, the UK has to gradually reduce its greenhouse gas emissions. Greenhouse gases are the main contributors to global warming and air pollution. During the Industrial Revolution, the UK was the main country that emitted the highest quantity of CO_2 to the environment [2]. In 1850, towards the end of the Industrial Revolution, the UK emitted 122.4 $MtCO_2$, while the USA ranked second with 19.79 $MtCO_2$. With the Industrial Revolution, machines were invented to produce goods and services for human

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use. Most machinery was powered by fossil fuels. While generating power and energy for the machines, carbon dioxide and other greenhouse gases were released into the environment [3]. However, the value of taking necessary actions has been identified, and recovery mechanisms have been launched to a certain extent. One of the major solutions was generating energy using renewable energy sources.

According to Figure 1, 71% of the electricity requirements have been generated using renewable energy sources, and the rest has been generated using fossil fuel (29%) in the UK during the year 2024 [4]. The UK has shown progress by reducing emissions by 50.4% in 2024 compared to 1990 [5]. In the current energy mix, wind has contributed 32.3% (9.86 GW), after 12.7% (3.89 GW) by nuclear, and solar has supported the grid by 6.7% (2.06 GW) [5]. Among the above-mentioned energy types, generating electricity using solar has become one of the blooming industries. This is significantly advanced in technical terms, which will support achieving the net-zero emission target in the year 2050 [6].

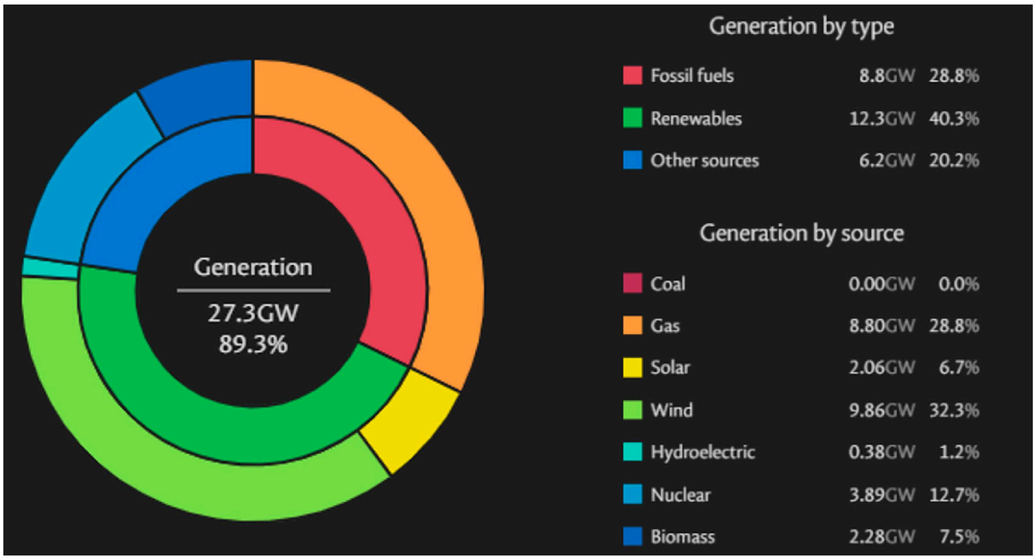

Figure 1. Current electricity generation mix in the UK as of 2024 [4].

According to the solar road map introduced by the UK government, solar energy is going to play a leading role in making the UK an emission-free country. It is considered one of the cheapest ways to ensure energy security in the country. This is going to be the best time to enhance the solar PV coverage of the country, since more than 1.5 million UK homes have already installed solar PV solutions [7]. The UK government intends to add 3 GW to the supply, which is three times more than the last 14 years combined [7]. Comparatively, the costs of the solar instruments are reducing gradually. These two can be taken as positive approaches and can be used to market the solar products among the people [8]. Currently, the UK relies on fossil fuels for 29% of its power generation. This forces the country to import gas, and that is one of the key expenditures in the balance sheet [9]. Latest solar PV systems can generate electricity for domestic use, and the latest systems are upgraded with Lithium-ion batteries, which can be used as decentralised units [10]. Additionally, advances in solar photovoltaic technology have significantly reduced installation and maintenance costs, making solar increasingly affordable [11]. Solar panels can reduce electricity costs and offer long-term financial savings for both homes and businesses.

At the national level, solar energy investment boosts local economies, encourages the creation of green jobs, and lowers public spending on fossil fuel imports. Rising energy costs are one of the major concerns about fuel poverty in the country. Solar power can reduce the energy cost of homes by self-consumption of electricity on average by around 26%, and in some cases up to 41% [12]. Solar energy is highly scalable from a small home to a large solar farm. It is also easy to implement compared to other renewable energy solutions. Another positive aspect of solar energy is that it can be installed in existing buildings and on any type of land. The importance of solar energy in the UK national energy supply has been recognised by the UK government's plan for energy security 2013 [13].

However, there are criticisms of the solar energy industry. One of the main points is weather dependency. Generating electricity is highly dependent on the sunlight, which can lead to low output in the winter months, when typically the electricity demand is the highest [14]. The UK is one of the countries which has low daylight and a cloudy sky. Although Germany has the same weather conditions, they have generated 16.2 GW in 2024. Two-thirds of the electricity had been generated through rooftop solar PV solutions, and most of the systems were battery combined systems [15].

Another major criticism concerns the higher upfront cost of the solar panels and inverters [16,17]. This is particularly challenging for lower-income households, which often lack the financial capacity to cover the initial investment despite potential long-term savings [18]. As a result, many households compare these systems with conventional energy sources and perceive them as more expensive in the short term, even if they offer savings over time [19]. In addition, relatively long payback periods, ranging from 5 to 10 to 20–25 years, may act as a barrier due to concerns over technological obsolescence and uncertainty surrounding the long-term consistency of government policies and financial returns [20,21].

The UK government has waived the 20% Value Added Tax (VAT) for solar-related instruments until 2027. After that, only 5% will be charged as VAT. This will offer significant concessions to potential customers [17]. Apart from that, there are government-supported programmes launched in the UK to promote solar PV solutions. One of them is Smart Export Guarantee (SEG) [18]. This scheme obliges the large-scale energy suppliers to pay homeowners for the surplus electricity that they export to the grid, generated by the solar PV systems. These payment tariffs vary from each supplier. The government has waived the 20% VAT for the solar PV equipment till 2027, which is a considerable concession for the customers [19]. Energy Company Obligation (ECO4) was a grant for vulnerable homes to improve their energy efficiency standards, including the installation of solar panels [9]. Another plan which has similar features is the Warm Homes Plan [20]. This will run from 2025 to 2028. The grant expects to retrofit 5 million houses up to £30,000 for each house, and the objective is to reduce fuel poverty and carbon emissions. Renewable energy installations can be part of these upgrades.

Although there are supportive programmes and concessions, only 1.5 million UK homes have installed solar PV solutions, and there are an estimated 30.4 million households in the UK as of 2023 [21]. There are practical reasons behind this decline; the high upfront cost has led homeowners to step back from the decision without significant government grants [22]. Weather and sunlight limitations are two primary requirements for solar electricity generation. The UK has a significant rental market, where tenants do not have the authority to install solar, while landlords hesitate to do so because they do not benefit from savings on electricity bills [23]. Policy inconsistency and reduced incentives are also crucial points. The withdrawal of FiT has diminished the initial financial attractiveness [24], and policies themselves undergo frequent changes, leading to a lack of trust in long-term regulatory stability [25]. The UK's housing stock is considered the oldest and leakiest in Europe, due to a lack of bearing capacity and the need for proper orientation before solar panel installation, which adds an extra cost [25]. Some UK residents do not want to disrupt their daily routine and consider it a practical reason to decline new additions to their homes [25].

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This means there is more than enough room for renewable energy, and more encouragement should be introduced to enhance solar adoption. This highlights the requirement of a proper business model to encourage the potential customer segment. When developing a sustainable business model, sustainable value capture, sustainable value proposition, sustainable value creation, and sustainable value delivery should be considered. A sustainable business model should be technologically, socially and organisationally sustainable [22].

