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A Study on Applicability of Distributed Energy Generation, Storage and Consumption within Small Scale Facilities

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Abstract: Distributed generation and storage of energy, conceived as one of the prominent applications of the Smart Grid, has become one of the most popular ways for generation and usage of electricity. Not only does it offer environmental advantages and a more decentralized way to produce energy, but it also enables former consumers to become producers (thus turning them into prosumers). Alternatively, regular power production and consumption is still widely used in most of the world. Unfortunately, accurate business models representations and descriptive use cases for small scale facilitates, either involved in distributed energy or not, have not been provided in a descriptive enough manner. What is more, the possibilities that electricity trade and its storage and consumption activities offer for small users to obtain profits are yet to be addressed and offered to the research community in a thorough manner, so that small consumers will use them to their advantage. This paper puts forward a study on four different business models for small scale facilities and offers an economical study on how they can be deployed as a way to offer profitability for end users and new companies, while at the same time showing the required technological background to have them implemented.

Keywords: distributed generation; distributed energy resources; business model; Smart Grid

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1. Introduction

The electricity market is not only one of most important and profitable business in Europe, but also one of the most critical infrastructures for all countries. Thus, the advances in Information and Communication Technologies (ICT) applied to power grids, along with the rise of the Smart Grid, provide the ideal ecosystem for new opportunities. These opportunities are optimal for European Small and Medium Enterprises (SMEs), either already existing or new ones, which can take advantage of this new market model to generate revenues for themselves.

1.1. A perspective of Distributed Energy Generation and Resources

Power is generated in a power plant as an output from consuming fuel, which might be of very different nature (coal, oil, natural gas, hydropower, nuclear, etc.). The power plant is usually—though not always, as it may vary depending on the specific legislation of the country where it is located—strongly participated by a Distribution System Operator (DSO). Scattered power plants may also be gathered as Virtual Power Plants (VPP) [1] where power is produced from a plethora of locations. The produced power is transformed into high-voltage electricity so that it can be transferred long distances. The transfer of this power is done by means of a power grid owned by a Transmission System Operator (TSO) that transports the high voltage electricity throughout the installed facilities, lowering the voltage when electricity approaches the location where it will be consumed. Finally, electricity is delivered to the arranged locations by means of the commercial agreements carried out by electricity retailers that often have the role of power aggregators, which will control the energy demand among different locations included in a cluster of end users. At this level, a new role appears when working with Renewable Energy Sources integration: the aggregator. The task of this actor is double-sided: on one side (the commercial), the aggregator gathers the customers in a cluster to provide tailored tariffs and attract new customers; on the other side (the power flow management), the aggregator aims to balance power generation and consumption within each cluster. The more the cluster is balanced, the less the aggregator needs to buy energy from the Distribution System Operator (DSO), increasing its benefits.

Related with the aggregator, a novel device appears along: the Home Load Controller (HLC). Despite the existence of smart meters, the HLC not only measures individual customer consumption, but also monitors the loads (appliances, lighting, etc.) consuming that energy. With this added functionality, the aggregator becomes enabled to use a clustering algorithm able to group customers depending on their consumption profile. This consumption profile is based on consumption periods, customer behavior or social profile (families, single users, shared or temporary house, etc.). Afterwards, tariffs are offered according to two parameters: the customer profile and, most importantly, the aggregator needs in order to balance the consumption for each time period. If the aggregator has a high demand curve in a cluster for the early-morning hours, a lower price for evening consumption could be offered to a specific cluster of customers, who will be persuaded to move their consumption peak from morning to evening, since the energy is cheaper at those hours. In the near future, this HLC will allow the aggregator (upon a commercial contract held with customers) to remotely disconnect loads in an unpredicted event of high energy demand. This leads to a powerful Demand Side Management (DSM) tool, useful to achieve the energy balance.

In brief, the DSM is the modification of the customer consumption profile using a wide range of techniques: price modification, customer consumption awareness, remote load disconnection, Demand Response methods, etc. The final goal of DSM is not reducing the energy consumed, but balancing the energy consumption pattern. Thus, from the aggregator point of view, applying DSM techniques using the HLC functionalities presented can lead to the desired energy balance result. This result will benefit not only the DSO (avoiding consumption peaks), but also the aggregator (balancing the energy consumption) and the final customer (obtaining lower tariffs).

1.2. Economic Approach to Distributed Energy Generation and Resourcers

Nowadays, the electricity market in Europe is undergoing a plethora of changes. Underpinned by ICT-related breakthroughs, new actors and business models are emerging in order to facilitate the transition from a monolithic market driven by large companies (in some cases, participated by the country governments) to a distributed and disaggregated scenario where SMEs are able to benefit from it. In addition, customer role is changing from a consumer actor to a dual consumer and producer (prosumer) role. Thus, the appearance of new actors (such as aggregators) and the consumer's role change clearly promote the ongoing changes in the energy markets.

1.3. Contributions of the Manuscript

This paper offers four different concepts for business models in the power grid that take into account the benefits that can be provided for both end users, who usually are numerous but have small scale facilities related to energy production, storage and consumption (such as solar panels or home batteries), and for business opportunities that can appear for new companies (startups, spinoffs, etc.) or well-established ones when energy is stored as a commodity to be traded. Furthermore, this paper presents not only theoretical new emerging business models applicable to the distributed energy generation scenarios, but also use case located in Steinkjer (Norway). In this scenario, the components needed were deployed within the living lab facilities, conforming a microgrid of consumers and producers. The business models profitability was evaluated using the user´s data and power balance, as depicted in the corresponding section of the paper.

1.4. Paper Structure

This paper is organized as follows: an introduction has already been provided as the first section. Section 2 is focused on the related works that have been produced according to what is the scope of this paper, namely, effective business models for the power grid, with a particular stress on the Smart Grid; open issues and challenges are depicted in this section as well. The four models that are put forward and how they can be used to provide a solution that will result in prosumers increasing their profitability and the creation of new companies are described in Section 3. Technological and economic analyses have been added to this section in each of the models. A successful use case is shown in Section 4, as a way to prove the profitability of the business models shown here. Conclusions are offered in Section 5; future works are mentioned here too.

2. Related Works

As mentioned in [2], business models under the Smart Grid paradigm have a growing interest and there are several areas to explore (such as Demand Response or load control for residential customers, etc.). While there are few complete studies and functional examples about how to provide profitability for end users and small scale facilities in the context of the Smart Grid, the ones that have been put here have a significant number of common objectives with this studio, such as describing business models for small scale facilities in microgrids.

2.1. A Systematic Survey of Business Models for Smart Micro-Grids

The authors of this paper put forward the convenience of integrating the great amount of small renewable energies plants that have appeared as a result of the spread of the Smart Grid [3]. According to the authors, there are several features than can be assumed by the different stakeholders present in a Smart Microgrid (in the presented paper they are abbreviated as SMiG): energy demand coverage by means of Renewable Energies (RE) supply, consumption of locally produced energy and ancillary services provided outside the SMiG used to make the electric system stable. Some of those roles can be combined in a single legal entity, whereas German legislation (the authors focus on the particularities of Germany) prevents that from happening in every possible case. As a result of the structure created by the participants, there will be an added value regarding the functionalities performed by the whole collection of participants (namely, willingness to pay for energy produced in RE plants, alignment to consumption of the electricity generated in RE plants, locally produced electricity, promotion of RE production, creation of a feed-in tariff for RE, promoting RE production aligned to consumption, incentives like exemption from electricity taxes, fees linked to network changes, promotion of batteries manufacturing, etc.) that will be used to interchange required data among all the participants, thus creating a network of actors in the system that will mutually benefit from each other. Furthermore, the ancillary services offered by grid operators that were mentioned before are used to influence in features such as the control reserve markets, interruptible loads and redispatching of electricity where it is required for load balancing; feed-in management and load shedding are some other facilities offered in this case as well. According to the market survey that has been performed by the authors, there are several business models that have already been adopted, like RE plants offering direct marketing with market premium with sale to EPEX (European Power Exchange SE, an exchange site for power trading in countries of Central Europe such as Germany, France, or Austria [4]) or direct marketing to local consumers.

The authors mention the issue of regulation, as many of the business models that are shown in their study take into account the legislation in Germany as a way to establish what can be done in a specific country. The main scope of this paper, though, is surveying the current business models that exist up to now, rather than offering the technical and economic background for new ones where both end users and third party companies will share the benefits of them. In addition to that, no business model canvas is provided to have a better grasp of the ideas put forward in the proposals. One claim that is made in this piece of work is that "*The role of storage operators only providing storage services to other market participant hasn't defined clearly yet*". This open issue is dealt with to an extent in this manuscript.

2.2. Business Interactions Modeling for Systems of Systems Engineering

The authors of this manuscript claim that the Smart Grid can be used as an example on how to create business synergies in Systems of Systems (SoS), as they have not been properly addressed in the area of systems engineering; these business interactions will be made in a context expected to include not only technology-related systems [5]. The authors claim that if managerial control is considered, SoS can be divided into three different kinds: directed (SoS are centrally managed during the long term operation), collaborative (with a central management organization that just develops standards rather than running the system) and virtual (with no central management authority), being collaborative and virtual the main focus of the paper. According to the authors, business interactions should be defined at the same stage that analysis and specification of system requirements in order to guarantee the optimal solution both from the technical and the economic perspective. In addition, they mention that in order to analyze business interactions there are two ways to use Business Interaction Models: Value Network Models (VNM) and business processes. As far as the Smart Grid itself is concerned, it is presented as a complex SoS with two different kinds of features, that is to say, the ones related to energy and Information and Communication Technologies (ICTs) and the entities that can be found from taking economic stakeholders into account (customers, distributors, service providers, etc.) If the different agents participating in the Smart Grid are taken into account, money and service transfers will be done as a Value Network Model. Business process interactions are carried out by three different kinds of entities: Customers, Service Providers and Operations; with customers containing two main actors: the smart meter (responsible for automatic readings of energy consumption and its communication to the corresponding entity) and the actual human user. Under these circumstances, if the business process and the signaled separation of actors are profitable, they will be used as a starting ground to define system requirements.

In this manuscript, the authors describe concepts such as the interaction between businesses and the actors in the Smart Grid, as well as the need to take them into account simultaneously when developing a system. However, any more specific description of a business model from a technical or economic point of view is not deeply provided, nor the main actors and characteristics involved in each of the potential business models. Furthermore, small scale facilities that may be owned by end users are not considered here either.

2.3. Smart Grid Solutions, Services, and Business Models Focused on Telco

The authors of this paper describe how to obtain a profit from the principles of microgrids based on a commercial point of view by describing the works done by the largest Korean telecommunications company [6]. According to their perspective, the Smart Grid can be divided in three different layers: (a) physical power layer used to transmit and distributed power, in a way not dissimilar to what would be done by a Transmission System Operator; (b) data transport and control layer (used with the purpose of offering two-way communications typical of a microgrid among different actors); and (c) the application layer where the facilities offered to the end users (Advanced Metering Infrastructure, Demand Response, Distributed Energy Generation and Storage) are located. The authors describe what they refer to as the Smart Green Service, that is to say, the solution that KT Corporation (formerly Korea Telecom) has conceived for home energy management. It is made up by four different devices: a smart tag (which monitors and controls electricity usage of each electrical device), a smart box (used to collect all the information from the electrical devices with a Smart Tag), a smart meter (for measurement of the dwell electricity usage) and a Smart Green Center (an energy management service platform utilized for the management of the system monitoring entities like the collection of smart boxes and tags that have been deployed or the application server system offered for customer services). These facilities rely on an interoperation sequence that involves the utilization of the elements previously described, as well as the remote control devices that provide the necessary hardware to operate on the system. Commonly, there will be three kinds of operations: registration requests (started by the smart box, which will received the answer after sending it to the platform), periodical transfers of power data (by means of smart tags) and control status operations.

Aside from the test bench that has been used to validate the platform that has been created (which can be conceived as a microgrid for home dwellers, not dissimilar to the original concept that is explained in this manuscript), four business models have been described by the authors of the paper: Smart Energy Saving (used to save energy from providing integrated billing and collection services and have the energy management operators sharing the profits from the saved energy), Smart Power Trading/Selling (where an energy seller can sell both electricity purchased from the electricity market and the power surplus generated from the consumers), Smart ICT Convergence (which deals with providing consumer with services based on Information and Communication Technologies) and Smart City Business (aiming to implement an efficient electric power infrastructure for a city).

