Assessment of the potential deployment of energy communities based on GIS approach

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Abstract

As the increased urbanization of the world progresses, allied with climate change and environmental degradation, the need for a paradigm change to decentralized energy systems, with increasing renewable energy supply arises. In this context, Energy Communities (EC) for collective self-consumption, leveraged on solar photovoltaic (PV) energy rise as crucial to meet energy transition goals.

This study assesses the potential deployment of energy communities, by developing a tool capable of, in a georeferenced way, estimate the solar production potential and the electricity demand needs, of a certain building or set of buildings, calculating key performance indicators to assess EC performance. The tool was tested in the city of Lisbon, for three case studies (city blocks), with different building's typologies and roof orientations. Regarding solar PV implementation, two approaches were taken: a first one where all the available effective roof area was used, and a second one using just enough effective roof area to obtain a Net Zero Energy Building (NZEB).

The results showcased that the first approach, producing the highest electricity surplus of up to 90%, comes at the expense of a substantial initial investment, which is not compensated by the low surplus grid injection prices. This approach is only economically viable for city blocks where buildings have smaller roof effective area compared to demand, where the surplus is smaller than 70% making up for more financially attractive ECs. The NZEB approach when applied reduces the higher surpluses to values of around 60% turning previously impracticable ECs into viable ones.

Keywords: Energy Community, Self-Consumption, Tool, Net Zero Energy Building

1. Introduction

According to the United Nations, by 2050 68% of the world population will be living in cities. As this urbanization continues, sustainable development is becoming increasingly reliant on successful urban growth management. Many countries will confront difficulties addressing the needs of their rapidly rising urban populations, including housing, transportation and energy systems [1]. This, allied with climate change and environmental degradation, has led countries to take measures, namely through the Paris Agreement, and in the case of the European Union (EU) to create the European Green Deal, a set of policy initiatives ensuring that by 2050 we will reach carbon emissions neutrality, decoupling economic growth from resource use, and that no one or place is left behind [2]. As part of the Green Deal, a set of intermediate steps towards its' accomplishment have also been released, namely the Fit for 55 package that states the intention of having reduced by at least 55% the greenhouse gas (GHG) emissions by 2030 [3].

For the EU to achieve the defined targets, citizens' participation is of crucial importance, being proposed the organization of citizens in energy communities, as a new business model for the acquisition and deployment of distributed renewable energy production (electricity). They foster a transformation of the energy purchase and sale market of the centralized producer, and retailer-customer relation, along with the expected evolution of renewable technologies such as solar photovoltaic panels, which turn consumers into prosumers. Further, new smart features, as new forms of data storage and exchange, to a decentralized environment in which the individual has the most control over where he buys electricity, who he sells it to, and how much he pays for it, are also emerging [4].

Several studies comparing the current system, which is typically centralized, with a decentralized system using distributed renewable energy sources effectively show that the latter not only provides economic benefits to all parties involved, but also improves transportation and electricity use efficiency, reducing emissions [5]. Two of those studies state that decentralized renewable and non-renewable energy production technologies can achieve reductions in carbon emissions of 65% [6] or 70% [7].

Taking everything into account, it is still unclear which configurations are most beneficial. As a result, being able to model various layouts of energy communities in order to determine which are the most energy and cost efficient based on the types of families and technology involved is of considerable importance. As a result, the objective of this work was to assess the potential deployment of energy communities, based on GIS available images or software.

This Thesis will then focus on enabling the assessment of the potential deployment of energy communities, based on GIS available images or software (such as Google Maps or Earth, QGIS, etc), and available open data regarding weather, building characteristics and electricity demand.

2. Methodology

In order to design a model that would allow to perform a preliminary assessment of possible energy community implementation, the following steps were addressed:

- Select the area for the Energy community implementation;
- Identify building characteristics such as, rooftop orientation, slope, area, number of households per building, etc;
- Estimate the PV electricity production potential for the available rooftop areas, given the solar availability;
- Estimate the buildings' typical electricity consumption profiles, according to families' typologies;
- Calculate key performance indicators of the EC.

2.1. Data Collection

To create a model able to determine the PV electricity production in any desirable location in the city of Lisbon, data regarding roof inclination and orientation for all the buildings was needed. The most viable way to do so was getting Lidar imagery for the entire city. With this need in mind, the Energy and Environment Agency of Lisbon, Lisboa E-Nova [8], who developed the SOLIS Platform, was contacted and they were able to provide three raster files (a matrix of pixels organized in a grid where each pixel contains a value representing information) with pixel wise information regarding all of the city's rooftops' on the following parameters: roof inclination,roof orientation, and annual incident solar radiation.

