Ciências ULisboa | Engenharia Geográfica, Geofísica e Energia

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Energy Systems

Island heat demand

Hot water and thermal comfort

Integrated Master in Energy and Environmental Engineering

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Capellari, Felix 55863
Churro, Carlos 49713
Cunha, Marta 50336
Lamy, Afonso 48057
Lourenço, Rodrigo 50372
Santos, João 55144
Varela, Fábio 50213

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1. Introduction

Heat is very important in our daily life for warming the house, cooking, heating the water and drying the washed clothes. The objective of this work is to evaluate the hot water and thermal comfort demand of an isolated island and how we can supply the necessary energy with the usage of renewable energy, comparing different scenarios.

2. Hot water

2.1 Hot water heat demand

The demand for hot water is estimated to be 60L per person, being this value considered enough for a person to take a bath per day. The water is heated by an electric boiler with an efficiency of 90%, and 45ºC for the water heating temperature set-point. To compute the necessary heat for this change in temperature, for 50 000 people, it was used the following equation:

$$Q = m.c_v.\Delta T(2 - \eta).5 \times 10^4$$

Where ‘m’, the mass of water was calculated considering its density due to the fluid’s temperature, cv is constant and has the value of 4180 J/(kg.ºC), and the initial temperature corresponds to the season average temperature, considering that water is transported via underground piping, hence its temperature will remain approximately constant during each season.

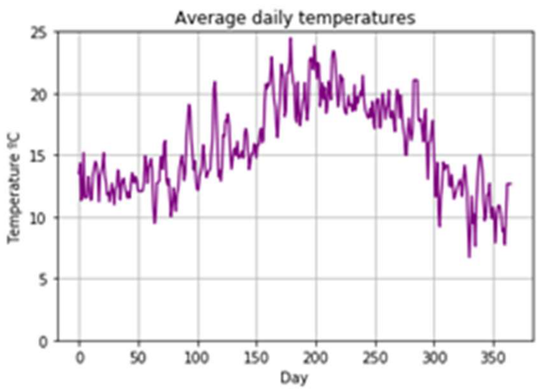

Figure 1: Average daily temperatures

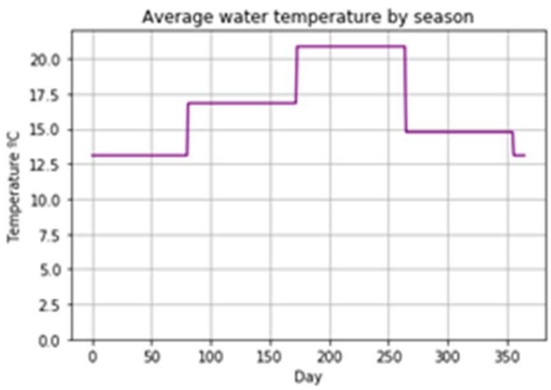

Figure 2: Water Temperatures by season

Average daily values of the energy demand were computed with the previous equation and shown in the following figure.

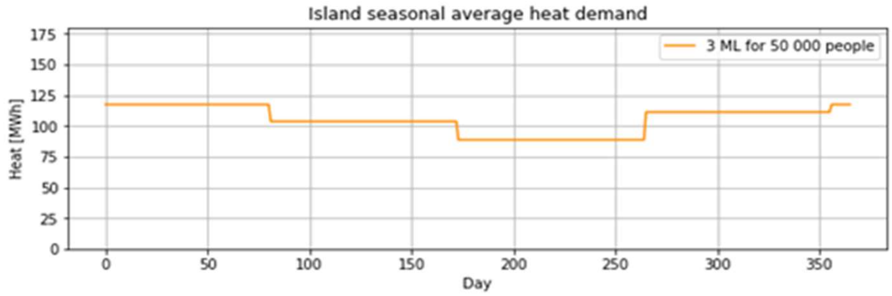

Figure 3: Seasonal Average Heat Demand

To make a better demand profile, various scenarios of synergy sources will be analyzed, being the solar thermic technology the best option for heating water for baths. Therefore, the installation of at least one panel in each house will be considered. Since the solar thermic production will not be enough in some days, the heat still missing to achieve the daily energy necessity will be considered as the remaining heat demand.

Solar thermal panels production is conditioned by the amount of radiation available, which depends on the meteorological conditions and, mainly, the season. To analyze the influence of the season in heat demand, the typical weeks demand and production were mapped. In Spring and Summer, the heat generated by either one or two panels will be enough, however in autumn and winter the solar thermic system will be insufficient in some days.

