Energy Resources Management in Residential Buildings: Business models

Aleksandra Wawrzyniak

Relatorio de Projecto Erasmus 10 ECTS

Mestrado em Energias Sustentaveis

Instituto Superior de Engenharia do Porto

Departamento de Engenharia Mecanica

Julho de 2019

Relatorio da Unidade Curricular de Projecto ERASMUS 10

Masterado em Energias Sustentaveis

Candidato: Aleksadra Wawrzyniak, Nº 1150113 1150113@isep.ipp.pt

Supervisores:

Sergio Filipe Carvalho Ramos

Joao Andre Pinto Soares

Mestrado em Energias Sustentaveis

Departamento de Engenharia Mecanica

Julho de 2018

Acknowledgment

Special thanks to my coordinators during the making of this project. Also, thanks to the friends that came along the way during this Erasmus semester that made this trip an adventure. This work was made in the context of Benefice Project with references PTDe/EEI-EEE/29070/2017.

Abstract

This work presents a business model for a multi-family house with on site generation. In this case business model describes the rationale of how the project delivers electricity and how does it optimize the consumption to fit the generation profile and specifies money flow in the buildings.

Solar energy technologies offer a clean and renewable energy source and are essential components of a sustainable energy future. The role of solar electricity production is increasing because the pressure to be environmentally friendly and have independence from fossil fuels import.

In every building-integrated PV system, the PV module is the basic element of the generator. In this project it is not specified the exact photovoltaics system just a general approach of metering the consumption.

A basic characteristic of sunshine is that it is variable on both daily and seasonable basis. This causes electricity production of photovoltaic modules to vary correspondingly. The mismatch between the electrical load and the electricity production must be balanced by using some kind of energy storage device. In grid-connected PV buildings an energy storage device is usually not needed, but in off grid houses the storage element plays an important role. The main characteristics of energy storage systems for PV building applications are cost, cycle life, availability, ease of operation and maintenance. The importance of volumetric and gravimetric energy densities will vary depending on the application. There are several energy storage possibilities from which only a few are suitable for PV-building applications.

Electricity metering systems measure energy consumption, monitor its quality and communicate this information from meter to concentrator or cloud so that utilities can better manage the use of energy by means of load management. Real-time reporting of energy measurement improves consumer awareness leading to waste reduction thus lower expenses. The data obtained through the use of smart meters enables utilities and energy distributors to optimize power distribution losses across the grid. The result is lower cost, higher reliability, reduced tampering and carbon emissions.

In the project there are presented two approaches, where the first one is shearing the installed photovoltaics panels and the other consider building energy management company that manages the on-site generated energy as well as the energy consumed from the grid.

Keywords: Residential Buildings, Renewable energy resources, Photovoltaic Generation

Declaration

Aleksandra Wawrzyniak with commitment of honor, that this project is original, and all the not original contributions were rightfully referenced, with an identified source.

17th of July 2018

Table of Contents

Figure index

Table index

1. Introduction

This work presents a business model for a multi-family house with on site generation. In this case business model describes the rationale of how the project delivers electricity and how does it optimize the consumption to fit the generation profile and specifies money flow in the buildings.

Solar energy technologies offer a clean and renewable energy source and are essential components of a sustainable energy future. The role of solar electricity production is increasing because the pressure to be environmentally friendly and have independence from fossil fuels import.

In every building-integrated PV system, the PV module is the basic element of the generator. In this project it is not specified the exact photovoltaics system just a general approach of metering the consumption.

A basic characteristic of solar irradiance is that it is variable on both daily and seasonable basis. This causes electricity production of photovoltaic modules to vary correspondingly. The mismatch between the electrical load and the electricity production must be balanced by using some kind of energy storage device. In grid-connected PV buildings an energy storage device is usually not needed because of possibility of selling energy to the gird, but in off grid houses the storage element plays an important role because there is no possibility of selling energy to the grid and if not stored it has to go to waste. The main characteristics of energy storage systems for PV building applications are cost, cycle life, availability, ease of operation and maintenance. The importance of volumetric and gravimetric energy densities will vary depending on the application. There are several energy storage possibilities from which only a few are suitable for PV-building applications.

Electricity metering systems measure energy consumption, monitor its quality and communicate this information from meter to concentrator or cloud so that utilities can better manage the use of energy by means of load management. Real-time reporting of energy measurement improves consumer awareness leading to waste reduction thus lower expenses. The data obtained through the use of smart meters enables utilities and energy distributors to optimize power distribution losses across

the grid. The result is lower cost, higher reliability, reduced tampering and carbon emissions.

Two approaches are presented in the project, one shearing the installed photovoltaics panels and the other consider building energy management company that manages the on-site generated energy and the energy consumed from the grid.

1.1 Objectives

An objective of this work is presenting the business model for a multi-family house with on-site generation. In this case business model describes the rationale of how the project delivers electricity, how does it optimize the consumption to fit the generation profile and specifies money flow in the buildings. The business model specifies the system elements influence on each other and possible options of the money and energy flow in the considered system.

1.2 Motivation

Motivation of the topic choice in case of this project was a challenge related to its realization due to dealing with theoretical approaches which are not yet applied as a real life solution. Other challenge was preparing the business model as it is something I have never done before. This topic as it is was a different type of project than ones done before, but it is something that knowledge of preparing brings certain benefit for future works.

The topic is also really interesting also because it is innovational and concerns really important nowadays issues, while removable resources are becoming more and more popular it is important to research the new solutions of its implementation, which is one of the points of this project. I find it highly rewarding for the university researches to in the way contribute to helping increase the possibilities of use of the renewable resources in our power systems.

Other motivation for pursuing this topic is that nowadays making the solutions for an application of renewable energy sources, because increasing its share in energy

mix is really important to solve environmental issues and for that it is important to prepare solutions both technical and business models so potential owners have options for creation the systems in their lots.

1.3 Organization of the thesis

After this chapter of Introduction comes Chapter 2 a part of the work concerning Portuguese law in this field of work which are presented to give context for the business model. In next unit (Chapter 3) one can find the state of the art which presents current developments in the field. Next stage (Chapter 4) presents the proposed Business Model for two different approaches, and finally, Chapter 5 contains the final remarks and conclusions.

2. Portuguese law

There are many Portuguese legislations that are necessary to analyze creating the business model for this project.

In this section, legislation and regulatory framework related to feeding and distribution of electricity in private low voltage fed buildings intended for collective use, allotment, urbanization and sets of private buildings are analyzed.

Current legislations in Portugal state that, each final consumer, owner of a fraction of a collective building, allotment, urbanization or set of private buildings, carries out contract of supply of low voltage electric power with an electric energy trader. Thus, for a collective building, allotment, urbanization or set of private buildings, there is a contract of supply of electricity for each of the fractions adding, as a rule, at least one more contract for the common services.

Analyzing the load diagrams of the installations, it is possible to verify that the power actually necessary to ensure the proper functioning of the various installations of use is less than the sum of the respective individual contracted powers.

There are many legislations that consider the matter of electrical installations in allotment, urbanizations and sets of private buildings:

- Decreto-Lei n.º 555/99, 16 December - which defined the municipal Councils and allowed the construction of buildings within private properties whose road and other infrastructures, including electrical ones, were considered private property.