While there are concepts of business models that are somewhat related to the ones described in this manuscript (such as using energy savings to trade with them, or selling power to the markets in a bidirectional fashion), these concepts are offered as a stub rather than more advanced business models explained by means of business model canvas; the required sequences to offer profitability to third parties (which would effectively take part of the market share of the company providing facilities to the electricity producers) or customers are not detailed either.

2.4. Other Related Works

The authors of [7] claimed that the increasing usage of the Smart Grid will cause a major impact to electricity retailers and supplying companies, which will be forced to change their business models to adapt to the new reality. With regards to prosumers, the authors mention that more complex relations will appear, as prosumers will eventually turn into competitors in the same market.

Furthermore, it is mentioned in [8] that customer segments can be obtained for smart potential grid users. It is mentioned as an output of this study that advantages offered by smart meters outweigh the concerns clients may have. Three different market segments can be distinguished according to the nature of their clients: supporters, ambiguous and skeptics. A set of business models is provided that bears in mind the different profiles that may be obtained from the end users. This study, though, is primarily focused on the end users as energy consumers, rather than in the possibilities that becoming prosumers may offer to them.

Finally, [9] puts forward the business models that can be enabled for an energy service company focused on the residential sector under the paradigm of the Smart Grid, as well as how savings can be obtained. Business model canvas is described as a suitable methodology to describe them. However, as far as energy storage is concerned, this work deals with batteries from Electric Vehicles, rather than the home batteries that assumed in this manuscript.

2.5. Open Issues and Challenges

Among the studies and examples that have been researched by the authors of this manuscript, there are several issues that have been identified as widespread. The ones to be considered are:

1. **Unclear business plans.** While several hints are offered about how to create business from the starting point that either scattered microgrids or the Smart Grid could provide, this idea is never addressed with enough level of detail, nor descriptions where key partners, activities or channels are shown.
2. **Unclear value propositions.** As it happened previously, it is hard to identify the services that would be offered under those new business models that would create the competitive advantages or the profitability for third party companies, even though there is a clear potential for them to happen.

3. **Inadaptability to new power infrastructures** beyond the mere description of what prosumers can offer. Despite having thorough descriptions of what can be used by consumers that are turned into prosumers, studies on how to enable to possibility for them to have a profit with accurate figures (source of the revenues, breaking points, etc.) are missing.
4. **Inability to provide any value to regular, current customers** of the power grid. Regular customers that use electricity in their everyday activities are not given a chance to have a better way to use their surplus, unused energy.

Some of these open issues were identified in [10] and business models were offered regarding prosumers, as they are expected to be one of the major actors in the Smart Grid. However, the participation of regular, non-Smart Grid oriented energy consumers was not taken into account in this study, whereas this kind of end user can benefit from the proposals that have been explained in this manuscript. In addition to that, [10] does not consider the possibility of having new companies providing services based on electricity trading with specific hardware infrastructure, such as home batteries or remote algorithms, as it has been done here.

3. Business Models for Dual Profitability

As described in the previous section, one of the main challenges to solve when considering new business models for small scale facilities and applications in a Smart Grid is the lack of a clear explanation about businesses plans. Furthermore, there are poor descriptions on how to create new business or third party companies that will benefit of the new possibilities that microgrids offer for retail trade. This manuscript, though, shows that profitability of a company that relies on the exploitation of electricity as a commodity is feasible, if the explanation on the value proposition that will be offered to the potential clients of the services that could be offered is detailed and end users can obtain a benefit as a result of the operations of the company. This manuscript attempts to solve those issues by offering simple and accurate descriptions on how to create those businesses. As far as small end users are concerned (basically, home dwellers, blue and white collar repair shops and offices, etc.) electricity is usually purchased in a predictable pattern with minor differences depending on the country where it is applied:

1. The produced electricity can either be purchased by an electricity commercializing company (especially if renewable energies are taken into account) or acquired via auctions. In this latter way, power generating companies offer their product (electricity) at a particular price based on an estimation on how much energy will be consumed during a certain period of time (being the next day one of the most usual ones). An electric pool is the location used by large companies to trade with the energy they provide. It is in this pool where electricity generating companies will set a price for the energy that they have produced.
2. A different kind of companies, namely the power commercializing ones, must apply for the electricity offered by the producer ones according to how much they estimate they will be able to sell during the set period of time. Commonly, applications must be aimed to national entities that, in the European Union, are the Nominated Electricity Market Operator (NEMO), aimed to regulate single day-ahead and/or intraday coupling in the electricity market.
3. The NEMO will establish the offered prices of the electricity that is provided by the power producing companies up until all the demand estimated from the commercializing companies is satisfied. Commonly, the NEMO will start assigning power supplies by choosing the cheapest offer done by the power producing companies, and finish with the most expensive ones, taking into account the estimations done by the power commercializing companies. The resulting price when finishing the auction will be the one to be charged to the end customers, provided that power is bought for the timespan that has been agreed in the auction. As it can be inferred, consumption forecasting will have a decisive role in fixing electricity pricing.

4. This final price has different names that depend on the location of the energy market. For instance, in Spain is called Voluntary Price for the Small Consumer (Precio Voluntario de Pequeño Consumidor, PVPC [11]).

It is of major importance highlighting that legislation, though, greatly varies from one country to another, and the actions described here are representative mostly of Spain. In addition, it can be inferred that this procedure has been conceived to be one-way only, and does not involve the interaction of end users of electricity with any different role than being consumers buying a commodity. Consequently, it is hard for prosumers to enter the electricity market and actively participate as electricity providers. What is put forward in the manuscript is that end users, regardless of their condition of actual end users or prosumers, can use the electricity market to their advantage with two key facts that take place in them:

1. **Variability of the electric tariff during a timespan.** In most of the cases, the price of the electricity has some variation during the 24 h of a day, regardless of how insignificant it may look like at first sight. Therefore, the cost of the energy consumed by a collection of loads may be controlled to an extent if mechanisms to optimize their electricity usage are implemented. For example, as it can be seen in Figure 1, electricity cost per kWh can greatly vary during a specific period of time, with a group of hours when energy cost is comparatively cheap due to the low demand of electricity (*off-peak hours*) and other period of time when price increases due to the higher demand (*peak hours*). In this figure, three different tariffs have been established: one default tariff with no particular incentives to consume electricity during certain periods of time, described in Figure 1 as *Tarifa por defecto (Peaje 2.0 A)* and represented with a red line; another one that clearly defines two periods to improve consumption efficiency, represented in Figure 1 with a blue line and named *Eficiencia 2 períodos (Peaje 2.0 DHA)*; and a third one used for Electric Vehicles (EVs) with minor differences when compared to the one that has two different pricing zones, named *Vehículo Eléctrico (Peaje 2.0 DHS)* in Figure 1 and represented with a green line. Even when tariffs are flatter (default tariff in Figure 1) there is still some variation that can be used to the end user´s advantage. There are several parameters that must be taken into account when dealing with electricity costs, such as the conditions used to supply electricity (small consumer pricing policies, active energy billing, energy cost, access toll, etc.). Again, it must be born in mind that the values and parameters described are done so according to national legislation, where energy and electricity pricing are part of a regulated sector. Consequently, electricity tariffing procedures may vary greatly from one country or location to another.
   With this price variation in mind, as well as how much electricity will be consumed by the end user, the supply contract that will be signed to charge energy usage of this end user should be strongly based on the consumption habits that they have (hence considering the amount of loads and how they are used in their dwell or facility).

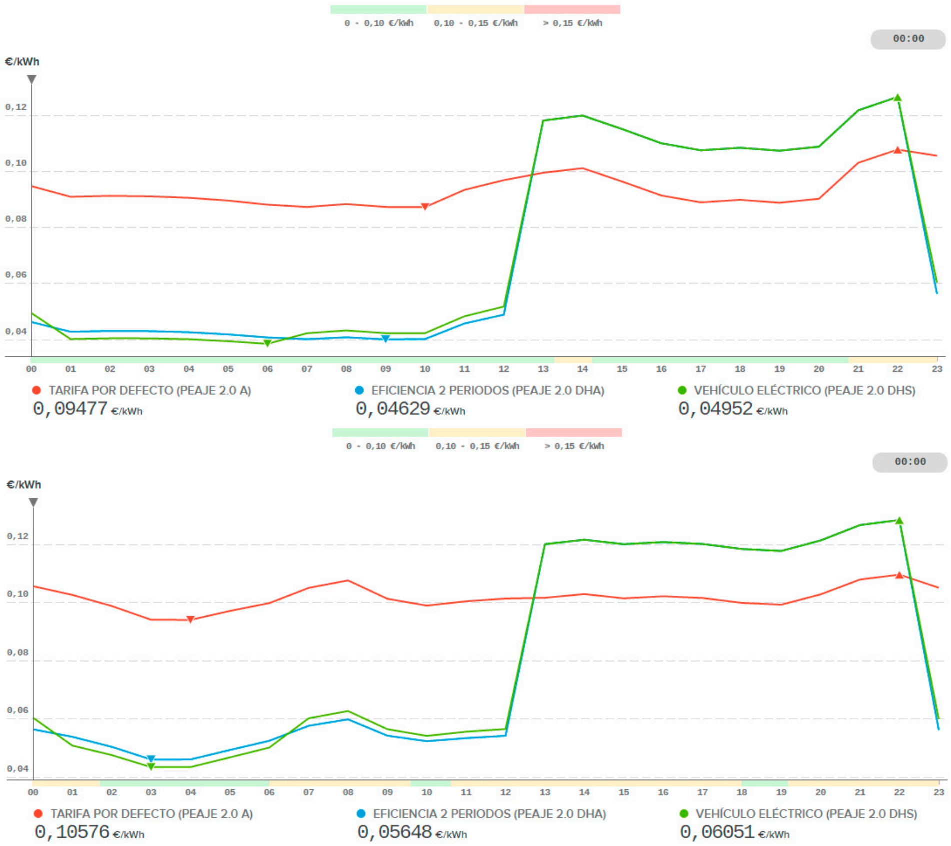


Figure 1. Voluntary Price for the Small Consumer for Spain, 19 (Sunday) and 20 (Monday) June 2016, as shown in [12]. Default tariffs (red) are 0.09477 and 0.10576 €/kWh, two periods (blue) are 0.04629 and 0.05648 €/kWh and Electric Vehicle (green) are 0.04952 and 0.06051 €/kWh, respectively.

2. **Infrastructure availability to store energy.** If energy storage capability is available, then electric energy can be saved if transformed into chemical energy into an "energy reservoir" for its most optimal usage, thus decreasing energy costs when energy might be most demanded and therefore its price is higher. What is more, trading strategies can be enabled for small consumers willing to use their stored energy as a resource in the market, since power can be acquired, stored and sold as any other commodity, with the difference that power availability is widespread and an instance of these storage technologies can be used by any person that is supplied electricity and is willing to save it during a specific period of time. Even though it is a technology that has yet to become fully mature, home batteries are gaining increasing success, with development works being done in their most prominent electric features, such as output current ripple [13]. Other solutions rely on designing power units to be installed on vehicles that could be used as power suppliers [14]. The most important home batteries to be known at the time of writing this manuscript are:

    1. **Tesla Powerwall.** This the most popular home battery available in the market, as it is regarded as the forerunner of all the other related technologies that, to an extent, mimic the idea and design of this solution. The capabilities that are provided by Tesla Powerwall are above the average of what is provided by the other manufacturers. By the time of writing this manuscript, it was claimed by Tesla Motors that this home battery was sold out until mid-2016 [15].
    2. **Panasonic LJ-SK84A.** This battery is sold with the same concept as tesla Powerwall, and its capabilities and features are comparable to the ones offered by the former, according to the specifications displayed by the Panasonic model. This solution is mainly focused on the

Smart Grid, as it is conceived and commercialized to an extent as a hardware element to make use of the energy obtained from solar panels [16].

