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Article

Business Models in the Smart Grid: Challenges, Opportunities and Proposals for Prosumer Profitability

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Abstract: Considering that non-renewable energy resources are dwindling, the smart grid turns out to be one of the most promising and compelling systems for the future of energy. Not only does it combine efficient energy consumption with avant-garde technologies related to renewable energies, but it is also capable of providing several beneficial utilities, such as power monitoring and data provision. When smart grid end users turn into prosumers, they become arguably the most important value creators within the smart grid and a decisive agent of change in terms of electricity usage. There is a plethora of research and development areas related to the smart grid that can be exploited for new business opportunities, thus spawning another branch of the so-called "green economy" focused on turning smart energy usage into a profitable business. This paper deals with emerging business models for smart grid prosumers, their strengths and weaknesses and puts forward new prosumer-oriented business models, along with their value propositions.

Keywords: smart grid; business model; prosumer

1. Introduction

The transition from the current energy distribution network towards a more sustainable and efficient one by means of the smart grid is expected to result in dramatic changes for energy markets in the short to medium term. It must be considered that the amount of world inhabitants living in cities has not surpassed people living in the countryside until recent years [1]. In addition to that, Earth's human population has become more abundant than ever, measuring more than 7170 million inhabitants as of July 2014 [2]. As can be figured out, this huge quantity of human lives demands an equally challenging quantity of energy to ensure the fulfilment of the usual duties of their daily life. Therefore, electricity demand is expected to grow at the same rate as the number of human beings on Earth increases, and since the Earth has profuse, yet limited, resources, it becomes of major importance to rationalize the use of energy, as well as trying out renewable energies that will provide electricity to consume with a lower impact on the planet.

A way to help the achievement of this goal is using the smart grid. It has been claimed by Gellings to provide power systems with intelligence by means of "the use of sensors, communications, computational ability and control in some form to enhance the overall functionality of the electric power delivery system" [3]. The underlying idea is that with the usage of information and communication technologies, this new power grid will offer a way to: (1) deliver additional energy into the power network, thus increasing the amount of energy that can be utilized; and (2) consume electricity in a more efficient way, as there will be more awareness about its cost. The inclusion of renewable energy sources (RESs) from the end user side implies a pivotal change: electricity consumers are also able to produce electricity now, hence turning them into "prosumers" with a different role in the whole power grid system. As can be observed in Table 1, significant changes are expected with the widespread use of the smart grid.

Table 1. Comparison between features with and without the smart grid.

Environment	Without Smart Grid	With Smart Grid
Data	Offline, scarce data One-way stream	Online, abundant data (big data) Two-way interchange
Business models	Producers and consumers Static business models	Prosumers Dynamic business models
Energy	Focus on fossil-based, non-renewable energies Centralized energy production	Focus on renewable energies Distributed energy production
Information and communication technologies	Weak preventive mechanisms Little use of information and communication technologies Infrastructure with scarce intelligence	Strong preventive mechanisms Widespread use of information and communication technologies Information inference and decision making features
Agents	Reduced amount of participating agents	Potentially huge amount of participating agents

Not only does the power grid of the future promise to be a dramatic technological, environmental and economic upgrade of its earlier counterpart, but it will be also a more pervasive technology influencing the common life of users. With this new environment, there are several new services that can be provided and that will constitute a basis for expanding business models where the smart grid plays a major role. For instance, there are three that can be regarded as of significant prominence:

Demand response (DR): DR is a collection of policies that has as a target flattening energy consumption during different times of the day, aiming especially to lower energy demand at peak hours. Since these are the most critical working times for a power station, incentives are offered to the end users that will reduce their electricity consumption during those particular moments. End users will get economic compensation for equipping devices to work as load controllers (since any piece of equipment consuming electricity will be regarded as a load). As claimed by the U.S. Federal Energy Regulation Commission, demand response is linked to: (1) changes made by end users in terms of their regular power consumption (basically due to modifications in the price of electricity during a period of time); (2) encouragement on payments tailored to induce lower energy consumption during high wholesale market prices; or (3) as a way to assist the system when its reliability is compromised [4].

Demand side management (DSM): This is another set of policies focused on rationalizing and lowering differences in energy usage peaks. Usually, smart grids encourage the introduction of DSM to allow demand to follow the energy supply pace. DSM is a well-known instrument developed to shift loads from peak periods to other time periods where power demand is lower. Although it is somewhat similar to demand response, DSM is not quite the same concept: DR tackles energy consumption with very little time in advance and is used as a punctual, temporary solution, while DSM is more about a long-term strategy that evaluates methods to save energy and energy planning in general, as, for example, storing energy during off-peak hours and releasing it during peak hours to reduce strain on the power network [5].

Electricity loads: This term, as introduced before, implies any sort of hardware device that will consume electricity. Consequently, they must be borne in mind when designing the infrastructure for the smart grid. As electricity becomes more widely available, electricity loads become more varied (plug-in hybrid electric vehicles, *etc.*).

Furthermore, it must be highlighted that despite minor differences in each country due to their local circumstances, the power grid is operated the same way almost everywhere. In order to find out what business models could arise when deploying the smart grid, it is advisable to understand which entities compose the value chain related to electricity production, distribution and consumption.

Power generation: This must be understood as turning raw energy resources into electricity. The major share of the produced energy is at high-scale power plants, either reliant on fossil fuels or nuclear energy. The infrastructure used for this power generation is owned by a relatively small group of companies.

Transmission system operator (TSO): This is the entity responsible for providing the power grid infrastructure used to transmit electricity, usually covering sections where high voltage power is needed. Transmission can be defined here as high tension electricity transfer by using a power network that covers long distances. Additionally, the TSO will be in charge of the offer/demand balance involving electricity in a certain area. Nowadays, the transmission system is designed to deliver electricity from central production locations to a huge number of clients.

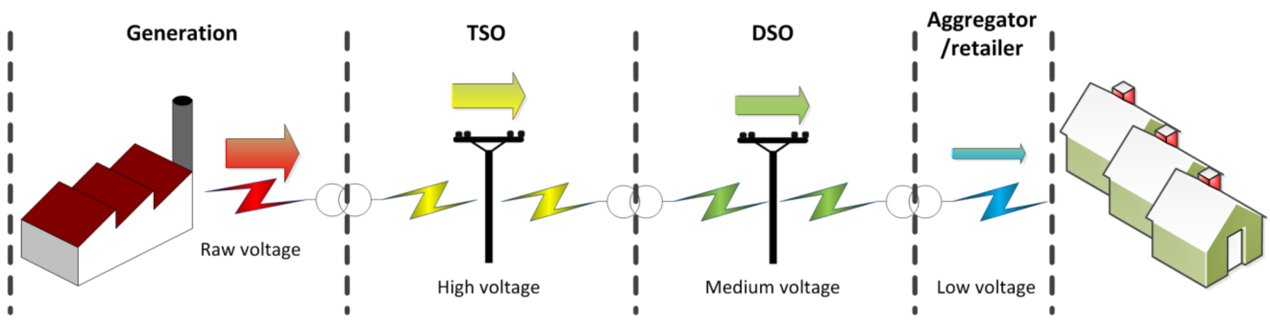
Distributed system operator (DSO): This is responsible for all of the features related to end user connectivity to the power network. In a smart grid scenario where consumers have been converted into prosumers and there are more energy generation places connected to the power grid, energy and information flows will be bidirectional. This new situation will create a need for increased flexibility in the distribution network.

Aggregator/retailer: This entity controls low voltage power that is transferred to the usual places where it is consumed. It is in charge of purchasing electricity, its metering and billing functionalities.

End consumer/prosumer: This last link in the electricity value chain is easily the most important creator of value within the smart grid. Prosumers will be given a more active role than mere energy consumers and, due to their number and their flexibility, are likely to become major actors in new business model generation.