- DGEG, 13 May 2005, “Guia Técnico de Instalações elétricas estabelecidas em condomínios fechados. Rede particular de distribuição de energia elétrica em baixa tensão e instalação de iluminação exterior” which established a set of general rules and principles to which must be obey in design, execution and entry into exploitation of electrical infrastructures established in gated communities

- Documento normativo DIT-C11-030/N , July 2005 “Condomínios fechados. Regras para a conceção, aprovação e ligação à rede de projetos de infraestruturas elétricas privadas Operacionalização do “Guia Técnico de instalações elétricas estabelecidas em condomínios fechados, DGEG 13 May 2005” which define connection conditions. a network for the distribution of low-voltage electrical energy,

including the extensions for supply of various collective use facilities, Installation for outdoor lighting, Other facilities not included in buildings, provided that property of the gated community.

- Decreto-Lei n.º 177/2001, 4 June with rights and obligations identical to those of horizontal ownership, the design, establishment and entry into operation of such networks shall comply with the following guiding principles and general rules stated by Decreto Regulamentar n.º 90/84, 26 December and Regras Técnicas de Instalações Elétricas de Baixa Tensão, publicadas pela Portaria n.º 949-A/2006, 11 September

Electrical Installations in collective housing buildings consist of installations intended to allow users of property for individual housing, with a collective part, the application of energy by its transformation into another form of energy.

There are also legislations and laws considering only electrical installations in collective housing buildings:

- Decreto-Lei n.º 740/74 of 26 December, which defined the new technical rules applicable to low-voltage electrical installations, expressed in the safety regulations of electrical energy facilities and the safety regulation of collective building facilities and entries with a view to the Protection of people and things and the safeguarding of collective interests. It was applied to the collective installations of buildings and entrances, fed from a public distribution network of low voltage electricity, a processing station or a generating plant, private.

- Decreto-Lei n.º 226/2005, 28 December, later ubdated to Declaração de Retificação n.º 11/2006, 23 February which provided the approval of the Technical Rules for Low Voltage Electrical Installations and revoked the Safety Regulations for the Use of Electric Power and Security of Buildings Facilities and Inputs. The technical rules for eight-part low voltage electrical installations define the installation and safety rules for electrical (use) electrical installations and indicate the rules for the design, execution and operation of electrical installations in order to ensure satisfactory operation and safety with regard to the intended use.

A collective installation is defined as an electrical installation, as a rule, in the interior of a building in order to serve electrical installations of use exploited by different entities.

A collective installation consists of a common section of the collective installation, consisting of an electrical conduit of the collective installation that begins at the door and ends at the switchboard. If there is no switchgear, the collective installation has its start in the switchboard.

In buildings fed from a public electricity distribution network, the supply of the respective switchboards can be done directly form transmission post, by switchgear or directly from a "distribution box".

The Electric Sector Tariff Regulation (RT), published by Regulamento n.º 619/2017, as amended by Regulamento n.º 76/2019 of January 18, that aims to establish the provisions applicable to the criteria and methods for the formulation of tariffs and prices of electric energy to be provided by the entities covered by it, also determination of allowed revenues and the procedures and obligations of entities in the electricity sector, in particular with regard to the provision of information.

In Artigo 41.º Estrutura geral das tarifas de Acesso às Redes aplicáveis às entregas em LV, regulation determines that the Network Access tariffs applicable to LV deliveries are composed of the following prices: Contracted power in Euro/month and Active energy in Euro/kWh

The following table shows the tariff options and respective contracted power levels for LV contracts.

Table. 1 Tarrifs structure in Poland

<table>
<tr><td colspan="2">Tariff options</td><td>Scale of contracted power (kVA)</td></tr>
<tr><td rowspan="3">LV ≤20,7kVA</td><td>Simple tarif</td><td rowspan="3">1,15 – 2,3 – 3,45 – 4,6 – 5,75 – 6,9 – 10,35 – 13,8 – 17,25 – 20,7</td></tr>
<tr><td>Tarif Bi-horária</td></tr>
<tr><td>Tarif Tri-horária</td></tr>
<tr><td colspan="2">LV>20,7kVA</td><td>27,6 – 34,5 – 41,4</td></tr>
</table>

According to the tariff regulation, the following electricity delivery times are considered: Rush hours, Full hours, normal empty and super empty.

In the LV tariff options, where there are three or two time periods, the prices of the active energy are broken down into four quarterly electric energy delivery periods.

For the Access to Networks in LV nothing is required, not as it is foreseen in the current tariff regulation.

There are other important legislations concerning self-production are necessary to consider preparing this business model.

Distributed production activities- small production and self-consumption, are governed by common provisions concerning their prior control and the rights and duties of promoters, and by specific rules that welcome the vicissitudes inherent in each One of the modalities.

The figure of small electric energy producer is consecrated in the Portuguese legal order since 1944, when Lei n. º 2002, of December 26, which promulgated the electrification of the country and states that the production facilities for private use cannot be authorized in the places where there is energy from public distributors with more daunting tariffs on the bases of previous bases except for specific cases defined in regulation. After that came many more regulations concerning this matter:

- In the decade of 70 of the XX century, motivated by the "oil shocks" that came to evidence the finite character not only of the most commonly used energy source. As well as the need to resort to all means to reduce dependence on imported oil, to take advantage of energy by-products and waste as much as possible, as well as to value renewable energy resources, it was justified to amend to current figure of the small producer of electricity. Due to that legislation numerous industrial and agricultural entities can produce electricity using waste or by-products, renewable natural resources, effluent energy or techniques that combine the Heat requirements for the production process with those of electric energy lead to a lower consumption of primary energy

- Decreto-Lei n.º 189/88 and other subsequent legislation, came to regulate the activity of independent production of energy through the use of fossil fuels, renewable resources or industrial, agricultural or urban waste. Allowing the opening of the market to new entrants, whose integration into the National Electrical System (SEN) under the Independent Electrical System (SEI), subsequently secured.

- Decreto-Lei n.º 312/2001 established the provisions applicable to the management of the electricity reception capacity in the networks of the public service electrical system (SEP), in order to allow the reception and delivery of electricity from new generation centers of the Independent electrical system (SEI).

- Resolution of the Council of Ministers N. º 154/2001 which came to give the body a wide range of energy policy objectives, aiming, Potentiate the use of renewable resources, increase energy efficiency and technologically modernize the national energy system

- Decreto-Lei n.º 2003/54/EC is laying down common rules for the internal electricity market in electricity. Classifying the production of electricity under ordinary arrangements and special regime. The special regime corresponds to the production of electricity with the use of endogenous and renewable resources or the combined production of heat and electricity.

- Decreto-Lei n.º 312/2001 established the provisions for management of the electricity reception capacity in the networks of the Public service electrical system (SEP), in order to allow the reception and delivery of electricity from new generating centers of the electrical system. It applies to all generation centers leading to excessive administrative centralisation of the micro-or small-dimension.

- Decreto-Lei n.º 363/2007 establishes the legal regime applicable to the production of electricity by means of microgeneration units. It assumes electricity produced is mainly for self-consumption, and the surplus is to be delivered to third parties or public network, with a limit of 150 kW of power in the event that the delivery is made to the public network. Decreto-Lei also simplifies the existing licensing regime, replacing it with a simple registration regime, subject to technical compliance inspection. It also creates two remuneration schemes: the general regime and the subsidized one. The first for the generality of the installations and the second only applicable to renewable energy sources, whose access is conditioned to the existence at the place of consumption of solar thermal collectors, in the case of individual producers, and the realization of audit measures, in the case of condominiums.

- Decreto-Lei n.º 80/2006 which establishes the mandatory installation of these systems in the new buildings.

- Council of Ministers 29/2010 resolution determine the drafting of the legal regime of access to of miniproduction activity and established the general guidelines for the new regime and the legal regime applicable to the production of electricity, from resources Renewable energy through Mini-production units.

- Decreto-Lei n.º 25/2013 establish the legal regime applicable to the production of electricity through micro-production units, and applicable legal regime To the production of electricity by mini-production units.