In order to analyze the information from the raster files, the images were first processed in QGIS software. Due to the high resolution of the raster files provided by Solis, the data size was too large to be efficiently used in the MATLAB model, so the first step on QGIS was to augment the size of each of pixel from the native $0.16m^2$ to $1m^2$. This allowed for a significant reduction in file size and enabled the manipulation of the files in way that otherwise would be too computationally intensive and impossible to do on a standard laptop. The next step was to convert the pixels into polygons (raster to vector) converting the Lidar images from a TIF (Tag Image File) into a SHP (shape-file) which is easier to manipulate and visualize on MATLAB. To do so, a function, by the name *raster pixels to polygon*, was used. This function converts a raster layer to a vector layer, by creating polygon features for each individual pixel's extent in the raster layer, employing the QGIS Processing Toolbox.

Having all the pixel wise necessary data already in the desired format, the problem that arose was how to associate each polygon to all the different buildings in Lisbon. The way this issue was dealt was by using free available online geographical database from Open Street Map (OSM), where a shape file containing polygons with the outline of every building in the city was retrieved. Additional features of interest contained in OSM's data were the number of floors of each building (not systematically available), and the relative coordinates of the polygons in the selected area, containing the longitude and latitude data for each vertex of the polygon outlining the shape of each building.

Having all the data regarding roof inclination and orientation organized and processed, the following step was the calculation of the hourly incident solar radiation in each section of the desired roofs. At this stage an existing Solar Radiation model for MATLAB [9], was adapted. The weather data (cloud coverage) utilized in the model was retrieved from *Renewables Ninja* [10].

As seen before, OSM also provides data regarding number of floors of each building. However, it is not systematically reported for every building. Thus, to calculate the amount of apartments per building, two different approaches were used. When OSM information is available, it is used, and if not, the average number of floors per building in that BGRI [11] statistical area is used.

In order to achieve the final goal of assessing Energy Community outputs, there is the need to know the electricity demand of the households in each building, detailing their, at least, hourly load profiles.

Regarding the load profiles, real data from Project OTGEN was used like in other works such as the one from Vilar et al, defining three consumption profiles [12] [13]:

- C1 - Working Couple, low consumption during the day, with an evening peak,only at home at night;
- C2 - Working Couple with two small children, similar to C1, but with peaks during off-peak period, half a day presence at home;
- C3 - Working Couple with three teenager children, larger consumer, with high demand during most of the day, a profile that already takes advantage of time-of-use tariffs.

After knowing the number of apartments per building the BGRI [11] database was once again accessed to obtain the typology of the families living the apartments on that area.

2.2. Tool Development

2.2.1 Buildings' GIS data processing

Firstly, the model takes as an input from the user two pairs off geographic coordinates. This coordinates can be obtained from a GIS software such as Google Earth and should draw a square over the desired location (neighbourhood) to be studied, then it imports to the MATLAB environment the respective data from both shapefiles.

Right after, it removes from the Lisboa E-Nova data all the polygons with an inclination of over 45º that correspond to building edges, skylights or other obstacles that are not part of the actual roof, since roof inclination of over 45º are considered as outliers [14]. The next step was the association of each $1m^2$ polygon to the respective building which was done by using the centroid of the polygons and checking to what building roof they belonged.

2.2.2 Clustering

Due to the nature of the data (Lidar) all the polygons had different values of inclination and orientation even in the same roof section therefore, there was a need to cluster the polygons of the same section. Taking into account that a typical roof does not have more than four different sections/slopes, a clustering algorithm was implemented to divide the roof into four different sections, each one with a specific inclination and orientation. Since the orientation data is circular in form (0º equals 360º), each polygon had a value of orientation between 0º and 360º (being 0º North and 180º South), a circular statistics toolbox for MATLAB was employed. Namely, a function that uses as input the orientation data and the desired amount of clusters, and outputs the data in four groups of polygons around the same orientation, corresponding to each roof slope. To cluster the inclination data, a K-means algorithm was applied on top of the orientation circular clustering, outputting for each roof four different sections with the same inclination and orientation [15].

2.2.3 Algorithm Solar Potential

The solar radiation model algorithm takes as inputs the latitude, inclination and orientation of each roof section, calculating, for every day of the year, the extraterrestrial solar radiation (I_0) and the sun's declination angle (δ), and, four every hour of the day, the hour angle (ω) and the solar altitude angle(α). As output it calculates the ground level solar irradiation for the inclination and orientation of the roof section(I_p), summing it to the diffuse (I_d) and reflected solar irradiation (I_r), lastly applying the cloud coverage to obtain, for every hour of the year, the solar radiation incident on the surface(I).

2.2.4 Effective Roof Area and PV System Implementation

Having calculated the hourly solar radiation incident at the rooftop level, it is possible to estimate the PV production potential. However, we need to make assumptions about the PV systems' characteristics. Firstly, using the approach of Google Project Sunroof [16], only rooftop sections with at least 75% of the maximum annual solar radiation for the city of Lisbon, which is 1994 kWh/m^2 for a surface facing south with a tilt angle of 33º [17], are considered eligible to install solar panels.

The solar photovoltaic module used as well as the inverters and installation cost, was retrieved from the Portuguese company Macolis [18], and is further detailed in the following table.