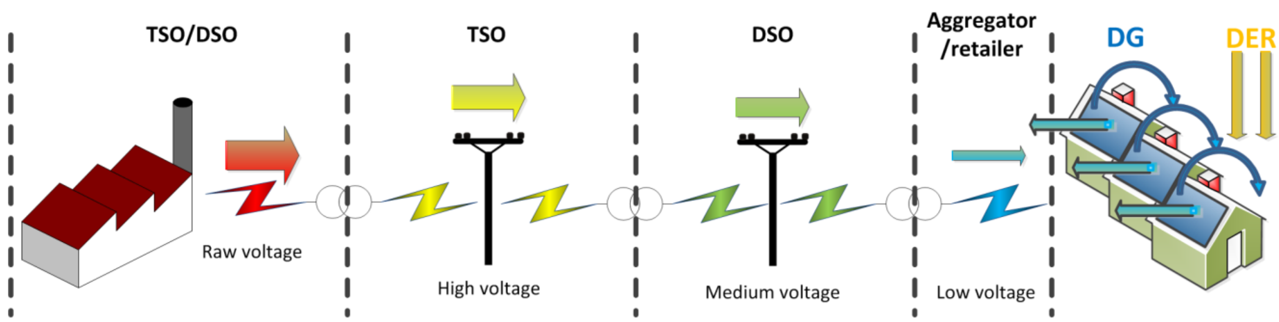
All of these considerations have been depicted in Figure 1. The power plants use natural resources of different origin (coal, petroleum, *etc.*) and process them by using internal machinery—for example, turbines and generators—thus obtaining raw electricity that is transformed into high voltage electricity to be transported through high voltage lines. Eventually, it is turned into medium and low voltage electricity that, in the end, is transferred to small-sized scenarios (typically, dwellings, department stores or public buildings).

Figure 1. Regular electricity production, distribution and consumption value chain. TSO: transmission system operator; DSO: distributed system operator.



While many already existing parties will remain in a smart grid-based scenario with the same services that they had before, there will be some other elements offering additional ones. The most obvious would be the distributed generation (DG) of energy that will take place by using distributed energy resources (DERs) and renewable energy sources (RES)—like solar power or wind power—that will be used to the prosumer's advantage, as shown in Figure 2.

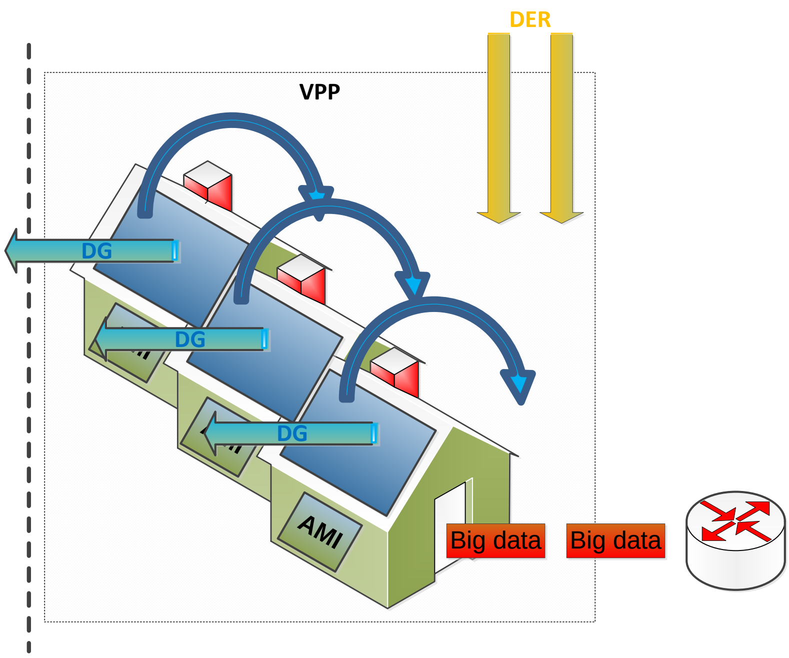
Figure 2. Electricity production, distribution and consumption value chain with a prosumer. DG: distributed generation; DER: distributed energy resources.



The utility that prosumers can get from electricity consumption/generation can be quantified in terms of economic benefit and comfort. Basically, their individual attitude will determine the power injected or withdrawn to the grid, as prosumers will not necessarily strive for the global welfare of the system; for instance, non-cooperative prosumers could be driven by their own utilities and influenced by their social environment. In this respect, efficient market-based operation and control are needed for emerging distribution systems with a large population of autonomous, self-interested prosumers, so as to obtain both coordinated participant behaviors and optimized global performance. As for emerging electricity distribution systems, the overall system performance is related to the interactions among macro-players (regulators, DSOs, retailers) and micro-players (prosumers) with different global or individual motivations and utilities. Usually, the global utilities pursued by the macro-player in terms of environmental control, energetic efficiency or technical feasibility of the power network can be pursued providing proper price signals to the micro-players and devising strategies expected to align global goals with individual utilities.

The prosumer part of the grid could become the most enriched one due to the added information and technology features. However, the upgraded features of the end user side come at the cost of requiring more technology in order to make them usable. Thus, an advanced metering infrastructure (AMI) will be required to control how electricity is being produced and consumed. AMI provides data that can be used, too, either for local statistics or trading purposes, resulting in an environment where big data can be deemed as another additional component prone to providing services. Finally, it must be considered that a cluster made up of several buildings producing energy can also be regarded as a virtual power plant or VPP, as represented in Figure 3. Applications and services can be expanded from the consumer point of view, being able to actively participate in the trade and consumption of energy resources, as well as using them in a more efficient, environment-friendly manner.

Figure 3. Close-up view of the prosumer scenario with a Virtual Power Plant (VPP). AMI: Advanced Metering Infrastructure.



The enhancement, rather than replacement, of the current power grid model in order to become the one represented by the smart grid will require the addition of new hardware (AMI, RES infrastructures, DG infrastructures, network infrastructures) and software (big data, ICT) elements that will result in brand new services, generating new markets and jobs. It is here where new business opportunities exploited either by using traditional business models or by finding out new ones will spring up. Not only are large DSOs or TSOs bound to be part of the new scenario, but small- and medium-sized enterprises (SMEs) will also be able to have their own share in it. While the evolution of the smart grid (both in information and communication technologies and power-related infrastructure) progresses, continuous research activities on technology, business models and prosumer perception and behavior is needed as a way of informing about the existence of new products, services and opportunities in it.

The main objective of this paper is to apply the business model concept to the smart grid. Emerging business opportunities around the smart grid regarding prosumers, along with their strengths and weaknesses, will be presented. These findings can foresee the future perspectives for the next few years and offer insights for policy makers and actors in the energy system. As a general concept, it is considered that prosumers will strongly participate in many of the business models of the future, going as far as being the actors at the very center of these business models in some cases. From our point of view, the main research challenges being presented are: the status of business models for prosumers in the smart grid so far, and given its state, whether there are proposals that could be put forward so as to improve the overall *status quo*. Consequently, the main contributions of the paper are:

- A review on the most prominent proposals related to business models for prosumers in the smart grid has been made. In order to do so, the literature has been studied to find out the most complete proposals regarding this topic and a way to classify the latter according to three non-functional requirements, namely focusing on the prosumer's side, focusing on the business model description and the generation of added value.
- A study on prosumers and their role in the smart grid has been put forward. The role of the prosumers in the electricity value chain is thoroughly explained in this paper.
- Proposals for prosumers business models. From the obtained results and considerations made before, business model proposals for prosumers are formulated. In this case, new prosumers value propositions are described, and some particular examples are provided.

This paper has been organized as follows: an introduction on the most significant stakeholders of the smart grid and the concept of prosumers has already been exposed. The next section deals with the related works done in the smart grid area considering business models that imply actions taken by prosumers to a greater or a lesser extent. Section 3 copes with the challenges that are faced by prosumers in the smart grid, taking into account the reviewed proposals of the previous section. Section 4 describes what must be expected from a business model, whereas Section 5 describes the role assumed by the prosumers in the new electricity value chain created as a result of smart grid deployment. Several business models for prosumers are put forward in Section 6. Finally, conclusions and an approach to future works have been added as the last sections.

2. Related Works

It can be presumed that the location where most of the changes of the smart grid take place compared to the regular power grid is on the former consumer's side, since they have become prosumers who are able to establish a bidirectional model of energy generation and consumption. In this way, this study of related works is focused on business models for the smart grid, where prosumers are taking part as a major actor of them. In order to make a more accurate study of the state of the art in terms of business models for prosumers, there are several non-functional requirements that must be taken into account. Thus, three of them have been chosen as critical for reviewing the existing proposals:

Focus on the prosumer's side: As the scope of this paper is dealing with the prosumer possibilities to obtain a profit by participating in the smart grid, it is only natural that this feature is taken into account.

Focus on the business model description: It is inevitable to provide a description, so as to have a good grasp on what the proposal is about, for it is necessary to know the way in which it is structured.