There are several parties included in a business model. Main parties are solar PV installation companies, customers, equipment suppliers and manufacturers, finance providers, grid operators, energy suppliers, the government and regulatory bodies [23]. A solar PV installation company has the responsibility of system design, installation, commissioning, maintenance, and revenue generation through sales. The customers create the demand and provide revenue through installation or long-term contracts. Manufacturing solar panels, inverters, and required electrical components is the responsibility of the manufacturer. Providing required capital for the projects and adjusting them for the convenience of the customer is the responsibility of the financing institution. Grid connection approvals and payments for the supplied electricity are done by the grid operator and the energy supplier. Implementing policies and regulating all these parties is done by the government and the regulatory bodies.

Different countries have introduced their own policies and strategies to promote renewable energy generation. Some countries have developed their own business models and implemented them in a particular area, a particular segment or covering the whole country. Some countries have introduced the same model with almost the same features. For example, the renewable energy community model has been tested and practised in Italy [24], Belgium [25], Indonesia [26], Denmark [27], and Latvia [28], and is widely reported in the literature as a successful decentralised energy model. In Italy, this model has demonstrated an internal rate of return (IRR) greater than 11% [24]. In Belgium, reported findings indicate a reduction in annual electricity costs by 10–26% [25]. Other than the financial benefits, there are environmental benefits, such as a reduction of greenhouse gas by 45% in Italy [24], while in Belgium, the results have shown emission reduction in 5–13% [25].

The policy implementation of the UK government reflects the ambition of the government to achieve net-zero emission targets. There are government-supported programmes in the UK to boost renewable energy and reduce fuel poverty in the country, such as the Smart Export Guarantee (SEG) [29], VAT relief on solar-related instruments, Energy company obligation (ECO4), Warm Home Plan and Green Home Grant [29]. Energy providers have introduced attractive packages for customers to install solar PV, such as on-billing financing [30], Virtual Power Plants Model [31], Peer-to-Peer (P2P) trading [32] and Smart Energy Apps. However, only 1.5 million households installed solar out of over 30 million households [7].

Despite the UK's strong policy commitment, latest technology and various types of financial support programmes, the spread of solar technology is comparatively low when considering the overall housing stock. This gap shows that technological readiness and policy incentives alone are not enough to achieve widespread solar adoption. There is a clear requirement for research to systematically explore how to design a business model, funding mechanisms, incentive programmes, and stakeholder requirements, and to identify methods that simplify the financial barriers, distribute the risk and reduce the risk, and enhance customer engagement. This study expects to find the key characteristics of the business models for the renewable energy market by way of a systematic literature review.

2. Materials and Methods

2.1. Search Strategy

A systematic literature review has been used as the research methodology of this study. The bias involved in the qualitative research method can be reduced when using the systematic literature review method. A step-by-step process is followed in the process of this review; rather than being subject to the researcher's worldview; the findings are objective and consistent. The PRISMA 2020 statement [33] has been used as the reporting guideline of this study (Supplementary Materials). Additionally, the approaches used by Panakaduwa et al. (2025) and Mendis et al. (2023) were referred to as guidance [34,35].

After the keywords were identified as Business Models, Financial Models, Funding Models, Renewables, and Energy, Boolean logic was used to develop the search string.

> "TITLE-ABS-KEY (business AND model* AND renewable* AND Energ*) OR TITLE-ABS-KEY (financial AND model* AND renewable* AND Energ*) OR TITLE-ABS-KEY (funding AND model* AND renewable* AND Energ*) AND PUBYEAR > 2020 AND PUBYEAR < 2026"

Using predefined inclusion and exclusion criteria, a systematic search was conducted across three databases, namely Scopus, Web of Science, ProQuest, using a consistent search string. These databases were selected due to their broad coverage of peer-reviewed, high-quality scholarly literature and their strong indexing of multidisciplinary research relevant to the study topic. The searches were carried out on 20 December 2025.

The search was limited to English-language publications to ensure consistency in interpretation and analysis, given resource constraints for translation. Only peer-reviewed journal articles were included to ensure methodological rigour and academic quality. The publication period was restricted to 2020–2026 to capture the most recent and relevant evidence, reflecting current developments in the field. All other records that did not meet these criteria were excluded from the review.

2.2. Selection of Articles

Figure 2 displays the selection of the articles for the systematic review. Study selection was carried out systematically and reported in accordance with the PRISMA 2020 statement [33]. There were 1210 articles in Scopus, 2125 in Web of Science and 506 in ProQuest. Duplicates were removed before the initial screening. Then the primary screening was done using the title, abstract and keywords. After retrieving and assessing the eligibility, 39 articles were selected for the study. The corresponding author first screened the publications, and the co-authors independently verified the articles that were chosen. There was no usage of automation tools.

Using the keywords and their synonyms, the corresponding author reviewed the articles for the data to be taken for this article. Table 1 with three columns was created with the headings of level of responsibility, ownership structure and delivery method. By going through the table, the co-authors reviewed and validated the data and the articles which were selected for the study. Automation tools have not been used.

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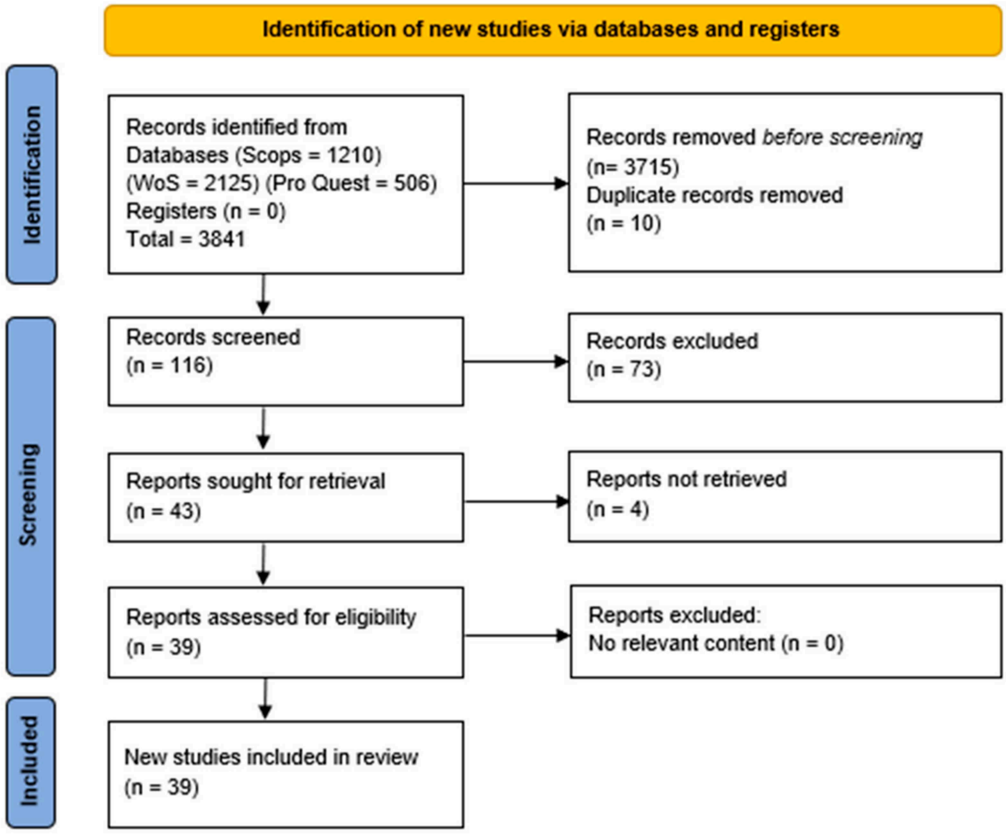

Figure 2. Study selection.

2.3. Data Items

The selected and included 39 articles are shown in Table 1. To determine which records qualified for each synthesis, a qualitative thematic analysis was applied. The compiled information was ordered into respective themes and shown in the Discussion Section. The respective articles and references are organised in tables according to each theme. When considering the nature of qualitative data, the synthesis of missing data can be considered very low. Additionally, analysis of data has been discussed, using academic literature and also the available grey literature to minimise biased results.

Table 1. Articles included in the review.