Table 1: Solar PV Module Characteristics

	Solar PV Module
Name	MEPV 120HALF-CUT
Power	340 W
Dimensions	1684 x 1002 x 35 mm
Area	1.68 m2
Efficiency	20.23%
Cost	189.10 €

Equation 1 is the one used to calculate the amount of electricity produced hourly for each roof section.

$$E_{rs}(h) = I_{rs}(h) \times A_{rs} \times \eta \times P_R \qquad (kWh) \quad (1)$$

E_{rs} is the electricity produced hourly by each roof section, I_{rs} the hourly incident solar radiation, A_{rs}

the roof section area and P_R the performance ratio of rooftop PV which according to [19] is of 0.7341. To calculate the electricity produced by each rooftop the production for each section is simply added.

2.2.5 Algorithm Families Characterization

The MATLAB algorithm starts by evaluation the percentage of each type of family in the desired statistical area including families with five or more elements (total number of families minus the two other ones). Then it calculates the total amount of apartments and average area per apartment per building.

Associating the BGRI data with the available consumption profiles a compromise is defined by associating the "C1" consumption profile with "Families with one or two elements", "C2" with "Families with three of four elements" and "C3" with the remaining which are families with five or more elements. Knowing the percentage of representation of each type of family the consumption for each apartment is calculated (2).

$$C_{P/B} = (F_{1,2} \times C1 + F_{3,4} \times C2 + F_{5,+} \times C3) \times N_{D/B} \quad (2)$$

Where C_{PB} is the hourly electricity consumption per building in kWh, $F_{1,2}$ the percentage of families with one or two elements in that statistical area,$F_{3,4}$ the percentage of families with three or four elements and $F_{5,+}$ the percentage of families with five or more elements.

2.2.6 Net Zero Energy Building

A NZEB, is when the electricity consumed by a building throughout a year is equal to its PV system production. This point is also the point where the building's self-consumption (SC) its equal to its self-sufficiency(SS), which is found by iterative decreasing the PV System size from the maximum effective area results, until reaching an equality of these two values.

2.2.7 Key Performance Indicators

The developed model, evaluates the overall performance of an Energy Community, by analysing the following key performance indicators (KPI):

- Yearly electricity cost savings;
- Internal rate of return (IRR);
- Discounted payback time (DPBT);
- Yearly CO_2 emissions;
- Percentage of self-sufficiency (SS);
- Percentage of surplus of electricity;
- Percentage of self-consumption (SC).

3. Case Study Definition

3.1. Case Study 1

From a city block in the parish of Areeiro, 22 buildings were selected to study the results of a conceptual EC. Two different analysis were made, the first is considering each building as an EC community by itself, the participants being the families living in each building. The other one was considering the 22 buildings as a large EC called Total EC (TEC). In Figure 1 is an aerial image from google earth showcasing the city block at study. It is important to point out that from the BGRI data this neighbourhood has relatively small buildings, with an average of three floors and three apartments (families) per building.

Due to the large amount of data generated for the twenty two buildings, only three were selected to do an extensive overview. One building having the major sections of the roof facing North and South (Building 1), another on with its roof sections facing East and West (Building 2) and lastly one building with a flat roof (Building 3) . In Figure 1 the three selected buildings can be seen. After that, the results for an EC composed of all the 22 buildings and an average building (AVB) were also analyzed.

Figure 1: City Block in Areeiro

3.2. Case Study 2

For the second case study in this work, it was decided to choose city-block of Lisbon where the selected buildings are higher and therefore have more apartments per building than the ones on Case Study 1, to see how it influences the results. A total of 5 buildings, also from the parish of Areeiro, were selected and as can be seen in Figure 2.

Like in Case Study 1 it was decided to consider both scenarios, one where each individual building is an EC and another where all the buildings together compose an EC. To analyze the results given

Figure 2: City Block in Areeiro with higher buildings

by the model only one building was selected to do an extensive overview (Building 1 in Figure 2), as well as the average building and the Total EC.

3.3. Case 3 Study

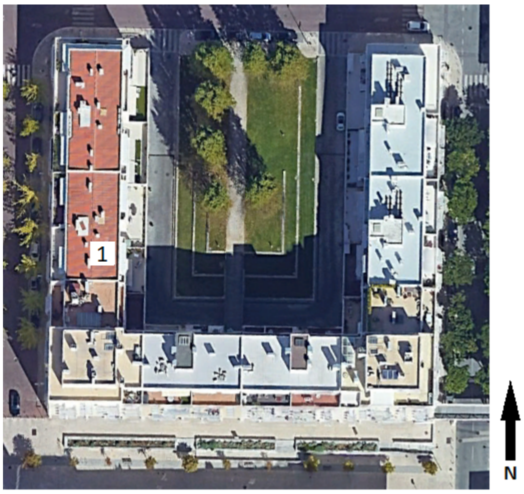

Figure 3: City block in Parque das Nações

The third case study is a city-block made up of eight buildings in Parque das Nações. The reason for this selection is the age of the structures, notably the fact that this city block is relatively new when compared to the previous two. The EC situations are the same as in the previous cases, and, as in Case Study 2, only one building (Building 1 in Figure 3) is chosen to provide a comprehensive perspective, alongside the average building and the Total EC.