Added value generation: How value is generated is a characteristic that can make a difference between proposals, as crystal clear information about how prosumers take a prominent role in the smart grid market is required.

With these requirements, an accurate way to review the presented proposals can be determined. Therefore, a table that describes the criteria chosen to assess each of the studied proposals has been elaborated. A three-grade scale has been built, with high, medium or low levels as values, depending on the degree of fulfillment of the proposals when taking into account the non-functional requirements. The table is depicted here as Table 2.

Table 2. Non-functional requirements assessment.

Focus on Prosumer's Side		**Description**
Grade	High	The proposal has been conceived around the prosumers. Detailed information about their behavior is provided.
	Medium	The proposal includes prosumers as a non-leading entity in a bigger scenario or as an afterthought.
	Low	The proposal offers next to no information about prosumers.
Focus on Business Model Description		**Description**
Grade	High	The proposal provides profuse information about the business model where prosumers are involved (diagrams, flowcharts, descriptions, *etc.*).
	Medium	The proposal offers information that is barely enough to understand the business model in which prosumers are taking part (high-level description, *etc.*).
	Low	Scarce information is given about the business model for prosumers (if any).
Added Value Generation		**Description**
Grade	High	Value generation is comprehensible and realistic, as described in the proposal. Plenty of information about how the value is generated has been depicted.
	Medium	Only high-level details regarding prosumers added value generation are provided by the proposal.
	Low	Very few data are offered by the proposal regarding added value generation for prosumers.

It must be noted, though, that what is being specifically assessed here is to what extent proposals are meeting the non-functional requirements defined before, rather than subjectively regarding these proposals as "good" or "bad". Keeping this detail in mind, the most compelling proposals are the ones described in the following subsections.

2.1. Goal-Oriented Prosumer Community Groups for the Smart Grid

Rathnayaka *et al.* [6] put forward their own ideas of what a group of consumers, organized as a cluster of communities (referred to as community groups) sharing the resources available from the smart grid, should be. The authors claim that a desirable business model for the prosumers is one where a plethora of the latter is cooperating to form a larger facility that is kept reasonably distributed. In this way, the problems that may appear either if the prosumers are kept too isolated and powerless to influence the energy market or become too centralized and reliant on one single coordinator, as may happen with virtual power plants, are avoided. Furthermore, the authors stress the benefits of a microgrid model, which is expected to require a lower amount of intermediary actors, thus reducing energy costs. Community groups aim to solve the issues that a group of individuals with heterogeneous interests may cause when pouring their produced energy onto the power grid (such as differing energy quantities during different periods of time). Goal-oriented prosumer community groups seek the integration of different actors that do not even require being technically interconnected. This proposal intends to select prosumers in accordance to their common interests and targets. The procedure is done in four steps: (1) the groups (or community) are defined, obtaining a segmentation of the profiles; (2) new prosumers are incorporated and evaluated during the process; (3) one goal is defined with a negotiation process among the partners involved; and (4) a raking of members is created with the purpose of deploying varying privileges among them. At this point, the authors claim that power can be bought from nearby prosumers in a more efficient manner, without requiring anything outside of the group. Besides, these communities are deemed as flexible enough to be re-arranged based on similar energy sharing behaviors.

Focus on prosumer's side: high. It is mentioned as being placed at the very center of the new *status quo* created by the inclusion of the smart grid in the electricity market.

Focus on business model description: low. Despite remarking on the importance of the prosumers, a detailed plan on how prosumer activities may become profitable is not present.

Added value generation: low. Since an explanation on the business model for prosumers is lacking, there are very few hints about the added value of the purpose researched by the authors, with the exception of providing a third way for prosumer organization that is neither a virtual power plant nor a microgrid.

2.2. Smart Grid Prosumer Grouping on Forecasting Accuracy

Da Silva *et al*. [7] offer their own work dealing with grouping prosumers for forecasting services, which somewhat resembles the previously described proposal. However, the authors stress in this work the importance of performing accurate forecasts for local electricity markets, or rather, energy communities, as a way to offer a service that could become the cornerstone of a business model about energy consumption forecasting. From the authors' perspective, local electricity markets are a desirable model for electricity production and consumption, because of their "software management control" facilities and efficient resource allocation and pricing. Under this business model, forecasting must take part as a service integrated in prosumer virtual power plants (pVPPs) able to minimize the possibility of forecasting being inaccurate when it uses only one or a few dwellings in its predictions. Retailer costs are the ones used as the starting point for market trading, so the goal will be obtaining a price below them. The authors describe how loose forecasting can result when a lack of efficiency in energy trade from the prosumers' side appears when using different forecasting algorithms. Moreover, the authors depict data obtained from simulations that strengthen their point of achieving more efficient energy purchasing and consumption by having the prosumers acting as a group rather than a set of aggregated individuals.

Focus on prosumer's side: high. The concept of providing business applications for a prosumer is of critical importance for the proposal presented by the authors.

Focus on business model description: low. While real market models are used to describe the proposal (such as NOBEL—Neighbourhood Oriented Brokerage Electricity and monitoring system—based on the European Energy Exchange [8]), it is not explained how they will become integrated into the smart grid, nor is the procedure for the end user to become a profitable prosumer.

Added value generation: low. Aside from a more optimized energy proposal, the exact features that the business model is using are not thoroughly described; the overall business model is hinted at instead of being specifically described. Besides, the proposal presented here seems to be oriented toward having prosumers saving energy costs rather than trading their produced energy.

2.3. Future Smart Grid Prosumer Services

Karnouskos [9] expresses his vision about how services will be used to the prosumers' advantage in the future. The author mentions the promising future of services for prosumers in the smart grid, highlighting that it behaves as a system of systems working under a bidirectional information exchange between energy production centers and prosumers at the other end of the communication. The author puts forward several examples of smart grid energy services that should be considered: (1) timely energy monitoring, with information about energy consumption habits that may or may not be shared with other third parties, and of major usefulness for automated decision procedures; (2) timely control/management to monitor the lifecycle of different subsystems and devices; (3) energy brokering, strongly related to energy trading in online market places, or at least, user reaction to energy provided price signals; (4) general real-time analytics and value added services, which need the available transferred information, so as to perform more sophisticated functionalities (for instance, real-time analytics); (5) community management services used to guide common interests for a group of prosumers; and (6) energy application stores, where users will be able to install energy related applications for mobile or mobile-like devices. In addition to that, the author stresses the importance of system interoperability, which, according to his point of view, is not given enough care in current developments, associating the efforts that must be done in this field with the ones involving the Internet of Things or the Internet of Services.

Focus on prosumer's side: high. The author's purpose of the presented piece of work is putting the prosumers at the center of future developments.

Focus on business model description: low. Although several examples are described and a number of ideas are suggested to get a grasp on how they would work, very little detailed information is provided.

Added value generation: low. The description that is provided about the services expected to be obtained is not enough to justify in a precise manner where the value generation is.

2.4. Prosumer-Based Smart Grid Architecture for a Flat, Sustainable Electricity Industry

Grijalva and Umer Tariq [10] put forward their own proposal aimed at achieving an electricity consumption curve that is as flat as possible, without any brusque peaks that may cause instabilities to the whole power grid system. The authors use the National Institute of Standards and Technology (NIST) model as a reference for their own vision of the smart grid, adding concepts from distributed systems and service oriented architectures for prosumers. Their proposal divides the usual characteristics a prosumer must rely on into a four-layered architecture. These layers are: a device layer for the physical connectivity of the electrical components, a local control layer to control hardware parts, like a battery charger or a transformer, a system control layer for control requirements (system restoration, economic and secure operation, *etc.*) and a market layer in order to make choices depending on the prosumers' available resources regarding economic objectives. This latter feature is the one most remarkable from the perspective of a business model; the authors claim it is able to use a system control data and financial, economic-based applications as risk management, price and load forecasting or reserve co-optimization. Additionally, the authors suggest ways to employ these services via interfaces that will grant access to each of the layers of this architecture, offering tagged messages about what the exchanged information should look like.

Focus on prosumer's side: high. The solution proposed by the authors involves prosumers as the main actor of the system, along with their energy needs.

Focus on business model description: low. The description is sound in terms of energy savings and the procedures that are used to provide it, but it struggles to find a way to describe how this achievement will be commercialized as a solution for an end user.