3. **Powervault models (Lithium ion and lead acid).** This company is a startup based in London that offers a myriad of products oriented to energy storage. According to [17], the main business lines are focused on the commercialization of either Lithium-ion batteries with a longer lifespan, or lead acid ones with better performance but shorter life. Unlike Panasonic and Tesla, the models that are sold by this company are the bulk of their business, rather than another branch of a broad range of activities. This is something to be taken into account overall as far as the applicability of the usage of batteries is concerned, since profit in this company regarding this activity is way more critical than in many of the other companies. Powervault battery models are usually regarded as more compact ones than the previous ones; therefore, their dimensions and energy availability are smaller.
4. **Orison (Tower and panel models).** This is another solely bent on the home batteries business. As it happened with Powervault, battery models offered by this company are overall smaller than the former ones in terms of available power, energy and dimensions. They make use of a home-friendly design [18], to the point that they are sold with an appearance that is either on towers and panels used for interior design purposes in order to enhance the ornamental possibilities of these devices.
5. **Mercedes Benz Power Pack.** The concept of the batteries manufactured here is different than the ones shown before, since they are sold as separated units that offer a comparatively low amount of power, but they can be combined to offer up to 20 kWh of energy [19]. While other manufacturers offer the same possibility (for example, Tesla Powerwall models can be combined to offer up to 90 kWh of energy) they seem lighter and easier to handle than the other models. By the time of writing this manuscript, there was little public information available regarding their major specifications.
6. **BYD Mini ES.** This manufacturer offers a plethora of solutions focused on energy storage for homes, offices and large-scale businesses [20]. Their solutions are sold under a modular concept, although the modules are conceived for industrial purposes, so they are larger and offer more capabilities than the other ones that have been conceived for a more domestic use. For the purpose of this manuscript, the Mini ES model has been chosen to be mentioned, since its dimensions and weight are roughly match the overall dimensions offered by other batteries. Overall, the capabilities that it offers are relatively high regarding the relation between its dimensions and available energy, but its weight is comparatively higher too.
7. **Nissan xStorage.** This product was yet to start being commercialized by the time this manuscript was written. Consequently, there was little information available regarding this home battery solution; it was expected that once it starts begin commercialized, specifications will be offered [21].
8. **sonnenBatterie eco.** This German manufacturer of batteries commercializes several models that, depending on their applicability, can be applied to a home environment or a company; taking into account the scope of this manuscript it has been decided to include in this study the home model called eco. It is strongly focused on working in cooperation with solar energy, as the web site where it is shown describes how energy stored from the one produced during Sun hours can be put to a use when there is an absence of sunshine [22]. Overall capabilities are within the range established by all the previously shown models.

Overall, the most prominent available features of each of the solutions put forward by the manufacturers have been depicted in Table 1. It is interesting to note that there are both well-established and startup companies among those involved in these developments. This is a sign of having a growing market in this application domain, which is still far from saturated with products or sold units.

Table 1. Main features of available home batteries.

Name	Dimensions	Weight	Operating Temperatures	Voltage	Current	Power	Energy
Tesla Powerwall	130 cm × 86 cm × 18 cm	97 Kg	−20 °C to 43 °C	350–450 VDC	9.5 A	3.3 kW	6.4 kWh
Panasonic LJ-SK84A	138 cm × 96.6 cm × 27.9 cm	84 Kg (159 Kg with batteries)	0 °C to 40 °C	230 ADC	8.7 A	2.0 kW	8.0 kWh
Nissan's xStorage	–	–	–	–	–	–	4.2 kWh
Orison Tower/Orison Panel	86.36 cm × 22.86 cm (Tower)/ 55.88 × 71.12 cm (Panel)	18.14 Kg (Tower)/ 17.24 Kg (Panel)	–	120 ADC	15 A	1.8 kW continuous, 3.5 kW peak	2.2 kWh
Mercedes-Benz Power Pack	–	29.94 Kg	–	–	–	–	2.5 kWh per pack (up to 20 kWh)
BYD Mini	68 × 25.6 × 61 cm	96 Kg	0 °C to 40 °C	240 V	–	3 kW	3 kWh
Powervault (Lithium ion/lead acid)	82 × 58 × 50 cm	85 to 125 Kg (Li)/ 185 to 245 Kg	0 °C to 35 °C	217 to 253 V	75 A	1.6 kW (peak power)	2.2 kWh to 6.6 kWh (Li)/ 6.6 kWh to 8.8 kWh
sonnenBatterie eco	129.54 or 180.34 × 66 × 35.56 cm	–	5 °C to 35 °C	240 V	–	3 to 8 kW	4–8 kWh, 10–16 kWh

In addition to the ones shown here, there are other projects that aim at achieving new home battery models that can be commercialized, such as the Jofemar RoxZell, which claims to provide 10 kWh of energy and a peak power of 1.5 kW [23]. What is more, Electric Vehicle batteries may be used in this system too, as they are capable of storing power for its later usage. Worsening of storage capabilities of home batteries must be taken into account, though, as their declining performance will strain the profitability of the business models put forward in this manuscript. In this context, batteries must be considered as an investment that must be renewed after a significant period of time that will usually range around 10 years.

3.1. Business Models Proposal

There are four different business models proposed in this section of the manuscript. The idea of introducing them is proving that new opportunities can appear with the energy transition, both for end users (or more accurately, prosumers) and new companies that will result from the new ways to satisfy the energy demand needs of the population. Consequently, the common underlying concept of these business models is that there will be a symbiotic relation between the end user, who will be able to save energy, and new companies supplying the required hardware and software components that will profit from the energy saved by the end user, who will effectively become their client. The latter company will be referred to as third party from now on in the manuscript. The role of the third party will vary according to the scenario, but will usually imply the following features:

1. **Storage solutions.** Energy storage solutions may be provided if the end user has no infrastructure available to begin with.
2. **Trading capabilities.** An algorithm must be used to trade with the energy that has been stored at the optimal moment and with the optimal partner in order to maximize the profits derived from that activity.
3. **Interconnectivity**. How to interconnect different energy storage facilities so that energy can be transferred from one location to another or to provide electricity to a cluster of users must be figured out when several of them are gathered under the same third party.

A more graphical way to describe the applicability of the business proposals is depicted in Figure 2. A glimpse of the required technologies that could be used by a battery owner are introduced in it (even though the scenario and the roles of the end user may change from one business model to another, they will still need a battery to store the electricity that will be traded for a profit). Even though the changes in the technology will not be significant, the third party will have some differences in the infrastructure and profitability offered to and obtained from the application domain. When the main role of the company is working as an aggregator (that is to say, will be involved in offering Demand Response or Demand Side Management to a collection of users gathered in a cluster, as shown in [24]), the core of the third party will be the Trading Algorithm, as it will be used to be aware of the prices to sell and buy electricity both from a higher level provider (such as a distributed system operator (DSO)) or from another users integrated in the cluster (provided that they have energy to deliver, obtained either from the power grid or from any distributed energy resource). Due to its importance in the profitability of the system it will be accessed remotely from the aggregator facilities when the third party behaves as an aggregator. Another option is having the third party as a provider for the home battery and the Home Load Controller (HLC) required to monitor energy usage in a small facility, such as a home or an office. While this option is less appealing from the profitability point of view, it works fine with offline infrastructures that cannot or are unwilling to remotely connect to any other participant in the microgrid.

In any case, the concept behind those business models is that they should be applicable for end users without special facilities of any kind, but a dwell and connectivity to the power grid from where they obtain the electricity they use. Therefore, end users are mere energy consumers in a first stage. This situation, though, can easily change if they obtain the necessary means to trade with electricity.

In order to do so, it is enough for them to be able to store energy as a way to have a commodity to trade and obtain a profit for new companies or end users that have been enabled to provide energy. Overall, the business model propositions can be described as shown in Table 2. It is important to take them into account, as their economic analyses will vary from one to the other and prosumers will effectively be treated as Independent Power Producers capable of offering their own energy to the electricity markets (IPPs) [25].

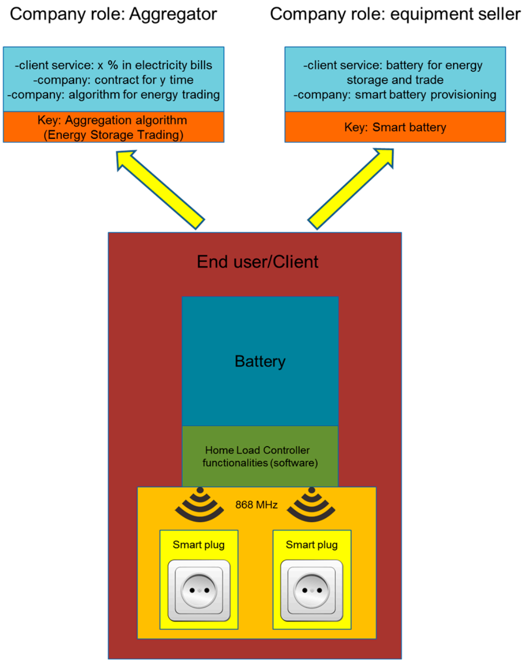


Figure 2. Third party possible roles in the business proposals.

Table 2. Business models proposition and roles.

Business Model Proposition	Customer Profitability	Third Party Profitability	Action Description
Offline hardware sell	Breaking even point	Hardware (battery + Home Load Controller) with embedded software	The consumer purchases a battery with a Home Load Controller and a locally installed Trading Algorithm
Online fixed time	User profit from trade	Hardware sell, business profit from platform access during a certain amount of time	The consumer purchases a battery with a Home Load Controller and access a remote platform with the Trading Algorithm during a certain amount of time
Online variable time	User profit from trade	Hardware sell, business profit from accessing the platform during particular instants	The consumer purchases a battery with a Home Load Controller and access a remote platform with the Trading Algorithm during a particular moments
Online distributed trade	User profit from trade	Hardware sell, "virtual DSO" operations	End users are interconnected among them to interchange electricity without using any other entity but the third party

Additionally, there will be a Trading Algorithm that will be used to perform several operations with electricity, as the latter will be used as an asset to trade and obtain a profit. These operations will be mostly focused on buying and selling electricity. These operations will alternate themselves with other periods of time when no trade will be done due to several circumstances (electricity has to be consumed locally, it is not a suitable moment to trade because prices discourage it, etc.). Trading Algorithm operations, along with their motivations, have been depicted in Table 3.

Table 3. Algorithm activities and motivations.

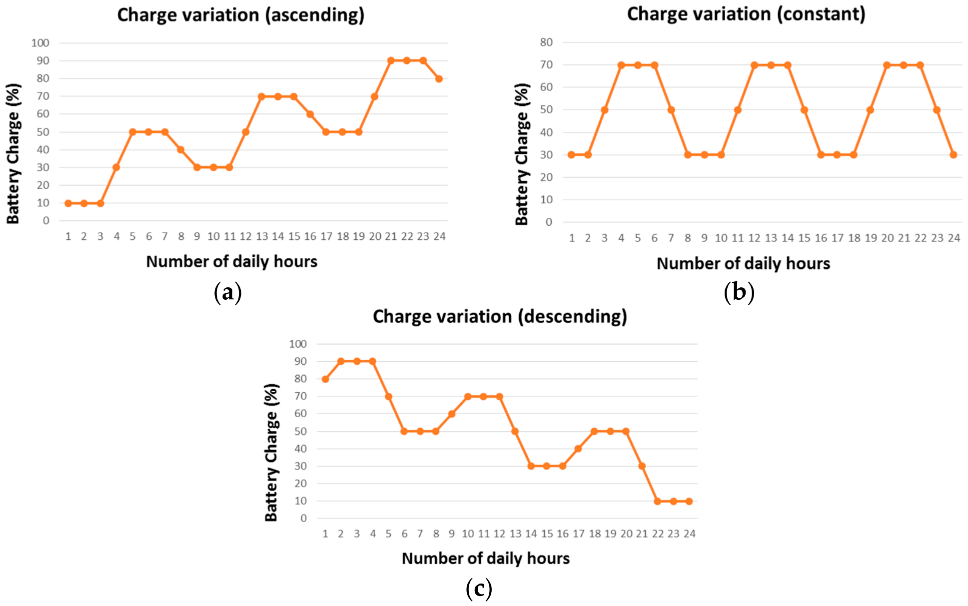
Input	Motivation for "Buy" Operation	Motivation for "Sell" Operation
Energy consumption forecast	Current electricity price is low, but it will be high in the foreseeable future	Current electricity price is high, but it will be low in the foreseeable future
Weather forecast	Future weather conditions will make Distributed Energy Resources or Renewable Energy Sources (if available) scarce in the foreseeable future	Future weather conditions will make Distributed Energy Resources or Renewable Energy Sources (if available) abundant in the foreseeable future
User Profiles	Energy is used during the current timespan by home dwellers	Energy is either not used or stored during the current timespan by home dwellers

It is important to note that, regardless of the specific use case scenario where the trading algorithm participates, there will be several actions that will be kept the same. For example, the trading algorithm activities will frequently be based on three possible strategies where it will be used to calculate the optimal action to take as far as energy storage is concerned:

1. **Ascending energy storage:** Power is gradually stored in the home battery. Rather than invariably increasing the power storage for a while, what matters is the tendency: it might be convenient in a particular lapse of time to discharge the battery (for instance, due to better prices in the markets), but the overall tendency will be increasing power storage. However, energy cannot be held during an indefinite amount of time because the home battery can only store a limited amount of energy. Even if the end user was able to extend power storage, saving it during an indefinite amount of time is rarely the most profitable option.
2. **Constant energy storage:** it may happen that power is being purchased from the power grid at a favorable price for the end user and either using it to charge the home battery during a certain amount of time or using the battery stored energy to power home appliances is not the optimal solution for the end user. Thus, the algorithm will just keep the remaining energy of the battery stored. While there might be small changes in the charge and discharge that is applied to the battery in this lifespan, the overall tendency will be directed towards keeping a particular level of charge.
3. **Descending energy storage:** here, energy is gradually discharged from the reservoir where it was kept. As in the two aforementioned strategies, it may happen that during the discharge process some charging is done, but it will be less significant than the tendency that is taking place during the discharge period of time. This strategy is useful when energy has been purchased at a comparatively low price and a high price cycle is taking place. On the contrary, energy discharges might take place when power is needed by the end users but buying it from the power grid is more expensive than desired (i.e., during peak hours). Typically, when that cycle ends or all the energy that used to be stored is depleted, this strategy will be put to a halt.