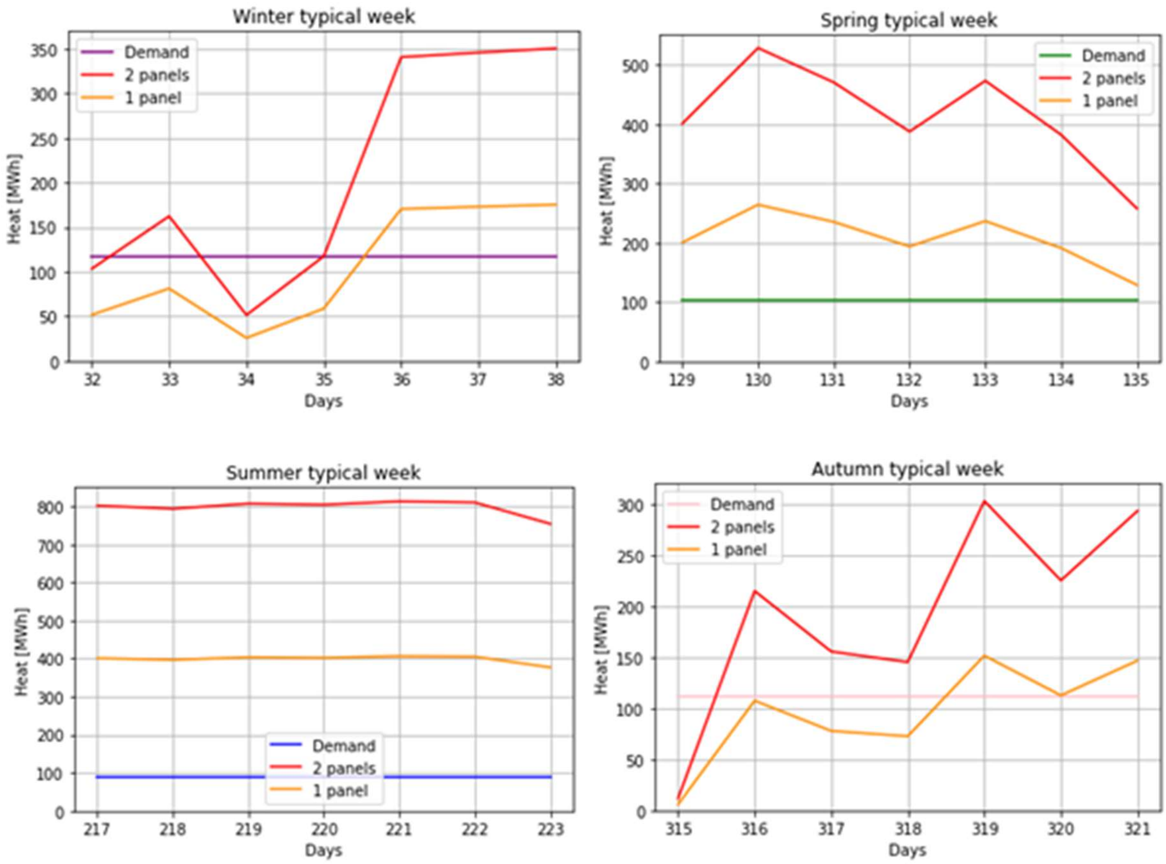

Figure 4: Typical Weekly Heat Demand for each Season

Since there exists excess production in spring and in the summer, and on the contrary, an energy deficit in winter, the number of solar panels installed needs to be balanced between reducing the energy losses in the summer and reducing the number of days of heat shortage in the winter. The number of days of heat shortage varies, but the highest energy demand values remain approximately constant since they occur in days without sunlight, therefore the number of panels in these days will not be important. To satisfy the remaining demand, other renewable sources need to be considered to be part of the energetic mix.

2.2 Energy production

For the evaluation of the amount of energy that can be produced by solar thermal it was used the recommendation made by the solar thermal group, the 4th solar collector, which the characteristics are given by:

Panel	Typology	η_p [%]	a_1 [W/m²·K]	a_2 [W/m²·K²]	Area [m²]	Price [€]
4	Vacuum tube (20 tubes) (Brand C)	71,5	1,550	0,012	3,23	680,00

Table 1: Solar Thermal Characteristics

by using those parameters, it is possible to calculate the collector efficiency by using the following equation:

$$\eta = \eta_p - a_1 \cdot \frac{\Delta T}{G} - a_2 \cdot \frac{\Delta T^2}{G^2}$$

As it can be seen in the equation, it has two parameters that change along the year, the ΔT which is given by the subtraction of the desired temperature(45ºC), and the environmental temperature, assuming that the environment temperature is a good approximation of the water temperature in a specific hour, and the global radiation of that hour. This situation means that the efficiency of the collector has an hourly variation that can be multiplied for the global radiation of the correspondent hour and give the power that the collector is able to produce. After that the daily energy produced was obtained.
This process was made for a collector and two collectors (solar thermal group advise), per house for all the 50000 people living on the island, and the average annual energy production was 70 MWh or 140 MWh by having a production with a solar thermal panel or two solar thermal panels respectively.