- Decreto-Lei n.º 25/2013 regulated the activity of production of electricity Low voltage intended predominantly for own consumption, without prejudice to the possibility of delivering surplus production to third parties or to the public network.

- Decreto-Lei n.º 153/2014 of 20 October, the previous schemes of Mini and Miro generation. The small production, keeping the general traits established by the diplomas identified above, is thus benefiting from a unique legal framework.

- Decreto-Lei n.º. 153/2014 establishes the legal regime applicable to the production of electricity, intended for consumption in the installation of use associated with its producing unit, with or without connection to the grid, based on technologies of renewable or non-renewable production.

The small production regime allows the producer to sell all of the electricity to the grid with tariff allocated on the basis of a bidding model, in which the competitors offer discounts to the reference tariff, eliminating the remuneration regime In the previous legal systems of miniproduction and micro-production. When not framed in the remuneration scheme applicable to small production, the production unit shall be subject to prior control and allocation of remuneration in accordance with the legal regime for the production of electricity on a special basis.

The electric energy produced in self-consumption is predominantly intended for consumption in the installation associated with the production unit, with the possibility of linking to the grid for sale, at market price, of electricity not self-consumed.

Finally, the measurement of electrical energy produced in units of production of self-consumption, with or without connection to the RESP, is expected to be fundamental for the purpose of monitoring compliance with the objectives assumed in relation to the use of sources Renewable energy primaries.

The Legislations for production intended for self-consumption are presented below:

Decreto-Lei n.º. 25/2013 establishes the legal regime applicable to the production of electricity by means of Small power plants, designated by microproduction units. It has significantly simplified the existing licensing regime, replacing it with a simple registration regime, subject to technical compliance inspection. Project delivery and analysis are replaced by the creation of a database of pre-existing type elements that the producer must respect, shortening a procedure lasting several months to a simple electronic register. It also creates the system of registration of Microproduction (SRM), which is an electronic platform of interaction with producers, in which the entire relationship with the administration, necessary to perform the activity of Micro producer, can be accomplished. It also provides for a simplified system of invoicing and business relationship, avoiding the issuance of invoices and VAT hits by individuals.

The micro producer receives or pays through a single transaction, for the net value of receipts for electricity produced and payments for electricity consumed. The diploma also creates two remuneration schemes: the general regime and the subsidized one. The first for the generality of the installations and the second only applicable to renewable energy sources, whose access is conditioned to the existence at the place of consumption of solar thermal collectors, in the case of individual producers, and the realization of audit and their measures in the case of condominiums. The incentive associated with the sale of electricity is thus used to promote the solar hot water, completing the Decreto-Lei n.º. 80/2006, of April 21, which establishes the mandatory installation of these systems in the new buildings.

Decreto-Lei n.º. 153/2014 regulates legal regime applicable to the production of electricity, intended for self-consumption in the installation of use associated with its production unit, with or without connection to the public electricity network, based on renewable or non-renewable manufacturing technologies. In this case the production of electricity for self-consumption is defined as a production activity intended to satisfy the producer's own electricity supply needs, without prejudice to the surplus of energy produced to be Injected into the utility grid (RESP).

It lays down the conditions of access and exercise of the activity, and for the systems whose installed power is equal to or less than 200 W are exempt from prior control. The systems whose installed power is greater than 200 W and equal to or less than 1.5 kW or whose electrical installation is not connected to the grid is subject to mere prior communication of exploitation. However, whenever it is intended to supply electricity not consumed in the electrical installation, it will be necessary to register and obtain a certificate of exploitation, as well as to observe the other standards applicable to producers.

The commercialization of the surplus of electricity produced, raises some problems, because the remuneration depends on an average tariff of production of the Iberian market, the energy provided and a correction factor; However, what the diploma calls "market tariff" does not refer to the domestic market (the value that the final consumer pays for energy), it relates to the value of the energy production market. To achieve the sale of the surplus to the network, the consumer also has to make a contract with an energy company; But the Decree-Law only establishes guidelines for these contracts; Therefore, the consumer must confirm whether it includes unfair terms, loyalty deadlines, mandatory electricity purchase quotas, and other unfavorable conditions.

3. State of the art

In this chapter, the state of the art will be presented. State of the gives ideas on what are the possibility for the business model.

In United States electric master meter was often installed in building built 20 or more years ago and this kind of buildings get electricity price included in the rent. In many states in case of buildings with master meter utility bills only the building owner commonly at a lower rate due to which the bill is lower than the usual retail, residential rate. [13]

Depending on the state there are many legislations concerning houses with a master meter and the way landlords can charge they tenants for the utilities in this case.

For instance, Arizona State Legislature Fifty-fourth legislature 33.1314.01 Utility charges; submetering; ratio utility billing; allocation; water system exemption states among others that:[12]

- Landlord may recover the charges imposed to him by the utility provider plus an administrative fee for actual administrative costs only.
- Landlord may also impose a submetering system or ratio utility billing system during the term of a rental agreement if the landlord provides notice

Landlords that include utilities often raise the rent to reflect the estimated value added for tenants. This is a very common method because it is usually viewed as the easiest and simplest method. However, this method can be inaccurate in regard to cost recovery, and it usually does not account for varying amounts of electric use between tenants.

With increase of electricity consumption and connected with it increase of electricity bill it started to raise question if it’s fair to equally divide electricity bill by the tenants and many owners are wanting to meter power to each apartment separately, because when no submetering appears to be issue of tenants complaining about prices not corresponding to their consumption and submetering resolves that problem, and there are several options to do so.

Table. 2 Method comparison

		Method comparison				
Benefits		**Rasing Rents**	**RUBS**	**Sub-metering**	**Indivifdual Utility meters**	**Grid+on-site generation**
Landlord Benefit	**No significant upront cost**	x	x			x
	Recoups 100% tenent utility cost		x	x	x	x
	Promotes energy conservation			x	x	x
	Generats net operating income					x
	Tax incentives available					x
Tenent Benefit	**Discounted tenant net energy cost**					x
	Billed on actual energy use			x	x	x
	Per unit consumptions billing		x	x	x	x

Table.2 presents comparison of different methods and shows their benefits for both the landlords and the tenants.

One of the most popular solutions is submetering. Submetering is another submeter that receives electricity from the master meter, and it permits building owners to measure the electricity usage in individual units by a sub-meter that is owned by the building and not the utility department. Landlords will sometimes simply add the tenant's usage cost to the rent or, more likely, have property management monitor, process, and bill the tenant for their usage. The property management firm or billing service can sometimes charge a small fee to the tenant for this service. [11]

Another option is RUBS (Ratio Utility Billing System). This method uses a formula comprised of the property's utility bill for the total cost of the utility, and then calculated based on a formula that includes a set of logical factors such as the number of occupants, square footage of the unit, and other factors to accurately estimate utility usage for each of the property's residences. This solution allows owners and property managers to separate utility costs from rent and keep rental rates competitive while effectively recovering utility costs.

RUBS is the next most popular method of recovering utility costs for properties without submetering. It is commonly used for situations where the constraints of space or construction do not allow a property to be sub-metered or the cost of sub-metering doesn't pencil out. RUBS require no initial capital investment, is considered to be fair by most people, and is legal in most states. RUBS formulas are based on simple

industry statistics and, therefore, most complaints regarding this method boil down to the fact that tenant invoices are not based off actual individual usage.