A representation of the described strategies has been included in Figure 3.

Depending on the cases, there will be a possibility (or even the need) to interconnect different services that can be allocated in the distributed system that is made up by the different users. Under these circumstances, prominent issues could appear when a collection of devices that use different information formats has to be interconnected and use different kinds of information sources. Fortunately, this issue can be solved by means of middleware, a software layer that can be located in several different pieces of hardware deployed in the distributed system. The main functionality of this software layer will be abstracting the heterogeneity and complexity of the underlying hardware components installed in a microgrid (or in several of the microgrids that are included to conform a Smart Grid) so that a collection of homogeneous-looking facilities will be provided to the higher, application-based layers (commonly offered via Application Programming Interfaces) [26]. The usage of middleware is enabled in different scenarios that often imply either a microgrid or a Smart Grid as a whole [27]; its usage can include several different software services when hardware appliances are unable to be enhanced with software components for any kind of reason (with the most usual ones being: (a) the device has too poor computational capabilities; or (b) the device is a proprietary solution that cannot be modified). The actors that will be implied in these proposals are quite similar in most of the cases, with the exception of the third party company that may provide or not aggregator capabilities. Consequently, a business model canvas has been prepared for all of them in the next subsection. By means of it, the main participants, actions, and revenue channels will be clarified.



(**a**) (**b**) (**c**)

Figure 3. Graphical representation three possible algorithm strategies: ascending (**a**); constant (**b**) and descending (**c**).

3.2. Business Model Canvas for End User and Third Party Symbiosis

Business model canvas can be used as a way to highlight the most important features of a business proposal. It can be regarded as a summarized, yet very effective way, to clarify the most critical aspects of a business so as it is clear what is needed from the business to work and what goods or services will provide to its clients. It can be said that business model canvas is a suitable tool to describe the business model proposals put forward in this manuscript, as they show in an accurate way the elements that are required in each of the cases. Figure 4 contains the overall appearance of the business model canvas, with all the required elements for its comprehension. They can be described as follows:

1. **Key partners:** The external entities required for the correct performance of the business are located in this part of the business canvas model. Being the proposals related to the power grid and Information and Communication Technologies, it should come as no surprise that they are a cloud infrastructure provider for all the use cases where a connection to a remote location is required (all but the first proposal), the Transmission System Operator (TSO) used to transfer the electricity traded from one location of the power grid to another and the battery manufacturer, which will provide the infrastructure for energy storage.
2. **Cost structure:** This part of the canvas involves the activities that will suppose a cost to the company to be developed, even though they will be mandatory for the maintenance of the infrastructure used by it. Some of them are to be expected from any company (marketing promotion and sales to keep the flow of profits, along with customer service to guarantee that any punctual issue is solved in an effective manner for end users), whereas others will be focused

on the assets used by the third party with the idea to keep them functional (battery replacement, Home Load Controller maintenance).

3. **Key activities:** Here, the most critical activities to be done by the company have been placed. Without them, there is no possibility for the third party to provide any kind of service. There are four of them in this case: software development (focused on hardware heterogeneity abstraction and the Trading Algorithm), hardware connectivity (dealing with the required cabling and electric protocols to connect the appliances used under this model), hardware installation (putting the devices to be used in a location good enough to guarantee that there will be no damage for them, apart from the one derived from normal usage) and data collection (used when there are several users with different profiles, under an aggregator-enabled business model, that will be included in a cluster with the idea of using profile data to complement each of the end users).
4. **Key resources:** The assets critical for the third party have been placed in this part of the business model canvas. There are four of them: home battery (for energy storage), Home Load Controller (to control and monitor how energy is being used in the facility where the battery is installed), the Trading Algorithm (used for energy balancing and, overall, to trade with the electricity that is stored in the facilities) and the cloud infrastructure (mandatory to store the algorithm in any business model that will depend on accessing the Trading Algorithm in a non-local scenario).
5. **Value proposition:** The services that are offered to the clients of the third party have been placed in this section of the canvas. There are three of them to be offered: profits obtained from trading the electricity that has been gathered from the power grid in case it is sold at a higher price than the one it was purchased at, prevention of power cuts that may affect or damage any equipment used in the facilities where the batteries are installed and electricity cost reduction, since trade will make possible that the obtained benefits will make up for the electricity bill required to be paid to the energy supplier.
6. **Revenue streams:** the ways that are going to be used to obtain a profit for the third party company have been placed in this part of the business canvas. They have been summarized as three different kinds, which correspond to the four business proposals that are put forward in the manuscript: the offline solution, the online solution that will require to have a contract signed, the online solution that will rely on sporadic connections to the aggregator platform to perform trading operations, and the fourth solution where electricity is provided to a cluster of users either from the one bought from the DSO or from other user with a different profile in the same cluster (hence, having the third party behaving as a DSO from the end user point of view).
7. **Relationships:** The different instruments for the third party to relate to its customers are shown in this part of the business model canvas. The operations that are going to be performed by the third party are mostly defined on the grounds that any trade should be done in an automated manner that will require as little intervention from the end user as possible, so that the utilities installed will not interfere with their everyday life. In a way, this concept has some resemblance to the ones used for the Internet of Things, where according to Mark Weiser, computers should recede to the background and become integrated to the environment for their unconscious usage [28]. Therefore, automated management is enabled as a way to guarantee that services will be provided in that way. In addition to that, the permanence of the clients that receive the services provided by the third party company will be tailored according to the kind of business model that is applied in each of the specific cases. Last but not least, social networks will be used to get in touch with the clients as a way to obtain fast and cheap feedback from them, in case there are issues to be fixed.
8. **Channels:** How the third party will become known for the customers of interest is what has been placed in this part of the business model. There are basically three channels that can be considered for the company: Smart Grid websites that will make popular the work that is being carried out by the company, the website used by the very third party involved in energy trading and the social network profiles of its customers, which will have the criteria to spread either positive or negative feedback from their experiences.

9. **Customer segments:** The profiles of the customers that will be making use of the services provided by the third party company will be portrayed in this part of the business canvas model. Basically, every end user with a facility or location where energy is consumed will be a potential customer for the third party involved in these business models. The most prominent groups have been highlighted: (a) home dwellers that live in a house or a building; (b) public institutions that have public buildings that need electricity to work and therefore can use it to trade as any private home dweller; (c) Small and Medium Enterprise owners that have some facilities where electricity is required and its usage can be optimized; and (d) overall facility owners that will make use of energy and can therefore benefit from its storage and commercialization as a commodity by means of a battery, an Internet connection and a Trading Algorithm.

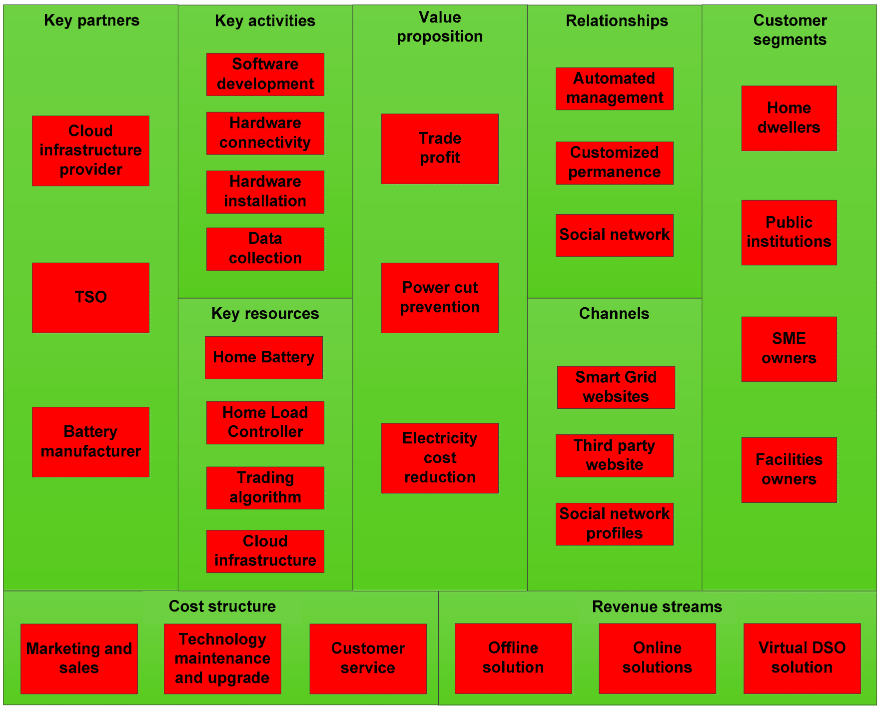


Figure 4. Business canvas model for symbiosis between end users/clients and a third party supplier.

Once all these features have been taken into account, the four business models are presented in the following subsections. It is important to take into account that, in each business model, two different situations have been taken into account: in the first case, the foundations of the model without the enhancements that the Smart Grid can provide, and in the second one the business models are presented under a smart grid paradigm. The reason to do it like this is that, according to the literature studied and the calculations undertaken as examples, there are several differences in applying the businesses models when the Smart Grid is present and when it is not, and despite all of them providing better results for the end user and the third party company when the former is available. Still, the absence of the Smart Grid has to be considered because so far there is a majority of locations that are lacking it, even though it is overall progressing in its deployment.

In order to have a more accurate idea of the benefits that the activities of this kind of business can offer, examples are provided where actual calculations have been made. These examples have been possible to include by making the following assumptions to have actual figures that can be operated:

1. **Battery energy:** At the time writing this manuscript, Tesla Powerwall is the most popular home battery used to store energy, either by itself or combined with Solar Photovoltaic (PV) installations. Consequently, its declared figures for energy (6.4 kWh), guaranteed cycles and cost have been used.

2. **Battery cycles:** According to the official figures that have been presented by Tesla, it is estimated that the 6.4 kWh battery should last for approximately 5000 charge cycles without significant worsening of its performance, which is roughly 10 years of life expectancy, regarded as the period of time falling within the warranty offered with the battery [29,30].
3. **Battery cost:** The cost of the battery that is used for the example is recommended to be $3,000. In addition to that, it is estimated that the cost to have it installed is around $500 [31] so the overall cost used for the examples will be $3,500.
4. **Electricity off-peak tariff:** In this case, the data that were provided in [13] will be used for the example as off-peak and on-peak tariffs. Therefore, off-peak cost of the energy will be 0.04 €/kWh.
5. **Electricity on-peak tariff:** Following the data provided before, on-peak tariff has been considered to be 0.12 €/kWh.
6. **Annual electricity consumption:** Since the information regarding tariffs was obtained for the particular situation of Spain, an average value of the annual energy consumption in a Spanish home has been used [32]. This value is 3.487 MWh.
7. **Legislation:** It has been considered that legislation should be kept out of these business models for two reasons: (a) it greatly varies from one country to another (even in the same country there might be different regulations and conditions); and (b) it may distort the results obtained in a negative (legislative constrains) or positive (fiscal incentives) manner. The main interest of this manuscript is describing the impact of energy storage and the Smart Grid (if available) for end users without external further interventions.