Added value generation: medium. Significant technical details are given about how the information regarding market data and services is used to control the system. However, there is not a defined exploitation plan dealing with the most specific requirements for prosumers' profitability. Furthermore, the proposal is mostly focused on energy saving instead of conceiving of the prosumers as actors with a trade impact.

2.5. Decentralized Control of Large-Scale Storage-Based Renewable Energy Systems

Decentralized electricity storage for smart grids could be a source of revenues for prosumers producing more energy than what they consume and to keep it stored until either it must be used or sold to another customer. Kato *et al.* [11] put forward their own research work on this topic. Its aim is achieving an optimal energy distribution able to have a significant, almost complete, independence from the previously existing power grid. In order to do so, energy collected in a distributed manner from different locations responsible for electricity storage and utilization is used. The authors refer to these locations as clusters. They comprise a number of photovoltaic units, electrical appliances, a router devoted to power management and a battery for energy storage purposes. By having several clusters cooperating with each other, a local energy network can be obtained, which, in turn, supports inter-cluster energy transfer and makes possible the effective usage of renewable energy under this distributed scenario. Optimal power distribution is dealt with using a mixed integer programming model; many features typical of energy storage are taken into account here, such as incoming power flow or the fact that batteries are not ideal energy storage devices (charges and discharges end up in some energy loss). Finally, the authors show results confirming that the objective values that were chosen are improved for an increasing number of clusters. A greater set of clusters also improves the charge speed and efficiency (clusters are enabled to interchange power among them).

Focus on prosumer's side: medium. Clusters fit in well with the concept of prosumers and their associated DERs, but are not explicitly mentioned in the proposal.

Focus on business model description: low. This work is valuable in terms of describing a solution for distributed energy storage in a manner that prosumers may obtain revenues, but it offers no information about how to exploit it in a profitable way.

Added value generation: low. Clearly, possibilities for the technology used can be inferred from the proposal, but there is not an explicit mention about how to use it to add value to the overall system by means of a prosumer-focused business model.

2.6. Advanced Metering Infrastructure in the Context of Smart Grids

Popovic and Cackovic [12] offer an accurate study of advanced metering infrastructure that is interested in the area of knowledge involving prosumers, for they are the ones that are most likely to have some AMI equipment to rely on. In this piece of work, the importance of machine-to-machine (M2M) communications is highlighted: the authors consider it to be a building block for the smart grid and a way to enhance flexible performance management. Furthermore, the authors go on by saying that the lack of standardization of the different smart metering devices is somewhat hampering their development and service usability. A layered architecture, including a middleware layer (that, at the same time, includes other components) is suggested as an example of how smart metering capabilities can be organized. This layer aims to provide a way to abstract the heterogeneity of hardware-based components, so that the upper, application-based layers could be presented with a homogeneous-looking set of facilities. All of the other layers are used for self-explanatory functionalities: the meter data management layer for data aggregation and management; an integration bus, a combination of different mobile and/or fixed networks for a lower communications stage; and the smart meters themselves at the lowest layer. Smart metering is also regarded as a stepping stone for more complex services (demand side management is mentioned as one of those). The prosumer-side is mentioned as being supported by smart metering for energy caching and storage facilities, as well as energy exportation.

Focus on prosumer's side: high. The prosumer side is mentioned in the proposal as the one using advanced metering infrastructure the most.

Focus on business model description: medium. Business possibilities are indeed suggested, but as a not detailed enough side goal. AMI is used just in a supportive role here.

Added value generation: medium. While a detailed description is provided by the proposal involving AMI (and therefore, added value can be inferred from the information to an extent), value generation is not mentioned as something to be obtained at the prosumer side.

2.7. Smart Metering and Decentralized Electricity Storage for Smart Grids: The Importance of Positive Externalities

Römer *et al*. [13] provide a study on the possibilities that both advanced metering infrastructure and decentralized energy storage (DES) offer. The authors provide the concept of a symbiotic-like relationship between advanced metering infrastructure and decentralized energy storage, as both are usually located at the prosumer side of the smart grid and are core components for RES usage. They claim that a system depending on renewable energy sources for its performance is prone to offer intermittent outputs due to their unreliability (for instance, wind and solar power), so AMI can be used as a way to expand demand elasticity. DES comes in handy for: (1) dissociation between energy generation and consumption; and (2) storage of surplus power that may be produced by renewable energies. As suggested by the title, the authors highlight the importance of positive externalities, that is to say, actions that have a positive outcome for other actors of one system, to spread these components of the smart grid. In order to further prove their point, they have interviewed eight people heavily involved in smart grid activities (a team leader of a DES system development, a scientist specialized in technology assessment and energy markets, *etc.*). As for the findings in positive externalities obtained by the authors, smart metering at the prosumer's side is welcomed and expected to grow in acceptance in the future. However, data obtained from the smart meters must be processed to have some value created; standardization efforts should be encouraged, too. DES development is more challenging: not only is its diffusion lower than expected, but also, technology likely to be used for this task is regarded as underdeveloped. In the end, monetary incentives are mentioned as desirable for further DES installations.

Focus on prosumer's side: high. AMI and DES look like typical applications that imply prosumer usage, as it is through their actions that AMI is required and energy is stored.

Focus on business model description: low. Business possibilities are not described in a detailed manner, and examples are described as representative of Germany, rather than any other place, regardless of the remark made by the authors claiming that these results may be applied elsewhere.

Added value generation: high. It is a matter of great concern, as exposed in the paper, for the cost and benefits for the involved parties are especially taken into account.

2.8. Sensing-Delay Trade-Off for Communication in Cognitive Radio-Enabled Smart Grid

Another area of study regarding prosumers and their behavior in the smart grid to get a good idea about the viability of business models for the former is trade-off balances. Commonly, trade-off will refer to making up with one feature a system that is lacking another one. As an example, the more services used to enrich data transfers (security mechanisms, semantic data treatment), the more refined a system with an improved treatment of information is. Yet, these advantages do not come for free: performance or speed in those data transfers may be lowered with the addition of these characteristics. One proposal that copes with delays that may take place when the radio interface is charged with sensor-related data is presented by Deng et al. [14]. The authors introduce the issue by mentioning that the main objective of their work is improving reliability and communication timeliness by means of sensing time optimization. Cognitive radio communications (CogHAN) are used to present the issues related with sensing delays. The trade-off study goes deeper by calculating how channels are accessed for meter data transmission, as well as channel switching probability and how the longer the sensing time used, the more likely the system is to switch from one channel to another, thus impacting the whole system delay. In addition to that, the authors put forward a solution to this issue by formulating a theoretical analysis to begin with and running a simulation to check the performance of the analysis afterwards.

Focus on prosumer's side: low. Prosumers are not mentioned in the proposal; if anything, they appear as regular consumers.

Focus on business model description: low. The main motivation of the authors is providing a solution for a trade-off due to sensing delays, rather than offering a business perspective for profitability purposes.

Added value generation: medium. The authors make clear the issue they tackle, but this proposal does not mention it as a way to add value to the power grid from a profitability-related perspective.

2.9. Malicious Data Attacks on the Smart Grid

Another issue involving trade-offs among different functionalities of the smart grid copes with security and, specifically, malicious attacks on the smart grid. According to Kosut *et al*. [15], there are two different regimes of attacks that must be borne in mind: strong attacks (a significant number of smart meters are attacked, and the network state is rendered unobservable) and weak attacks (only a small number of smart meters are controller by the attacker). In this piece of work, the trade-off between maximizing estimation error at a control center and minimizing the detection probability must be considered by the adversary willing to attack the system. On the one hand, according to the authors, when strong attacks manage to become unobservable, network observability and/or AC power flow are targets prone to be affected by them, as an unobservable network is unaware that it is even being attacked at all, or AC power flow can be utilized as a small version of a DC attack model. On the other hand, the weak attack regime is often detectable, so methods noticing it become appealing. A Bayesian framework (able to prove that the attacker must increase the energy of the attack, thus increasing the probability of being detected), a statistical model (used to formulate the detection problem at a control center) and a likelihood radio detector are described here. Additionally, the authors put forward a study on optimal attack formulations and attacks on electricity markets.

Focus on prosumer's side: low. The trade-off study involves techniques from a security perspective, but does not include prosumers or an advanced metering infrastructure used by prosumers.

Focus on business model description: low. Despite the fact that malicious data attacks are of critical importance for businesses, it is a perspective that has not been reviewed by the authors.

