Renewable energies contribution to a low carbon community

Baltazar Maria Gemperle de Medeiros Frazão Cordeiro

baltazar.cordeiro@ist.utl.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal

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Abstract

Society's evolution has been done hand by hand with energy sources and the quantity of energy that each one of those societies consumes. The energy sector has been one of the most important factor in what civilization development is concerned with the sector itself suffering changes through this evolution. Even though this sector is now optimized other questions are raised and a reflexion is asked in order to change the sectors paradigm.

The sector state made us highly dependent on fossil fuels which are now designated as limited and highly pollutant. For this reason, a revolution in needed, one that is capable to incorporate renewable energies more efficiently.

Residential zones are responsible for a major share of the energy consumption and these are also locals where the energy consumption is highly dense. The energy delivered in these areas is produced in enormous power plants being then delivered through the national grid.

The main goal of this work is the analysis of this areas in what energy production is concerned, trying to reach higher levels of energy efficiency with a higher and smarter usage of renewable sources. With Zero Carbon communities being a reality, this work will also investigate how these sources can contribute towards this reality. The Zero carbon stage is only reached after all the existent resistances get passed. These challenges are related to social, economic and legal reasons. The solution that will be presented in this work can only be considered a viable option if it represents a better option while being compared with the existent ones.

Keywords: energy sector; renewable energies; residential zones; zero carbon; communities

1 Introduction

The societies and their evolution is done hand to hand with the energy sector. It is possible to characterize a society level through an analyse of that society energy consumption. The actual context presents not only a general growth of the existent cities but also a growth in the number of cities. The growth of these types of communities, in number and size, is highly exigent to the energy sector. The residential sector is responsible for, approximately, 30% of the world energy consumption (496583 toe of a 1 800 000 toe total (IEA,2017)). The trend is, naturally, for this percentage to grow with the years.

This growth of energy consumption is highly concerning in an era where is known that the world is running spending resources at a higher pace than the natural processes, that creates those same resources, is done. With this in mind is at the most importance to promote an energy transition. This transition is done through the implementation of renewable energy sources. These implementations have a high cost and so the public sector must take the first step. This step must be taken not only to show confidence to other investors but also because unfortunately the world is getting to a no return point. The importance of the public sector in these field has also to do with the high costs of initial investment that have to be done in order to install these renewable technologies.

Dr. Fatih Birol (IEA Executive Director):

"Over 70% of global energy investments will be government-driven and as such the message is clear – the world's energy destiny lies with decisions and policies made by governments"

This thesis is done having in mind this concern, looking for new solutions that are able to incorporate renewable energy sources while trying to stop the consumption of fossil fuels. These solutions are limited for the constraints renewable sources have.

1.2 Objective

The main goal of this work is to understand how the renewable energies can help in the reduction of the carbon levels in communities. Through the generation of an energy community this study will try to compensate the constraints that characterize the renewable energies. The object of study of this thesis is Bairro Marechal Carmona. After studying this community it will be studied the possibility of implementation of a system capable to answer to the energetic needs presented. This problem will be evaluated from different points of view, from an individual perspective to a community one in order to understand how these communities can maximize the capabilities of renewable energy sources.

1.3 Methodology

Firstly an introduction to the energy market is done, in this introduction is presented the past of this industry as the present panorama. This introduction is important to understand how we got here and what are the main difficulties found to change this implemented system.

Then an introduction of the existent solutions is done in order to understand the potential of applicability for each one of these solutions.

The object of study is presented with all the characteristics that matter for the subject. A concept of home is created in order to represent the average residence in Portugal. This concept is created with data from the country in an attempt to represent the country in the better way possible. With this residence defined, and knowing the number of residences in Bairro Marechal Carmona, is then calculated the energy needs of this community.

A model is created in order to answer to these needs. Firstly is conceptualized a solution where each residence has its own system and then this system is studied with the perspective of the community. The data is analysed in order to understand if there is an advantage with the community approach and how can this community get a leverage from this approach.

After the demonstration of the results these same numbers are evaluated in order to understand if these solutions make sense. This is done through financial analysis, swot tables and sensitivity analysis.

With the analysis of the values done a conclusion is done. The conclusion covers all the sectors that one should take in account when projecting these solutions.

