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Mário Jorge de Freitas Martins

Comparative economic analysis of different solar energy technologies for domestic hot water production

Análise económica comparativa de diferentes tecnologias de energia solar para produção de água quente doméstica

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia Mecânica, realizada sob a orientação científica do Doutor Fernando José Neto da Silva, Professor Auxiliar do Departamento de Engenharia Mecânica da Universidade de Aveiro, e coorientação do Doutor Ismael Alagili Sassi Ehtiwesh.

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I dedicate this work to my mother, my father, and my brother for all the support that was given to me throughout this journey.

o júri

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palavras-chave solar térmico; análise económica; comparativa; água quente sanitária; energia solar; fotovoltaico; ambiente; análise de sensibilidade;

resumo

Este trabalho tem como objetivo efetuar uma análise económica comparativa entre diferentes sistemas de produção de água quente sanitária: aquecedor elétrico convencional, sistema solar térmico e um sistema fotovoltaico. Os sistemas foram analisados para duas localizações em Portugal, diferentes necessidades diárias de água quente e sob diferentes condições económicas. Foi desenvolvido um modelo de simulação TRNSYS para cada sistema e validado com dados experimentais ou simulados da literatura. Foi efetuada uma análise paramétrica de modo a avaliar o impacto do aumento do número de painéis e capacidade de armazenamento de água no desempenho e esses resultados foram usados numa análise económica a fim de determinar a sua viabilidade económica considerando diferentes indicadores económicos, em conjunto com uma análise de sensibilidade para estudar o impacto do preço da eletricidade, taxa de desconto e inflação do preço da eletricidade na viabilidade dos sistemas solares de produção de água quente. Os resultados mostraram que um sistema de produção de água quente fotovoltaico é melhor que o sistema solar térmico do ponto de vista económico devido a um menor custo de investimento e menor manutenção. Um sistema solar térmico tem melhor desempenho devido à maior eficiência na conversão de energia solar para calor. As condições económicas e perfil de consumo de água quente sanitária têm um grande impacto na viabilidade económica destes investimentos visto que, para preços baixos e pouca necessidade de água quente, um sistema solar térmico pode ter um valor atual líquido negativo e períodos de retorno de investimento muito elevados que normalmente são inaceitáveis.

keywords

solar thermal; economic analysis; comparative; domestic hot water; solar energy; photovoltaic; environment; sensitivity analysis;

abstract

This work aims to conduct a comparative economic analysis on different domestic hot water production systems: a conventional electric water heater, a ST (solar thermal) system, and a PV (photovoltaic) system. The systems were analysed for two different locations in Portugal, different daily hot water demands and under various economic conditions. A TRNSYS simulation model was built for all systems and validated with experimental or simulated data from the literature. A parametric study was made in order to assess the impact of increasing the number of panels and hot water storage capacity on the performance standpoint. Those results were utilized in an economic analysis to determine their economic viability considering different economic indicators. A sensitivity analysis was also conducted to study the impact of the price of electricity, the discount rate and inflation of prices of electricity on the viability of SWHS (solar water heating systems). The results showed that a photovoltaic solar water heating system is better than a solar thermal system from the economic standpoint mainly due to a lower investment cost and low maintenance. A solar thermal system still has better performance due to a higher efficiency at converting solar energy to heat. The economic conditions and DHW (domestic hot water) profile have a big effect on the viability of these investments, as the research showed that for low electricity prices and low hot water necessities, a ST can have a negative NPV (net present value) and high payback periods which are usually not acceptable.

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Nomenclature

SWHS – Solar water heating systems
DHW – Domestic hot water
HTF – Heat transfer fluid
ST – Solar thermal
PV - Photovoltaic
PV/T – Photovoltaic- thermal
STP – Solar thermal panel
PVP – Photovoltaic panel
FPC – Flat plate collector
ETC – Evacuated tube collector
ICS – Integral collector storage
CPC – Compound parabolic collector
PTC – Parabolic through collector
NPV – Net present value
DPP – Discounted payback period
SPP – Simple payback period
IRR – Internal rate of return
LCoH – Levelized cost of heat
LCoE – Levelized cost of energy
CCF – Cumulative cash flow
CDCF – Cumulative discounted cash flow
DCF – Discounted cash flow
d – Discount rate
CF – Cash flow

1. Introduction

The transition from non-renewable energy sources to renewable ones, has been one of the main topics discussed worldwide. According to millennials, climate change is the most important problem in the world and there is a big need for political and economic changes [1]. In order to tackle these demands, it is crucial to shift from finite resource intensive energy sources to renewable ones. Domestic consumers will play an important role in this transition, and the use of renewable resources for self-consumption is spreading all over Europe supported by national sustainable energy policies [2]. In 2017, Europe reached a value of 35 GW_{th} (giga-watt thermal) of total installed thermal capacity, with an area of 50 million m^2 [3].