3.3. Business Model 1: Offline Model

This is the simplest business model that can be implemented when using the trading capabilities resulting from the difference in prices of electricity during a specific timespan (for example, a 24 h-long period of time where there is a certain amount of peak hours, when electricity is more expensive, and off-peak hours, when the cost of purchasing electricity is cheaper) and the availability of energy storage solutions.

3.3.1. Offline Model without the Smart Grid

Under this scenario, an end user will buy a hardware solution set that will consist of: (a) an energy storage solution used to save energy; (b) a Home Load Controller that will monitor the energy consumed in a dwelling; and (c) a Trading Algorithm that will be able to access the electricity markets to perform trade operations using the stored energy as an asset available for the end user. Unlike the other business proposals, the Trading Algorithm will be installed in the Home Load Controller locally, rather than requiring accessing it from a remote location. Should the contract between the end user and the third party not be renewed, then this algorithm will be nullified. The capability to interchange electricity with other end users is not enabled here either, as the business model is conceived as an isolated development that will rely solely on the resources installed by a single user.

As far as profitability is concerned, in all the presented business models there will be a way to enable both end users and the third party company to obtain a monetary benefit at the same time (albeit playing different roles since their location in the business infrastructure is different). In case of the offline mode business model, the procedure that will guide all the actions to be taken by both entities followed will be as shown:

1. The energy storage solution is connected to the power grid as any other home appliance. Additionally, the Home Load Controller is connected to the same infrastructure and both monitors and controls energy usage in the power plugs where it has been given a degree of control, offering information at the will of the end user.
2. The Trading Algorithm installed in the Home Load Controller will be responsible for the periods of time used to charge and discharge the energy reservoir. Commonly, it will favor charging

the battery when electricity is cheaper (therefore, the Trading Algorithm will *buy* electricity) according to the pricing forecast that has been made previously available by the DSO. On the other hand, it will encourage offering energy to the power grid (thus *selling* electricity) when it is economically more convenient. This buying price, considered for Kilowatts-hour, has been named as *Bpk*.

3. During the timespan when electricity is most expensive, the Trading Algorithm will receive as input the energy demanded by the home appliances of the facility where it has been installed, which is monitored by the Home Load Controller. Therefore, rather than having the dwell accessing the regular power grid to gather electricity (and thus, spending money on the procedure), energy will be obtained from what has been stored by the home battery and will save the end user the expenditures that would be incurred if the commodity had to be accessed from the market during the timespan when it is more costly.
4. Furthermore, it is likely that not all the stored electricity will be required during a certain period of time. Consequently, it will be sold at a higher price than the one it was bought, as seen in Equation (1), where selling price per Kilowatt-hour (*Spk*) is higher than zero when *Bpk* is subtracted from it, obtaining a User Profit per Kilowatt-hour (*Upk*). As a way to simplify the operations, it has been assumed that the energy that was acquired during the off-peak hours will be sold during the peak hours.

$$Upk = Spk - Bpk \tag{1}$$

Therefore, the User Profit that can be obtained from a home battery will be determined by the number of Kilowatts-hour that can be used from it. Ideally, the energy obtained from the battery is done so by purchasing energy at the lowest price possible and selling it at the highest one, so each of the charge cycles used when the battery operates will provide a benefit proportional to the quantity of energy that it can store. Thus, savings obtained from each of the charge cycles from the battery can be expressed as shown in Equation (2), where *Upc* represents the User Profit for each of the battery charge cycles and *Ec* the energy that can be stored by a battery during its warranty period. Note that the concept of *charge cycle* can be ambiguous to an extent; as a way to provide a clear point of view of it, the definition offered by Apple Inc., describing charge cycle as "*A charge cycle happens when you use all of the battery's power—but that doesn't necessarily mean a single charge. For example, you could use half of your notebook's charge in one day, and then recharge it fully. If you did the same thing the next day, it would count as one charge cycle, not two*" has been used is this context as well [33]. While this definition is used for appliances and devices that are completely different from a home battery, it can be used as a way to get an idea of how a charge cycle is supposed to work.

$$Upc = Upk \cdot Ec \tag{2}$$

Additionally, it can be considered that the User Profit will be extended during a succession of time units that will increase the overall figure. Let this profit be the User Profit during a period of Time (*Upt*) that will extend from 0 to *n* for every *i*. This reasoning has been settled in Equation (3).

$$Upt = \sum_{i=0}^{n} Upci \tag{3}$$

As a consequence, and as described in Equation (4), the electricity Invoice that the end user is charged with for their energy consumption during a certain period of time (*Int*) is no longer based on just the electricity Expenditures during that timespan (*Ext*), but the User Profit that is subtracted to the Expenditures (*Upt*).

$$Int = Ext - Upt \tag{4}$$

Furthermore, it has to be considered that under this model, the end user makes an investment utilized to have the energy reservoir (in case they do not have one) and the Home Load Controller with the trading algorithm running locally. The end user, nevertheless, will eventually obtain a return on their investment once the Break Event Point, named as *BEP* in Equation (5), is not only reached but also surpassed as a result of having cumulative User Profits during a period of time surpassing the overall investment (*Inv*) that the client did regarding the home battery and the Home Load Controller with the Trading Algorithm installed. It is expected that home battery prices will drop significantly during the next years, thus shortening the required amount of time required to reach the Break Even Point, so it is very likely that this business model will increase its plausibility and profitability during the next years.

$$BEP \rightarrow Upt = Inv \tag{5}$$

Lastly, the number of charge cycles that can be provided by the battery must also be considered in the economic analysis of the business model proposals, as the more expensive a home battery is, the more profit per charge cycle it will have to provide in order to become paid off and start creating a net profit for the end user. Thus, the number of charge cycles required (*Nc*) has been included in Equation (6), as the relation between the investment made in buying and installing the home battery (*Inv*) and the User Profit for a charge cycle (*Upc*).

$$Nc = \frac{Inv}{Upc} \tag{6}$$

Under the current scenario, which has been explained considering that the Smart Grid has not been deployed where the end user/consumer is present, several calculations can be done taking into account both the assumptions that have been made before and the described formulae.

1. *Upk* is assumed to be the difference between off-peak price (0.04 €/kWh) and on-peak price (0.12 €/kWh), since the former is the price where the algorithm is triggered to buy energy and the latter the one used to sell it. Thus, the value is $0.12 - 0.04 = 0.08$ €/kWh.
2. Thus, by means of Equation (2) and the fact that Tesla Powerwall can store up to 6.4 kWh of energy, it can be said that for every charge cycle, the end user will have generated 0.08 €/kWh × 6.4 kWh/cycle = 0.512 €/cycle from the stored energy, as it is either poured into the grid or used in the dwelling or facility where the battery is located (and therefore power does not have to be purchased).
3. The break-even point *BEP* will be reached when the $3,500 made as the investment have paid off by means of the savings or profits done when trading with the energy stored. At the time of writing this manuscript, 1 € has an exchange rate of 1.11811 USD, resulting in $3,500 being exchanged at 3,130.14 €. Considering the result obtained previously, it can be stated that the number of cycles *Nc* required to get to the BEP is 3,130.14 €/0.512 (€/cycle) = 6113.56 charge cycles, or 6114 as an integer number. This result is past what Tesla estimates as the typical lifetime of a Powerwall battery (around 5000 charges).
4. Additionally, considering 3.487 MWh as the yearly electrical consumption of a Spanish household, it can be said that 3.487 MWh/6.4 (kWh/cycle) = 544.84 charge cycles are performed yearly. This figure is higher than the one effectively provided (5000 charge cycles/10 years = 500 cycles/year), so even if possible, using the battery alone to provide energy would result in an overuse that would rapidly degrade it. Besides, if the former number of charge cycles to pay the battery off is considered, it will have to be used for 6114 cycles/545 (cycles/year) = 11.22 years, which goes beyond the warranty established for the product. At this point, underperformance of the acquired battery is very likely to happen and it will have to be extended even during a longer period of time.
5. The estimations done here do not take into account other factors, such as temperature, that are likely to worsen the performance offered by the home battery.

Several conclusions can be inferred from the previous example. On the one hand, getting a return on the investment done in a home battery without any kind of alternative power source is a long process that may go beyond the usability of the purchased pieces of hardware. Even though assuming that prices regarding domestic energy storage will go down, it will still take a significant amount of time to have important cost reductions. What is more, new legislation can be introduced in the meantime that will significantly alter the costs and revenues obtained from trading electricity. On the other hand, using a single battery as a way to provide power to a dwelling or facility when: (a) it is not connected to the network; and (b) there is not any other source of power, is not an advisable solution for prolonged periods of time (in magnitudes of years). While more batteries can be used by having them working in a cooperative manner (and in this way, having more energy storage capabilities available), this also raises the required budget dramatically.

3.3.2. Offline Model within the Smart Grid

For the context of this manuscript, the presence of the Smart Grid will be understood as having an end user that has previously acquired the necessary means of production of electricity in a local way (and can be regarded as a prosumer encased in a microgrid) and they are usually matching what can be expected from Distributed Generation of energy (typically, photovoltaic panels, low-sized wind turbines, etc.). This implies that the end user/prosumer (note that "prosumer" will be used in this scenario, as they are able to supply power even if they do so at a small scale) has the means to produce their own energy, and can either store it or sell it to the electricity markets.

When compared to the previous case, there are some major differences in the formulae that were used previously. To begin with, the end user will not only save electricity costs from the battery itself, but also from the Smart Grid-related infrastructure that has installed. Therefore, as stated in Equation (7), the User Profit obtained with a Smart Grid-like installation (*Upsg*) will be determined by the User Profit per Kilowatt-hour (*Upk*) and the time that the Smart Grid facility is active (*t*). For example, according to the data provided by [10], the on-peak hours could be used by either injecting power to the grid (thus obtaining a profit) or having it for the dwell appliances (thus reducing costs) depending on the incentives that are provided to shift energy demand from one time zone to another one.

$$Upsg = Upk \cdot t \tag{7}$$

As a result of this, the resulting user profits during a certain period of time needed to charge an energy cycle also include the profit obtained from the Smart Grid installation. This idea is expressed by Equation (8), where these profits are represented as *Upcsg*.

$$Upcsg = Upc + Upsg \tag{8}$$

With these new aspects in mind, if the previous example is applied again a new result is obtained that can improve the overall performance of a system where Distributed Generation and energy storage are combined.

1. *Upk* is still the same as the one that was calculated before with the available data, that is, $0.12 - 0.04 = 0.08$ €/kWh.
2. Although the User Profit per battery charge cycle is still the same as the one obtained before, the profit obtained from the Smart Grid installation is added to the general result. Consequently, gross profits are not only 0.512 €/cycle but also 0.08 €/h that are obtained from the Smart Grid installation. Ideally, the microgrid deployment will be able to provide enough electricity during the peak hours that, according to the data obtained in [10], can be roughly estimated as 10 h/day. Thus, daily added profit inferred from Equation (7) is 0.8 €. Considering that 545 charge cycles are performed every year, 545 (cycles/year)/365 (days/year) = 1.49 charges are made as an average

value every day, so a profit of 1.49 × 0.512 = 0.76 € are obtained every day from the home battery. Overall = Upcsg = 0.8 (€/day) + 0.76 (€/day) = 1.56 €/day.

3. Taking the latter figure into account, it can be said that the final time require to have the home battery paid off is 3130.14 €/(1.56 €/day × 365 (days/year)) = 5.5 years. This is a much more reasonable scenario than the one where no Smart Grid is used at all, since the timespan required is well within the warranty offered by the Tesla Powerwall used in the example.