There are many databases available for RUBS calculations. In general, there are six basic RUBS formulas used throughout the industry. In one of the options the calculations are based on master meter bill, and there is common area deduction percentage often regulated by state and billing fee is added. For calculations number of Total billing days is multiply by number of occupants what gives the number of occupied days. Then number of occupied days of each apartment is divided by total number of occupied days what gives the percentage of the entire bill that the owner of the apartment will be charged.

Master metered buildings that are good candidates for on-site power generation (usually solar PV) have the option of implementing solution, which is a revenue generating strategy leveraging two unique components. With a special software and hardware solution can deliver a sub-metering solution. These components mesh together to allow a property owner to bill tenants based on real individual consumption in order to recover the buildings overall “pre-solar” electrical cost, while the solar PV reduces the owners obligation to the power company. This creates a margin for the property owner that can be taken home as increased net operating income while also passing some savings to the tenants.

In United States Net Energy Metering (NEM), or Net Metering, which is a billing system that credits utility customers for any excess electricity they generate on-site (by PV panels or other methods) and provide back to the electric company via the electric grid. The current NEM program was adopted by the Commission in Decision (D.)16-01-044 on January 28, 2016.

Benefits of NEM:

- Allows for excess electricity to be “banked” for use at a later time such as: At night, Winter months, Rainy or snowy days;
- Customers are generally credited full retail electric price for Net Metered energy;
- Eliminates the need for costly & high maintenance battery storage systems;
- Provides a level of security knowing the power company will have inspected the solar system & approved interconnection to the electric grid.

NEM has various branches which have been put in place in many states to cater to not only residential but also multi-unit, commercial, and multifamily properties.

Net Energy Metering Aggregation (NEM-A) is a sub schedule billing system to NEM that allows a single utility customer with multiple meters on the same property, or on adjacent or contiguous properties, to use distributed generation to serve the aggregated load behind all meters and receive the benefits of NEM.

Benefits of NEM-A:

- Simplifies solar PV installations for multi-metered properties;
- Eliminates the added fixed costs of separate solar PV systems;
- Provides all the benefits of NEM to all eligible meters.

Other version of NEM, which could be the foundation of more solar adoption on larger multifamily buildings is Virtual Net Energy Metering (NEMV). NEMV allows a building with multiple meters that are individually metered to use a single distributed generation system to receive bill credits to offset each benefiting account bill.

The generation meter monitors the amount of total solar generation, while separate meters monitor each unit and common area's consumption. Units within the building and common areas are allocated a percentage of the solar-generated electricity as predetermined by the building owner or manager.

Benefits of NEM-V:

- Allows multifamily tenants with their own individual utility meters to directly benefit from a building's solar PV system (prior to NEMV this was not generally possible);
- Enables the building owner to allocate desired percentages of generated electricity to specific units;
- Provides all the benefits of NEM to allocated units.

Based on that it is possible to see that adding removable energy sources to the building can also influence billing of tenants.

Prosumers are consumers that have their own energy source and consequently they reduce their energy consumption from the grid. Portugal differentiate between 4

different types of prosumers, with different legal and regulatory requirements and conditions applied based on the capacity to generate energy. The different types are: Less than 200 W; between 200 W and 1.5 kW, between 1.5 kW and 1MW or more than 1MW.

Prosumers are remunerated for the electricity fed into the grid. Portugal defines self-consumption on the basis of the production of electricity aimed at satisfying the producer's needs, without prejudice to the energy surplus being injected into the electric power network. The new framework for small production units up to 250 kW, which entered into force in January 2015, replaced the FiT scheme for micro- and mini production and promoting self-consumption of renewable electricity. Prosumers in Portugal are remunerated monthly for the electricity fed into the grid on the basis of a contract with the distribution system operator according to the energy provided in kW/h per month. The price is set through a bidding system based on a benchmark tariff set by the government and the average of the prices at closure of the Iberian Energy Market for Portugal in that month in Euros. No feed-in-tariff system is applied. [6]

In case of the prosumers with the self-consumption important role have also demand response, which allows regulating the consumption to the production of the installed energy source. That being said there is many methods and available solutions for tracking the consumption of the tenants and decreasing consumption of the building and by that utility bill.

Building Energy Management System is an element of smart grid system that control, monitor and optimize energy for the building. BEMS systems are mainly applied in large premises such as industrial, high-rise office buildings, department stores, hotels, hospitals for better power management and in order to save money in the long run. Residential solutions are also available.

Some of the basic features provided:

- Control - Handling – Information;
- Alarm;
- Access (Input - Output);
- Heating, ventilation;
- Lighting, audio and video control;
- Hot water and electrical appliances automation;

- Energy consumption measurements for further improvement;
- Automatic notification in case of emergency.

Electrical installations of a building communicate with each other for the optimal and most cost effective management of resources with easy, flexible and simple handling. A BMS system smaller scale which applies to houses are known as the "smart home." By this term we refer to the control of the electrical installation and electrical appliances home environment, through the installation of various sensors.[10]

The installed system automatically adjusts to the environment of space, according to the predefined settings remotely, using mobile phone by SMS or internet.

Occupants' attitudes and preferences pose significant impact on the usage of energy resources and consequently, the optimization of building energy and comfort management is yet an open challenge for real time interface and computational support. Other aspect is Supply side Management (SSM) which is identified as optimizing the electrical supplies from various power sources. Other subject to be talk about in this work is possibility of reducing the electricity bill with electrical vehicles.

Electrical vehicles can be considered "decentralized mega-battery" that can store excess renewable energy for return to the grid during periods of high electricity demand and charge the vehicle batteries during periods of low demand when the electric grid is supplied by renewable energy.

The prosumer which has its own energy generation unit and parking lot with electrical vehicles can benefit from optimal disposal of these distributed resources.

Using battery storage system in Smart Grid have been researched for many years. The most challenging part in this case are side effects caused by electrochemical reactions in the battery like self-discharge, capacity fading and degeneration on time. But nowadays battery conditions can be estimated fairly accurately with help od Battery Management systems. Batteries are important component of systems with Distributed Energy Sources, but its also expensive solution and using electrical vehicles as temporary energy storage is a way to avoid the cost, but it causes different obstacles due to the fact that driving remains main vehicle's purpose, and it means that the presence of EV in the connection point will be

inconstant. Then, the battery is subject to gradual degradation from each use. This important problem was investigated [14] and it discovered that EV owners could not reach positive balance in hand in near future. However, they considered high battery cost of 825$ per kWh, with forecast for reducing to 475$ in the coming years. Nowadays, the General Motors had declared the price to be paid just 145$ per kWh for Li-Ion battery [15]

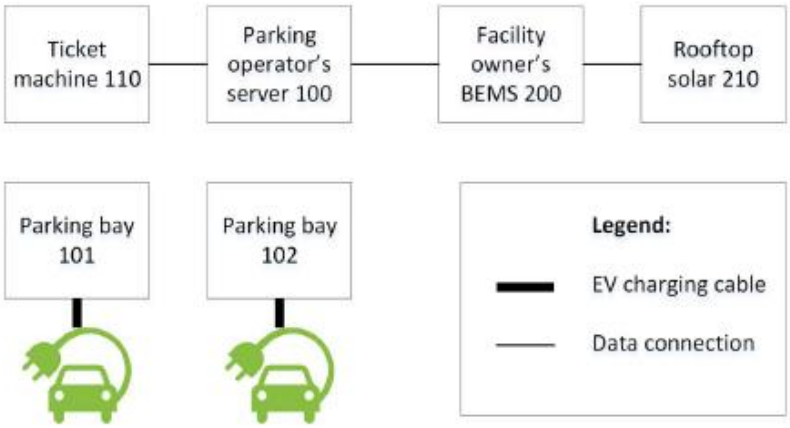

Figure 1. Structure of system [3]

Considering structure of the system presented above a new method based on specific contracts that the Prosumer can make with vehicle owners was implemented. In the recalled study Prosumer use the arriving EVs as energy storages, consuming energy from them when the power balance is negative; and store the surplus in their batteries when the generation dominates. [8]

The benefit offered by the Prosumer is charging the EV free of charge. The solar generation is limited so contracts are made only with enough EVs to get the required battery capacity to handle the surplus solar energy generation. The terms are being negotiated in contracts are the state of charge at departure time and financial reward for providing vehicle as energy storage. [2]

The presented mechanism resolves the common problem of such electric vehicles utilization: their heterogeneous presence at the parking lot. The large number of vehicles allow Prosumer to maximize the efficiency of its local energy generation, and the owners of electric vehicles get an opportunity for reducing their electricity bills.

