



## Review

## Business and pricing models for smart energy at building level: A Review

Fabio Lilliu<sup>a</sup>, Marco Pietrobon<sup>b</sup>, Diego Reforgiato Recupero<sup>a,\*</sup><sup>a</sup> Department of Mathematics and Computer Science, University of Cagliari, Via Ospedale 72, 09124 Cagliari, Italy<sup>b</sup> R2M Solution s.r.l. Polo Tecnologico di Pavia, Via Fratelli Cuzio, 42, 27100, Pavia, Italy

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## ABSTRACT

The transition that energy grids have undergone in recent decades has brought significant changes: grid users can now produce energy as well as consume it, allowing energy to flow in both directions. Due to this and the evolution of appliances, prosumers (users that produce and consume energy) can now shift their energy loads in time and amount, providing what is known as energy flexibility. In return, energy flexibility allows users to assist energy providers through a process known as demand response. Additionally, the ability of grid users to both produce and consume energy has led to the rise of new structures like energy communities. These innovations have paved the way for new business and pricing models, enabling prosumers to obtain benefits for assisting providers, financially exploit flexibility, and regulate interactions in energy communities.

This work aims to analyze and review novel business models in smart energy. Although there are many levels at which this transition has evolved the grid, one of the main changes has been enabling buildings to become energy producers. Specifically, this paper will concentrate on three main areas of interest: energy flexibility, demand response, and energy communities. It provides a comprehensive review of novel business models related to these topics, including both relevant reviews and actual novel business or pricing models that have been proposed in the past. We defined some features to classify these papers and that we used to carry out a comparative analysis of the retrieved papers. We discuss the overall findings, highlighting common patterns and similarities between the models.

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\* Corresponding author.

E-mail addresses: [lilliu@unica.it](mailto:lilliu@unica.it) (F. Lilliu), [marco.pietrobon@r2msolution.com](mailto:marco.pietrobon@r2msolution.com) (M. Pietrobon), [diego.reforgiato@unica.it](mailto:diego.reforgiato@unica.it) (D. Reforgiato Recupero).<https://doi.org/10.1016/j.epsr.2024.111196>

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## 1. Introduction

In recent decades, a significant transition has been occurring in energy grids: grid users are no longer just energy consumers, but an increasing amount of them are becoming energy producers as well. Consequently, grids have undergone transformations to enable bidirectional energy flow, allowing energy to move from providers to users and vice versa. This evolved grid structure is commonly referred to as a *smart grid*.

The implementation of smart grids has unlocked numerous opportunities. Users can be not only consumers but also producers, and are called *prosumers* for this reason. Prosumers have the ability to sell their surplus energy and adjust their energy consumption both in terms of timing and amount: this adaptability is called *energy flexibility*. Energy flexibility enables prosumers to optimize their energy usage patterns to meet the needs of energy providers, a process known as *demand response*. Because of this, innovative business and pricing models for energy have emerged in recent years [1,2], enabling the economic benefits of demand response [3,4] and energy flexibility exploitation [5,6].

These models have made a significant impact in the context of energy communities [7,8]. They have facilitated the creation of incentive mechanisms that encourage grid users to become prosumers, therefore contributing to energy production [9,10]; also, these mechanisms motivate consumers to shift their energy loads to time slots that are more beneficial to the community [11,12].

Business and pricing models are often unique, targeting different user categories, devices, energy vectors, and various use cases. Additionally, since energy flexibility can be exploited for multiple objectives, different business or pricing models can be tailored to pursue specific goals, such as reducing energy consumption costs, lowering CO2 emissions, or increasing *self-consumption* of energy produced by prosumers.

All these opportunities arising from the introduction of smart grids have paved the way for the development of business models that, in turn, promote the improvement of grid management [13], efficiency [14], and performance [15]. Business and pricing models have therefore become a key aspect of this domain. In this paper, we aim to explore their advancements and achievements in recent years.

The topic of pricing and business models in smart grids is still a broad one, with many levels of application. The evolution brought by smart grids has significantly transformed the entire energy distribution process, impacting every stakeholder from top to bottom, including Transmission System Operators (TSOs), Distribution System Operators (DSOs), Balance Responsible Parties (BRPs), aggregators, and prosumers, who are primarily buildings or building units. Given the broad scope of business and pricing models affected, we have chosen to focus on one specific level: the building level. Our focus on this level is due to the following reasons:

- While business and pricing models impact all levels, the levels closest to the end user (prosumer, building, energy management system) are usually the most affected. These models aim to encourage more buildings and prosumers to join and actively participate in the smart energy context.

- The critical factor enabling most of these models is energy production, which typically occurs at the building level rather than solely at the prosumer level.

This motivation drives our literature review on pricing and business models at the building level. Given that smart grids and, more precisely, smart energy are our main topics, we decided to focus on what we consider the most relevant aspects of this domain. We identified three main subtopics:

1. **Energy flexibility:** This is fundamental, as energy flexibility is what enables almost all of those business models.
2. **Demand response:** This is one of the main applications of energy flexibility and a primary method for grids to address the challenges of the new grid model.
3. **Energy Communities:** This is a common context for business models to emerge, offering interesting applications due to mutual user interaction.

Our goal is therefore to conduct a literature review on business models at the building level, focusing on energy flexibility, demand response, and energy communities.

This study has been conducted within the framework of the EU COLLECTiEF research and innovation project,<sup>1</sup> which aims to develop and test an interoperable and scalable energy management system based on collective intelligence to be integrated into existing buildings and urban energy systems. One of its main goals is to enhance energy flexibility by providing automatic controls for installed systems and appliances. The COLLECTiEF project is developing a comprehensive set of solutions [16], including: (i) control algorithms [17,18] for application at both single building and building cluster levels, (ii) software and hardware solutions to allow the implementation of the algorithms to the installed systems and devices,<sup>2</sup> (iii) a set of sensing components for the monitoring the conditions of the indoor spaces, (iv) a dashboard, which represents the user graphical interface. The development of analyses and strategies to help the exploitation of the research results is one of the objectives of the project. To this end, specific business models have been defined specifically within the project. They can be classified as business models for service providers, acting in the emerging fields of the smart controls of buildings and energy flexibility, and providing the know-how and the related software and hardware components. They can be part of models already applied in the market of energy flexibility like for example the ones related to the digital platforms for energy management or to providing services for flexibility solutions. They could be also integrated into wider business models in the field like demand aggregators or energy-as-a-service. In this context, the study presented in this paper focuses on innovative business and pricing models that enrich the analyses developed in the COLLECTiEF project. The models analyzed in the present study provide relevant references and points of comparison to strengthen the business models selected for the solutions developed in the project and to consider further opportunities and important trends regarding the business and pricing models in this field.

<sup>1</sup> <https://collectief-project.eu/>

<sup>2</sup> <https://collectief-project.eu/about/our-project>

The remainder of this paper is organized as follows. Section 2 reviews the state of the art on business models in smart energy and explains how our work differs. Section 3 details the methods used for our research and paper selection, including our rationale for including or excluding the papers we found. Section 4 presents the review papers we identified and describes how they address business and pricing models according to a set of features we established. Section 5 describes and classifies the novel models we analyzed using a different set of features specific to the models. Section 6 discusses the main results and takeaways, highlighting emerging patterns. Finally, Section 7 concludes the paper with a summary and directions on where we are headed.