Therefore, it becomes clear that combining the Smart Grid with power storage (or in a more holistic manner, enhancing the Smart Grid with energy storage) is a welcome addition to the business model. One aspect that still must be taken into account is the optimal sizing of the Renewable Energy Sources (RESs) that are used by the prosumer. It is stated by Bianchi et al. [34] that a system that includes batteries and photovoltaic cells can be optimized taking several parameters into account, such as the inclination of the PV panels, cycle lifetime, average annual costs, etc. Despite orienting the study only to Germany, the authors of the paper point out several important conclusions: the orientation of the PV generation is a pivotal point in the viability of a combined PV-battery system, and points out the tendency to have smaller PV battery systems that will be gradually more focused on self-consumption and self-sufficiency. In addition to that, Allain et al. [35] confirm that choosing the most suitable inclination and installation place are choices with a major impact, and expands towards the possibility of adding a fuel cell to the system that is being studied here. Even though the most prominent commercial solutions have been included in this manuscript, and therefore there is little margin to improve them (other than choosing one model over another one depending on the budget that the end user/prosumer can afford), it is worth mentioning them, as tailoring home batteries is a promising solution for the near future. From a different, more purely physical point of view, [36] puts forward a use case where the acceptable dimensions for a home battery are measured. It is inferred for this latter reference that tailoring an energy storage solution is possible while at the same time retaining reasonable dimensions. Note that as far as this manuscript is concerned, the effect of adding a power storage solution is the main targeted idea, so it is assumed that, in the case of the Smart Grid, the prosumer already had the required installations to be included in a microgrid with Distributed Generation of energy.

3.4. Business Model 2: Online Fixed Time

When compared to the previous business model, there is a major difference in this case: rather than having the Trading Algorithm as a local piece of software installed in the Home Load Controller, access to the algorithm will be offered in a remote manner as it will be installed in the remote facilities of the third party company. Access will be done in a transparent way from the point of view of the end user, in any case. Therefore, the Trading Algorithm can be considered as located in the cloud, as one of the services owned and required by the third party company to offer its capabilities, and it will be accessed under a client/server or a publish/subscribe paradigm by the end user that has installed the same hardware provided previously (with the mentioned difference that the software used for trading will not be installed in the Home Load Controller). This access will be offered during a fixed period of time that will be agreed on according to the contractual terms that enabled by both the end user and the third party company involved in the business model.

3.4.1. Online Fixed Time without the Smart Grid

As it can be expected, there will be a way to guarantee profits both for the end user of the solution and the third party company providing the service. Those profits will be obtained in a different manner in this business model, though. Rather than relying on providing the hardware for the end user, the necessary components (energy reservoir/home battery and Home Load Controller) will be sold at a lower price that will be compensated by charging the end user for accessing the platform where the trading algorithm is located. There are two concepts that must be introduced here: on the one hand, the selling price during a period of time (*Spt*) must be taken into account, since it will the one used to determine the earnings that have taken place during the period of time that the User profit *Upt* has been gained. On the other hand, and in order to determine this *Upt*, the average Buying price during a certain period of time (*Bpt*) must also be known so as to infer *Upt*. These concepts have been presented in Equations (9) and (10).

$$Spt = Spk \cdot t \tag{9}$$

$$Bpt = Bpk \cdot t \tag{10}$$

One key feature of this business model is that it is not expected from the end user to acquire a home battery; rather, it will be supplied by the third party company that is involved. This can be done like that because the source of profits for the company is the price charged to the end user to access the cloud platform (referred to as Platform charge or *Pch*) which is defined as a percentage of the User Profit that is obtained by the end user in Equation (11). This business model is more attractive for end users that are unable or unwilling to make an initial significant investment, since it becomes effectively divided during a prolonged time period as platform access payments. Although the platform charge could be applied in several ways (and in fact, it will be applied in a different way in the next example) here it becomes linked to the User profits that have been obtained during a certain period of time.

$$Upt = (1 - Pch) \cdot (Spt \ - Bpt) \tag{11}$$

The Platform charge is an idea of critical importance for the third party company, due to the fact that it will enable making up for the investment done when offering the home battery to the client if the Platform charge is done during the contracted time, as reflected in Equation (12).

$$Inv = Pch \cdot t \tag{12}$$

Lastly, taking into account that hardware components are way less profitable for the third party company, and the fact that Platform access is charged, a new variable can be formulated, namely the Business Profit during a period of time (*Bspt*), which is obtained as the percentage that the third party will obtain from energy trading done by the Trading Algorithm (which will involve a collection of operations implying buying electricity when its price is low in off-peak hours and selling it during peak, more expensive hours), as stated in Equation (4). While business profits existed previously for the third party, they consisted just of the cost of providing and installing the home battery (in case the client had no previous energy reservoir) and the Home Load Controller.

$$Bspt = Pch \cdot (Spt - Bpt) \tag{13}$$

The procedures used to obtain profits for both the end user and the third party company can be described as follows:

1. The pieces of equipment are plugged to the power grid and connected with each other in the same fashion that was used in the previous case, as if they were regular home appliances.
2. While the Trading Algorithm is still responsible for the trading activities carried out by the overall proposal, it works in a different way, as it will be remotely accessed every time that an operation of either purchasing or selling electricity is done. Consequently, trading operations will be done by means of the support provided by the platform during the specified period of time that was arranged in the contract.
3. When trade is done and a profit is obtained (as it was done before, mostly by buying energy when it is cheaper and selling it when it is more expensive) a percentage will be deduced from the profits made by the user to make up for the reduced cost of the hardware infrastructure offered in this use case scenario and the cloud platform that is used to store the algorithm.

4. The operations used to define when electricity will be spent by the end user, sold or stored will work as they were described before. If the contract is cancelled, then the access to the platform is shutdown, but the end user will still keep the hardware that has been purchased, provided that they hired the services of the third party company for a minimum amount of time.

As it can be inferred from previous steps, this business model basically requires the permanence of a client during a certain period of time, where access will be provided to the installed infrastructure to the algorithm used to commercialize electricity. It presents the same challenges and differences than the previous one regarding its usability when it is not included as part of the Smart Grid. The previous example can be applied here as well, with all the assumptions that were made before.

1. *Upk* is still the same, so it is estimated to be 0.08 €/kWh according to the estimations previously done.
2. According to the previous calculations done, the home battery still makes possible earnings of 0.512 €/cycle.
3. In this case, it is considered that the home battery is offered by the third party company, so there is not a concept of "breaking even" for the end user, since the only investment that has to be done from their side is signing a contract where they will commit to allow the company to provide the end user with electricity. If the 3130.14 € budget for home battery purchase and installation is maintained, then there are two sources of profits that must be taken into account by the end user and the third party company in order to have a fair share of both of them.
4. Depending on the contracted terms, Platform charges may be lower or higher depending on the timespan defined, as well as the share that the third party company might take from the earnings per cycle. Should the third party not take anything from the latter, either the platform charges will be higher, or a longer timespan will be negotiated with the end user. This business model offers a high degree of flexibility because there are several revenue sources that can be used to both partners' advantage.

3.4.2. Online Fixed Time within the Smart Grid

This business model offers the same advantages that were explained in the previous business proposal, as the installation of facilities related to the Smart Grid are still valid. Overall, when the prosumer has a way to produce their own electricity they will find it easier to obtain a profit from their assets, as they will be paid off sooner. What will happen under this paradigm is that the user will combine the profits obtained from the Smart Grid-like installation (*Upsg*) with the capabilities provided by the Trading Algorithm. Since it has been considered that the prosumer has an installation previous to what is provided by the third party (home battery, HLC and trading facilities), it will remain oblivious to the infrastructure provided by the company. Therefore, the example that was provided before can be re-edited for this new proposal:

1. *Upk* has not varied from the previous scenario, being 0.08 €/kWh.
2. The earnings obtained on a daily basis from the Smart Grid installation and the home battery are still the same, that is, 1.56 €/day.
3. The time required to pay off the battery is not relevant, as it is provided by the third party company. However, more flexibility can be offered to the end user here, as they already have an installation (PV, wind turbine, etc.) that, while not related to the facilities provided by the third party company, provides the prosumers with benefits.
4. Consequently, having the home battery paying off by itself is a matter to be solved for the third party company. It will be done so by at least using Equation (12), since the revenues provided from the battery cannot be the only source used for profitability.
5. For example, if the only objective of the company was paying off the investment it does on the home battery and its installation it can be said that 3130.14 € = $Pch{\cdot}t$. For a period of 10 years,

annual charges to the platform must be 313.01 €, or a monthly tariff of 26.08 €. On the other hand, if a third of the daily profits made with the home battery where to be included, then the third party company would have gained 1898 € by the end of the 10-year period from the battery itself, so it would have just to make 3130.14 − 1898 = 1232.14 € from the platform access charging to have the home battery fully repaid, which would be 10.27 € every month during 10 years. This estimation, as well as the other ones, is likely to improve in the future, as battery prices have a decreasing tendency, so shorter periods of time can be enabled if required.

3.5. Business Model 3: Online Access-Demand

This business model proposal relies heavily on the ideas that have been previously presented with a major difference: rather than having the contract signed during a specific amount of time, the end user will sign an agreement where it will be possible for them to use the platform where the trading algorithm is still located (in the same seamless, transparent way that was used previously). Therefore, this business model is quite similar to the one where online access is provided during a certain period of time.

3.5.1. Online Access-Demand without the Smart Grid

In this way, the end user/client will be charged a certain percentage of the earnings obtained from trading activities, although this percentage will be smaller since the platform is used less frequently than the case that was shown before when there was an agreement to do so during a fixed period of time. As shown in Equation (13), the profits obtained by both the end user and the third party company are dependent solely on the profit obtained from selling the energy at a higher price than the one that was effective when it was acquired. It has to be noted that in all this business models put forward, the overall profits obtained from the end user and the third party provider come from trading with electricity from a simple procedure (that is performed in a complicated manner, though, since trading algorithms can be quite complex depending on how they are used). This is the concept that has been expressed in Equation (14).

$$Upt + Bspt = Spt - Bpt \tag{14}$$

Under this business model proposal, the steps carried out to ensure profitability both for the end user and the third party are as follows:

1. The appliances used to store energy (home battery) and monitor the patterns used to consume it (Home Load Controller) are connected to the power grid as it was done before. Their usage of electricity is the same as in the other cases.
2. Profitability for the end user and the company is guaranteed in a quite similar way too: actions performed by the Trade Algorithm used in order to buy, store, or sell electricity will guarantee an economical benefit in those operations. The Trading Algorithm is still located in the third party platform and used in a remote manner.
3. However, the equipment installed in the client´s facilities (that is to say, the Home Load Controller) may access the platform at will to make use of the algorithm, in a way that will be defined according to the agreement signed in the contract that links both the end user/client and the third party company. While the same formulae shown in the previous business model proposal can be applied here, they will differ in the Business profit based on the Platform charge or *Pch*, as it will be lower to reflect the fact that the platform is accessed during a less significant amount of time and therefore is available for longer periods of time for other users.
4. Charges done on the hardware equipment that is purchased by the end user (if required) will be different in this business model as well: they will be higher to make up for the lesser access to the platform made by the end user, although they will not be at the level of the offline business model, as the Trading Algorithm is still located out of the hardware that is brought to the dwell of the end user/client.

When all is said and done, this business model proposal can be implemented in the same way that the former one, albeit the difference in the access frequency (established as something sporadic rather than as a continuous) will change the parameter values. In a way, this and the previous business model represent the differences between a telephone contract based on a fixed monthly payment, and another one using a prepaid card, with charging being done on the ground of the specific phone calls made by the end user. When actual figures and numbers are taken into account, similar results than the ones that have been presented before can be included here. However, there will be a major difference, which is that the third party may chose different criteria to charge the end user when they access to the platform, rather than having a formal contract. There are several options to carry out this: (a) end users can be charged according to the period of time between a log in and a log out from the platform; (b) it can be calculated how many Kilowatt-hours have been traded and deduct a commission from them; and (c) a percentage of the earnings obtained from the trading can be redirected to the third party company. As it happened before, the home battery will not be provided or installed with the budget of the end user, so it will have to be considered when the third party engages in businesses with end users.

3.5.2. Online Access-Demand within the Smart Grid

There are few changes that take place in this business model when the Smart Grid becomes enabled when compared to the previous one. The Smart Grid-related facilities are still providing the required energy that can be consumed, stored or traded, so as long as the remote platform can be accessed, the businesses will be performed in the same fashion. However, pricing policies will have some minor changes derived from the fact that, rather than guaranteeing unrestricted access to the remote trading platform for a limited amount of time, charges will be done on different grounds that will be more related to punctual usages of the remote facilities. In addition, the charging price for the usage of the remote platform will have to be balanced with the profits that are obtained from the installed battery in an almost certain manner, as the lower Pch value charged in this business model is advantageous for the prosumer but disadvantageous for the third party company.