US Department of energy-Electricity Delivery & Energy Reliability has posted the evaluation of Electric Vehicle Charging Impacts and Customer Charging Behaviors Experiences form Six Smart Grid Investment Grant Projects. In the summary it is possible to say that:

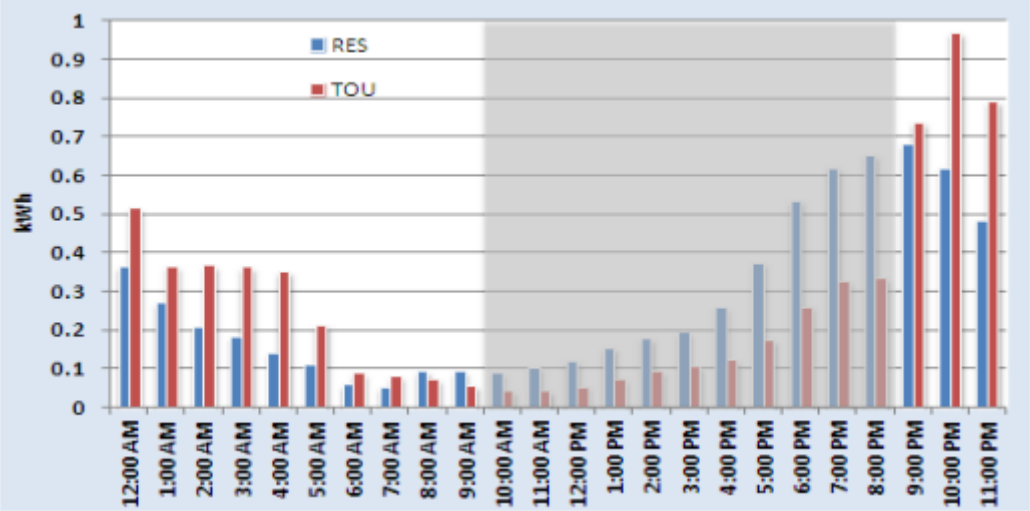

Figure 2.time-based rates to save on overnight residential charging [9]

As presented on figure above when offered customers took advantage of time-based rates to save on overnight residential charging. Participants generally prefer charging their cars overnight at home. Time-based rates encouraged off-peak charging and provided savings for overnight chargers. The rates were especially convenient when customers could pre-program charging sessions to start when off-peak rates came into effect.

It was also observed that average power demand to charge most vehicles was 3 to 6 kilowatts, which is roughly equivalent of powering a small residential air conditioning unit.

4. Business model

Business model is the strategy that is used to generate the revenue. The business model encompasses a wide range of factors, such as defining the characteristics of the system that is used and the way that it generates income.

Business model is prepared for a building presented on the Fig. 3. below. The building has multiple apartments and common space. This apartment building has also garage with electric vehicles, storage and generation from PV panels.

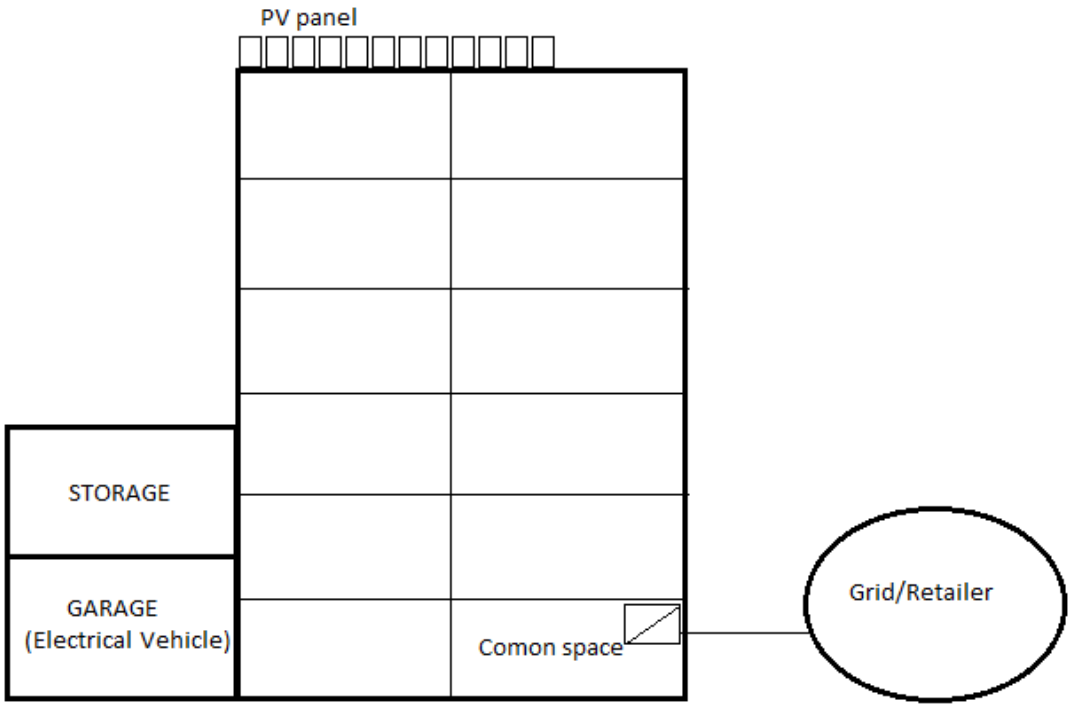

Figure 3. Building scheme

Two approaches to the business models are considered, in the first shearing PV panels is considered and in the second option is considering external company managing building energy resources. The building has also grid connection and buys electricity from the retailer.

4.1 Approach 1 – Schering photovoltaics panels

In this approach it is considered shearing of the photovoltaics panels what allows a better use of its generation than in case of each apartment owning one of the solar panels and using its energy generation only for owning apartment.