2. Evolution of the energy sector

Energy has been present since the beginning of times. At the beginning energy was considered simply a mean of subsistence. Energy was explored through the usage of wood and animal force (as calorific energy and work) as a necessity to develop everyday tasks. This concept was object of a major change during the industrial revolution. Many authors consider this revolution as the energy revolution. This revolution was done in major because of the development of new ways to produce energy. During this time energy started to be seen as a mean of proliferation instead of a mean of subsistence. During the year of 1840 and with the discover of coal the railways are developed and with these the society gains a new way of life.

In 1901 the potential of petroleum is found and after that the same happens to the natural gas. These are now the main sources of energy because they have high energy density, are easy to transport and are easily available.

2.1 Climatic challenge and the renewables opportunity

The context presented in the previous chapter is the reason why the energy sector is created as we know it.

When this system was conceptualized the main priorities were delivering energy where it was needed, in order to sustain the development of communities, at the lowest prices possible. The only technologies that made this possible were the fossil fuels. These technologies made it possible so that the evolution during these times was done at an incredible pace. Now, after some years, is possible to access the damages created by this system and is recognized that an energy transition, another energy revolution possibly, is mandatory.

This energy system is responsible for a number of damages that are almost beyond repair. During the exploitation of the resources habitats and soils suffer from contaminations, and during the usage of these same resources pollutants are released to the atmosphere. One could argue that the amount of carbon dioxide in the atmosphere has nothing to do with the massive consumption of fossil fuels butt science has already proved that this is not the case. That gases released during the combustion of fossil fuels is highly pollutant and the consequences of the release of those pollutants are already noticeable.

2.2 Renewable energies

Renewable energies are considered the solution to this climatic challenge. The integration of these technologies in the energy mix it is of the utmost importance.

Renewable energies are the ones generated by the natural flux of the nature. As examples of these energies one can consider the sun, wind and waters in motion.

Renewable energies are presented as having a major strong point in the fact that they don’t pollute as they are being produced. Renewable energies present the capacity of being independent form the grid and have a low cost per unit produced (the fuels used to produce these energies are free).

These energies got, as a main negative point, the fact that they, usually, require big initial investments .The technologies used to produce these energies are not aesthetically pleasant making it hard to implement them in urban areas. A crucial characteristic of these energies is the fact that they are highly dependent on atmospherically conditions, for example the solar energy is only available during day time.

2.2.1 Solar energy

Solar energy is all the energy received through the solar radiation. Solar energy is mainly used in three different ways, thermal energy, photovoltaic energy and in chemical processes. There is eight thousand times more energy available through solar energy than all the primary energy consumed.

Solar energy is available at a low cost, safely and as all the renewable energies it presents the possibility to go off-grid.

Solar energy is also limited in time of production and demands a high initial investment.

Solar thermal energy

This energy is produced through the reception of solar radiation using a panel.

In conventional solar panels a fluid is running inside tubes where suns radiation makes this fluid temperature to raise. This technology has a high potential of applicability in this project as it is a very mature technology. In Portugal legislation makes it compulsory for recent constructions to include these panels in their projects.

Photovoltaic energy

Photovoltaic energy is electricity produced through the incidence of solar radiation in photovoltaic panels.

Photovoltaic panels can realistically reach an efficiency of 20%. Inside the panels the radiation is converted in to electric current. This is possible because of chemical processes that occur inside the panel. The most used material for these panels is the silicium.

This technology has a high potential of applicability in this project.

Eolic energy

This energy is all the energy that is generated by the movement of air masses. The wind energy is normally captured by using structures that present some kind of resistance, this resistance, when enough, makes these structures to move and this energy is used to produce electric energy or work. Structures used to generate electric energy are called eolic generators.

This energy has in a small cost per unit and in safety the principal positive points. As negative points, as normal, there is the high initial costs and the dependence on atmospherical events.

The potential of applicability of this technology is dependent on the area available to implement the same.

2.3 Energy communities

The fact that cities are responsible for a major part of the energy consumption means that these are also responsible for the majority of the pollutants released to the atmosphere.

In residential zones should be studied the possibility to incorporate new, renewables and decentralized solutions to produce energy. These solutions can be incorporated in energy communities. These communities aim for neutral carbon levels and for energetic Independence.

Scotland was the first energy community, the country set goals for renewable energy production and accomplished those same goals before the period of time that was agreed. This country is no now trying to reach a new level of production while trying reach energetic Independence from fossil fuels. In Barcelona the community is active in energy production by intervening in energetic public projects. This intervention is done in a website where the population can vote in favour or against the construction of new solutions.