Added value generation: low. Again, the benefit of a study on security threats and attacks is most valuable, but there are no explicit mentions about adding value to a deployed smart grid.

2.10. Research Projects about Prosumers as Part of the Smart Grid

In addition to the presented proposals, there are numerous research projects that are aware of the development of the smart grid. In fact, their number is so significant that there is a web portal sponsored by the European Commission's Joint Research Centre devoted to smart grid research developments in Europe directed at dissemination and social communication duties [16]. The primary goal of all of these research projects is the enhancement of the regular power grid and the generation of a cluster of ancillary services around it. Consortiums are created among partners with similar interests, but somewhat differing knowledge; it must be taken into account that the smart grid is a subject of research involving both information and communication technologies and the power grid, so there will be heterogeneous stakeholders willing to take part in it. Here, several examples are portrayed to have a general idea of the most prominent smart grid-themed research projects. For example, the e-GOTHAM (Sustainable-Smart Grid Open System for the Aggregated Control, Monitoring and Management of Energy) project attempts to "implement a new aggregated energy demand model (based on the microgrid concept) to effectively integrate renewable energies sources, increase management efficiency, reduce carbon emissions, raise energy consumption awareness and stimulate the development of a leading-edge market for energy-efficient technologies." [17]. Apart from the traditional goals foreseeable from a smart grid project, e-GOTHAM intends to implement a middleware layer for additional services and devices integration onto a system. Another example of a progressing research project involving the smart grid is GRID4EU (Large-Scale Demonstrator of Advanced Smart Grid Solutions with wide Replication and Scalability Potential for EUROPE) [18]. This project is focused on creating a smart grid with a wide range of features (electric vehicle development, energy storage, grid automation, renewable energy integration, load reduction, *etc*.) expected to be the most common ones available once the smart grid has become dominant as the power distribution infrastructure. One more example of the benefits that the smart grid can provide are the main goals of a research project called MeRegio [19]. This project aims to "use energy intelligently, increase energy-efficiency and reduce CO2 emissions". Therefore, an awareness of energy consumption habits is introduced as an effort to extend the durability of the available energy resources. Finally, the I3RES (ICT-based intelligent integration of Renewable Energy Sources) project has as its goal creating management tools for the smart grid that will allow the integration of existing information, network management and energy forecasting algorithms, along with data mining and artificial intelligence features [20].

In a nutshell, these research projects point to the importance of providing attractive business models for the smart grid, since if there are no prominent economic advantages to shift towards the smart grid, very few end users will adopt it and turn into prosumers.

2.11. Other Proposals for Prosumer Business Models in the Smart Grid

Finally, there are some other proposals that, although not exclusively considering the prosumer side, involve features that come in handy for them. For example, Lee *et al*. [21] describe a proposal that is split into four different layers: the physical power layer, the data transport and control layer and the application layer. The architecture division is the one that could be foreseen, as it divides the functionalities from the ones that are more hardware-focused into the ones more related to what a non-technology proficient user could utilize. Stress is put on the application layer, rather than the other ones; the possible applications are diverse (smart charging of different loads, business and customer care, energy trading). However, the other levels do not seem as developed as the uppermost layer. Additionally, Arnautovic *et al.* [22] deal with how to use a smart grid from a business perspective, so after enumerating the four different components of a business (customer value, proposition, profit formula, key resources and key processes), they suggest an example based on a particular case of business exploitation (energy billing). Unfortunately, not many details are provided on how to implement such a model. Furthermore, more business models are analyzed by Vos [23], who claims that there are possible opportunities in direct load control for residential customers or commercial and industrial offerings. However, not many details are provided by the author.

Judging from the results of the study that has been undertaken, it seems that although there is a large collection of proposals, they fall short in providing enough information about how the prosumer gets a significant advantage by managing electricity in a bi-directional way as part of the role assumed in the smart grid.

3. Main Challenges for Prosumer Business Models

After studying what the latest developments in the smart grid are, the role of the prosumer in the energy market value chain and the main features of the new prosumer-oriented business models, the main challenges for the latter should be reviewed. Since there is a certain degree of disparity among the studied business proposals and their introduced business models, they have been summarized in Table 3 with all of their most prominent features, specifically considering the role of the prosumers in the reviewed related works.

According to the research that has been done, there are several common challenges that must be overcome for the presented models:

- Infancy of smart grid businesses: Although the technology is already present and in fact has been regarded as consolidated in several cases, the manufacturers and vendors still struggle to make it visible. What is more, the smart grid has still a low impact and is often mistaken for the advanced metering infrastructure, rather than all of the systems behind it.
- Lack of interconnectivity: The different manufacturers that develop goods and services for the smart grid are unlikely to cover all of its various aspects, so the final system will be prone to incorporate devices from different vendors. It is not clear how they are going to interact with each other with ease; nowadays, there are several different standards covering information and communication technologies and power separately, but these remain poorly merged as a common effort.
- Unknown response for established business partners: The entrance of new SMEs, competitors and users in the electricity trade may be received with hostility from the already well-established DSOs and TSOs. Legislation must be created to prevent that from happening.

As focus on businesses models for prosumers seems to be weak, providing a starting framework with the definition of the concept of business models is an appealing idea.

Table 3. Main features of prosumer business models and proposals. ESCO: energy services company/provider.

Business Proposal	Business Model	Features	Advantages	Disadvantages
Goal-oriented prosumer community groups	Not explicit, based on prosumer clustering	Common objective among prosumers	Prosumer-based; community oriented	Weak description of business model ideas
Smart grid prosumer grouping	ESCO business model; VPP business model	Clustered electricity markets for energy forecasting	Prosumer-based; realistic procedures	Weak description of business model ideas; proposals focused mostly on energy forecasting
Future smart grid prosumer services	DSO business model; aggregator/retailer business model	Plethora of applications	Prosumer based; plentiful business proposals	Weak description of business model ideas; vague proposals
Prosumer-based smart grid architecture	DSO business model	Layered prosumer architecture	Depiction of very specific features	Weak description of business model ideas
Decentralized control of large-scale storage-based renewable energy systems	DERs-based business model	DERs structured as interoperating clusters	Interconnectivity among prosumers is implied	Weak description of business model ideas; focus on energy storage
Advanced metering infrastructure in the context of smart grids	AMI, prosumers	AMI managed with a layered model	AMI tightly interweaved with prosumers	Business model as an afterthought
Smart metering and decentralized electricity storage for smart grids	AMI, distributed energy storage	AMI and DES as business creators	AMI and DES business depicted in a realistic manner	Sketchy description, focus on one single country
Sensing-delay trade-off for communication	Not explicit, regular consumers	Trade-off between sensing and data delay	Trade-off balances are evaluated	Weak description of business model ideas
Malicious data attacks on the smart grid	Not explicit, security threats	Study on malicious attacks	Security threats are described and studied	Weak description of business model ideas
Research projects	Not explicit, developments for the future smart grid.	Energy peak shavings, environment-friendly applications	Great potential for business models	Still in research stages

4. The Business Model Concept

A business model can be defined as the tool that companies use to deliver value to customers, entitle customers to pay for value and convert those payments into profit [24]. A business model establishes the content, structure and governance of transactions designed to create value through the exploitation of business opportunities [25]. Despite the growing importance of the concept of the business model, there is not an established definition about it generally accepted in the scientific literature [26]. The business model definition and conceptualization from [27], named business model canvas, has been chosen for this work because it provides a consistent and reliable framework that has been extensively tested and recently applied in the areas of the smart grid and energy management [28–31]. Business model canvas is used as an analytical framework, due to the fact that energy transformation is primarily concerned with questions of value creation and value capture for prosumers [29]. According to [32] and [27], business model canvas is characterized by the following parameters:

Customer segments: Groups of people or organizations a company aims to reach and serve.
Value propositions: Products and services that create value for a specific customer segment.
Channels: Company's means of communication with its customer segments.
Customer relationships: Types of relationships a company establishes and maintains with specific customer segments.
Revenue streams: Revenue a company generates from each customer segment.
Key resources: Assets required to offer and deliver the aforementioned elements.
Key activities: Activities involved in offering and delivering the aforementioned elements.
Key partners: Network of suppliers and partners supporting the business model execution.
Cost structure: Costs incurred when operating a business model.

As for the emerging business models with smart grid prosumers, some of the elements described before are common to all smart grids; prosumer-oriented ones and some others are specific to each one, as explained later in Section 6. Although the elements of the business model canvas are interrelated, Figure 4 provides a precise description to facilitate their understanding.