4. Results

4.1. Solar Radiation Model Validation

To validate the developed Solar Radiation Model a comparison between the obtained values and the ones on the European's Commission Photovoltaic Geographical Information System is made, and can be seen on Figure 4.

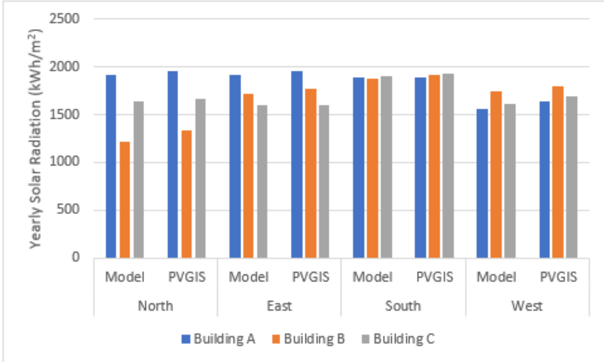

Figure 4: Yearly Incident Solar Radiation on each roof section

Inspecting Figure 4 the radiation calculated by the developed model is very close to the values found on the European Commission's data base (around 2.7%). Taking into account the relative errors found for solar radiation models in [20], one can determine that the results from the developed model are accurate enough to be trusted and produce faultless values that can be used on the rest of this work.

4.2. Roof Sections Orientation, Inclination and Yearly Solar Radiation for Case Study 1

Tables 2 and 3 show the first results outputted by the model, the orientation and inclination data organized in four different sections (clusters) per rooftop and the yearly incident radiation on each section.

One preliminary observation can be made regarding the pronounced differences in radiation values for the different orientations. When the roof orientation is North, or closer to it, the radiation values are smaller, so much so that they are below the 1495$kWh/m^2/year$ threshold, and are removed from consideration, as seen on Tables 4 and 5. When they are facing South, the maximum values of radiation are observed. For East or West, the values are in-between the ones observed for South and North facing rooftop sections.

Table 2: Orientation and Inclination of the different roof sections in the three selected buildings

Building:	Roof Section Orientation (°):				Roof Section Inclination (°):			
	North	East	South	West	North	East	South	West
1	358.7	102.3	184	264.4	24.5	25.6	23.7	24.5
2		56.5/92.6		272.6/309.1		26.2/27.2		23.5/29.7
3	358.8	106.7	201.9	273.9	11.5	13.9	6.8	11.0

Table 3: Yearly Incident Solar Radiation on the different sections of the three roofs

Building:	Roof Section Yearly Incident Solar Radiation (kWh/m2/year):			
	North	East	South	West
1	1200.7	1709.2	1943.4	1656.0
2		1390.7/1642.7		1619.6/1304.3
3	1483.7	1729.8	1781.7	1661.7

4.3. Roof Area and Radiation, Case Study 1

Inspecting Figure 5 one can see how the effective roof area (area where the yearly incident radiation

Table 4: Orientation and Inclination of different roof sections in the four buildings after the threshold for minimum accepted yearly incident radiation

Building:	Roof Section Orientation (º):				Roof Section Inclination (º):			
	North	East	South	West	North	East	South	West
1		102.3	184	264.4		25.6	23.7	24.5
2		92.6		272.6		26.2/27.2		23.5
3		106.7	201.9	273.9		13.9	6.8	11.0

Table 5: Yearly Incident Solar Radiation on the different roof sections in the four buildings after a threshold for minimum accepted yearly incident radiation

Building:	Roof Section Yearly Incident Solar Radiation (kWh/m2/year):			
	North	East	South	West
1		1709.2	1943.4	1656.0
2		1642.7		1619.6
3		1729.8	1781.7	1661.7

is above the threshold) is significantly smaller when compared to the total area for Building 1. This happens because Building 1 has a large roof section facing North with a low yearly incident radiation that is discarded.

On the other hand, almost all roof area for Buildings 2 and 3 is effective. In the case of Building 2, its larger sections are facing East and West having a good amount of yearly solar radiation, only the other two sections with a relatively small area are eliminated. Building 3 has a section directly facing North (358.83º) and, because this section is not exactly flat (11.4º of inclination), the amount of yearly solar radiation is also below the defined threshold and was removed from consideration. As expected, the Average Building (AVB) is similar to the other buildings and the Total EC (TEC) also follows the same relation as the average building, being the sum of all rooftops into a larger one.

In Figure 6 the total yearly incident radiation is compared to the effective one and, even though incident radiation depends on many factors, it is easy to see that, proportionally, the difference is fairly similar to the area difference.