More examples of energy communities exist, as the case of Astypalaya (Greece), where the main characteristics of the Island were used to produce energy, or the case of Utrecht. In Utrecht the growth in number of people driving electrical cars has been taken advantage off as a mean to store energy produced by the renewable energy sources.

3 Bairro Marechal Carmona

This neighbourhood is situated in Cascais, Portugal. This neighbourhood was conceptualized during the 50´s and so is characterised by old and degraded constructions. There are two types of buildings that compose this neighbourhood, one floor residences (1946) and two floors buildings.

This neighbourhood is going to be rebuild and so the necessities, in terms of energy, have to be calculated for the future disposition of the neighbourhood. In the next table (table 1) are illustrated the characteristics of this new community:

Table 1 characteristics of the neighbourhood

Number of houses	460
People per house	3
Total population	1380
Mean area per house	107,3 m^2

In the next table is presented the characteristics of the concept house having in account the data given by a national survey (ICESD,2010).

Table 2 Average energy consumption of the portuguese household

Area (m^2)	107,3
Total annual energy consumption	31 Gj
Water heating	23%
Electricity	77%
Consumption per m^2	80,25 kWh

Energy needs

The calculation of the energy needs of this neighbourhood is done taking into account the values of the average Portuguese household.

Bairro Marechal Carmona will have 460 with a total construction area of 49358 square meters. The energy needs per square meter are of 18,45 kWh (waters) and 61,8 kWh(electricity). The total energy needs are **3,96107 GWh** per year.

4 Solutions

In this chapter the solutions are presented starting from individual to a community solution. The solution is divided in two parts, hot waters heating (HWH) and electricity production.

4.1 Hot waters heating

In order to calculate the energy needed to heat waters for the population of a house one must know the energy needed to heat 1 litre of water by 1 degree (specific heat capacity of water) and the quantity of water needed. Taking into account that each house has 3 people living inside and that each person spends, approximately, 22 litres per day, then each household has a water consumption of approximately 60 litres.

Specific heat capacity of water: 4179.6 Joules

Energy needed & energy available:

The calculation of the energy needed is done taking into account the average temperature for each month and a final temperature of 60 degrees C. Multiplication this variation of temperature for the water quantity and the specific heat one can get the total energy needed (these values are presented in table 4.1)

The energy available is calculated based on the average radiation per month and considering an efficiency of 70% from the collectors. Matching the energy needed and the available energy per area one can get the area of panels needed for the system (table 3)

Table 3 Water heating table

Month	Average temperature	Energy needed (kWh/house)	Energy available per square meter (kWh)	Area needed (m^2)
January	12	3,310243	2,065	1,603023
February	13	3,24128	2,604	1,244731
March	14	3,172316	3,122	1,016117
April	15	3,103353	3,934	0,788854
May	17	2,965426	4,522	0,655778
June	20	2,758536	4,739	0,582092
July	22	2,620609	5,131	0,51074
August	23	2,551646	4,956	0,51486
September	21	2,689573	3,941	0,682459
October	19	2,827499	3,066	0,922211
November	15	3,103353	2,394	1,296305
December	13	3,24128	2,086	1,553825

Taking into account this table the area needed per house is the value from January (1,602 m^2). The average household area available on top of each house is 53,6 square meters and so this solution is possible to implement on top of each house.

Financial analysis:

The financial analysis of this solution is very positive resulting in a positive NPV with an IRR of 8,42%. The investor is expected to save 4120 euros on a 20 year period after an investment of 2500 Euros.

This is considered the best solution for heating waters because of the portuguese legislation and also taking into consideration the house roofs utilization.

4.2 Electric energy production

4.2.1 individual solution

When evaluating an individual solution the only source available is the photovoltaic technology. This technology when evaluated individually is highly limited because of its times of production.

In this solution is impossible to consider any storage of the energy because this is an individual solution and storage energy systems for individual solutions make the energy cost to high. It is considered that all the energy produced matches the energy needs and that all the energy is pumped to the grid and sold to the distribution company.

Based on a Portuguese study (Manuel Collares Pereira in 2015) is considered that there is a potential of energy production of 270 kWh per square meter and a necessity of 61,8 kWh per square meter . In terms of an individual house this necessity can be satisfied with the installation of 15 250W PV panels with a total area of 24,6 square meters. This study is based on a Portuguese PV panels company called Open Renewables where the model OPEN 2XX-PM60 G2 is used (15% efficiency).

Financial analysis

The financial analysis for this project was considered negative since the total cash flows amount is smaller than the initial investment. For this solution the investor was expected to spend 4244 EUR while only expecting a profit of 177,4 EUR per year .