Solar water heating systems (SWHS) have become more frequent in domestic households due to the energy efficiency requirements of residential buildings, due to the energy cost savings associated with them and to the fact that these can be installed in any climate. In 2017, the International Renewable Energy Agency (IRENA) identified that, from the cost effectiveness point of view, solar PV (photovoltaic) and solar heat in buildings had negative substitution costs, meaning they were cheaper than conventional technology [3]. Despite these advantages, there's a couple of hurdles to be fought. Domestic consumers tend to only replace their heating system because of either a breakdown or a malfunction of the equipment. Not only that but, usually, the fastest solution to these issues is the replacement of the existing equipment by a similar one, making it harder to integrate renewable energy systems. However, solar water heating systems may not be economically viable due to a few important factors such as solar radiation, equipment costs and efficiency, water consumption profiles and electric energy cost.

In recent years, the small-scale (single-house, multifamily houses, etc.) market share of solar thermal systems has been declining mainly due to photovoltaic systems and heat pumps [4]. The introduction of new technologies such as PV/T (photovoltaic-thermal) panels can also contribute in a small amount to this fact. This reality strengthens the need for a correct mean of comparing different solar alternatives than can be used for domestic hot water production from the performance and economic standpoints and compare them with some conventional alternatives which may be cheaper in the short-term. The initial cost of conventional water heating systems is much lower than the cost of a solar water heating system but when looking at the increasing energy prices and inflation, this statement becomes easily refutable since solar water heating systems exist to lower the necessity of purchasing electricity thus reducing the overall costs of solar systems.

2. Background

To assess the economic viability and performance of a solar water heating system there are some important aspects to consider: the type of system, solar energy availability, water heating needs, technology costs, electric energy costs and potential legal constraints. There are two main types of system that can use solar energy for domestic water heating: solar thermal systems and photovoltaic systems. In this chapter, a view of these systems will be given to give an insight on the systems involved and its components for this work.

2.1. Solar thermal water heating systems

Producing hot water using solar energy is not a recent method and it has been largely optimized in the past years. A solar thermal system converts solar energy into heat which is then used to increase the temperature of a fluid. The components usually found in a solar thermal system are the following [5]:

- Solar collector/Solar panel: converts solar energy into thermal energy.
- Heat transfer fluid (HTF): transports heat from the panel to a storage tank.
- Heat-exchanger: transfers heat from the heat transfer fluid to domestic hot water.
- Storage tank: stores hot water whenever it is not being used.
- Pumps: circulate the fluid within the system and control its flow rate.
- Auxiliary unit: assists the main system when it lacks solar heating capability.

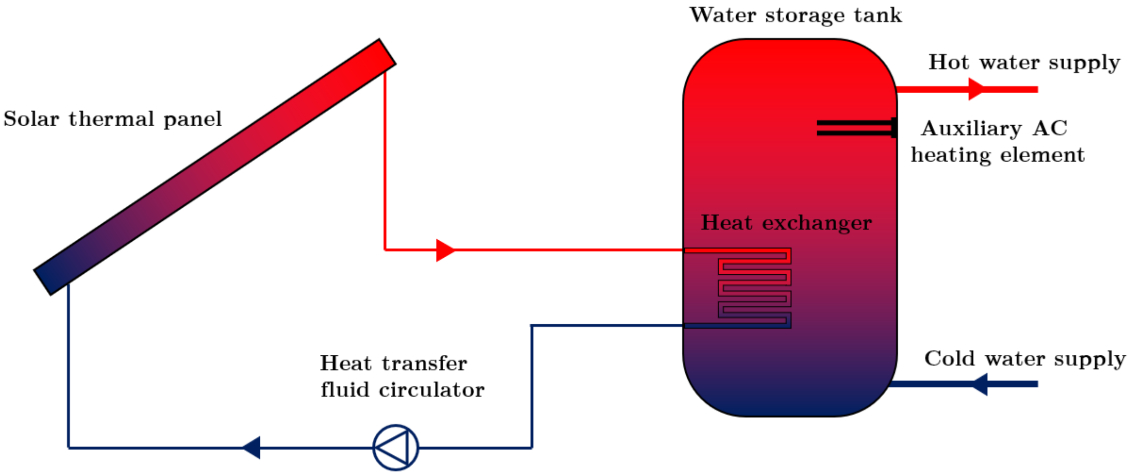


Figure 2.1 - Simplified schematic of a solar thermal DHW system

Although the mentioned components are the ones more often found in these kinds of systems, some may be absent since a system's equipment depends on the type of application and the atmospheric conditions on the site where it is installed. An in-depth description of the different components and equipment will be presents in the next sections.