No.	Study	Year	Authors	Title	Journal	Research Area	Country	Methods
1	[24]	2021	Cielo et al.	Renewable Energy Communities business models under the 2020 Italian regulation	Journal of Cleaner Production	Renewable Energy	Italy	The renewable energy community (REC) case study
2	[22]	2022	Samborski, A.	The Energy Company Business Model and the European Green Deal	Energies	Energy efficiency	Poland	Qualitative case study
3	[31]	2025	Papapostolou et al.	Innovative Business Models Towards Sustainable Energy Development: Assessing Benefits, Risks, and Optimal Approaches of Blockchain Exploitation in the Energy Transition	Energies	Energy efficiency	Europe	Literature reviews and real-life case studies
4	[25]	2022	Felice et al.	Renewable energy communities: Do they have a business case in Flanders?	Applied Energy	Energy efficiency	Belgium	Case study and scenario analysis
5	[36]	2024	Sułek et al.	Business Models on the Energy Market in the Era of a Low-Emission Economy	Energies	Energy Efficiency	Poland	Comprehensive literature review
6	[37]	2021	Rajshree, B. & Shah, S.	Solar photovoltaic energy in India: business feasibility study and analogy of policies	International Journal of Energy and Water Resources	Solar PV installation	India	Literature review
7	[38]	2022	Hu, B. Zhou, P. & Zhang, L. P.	A digital business model for accelerating distributed renewable energy expansion in rural China	Applied Energy	Solar PV Fishery and digital inclusion	China	Single-case analysis of a business model
8	[39]	2021	Monsberger, C. & Fina, B., Auer, H.	Profitability of Energy Supply Contracting (ESC)and energy sharing concepts in a neighbourhood energy community: Business cases for Austria	Energies	Energy efficiency with solar PV and heat pumps.	Austria	Case study approach
9	[32]	2022	Xia-Bauer et al.	Business Model Innovations for Renewable Energy Prosumer Development in Germany	Sustainability	Sustainable energy transition	Germany	Literature review and primary data
10	[40]	2022	Botelho et al.	Prosumer integration into the Brazilian energy sector: An overview of innovative business models and regulatory challenges	Energy Policy	Policy recommendations for the energy sector	Brazil	Literature and secondary data
11	[26]	2023	Erdiwansyah et al.	The Business Model for Access to Affordable RE on Economic, Social, and Environmental Value: A Review	Geomatics and environmental engineering	Business models for renewable energy	Indonesia and Africa	Systematic literature review
12	[41]	2021	Isaza et al.	Photovoltaic power purchase agreement valuation under real options approach	Renewable Energy Focus	Renewable power purchase agreements	Colombia	Existing literature and case study
13	[42]	2021	Plewnia, F. & Günther, E.	The Transition Value of Business Models for a Sustainable Energy System: The Case of Virtual Peer-to-Peer Energy Communities	Sage -Organisation & Environment	Peer-to-peer energy (p2p) communities, procedures and platforms	Germany	Case studies and expert interviews
14	[43]	2021	Yu et al.	Research on Decision-Making for a Photovoltaic Power Generation Business Model under Integrated Energy Services	Energies	PV microgrid power generation and integrated energy services	China	Fuzzy mathematical theory and grey system theory
15	[44]	2022	Heirani et al.	A Business Model for Developing Distributed Photovoltaic Systems in Iran	Sustainability	Solar PV installations	Iran	Literature review and primary data

Table 1. *Cont.*

No.	Study	Year	Authors	Title	Journal	Research Area	Country	Methods
16	[45]	2023	Laur, I. & Berntzen, L.	Opposing forces of business model innovation in the renewable energy sector: Alternative patterns and strategies	Entrepreneurship and Innovation	Electrical Sector	Scandinavia, Sweden and Norway	Case studies and interviews
17	[46]	2024	Taranova, I. & Uzdenova, F.	Green Economy And Sustainable Development: Transforming Traditional Business Models	Green economy and sustainability	Green Economy	Europe	Case Studies, semi-structured interviews with experts
18	[47]	2022	Brzoska et al.	Antecedents of Creating Business Models in the Field of Renewable Energy Based on the Concept of the New Age of Innovation	Energies	Photovoltaic and biogas energy	Poland	Case studies and existing literature
19	[48]	2021	Schaefer, J. L. & Mairesse Siluk, J. C. M.	An algorithm-based approach to map the global players' network for photovoltaic energy businesses	Sustainable Energy Planning and Management	Solar PV business from a global perspective	Global	Systematic Literature Review with PRISMA and PESTEL
20	[49]	2024	de Leon, J. A., Tan, R. R. & Billones, R. K.	Multi-Objective Linear Programming for Optimizing a Local Energy Community DC Microgrid System and Business Model	IEEE Access	Solar installation	Philippines	Case study and Multi-Objective Linear Programming (MOLP)
21	[50]	2024	Strupeit, L. Bocken, N. & Van Opstal, W.	Towards a Circular Solar Power Sector: Experience with a Support Framework for Business Model Innovation	Circular Economy and Sustainability	Solar PV installation	Europe	Mixed method research
22	[51]	2021	Kamp et al.	The dynamic business model framework-illustrated with renewable energy company cases from Indonesia	Technology, Market and Complexity	Business models and their dynamics	Indonesia	Literature review and conceptual framework development
23	[30]	2023	Marques et al.	Categorizing shared photovoltaic business models in renewable markets: An approach based on CANVAS and transaction costs	Energy Reports	Business models related to the solar PV business	Brazil and India	Case study analysis
24	[52]	2024	De Tommasi et al.	Analysis of business models for delivering energy efficiency through smart energy services to the European commercial rented sector	Open Research Europe	Smart energy service in the commercial rented sector	Europe	Participatory Research
25	[53]	2021	Karami, M. & Madlener, R.,	Business model innovation for the energy market: Joint value creation for electricity retailers and their customers	Energy Research & Social Science	Low-carbon emission and business models	Europe	Qualitative exploratory multiple-case study
26	[27]	2023	Mohammadi, N.	Investigation of Community Energy Business Models from an Institutional Perspective: Intermediaries and Policy Instruments in Selected Cases of Developing and Developed Countries	Sustainability	Community Energy Business Models	Europe	Qualitative case study analysis
27	[54]	2023	Sumarsono, N. Kasali, R. & Balqiah, T.	Circular business model, technology innovation and performance: A strategic-based theoretical framework in the Indonesian energy transition	Renewable Energy Focus	Energy transition and technological innovations	Indonesia	Literature review-based theoretical research

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Table 1. *Cont.*

No.	Study	Year	Authors	Title	Journal	Research Area	Country	Methods
28	[55]	2025	Hao, N. & Dragomir, V. D.	Renewable Energy, Sustainable Business Models, and Decarbonization in the European Union: Comparative Analysis of Corporate Sustainability Reports	Sustainability	Sustainable business models in renewable energy sector	Europe	Qualitative analysis
29	[56]	2021	Roevekamp et al.	Renewable electricity business models in a post feed-in tariff era	Energy	Renewable electricity business models	Germany	Literature review, workshops with experts
30	[57]	2022	Rigo et al.	Competitive business model of photovoltaic solar energy installers in Brazil	Renewable Energy	Enhance PV installations	Brazil	Systematic Literature Review
31	[58]	2023	Bhola et al.	Business Model Selection for Community Energy Storage(CES): A Multi Criteria Decision Making Approach	Energies	Community Energy Storage	Greece	Multi-Criteria Decision Making (MCDM) approach
32	[59]	2023	Yamashiro, R. & Mori, A.	Combined third-party ownership and aggregation business model for the adoption of rooftop solar PV–battery systems: Implications from the case of Miyakojima Island, Japan	Energy Policy	PV Battery Systems	Japan	Semi-structured interviews and case studies
33	[60]	2025	Zhang et al.	Multi-objective optimization for customized solar business models considering technical-economic-environmental performance: A NSGA-II integrated TOPSIS method	Energy Policy	Energy Policy and Solar Business Models	Hong Kong	Energy Policy and Solar Business Models method
34	[61]	2024	Shakeel et al.	Business models for enhanced solar photovoltaic (PV) adoption: Transforming customer interaction and engagement practices	Solar Energy	Solar PV installation encourages business models	Finland	Semi-structured interviews, academic literature
35	[62]	2022	Koerner et al.	Energy policies shaping the solar photovoltaics business models in Malaysia with some insights on COVID-19 pandemic effect	Energy Policy	Energy Policy and business models	Malaysia	Literature review and semi-structured interviews
36	[28]	2023	Korõtko et al.		Energies	Local energy communities	Latvia	Case study
37	[63]	2025	Tran, T. H. & Duong. V. T.	Enhancing Renewable Energy Product Consumption of Young Customers Through Sustainable Development Goals Knowledge: An Application of the Theory of Planned Behavior	Sustainability	Consumer Behaviour and Renewable Energy Adoption	Vietnam	Quantitative data using a questionnaire
38	[64]	2023	Van Opstal, W. & Smeets, A.	When do circular business models resolve barriers to residential solar PV adoption? Evidence from survey data in Flanders	Energy Policy	Renewable Energy Adoption, Circular Economy	Belgium	Quantitative survey analysis
39	[65]	2022	Haile, Y. & Min, H.	Success factors for renewable energy businesses in emerging economies	Renewable Energy businesses	Renewable Energy Business	China/India	Quantitative empirical study