## 2. Related work

### 2.1. Literature

Several works in the literature address business models in smart energy, but none specifically target our focus. For instance, [19] and [20] provide a comprehensive review of smart energy business models, aiming to give a precise classification of them, in particular by model type. However, those reviews remained very generic about the smart energy domain and did not specifically focus on energy flexibility, demand response, and energy communities. Conversely, [21] analyzes business models and energy services for buildings to identify key elements that enable these models and services, suggesting potential advancements from the current state of the art. However, this work does not specifically address our subtopics and has a broader scope, including energy services. The absence of our main subtopics also appears in [22] and [23]: [22] focuses on energy-efficient measures, analyzing and classifying the main barriers for their implementation, and then analyzing business models from the perspective of those measures, and suggesting how to implement them. [23], on the other hand, examines circular business models, analyzing their classification and strategies. Furthermore, [24] provides a comprehensive review of energy business models with a primary focus on energy communities, classifying them by archetype and business model canvas, while [25] reviews business models specific to peer-to-peer energy trading, classifying them by approach (e.g., game theory, auction). The work performed by authors in [26] discusses energy communities but primarily focuses on on-bill schemes and the classification of grid actors involved in these models. Additionally, [27] reviews business models for distributing energy resources, classifying them by resource category. However, it remains very generic and does not focus on the specific topics we are interested in, and in particular not on buildings, although the specific instance of demand response is considered. Finally, [28] treats sustainable business models in general, with only a minor emphasis on energy.

### 2.2. Comparison against the state of art

In Table 1, we compare the existing literature reviews with our paper in terms of the topics covered. Specifically, in Section 1 we outlined the purpose of this paper: a review on business and pricing models, at building level, focusing on three main smart energy subtopics, i.e., energy flexibility, demand response and energy communities. Therefore, the comparison done in Table 1 shows which of those subtopics are covered by each state-of-the-art paper. The only paper that addresses them all is [19], but there are two important differences compared to our work. First, [19] has a structure where papers are sorted into different subsections according to the business model they propose (e.g., there is a subsection for models based on smart homes, one for models based on smart EVs, and so on), while our paper compares the reviewed works according to their compliance with certain features. Second, [19] was published in 2019, while our review covers literature from 2020 to 2024. Among the other papers, [24] is the only one giving relevance to the topic of flexibility, and is one of the few papers that

**Table 1**  
Topics comparison between our paper and the state of art.

Paper	Energy flexibility	Demand response	Energy communities
[19]	✓	✓	✓
[21]			
[20]			
[26]			✓
[22]			
[27]		✓	
[28]			
[23]			
[24]	✓		✓
[25]			✓
Our paper	✓	✓	✓

**Table 2**  
Number of eligible papers after each stage.

Papers found in the research	63
Papers relevant to our study	16

highlights the topic of energy communities, along with [25,26]. Finally, demand response is thoroughly examined only in [27].

The novelty of the proposed paper, compared to existing reviews on smart energy business models, lies in the combination of the following three aspects:

1. Addressing the key subtopics of energy flexibility, demand response, and energy communities.
2. Focusing on recent, state-of-the-art publications.
3. Comparing papers based on specific features of the business models they discuss.

## 3. Papers retrieval

This section describes the method we have used to search for pertinent papers. The research was done on Scopus, in April 2024. We conducted a search using all possible combinations of three keywords. The first keyword was either *business model* or *pricing model*, as we are making a review centered on them. The second was either *demand response*, *energy flexibility*, or *energy community*: they correspond to the main subtopics we identified in Section 1. The third keyword was always *building*. In other words, the search string we utilized was:

`("business model" AND "demand response" AND "building") OR ("business model" AND "energy flexibility" AND "building") OR ("business model" AND "energy community" AND "building") OR ("pricing model" AND "demand response" AND "building") OR ("pricing model" AND "energy flexibility" AND "building") OR ("pricing model" AND "energy community" AND "building")`

We searched for papers with that search string in at least one of the *title*, *keywords*, and *abstract* fields, spanning from 2020 to 2024. As illustrated in Table 2, a total of 63 eligible papers were identified.

We carefully reviewed each paper and excluded those that did not primarily focus on new business or pricing models. We then conducted a thorough examination of the remaining papers and found 16 to be useful for our research: 6 were reviews or surveys that partially or fully described pricing or business models for energy communities, while the other 10 featured novel business models. These two sets are described in detail in the following sections according to some features that we have defined. Regarding the other 47 papers that were excluded, the reasons for their exclusion varied:

- 29 papers were only marginally related to new business or pricing models. For example, the work performed in [29] is a review

**Table 3**  
Review papers.

Number	Title
[33]	Ten questions concerning energy flexibility in buildings
[34]	Overcoming the incumbency and barriers to sustainable cooling
[35]	Investments and Governance Models for Renewable Energy Communities
[36]	Governing energy communities: The role of actors and expertise in business model innovation
[37]	Distributed Energy Resource-Assisted Industrial Demand Response: A Survey on Technologies, Business Models, and Applications in China
[38]	PV Energy Communities—Challenges and Barriers from a Consumer Perspective: A Literature Review

**Table 4**  
Compliance of each review paper to the three subtopics from Section 1.

Paper	Energy flexibility	Demand response	Energy communities
[33]	✓	(✓)	
[34]	✓		
[35]	✓		✓
[36]			✓
[37]		✓	
[38]		✓	✓

of energy modeling and analytics in the built environment. This paper mentions the possible impact of some works and techniques on business models, but never actually discusses them.

- 14 papers were not related to new business or pricing models. For example, [30] simulates the functioning of an energy community and the impact of employing flexible devices under various tariff systems. However, we decided not to include it, as it did not present any novel pricing system on top of existing ones.
- 3 items were not papers, but a summary of conference proceedings, which only contained the titles of the papers of the conference;
- 1 paper is redundant, as the business model there described is the same as one of the papers we found. This is the case of [31], which describes the same models as [32].

#### 4. Reviews

This section describes the content of the six review papers, the features used for their analysis, and how these works adhere to each feature. The titles of the papers are listed in Table 3.

We searched for papers addressing business or pricing models that focus on at least one of the following subtopics: energy flexibility, demand response, or energy communities. Table 4 shows which subtopics each paper is related to. The checkmarks identify papers where the corresponding subtopic has high importance, while the checkmarks in brackets identify papers where the subtopic has marginal importance, but is still mentioned.

As indicated by the titles, three out of six papers [35,36,38] focus primarily on energy communities, which is their central topic. Besides that, [35] adopts a strong flexibility-oriented approach, while [38] dedicates an entire subsection to analyzing demand response in PV energy communities. Among the other papers, [33] focuses mainly on energy flexibility, as its title suggests, with only a brief mention of demand response. In contrast, [34] is a review on sustainable cooling, where flexibility is discussed in the context of managing cooling systems. Lastly, [37] is centered on industrial demand response, which is the core topic of the paper.

We quickly describe the content of those papers. The work performed in [33] is not exactly a review but addresses 10 fundamental questions regarding energy flexibility in buildings. One of these questions concerns the presence of business models that can effectively develop and utilize energy flexibility. The paper describes those models

based on their objective or the actors involved, without an actual comparison between them. Another paper, [34], takes a fundamentally different approach. While the previous work explores energy domains in general terms, this study specifically focuses on the domain of cooling, discussing the obstacles to developing sustainable cooling and business models and describing possible changes that may help overcome those obstacles. Conversely, [35] does not focus on a certain type of device, like [34] did with cooling devices. Rather, it centers on Renewable Energy Communities (RECs), providing an overview of their financial mechanisms, governance, and resulting business models. Moreover, it describes the related stakeholder involvement, their potential business models, and examples within a REC.

While the previously considered works have only a poor part dedicated to business models, the paper introduced in [36] is a review of the governance arrangements of business models for energy communities, analyzing them based on governance types, and identifying three main governance categories: self-governance by community members, forming an alliance, or outsourcing to a third party. Another review, [37], on the other hand, is a survey on industrial demand response in China, detailing technologies and business models, including traditional systems like Time-of-Use (TOU) pricing and newer ones involving virtual power plants and blockchain applications. Finally, the work performed in [38] addresses challenges for PV energy communities, categorizing them by policy, economic, technical, and social areas, and specifically showing the state of the art in business models and the various solutions they propose. However, only one of these works is primarily centered on business models for energy communities, and none of them actively compare and evaluate these models based on specific features.