2.1.1. Active *versus* Passive Solar Water Heating Systems

When it comes to the typology of these systems, they can be divided in two: active and passive systems. Active systems are the ones that have pumps and controls to circulate fluid inside the system. Within this type of system, there are direct and indirect circulation systems [6].

In a direct circulation active system, a pump circulates water throughout the solar collector and into the storage tank. This option is more suitable for locations in which air temperature does not allow water to freeze. The alternative is an indirect circulation active system, where instead of water, there is an HTF being circulated from the collector to a heat exchanger in a closed circuit. This fluid is then responsible for heating the domestic water inside a storage tank. These kinds of systems are more popular is places where climate conditions allow water to freeze since the heat transfer fluids used have a lower freezing temperature than water.

Table 2.1 – Advantages and disadvantages of direct and indirect active systems

System	Advantages	Disadvantages
Direct system	• Lower overall costs • High efficiency	• Freeze risk • Overheating risk
Indirect system	• Little risk of HTF freezing or overheating	• Higher operational costs • Higher maintenance

Passive systems, on the other hand, are divided in two main types: integral collector storage and thermosiphon systems. An Integral Collector Storage (ICS) is a system in which the collector and the storage tank are combined, without need for a pump to circulate water between two different components. In this arrangement, an insulated glazed box absorbs solar radiation and transfers it by means of natural convection to water that circulates inside insulated tubes located inside the collector. Hot water then circulates thanks to gravity or the pressure of cold water being forced inside the tubes [7]. Another kind of passive system is the thermosiphon system where the collector and tank are close to each other. The HTF circulates through the collector, which is installed directly below the storage tank, and as it rises in temperature, it flows to the top of the collector and into the tank, heating the stored water. Thermosyphon systems can also have an AC resistance located inside the storage tank to compensate for the lack of heat production from the collector.

Table 2.2 – Advantages and disadvantages of direct and indirect active systems

System	Advantages	Disadvantages
ICS system	• Cheap	• Small capacity • Freeze and overheating risk
Thermosyphon system	• Roof-mounted (usually) • Cheaper than active system	• Heat losses to environment

2.1.2. Solar collectors

The most important component or a solar water heating system is the equipment capable of converting solar energy into heat that subsequently is responsible for increasing water temperature. This heat can be generated and transferred in different ways and, therefore, different types of solar collectors are capable of such. The main types of collectors are [8, p. 125]:

- Flat-plate collectors (FPC)
- Compound parabolic collectors (CPC)
- Evacuated-tube collectors (ETC)

Flat-plate collectors are the most common type of solar thermal collectors in domestic applications, and these can be classified as glazed and unglazed. The former are characterized by having a glass or polymer cover while the later do not.

Unglazed flat-plate collectors are a very cost-effective manner of preheating water for domestic or industrial applications [8, p. 132]. These collectors are composed by a dark metal or plastic plate that absorbs sunlight and transfers it to a fluid that passes through or behind said plate. Since this kind of collector has no way of preventing heat loss to the environment (when ambient temperature is lower that the panel's), it does not have the ability to retain heat, ergo leading to lower operating temperatures when compared with the alternative. These panels are good for applications such as swimming pool water heating or agricultural applications since they do not demand high temperature water.

Glazed FPC's on the other hand, manage to "trap" heat inside them by having a well-insulated structure that mimics the greenhouse effect. As mentioned previously, these have a glass cover that promotes solar radiation transmission and reflects radiation back to an absorber plate (typically in a dark colour) that retains and transfers heat to the working fluid inside the tubes. These components are mounted inside a well-insulated case which has the objective of protecting all elements from bad weather conditions and to prevent heat loss through the sides and back of the collector. Figure 2.2 shows a glazed FPC [9].

Figure 2.2 - FPC solar thermal collector

Another kind of solar collector is a CPC or Compound Parabolic Collector which, as the name mentions, have a parabolic shape instead of a flat one. These systems consist of a parabolic "mirror-like" surface that concentrates all received radiation, from different angles, into a small area. CPCs are suitable for situations where a fluid is needed at a very high temperature, as high-pressure steam, or superheated fluids, such as electricity generation or food processing. These systems will not be studied during this dissertation due to the fact of not being usually used in domestic hot water production. This type of collector is also named as Parabolic Through Collector (PTC). Figure 2.3 shows an installation of these types of solar collector for energy production purposes [10].