3. Results

3.1. Demographics of the Studies

According to Figure 3, Poland, Germany, Indonesia, India, China and Brazil can be identified with three citations of the articles selected for the study. Apart from that, there are seven articles studied about the business models focusing on Europe in general. Other countries mentioned in Figure 3 have either one or three citations, and there was one article focused on the global context.

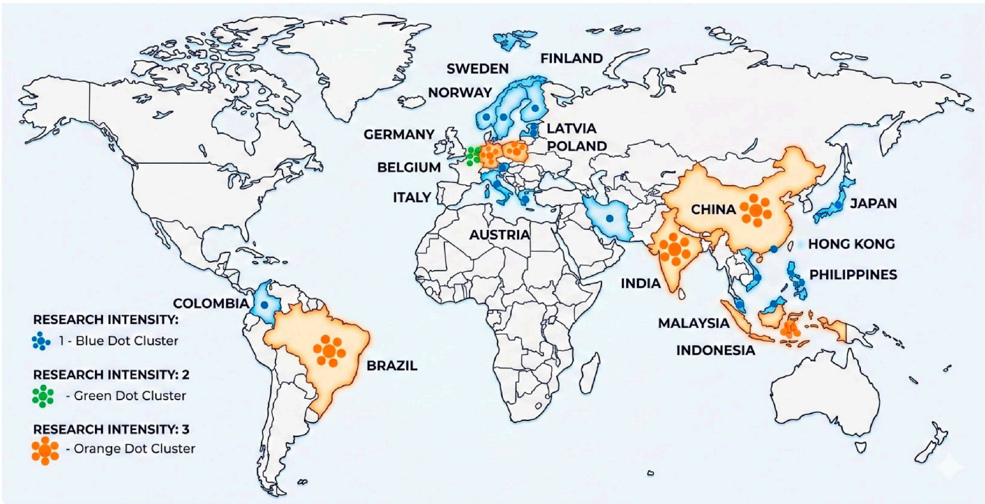

Figure 3. Geographical distribution of the articles.

Figure 4 shows the publication years of the selected articles for the systematic review. It can be observed that most of the articles were published during the years of 2021, 2022 and 2023. There has been a decline in research interests in business models in renewable energy during the past two years.

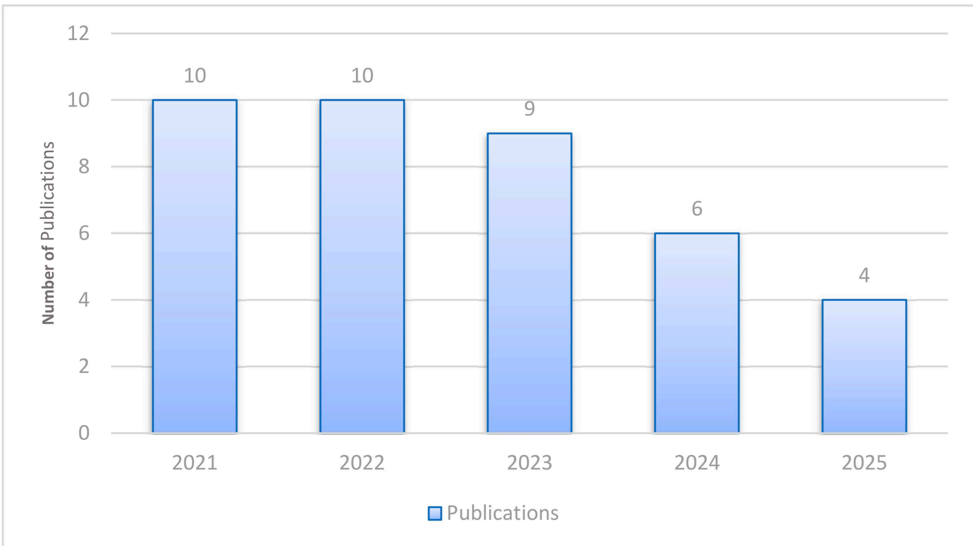

Figure 4. Publication years of the articles.

Figure 5 shows how the articles are distributed among the identified business models. According to the data collection, there are six key business models and three other business models. Renewable energy community model, pay-as-you-go and power purchase agreement/Fit can be identified as the key business models related to the renewable energy industry.

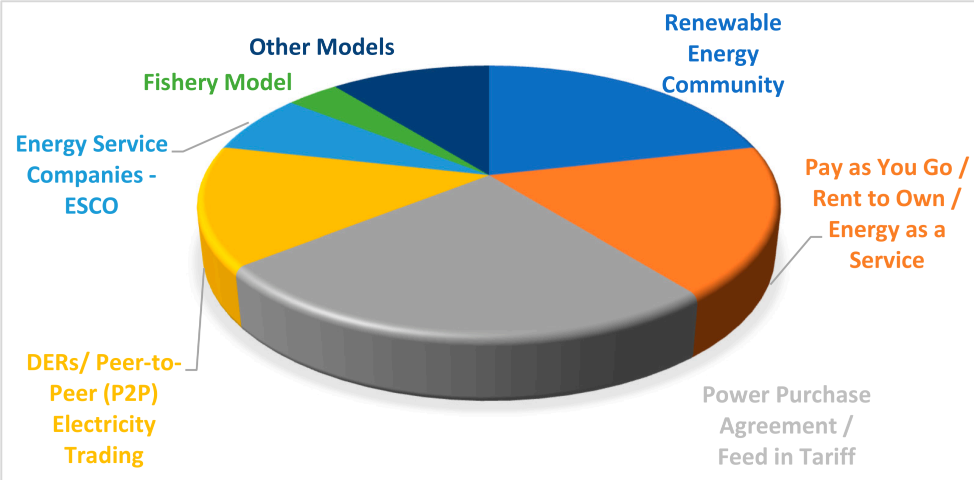

Figure 5. Distribution of references to the business models.

3.2. Business Model—Renewable Energy Community

This is one of the key business models observed in the articles studied. This model promotes collaboration among the local community members to produce and consume renewable energy collectively. Usually, the homeowners, small businesses, and local groups work together to achieve self-sufficiency for the energy requirements by sharing gains and risks of the renewable energy production. Table 2 shows the details of Renewable energy community model.

Table 2. Renewable energy community model.

Reference	Scope	Country
[24]	A small village of 2500 families in the northwestern part of Italy	Italy
[25]	Eleven residential buildings in Flanders	Belgium
[26]	REC discussed as one model	Indonesia
[49]	Sharing electricity within the community has been discussed at the country level	Philippines
[27]	Decentralised Community-owned or collectively managed model in Denmark	Denmark
[28]	Energy Cooperative model (EC)	Latvia

The Paris Agreement (2015) has made a substantial intervention to encourage the implementation of renewable energy, and the European Union's Clean Energy Package has insisted that European countries enhance the network of renewable energy [24]. The EU's Renewable Energy Directives have introduced Renewable Energy Communities, and the Electricity Market Directives introduce Citizen Energy Communities in Italy [24]. The same types of renewable energy community models have been practised in Belgium, Germany, and Denmark [25,27]. Despite Europe, this initiative has been practised in Indonesia and the Philippines as well [26,49].