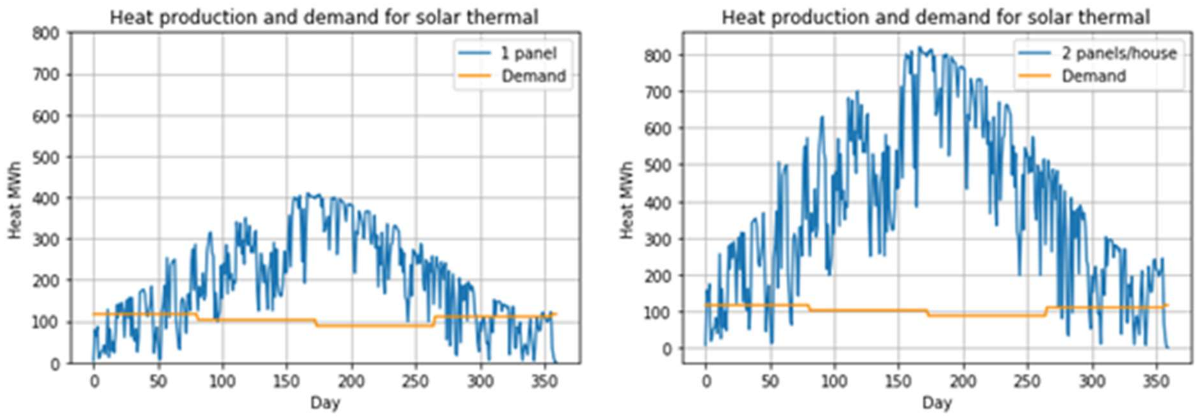

Figure 5: Heat Demand and Production 1 & 2 Panels

2.3 Electricity production mix

To have a guarantee of power on the days of need, production values below need´s values shown before, it was evaluated among many sources of energy which could be a bifocal energy mix.
The second main energy source that was chosen to focus on beyond the main one, Solar thermal, was wind energy which led to a dimensioning process, either onshore and offshore, being a source of energy that produces the most during the periods of energy shortage, Autumn and Winter. Besides these two sources were also evaluated in more scenarios, combining them with other energy sources, and so considered various options available to fulfill the energy needs.
The following tables shows the options considered:

Off-shore Wind	MAX Energy [MWh]	Nr turbines	E [MWh]	I (€)	M (€)
OSP*	130,47	7	51 895	40 855 500	2 042 775
OSP + Waste	65,86	4	29 654	23 346 000	1 167 300
OSP + Waste + Hydro	46,88	3	22 241	17 509 500	875 475
TSP**	129,30	7	51 895	40 855 500	2 042 775
TSP + Waste	64,69	4	29 654	23 346 000	1 167 300
TSP + Waste + Hydro	45,71	3	22 241	17 509 500	875 475

Table 2: Electricity Production Mix with Off-Shore Wind

On-shore Wind	MAX Energy [MWh]	Nr turbines	E [MWh]	I (€)	M (€)
OSP	130,47	11	50 054	25 680 600	1 284 030
OSP + Waste	65,86	6	27 302	14 007 600	700 380
OSP + Waste + Hydro	46,88	4	18 201	9 338 400	466 920
TSP	129,30	11	50 054	25 680 600	1 284 030
TSP + Waste	64,69	6	27 302	14 007 600	700 380
TSP + Waste + Hydro	45,71	4	18 201	9 338 400	466 920

Table 3: Electricity Production Mix with On-Shore Wind

The first table relates to Off-shore wind energy and the second one to On-shore wind energy. For both tables, the first column gives the possible combinations of energy sources that were studied. The second column shows the highest amount of energy demand for a specific day during the year for a specific energy mix respectively. The third column translates the number of turbines needed to install considering the respective scenario and the fourth one the yearly energy production of the turbines. The fifth and sixth columns relate to the initial investment and the yearly maintenance costs of the turbines. After considering all those scenarios an economic analysis was performed to each one of them to understand which is the more viable, and for what perspective.

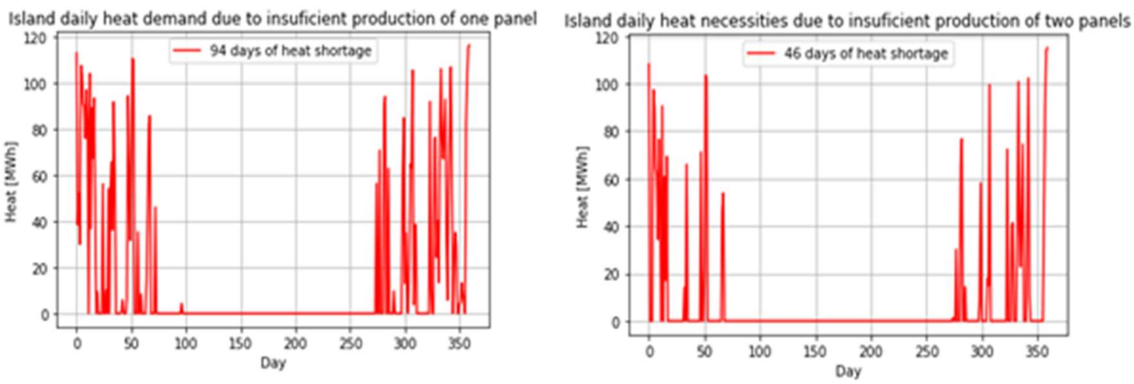

Figure 6: Remaining Heat demand with 1 & 2 Panels

To evaluate if the resources available on the island could supply the heat demand, various scenarios with energy sources combinations were created. Scenario 1 corresponds to one solar panel and waste burning plant, both producing energies to heat the water. Scenario 2 corresponds to two solar panels and waste, scenario 3 to one solar panel, waste and hydro, and scenario 4 to two solar panels, waste, and hydric energy.