Figure 2.3 - Concentrating solar power plant in the Mojave Desert (USA)

The last genre of solar collector is the ETC or evacuated-tube collector. These are made of multiple glass tubes connected in parallel and housed within a protective structure for physical protection and insulation [11, p. 505]. Inside these vacuum-sealed tubes, which prevent losses through convection and conduction, there is a heat pipe filled, usually, with an alcoholic substance. This kind of fluid, has a low evaporation temperature, is heated inside the tube until its phase changes from liquid to gas. Since a phase change occurs, the gas flows to the top of the heat pipe where a condenser bulb is located and surrounded by water (or a water/glycol mixture). Through another phase change, the fluid releases all energy heating up the surrounding liquid/mixture and then flowing back down the heat pipe. Like FPC's, this type of collector can absorb both direct and diffuse radiation but have a higher efficiency at low incidence angles, meaning it has an advantage in daylong performance over FPC's [8, p. 138]. ETC's are more expensive and more fragile, but they usually grant higher fluid temperatures. Evacuated-tube collectors are suitable for domestic hot water production in locations where very cold winters occur since they have less heat loss to the surrounding environment. Figure 2.4 shows an ETC [12].

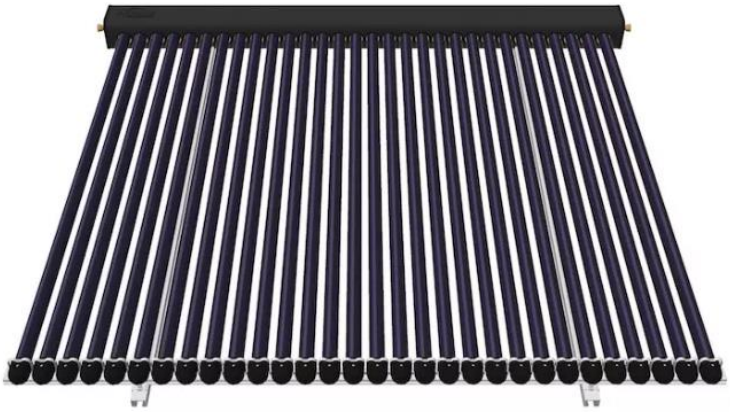


Figure 2.4 - ETC solar thermal collector

2.1.3. Heat transfer fluids

In solar water heating processes, it is important to maximize the amount of heat transferred from the collector to domestic water. Heat transfer fluids play a crucial role in this task since they are responsible for storing heat momentarily and transfer it as efficiently as possible. The kind of solar water heating system usually dictates the type of HTF to be used but, geographic location, components' materials, environmental aspects and fluid deterioration also have an impact in this selection [13, p. 61].

To select a heat transfer fluid, one must bear in mind its physical properties which can make or break a water heating system's size, efficiency, and longevity. The most relevant properties are viscosity, specific heat, volume expansion coefficient, freezing point, boiling point and flash point [13, p. 61].

The heat transfer fluids usually found in solar thermal water heating systems are water, water/glycol mixtures, hydrocarbon oils and silicones.

Water is a fluid that is very abundant and is very good at transferring heat since it has a higher specific heat value than most fluids. Despite this advantage, water is not suitable for very cold climates since it can freeze at 0°C. If using untreated water, issues may occur due to the eventual presence of substances such as calcium carbonate, whose solubility decreases with temperature increase [13, p. 61], which can clog up a solar water heating system.

Another type of heat transfer fluid is a water/glycol mixture. It consists of mixing propylene glycol with water usually at a 50/50, 60/40 or 70/30 glycol to water ratio [13, p. 62]. This heat transfer fluid has a lower freezing point than water, making it more suitable for very cold climates and a higher boiling point than water. Despite these advantages, water/glycol mixtures have downsides due to its decomposition which produces sludge and organic acids.

Hydrocarbons are a good substitute to water/glycol mixtures and are classified as either synthetic, paraffinic mineral oil or aromatic refined mineral oil. Synthetic hydrocarbons are the ones recommended for DHW since the other alternatives are toxic and can require extreme care when being used. This kind of heat transfer fluid is nontoxic and can remain stable for 5 to 10 years, meaning it requires less maintenance.

Silicones are fluids which are inert, virtually nontoxic, are odourless, do not freeze or boil and have a high flash point. These are typically more expensive, but have a life expectancy of 20 years or more [13, p. 63]. The disadvantages of silicones as heat transfer fluids are their higher viscosity, which requires more energy expense to pump it, the lower heat capacity, and the fact that they can leak very easily.