3.6. Business Model 4: Enhanced Cooperation

This business model offers some major differences when compared to the others in the sense that rather than having a purely local focus in individual end users/clients, it will manage the stored (or lack of) electricity as an asset that can be used to perform trade operations among a myriad of end users located in a cluster of clients known to the company. Thus, the third company will behave assuming the role of an aggregator from the point of view of the Smart Grid where it is operating and an actual Distributed System Operator from the end user´s one. As it can be inferred, this model has no non-Smart Grid scenario because it demands the cooperation among Distributed Energy Resources. Operations that will be carried out by the Trading Algorithm will be overall the same, but they will use different inputs than in previous cases, such as:

1. Energy stored by the different end users of a cluster. Trading operations will be done not only taking into account the cost of electricity in the market, but also the energy availability of each of the end users, in case they have energy available that can be transferred from a user that has no energy and needs it, from another one that has unused energy.
2. User profiles stored by the third party company will be accessed to look for the end users or users that are potentially the best match in terms of electricity usage (for example, if a user stores energy from 7:00 a.m. to 7:00 p.m., and there is another one consuming energy from 7:00 a.m. to 7:00 p.m., they will be born in mind to provide energy supply to each other).

The steps that will be carried out to trade electricity in this case are described below; note that in all these steps the presence of prosumers may increase the effective of this model, since there will be more energy available to interchange among clients:

1. The appliances that were installed locally in previous businesses models will be installed here too. However, the information regarding different users in a certain area will be gathered as a cluster at a higher level that will be oblivious to them, but not to the power grid. This level is where data aggregation will be made by the third party company, and will provide the necessary user profiles that will be taken into account for energy trade among several members of the cluster where all of them have been integrated.
2. Electricity is bought, stored and sold in the same way that it was done before, as there is still a Trading Algorithm that is stored remotely in the domains of the third party company. There is a major difference in this step, though, which deals with how the operations are done by the algorithm, due to the fact that it will take into account not only the cost of electricity in the market, but also the electricity offer and demand situation in the cluster of users that has been built before.
3. Under this model, Platform charge (Pch) will be the lowest one that the end user will be required to pay, since earnings will be obtained from allowing the third party company to access the energy storage equipment installed in the dwells of the end users.
4. Most of the earnings obtained by the third party company will come from their operation as if they were a DSO providing electricity for end users, albeit the way utilized to obtain the commodity greatly differs from the one use by a conventional DSO. Hence, the third party company will be regarded as a "virtual DSO" for the end users. As it has been represented in Figure 5, the third party company will play the role of an aggregator, so it will trade with the energy provided by the end users in the first place. Ideally, the net balance of the energy that is to be traded among the users will be zero, as the most desirable situation is that a whole cluster of users will not need any other power injection from any other entity, but if it is required, energy offered by the DSOs will be acquired in a punctual manner.

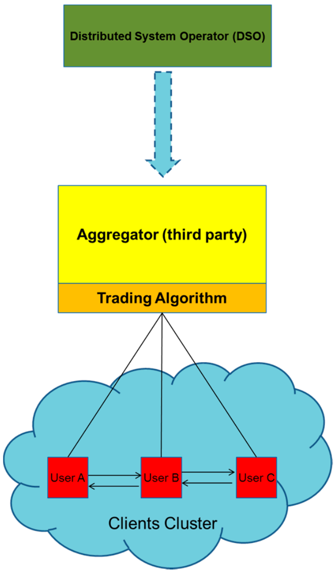


Figure 5. Third party company and relations with DSO and clients.

In this last way to operate with electricity, it must be taken into account that, if a lower amount of energy is demanded in the electricity market, DSOs may actually lower its cost, as electricity would become a good less demanded than what was expected. Nevertheless, the variation of electricity cost to a lower level can be foreseen by the Trading Algorithm to tune up its performance according to the behavior that has been experimented in the past. Last but not least, under a scenario where there are many different facilities cooperating with each other, it is very convenient to make use of a middleware solution, so as all the problems related to interoperability and interconnectivity of the devices playing a role in a microgrid where this business model is implemented. An example on how middleware can be used has been included in the next section. From the purely economic analysis point of view, the example that was used in the previous business model proposals can be applied here, with the difference that it will become multiplied due to the presence of several prosumers cooperating with each other. While the Smart Grid-related infrastructure will be left aside when considering the profits that can be provided to the third party company and the prosumers—and the budget regarding home batteries purchasing and installation will be multiplied as well—the profitability that was proven before will escalate in this case when several prosumers are connected to each other.

4. Study of Related Use Cases

When small scale applications and facilities are taken into account, there are several use cases that can be provided as examples of conceived solutions that have added the features typically enabled to produce profitability for end users in microgrids or the Smart Grid. Middleware is usually a very convenient addition to be included, as it will guarantee that interconnectivity can be carried out among the different facilities that have been embedded within the microgrids. As for topics such as business models and advantages that can be provided by home batteries for end users and prosumers alike, there are several use cases where they are used than are noteworthy, in the sense that they are combining energy reservoir with other technologies (most frequently, Renewable Energy Sources) to save costs and positively impact the users of this kind of systems.

4.1. Simulated Scenarios

Fitzgerald et al. put forward four different simulated use cases that have been presented in [37]. Since large and complex facilities (building blocks, town halls, etc.) can also use energy storage as long as the required infrastructure to charge and discharge the battery is present, these use cases puts forward infrastructures such as a large hotel in San Francisco, distribution upgrades in New York, residential bill management in Phoenix and solar self-consumption in San Francisco. According to the authors, the follwingcfeatures can be considered:

1. In the use case involving a large San Francisco hotel, if a threshold of 500 kW is fixed as the power consumed every day, should a perfect load forecast knowledge be assumed, a system sized 140 kW and 560 kWh would be able to supply the hotel with the energy needed not to surpass the threshold that was chosen before. This will be done so by charging the energy reservoir mostly during off-peak daily hours (8:00 and 9:00 a.m. and 4:00–7:00 p.m.) and discharging it during on-peak hours (10:00 a.m., 8:00–11:00 p.m.). By following this procedure, a demand charge reduction can be guaranteed and, over a period of 20 years, revenues of around $100,000 will be obtained, even when the cost of substituting the batteries is also taken into account.
2. As for the distribution upgrade deferral of New York, it is based on a proposal that was made so as to avoid the taxpayers the installation of two substation upgrades in Brooklyn and Queens that were expected to cost $1,000 million. According to the authors of the report, demand response and energy efficiency programs could be used as a tool that would reduce load growth by a 50%. Furthermore, an energy storage fleet would also be provided to reinforce the aforementioned policies. In this particular case, the cost of the solution was reckoned to be higher than the revenues that it would provide in 20 years (more than $250 million of costs compared to $200 million revenues) due to the fact that batteries do not provide direct services to the end users. However, no value has been given to backup power under this model, so a less strict model is likely to produce more favorable results.
3. Residential bill management in Arizona takes advantage of rooftop photovoltaic systems combined with energy storage. The model matches the typical pattern where solar power production reaches its maximum levels around noon, is lower before and after them, and is nonexistent at night. It is shown how energy consumption flattens whenever there is energy storage enabled, as it effectively shaves off demand peaks and makes possible a more constant energy usage during the night. Under this model, it is estimated that customer bills can be

reduced up to a 20% every year. One of the conclusions of this use case is that prosumers with "peaky" consumption patterns (namely, those who consume electricity in a more irregular manner with load peaks rather than in a more regular way) are the ones that can benefit the most from energy storage solutions.

4. Solar self-consumption in San Francisco uses the same ideas that were presented in the residential bill management case: due to customer loads and solar radiation, batteries will be charged in the period between 8:00 and 11:00 a.m. and discharged from 6:00 to 11:00 p.m. The policy followed according to this model is that the excess power produced by the PV installation will firstly be used to charge the battery and once this process is completed the generated electricity will be exported to the grid. As was described in the previous business models, by following this pattern, it will be possible to use the stored energy to supply electricity to the loads used during the evening (peak hours), thus preventing the customer from purchasing electricity from the grid.

As it can be inferred, these simulated use cases are close to the ideas that were presented in the first business model of this manuscript, as energy reservoir devices are used to guarantee savings during a long period of time.

4.2. Large Energy Storage Facilities

Aside from small-scale facilities, there are large developments that should be mentioned due to the fact that, despite being of very different nature to the ones that are shown in this manuscript, show how similar solutions are being tried for different application domains. An example of these is the facility that became operational by the end of 2014 in the UK as a joint effort between S&C Electric Europe, Samsung SDI and Younicos [38]. This is a $29.1 million project that basically consists of a 6 MW/10 MWh lithium-ion battery being utilized as a way to decrease capacity constraints and energy balance between Distributed Energy Sources. Even though one of the main targets of the project is saving costs in regular power grid reinforcement (cabling, transformers), alternative revenues for energy storage is cited as another objective as well. A similar initiative is being carried out by E.ON and RWTH Aachen University [39]. Here, a 5 MW battery storage system is being built so as to assess the possibilities of increasing modularity in electricity networks, along with using different sorts of batteries into one single system.

These projects have in common that, despite their large dimensions, they are still looking for the same goal that is mentioned in the presented business models: energy storage and trading as a way to obtain a profit, either as net revenues or cost reductions.

4.3. NETfficient Research Project

Intense research activities are being carried out in the area of energy storage for small scale facilities. Among the projects that deal with the open issues and challenges on these matters, NETfficient can be mentioned as one of them [40]. According to the web site of the project, "*An innovative approach will use locally available renewable energy sources on the island, store it and distribute it when needed responding the energy demand of domestic households*". One of the key objectives of the project is being able to use Renewable Energy Sources even though when they are not available at a precise moment; therefore, having some kind of energy reservoir becomes of critical importance. There are five different use cases planned to be carried out in the project: (a) peak shaving to reduce maximum load consumption; (b) homes scenario where dwells will be supplied with a combination of PV, smart metering and storage solutions; (c) buildings that will apply the same solutions that are proved for houses; (d) public lighting that will make use of energy storage and photovoltaic generation; and (e) heating integration for an aquarium. Among them, the most interesting from the point of view of the scope of this manuscript are (b), (c) and (d), due to the fact that they are using power storage solutions to provide electricity to diverse dwells and infrastructures. They will effectively measure how costs can be saved (and benefits obtained) with Smart Grid and energy storage solutions installed in the context of actual pilots held in the German island of Borkum.

4.4. Steinkjer Living Lab Pilot

This use case differs from the other ones in the sense that instead of being focused on energy trading it relies on middleware to provide a greater variety of services that is unseen in the previous use cases. It has been proved that depending on the capabilities of the middleware, new services could be offered in a distributed manner, from applications related to semantic requests to different levels of context awareness [41]. This is something that has been taken into account in the presented successful use case that was developed in Steinkjer, and is offered as an example of additional contributions that can be done by means of the usage of the Smart Grid, rather than being part of one specific business model, that will still result in a benefit for the end user/prosumer.

Steinkjer Use Case Description

Steinkjer is a town of Central Norway that has constituted itself as a living lab regarding the usage of facilities and appliances related to the Smart Grid [29]. This town was used as the location to deploy most of the hardware and software works done during the I3RES project [42]. In this case, the principles applied to the appliances for small scale applications were put into practice taking into account that most of the home dwellers had smart meters integrated in their locations. Therefore, the energy that was being consumed by them was being monitored, as it would be done with a Home Load Controller (HLC), which can be regarded as a device used to monitor how energy is being consumed in a small size facility that will be given a certain amount of control among the appliances that are used in the facility, since it will be able to disconnect or turn down any appliance that is consuming electricity in case they are using more than the one that was planned for a certain period of time. Therefore, energy usage can be balanced during certain periods of time, providing its use in a sustainable, distributed manner and saving the cost that would be incurred if too much energy was consumed, or in the worst case scenario, a power cut happened during peak hours. Figure 6 shows the overall deployment that has been done in Steinkjer, typical devices and appliances that can be expected from a microgrid (Phasor Measurement Units, communication infrastructures and databases, etc.) where deployed. From the perspective of the manuscript, the most important devices to be deployed were the Home Load Controllers, as they play a major role in the optimization of energy usage in this prototype.