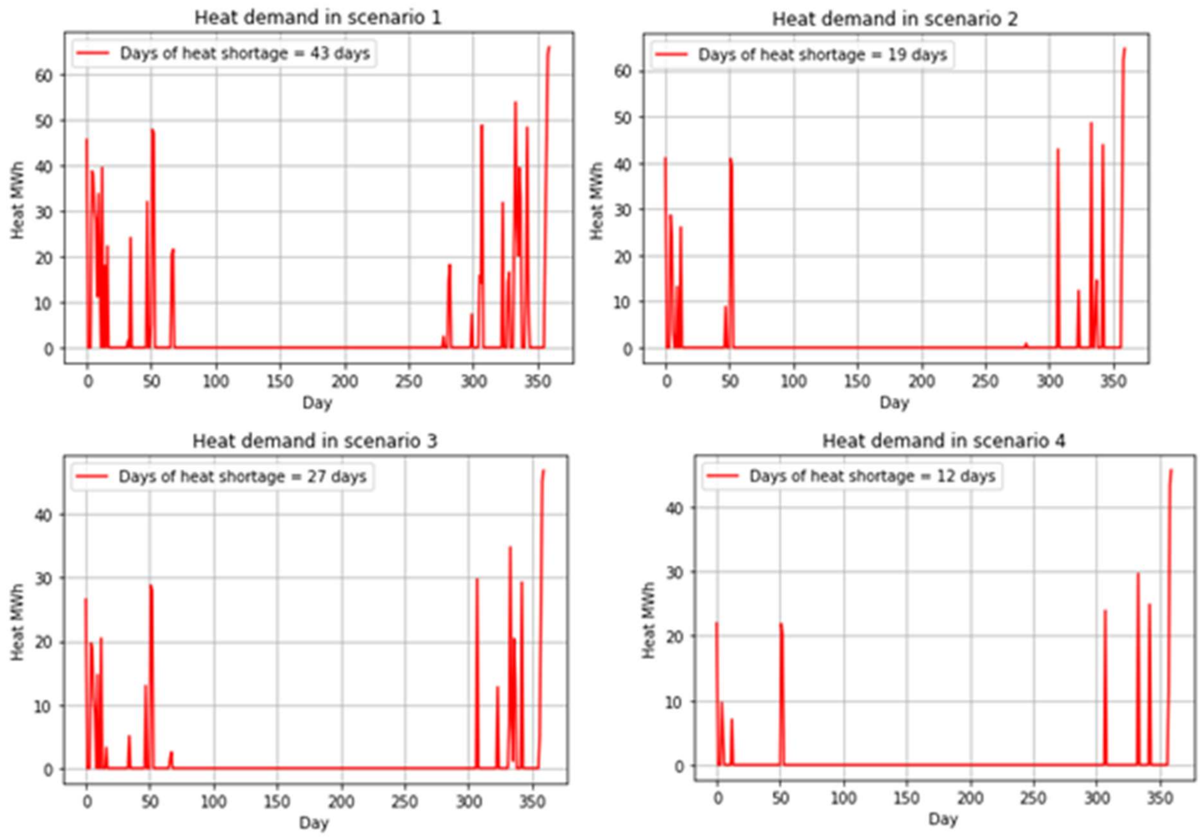

Figure 7: Remaining Heat Demand for different Scenarios

2.4 Economics Analysis

An economic analysis is a robust method to make the decision about what should be the energy mix production. In order to do that there was information necessary about the energy sources shown before that had to be considered.

Energy Source	E [MWh/year]	I (€)	M (€/year)	LCOE [€/kWh]
Solar thermal (OSP)	70 423	2 366	23,80	0,003
Solar thermal (TSP)	140 847	4 732	47,60	0,003
Waste	23 584	14 200 000	284 000	0,139
Hydro	6 927	4 605 034	68 528	0,049

	E [MWh/season]	I (€/turbine)	M [€/year/turbine]	LCOE [€/kWh]
Wind (on-shore)	1 122,00	2 334 600	46 692	0,060
Wind (off-shore)	1 828,00	5 836 500	116 730	0,080

Table 4: Data for Different Electricity Sources

From the reports about the energy sources, it was possible to obtain information like annual energy production, initial investment, annual maintenance cost and the levelized cost of electricity for a given energy source.
With this information, it was possible to evaluate the net present value (NPV) and the levelized cost of electricity (LCOE) for different situations. For the NPV evaluation it was considered that the discount rate was fixed and equal to 5%, the lifetime was 40 years and energy sources can work during the life-time period (no need to change the equipment).
The net present value followed the equation:

$$NPV = \sum_{t=0}^{N} \frac{B_t - C_t}{(1+d)^t}$$

- Bt - Benefits in year t
- Ct - investment costs in year t
- d - discount rate

For the LCOE evaluation were made additions of the LCOE values obtained from the reports of the energy sources reports.
The results obtained from those were:

wind off-shore	**I(€)**	**m(€)**	**NPV(€)**	**LCOE(€/kWh)**
osp+wind	40,857,866	2,042,799	221,289,481	0.083
osp+waste+wind	37,548,366	1,451,324	238,012,417	0.222
osp+waste+hydro+wind	28,145,800	1,228,027	241,893,256	0.271
Tsp+wind	40,860,232	2,042,823	392,396,221	0.083
Tsp+waste+wind	37,550,732	1,451,348	409,119,157	0.222

Tsp+waste+hydro+wind	36,319,266	1,228,051	412,999,996	0.271

Table 5: Economic Analysis for Different Electricity Mixes with Off-shore

wind on-shore	I(€)	m(€)	NPV(€)	LCOE(€/kWh)
osp+wind	25,682,966	1,284,054	245,010,085	0.063
osp+waste+wind	28,209,966	984,404	249,647,480	0.202
osp+waste+hydro+wind	28,145,800	819,472	247,260,311	0.251
Tsp+wind	25,685,332	1,284,078	416,116,825	0.063
Tsp+waste+wind	28,212,332	984,428	420,754,220	0.202
Tsp+waste+hydro+wind	28,148,166	819,496	418,367,051	0.251