After analyzing the content of the 6 review papers, we classified them according to the following features:

- **Importance:** Describes the extent to which the paper addresses business models, i.e., how much business models are important in the paper. One paper [36] focuses entirely on business models, while in others, business models are just one aspect of a broader analysis.
- **Devices:** Specifies whether the review targets specific devices and, if so, identifies the specific device(s) covered.
- **Domain:** Indicates whether the paper focuses on a particular domain (e.g., residential, industrial) and, if so, specifies which one.
- **Use case:** Indicates whether the review targets a specific use case (e.g., single buildings, energy communities) and, if so, specifies which one.

Table 5 describes, for each paper indicated in Table 3, its compliance with each feature. The meaning of each abbreviation is described in Table 6.

In the following, we will detail and comment on how each feature is adhered to by the papers, and identify patterns that emerge from this analysis. Specifically, we will examine whether the papers comply with the features all in the same way, or not, showing the differences among them.

**Table 5**  
Classification of the review papers according to the four defined features.

Paper	Importance	Devices	Domain	Use case
[33]	One subs.	Not specific	Res. Comm.	Building
[34]	One subs.	Cooling	Res. Offices	Building
[35]	One section	PV Batteries	Not specific	Community
[36]	Whole paper	PV Batteries	Res. Munic. SMEs Business	Community
[37]	One section	PV AC Storage	Ind.	Building
[38]	One subs.	PV HP Batteries	Res.	Community

**Table 6**  
Acronyms used in Table 5.

Devices	
PV	Photovoltaic
AC	Air conditioning
HP	Heat pump
Storage	Electric and thermal storage
Domain	
Res.	Residential
Comm.	Commercial
Munic.	Municipalities
SMEs	Small and Medium Enterprises
Ind.	Industrial

#### 4.1. Importance

Among the six papers we identified, only [36] is entirely focused on business models, making them the main topic throughout the paper. Business models are also significant for [35], as the governance models for RECs depend on them, and for [37], where they are a key aspect of the analysis of industrial demand response in China. However, business models are less relevant for [34], as they are just one of many aspects considered in the analysis of sustainable cooling, and for [38], since the main topic is broader, covering the challenges for PV energy communities, with business models being only a minor part of the discussion. In [33], the topic is also broad—energy flexibility in buildings—and business models are addressed in the ninth of the ten questions presented in the paper.

#### 4.2. Devices

Many of the review papers are not device-specific and discuss topics that are not strictly related to the use of certain devices. The most notable exception is [34], which has sustainable cooling as its main theme and therefore requires the presence of cooling devices in the analyzed contexts. [38] is also specifically targeted at PV energy communities and thus requires those communities to have solar generation, therefore focusing on the presence of PV panels. However, [38] also mentions the importance of batteries in several PV energy communities, as they allow for the management of PV-generated energy. Furthermore, [38] also describes heat pumps and hybrid PV-heat pumps energy communities. PV generation and batteries are also important in [35] since the main topic of this work is renewable energy communities, and therefore both generation and storage of renewable energy are key aspects. [36] also refers to PV generation and batteries. However, in this last paper, the main topic is the governance of business models for

energy communities, so the types of devices used in the cited works are a secondary aspect of the paper. The non-centrality of device type also applies to [37], which focuses on industrial demand response. This review describes several works that focus on either PV, air conditioning, or storage (both batteries and thermal).

#### 4.3. Domain

Many works that operate at either the building or energy community level primarily focus on the residential domain, and the works we found are no exception. The work performed in [38] mainly focuses on this domain, specifically for markets that include many households and energy communities. The residential domain is also relevant for [33,34,36]. They all refer to several literature works centered on this domain. However, [33] also addresses some questions related to commercial buildings, while [34] marginally mentions offices and the increase in productivity in optimal thermal conditions. The work performed in [36] mentions that an alliance-based system can be implemented by various actors, specifically citing municipalities, SMEs, and business entities. Finally, [37] differs from the others, as it centers on industrial demand response in China, making its domain exclusively industrial, and often remarking the difference with the residential and commercial cases.

#### 4.4. Use case

Three papers mainly focus on energy communities. Specifically, [35] is a review of renewable energy communities, describing how to invest in them. It also shows how to build an energy community and the governance models for it. [36] is still centered on governance models on energy communities, but enters more in detail on business models, while [38] targets specifically PV energy communities and describes their challenges. Regarding the other works, they are still centered on demand response or energy flexibility, but more on the buildings' perspective. [33], for example, describes ten questions about demand response but at the building level, while [37] focuses on industrial demand response and [34] on sustainable cooling. Those topics are in general unrelated to energy communities, this is why they have not been discussed in these papers.

It is important to highlight the impact of governance models in energy communities and their influence on business models. The work carried out in [35] emphasizes that the business model is established before the community is implemented, and therefore shapes the governance model itself. A successful business model for a community depends on three key factors:

- Stakeholder involvement, determined by the model's influence and relevance to them.
- The type of model, whether it is centered on prosumers, local energy markets, or flexibility aggregation.
- Existing models that have already been deployed.

Another work performed in [36] adopts a different perspective, identifying three main types of governance arrangements for energy communities:

- *Do it yourself*, based on collective decision-making. These models focus on collective generation and self-consumption and are typically disconnected from the wider energy market.
- *Form an alliance*, where various actors collaborate in designing and delivering business activities. These models often rely on local supply arrangements or energy service companies.
- *Someone else does it for you*, based on non-local institutions working in partnership across sectors. Business models are typically peer-to-peer, or based on local energy markets or aggregators.

**Table 7**  
Papers about novel business models in buildings.

Number	Title
[39]	A novel deep reinforcement learning based business model arrangement for Korean net-zero residential micro-grid considering whole stakeholders' interests
[40]	Machine learning based demand response scheme for IoT enabled PV integrated smart building
[41]	Multi-agent game operation of regional integrated energy system based on carbon emission flow
[42]	Energy flexibility and viability enhancement for an ocean-energy-supported zero-emission office building with respect to both existing and advanced utility business models with dynamic responsive incentives
[43]	Evaluate Peak Usage Reduction of a Multi-round Real-time Pricing Model Using Co-simulation
[44]	Efficient, effective and fair allocation of costs and benefits in residential energy communities deploying shared photovoltaics
[45]	Stochastic Optimal Energy Management and Pricing for Load Serving Entity with Aggregated TCLs of Smart Buildings: A Stackelberg Game Approach
[46]	A business service model of smart home appliances participating in the peak shaving and valley filling based on cloud platform
[32]	Optimal simulation of three peer to peer (P2P) business models for individual PV prosumers in a local electricity market using agent-based modeling
[47]	Comparison between economic and environmental drivers for demand side aggregator

**Table 8**  
Compliance of each paper about business models in buildings to the three identified subtopics from Section 1.

Paper	Energy flexibility	Demand response	Energy communities
[39]		✓	
[40]	(✓)	✓	
[41]		✓	
[42]	✓	(✓)	
[43]		✓	(✓)
[44]			✓
[45]		✓	
[46]		✓	
[32]			✓
[47]	✓	✓	(✓)

## 5. Novel business/pricing models

This section outlines the content and relevance of papers about business models in buildings based on a new set of features that we established. The titles of the papers are listed in Table 7.

Our research focused on papers discussing business or pricing models and related to at least one of the following subtopics from Section 1: energy flexibility, demand response, or energy communities. Table 8 outlines which subtopics each paper addresses. Like in Table 4, the checkmarks refer to papers where the corresponding subtopic has high relevance, while the checkmarks in brackets refer to papers where the subtopic is still mentioned, but with less relevance.