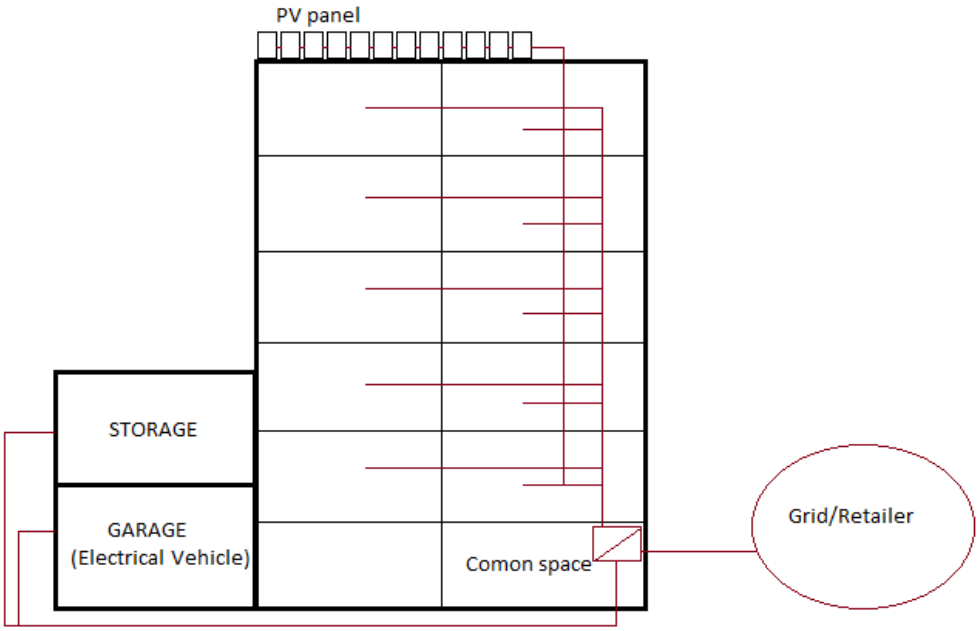

Figure 4. General scheme

Installation of shared PV system has advantage that the roof is shared resource. Distribution of PV generation throughout the building can be organized via an embedded network where owners corporation sells electricity to the residents through a child meter for each apartment as well as selling electricity generated on-site. Alternative arrangement for utilizing shared PV is behind the meter system which may help avoid the potentially high capital costs and increasingly difficult regulatory environment faced by embedded networks. In this case a secondary metering arrangement is used to distribute the on-site generation whilst residents continue to purchase their off-site generation directly from their energy retailer. [7]

In this approach the second option of sharing photovoltaics panels with the behind the meter system is going to be applied.

In this approach it is considered that each apartment has its own contract with the retailer.

Fig.5. presents the flow of energy in this approach. It presents the solution used for this approach. In this approach all of the photovoltaics panels are supplying all of the apartments. Apartments also have a two way meters which count both energy consumed from the on-site generation and also from the grid.

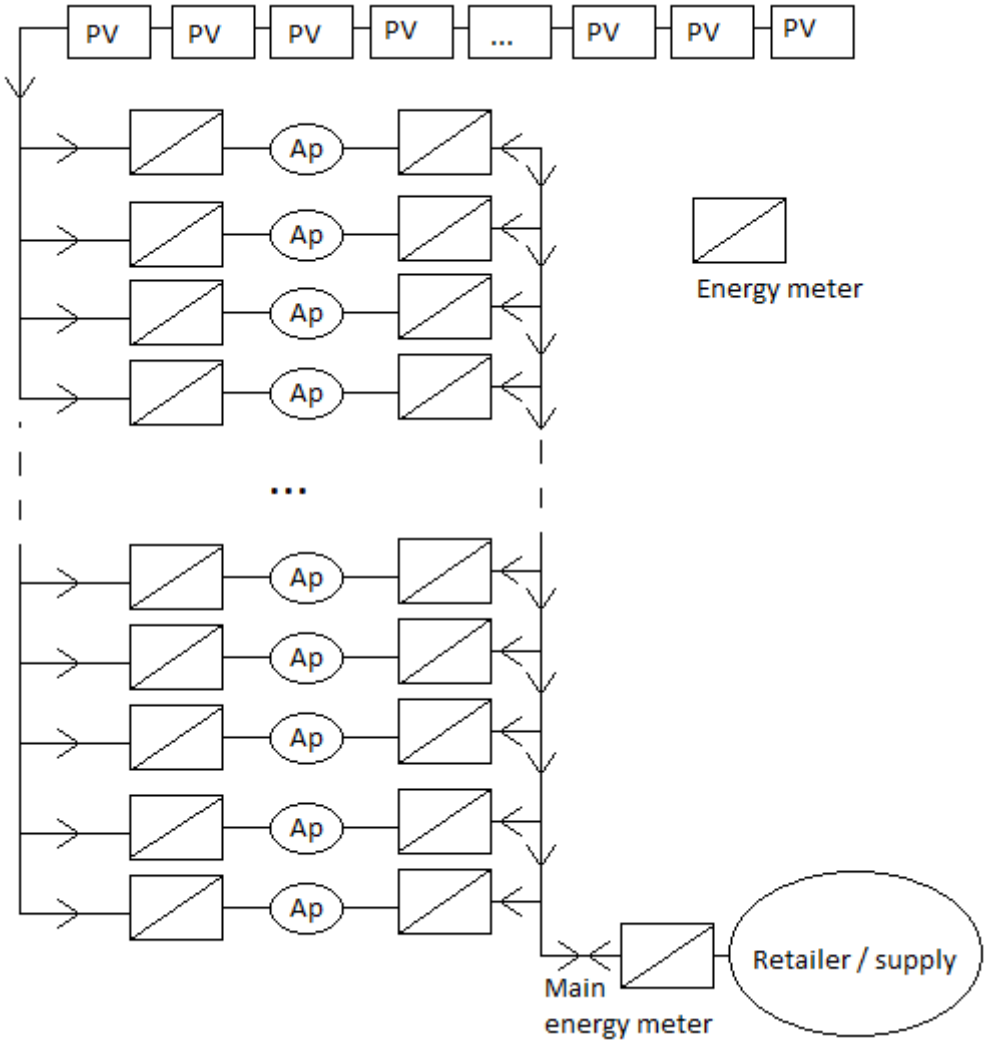

Figure 5. Energy Flow

Fig.6 . presents the flow of money in this approach. Total monthly bill to electricity supply company is paid separately by each apartment owner, which each have their own contract with the supplier.

The Supplier company do the accounting from the double sided meters and main meter and provides the apartments with the monthly bill. In this case submetering of the energy consumption of each apartment is performed and system similar to American RUBS is used to divide produced energy.

So, in the creating of the monthly bill for the apartment all off energy generated on site is first calculated and then divided in between all of the apartments, than apartments that used less of on-site generated energy than the energy that is calculated for their apartment get the monthly bill decreased by the amount that they “sold” to the grid. If the apartment used more on site generated energy than what was calculated for them, they have to pay for an excess energy like for a standard energy form the grid.

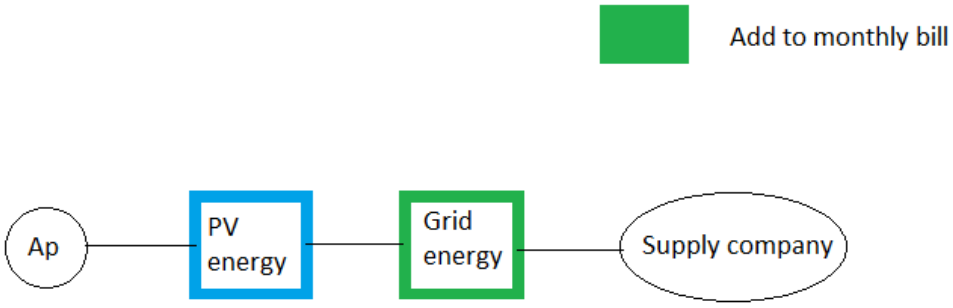

Figure 6. Money Flow

4.2 Approach 2- Building energy management system

In this approach Building management control supply, storage, generation and consumption of each of the apartment.