Table 6: Economic Analysis for Different Electricity Mixes with On-shore

2.5 Recommendations

By analyzing the previous tables, it can be inferred that the highest NPV, which corresponds to the scenario where two solar panels per house, waste energy and 6 wind turbines onshore are combined, does not translate into the lowest LCOE. In fact, one solar panel per house plus 11 wind turbines scenario is the one which represents the lowest value for this economic method. A recommendation will be proposed in the attempt to achieve an optimal solution, considering different criteria factors.

If the criteria factors are based on economic indicators, the one that offers a high NVP and a low LCOE is the two solar panels plus 11 onshore turbines scenario.

If sustainability is the main criteria, then burning waste as a source of energy would be the best choice, since it would represent an energy source and a method to reduce the amount of waste disposal in the environment. Since waste represents lower score values in the economic evaluation, it should be considered dispatchable instead of burning daily constant amounts of waste. If a dispatchable waste energy source was considered the NPV and the LCOE values would be totally different because the installation would be prepared to have a very high-power capacity instead of a medium power capacity to burn the daily waste production.

3. Thermal Comfort

3.1Thermal comfort heat demand

For the estimations of the heat demand for thermal comfort, we wanted to know the amount of heat necessary to heat all households during the designated seasonal weeks of 9 to 15 January (Winter), and 26 July to 1 August (Summer). To assess this problem, we used the following formula:

$$Q = \frac{A * \Delta T}{R} \, [\frac{W}{h}]$$

For a given common house area of 100 m^2 and considering the average R value of 2 $m^2*K\ W^{-1}$, plus that we have 1 renovation of the air per hour. For the calculations, we started by knowing the outside temperature using the radiation time series provided in the island data. Since the ideal thermal comfort temperature inside a house is of 18ºC for Winter and 25ºC for Summer we did the calculations of the average daily heat needed to reach the ideal temperatures in a house for a year, Figure 8, considering that Summer went from April to September and Winter from October to March, to know the general amount of heat required:

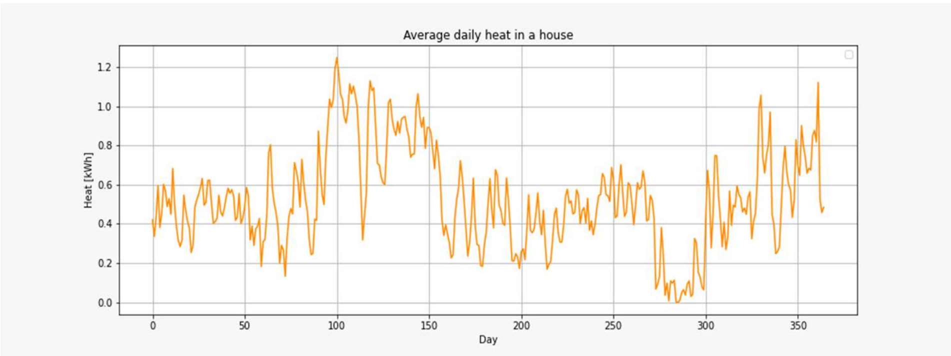

Figure 8: Average Daily heat for Thermal Comfort

Following with the calculations of the hourly heat demand for each one of the designated seasonal weeks, in a single house:

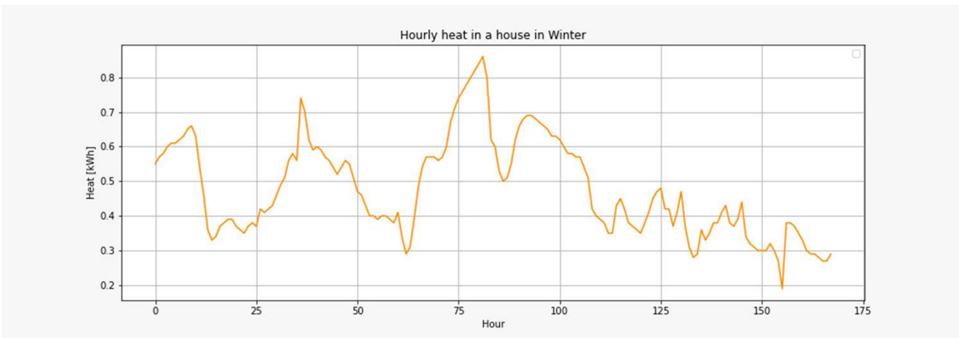

Figure 9: Hourly heat for Thermal Comfort in Winter

Analyzing the graphic of the hourly heat demand in one of the buildings during Winter we can conclude that heat demand varies from 0.2 kWh to 0.85 kWh.

Figure 10: Hourly heat for Thermal Comfort in Summer

Observing the graphic of the hourly heat demand in one of the buildings during Summer, and not considering the cooling demand, we observe the heat demand variations from 0 kWh to 0.82 kWh.