The most recurring theme is demand response, which is the primary focus in several models [39–41,43,45–47]. Specifically, [39] and [41] feature demand response models, [40] is centered on a specific demand response scheme, while the remaining cited papers [43, 45–47] address demand response more implicitly. Flexibility is also mentioned in [40], as it underpins the operation of demand response schemes, while [47] details how flexibility is incorporated to achieve demand-side management. Flexibility is central also in [42], where its enhancement and control for the specified use case is the main focus. Lastly, two papers, [32,44], focus on energy communities, deploying either shared [44] or individual [32] photovoltaic systems.

In the following, we will briefly describe the content of these papers. [39] presents a business model for scheduling an energy management system (EMS) in South Korea that respects local regulations while maximizing stakeholder interests, based on deep reinforcement learning. Similarly, [40] employs a machine learning approach in a different context, proposing a day-ahead dynamic pricing model for the demand response scheme based on a supervised reinforcement learning approach, implemented in an educational institute smart substation. In contrast, [41] introduces a pricing model based on game theory in its description of the interactions between DSO and prosumers, aiming to reduce CO<sub>2</sub> emissions for a regionally integrated energy system: this is defined as a *multilevel complex coupled system of multiple energy inputs, transformations, and outputs, consisting of the main bodies of distribution grids, distributed energy stations, and prosumers*.

Unlike the previous works, [42] operates in a more unusual context, describing the impact of flexibility control for an ocean-powered, zero-energy office, endowed with floating PV and a tidal stream generator system, and investigates its performance via some existing business models. [43] also addresses a specific context, proposing a Heating, Ventilation, and Air Conditioning (HVAC) control strategy in a transactive energy grid (TEG), and evaluating its effectiveness for peak shaving by proposing a pricing model. A TEG is defined as a *system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter*.

The context of [44] is different, as it describes the use case of an apartment complex with a PV system, studies a model to distribute costs and benefits between owners and residents, and analyzes the sustainability of the model depending on the pursued type of benefit. Conversely, [45] proposes a game theoretical model for a load-serving entity (LSE). This entity acts as a demand-side aggregator, for the management and pricing of thermostatically controlled loads (TCL), a generic term that encompasses HVAC systems and electric water heaters. A different scenario is considered in [46], which proposes a business model for managing appliances related to the same aggregator in a cloud platform, targeting as objectives peak shaving and valley filling. [32] pursues a different objective instead, and builds a peer-to-peer business model for PV users, targeting three different cases depending on the ownership structure (Local Energy

Provider/Community/Market), aiming to encourage grid users to participate in local communities by installing PV and improving their profits and energy self-sufficiency. This paper uses a mathematics-based model, similar to [47], which compares two demand aggregator strategies for buildings with multiple flexibility sources, within the demand aggregator business model, by pursuing the objective of reducing CO2 emissions and analyzing three cases depending on the CO2 emission allowance.

It is important to notice that, in the description of those business models, stakeholders are not always mentioned explicitly, either because the focus is on the structure of the model itself or because the model is designed for a single building or prosumer, which, apart from the provider, is the only stakeholder. In [39], the stakeholders are explicitly identified as the residential community, the TSO/DSO, and the power company/exchange company. In contrast, [40] only mentions the building itself and the utility grid as the involved parties. In [41], the DSO, distributed energy station, and prosumers are identified as the main actors in the model, and the decision-making model for each of them is also detailed. The scenario in [42] is quite different, describing a single building with tidal generation, where only the building and the system operator are involved. In [43], only the prosumers, utility, and system operator are mentioned, although the prosumers are presented as a small community. [44] is more accurate in its description, outlining a model that includes the electricity retailer for energy sales and the network operator to aggregate and manage the network. [45] is a rather simple model, and the only parties involved are the prosumers and the load-serving entity, while [46] adds the cloud service provider as a key actor, alongside the prosumers, with other market participants like the power grid, power generation enterprises, and load aggregators also involved. Finally [32] focuses only on the community itself, in the context of a local energy provider/community/market, while [47] only includes the users and aggregator.

As in Section 4, we have established a set of features to classify the papers describing the novel business and pricing models, which are outlined below.

- **Granularity:** Describes the time granularity at which the proposed business model operates, or in other words, the duration of a single time step. In the vast majority of cases, its duration is expressed in seconds, minutes, or hours.
- **Vector:** Describes the energy vector involved in the business model. Many works on energy flexibility and demand response are focused on electricity. However, some of them may consider different vectors, such as heat or gas.
- **Devices:** Describes which devices have been considered in the business model or its applications or simulations. The most common choices include batteries, photovoltaic (PV) generators, and heat pumps, although other appliances, storage, or generation devices can be used.
- **Domain:** Describes the domain for which the business model has been designed or simulated. While many business models are for residential applications, some may refer to offices or factories.
- **Use case:** Describes the use case to which the business or pricing model is applied, whether it is for single users/buildings or larger entities like energy communities or grids. The number in parentheses shows, when available, the number of units/customers in the analyzed use case.
- **Customer type:** Describes the type of customer/end-user to which the model or its simulation refers. It can refer to single users or prosumers, but also to companies or aggregators.
- **Provider type:** Describes the type of provider who would implement the business or pricing model. This is typically an actor that engages in transactions with many customers, such as aggregators, utility providers, or service operators.

- **Benefits:** Describes the type of utility that the business model provides, and more generally, the aim of the business or pricing model. Pricing models usually aim for cost optimization as a means to achieve other objectives, such as CO2 emission reduction or increased self-consumption.
- **Constraints:** Describes the types of constraints for the model to function, such as minimum/maximum numbers of customers, or specifications for which the model has been built, such as a particular type of customer.
- **Market readiness:** Describes whether the model has already been implemented and used or not.
- **Methods:** Describes the type of method used to build the model, such as machine learning, mathematical or statistical formulation.

Table 9 describes the information related to each feature related to each paper. The meaning of each abbreviation is described in Table 10. To enhance clarity, the information from Table 9 is also presented in two figures: Fig. 1 illustrates how each paper aligns with the various features, while Fig. 2 shows, for each feature, which paper adheres to it.

In the following, we will comment on the details of each feature for each paper, and identify patterns that emerge from this analysis.

### 5.1. Granularity

All the proposed models operate with granularities ranging from 1 min to 1 h. The most common occurrence for granularity is hourly, as seen in [32,41–43,45,47]. This is logical for the majority of the business models since price data is expressed hourly in many energy markets. In contrast, [44] utilizes half-hourly granularity. Finally, [39] and [40] adopt finer intervals of 5 min and 1 min, respectively. This finer granularity is likely due to the use of machine learning (ML) models, which require a higher frequency of data points to function effectively. Specifically, [39] produces 5-minute schedules because it has data available for 365 days, of which 243 days are for training data and the remaining 122 days are for testing. This granularity allows the sampling of size 69,984 (number of 5-minute intervals in 243 days) for training, and size 35,136 (number of 5-minute intervals in 122 days) for testing. Regarding [40], data has a granularity of 1 min and 5 min for both electric power consumption and renewable energy generation, as the authors decided to show both approaches and compare the results. Finally, [46] does not specify a time granularity, although it measures delay times with a granularity significantly finer than 30 min.

### 5.2. Vector

As anticipated, all the proposed models primarily focus on electricity as their main energy vector. This emphasis is understandable, given that the electricity market is the most significant segment of the energy sector. However, some studies also incorporate devices operating on different energy vectors. As discussed in the next paragraph, several works have examined devices that utilize heat, such as combined heat and power systems [41], thermal storage [41], heat pumps, air conditioning, and HVAC systems in general [41,43,45–47]. In particular, the study performed in [47] distinguishes between the amounts of heat and cold generated. Additionally, another study, [41], includes gas boilers in its analysis and presents the daily electrical and thermal loads separately.