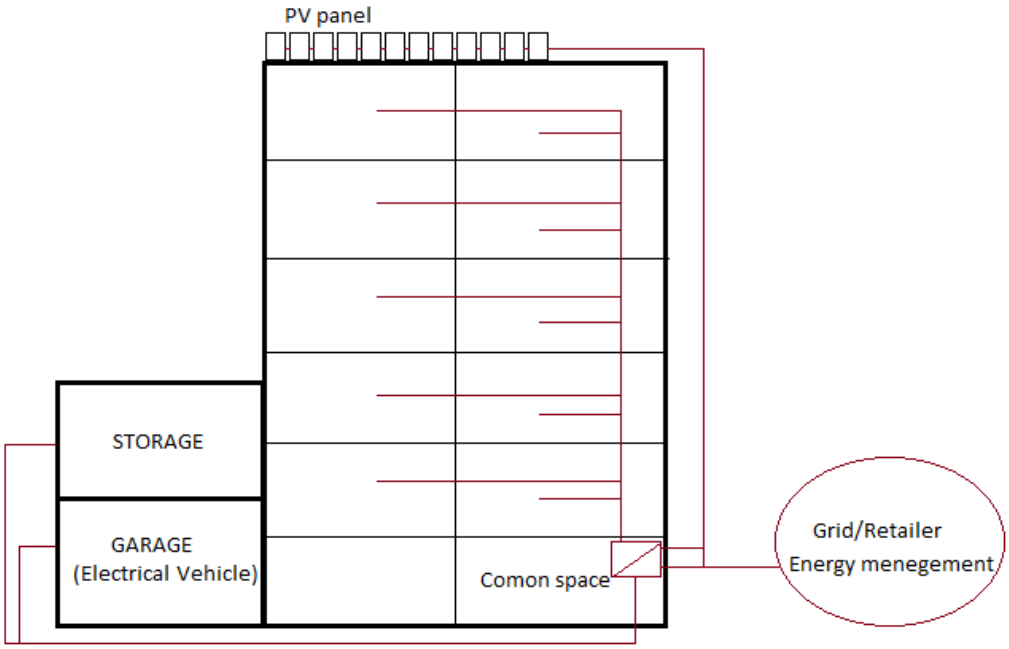

Figure 7. General scheme

For this business model it is considered that retailing company that supply energy to the building is also the company that manages the building energy resources or there is separate energy resources management company hired by the building.

In this case it is also considered that there is one electricity contract for the entire building and each apartment do not has specific contracted power, what allows more flexible electricity use by the tenants as long as the overall building contracted power is not exceeded.

The apartment building also has its own solar generation which supply the main switchboard what allows all the tenants to use that generation.

What is more the building having storage what allows collecting excess energy and a garage with electrical vehicles which can also be charged while having excess energy production.

In this approach it is also considered that some of the tenants provide the energy management company with demand response. Each of the tenants that take a part of the demand response agrees to decrease their electricity consumption while electricity generation is low what can decrease overall energy bill. The tenants that take part in the demand response get the discount on their monthly bill.

It can also be considered that owners of electrical vehicles that are charging them while the building has excess of energy can pay lower price for the charging than if they would charge their vehicle any other time.

Fig.8. presents the flow of energy in this approach. It presents the solution used for this approach. In this approach all of the photovoltaics panels are connected to the main switchboard and main mater, all of the apartments also have a one way meters, other elements are like storage and electrical vehicles connections are also connected to the main switchboard. Energy supplier also manages the energy system of the building.

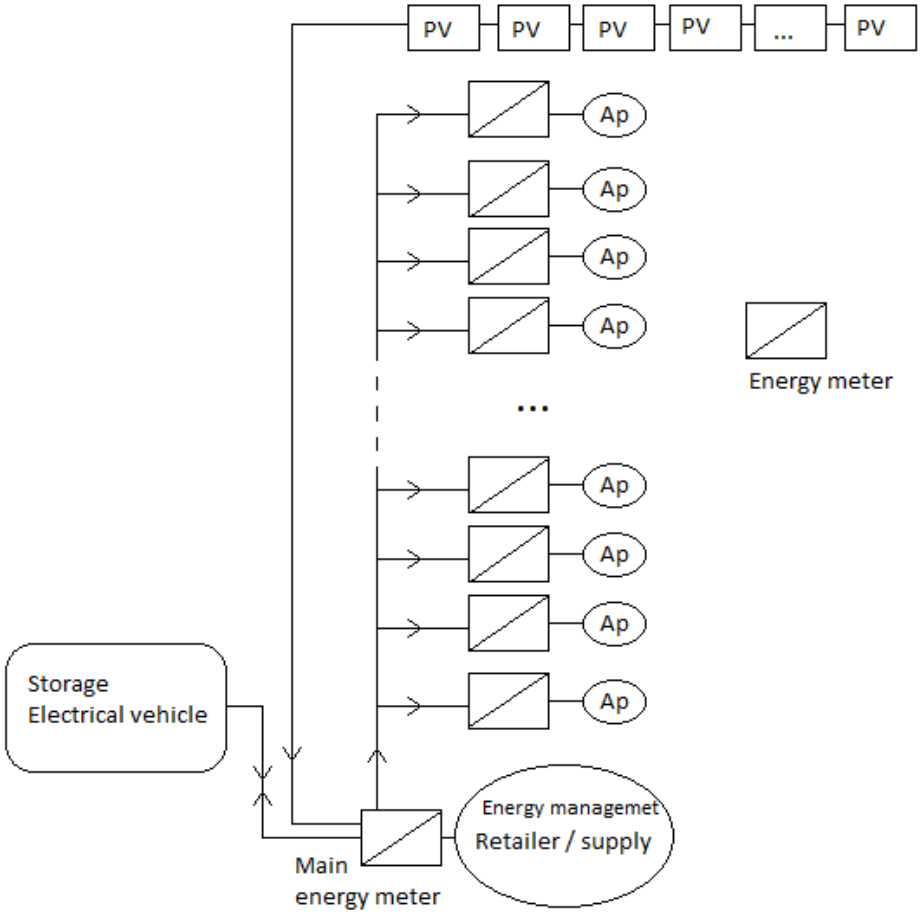

Figure 8. Energy Flow

On Fig.9. it is presented Money flow in this approach.

In this case submetering of the energy consumption of each apartment is performed and different solutions are used to obtain monthly bill of each tenant.

In this approach all it is also considered that the tenants are provided with mobile app which provides them with the real time information's about the electricity generation available, in case of owners of electrical vehicles about time whit energy excess allowing for cheaper charging of the vehicle, and options of providing the demand response.

Total monthly bill to electricity supply company is paid by the building energy management company. As it is presented the main part of the monthly bill payed by apartment owners to the building energy company is the energy that they consumed from the grid. The monthly bill can be decreased by providing the demand response. Charging the electrical vehicle in the hours of excess of the energy also can provide a

discount in the monthly bill. Amount of the energy generated by the on-site photovoltaics also can decrease overall bill and by that the bill of each apartment depending on the usage.

In the creating of the monthly bill for the apartment all off energy generated on site is first calculated and then divided in between all of the apartments, than apartments that used less of on-site generated energy than the energy that is calculated for their apartment get the monthly bill decreased by the amount that they “sold” to the grid. If the apartment used more on site generated energy than what was calculated for them, they have to pay for an excess energy like for a standard energy form the grid.

Another factor counting into the monthly bill is if the apartment has the Electrical vehicle. If the electrical vehicle is charges in the time of excess of on grid generated energy the price for charging it will be lower. Other important part of the bill is willingness of providing the demand response, and if they provide demand response, they get the discount on the monthly bill.