The system design was a decentralised microgrid with peer-to-peer energy sharing. The selected community homeowners had the solar panels fixed on their roofs, and the other required hardware instruments, such as inverters or batteries, were also installed in the same households. After installation, performance of the Italian systems was monitored by using two Key Performance Indicators(KPI): Self-Consumption (SCI) and Self-Sufficiency (SSI) indices, to determine whether the locally generated electricity covers the local demand [24]. Before choosing homes for the community, their average consumption was measured using previous bills and the total estimated units from the community were tallied together. When excess electricity was generated that was sold to the grid to generate additional revenue. Indonesia has used pay-as-you-go (PAYG), leasing, renting, fee-for-service, and product–service systems (PSSs) as the financial solution when developing the system [26].

Italy (Monticello d'Alba) is one of the best real-world test cases for an energy community of 2500 community homeowners. The optimal configuration utilised a 50 kW solar PV system integrated with 30 kWh of battery energy storage (BESS). This combination achieved a self-consumption index of 75%, a self-sufficiency level of 60%, and a greenhouse gas emission reduction of 45%. Financially, the model demonstrated an internal rate of return (IRR) higher than 11% [24].

As the policy creators of the country, governments have extended support to these initiatives by implementing policy support and various programme types such as feed-in tariffs (FiTs), net metering, low-interest loans, Grants, tax credits and green certificates [24–27,49]. A specific Feed-in Premium of 110 €/MWh in Italy was established for energy shared within a renewable energy community [24]. Additionally, Italy provided grid cost reimbursement of 8.22 €/MWh for shared energy [24].

Due to the continuous upgrade of solar technology, lower solar component costs and fewer battery replacements have the largest impact on reducing the cost. Electricity generation from a renewable energy company is 10–20% lower than the usual prices and reduces emissions by 5–13% [25]. While opening the opportunity to the homeowner to enjoy electricity at a fixed, reduced price for a longer period, renewable energy community systems allow the community to be part of the net-zero journey of the country.

3.3. Business Model—Pay-as-You-Go/Rent-to-Own/Energy as a Service

Although there are three names, all of these three models share the same characteristics. Customers can pay for energy in small, flexible instalments with the pay-as-you-go (PAYG) model. Customers can rent energy systems with the possibility to purchase them after a predetermined amount of time through the Rent-to-Own (RTO) model. Customers pay for the energy used rather than the equipment when using Energy as a Service (EaaS), which offers energy solutions without ownership. Table 3 shows the details of Pay-as-you-go/Rent-to-Own/EaaS models.

Table 3. Pay-as-you-go/Rent-to-Own/EaaS.

Reference	Scope	Country
[26]	The models have been discussed in a literature review.	Indonesia
[45]	Energy as a Service has been discussed.	Norway and Sweden
[50]	Product–Service Systems (PSSs) for circular solar PV: (leasing, Power Purchase Agreements), Europe-focused.	Europe
[59]	Third-party ownership (TPO) models were discussed.	Japan
[64]	Solar Product–Service Systems (PSSs)—Rent-to-Own model, (PV rental with transfer of ownership after 20 years).	Belgium

These three models mainly broaden the accessibility to renewable energy to the rural areas which were not covered by the national grid. The models have given the opportunity to provide the comfort of electricity to the people who have been dependent on kerosene for a long time. These models address the major challenges of affordability, such as upfront cost and financing accessibility.

PAYG model and Rent-to-Own models spread the payments for the payment flexibility of the customers, making clean energy accessible for low-income households. PAYG models use a mobile money platform to receive payments, which can be accessed from most mobile phones in use. [26,59]. On the other hand, Rent-to-Own provides a pathway for the customer to own the solar unit at the end of the agreement period [45]. By eliminating the requirement of maintaining and servicing the expensive equipment, Energy as a Service lets the homeowner pay only for the electricity [50].

Off-grid solar systems utilising PAYG models have supplied electricity to more than 420 million individuals worldwide in Sub-Saharan Africa [66]. In 13 African nations, the Levelised Cost of Energy (LCOE) for prosumer systems within these frameworks fluctuated between USD 0.07/kWh and USD 0.18/kWh, depending upon loan interest rates [26]. The Rent-to-Own model in Miyakojima Island (Japan), launched as a hybrid approach of third-party ownership and aggregation, employs 10-year lease agreements. Under the "PV-only" option, the company offers systems without any initial expenditure in return for a fee of US$0.18 every invoice [59]. E.ON and Sonnen, two German companies, offer cloud-based Energy-as-a-Service (EaaS) solutions, such as "SolarCloud" and "SonnenCommunity," enabling prosumers to share excess electricity through subscription. These digital business models contributed to E.ON's "Customer Solutions" segment, which generated €21.5 billion, representing 56.8% of total sales in 2017 [53].

These models have transferred the risk of operating, servicing and performance risk to the service provider, which homeowners do not want to hesitate when entering contracts with the solar providers. EaaS has allowed customers to feel the benefit of renewable energy without either taking the financial burden or the service burden, because both are taken care of by the service provider [50,59]. Moreover, these models are aligned with sustainability goals, while giving people the opportunity to feel the comfort of electricity and benefit from their energy bills.

3.4. Business Model—Power Purchase Agreement/Feed in Tariff

A long-term contract known as a Power Purchase Agreement (PPA) commits a buyer to buying power at a set price from a renewable energy provider. A government-backed programme known as a feed-in tariff (FiT) guarantees producers a set amount for the power they create and supply to the grid. By giving producers financial security, both models encourage the use of renewable energy. Both of these financial mechanisms are designed to enhance and encourage the adoption of renewable energy, especially solar power systems. There are common features of these two designs as well as the differences. Table 4 shows the details **of the** Power Purchase Agreement/FiT models.

Table 4. Power Purchase Agreement/FiT.

Reference	Scope	Country
[41]	City of Medellín, Colombia's second-largest economic and population centre.	Colombia
[43]	Feed-in Tariff (FIT), Self-Consumption Model, and Net Metering Model were discussed in China's 14th Five-Year Plan for renewable energy.	China
[44]	Three business models have been discussed: Third-Party/Customer-Owned and Controlled, Utility-Controlled, Third-Party/Customer-Owned and Utility-Owned and Controlled.	Iran
[27]	PPA has been discussed. E.g., Germany's BürgerEnergie Jena and the UK's Plymouth Energy Community.	Europe
[56]	The Power Purchase Agreement (PPA) was discussed.	Germany
[60]	Several types of Power Purchase Agreements (PPAs) were discussed.	Hong Kong
[62]	PPAs in large-scale solar farms were discussed.	Malaysia

Both of these models have long-term contract designs. PPA typically are between the energy producer and the energy consumer, while the Feed-in-Tariff is between the homeowner and the government [41,60]. Feed-in-Tariff offers attractive rates to attract customers to invest in hardware instruments related to solar energy. PPA, on the other hand, enables the solar energy provider to sell the generated electricity at a competitively agreed rate to the energy buyers, which ensures a sustainable profit share to the investors [44,56].

Feed-in tariff and PPA both reduce the financial uncertainty, while FiT gives a predictable long-term cash flow, and PPA provides a sustainable buyer for generated electricity. This initiative gives positive facts to the investors who are sometimes hesitant to invest in the renewable energy business [44,56].

Through the integration of Chinese government and municipal subsidies with feed-in tariffs (FiTs), China emerged as the preeminent solar producer worldwide, attaining an installed capacity of 392 GW by 2023 [66]. Brazil has experienced a notable increase in corporate Power Purchase Agreements (PPAs), which are long-term contracts between energy providers and users. A significant feature is the 15-year Power Purchase Agreement established in 2020 with the mining firm Anglo American, providing 9 TWh from the Casablanca solar photovoltaic facility [57]. In 2020, Brazil attained a cumulative solar Power Purchase Agreement capacity of 625 MW [41].