### 5.3. Devices

Many different devices have been considered for the described models, either in their formulation or validation. The most common devices include PVs [32,39–42,44,47] and batteries, referred to as Battery Energy Storage System (BESS) [39,41,42,45,47]. The high prevalence of PV systems is due to their common use in enabling buildings,

**Table 9**  
Classification of the papers.

Features	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[46]	[32]	[47]
Granularity	5 m	1 m	60 m	60 m	60 m	30 m	60 m	ND	60 m	60 m
Vector	Elec.	Elec.	Elec. Heat Gas	Elec.	Elec. Heat	Elec.	Elec. Heat	Elec. Heat	Elec.	Elec. Heat
Devices	PV BESS Fuel cells	PV	CHP HP Boiler Storage PV	PV BESS Tidal gen.	HVAC	PV	HVAC BESS	AC	PV	PV BESS HVAC EV
Domain	Res.	Edu.	ND	Office	Res.	Res.	Fact. Office	Res.	Res.	Res. Tert.
Use case	(130) MG	(1) Buil.	(ND) RIES	(1) Buil.	(50) Comm.	(72) Apt. comp.	(100) Aggr..	(ND) Aggr.	(48) LEP LEC LEM	(2) Buil.
Customer type	Buil. (Apt. com.)	Buil. (Edu.).	Buil. (Res.)	Buil. (Off.)	Buil. (Res.)	Apt.	Buil. (Fact. Off.)	Buil. (Res.)	Apt.	Buil. (Res. Lib.)
Provider type	TSO DSO	Grid	DSO	TSO DSO	TSO	Netw.	Aggr.	TSO DSO	LEP LEC LEM	Aggr.
Benefits	Profit	Profit Peak	CO2 Comf.	Peak	Peak	Load Peak Self	Profit	Peak Valley	Self	Profit CO2
Constraints	ND	ND	RIES	Tidal gen.	TEG	ND	ND	Cloud	ND	ND
Market readiness	No	No	No	Yes	No	Yes	No	ND	No	No
Methods	ML	ML	Game	ND	Seq. alg.	ND	Game	Cloud	Mat.	Mat.

particularly residential ones, to generate energy, which is crucial in the contexts of energy flexibility, demand response, and energy communities. PV and BESS devices are often related because PV generation is intermittent, depending on the time of day and weather conditions. Batteries help to manage this inconsistency by storing excess energy when production is high and supplying energy when production is low. Some notable exceptions include [44], which focuses on directly rewarding energy production and sharing the profits, and [32], which aims to increase self-consumption by aligning consumption as closely as possible with PV generation. Other types of devices are also considered. For instance, [39] includes fuel cells, which have a role of energy production when PV generation is not available, while [41] examines Combined Heat and Power (CHP) units, gas boilers, and thermal storage (referred to as *storage* in Table 9, since it includes both electrical and thermal storage). However, this applies to energy stations, whereas prosumers in the scenario analyzed in [41] have only PV systems. The work in [42], in addition to floating PV generators, explores the specific case of tidal generators. The uniqueness of this case comes from the fact that [42] examines energy generation for an ocean-powered building. Two other works, [43] and [46], focus on HVAC devices, another common type of device in flexibility. Heat is quite common as an energy vector, as we saw in Section 5.2, and many works are centered either in generic HVAC devices [43] or specifically air conditioning [46]. The work in [45] discusses a more generic case of TCLs, which include HVAC and/or storage devices used for buying energy at a low price and selling it at a higher price. Finally, [47] considers HVAC devices for both heating and cooling, as well as electric vehicles (EVs), in the context of a public library.

#### 5.4. Domain

The majority of the models pertain to the residential domain [32, 39,43,44,46,47], which is often the focus of research on flexibility and demand response. However, it is challenging to find cases where

residential buildings are single homes. In the work carried out in [46], the type of residential building was not specified, while others [32, 39,43,44,47] involve apartment complexes or buildings with multiple habitable units. Additionally, some papers also address non-residential buildings. For instance, [40] addresses the specific case of an educational institute, endowed with a smart substation and a weather station, while [42] focuses on an office building located near the ocean, utilizing floating PVs and tidal generators to take advantage of its location. The topic of another work, [45], is TCLs, and it focuses on two types of buildings that support these loads: factories and office buildings. The work in [47] explores the case of tertiary buildings, specifically libraries, in addition to residential buildings. Although [41] does not specify the domain, it appears to be designed for residential use. However, since the prosumers in the use case are required to have only PV generation, it may apply to different domains as well.

#### 5.5. Use case

Many of the business and pricing models of Table 7 refer to single or multiple buildings. Such is the case of [40,42,43,47]. For [43] and [47], the focus is still at a higher level than a single prosumer, i.e., the considered use cases include multiple residential units (apartments) within one building. Moreover, [40] and [42] refer to educational institutes and ocean-powered buildings, respectively, which are uncommon types of buildings, making the use cases building-specific for this reason. Other models refer to larger entities. For example, [39] has been designed in the context of a microgrid, [41] focuses on a regional integrated energy system, [44] addresses an apartment complex, and [32] examines a local energy provider, community, or market, depending on the specific case. Additionally, [45] addresses the case of a load-serving entity. Finally, [46] is a unique case, as it deals with appliances operating online and belonging to the same aggregator. Regarding the number of units involved, some studies focus on single buildings [40,42], since, as mentioned earlier, the buildings in those

Papers				
[39]	[40]	[41]	[42]	[43]
Granularity: 5m	Granularity: 1m	Granularity: 60m	Granularity: 60m	Granularity: 60m
Vector: Electricity	Vector: Electricity	Vector: Elec, heat, gas	Vector: Electricity	Vector: Electricity, heat
Devices: PV, BESS, fuel cells	Devices: PV	Devices: CHP, HP, boiler, storage, PV	Devices: PV, BESS, Tidal generator	Devices: HVAC
Domain: Residential	Domain: Edu.	Domain: ND	Domain: Office	Domain: Residential
Use case: Microgrid	Use case: Building	Use case: RIES	Use case: Building	Use case: Community
Customer type: Building	Customer type: Building	Customer type: Building	Customer type: Building	Customer type: Building
Provider type: TSO/DSO	Provider type: Grid	Provider type: DSO	Provider type: TSO/DSO	Provider type: TSO
Benefits: Profit	Benefits: Profit, peak	Benefits: CO2, comfort	Benefits: Peak	Benefits: Peak
Constraints: ND	Constraints: ND	Constraints: RIES	Constraints: Tidal gen.	Constraints: TEG
Market readiness: No	Market readiness: No	Market readiness: No	Market readiness: Yes	Market readiness: No
Methods: ML	Methods: ML	Methods: Game theory	Methods: ND	Methods: Seq. Alg.
[44]	[45]	[46]	[32]	[47]
Granularity: 30m	Granularity: 60m	Granularity: 60m	Granularity: 60m	Granularity: 60m
Vector: Electricity	Vector: Electricity, heat	Vector: Electricity, heat	Vector: Electricity	Vector: Electricity, heat
Devices: PV	Devices: HVAC, BESS	Devices: AC	Devices: PV	Devices: PV, BESS, HVAC, EV
Domain: Residential	Domain: Factory, office	Domain: Residential	Domain: Residential	Domain: Res., tertiary
Use case: Apt. Comp.	Use case: Aggregator	Use case: Aggregator	Use case: LEP/LEC/LEM	Use case: Building
Customer type: Apt.	Customer type: Building	Customer type: Building	Customer type: Apt.	Customer type: Building
Provider type: Network	Provider type: Aggr.	Provider type: TSO/DSO	Provider type: LEP/LEC/LEM	Provider type: Aggr.
Benefits: Load, peak, self-consumption	Benefits: Profit	Benefits: Peak, valley	Benefits: Self	Benefits: Profit, CO2
Constraints: ND	Constraints: ND	Constraints: Cloud	Constraints: ND	Constraints: ND
Market readiness: Yes	Market readiness: No	Market readiness: No	Market readiness: No	Market readiness: No
Methods: ND	Methods: Game theory	Methods: Cloud	Methods: Mathematical	Methods: Mathematical