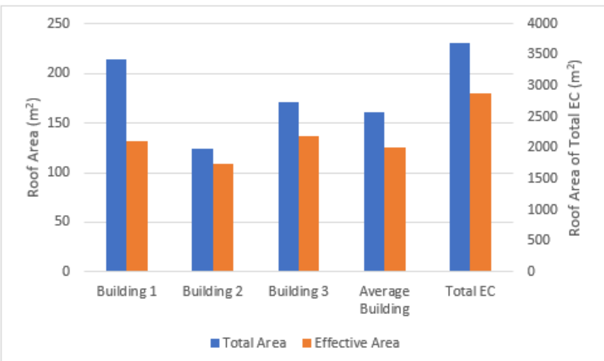

Figure 5: Total Area vs Effective Area for the installation of a PV system

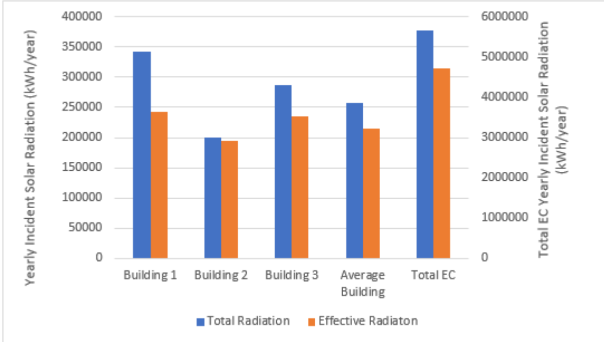

Figure 6: Total Radiation vs Useful Radiation for the installation of a PV system

4.4. PV System

It was decided to utilize all the roof effective area to install solar panels, taking into account the characteristics of each panel already mentioned in the Methodology. The number of installed solar panels per roof and yearly electricity production can be seen on Table 6.

Table 6: PV Systems Characteristics and Outputs from the MATLAB tool

Building:	Number of Solar Panels:	Investment Cost (€):	Yearly Electricity Production (kWh):
Case Study 1			
1	78	24449	36003
2	64	21802	26354
3	81	25017	35053
AVB	74	23693	31841
TEC	1702	521254	700523
Case Study 2			
1	160	39956	74505
AVB	168	41594	72995
TEC	1012	249569	437973
Case Study 3			
1	153	71374	64415
AVB	134	63508	57436
TEC	1079	508065	459489

4.5. Typology of the families in the city blocks under study

Figure 7 shows the percentage of each of the three considered families for the three case studies, retrieved from the BGRI data. For Case Study 1, working couples are clearly the majority of the families, which will mean the greatest influence when it comes to electricity consumption, as shown on Figure 8.

The families typology on the second Case Study are slightly different from the previous one, where the percentage of working couples is smaller, and there are more couples with two young children changing a bit the consumption profiles of the families living here.

The type of families living in the zone of Lisbon selected for Case Study 3 have quite of a significant change when compared to the previous selected ones, the percentage of working couples (53%) is significantly smaller as well as the couple with three children that represents only 1%, meaning an increase in couples with two young children for almost 50%, which produces a fairly different consumption curve.

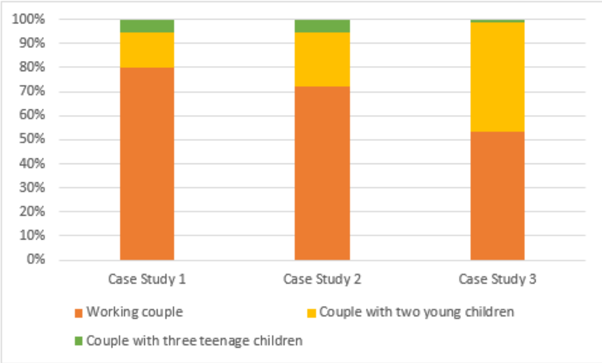

Figure 7: Typology of the families in the city block under study.

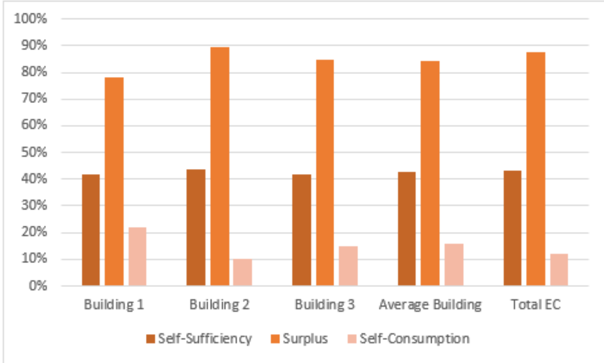

Figure 9: Electricity Self-Sufficiency and Surplus

4.6. Daily Average Electricity Consumption Vs Production, Case Study 1

In Figure 8 the daily average electricity demand and supply for each building is shown. As expected, the production of electricity starts only at 6 o'clock which is the earliest sunrise hour for Lisbon, and it stops at 21 o'clock which is around the latest sunset.