This means that in the Summer, due to the climate conditions of the island and because of the change in the thermal comfort temperature from 18 ºC to 25ºC, despite the ambient temperatures being superior, the average heat demand in Summer (0.42 kWh) is not drastically lower than the average heat demand in Winter (0.48 kWh).

With this information we can proceed with the calculations of how we can provide this amount of energy to the buildings, studying the most efficient methods.

3.2 Heating Systems to provide thermal comfort

In order to plan the thermal heat supply for all households on the island. We compared two different scenarios to see which one would make more economic sense. In the first scenario, we tried to cover the entire demand with heat pumps. On the other hand, for our second scenario we use all the available biogas produced by waste, which represents 45% and 55% with electricity (25% joule heating and 30% heat pumps). We selected a higher proportion of heat pumps because they are cheaper the joule heating systems on the long term. First, the different technologies are presented and then the results of the economic analysis.

3.2.1 Electric Joule Heating

Joule heating also known as electric resistance heating or Ohm heating uses the heat generated by the flow of an electric current through a conductor. This type of space heating is very popular due to the fact that it is relatively cheap, easy to install and takes up little space. It requires a continuous power supply and, depending on the source of the electricity, can be considered environmentally friendly (Hughes, L., 2010).

3.2.2 Gas boiler

One of the most widespread methods of heating rooms in Europe is heating with gas boilers. Gas boilers can be used to heat rooms as well as hot water. In our case, however, it is only used for heating rooms. Conventional gas boilers have efficiencies around 75% and exhaust flue gas with a temperature of 150-200 C° into the atmosphere, which means that a large amount of heat is lost, and efficiency is reduced. Condensing gas boilers, on the other hand, can reduce the loss of latent heat through a condenser and thus achieve higher efficiencies of over 85% (Qu, M. et al, 2014). In our case, a condensing gas boiler with an efficiency of 85% was considered and operated with biogas.

3.2.3 Heat Pump

Other commonly explored systems for thermal comfort are machineries that use heat pumps like HVAC systems. A heat pump extracts heat from a source and transfers it to a 'heat sink' at a higher temperature (ASHRAE, 2012). HVAC systems are milestones of building mechanical systems that provide thermal comfort for occupants and indoor air quality. Depending on outdoor conditions, the outdoor air is drawn into the buildings and heated or cooled before it is distributed into the spaces, then it is exhausted to the ambient air or reused in the system. The selection of HVAC systems in each building will depend on the climate, the age of the building, individual preferences of the owner and project budget. (Seyam, S., 2018). In terms of efficiency, we considered that it had a coefficient of performance (COP) of 3.

3.2 Economic Analysis

As already mentioned, two different scenarios were compared in order to cover the heating requirements and to determine the most favorable variant. The Study "Electrification of residential Space Heating Considering Coincidental Weather Events and Building Thermal Inertia: A System-Wide Planning Analysis" of Heinen. S. et al 2017 has already conducted an economic analysis to compare gas boilers, heat pumps and resistance heaters. Therefore, the same data for investment costs, installation costs and efficiencies were applied. In order to compare the scenarios, the NPV was calculated for all heating systems individually with a term of 15 years and a discount rate of 5%, which can be viewed as an attachment in the appendix. The cumulative NPV was then calculated for the two scenarios. For scenario 1 all households were equipped with heat pumps. For scenario 2, 45% of the households were equipped with gas boilers, 25% with resistance heaters and 30% with heat pumps. We assumed a value of 0.06 €/kWh for the electricity price and 0.011 €/kWh for the Biogas. The biogas is produced by waste and the available amount was taken from the report on waste. It shows that 52.47 GWh is annually available in the form of biogas to meet our needs for thermal comfort, about 48,99 GWh (93%) of that amount is required. In figure number 11 and 12 we show the energy demand for the different scenarios.