Fig. 1. Papers by features.

studies are uncommon, although the models could potentially be extended to multiple units. [41] does not mention the number of buildings or units, nor its domain, but refers to one single RIES. Other models have been directly implemented in cases with multiple customers [32, 39, 43–45], whether referring to users in a microgrid [39], or users in a community [32, 43], or apartments in a complex [44] or users referring to the same aggregator [45]. [47] describes two projects involving several buildings, but only one building per project has been analyzed in detail: a library and a residential building. Finally, [46] does not specify the number of buildings involved but mentions operating in a context where millions of devices are aggregated. More precisely, the total data covers 443 cities and 63483 residential areas, although it is not mentioned if they all refer to the same aggregator.

### 5.6. Customer type

Reflecting the results for the use case, many of the considered models target single buildings, particularly residential buildings. This includes [43, 46, 47] which indeed refer to residential buildings, but also [40] which describes an educational institute, [45] which refers

to factories and offices, and [42] which focuses on a specific type of ocean-powered office. The models discussed in [32, 39, 44] also belong to the residential domain, targeting specifically apartment complexes; however, they are different from the others, because they focus on individual apartments within a complex, rather than the whole building. [41] targets single prosumers, although the type of prosumer is not specified and, while implied to be residential, it may also adapt to non-residential cases. Finally, [47] still refers to buildings, both residential and libraries. We provide a brief overview of the power and energy capacities considered in these studies. [39] focuses on a community of 130 prosumers, with a total power of 400 kW PV and 300 kW fuel cells, while the total battery capacity is 600 kWh. In contrast, [40] examines a single building and provides several forecastings of its power consumption, which ranges between 70 kW and 215 kW in the considered week. [41] reports a power consumption fluctuating between -500 kW (indicating production) and 3 MW throughout the day, although the number of prosumers is unspecified. [42] mentions a variable power consumption, with a peak of 255 kW for an office building, while [43] models houses, each equipped with 3.9 kW of cooling capacity and 4 kW of heating capacity. The study in [44] details daily energy consumption in apartments ranging from 5 kWh to 22

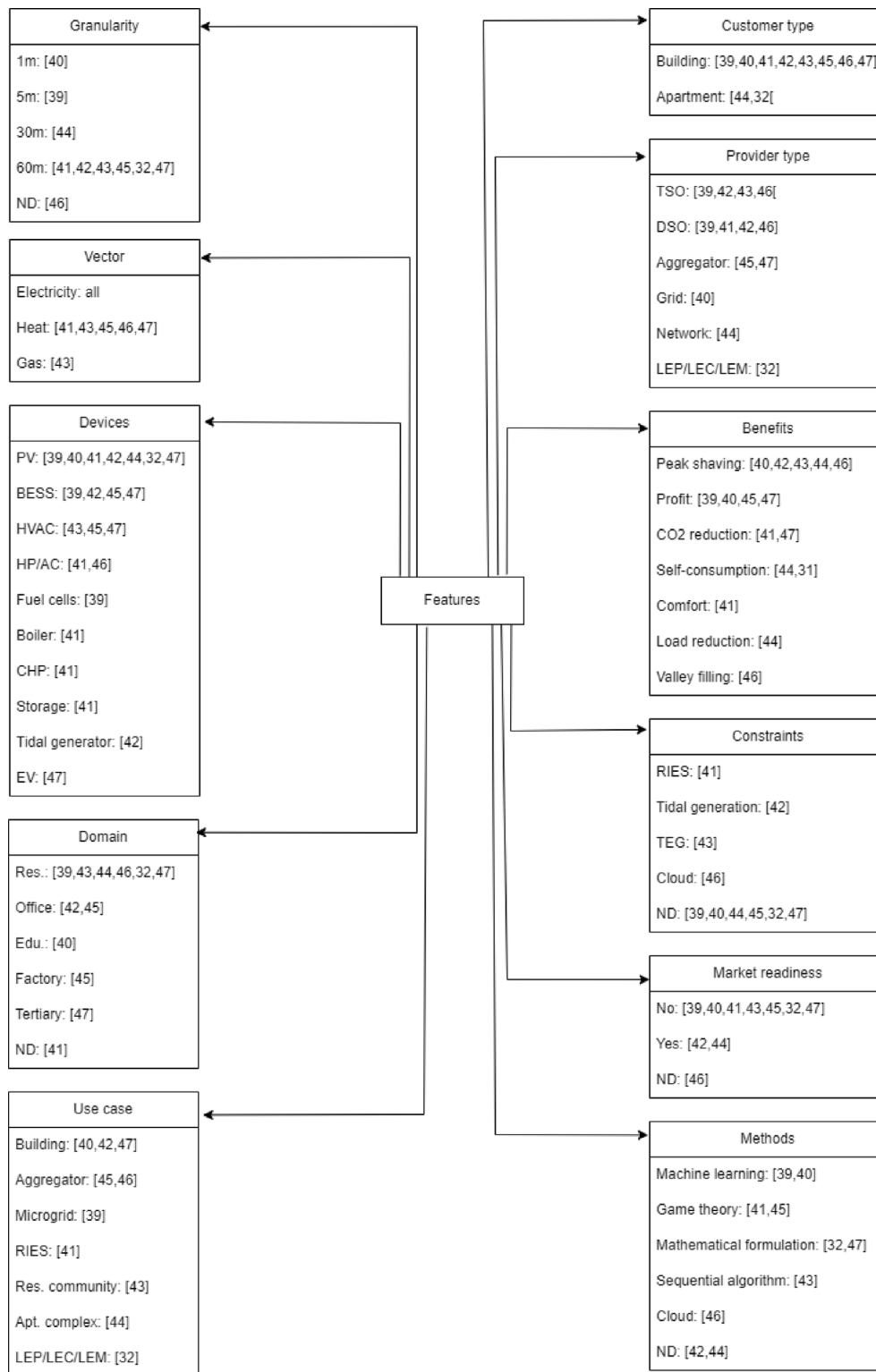


Fig. 2. Features by papers.

kWh, depending on occupancy. In contrast, [45] focuses on factory and office buildings, with peak power consumption of 120 kW and 2 kW, respectively, for TCLs. The details in [46] are less specific, reporting only the total peak power reduction. Finally, [32] mentions the total capacity of the shared PV system as 65.5 kW, and [47] describes a library with 19 kW peak power from its PV system, a 10 kW second-life battery, and a 39 kW peak power HVAC system.