Both schemes are supported by the government, while Fit is directly governed by the government. There are various financial support programmes to encourage investors. Additionally, most of the governments of the world introduce policies which are supportive of enhancing renewable energy initiatives. German Renewable Energy Sources Act (EEG) of 2000 instituted 20-year feed-in tariffs (FiTs), which markedly expedited the deployment of solar photovoltaic technology [27,42]. Since 2012, charges have been consistently decreased to promote market integration and self-consumption [32,42]. The Brazilian government promotes Power Purchase Agreements (PPAs) within the Free Contracting Environment, enabling major consumers to negotiate costs directly with generators. Recent regulations are broadening this sector to include medium-voltage consumers [57].

Although there are similarities, FiT mainly focus the residential customers while PPA mostly focus on large-scale solar projects. However, both FiT and PPA play a vital role in the transition of solar energy, each providing unique advantages to their customers and providing sustainable solutions for energy generation, reducing greenhouse gas emissions and the dependability of the fossil fuels and saving money for the governments.

3.5. Business Model—Aggregation of Small-Sized Distributed Energy Resources (DERs)/Peer-to-Peer (P2P) Electricity Trading

Small-Size Peer-to-Peer (P2P) electricity trading and Distributed Energy Resources (DERs) are two cutting-edge energy technologies that seek to decentralise power delivery and enable direct energy trade between consumers and prosumers. In order to sell aggregated electricity or offer grid-balancing services, aggregation involves combining several small DERs, such as rooftop solar PV, house batteries, and electric cars, to create a Virtual Power Plant (VPP) [40,42]. In places like Germany, where VPP operators combine small-scale DERs to improve grid stability and maximise energy trading, this strategy is becoming more popular [42]. A pilot project called InEExs in Berlin, Germany, deployed an Energy Performance Contracting(EPC)model for 60 households, employing smart-metering infrastructure for electric vehicle chargers, photovoltaic panels, and heat pumps. This collection of home assets is projected to realise 40% energy savings [31]. Table **??** shows the details of DERs/P2P Models.

Table 5. DERs/P2P Model.

Reference	Scope	Country
[32]	Pool and coordinate many small, decentralised energy assets.	Germany
[40]	DERs and P2P have been discussed.	Brazil
[42]	Peer-to-Peer (P2P) has been discussed using 7 companies.	Germany
[27]	Peer-to-peer (P2P) trading has been discussed.	Europe

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P2P electricity trading, on the other hand, allows prosumers to purchase and sell renewable energy locally by connecting them directly with consumers via a digital platform. Both centralised and decentralised versions of this paradigm are possible. While decentralised models function within local communities and may employ blockchain technology for security and transparency, centralised P2P systems enable transactions at regional or national levels [40]. Tal.Markt Peer-to-Peer platform developed by the German municipal utility Wuppertaler Stadtwerke (WSW) is a blockchain-based platform that enables customers to choose specific local renewable producers and prosumers for their energy supply [32].

Both strategies seek to boost energy efficiency, lower energy prices, and empower consumers. However, DER aggregation is usually centralised and concentrates on large-scale grid integration, whereas P2P trading tends to concentrate on local, community-driven energy markets. The degree of decentralisation and the use of middlemen like Virtual Power Plant operators for aggregation, as opposed to a direct marketplace for P2P, are the primary distinctions [40,42]. These two models have given an innovative approach to the achievement of global renewable energy and the reduction of tons of greenhouse gases.

3.6. Business Model—ESCO (Energy Service Company) Model

Comprehensive energy management services, including audits, installation, and maintenance, are provided by the ESCO (Energy Service Company) model. Payment is frequently performance-based and linked to improvements or energy savings. Third-party financing is frequently utilised, with ESCO paying the initial outlay and repaying it through savings. By lowering energy costs, increasing efficiency, and promoting sustainability objectives, ESCOs provide value by taking on technical and performance risks. Energy consumers, financiers, technology suppliers, and regulators are important players. Table 6 shows the details of ESCO model.

Table 6. ESCO model.

Reference	Scope	Country
[47]	ESCO discussed at the country focus level.	Poland
[52]	ESCO has been discussed in the country scope, with two main categories: the Guaranteed Savings Model and the Shared Savings Model.	Europe

Energy service companies provide comprehensive energy solutions such as energy calculations, installation of systems and energy saving improvements. The company mostly focuses on energy-saving mechanisms and takes advantage of energy saving as a financial benefit [47,52]. They use that cost saving as their profit while offering a benefit to the homeowner. As the energy market moves forward, ESCO introduces two innovations: Demand Side Management and Energy as a Service, which offers customers energy savings as a service other than infrastructure [47,52]. One of the major challenges ESCOs face is market fragmentation and financial risks. However, most of the time they are covered with government grants, tax benefits and feed-in tariffs.

"Sunny Hill" Residential Development in Poland, Katowice, is a project that comprises 24 buildings and employs elements of the ESCO concept, including energy management, balancing, and consumption optimisation. The system generates 230,400 kWh of electricity per year. The numeric savings of the project reached an average annual total savings of €27,467 for residents [47]. ESCO is one of the models which has gathered the latest technology and supported the sustainable energy transition, benefiting the homeowners, service-providing companies and the environment [47,52].

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3.7. Business Model—Digital Photovoltaic (PV) Fishery Model

This business model combines power generation, fish farming, digital services, and tourism to offer sustainable solutions. Customer relationships are built with grid operators, farmers, tenants, tourists, and strategic partners. Key resources include a digital PV system, innovative digital platforms, and a skilled team driving operations. Sales of power and fish, rents of real estate, consulting services, and stock investments all contribute to the income stream's diversity and scalability [38]. Table 7 shows the details of the Fishery model.

Table 7. Fishery Model.

Reference	Scope	Country
[38]	A hybrid business model that integrates solar PV power generation with aquaculture (fishery) using digital platforms to create value for multiple stakeholders.	China

In rural China, a model integrating PV energy generation and aquaculture has been successfully implemented. This model addresses the requirement of expanding the renewable energy demand and adding value to the project due to the aquaculture model they have used [38]. This model uses digital platforms to monitor the performance of the solar electricity generation and the details of aquaculture. The digital platform assists in managing the aquaculture system and solar electricity generation, opening the gates for dual revenue streams. Making profits by selling generated electricity, additional income is generated by selling fish to the local or international market [38]. In this innovative concept, tourism has also been integrated, which will again generate additional revenue for the project and also further job opportunities [38]. This business concept is a highly sustainable concept due to its diversification of income generation, while saving tons of carbon dioxide from the environment.

3.8. Other Business Models

Apart from the above-mentioned business models, there were three other business models found during the systematic literature review. These models are not observed to be rigorously popular like the previous ones. However, they also have substantial potential for facilitating renewable energy adoption. Table 8 shows details of other models.

Table 8. Other models.

Reference	Scope	Country
[56]	Core Concept of On-Site Power-2-X—The primary value shifts from electricity supply to the supply of a renewable, "green" secondary product or service.	Germany
[58]	The Energy Arbitrage (EA) Model. Buying energy when the prices are lower and selling when the prices are higher.	Greece and India
[39]	The Housing Association model discusses how renewable energy can be promoted among the tenants.	Austria

Core Concept of On-Site Power-to-X (Power-2-X): Instead of putting the electricity into the grid, the Power-to-X (Power-2-X) concept uses on-site renewable energy (such as solar or wind) to generate valuable secondary products or services. This method transforms surplus renewable energy into other goods or kinds of energy, such as green heat, green Hydrogen, or even synthetic fuels [56]. Because of their reduced carbon impact, these secondary products are preserved and can fetch higher market prices, attracting a further range of customers. To maximise the economic potential of renewable energy production and enable energy self-sufficiency, the income generation changes from the delivery of power to these higher-value renewable products [56].

Energy Arbitrage (EA) Model: Energy storage devices are used in the Energy Arbitrage (EA) Model to store inexpensive electricity during off-peak hours and release it during periods of high demand when electricity costs are higher [58]. With this strategy, the aggregator or energy service provider can purchase electricity at a discount from the grid, store it in batteries or other energy storage devices, and then profitably sell it back to the grid when the market price rises. In Community Energy Storage (CES) systems, where the energy stored can also be utilised to balance local supply and demand, EA is particularly helpful. By reducing peak demand and promoting grid stability, the Energy Arbitrage Peak Shaving (EA-PS) model, an expansion of EA, further improves this [58].