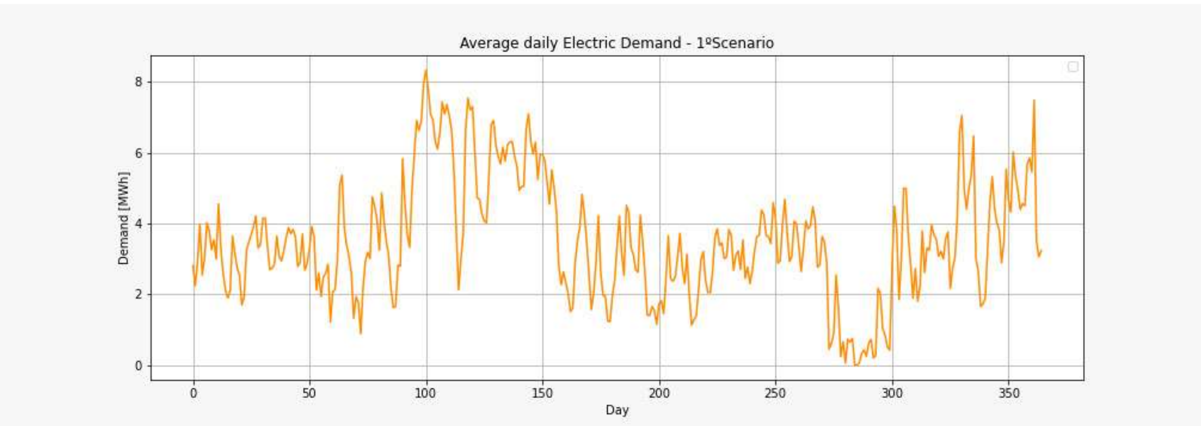

Figure 11: Energy Demand Thermal Comfort Scenario 1

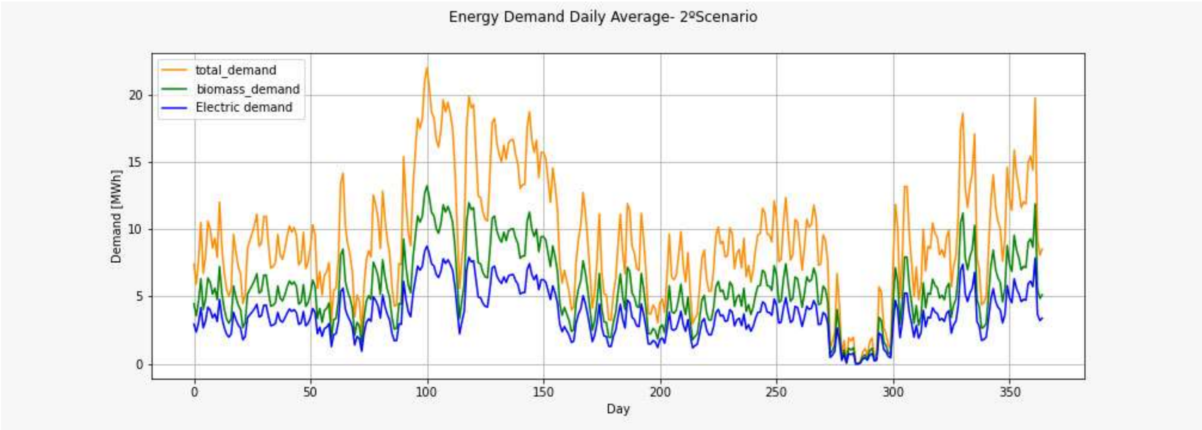

Figure 12: Energy Demand Thermal Comfort Scenario 2

Even though the energy consumption for scenario 1 is significantly less, after our economic analysis we had to conclude that scenario 2 is the cheaper option in the long term. Results are shown in Table 7&8 and it can be seen that the cumulative NPV of scenario 2 is about 3,2 Million € cheaper, which is why we choose this one.

Scenario 1: 100% Heat Pump				
NPV				
t	Bt	Ct	Bt-Ct	NPV
0		€ 60 600 000,00	-€ 60 600 000,00	-€ 60 600 000,00
1	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 762 853,33
2	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 678 907,94
3	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 598 959,94
4	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 522 818,99
5	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 450 303,80
6	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 381 241,71
7	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 315 468,30
8	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 252 826,95
9	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 193 168,53
10	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 136 350,98
11	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 082 239,03
12	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 1 030 703,83
13	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 981 622,70
14	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 934 878,76
15	€ -	€ 1 850 996,00	-€ 1 850 996,00	-€ 890 360,72
			NPV	-€ 79 812 705,51

Table 7: Cumulative NPV Scenario 1

Scenario 2: 45% Biogas, 30% Heat Pump, 25% Joule heating				
NPV				
t	Bt	Ct	Bt-Ct	NPV
0		€ 50 830 000,00	-€ 50 830 000,00	-€ 50 830 000,00
1	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 2 364 297,41
2	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 2 251 711,82
3	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 2 144 487,45
4	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 2 042 369,00
5	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 945 113,33
6	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 852 488,89
7	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 764 275,13
8	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 680 262,03
9	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 600 249,55
10	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 524 047,19
11	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 451 473,52
12	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 382 355,73
13	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 316 529,27
14	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 253 837,40
15	€ -	€ 2 482 512,28	-€ 2 482 512,28	-€ 1 194 130,85
			NPV	-€ 76 597 628,57

Table 8: Cumulative NPV Scenario 2

3.4 Effect of electrification on heat production

On the topic of the effect of electrification on heat production, heat demand today represents roughly half of the final energy demand in the EU. But in the past, heat was largely absent in the energy debate, given the traditional focus on energy supply data, which only shows heat fuels, mainly fossil fuels and a small fraction of electricity. The increasingly decarbonized electricity system powered by renewable electricity can provide clean heat supply, while the flexibility of heat demand can support electricity peak management and the integration of variable renewable energies. Heat electrification represents a growth area for the electricity industry, but balancing challenges are a major concern for short-term operations as well as long-term capacity planning. Electric heating, if deployed in an uncoordinated manner, results in proportionally stronger winter peak growth than average demand growth and could further decrease asset utilization. However, heat can be stored more efficiently and economically than electricity, which offers new opportunities for energy system integration solutions. An intelligent or controlled integration of electric heat can draw on the flexibility of the heating sector (thermal storage and inertia) to facilitate the integration of renewables and manage peak loads (Heinen, 2018). So, an efficient electricity system integration on the island will hinge on increasing building energy efficiency and harnessing heat system flexibility.

Schüwer, 2018 refers that converting electricity into heat offers the opportunity to make use of large scales of renewable (surplus) energy in the long run, to reduce shutdowns of renewable power plants and to substitute the use of fossil fuels. Electrification seems to be also very promising for industrial heat applications, as it enables high process temperatures to be achieved in a tailor-made and efficient way and enables the utilization of other energy sources like waste heat, geothermal or ambient heat (via heat pumps).
A standpoint that is also supported by Fawcett T, that alleged that electrification is seen as an important global contributor to mitigate climate change because low carbon electricity can, in theory, replace current fossil fuel use in buildings. Which can be beneficial on our island.