Going through Figure 8, it is easily noticeable how the PV electricity production vastly surpasses the consumption needs during the sun-shining hours of the day. The effective area used is far greater than the necessary to just satisfy the SC needs of each building, this happens due to the high effective roof area per apartment, that translates into higher PV power installed, as can be seen on Figure 10.

Taking a close look into Figure 9, one immediately notices how the Self-Sufficiency is nearly the same for all the cases. Even though they all have different amounts of installed PV power and consumption profiles, due to a far greater electricity production than consumption needs during the day, the SS tends to be around 42% as can be seen on Figure 8, from around 8 am to 7 pm the consumption needs for all cases are satisfied by production, only a small discrepancy happens during the early and late sunshine hours hence the nearly identical SS. This is due to the low demand profile during day hours of the C1 family which is the majority in Case study 1.

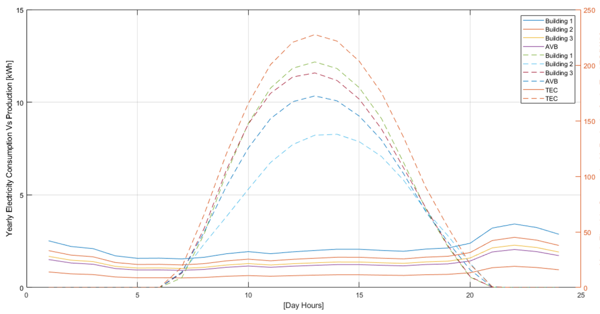

Figure 8: Daily Average Electricity Consumption and Production

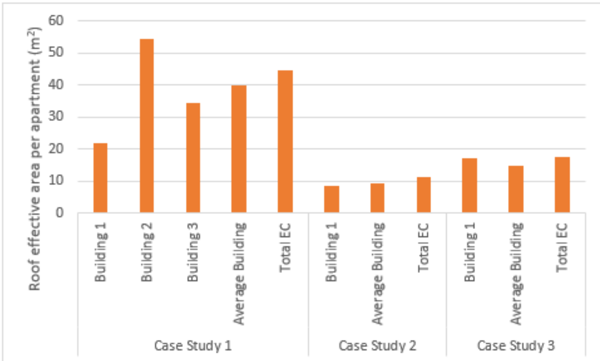

Figure 10: Effective Roof Area per Apartment

For the Surplus, even though it varies a bit more, the values are still pretty similar once again due to how small the self-consumption is, compared to production, regardless of the number of apartments per building that in this city block is always quite small. These means that the PV system is overdimensioned when it comes to SC, since the produced electricity surpass by far the consumption needs.

The Total EC behaves similarly to the individual ECs, the difference being on the magnitude (right axis for the Total EC on Figure 8) of both the consumption and electricity production (which are aggregated). The latter could be used as *bargaining chip* to get better value for the surplus of electricity, however in this work that possibility its not studied.

4.7. Financial Analyses

4.7.1 Tariff Analyses, Case Study 1

When it comes to the yearly electricity costs for Case Study 1 from Figure 11 the Dual Tariff regime is, in average, 36% lower than the Flat Tariff One. Such difference is explained by the cheaper price of electricity in the night period and the fact that during sunshine hours the electricity consumed is the one produced by the PV System as seen on Figure 8. The savings displayed on Figure 12 also confirm that a Dual Tariff is the most beneficial. For the other two Case Studies the same conclusion is also drawn.

It is also interesting to notice how Building 2 is the one with the least savings, a direct consequence from being the Building with the highest roof effective area per apartment. The higher surplus of electricity that is sold to the grid at the lower OMIE price allied with the lowest Self-Consumption creates the fewest yearly savings.

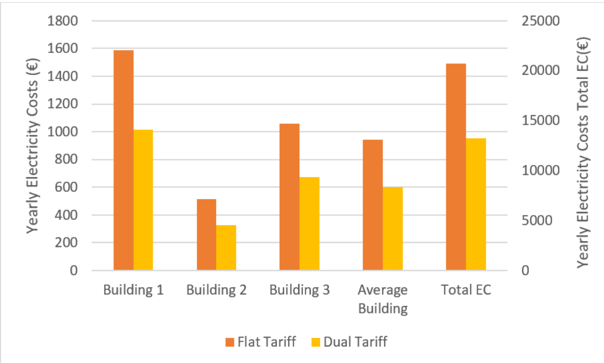

Figure 11: Costs with an EC

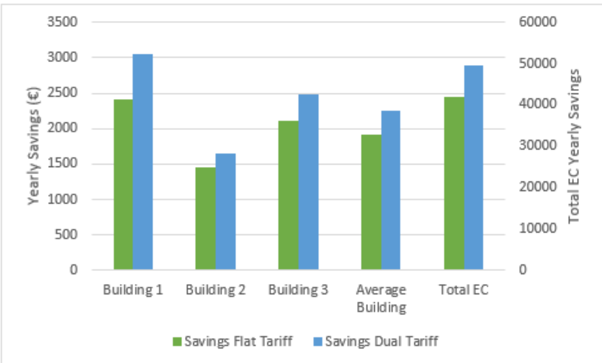

Figure 12: Savings with an EC

4.7.2 Discounted Payback Time

From Figure 13, Case Study 1, Building 2 has a DPBT far longer than the other ones. This happens because even though Investment Costs and Yearly Profits are fairly similar to the others buildings, the Yearly Savings are in average 30% smaller, extending the time it takes to payback the initial investment on the PV System.