### 5.7. Provider type

The type of provider depends on the specific use case and can be either the system operator, the energy provider, or any entity that serves multiple customers. The most common provider is the system operator, as seen in [39,41–43,46]. In some cases, it is not specified whether the provider is the Transmission System Operator (TSO) or the Distribution System Operator (DSO) [39], or it may be a specific entity

**Table 10**  
Acronyms used in Table 9.

<b>Vector</b>	
Elec.	Electricity
<b>Devices</b>	
PV	Photovoltaic
BESS	Battery energy storage system
Boiler	Gas boiler
Storage	Electric and thermal storage
<b>Domain</b>	
Res.	Residential
Edu.	Educational institute
Fact.	Factory
Tert.	Tertiary
<b>Use case</b>	
MG	Microgrid
EISS	Educational institute smart substation
RIES	Regional integrated energy system
Buil.	Single building
Comm.	Residential community
Apt.Comp.	Apartment complex
Appl.	Appliances
LEP	Local energy provider
LEC	Local energy community
LEM	Local energy market
<b>Customer type</b>	
Pros.	Prosumer
Apt.	Apartment
Aggr.	Aggregator
Lib.	Library
<b>Provider type</b>	
TSO	Transmission System operator
DSO	Distribution system operator
Netw.	Network
<b>Benefits</b>	
Peak	Peak shaving
Comf.	User comfort
Load	Load reduction
Self	Self-consumption
Valley	Valley filling
<b>Constraints</b>	
High cons.	High consumption users
TEG	Transactive energy grid
<b>Methods</b>	
ML	Machine learning
Game	Game theory
Seq.Alg.	Sequential algorithm
Mat.	Mathematical formulation

covering both roles in the energy market [42,46]. Only [41] specifically addresses the case of a DSO, which is the highest-level actor (i.e., the closest to production from the main grid) in the considered RIES use case, while [43] presents the TSO operating in that role, being specific to a TEG. In other cases, the provider might be indicated as the grid itself [40], the embedded network serving the apartments [44], or the load-serving entity, which acts as an aggregator in the grid [45]. [32] presents a specific case with three possible scenarios. Depending on the considered scenario, the provider may be the local energy provider (LEP), the local energy community (LEC), or the local energy market (LEM), with the LEM being the most complex. Finally, [47] refers to the Demand Aggregator (DA) for this role. We can note that, in all the cases, the provider is the highest-level grid actor, in the sense specified in this subsection.

### 5.8. Benefits

Business and pricing models bring several benefits to their customers and providers, often translating into reduced energy

consumption or CO<sub>2</sub> emissions. Profit maximization and cost minimization are common benefits, explicitly mentioned in [39,40,45,47]. Specifically, [39] models it in terms of profit maximization, while [40] has the objective of energy cost reduction. [45] aims to maximize profit at LSE level, and [47] targets directly cost reduction at the building level. In other cases, these benefits may serve as optimization objectives to achieve other goals. One of the most common goals is peak shaving, achieved in [40,42–44,46]. Cost optimization is often closely related to peak shaving, as pricing models typically increase energy costs when demand is high and decrease costs when production is high or consumption is low. This encourages prosumers to shift their loads to times when energy is cheaper, which often results in valley filling, i.e., increasing net consumption when it is at its minimum. However, valley filling is explicitly stated as an objective only in [46]. CO<sub>2</sub> emission reduction is another common objective for flexibility optimization, targeted in [41] and [47]. Increasing self-consumption is pursued in [44] and was also a primary motivation for [32]: specifically, the aim of [32] was to address positive energy districts, i.e., districts that produce more energy than the amount they consume. Again, self-consumption is often tied to peak shaving and valley filling, as in many cases the *valley* is represented by production, and *filling* means increasing self-consumption. Finally, [44] strives to achieve load reduction, and [41] aims to maximize user comfort. It is also important to separately highlight the economic benefits of each model, although it should be noted that they are compared against different baselines and metrics, and not all the models are designed to generate profit. The model proposed in [39] allows for savings between 7% and 12% in operational costs with respect to the considered DQN baseline, while in [40] dynamic day-ahead pricing can fluctuate to promote peak shaving, with tariff reductions of around 21% during low-price time slots. In [41], profits for the DSO increase by 24%, while prosumers experience a 4% reduction in costs in the best-case scenario. [42] reports a maximum tariff reduction of 33% in the all-grid scenario, and even better results in the zero-emission cases. The economic benefits in [43] are marginal, offering at most a 1% cost saving for consumers, although the primary focus of the paper is peak shaving. In [44], economic benefits are discussed but in absolute terms, i.e., specifying the amount of money by which energy costs can increase or decrease depending on the tariff applied, but without describing the total amount paid. Specifically, in the best case, the average yearly prosumer saving is 405\$. Similarly, in [45], profits are described in absolute terms and it is not provided relative profit changes for the load-serving entity. The case of [46] is different, as energy savings are reported, but no economic benefits are specified. Furthermore, [32] evaluates different scenarios, quantifying economic benefits in terms of the internal rate of return on investments, ranging from 1.9% to 6% in the best case for the LEC scenario, and 3% in the best case for the LEP scenario. Finally, [47] reports savings of 5% and 26%, respectively, in two use cases, with the difference attributed to the presence of an energy management system that reduces consumption and limits the number of flexibility activations.

### 5.9. Constraints

Many of the described models do not impose specific constraints or restrict themselves to particular users or circumstances. Indeed, the models [32,39,40,44,45,47] do not require a specific setting or type of user to function. Most of these models are designed for particular domains but can be applied in different contexts like models initially intended for residential use that can also be adapted for other scenarios [32,39,44,47] or vice versa [45]. [40] has only been simulated in the context of an educational institute, but it is reasonable to assume that the proposed model could work in other contexts as well.

Exceptions usually pertain to very specific cases with particular setups or devices involved. One such example is [42], which focuses on an office complex near the ocean that produces energy from the

sea using floating PV and a tidal generator, and therefore is difficult to envision in a different context. This specificity defines the entire paper. [43] has been built for the specific context of transactive energy grids, while [41] addresses regional integrated energy systems. These works are also very specific to the described cases, and it is not certain whether they could be applied to different contexts. Additionally, it is worth mentioning [46], which involves aggregating and managing several devices in a cloud environment, and it is unclear whether this approach would work in different scenarios.

#### 5.10. Market readiness

Almost none of the proposed models have been implemented or used in a wide, real-world scenario. The only exceptions are [42] and [44]. [42] uses an existing business model to examine the feasibility of the proposed specific scenario and aims to improve the model to enhance energy generation and market interaction for the apartment complex. [44] compares five types of tariff models over seven indicators, evaluating the benefits of each one. All the other models proposed are either novel, significantly modified from existing ones, or it is unclear whether they have already been implemented [46]. The reason why many of these models are not yet considered market-ready is that they are primarily prototypes or academic studies that have not been implemented in real-world scenarios. However, some authors identify challenges that must be addressed to advance these models. In [39], the viability of providing privacy for stakeholders and the economic feasibility of the required investments need to be established. Moreover, the work performed in [43] requires the implementation of a more sophisticated algorithm to manage all appliances, along with a more accurate hourly prediction model for the management system. The efforts performed in [45] need improvements in estimating price bounds for the load-serving entity and should consider peer-to-peer energy trading and market price uncertainty. Furthermore, the work presented in [32] would benefit from studying the impact of EVs and batteries, as well as further investigation into demand to advance toward market readiness. Finally, the business model proposed in [47] still needs to examine the cost of deployment and development of a method to quantify environmental benefits.

#### 5.11. Methods

A wide variety of methods and techniques have been employed to develop the models discussed in Table 7. Machine learning has been utilized in two works. [39] uses deep reinforcement learning and deploys a value-based technique called dual deep Q-learning (DDQN) for defining models and rewards. On the other hand, [40] uses a supervised reinforcement learning approach for predictions, on which the demand response behavior and pricing model are based. Game theory has been used by two other works: [41] and [45], both employing a Stackelberg game approach to model the grid and users' behavior. The former is supported by a genetic algorithm for decision-making, while the latter solves a mixed-integer linear optimization problem. A sequential algorithm has been employed in [43] to define the price for each user and predict the amount of consumed energy by each agent. Conversely, a cloud-based approach has been used in [46] for both the aggregation of loads and the management of rewards via an online platform using a specific currency. Finally, the formulations of the models in [32] and [47] are strictly mathematical. In the first case, the price is determined by a simple formula based on self-sufficiency and the price of energy bought from other users or the parent grid. In the second case, the cost is defined not as a function to optimize, but as a set of constraints to the device model. Specifically, the model in [32] is quite simple, based on purchasing electricity from the cheapest source, either locally or from the main grid. In contrast, the model in [47] resembles a linear optimization problem, a common approach in flexibility modeling literature. Both

approaches are relatively straightforward compared to other models in the field, as they address problems with simple formulations. It would be interesting to extend these models to include more devices or actors, making them more comprehensive and bringing them closer to market readiness.