Housing Association Model: A Housing Association supplies and oversees energy systems, such as renewable technology and energy-saving techniques, for the inhabitants. The housing association has two options for funding the energy systems: directly or in collaboration with outside contractors. Energy systems installation, operation, and maintenance can be managed by the association using energy supply contracting (ESC) or energy performance contracting (EPC) models. In certain situations, tenants maintain a direct connection to the grid for additional energy requirements while paying rent for components of the energy system (such as solar panels and heating systems). By accounting for the upfront expenses and facilitating communal energy sharing, this concept helps residents overcome financial obstacles [39,42].

4. Discussion

4.1. Overview of the Selected Business Models

There are many types of business models in practice. One of the solutions is the renewable energy community model. This model is in practice in European countries, such as Italy, Denmark, Belgium, and Latvia [24–28,49]. The governments of those countries have introduced required policies to encourage new projects. This model could work in the UK since it is in the same region. Asian countries have developed these types of modes in their countries by absorbing the right characteristics of the model and customising it accordingly and compatibly to the country. A successful example can be found in Indonesia [26].

Pay-as-you-go and Energy as a Service are models which are practical solutions for those who wish to consume the solar-generated electricity for a discounted price without investing their hard-earned money [26]. Rent-to-Own is an extension of this method, paying a small rental fee for a longer period and transferring ownership of the system at the end of the agreed-upon period. These models are not very popular in the UK, which has better potential of succeeding. Feed-in tariffs and power purchase agreements have similar characteristics; feed-in tariffs are used mostly by governments, and power purchase agreements by the private sector. However, the mechanism seems mostly the same: purchasing solar-generated electricity for an agreed rate for an agreed time period. The feed-in tariff model is functioning in the UK; this model was started in 2010 and continued until 2019 [67]. After 2019, there have been some modifications to the tariff, and it was launched as the Smart Export Guarantee system, which has poorer performance than the FiT model [29]. When considering the example of Germany, the UK has to do more to get the ultimate benefit of the existing housing stock to fill the gap of fossil fuel dependency.

Small-sized distributed energy resources (DERs) and peer-to-peer (P2P) are two models that can be used for small communities and are decentralised from the national grid; these can be used in rural areas that are either not covered by the national grid or where the operational and service costs are higher [27,32,40,42]. China has combined fishery and solar power generation together and introduced a model called the Digital Photovoltaic (PV)

Fishery Model [38]. They have used lakes as solar farms and continued the fishery business together, and digital technology has been used for both controlling the solar project and increasing the fish harvest. Tourism has also been developed as an additional income source for the local people. Some community-based solar projects have used housing associations as the contractor and the service provider, who will take care of all services and revenue collection [39].

The study identified nine business models. Table 9 presents the categorisation of those models and evaluation of them under four key themes.

Table 9. Evaluation of the selected business models.

Business Model	Geographical Reach/ Reputation	Economic Performance Highlights	Environmental/ Energy Impact	Project Scale/Scope
Renewable Energy Community (REC)	Italy, Belgium (Flanders), UK (Scotland) [24,25,29]	IRR: >11% (Italy); Electricity cost reduction: 10–26% (Belgium) [24,25]	CO_2 reduction: ~45% (Italy), Emissions reduction: 5–13% (Belgium) [24,25]	2500 inhabitants (Monticello d'Alba), £2 M raised for 24 solar arrays (Edinburgh) [24,27]
DERs/Peer-to-Peer (P2P) Trading	Germany, Spain, USA (Brooklyn) [31,32,42]	Producers earn up to 23% more per kWh vs. standard FiT (Germany) [32]	Energy savings: 5% (Spain) to 40% (Germany aggregation pilot) [31]	5500 residential units (Spain), 60 households (Berlin pilot) [31]
Power Purchase Agreement (PPA)/FiT	Germany, UK, China, India, Brazil, Hong Kong [29,32,41,60]	5% annual return for community shareholders (UK), 15-year PPA for 9 TWh (Brazil) [27,57]	China: reached 392 GW installed capacity (FiT driven) [66]	32 schools/buildings (Plymouth), 1469 MW total connected capacity (China TWG) [38]
PAYG/Rent-to-Own/Energy-as-a-Service (EaaS)	Sub-Saharan Africa, Germany, Japan (Miyakojima) [26,53,59]	E.ON EaaS segment sales: €21.5 Billion (56.8% of total), Default rates: 7–11% (PAYG) [26,53]	Replaced kerosene and wood with clean microgrids (Kenya) [66]	420 million people reached globally (PAYG), 10-year leasing contracts (Japan) [59,66]
ESCO (Energy Service Company) Model	Germany, Poland, France [24,31,52]	Total cost savings: €20.7 M (Berlin renovation pilot), NPV: €99,500 [31]	40% energy savings (Berlin), Office uses 12.5% energy of conventional building [31,47]	60 households (Berlin); 24 buildings (Sunny Hill Katowice) [31,47]
Digital PV Fishery Model	China (Nanjing, Sheyang, Shandong) [38]	NPV: ¥352 M (200 MW project), Payback: 13–14 years, 1 MW return: ¥19.8 M [38].	CO2 reduction: 115,000 tons, Saves 202,500 tons standard coal annually [38]	200 MW planned capacity (Dongying project), 1469 MW total (TWG) [38]
Energy Arbitrage (EA) Model	Greece, India (Comparative Study) [58]	Highest ranking model for community storage deployment. [58]	Reduced diesel use and GHG emissions in remote microgrids [58]	Remote microgrids: Gaidouromantra (Greece) and Ghoramara (India) [58]
On-Site Power-2-X	Sweden, China, Spain, Algeria [38,56,68]	Shifts value to secondary "green" products (Hydrogen, Methanol Computing) [56].	Absorbs 14 million kWh/year of "abandoned" PV power (China) [38].	10 MW Hydrogen production/storage equipment base [38]
Housing Association Model	Austria (Simulation), Finland [39,61]	Contractor profit: +39% (€117 k/yr); Resident energy savings: +13% (€48 k/yr) [39]	Heat load reduction: 22% via building efficiency interventions [39]	70 housing units (Vienna simulation); 2 M Finnish residents in target units [39,61]

Some solar projects have used a different strategy by converting additional generated electricity into a secondary product, such as hydrogen fuel, because of its financial value and also because it is a clean fuel [56]. This model has been successfully implemented in Germany, suggesting that it could also be applied in the UK. Hydrogen can be used to fulfil the commuting requirements with zero environmental impact. Further research should be carried out to refine the existing models and include characteristics that reduce the upfront financial barrier and methods that match electricity production and demand. Flexible financial solutions, easily scalable installation methods, and supportive policy enforcement can have a positive impact on spreading solar in the UK. Further studies should be conducted to assess the future financial benefits of solar investments, including the time required to break even and the maximum return on investment (ROI) that can be achieved.

4.2. Recommendations for Decision Making

A decision analysis for adopting a renewable energy business model shall consider internal organisational capabilities, including revenue and technical proficiency, with external environmental elements, such as regulatory maturity and market liberalisation. By reviewing the literature, the following evaluation criteria were identified for selecting a suitable renewable energy business model for a given context.

Figure 6 presents six key criteria proposed for selecting a business model for renewable energy systems. As no established framework was identified that directly evaluates renewable energy business models, the criteria were developed inductively based on evidence extracted from 39 selected articles. The first criterion, organisational size and employee attrition, reflects that high-turnover enterprises can maintain capital-intensive infrastructure, while smaller organisations typically depend on service-oriented or data-centric models [53,61]. The second criterion is the regulatory framework, which includes mechanisms such as feed-in tariffs (FiT), net metering schemes, and enabling legislation (e.g., Law 14.300 in Brazil). These policy instruments directly influence the financial viability and compensation structures of renewable energy business models [40,43,56]. The third criterion concerns Ownership and Control of the project, where decision-makers may adopt asset ownership (CAPEX model), third-party ownership (TPO), or community-shared infrastructure approaches [30,44]. The fourth criterion is technological maturity of the project, including the availability of enabling technologies such as smart metres and blockchain, which are essential for sophisticated models such as peer-to-peer trading or Energy-as-a-Service (EaaS) [31,36,53,55]. The fifth criterion is market context, which differentiates between mature energy markets characterised by stable grid infrastructure and emerging economies where energy access and affordability are paramount issues [26,27,65]. The sixth criterion is the target customer segment, where business models vary depending on whether the end users are prosumers, business subsidiary chains, or industrial establishments [30,57,61].