4. Conclusion

With this case of study, we can conclude that even with the capacity of supplying the total heat demand, for a year, of 119,7 GWh/a, being 67.99% (81.4 GWh/a) for thermal comfort and only 32.01% (38.32 GWh/a) for hot water, with renewable energy in this isolated island, the way we supply this energy haves different environmental, economic, and social impacts. It would depend on what type of main criteria the project designer would be more inclined to consider and the project budget to choose the right option to supply the energy required for the hot water. All though to solve the thermal comfort problem, the options are simpler, since they are only two scenarios, and one is much cheaper than the other one, the awareness of the impacts shouldn´t be discarded.

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Appendix

Joule Heating:		
Efficiency:	100	%
Investment+ Installation:	1760	€
Electricity price:	0,06	€/kWh
Amount of Electricitry	4627	kWh/year
Lifetime	15	years

NPV				
t	Bt	Ct	Bt-Ct	NPV
0		€ 1 760,00	-€ 1 760,00	-€ 1 760,00
1	€ -	€ 277,65	-€ 277,65	-€ 264,43
2	€ -	€ 277,65	-€ 277,65	-€ 251,84
3	€ -	€ 277,65	-€ 277,65	-€ 239,84
4	€ -	€ 277,65	-€ 277,65	-€ 228,42
5	€ -	€ 277,65	-€ 277,65	-€ 217,55
6	€ -	€ 277,65	-€ 277,65	-€ 207,19
7	€ -	€ 277,65	-€ 277,65	-€ 197,32
8	€ -	€ 277,65	-€ 277,65	-€ 187,92
9	€ -	€ 277,65	-€ 277,65	-€ 178,98
10	€ -	€ 277,65	-€ 277,65	-€ 170,45
11	€ -	€ 277,65	-€ 277,65	-€ 162,34
12	€ -	€ 277,65	-€ 277,65	-€ 154,61
13	€ -	€ 277,65	-€ 277,65	-€ 147,24
14	€ -	€ 277,65	-€ 277,65	-€ 140,23
15	€ -	€ 277,65	-€ 277,65	-€ 133,55
			NPV	-€ 4 641,91

Heat pump:		
Efficiency:	3	%
Investment+ Installation:	3030	€
Electricity price	0,06	€
Amount of Electricitry	1542	kWh/year
Lifetime	15	years

NPV				
t	Bt	Ct	Bt-Ct	NPV
0		€ 3 030,00	-€ 3 030,00	-€ 3 030,00
1	€ -	€ 92,55	-€ 92,55	-€ 88,14
2	€ -	€ 92,55	-€ 92,55	-€ 83,95
3	€ -	€ 92,55	-€ 92,55	-€ 79,95
4	€ -	€ 92,55	-€ 92,55	-€ 76,14
5	€ -	€ 92,55	-€ 92,55	-€ 72,52
6	€ -	€ 92,55	-€ 92,55	-€ 69,06
7	€ -	€ 92,55	-€ 92,55	-€ 65,77
8	€ -	€ 92,55	-€ 92,55	-€ 62,64
9	€ -	€ 92,55	-€ 92,55	-€ 59,66
10	€ -	€ 92,55	-€ 92,55	-€ 56,82
11	€ -	€ 92,55	-€ 92,55	-€ 54,11
12	€ -	€ 92,55	-€ 92,55	-€ 51,54
13	€ -	€ 92,55	-€ 92,55	-€ 49,08
14	€ -	€ 92,55	-€ 92,55	-€ 46,74
15	€ -	€ 92,55	-€ 92,55	-€ 44,52
			NPV	-€ 3 990,64

Gas boiler:		
Efficiency:	85	%
Investment+ Installation:	2650	€
Natural Gas price:	0,011	€/kWh
Primary Energy	5444	kWh/year
Lifetime	15	years

NPV				
t	Bt	Ct	Bt-Ct	NPV
0		€ 2 650,00	-€ 2 650,00	-€ 2 650,00
1	€ -	€ 59,89	-€ 59,89	-€ 57,03
2	€ -	€ 59,89	-€ 59,89	-€ 54,32
3	€ -	€ 59,89	-€ 59,89	-€ 51,73
4	€ -	€ 59,89	-€ 59,89	-€ 49,27
5	€ -	€ 59,89	-€ 59,89	-€ 46,92
6	€ -	€ 59,89	-€ 59,89	-€ 44,69
7	€ -	€ 59,89	-€ 59,89	-€ 42,56
8	€ -	€ 59,89	-€ 59,89	-€ 40,53
9	€ -	€ 59,89	-€ 59,89	-€ 38,60
10	€ -	€ 59,89	-€ 59,89	-€ 36,76
11	€ -	€ 59,89	-€ 59,89	-€ 35,01
12	€ -	€ 59,89	-€ 59,89	-€ 33,35
13	€ -	€ 59,89	-€ 59,89	-€ 31,76
14	€ -	€ 59,89	-€ 59,89	-€ 30,25
15	€ -	€ 59,89	-€ 59,89	-€ 28,81
			NPV	-€ 3 271,59