With a DPBT below 20 years, Building 1 is the most attractive investment in case study 1, a direct consequence of having the highest yearly savings.

To have in consideration is the fact that although it takes several years to payback the investment, after that the revenue from the high surplus of electricity continues to be quite high.

Major differences appear when comparing Case Study 1 and 2 average buildings, having a DPBT of 35 years in the first in comparison to 8 years on the latter. An EC using the total effective area is

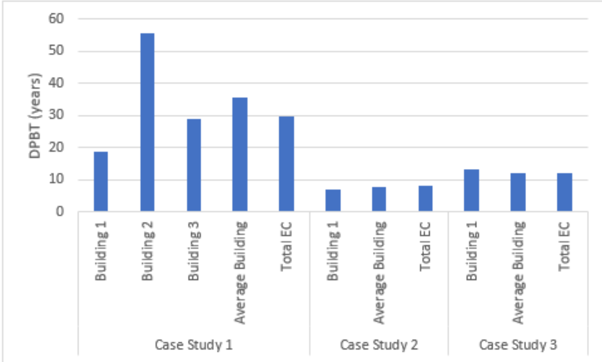

Figure 13: Discounted Payback Time

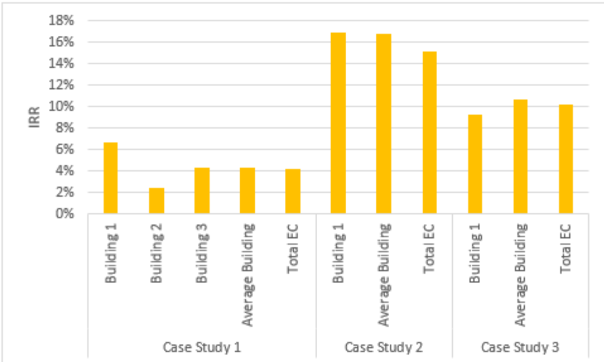

Figure 14: Internal Rate of Return

much better from the perspective of an investment in this neighbourhood where the buildings have a much larger number of apartments and therefore smaller roof effective area per apartment. This can be even better seen on Figure 14 where the IRR is more attractive from an investment point of view.

Case Study 3 also presents interesting DPBTs, like for the second case study, the roof effective area per apartment is relatively small which reduces the investment costs and the surplus, increasing the self consumption of electricity to the point of making it a good investment for all the cases. Also, one interesting thing is how the difference from having single building ECs or a Total EC is negligible, since the AVB and the TEC have similar values with the AVB being slightly better.

4.7.3 Internal Rate of Return

The IRR (for a 25 years period) being a complementary economic indicator to the DPBT shows the same conclusions. The first Case Study is by far the worst, with IRR values for all cases smaller than 10%. Case 2 is the best one with IRRs of over 15% for all cases, while Case 3 is in-between the other ones.

4.8. CO2 Emissions

Figure 15 showcases the positive environmental impact of ECs, for the average building of each case study. For Case Study 1, the yearly CO2 emissions decrease to almost half (a reduction of 43%) of the ones in a scenario without an EC, almost reaching the 55% EU meta for 2030. However, it is not the best case from a financial perspective.

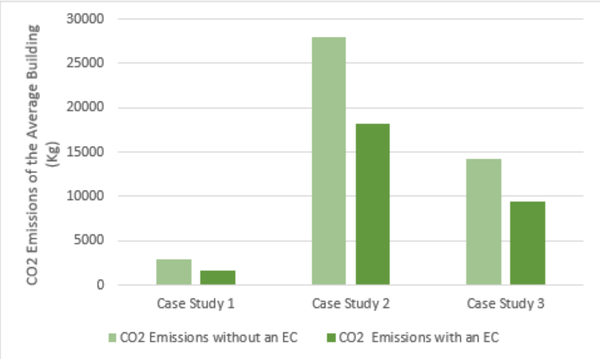

Figure 15: Yearly CO2 Emissions for the average building of each Case Study (Kg)

The other two case studies, not having such a high amount of reduced CO2 emissions, still make good progress in trying to achieve the 55% goal: for Case Study 2 a reduction of 35% and for Case Study 3 of 34%, validating the importance of this type of solution when it comes to the achieving a carbon neutral and more sustainable future. However, given the different electricity demand scales of the case studies, in absolute terms (kg) Case study 2 and 3 contribute much more to decarbonization of urban environment.