Hence, there are four elements in the business model as the main distinctive concepts for emerging prosumer-oriented business models in the smart grid. Osterwalder and Pigneur's business model conceptualization of four basic elements [26] offers two main advantages. First, the concept has been extensively tested in practical scenarios, and it is easy to apply [29]. Second, it has already been implemented in the field of smart grids as an analytic tool (as described in [28,33–36]). In a more graphical way, the conceptualization of the business model canvas defined here behaves as four different features cooperating with each other, so as to guarantee a complete degree of interaction, as depicted in Figure 5.

Figure 4. Elements of the business model canvas.

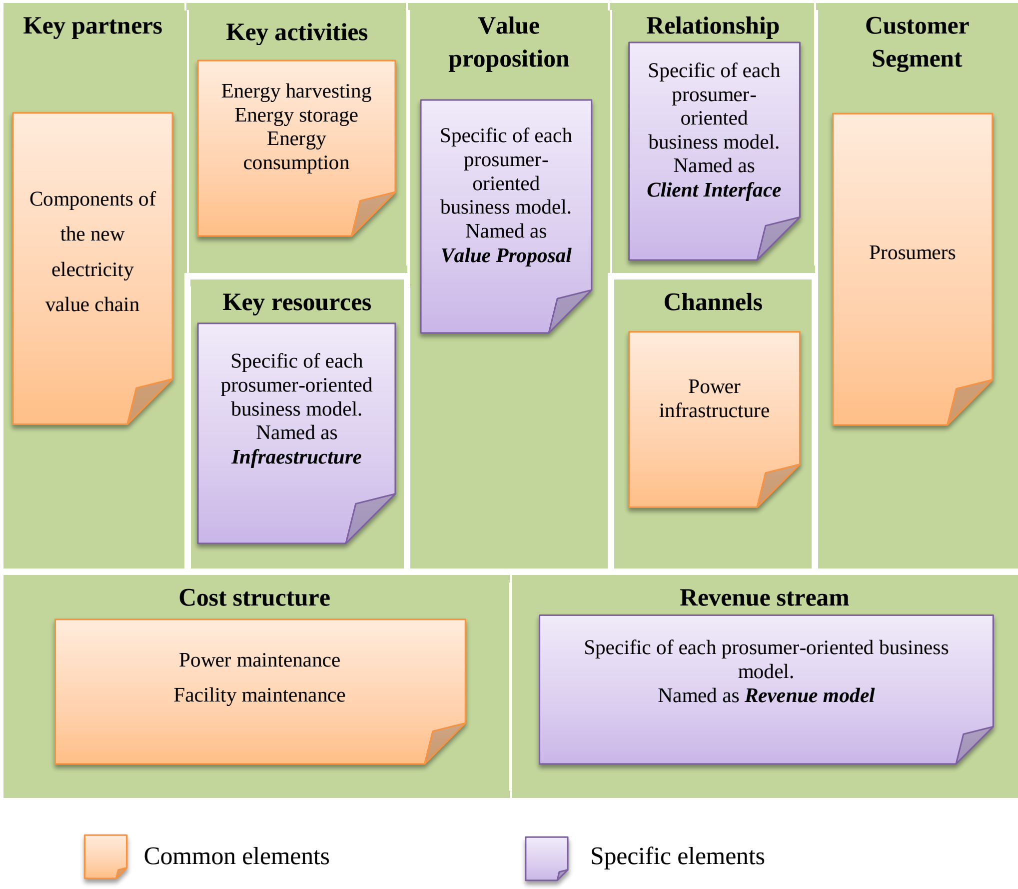
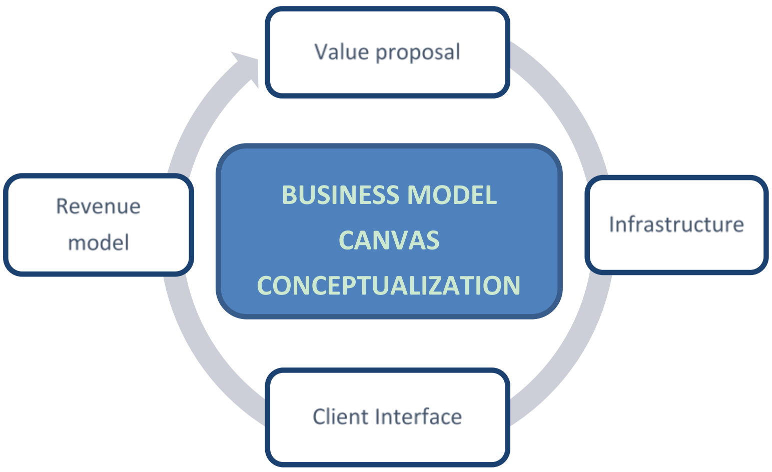


Figure 5. Conceptualization of business model canvas.



Several different authors agree on the importance of the business model concept for management and analysis in research and practice [37–40], as this concept allows both evaluation and market and company comparison in a structured way [31]. The concept of business model can be used as a means to classify and build categories or blueprints that will help to understand business phenomena. As a management tool, this idea of business comes in handy for managers to design, implement, operate, change and control their own businesses [41,42].

5. The Prosumer in the Electricity Value Chain

5.1. Considerations on Prosumer-Oriented Business Models

Up until now, users and the smart grid have had an uneasy relationship due to the fact that people have not been actively involved in other grid innovations. However, they are expected to play a major role in the future of smart grids, especially in the management of electric power supply and demand [43]. As already explained in the Introduction, end users are expected to shift from a passive role as consumers of electricity to an active role as prosumers (in particular, stakeholders in the Dutch energy sector recognize the importance of the active participation of residential end users towards the successful implementation of smart grids [44]). There has been a lack of products and services designed to support end users in their role as prosumers in a smart grid so far, as reflected in the poor thought given to how the end users' process of behavioral change can be supported to enable the transition from consumer to prosumer [43]. Plus, as described in Section 3, there are several challenges that are yet to be solved (business maturity, third party coexistence, device interoperability and interconnectivity).

In order to change this behavior and complete the shift, end users must get through several stages: (1) becoming aware that one has made or is willing to make a change; (2) finding out how to change; (3) implementing the wanted changes; and (4) consolidating these changes [45,46]. Interventions to stimulate behavioral change should include multiple strategies based on education and information, incentives and community-based approaches. Education and information can increase knowledge and skills to perform a certain behavior, whereas incentives can lower barriers to action (e.g., [47]). Community-based approaches take advantage of the influence that other actors may have on one end user behavior through the formation of social norms, comparison with others, peer learning and cooperation [47–49]. Governance at the community level could support the development of solutions that fit local issues, both in terms of end user needs and technological possibilities [50]. The examples shown in Section 2 about energy cooperative initiatives are a form of organization for the management of community resources: end users clustered in cooperatives are generally involved in organizing their own energy provisioning. For example, joint investment in photovoltaic solar systems may be accompanied by agreements on how to distribute the financial gains from the electricity produced by the cooperative.

Another key for the change of behavior from end user-like to prosumer-like roles is the development of products and services that stimulate or ease communication and interaction between end users and all of the remaining entities belonging to the smart grid. These interactions may include: (1) asking and providing advice about energy with regards to the usage of products and energy-related services; (2) discussing the comparison between energy consumption and production levels; (3) interchanging ideas for the improvement of smart energy systems, including new community initiatives; and (4) starting required organizational structures, so as to allow the appearance of a federation made up of intelligent networks.

The transition to smart grids from the end user to the prosumer point of view suggests that household energy management does not only involve efficient energy usage, but also includes demand response and production of electricity. Additionally, the social dimension of smart grids generally implies the introduction of some kind of demand side management. All of these facts generate a market flexibility that, combined with price incentives, fuels the change of end user behavior [51]. The behavior of each prosumer can be characterized by their attitude toward benefits under an economic dimension, in terms of avoiding cost from consumption or maximizing earning from power injection and their attitude towards comfort, as well as in terms of desire or willingness to use appliances and devices to satisfy their living standards, bearing in mind here a more physiological/social dimension [52]. In order to choose a proper regulatory strategy, comprehensive models of emerging distribution systems able to incorporate both social and technical layers are needed. They can be used to test *ex ante* the strategies; managing self-interested distributed decision makers by simultaneously optimizing multiple objectives in terms of network and market performance seems a promising way to capture the dynamics of complex smart energy systems.