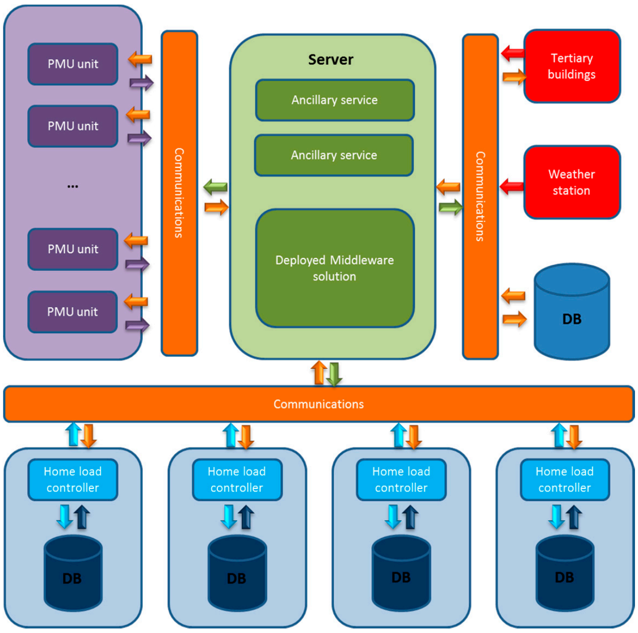


Figure 6. Deployment of hardware and software entities in Steinkjer demo lab.

As has been previously shown, middleware was deployed as a distributed software component in the Steinkjer pilot that was defined for I3RES. Performance tests were done on the middleware solution to get an accurate view of how long service request procedures were taking while handling concurrent client application queries. In this way, the viability of using the implemented middleware in a non-controlled environment, such as the one when it was going to be provided, could be assessed in an objective manner. The result of the tests made has been displayed in Figure 7. It is shown that one thousand concurrent queries were made to the tested middleware solution; the most prominent features that can be seen in the figure are as follows:

1. **Average value:** The average time to attend a query done through the middleware was 1602 ms, a satisfactory result for end clients. Interestingly, this value does not increase significantly when more requests are sent to the system, showing a remarkable degree of robustness.
2. **Median value:** Rather than its own value (1582 ms, still satisfactory), the small difference between average and median values is significant. This proves that queries were dealt with in a rather stable manner, without significant delays or punctual underperformance moments that would distort the average value away from the median one.
3. **Deviation value:** It reflects the stability hinted by the narrow difference between the average and median values. The dispersion level in the tests done shows that figures obtained for each of the queries vary in a small proportion, as deviation represents less than one quarter of the average and median values (364 ms).
4. **Throughput value:** this value shows the number of concurrent client requests that could be answered in a specific amount of time, resulting in nearly 150 queries answered every minute (148.543 queries/min), a result that can again be regarded as satisfactory for end clients.

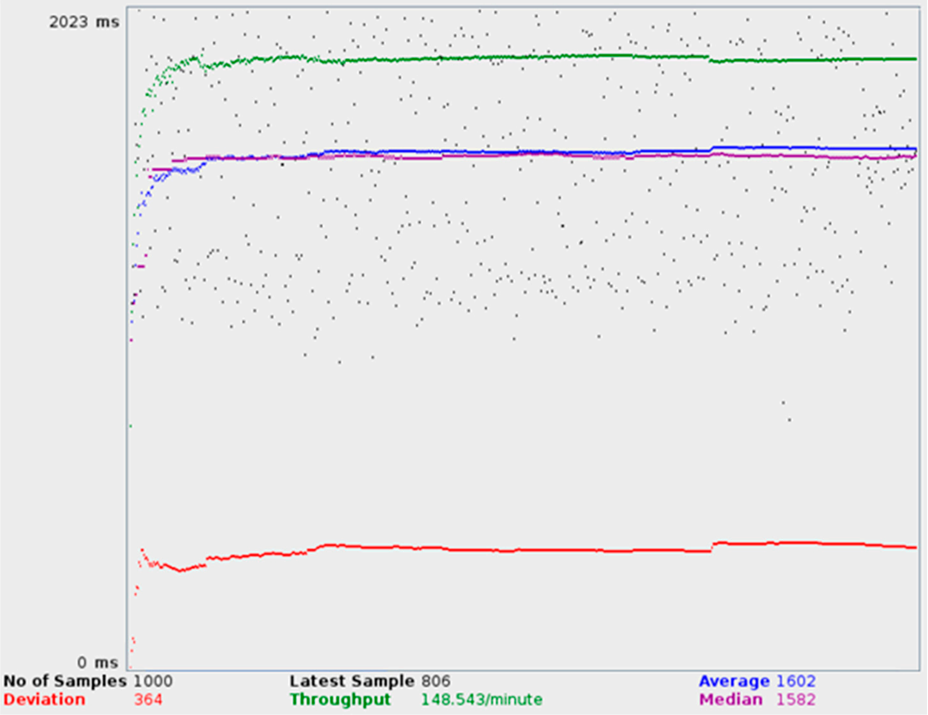


Figure 7. Middleware performance in the Steinkjer pilot. Note the deviation (red), average (blue) and median (purple) lines reflecting the value of the parameters.

This results show that, if applied as an extension of the services that can be provided by the electricity facilities deployed in a microgrid (where prosumers are participating with their home-sized infrastructure), middleware can also provide a prominent role in either enhancing the services used to obtain a profit (for example, deploying in it a security component that will provide security to encrypt and decrypt the information that is transferred regarding electricity trading) or even new services can be offered as part of the software components deployed in it.

5. Conclusions

This manuscript has shown several different options regarding the possibilities that business models for the Smart Grid can offer for end users that will usually have small scale installations to use as an energy resource and/or reservoir. The applicability of these solutions is feasible, so the usability of the Smart Grid as a way to obtain revenues for small-scale facilities that will work in a cooperative, distributed way is proven, as has been shown with the previous examples that have been enabled in different scenarios and projects.

When the new business models for end users and prosumers are fully applied to the power grid, there will be a major shift between the current status of the energy producers and the energy consumers. Not only will prosumers become the prominent actor at the microgrid end, but there will also be some businesses that will benefit of the usage of the hardware and software technologies used at this part of the grid. It can be foreseen that home battery manufacturers, distributed systems-related companies and aggregator companies will increase their importance in the electricity market as service and energy providers. As has been shown in the fourth kind of business model, electricity will often be provided in a transparent manner to the users that require it by means of the energy stored by other users, so the need for a Distributed System Operator will greatly diminish; in a scenario where the net balance between all the electricity loads and producers is zero or positive, there will be no actual need for a DSO to provide electricity outside the aggregator, even though it is not foreseen as a permanent situation for a cluster of users. The kind of business model that is put forward in this manuscript resembles in a great extent the one that has been used for Internet provisioning for quite a time, where the internet providers play a role (providing the Internet as a commodity) that is shared by the power producing companies (such as the DSOs) and the hardware that is used for data transmission resembles the grid infrastructure used by the TSO for electricity transmission. An even more obvious equivalence, where all the hardware devices used and the cooperative entities are shown in each of the facilities according to their roles has been depicted in Figure 8.

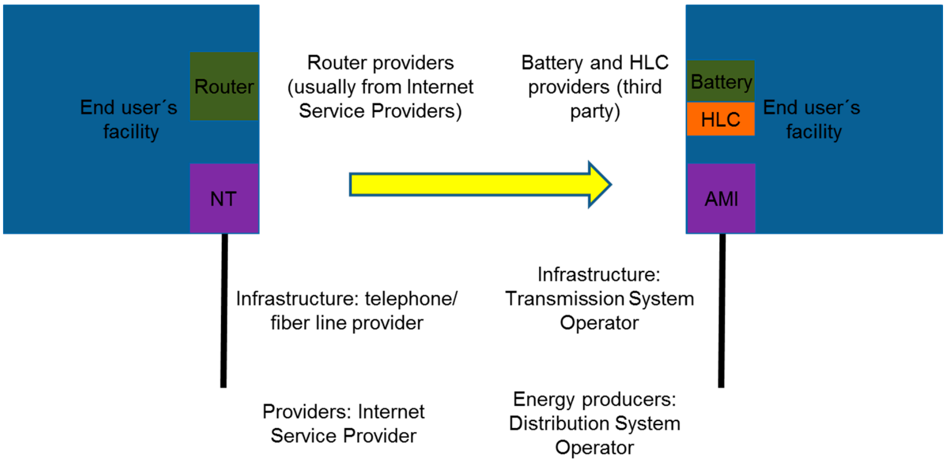


Figure 8. Comparison between the Internet and small scale appliance business roles.

In a similar manner, there will be other kind of activities that will require readapting themselves for the new paradigm used for their business, as the roles that use to play will become diminished due to the competence of distributed, renewable energies participating in the overall power grid. Those will be related to: (a) centralized production of electricity, since there will be other agents that will already be producing it from their Renewable Energy Sources; and (b) fossil fuels, as there will be new, alternative energy sources that will inject power to the grid. Furthermore, companies that transmit electricity like Transmission System Operators (TSOs) will also have to update their technology, as they will require to deliver it to consumers that may or may not require the intervention of an aggregator or a DSO, and in any case, clients are likely to pour some of their own electricity production onto the power grid (thus requiring a bidirectional way for energy transfer). This recalibration of the prominent agents participating of the Smart Grid, from the end user, small producer point of view, has been included in Table 4:

Table 4. Role shift for small scale, end user business models in the Smart Grid.

Agents Present in the Power Grid	Agents that will Benefit from End User Business Models	Agents that Must Readapt to End User Business Models	Reasoning for the Shift in Their Procedures
Energy reservoir manufacturers	Yes	No	A way to store the asset to sell it at the most suitable moment is required. Cost is expected to fall as time goes by
Advanced Metering Infrastructure manufacturers	Yes	No	Electricity consumption must be measured accurately to better trade with it
Aggregator	Yes	No	Its appearance will make possible the usage of electricity in a way that users will balance with each other to an extent. Potential demand for a DSO will be reduced
Distributed System Operators	No	Yes	Demand of electricity will be partially covered by the Aggregator and Distributed Energy Resources
Transmission System Operators	No	Yes	Electricity will be transferred in two ways rather than one. End user level produced electricity will greatly vary from one moment to another

The work that has been done here will overall boost the possibilities of what has been referred to as the third party, which might be a spin-off, a startup or another, longer established kind of company that will provide the services that have been mentioned here, that is to say: electricity trading, tariff reduction, interconnectivity among users, etc. In this way, end users will benefit from a resource that will be turned into an asset to trade with. In the case of prosumers, the benefits of the business models that have been put forward here are even more obvious, since they are capable of providing electricity either for their own consumption or for others, thus enhancing their trading capabilities if they become interconnected as members of the same cluster of clients that is managed by an aggregator (the role that would be assumed by the third party company).

There are several different future works that will be carried out in this scenario. One of the major features to take into account will be legislation. While the main interest of this manuscript is showing that it is feasible, from a technical and economic point of view, enabling business models for small scale facilities, main issues might come from legislation rather than other areas of knowledge. What is more, law has severe differences depending on the place where it is enforced—to the point that what might be possible in one country might be illegal in another one. Homogenization of legislation is a huge task that must be tackled by countries and stakeholders in order to improve business opportunities. From a more technological perspective, one of the most promising future works is including the Electric Vehicle (EV) as the entity providing the energy reservoir where electricity will be stored as chemical energy to be reverted back to electric energy when trade is done with it. From the storage point of view, EV batteries can perform the same functionality that home batteries do, provided that the batteries can be accessed with no issues, or at least the way they are accessed in the previously shown business models (again, this procedure should be transparent for the end user, who must remain oblivious to the different technologies used to guarantee this use case). Taking into account the mobility that these batteries provide when compared to home reservoirs, there are several models that are already applied for mobility (for example, renting the batteries for a fixed price every month to make up for the comparatively fast deterioration of them) that can be applied to an extent to the usage of electricity. Last but not least, a thorough study on how middleware can be used to obtain services in small scale applications could be performed as well. According to the works done in the e-GOTHAM project [43], middleware services can be used to obtain information from a facility [28] that will make possible the monitoring and action triggering in case any anomaly is detected during the production of goods. These are activities that will be carried out by the GRyS research group [44] in its headquarters at CITSEM [45].

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Author Contributions: The authors have contributed in the manuscript taking into account their experience and areas of interest. Pedro Castillejo has contributed mostly in the first and third sections, providing most of the introduction and a significant part of the business models definitions. Jesús Rodríguez-Molina has worked mainly in the business models (Section 3), and the state of the art. Lastly, José Fernán Martínez Ortega has made prominent additions in Section 4 gathering and ordering information about the Steinkjer laboratory city, as well as analyzing conclusions and future works that can be done using the one shown here as a starting ground. The authors are part of the GRyS research group, which belongs to the research software center CITSEM.

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