The avoided CO2 emissions from the surplus of electricity sold to the grid in the ECs is not accounted for in here, meaning that there are emissions that will be avoided locally where this surplus of electricity will be injected and thus consumed.

4.9. Net Zero Energy Building, Case Study 1

As seen above by using all the available effective roof area, the PV System is over-dimensioned for SC causing the DPBTs to be too long and the IRRs too low. Therefore, an analysis to encounter the amount of effective area to be used in an EC was made, in order to attain a Net Zero Energy Building, which produces the same amount of electricity that consumes. This corresponds to a balance between self-consumption and self-sufficiency that leads to a proper dimensioning of the PV System when wanting the SC to be the same as the yearly electricity consumption needs and not overshooting that value.

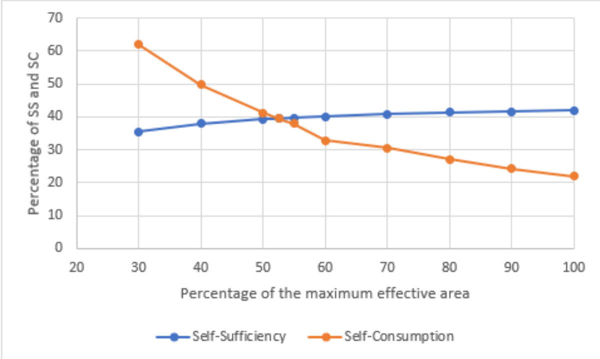

Figure 16: Change on SS and SC with the percentage of maximum effective area for the installation of a PV System in Building 1

In Figure 16, the percentage of effective area is progressively diminished from the max down to 30%, and at 52% the values of SS and SC match and the point of the NZEB is found. This really showcases the potential of a PV self-consumption EC, where the yearly consumption needs of a building cannot only be obtained but also surpassed.

As for the changes in the KPIs, Table 7 summarizes them. For all the Buildings and the TEC scenario the changes are remarkable: the DPBT is way smaller and consequently the IRR way higher, this comes due to the large reduction in the initial investment to have the NZEB scenario which does not translate in a reduction of the savings at the same proportion. Even though, for example in the case of Building 3, the initial investment is reduced in 60% the savings only reduce in 40%, once again a reflection on the smaller price that the surplus electricity is sold to grid in comparison to the price for which it is bought.

Table 7: NZEB and Max effective area Case Study 1 KPIs comparison

Building:	1		2		3		AVB		TEC	
Effective Area:	Max	NZEB	Max	NZEB	Max	NZEB	Max	NZEB	Max	NZEB
Investment (€):	38740	21544	32354	8557	40093	15688	36671	14434	806764	315495
Nº of Solar Panels:	78	41	64	15	81	29	73	26	1626	582
SC (%):	22	39.5	10.4	40	15.1	39	15.9	39	15.3	40
SS (%):	41.9		43.6		42		42.7		43	
Savings (€):	3043	2190	1644	734	2485	1447	2250	1320	49504	28875
DPBT (years):	18.8	11.9	55.6	15.57	28.9	13.9	35.54	16	29.7	14
IRR (%):	6.7	10	2.4	8	4.3	9	4.3	9	4.2	8.8

5. Conclusions

With the goal of being able to assess the potential of self-consumption Energy Communities in the city of Lisbon, a MATLAB tool was developed to capture with high spatial resolution the influential variables of an EC. The final goal is to allow anyone, just trough the insertion of geographical coordinates, to obtain an accurate estimation of the PV potential and electricity consumption needs of any desired location in the city. This capacity is particular useful to rapidly pre-assess the potential benefits (or not) of joining/creating an EC in that particular location.

After the validation of the solar production model, the EC KPI are analysed for three neighbourhoods with different building typologies and occupancy profiles, in order to evaluate the produced results.

The implementation of ECs proved to be, not only from a financial perspective, but also environmentally, a good decision. A significant decrease on CO2 emissions (ranging from 35% to 43%) is observed in all three Case Studies, allowing a step further towards decarbonization, as envisioned by the EU.

Another interesting outcome regards the usage of all the roof area to install a PV System. Due to the low grid injection price for which PV surplus can be sold to the grid, having a large installation compared to the consumption needs is a bad financial decision, having the largest savings coming from PV self-consumption. This is better shown by the effective roof area apartment ratio, in Case Study 1 where this ratio is high for buildings the ECs perform poorly financially, looking into the second Case Study the ratio is 75% smaller, for the average building, which translates on a much better financial performance, with lower DPBTs and higher IRRs. Consequently, reducing the PV array size to obtain a NZEB proved to be the better financial decision, denoting better DPBT and IRRs.

Additionally, the results enabled observing that the differences between single building ECs and the Total EC are almost negligible , with the only difference superior to 10% occurring for the DPBT in Case Study 1 (14%), when considering the same electricity tariffs, such is the case of this work.

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