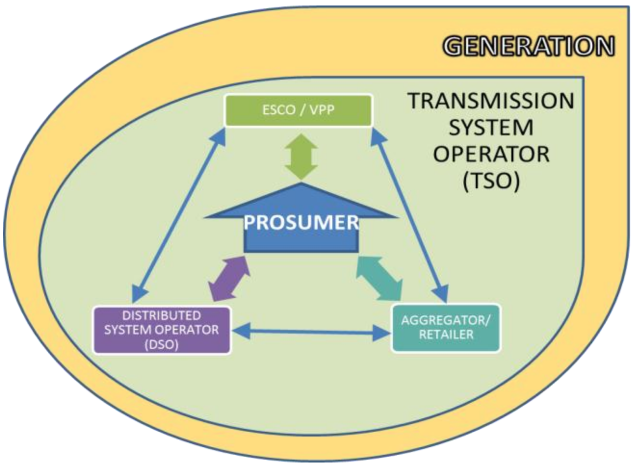
5.2. A Description of a Prosumer and Its Role in Business Models

As already mentioned, the prosumer concept entered the energy business [53,54] as soon as the smart grid development took off. In the energy market, a prosumer is not only a consumer that starts producing energy, but also a market participant and must be engaged in this market, as prosumers are expected to turn into active agents in it, either directly or indirectly [55]. The ever-increasing development of smart grid technologies allows prosumers to be economically active/motivated ntities that:

- consume, produce and store electricity;
- take part in economic and technological optimization in electricity consumption;
- get actively involved in the creation of value for electricity services.

Thus, the prosumer is included in the new electricity value chain, as depicted in Figure 6, and cannot be deemed as an isolated entity. Its position in the value chain will have to be studied [56], as well as its relationships with the other components of the new electricity value chain.

Figure 6. New prosumer-centered energy market value chain.

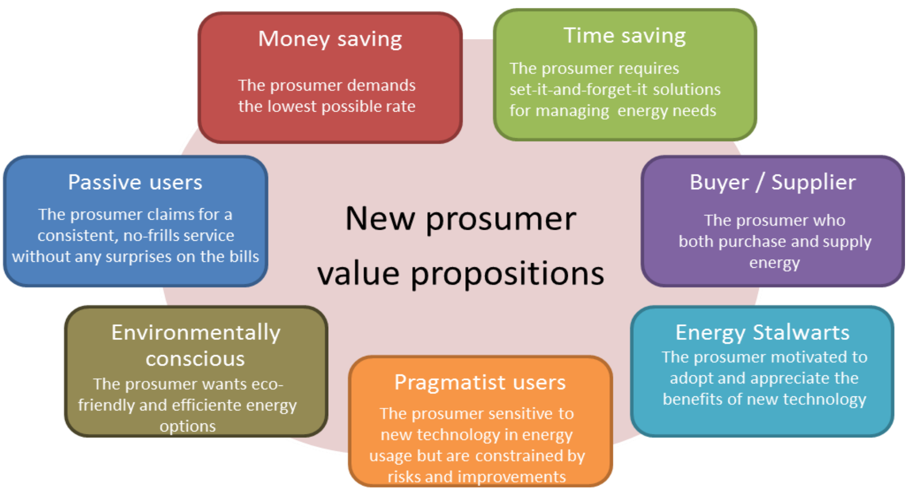


The more important connections for prosumers in the electricity value chain are its closest components in it, like the distributed system operator or the aggregator/retailer, in addition to energy services company/provider (ESCO) or virtual power plants (VPP), which are also new components in the energy market value chain. Consequently, a bi-directional relationship between the prosumer and the market has been depicted in Figure 6. This relationship suggests a partnership where the prosumer becomes a more integrated part of the market than before. This integration will be eased by a new set of roles and supported by new types of business models. The bi-directional value chain projected in Figure 6 is the result of an evolving market change, as new business models and roles will be required to answer the needs of and to facilitate prosumers integration in the electricity market.

Therefore, when combining smart grid technologies and the new role taken by prosumers, a much more dynamic electricity market is created. The more integrated prosumers in this new energy market are and those that are more aware of their needs in terms of energy become, the clearer their energy needs, preferences and expectations will be with regards to their experience in electricity (putting somewhat aside very basic actions, such as having lights turned on or off), thus looking for value beyond the regular electricity products and roles [57]. Besides, prosumers may adopt new communication channels (web channels, self-service, social networks), modifying their interaction with energy providers. Clearly, there is a growing trend to establish two-way services in energy-related interchanges. Some of these new prosumer preferences and expectations have been identified; a secure and stable service is foreseen to be obtained at any moment it is requested, receiving at the same time specific value propositions and offers. Plus, a significant portion of prosumers is willing to reduce their impact on the environment, to have more energy management options available (usually involving electricity consumption) and to access innovative procedures to reduce energy costs.

Furthermore, the degree of user control will be one of the most influencing factors over the future of the utility industry [58]. The adoption of prosumers integrated as part of the smart grid makes the information flow a more affordable task among every component of the electricity value chain and increases the willingness of a consumer to make decisions and take actions based on specific objectives, such as cost control, safety, accessibility and climate change impacts. Taking the polls made in [58,59] as a starting point, it can be considered that the prosumer concept and features have been well inserted into this value chain. All of this information has been gathered, and seven new value proposals have been identified for prosumers, as shown in Figure 7.

Figure 7. New prosumer value propositions.



By merging the connections established among the new prosumers, focused on the energy market value chain (Figure 6) and the new prosumer value propositions (Figure 7), new business relations and services are developed; eventually, they will act as a catalyst for new prosumer-oriented business models.

6. New Prosumer-Oriented Business Models for the Smart Grid

When applying the business model concept to the prosumer-centered energy market value chain, new business opportunities are prone to spring up, as modelled and described in the next subsections.

6.1. Energy Service Companies /Virtual Power Plant Prosumer-Oriented Business Model

The Energy Service Companies (ESCOs) will play an important role in the future electricity market as specifically energy-oriented commercial businesses. ESCOs can be described as specialists in providing a broad range of comprehensive energy solutions, including the design and implementation of energy saving projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply and risk management. ESCOs are capable of offering services for prosumers actively implied in the management of electricity, which correspond to four out of the seven prosumer value propositions displayed in Figure 7, namely: “money saving”, “pragmatist users”, “environmentally conscious”, and “energy stalwarts”. The four basic elements introduced in Section 3 applied to an ESCO prosumer-oriented business model are presented in Table 4.

Table 4. ESCO prosumer-oriented business model characteristics.

Value Proposition	Prosumer Interface
Improved energy efficiency Reduced energy costs Energy performance contraction	Prosumer interactions management Prosumer segmentation Real-time media- or web-based communications
Infrastructure	**Revenue model**
Smart grid data management Grid monitoring	Energy savings Energy efficiency enhancements Charge for performance/service level offered

As far as the usability of ESCOs and prosumer-oriented business models are concerned, there are several proposals that are already working towards this direction; according to Karnouskos, both residential and commercial prosumers can be considered as partners at the same level as energy servicing companies [9]. Here, these agents behave as actors that use the smart city energy marketplace to their advantage. Prosumers are expected to obtain lower electricity prices by using this marketplace, as well as revenues from controlling or rescheduling the more energy-demanding processes (thus, matching values propositions, such as “money saving”, “pragmatist users” or “energy stalwarts”). At the same time, energy servicing companies are implicated in energy-related feature prediction or aggregation of the energy produced by end users, which, in turn, are likely to end up as prosumers.

Likewise, a virtual power plant is a flexible representation of a collection of distributed energy resources, like distributed generation (micro-combined heat and power systems, solar electric systems, wind turbines, small wave-hydroelectric generators), demand response or electricity storage [60]. A VPP can either operate large numbers of relatively small-sized generators, responsive loads and storage units on behalf of owners (in this case, prosumers) or operate its own DERs. The VPP prosumer-oriented business model is suitable for prosumers able to produce, store and consume electricity in a way resembling some of the other value propositions presented in Figure 7 (that is to say: "buyer/supplier" and "environmentally conscious"). There are several examples on how virtual power plants and prosumers are prone to cooperate with each other: Mauri *et al*. provide an example on how prosumers are incorporated to become the parts of microgrids that are regarded as virtual power plants [19]. Considering the energy savings obtained in the testing facility that was used for this piece of work, synergy between prosumers and VPPs can be regarded as plausible and desirable. Alas, under certain circumstances, VPPs complement ESCOs' functionalities, as well, such as using the virtual power plants as aggregators of the energy produced by DERs owned by the prosumers, so that virtual power plants will deal with ESCOs able to improve the market position (as far as shifts of loads, energy production or consumption are concerned) of the prosumers that aggregated their energy into the VPPs in the first place, as mentioned before in [56].