4.2.2 Optimal solution

In this solution is expected to promote the characteristics of a community approach. With more space it is now possible to consider eolic energy as an option and take an advantage on the different times of production of this source.

Figure 4.2.2.1 Consumption graph

First is calculated a consumption graphic (load curve) in order to understand the quantities and times at which energy is being spend (figure 4.2.2) . Then is calculated, for the place in question, the average hours when the considered sources produce energy.

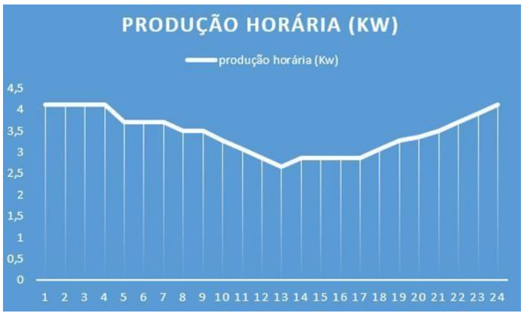

Figure 4.2.2.2 eolic production

Mixing these two sources it is possible to reach an optimal solution where the total daily production is 18,34 kWh. Pv cells are responsible for 11 kWh while the eolice generators are responsible for 7,41 kWh. This solution is possible with the installation of 9 pv panels per house and 30 eolic generators of 15 kW.

Figure 4.2.2.3 Pv production

This solution is reached while trying to generate the least amount of energy surplus per hour and to get least amount of hours in energy deficit. Still this is impossible to reach and so it is necessary to store energy. Two methods of energy storage are studied, energy storage in batteries and grid storage. The grid storage in this case is the storage of the excess of hourly energy in electric vehicles. This storage represents virtually no costs but unfortunately is impossible to store all the excess of energy with this method. During one day the neighbourhood will store 768,2 kWh in the grid , the equivalent of charging 13 cars. This is possible as it is demonstrated on recent studies. The conventional storage will require 1 battery per 4 houses. This represents a cost of 1375 EUR per house .

Financial analysis of the first approach:

This analysis is positive, each house is expected to invest 5242 EUR and in return each will get a positive NPV and an IRR of 9%. The investors are expecting to save 570 EUR per year.

4.3 Community approach

In this last approach the potential of the community approach is explored to the maximum possible.

It is determined that it is impossible to get more efficient on the solar thermal and PV sources since it is crucial to use the area available on top of each house.

For the eolic solution it is proposed a solution where the 15 kW generators are replaced by a 500 kW generator. This generator would represent a cost that is 77% lower than the initial one. The only problem with this solution is the acceptance of the population to the presence of an eolic generator with an height of 40 meters.

Financial analysis

Since this solution represents a lower initial investment and also a lower annual cost (O&M) then the IRR is higher than the previous (12%) and this could make the investors to get more comfortable to invest. The investors will save 578 EUR per year with an investment of 4362,7 EUR , this results in to an NPV of 3026 EUR (discount rate of 6%).

5 Results discussion

This project is put under stress by a sensitivity analysis. This is done taking into account the following variables:

- variation in 10% of the initial costs

-Variation in 25% of the annual costs

-1% decrease per year in pv modules production

-0,2% decrease in eolic production per year , during the first 6 years an 1,6% decrease during the remaining of the project.

This analysis was done without putting in cause the viability of the project. If all these happened then the IRR would only decrease to 9%.

6 Conclusion

This study concludes that the formation of energy communities can contribute to lower carbon communities by taking advantage of the potentialities of renewable energies. By taking the approach as community the financial analysis makes more sense but sometimes it will require some kind of adaption from the population. In the last case the financial analysis is more robust than the previous one even with more energy being produced , but in this solution there is the necessity for the population to accept the generator in their neighbourhood.

Solution	1st	2nd
Eolic	30 x 15 kW	1 x 500kW
PV	9x 250 W (per house)	9x250W (per house)
Battery	1 x 14 kWh/4 houses	1 x 14kWh / 4 houses
Initial investment(per house)	5242 EUR	4362,7 EUR
Annual cost (per house)	38 EUR	29,4 EUR

Table 6 Final data

It is more clear now that it is possible to create communities like this and generate energy in a clear way without losing money. It is necessary to update the grid and to make it more smart in order to increase the efficiency rate of energy usage. Grid storage could be the solution for most of these projects but for that to happen it is necessary to improve the national grid.

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