Considering the mentioned facts, a decision support framework is proposed. Table 10 demonstrates these criteria in the selection of a business model, based on the analytical evidence from the selected articles.

When selecting a renewable energy business model for the UK, the organisation's size matters significantly. Government policies and regulations should be considered, although most business models have positive characteristics for implementing solar PV, based on their global performance. Yet they have not been tested or practised in the UK. Although the government has implemented supportive policies such as the Warm Homes Plan, some may not align with the business model's operational requirements. Most UK citizens admire privacy, and the models with third-party ownership might have poor engagement from the residents.

Our search was limited to the English language and had a time span of 2020 to 2026. Consequently, the information extracted was limited to these parameters. Furthermore, our databases were limited to Scopus, Web of Science, and ProQuest. Additionally, the research is based on a restricted fraction of the literature, with 39 publications for this study. Despite these limitations, the study was able to identify nine business models. A decision support framework was produced to help the decision-makers to select a suitable business model, which is considered the key research outcome. Based on the data analysis from the selected 39 articles, the authors have developed this framework from a qualitative perspective. The absence of a quantitative validation can be another limitation. The authors expect to quantitatively model the scenarios under different business models for the UK context as a future research task.

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Table 10. Categorisation of business models according to organisation profile and turnover.

Organisation Profile/Turnover	Recommended Business Model	Key Selection Rationale	Supporting Evidence/Case Study
Multinational (>€10 Billion)	EaaS	Demands substantial initial investment in IT, and energy platforms to convert legacy fossil fuel portfolios.	E.ON/Innogy: Around 56% of total revenue (€21.5 B in sales in 2017) [53].
Medium-Sized (€100 M–€10 B)	On-Site Power-2-X	Focusing on a "green" secondary product or service, deviating from primary electricity provision [38].	A 14 million kWh of surplus photovoltaic power each year to generate 3290 tonnes of magnesium hydride for energy storage [38].
Small Firms/Start-ups (<€10 M)	Aggregation & P2P Trading Platforms	Minimal capital entry threshold; emphasises data management and virtual power plants (VPPs) instead of hardware ownership.	Fresh Energy and GridX: Digital business models to educate consumers on actual consumption and provide real-time billion [24,53,61].
Community/Local Authority	Renewable Energy Community (REC)	Enhances social value and local self-sufficiency; yields substantial profitability (IRR > 11%) when bolstered by tax incentives or shared energy premiums.	Monticello d'Alba (Italy): A real-world case study where a 50 kW photovoltaic system combined with 30 kWh of storage attained 75% self-consumption [24].
Low-Income/ Emerging Markets	Pay-as-you-go (PAYG)/Rent-to-Own	Surmounts the primary obstacle of substantial initial capital expenditure and insufficient credit history for residential customers in rural regions.	Sub-Saharan Africa/Kenya: Off-grid technology has supplied electricity to 420 million individuals using mobile money payment methods [26,59].
Post-FiT Era Markets	Power Purchase Agreements (PPAs)/ Self-Consumption	Avoids power price concerns at the expiration of guaranteed government subsidies; reallocates value to long-term "green" contracts.	Brazil: Signing 15-year PPAs for 9 TWh volume (mining sector) to ensure stable long-term energy costs [57].

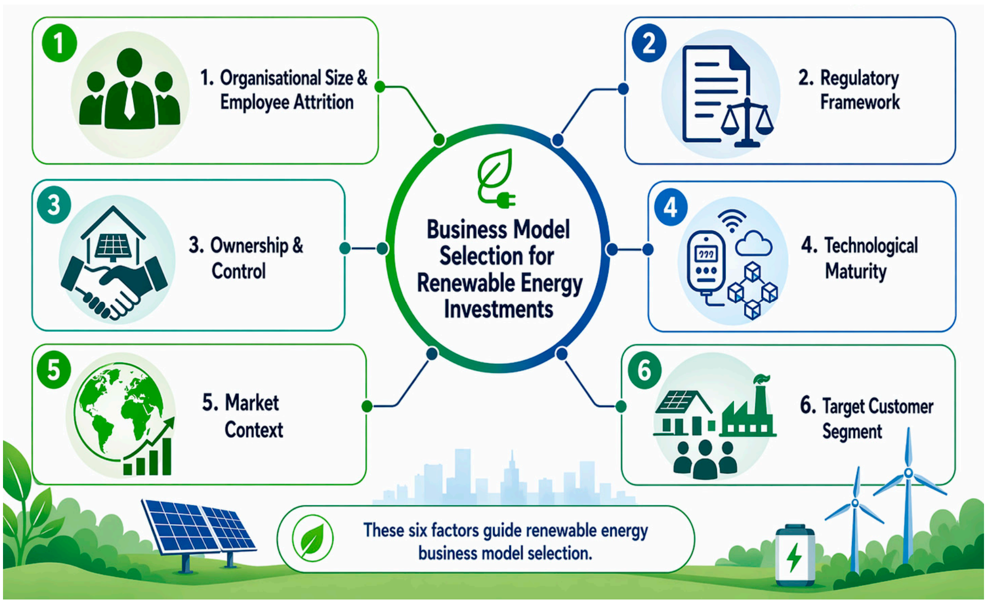

Figure 6. Business model evaluation criteria.

5. Conclusions

Empowering the UK housing stock with solar power is highly beneficial, not only for the environment but also for homeowners and governments. While consuming the cleanly generated electricity, homeowners benefit from a long-term investment. Governments will achieve their emission reduction targets and save on gas import bills. A systematic literature review was conducted using 39 selected research articles. This review evaluated several business models which have been introduced to mitigate the issues of the implementation of residential solar panel installation.

The study was able to identify nine business models, which are already in the market. The main purpose of the models is to remove the upfront cost barrier, and in most models, solutions have been successful. There are business models that have been successful in many parts of the world and that have characteristics that match those of the UK. Although the feed-in tariff model is already in the UK [67], models such as the renewable energy community (REC) have been shown to have better success in European countries such as Germany, Belgium and Italy. This model has shown better performance, achieving an IRR greater than 11%, reducing electricity bills by 26%, and reducing carbon emissions by 45%.

The REC model is mostly a community model which can be easily practised in rural and suburban areas of the UK. When considering large solar projects, such as solar farms, PPA and FiT models have shown better results. China has projects that have generated 392 GW under the FiT scheme. However, the Fit model was able to deliver a 5% return to investors in the UK and power 32 school buildings in Plymouth. PPA and FiT models, which share similar characteristics, can be recommended for large-scale renewable energy projects. The ESCO concept is exceptionally effective at enhancing energy efficiency in urban environments, particularly within the UK's current infrastructure. Its efficacy in reducing energy consumption by up to 40% in buildings and yielding cost savings (€20.7 M) makes it an essential model for renovating the UK's antiquated structures and promoting sustainable energy use.

It is clear that there are solutions which can be considered to enhance the spread of solar installations. It is proposed that, considering the existing features of the business models and customising them according to requirements, the UK can take a better initiative to broaden this residential solar network. Government policies and legislation should also be either amended or freshly proposed to encourage the renewable energy segment. The novelty of the study lies in the recommendations for business models in a specific context as a decision support framework.

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Abbreviations

The following abbreviations are used in this manuscript:

VAT	Value Added Tax
SEG	Smart Export Guarantee
ECO4	Energy Company Obligation
KPI	Key Performance Indicators
FiTs	Feed-in tariffs
PAYG	Pay-as-you-go
PSS	Product–Service Systems
RTO	Rent-to-Own
EaaS	Energy as a Service
TPO	Third-Party Ownership
PPA	Power Purchase Agreement
P2P	Peer-to-Peer
DERs	Distributed Energy Resources
VPP	Virtual Power Plant
ESCO	Energy Service Company
EA	Energy Arbitrage
CES	Community Energy Storage
EA-PS	Energy Arbitrage Peak Shaving
ESC	Energy Supply Contracting
EPC	Energy Performance Contracting
ROI	Return on Investment

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