The four basic elements introduced in Section 3 that apply to a VPP prosumer-oriented business model have been depicted in Table 5.

Table 5 VPP prosumer-oriented business model characteristics.

Value Proposition	**Prosumer Interface**
Flexibility of energy generation Providing a prosumer with market access	Advanced systems for energy management
Infrastructure	**Revenue Model**
Distributed generation systems Electricity storage devices	Electricity sale Energy consumption/production/storage based on real-time energy pricing

6.2. Aggregator/Retailer Prosumer-Oriented Business Model

Aggregators/retailers are responsible for purchasing electricity and actions related with metering and billing. In the new energy market value chain, they are most likely to evolve towards research and development activities aimed at investing and creating innovative solutions for active prosumer participation in the electricity market. As far as this paper is concerned, the aggregator/retailer prosumer-oriented business model can be deemed as suitable for "money saving", "passive users" or "time saving" prosumer value propositions. Furthermore, it is suitable for economically motivated users aiming to optimize their own technology for electricity usage as the "energy stalwarts". One example of how aggregators and/or retailers work together to complete value propositions as "money saving" is offered by Agnetis *et al.* [61], which deals with model optimization for consumer flexibility aggregation. Here, it is shown how the aggregator is used as a messenger between end users and the market (albeit, end users are treated as consumers more than anything else) and shows how consumer flexibility is a plus when coping with prices and bids offered by energy markets. In any case, other entities, such as virtual power plants, also work closely in terms of energy aggregation, as they can gain control of the distributed energy generated by prosumers in a specific area, as explained in the previous subsection.

The four basic elements introduced before can be applied to this aggregator/retailer, prosumer-oriented business model, as presented in Table 6.

Table 6. Aggregator/retailer prosumer-oriented business model characteristics.

Value Proposition	Prosumer Interface
Operate and optimize energy consumption made by prosumers Demand response Flexible electricity tariffs according to momentary market conditions	Prosumers community Prosumer relationship management Automatic energy price information
Infrastructure	**Revenue Model**
Advanced metering infrastructure Automatic metering services (AMS)	Real-time and critical peak pricing (RTP) Time of use pricing (ToU)

6.3. Distributed System Operator (DSO) Prosumer-Oriented Business Model

As mentioned in [62], DSOs will have to apply new business models upon completion of the smart grid rollout. The current core responsibilities of the DSO—distribution of electricity and securing the stability and safety of the power supply in the distribution network—must evolve to an active electricity network management and integrate increasing shares of renewable and distributed energy resources, while ensuring the safety of the system supply. The DSO prosumer-oriented business model is suitable for users that produce, store and consume electricity and, at the same time, are heavily implied in creating value for electricity services. Taking prosumer value propositions into account as described in Figure 7, distributed system operators matching "buyer/supplier", "environmentally conscious", "passive users" and "pragmatist users" are the most suitable prosumers value propositions. Distributed system operators are greatly taken into account as far as prosumers relationships are concerned; Bompard and Han consider how prosumers interact with DSOs in order to optimize the resources generated in a distributed manner [63]. It is claimed by them that by using a distributed market-based control that sends adaptive signals to prosumers, the latter will become aligned with the concerns of the regulator/DSO, and both stakeholders will be satisfied. These basic elements introduced in Section 3 applied to a DSO prosumer-oriented business model have been further developed in Table 7.

Table 7. DSO prosumer-oriented business model characteristics.

Value Proposition	Costumer Interface
Security of supply and quality of service Choice of energy source System flexibility services Market facilitation	Active demand program Real-time media- or web-based communications In-home displays
Infrastructure	**Revenue Model**
Grid connection Smart metering systems Local network services	Energy selling Static pricing Provision of connection services Transmission/distribution fees

7. Conclusions and Future Works

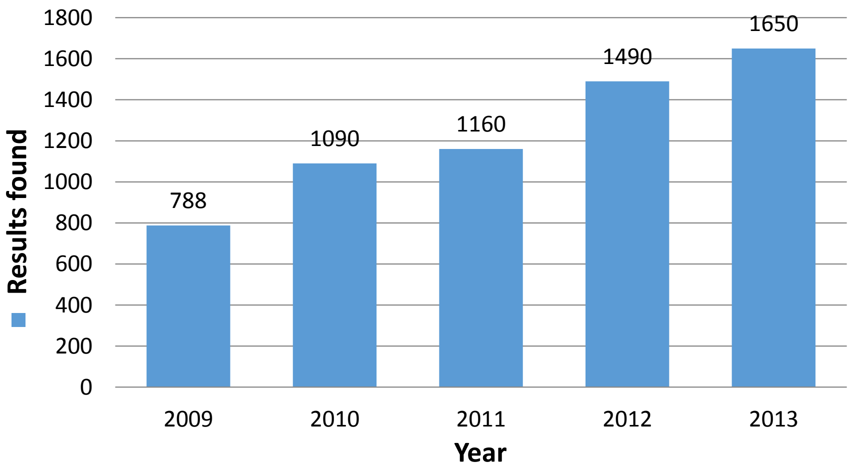
In this paper, a thorough description of the main components of a smart grid has been offered, along with the new goods and services expected from the emergence and extension of the smart grid and a depiction of the most prominent related works that have been done so far. After the main challenges for prosumer business models have been tackled, a detailed explanation on what can be expected from a prosumer, both as a concept and in terms of business models, has been described, too. Prosumers are likely to become the major actor in the development of the smart grid and are no less than the part of the energy market value chain with the greatest potential of business creation based on the services in which they can take part. Then, different examples of business models have been put forward as a way to prove that businesses based on a prosumer integrated in a smart grid are feasible and hint at a compelling future when the smart grid has become the predominant kind of power grid system. The value proposition of each of the prosumer-oriented business models generates new business opportunities; the evolution and transformation of the economic agents of the electricity market that should not be overlooked. The viability of businesses devoted to electricity consumers turned into prosumers is proven, both to save energy costs and to obtain a profit by trading with the surplus of energy created by using distributed energy resources. Besides, the new prosumer value propositions provided are done so in a realistic manner, bearing in mind the different features that can be expected by the different parties involved in the smart grid and the prosumers themselves. It is remarkable that rather than porting regular business models to the environment of the smart grid, business models have been created from scratch, as there is not a directly portable model for the features presented here.

There are several works expected to be performed in the future. The proposed business models have been designed as having regular home dwellers, but they could be expanded to other scenarios, such as facilities, department stores or country farms. As long as there are distributed, renewable energy sources to be employed to the end user's advantage, there will be an opportunity for a consumer to take a more active role in the smart grid. In addition to that, synergies among business models that focus on different elements of the smart grid (aggregators, DSOs, TSOs, *etc.*) may be studied, as well, in order to extend the usability of the presented business models for prosumers.

As an outlook for future works, despite the fact that business models for prosumers involved in the smart grid are yet to be fully implemented and to become widespread, the number of research works where prosumer business models are involved is on the rise. If a Google Scholar search with the phrase "prosumers business" is performed and the results are filtered for each of the last complete five years, a growing number of results is obtained, as shown in Figure 8 [64–68].

These figures should come as no surprise, as the technology, procedures and motivation for prosumer business development are already present, so these becoming significant as a way to obtain energy-related revenues or to reduce energy costs for former end users is a matter of time.

Figure 8. Number of results for a "prosumer business" Academic Google search.



Authors Contribution

Jesús Rodríguez-Molina has made contributions regarding the study of the prosumers-oriented business proposals, their assessment and the challenges that business models face in the context of the smart grid.

Margarita Martínez-Núñez has contributed to the development of the proposals for the new business models for the prosumers according to business model canvas.

José-Fernán Martínez has cooperated in the evaluation of the proposals that have been presented, along with the description of the main features of the smart grid as shown in the introduction.

Waldo Pérez-Aguiar has contributed to the conception of the new business models. Prosumer value propositions have been enriched by him as well.

Conflict of Interest

The authors declare no conflict of interest.

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