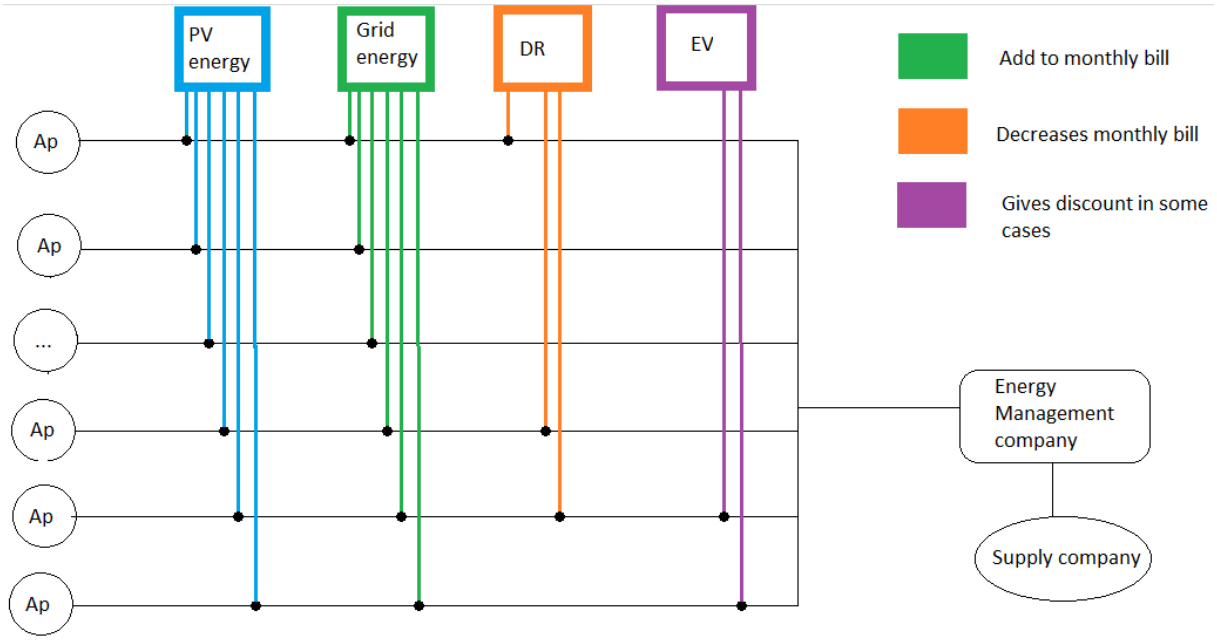

Figure 9. Money Flow

5. Conclusions

This work presented business model for a multi-family house with on-site generation. Efficiency, availability and popularity of solar panels keep growing, and ecological tendencies in our community are getting stronger than ever, it is important to find solutions of microgrids equipped with solar photovoltaics as a main source of electrical power.

In the project there was considered two different approaches one where the first one is shearing the installed photovoltaics panels and the other consider building energy management company that manages the on-site generated energy and as well as the energy consumed from the grid.

Many Portuguese legislations was analyzed while creating the business model for this project.

Current legislations in Portugal state that, each final consumer, owner of a fraction of a collective building, allotment, urbanization or set of private buildings, carries out contract of supply of low voltage electric power with an electric energy trader. Thus, for a collective building, allotment, urbanization or set of private buildings, there is a contract of supply of electricity for each of the fractions adding, as a rule, at least one more contract for the common services.

In buildings fed from a public electricity distribution network, the supply of the respective switchboards can be done directly form transmission post, by switchgear or directly from a "distribution box".

Distributed production activities- small production and self-consumption, are governed by common provisions concerning their prior control and the rights and duties of promoters, and by specific rules that welcome the vicissitudes inherent in each One of the modalities.

Measurement of electrical energy produced in units of production of self-consumption, with or without connection to the RESP, is expected to be fundamental for the purpose of monitoring compliance with the objectives assumed in relation to the use of sources Renewable energy primaries.

One of the most popular solutions for building with master meter is submetering. Submetering is another submeter that receives electricity from the master meter, and it permits building owners to measure the electricity usage in individual units.

Another option is Ratio Utility Billing System. This method uses a formula comprised of the property's utility bill for the total cost of the utility, and then calculated based on a formula that includes a set of logical factors such as the number of occupants, square footage of the unit, and other factors to accurately estimate utility usage for each of the property's residences.

In case of the prosumers with the self-consumption important role have also demand response, which allows regulating the consumption to the production of the installed energy source. That being said there is many methods and available solutions for tracking the consumption of the tenants and decreasing consumption of the building and by that utility bill.

As presented in the project customers tend to take advantage of time-based rates to save on overnight residential charging.

First case considered shearing of the photovoltaics panels with the behind the meter system and each apartment has its own contract with the retailer. The Supplier company do the accounting from the double sided meters and main meter and provides the apartments with the monthly bill and there is one electricity contract for the entire building and each apartment do not has specific contracted power, what allows more flexible electricity use by the tenants as long as the overall building contracted power is not exceeded

What is more the building having storage what allows collecting excess energy and a garage with electrical vehicles which can also be charged while having excess energy production.

In this approach it is also considered that some of the tenants provide the energy management company with demand response. Each of the tenants that take a part of the demand response agrees to decrease their electricity consumption while electricity generation is low what can decrease overall energy bill. The tenants that take part in the demand response get the discount on their monthly bill.

It can also be considered that owners of electrical vehicles that are charging them while the building has excess of energy can pay lower price for the charging than if they would charge their vehicle any other time.

Total monthly bill to electricity supply company is paid by the building energy management company. As it is presented the main part of the monthly bill payed by apartment owners to the building energy company is the energy that they consumed from the grid.

Second considered approach might be more extensive but it provides more optimized solution and allows more flexibility.

6. References

[1] Power Consumption Pattern in Residential Buildings: A Case Study; Shashidhar Kasthala , Rajitha Saka

[2] Towards Electric Vehicles Integration to Distributed Energy Resources of Prosumer; Evgeny Nefedov , Seppo Sierla , Valeriy Vyatkin

[3] Can electric vehicles reduce electricity bill?; Rodolfo Dufo-López, Jesús S. Artal-Sevil, José L. Bernal-Agustín, José A. Domínguez-Navarro

[4] Design and Implementation of Building Energy Management System with Quality of Experience Power Scheduling Model to Prevent the Blackout in Smart Grid Network; Delphine, Byeong Wook Jang, Yong Seop Shin, Seong Tae Kang, Jin Seek Choi

[5] A Low Cost Energy Usage Recording and Billing System for Electric Vehicle; Ishan Nagar, Rajesh M., Manitha P.V

[6]U.S. Commercial service Country: Portugal, Opporrtunities for Electrical Vehicles, Parts and System

[7] PV for Apartment Buildings:Which Side of the Meter? Mike B. Roberts

[8] Prosument − nowe możliwości dla odbiorcy energii; dr Anna Pamuła

[9] Evaluating Electric Vehicle Charging Impacts and Customer Charging Impacts and Customer Charging Behaviors- Experiences from Six Smart Grid Investment Grand Projects, U.S. Department od Energy, American Recovery and Reinvestment Act of 2009, December 2014

[10] Research on Demand Response Strategy of Electricity Market Based on Intelligent Power Consumption; HAN Jiarui, XIA Dong, XU Jing, LIU Chen, XU Ke , CUI Rongjing , CUI Chenlei

[11] http://www.gogrid.tech/single-post/2018/07/13/Methods-of-Electric-Billing-for-Master-Metered-Buildings Open: 10.05.2019

[12] https://www.cpuc.ca.gov/general.aspx?id=3800 Open: 10.05.2019

[13] https://www.utilityproducts.com/home/article/16003874/metering-options-for-multifamily-housing Open: 10.05.2019

[14]D.R. Shang, G. Sun," Electricity-price arbitrage with plug-in hybrid electric vehicle: Gain or loss?," in Energy Policy, vol. 95, 2016, pp. 402- 410.

[15] Hybrid Cars: Chevy Bolt Production Confirmed For 2016