## 6. Discussion

### 6.1. Key takeaways

In this section, we summarize the main findings of our review, whose focus was to find and classify novel business and pricing models at the building level. In Section 2, we compared our work against current literature, and showed how our paper covers the gap in literature of a review paper on building-level business models covering the three main subtopics identified in Section 1. The only exception is [19], which, however, adopts a very different approach from our work and focuses on a different time frame (the paper is from 2019, whereas our study covers the period from 2020 to 2024). In Section 4, we identified a total of six review papers: among them, only one [36] had business models as its main topic, focusing specifically on their governance arrangements. The majority of these works focus primarily on residential buildings, which are the most common context for energy communities, a central topic in half of the papers. Review papers are often not device-specific, although PV generation and batteries are frequently mentioned. This is logical, as PV allows energy communities to produce energy, and batteries are the most common way to manage the uncertainty of energy production. Additionally, some works specifically address renewable energy communities [35] or PV energy communities [38], further supporting this point.

Regarding papers describing novel business or pricing models, there are several interesting insights. First, it is evident that most of the works focus on demand response, while energy flexibility is often utilized implicitly, but is rarely the main focus of these papers. Similarly, there are relatively few papers centered on energy communities. Regarding energy vectors, all the works consider electricity as a source of energy. This was expected since the electric energy market is the most active and logical for business models to operate in. However, 5 out of 10 works also include heat, as heat pumps/HVACs are good devices for generating energy flexibility, so they are among the most popular devices to be considered for this kind of research, along with PV (7 out of 10) and batteries (5 out of 10). PV systems are widely considered because they enable grid users to become prosumers, allowing energy communities to have both production and consumption, which is crucial for topics like self-consumption and peer-to-peer energy trading. Batteries are common because, like HPs/HVACs, they provide energy flexibility and allow energy generated within the community to be used when demand is higher.

Analyzing the actors involved in these business models reveals that customers are usually buildings, whether residential or office, while providers are higher-level actors like DSOs and/or TSOs (5 out of 10 cases). Many of these models are not yet market-ready, which is expected since research papers often discuss completely novel ideas. Only in some cases there are modifications to previously existing models [42] or already existing models [44]: in the latter case the novelty lies in their application rather than in the models themselves.

Finally, the features that show the most variety are the benefits pursued and the methods used. The variety in benefits pursued is due to the different optimization objectives, with our sample showing diverse goals, though some were more common, such as peak shaving, which was an objective in half of the works. The methods used exhibit even more variety, which makes sense given the multiple ways to formulate a business model and the various approaches that can be taken, such as machine learning [39,40], game theory [41,45], mathematical formulation [32,47], and others.

## 6.2. Future directions

The literature analysis in this paper highlights several research areas that remain largely unexplored. From the analysis of review papers in Section 4, we observe that only one paper [36] explicitly focuses on smart energy business models. Similarly, Section 2 shows that the number of papers on this topic is limited, and most are outdated. As a result, the field of smart energy business models remains largely untapped, making it worthwhile to explore some of its subtopics. In terms of devices, while many papers mention batteries, none focus specifically on their use in business or pricing models, despite their significant importance. In terms of domains, the industrial and office sectors lack reviews specifically targeting business models designed for them, representing another gap in research. Finally, at the building level, business models are only a marginal topic in existing papers. This paper addresses that gap by reviewing smart energy business models at the building level.

For papers describing actual business models, we observe patterns in the features identified and additional research gaps that could inspire new models. From the compliance of each analyzed paper about business models with respect to the three subtopics identified in Section 1 (energy flexibility, demand response, and energy communities), and shown in

Table 8, we can see that business models focused on flexibility modeling are scarce, and there are relatively few models for energy communities. These areas offer promising directions for developing new business or pricing models. In terms of features, business models for electricity are prevalent, while heat-related models are less common. Business models for district heating or combined heat and power are particularly rare, with only [41] addressing the latter, and only in a marginal way. This represents a promising area for future research, especially as heating becomes an increasingly important topic, both in combination with electricity and as a standalone issue. When considering the domain, industrially-oriented business models at the building level are less common than those targeting residential sectors. Only [45] focuses on factories and offices, while [42] addresses a very specific case related to tidal generation. In terms of benefit, the most common objectives are being pursued by the existing models, although comfort is only considered by [41]. Therefore, a good direction for a new business model could be the optimization of cost and comfort. Lastly, the wide range of methods used in existing models suggests there is no single dominant approach, allowing flexibility in tailoring solutions to specific models based on their focus. Mathematical models, while relatively simple, could be extended to address more complex problems, such as involving more devices or stakeholders, bringing them closer to real-world implementation.

## 7. Conclusion

In the context of smart energy, the use of flexibility has opened many possibilities for grid management and user interaction. Demand response enables users to react to the grid's needs and cooperate, usually in exchange for monetary compensation, while energy communities allow prosumers to interact with each other, facilitating peer-to-peer energy trading and other economic transactions. With these changes, it is no surprise that several business and pricing models have emerged, aimed at reducing energy costs and encouraging prosumer behavior that benefits the grid, such as improving self-consumption, enhancing grid stability through peak shaving, and reducing CO<sub>2</sub> emissions. This work explores the state of the art in pricing and business models for buildings within the main relevant contexts for the grid: demand response, energy flexibility exploitation, and energy communities. From 2020 to 2024, we identified 16 works that meet these criteria: 6 review papers and 10 novel proposals for models. Several common aspects can be observed among these works. First, they all focus on electricity as the primary energy vector, which is logical

given the prominence of the electricity market. Additionally, most works address the residential sector, with PV systems and batteries being the most common devices. This is because PV generation allows energy communities to produce energy, and batteries are effective for managing energy flexibility and allowing grid users to consume PV-generated energy at the most convenient times for them. Regarding the methods used to develop these pricing and business models, there are many different approaches, with no single method prevailing over others.

This work provides insight into these pricing and business models, showcasing the state of the art in research and highlighting the main similarities and differences among the currently available papers. In the future, we plan to develop specific models targeting the gaps identified by this research, aiming to improve the objectives and performance compared to the currently available works.

Moreover, feasibility analyses of various business model typologies can be conducted by considering different countries and contexts, including regulation, legislation, market conditions, and the technical features of the grids.<sup>3</sup> Additionally, other aspects of the business models could be further explored, such as methods and criteria for engaging users and potential customers, as well as identifying the geographical contexts most suitable for these models. Furthermore, the application of selected business models can be analyzed, assessed, and simulated based on ongoing experiences in energy flexibility within the research activities of the COLLECTiEF EU project and its pilot case studies.

## CRediT authorship contribution statement

**Fabio Lilliu:** Writing – original draft, Writing, Software, Methodology, Formal analysis. **Marco Pietrobon:** Writing – review & editing, Project administration, Investigation, Funding acquisition. **Diego Reforgiato Recupero:** Writing – review & editing, Supervision, Investigation, Funding acquisition, Formal analysis, Conceptualization.

## Declaration of competing interest

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

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## Data availability

Data will be made available on request.

<sup>3</sup> Market and stakeholder analysis. <https://collectief-project.eu/resources>.

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