2.1.4. Heat exchangers

A heat exchanger is an equipment with the task of transferring heat between two or more fluids and are present in indirect water heating systems. These components are made of a conductive material, such as aluminium, stainless steel, copper, bronze or cast iron [14].

Heat exchangers are divided in two categories: internal and external. In the internal heat exchanger configuration, there is a direct contact between the stored water and the heat exchanger while in the external configuration there is not.

An immersed coil or coil-in-tank heat exchanger is a very frequent type of heat exchanger in solar water heating systems. It can consist of single-wall or double wall heat exchanger, depending on the type of fluid that runs inside it. If toxic heat transfer fluids are used, then a double-wall coil is needed to prevent contamination of potable water inside the tank. These heat exchangers usually are cheaper and have a good efficiency, but less than some external heat exchanger alternatives.

As mentioned previously, heat exchangers are usually made of metals such as aluminium or copper, and this means their thermal conductivity is very high. Thermal conductivity (k) is described as a measure of the ability of a material to conduct heat [15, p. 627]. This means, the higher the value of k, the higher is the amount of heat capable of being transferred.

2.1.5. Storage tanks

Storage tanks are one of the components of a water heating system and these are usually made of steel which makes them easy to install, but it is possible to have them built in concrete or even fiberglass [14, p. 181] and have the task of storing potable hot water and retain its thermal energy as much as possible. To achieve this goal, it is key to have a great insulation on the walls of the storage tank and there are several kinds of materials capable of fulfilling this task. Conventional storage tanks usually have an insulation material of one of two main types: inorganic fibrous materials and organic foamy materials. When talking about inorganic fibrous materials in insulation, these are normally glass wool and rock wool which, in the Europe, accounts for 60% of the market share and when referring to organic foamy materials, these are usually expanded polystyrene (EPS) and extruded polystyrene (XPS) which account for 27% of the market [16, p. 74].

A very important aspect regarding a storage tank is its thermal resistance (R), which depends on two variables: thermal conductivity (k) and thickness (L) of the insulation layer. With Equation 2.1, we can understand that the thermal resistance is inversely proportional to the thermal conductivity of the material and directly proportional to the insulation thickness. This means that one can increase the thickness of the insulation so as to reach a very high thermal resistance and minimize the amount of heat lost through the wall of the storage tank or reduce the material's thermal conductivity whilst maintaining the same insulation thickness to reach the same goal.

$$\mathrm{R} = \frac{\mathrm{L}}{\mathrm{k}} \tag{2.1}$$

Regarding storage tanks' sizing, these equipment are usually dimensioned proportionally to the total solar collector area, and the normal range is between 30 to 100 litres/m^2 [17, p. xxii]. The conditions of the water inside the storage tanks can be classified as mixed or stratified (Figure 2.5), the latter being a tank where there is a temperature gradient between the water at the top of the tank (hot water) and the water in the bottom (cold water) and the former a tank where the water is at the same temperature in any location of the tank.

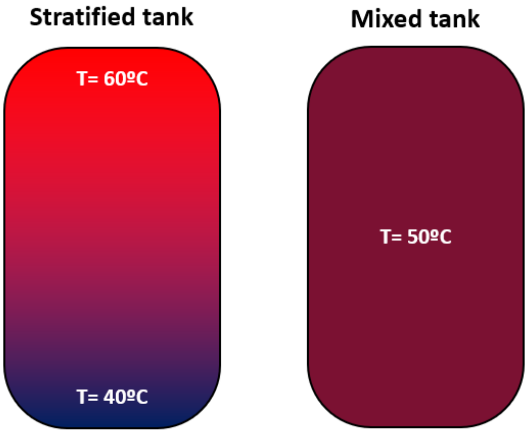


Figure 2.5 - Stratified vs mixed tank temperature distribution

2.1.6. Pumps

Pumps are also an important component in domestic solar water heating systems, whenever an active system is in use. These components have the responsibility of circulating the heat-transfer fluids through the system, compensating for pressure losses. Pumps are very important to make sure a system works flawlessly, and regular maintenance is advised to prevent malfunctions. If water is being used as an HTF, the pump must have a non-corrosive material, such as stainless steel or bronze. These components are important to mention because they are responsible for some parasitic energy consumption which can affect the economic viability by a smaller or bigger amount, depending on the system.

For ST systems, despite sometimes being called pumps, the system responsible for circulating the HTF in the primary circuit is called circulator. Figure 2.6 shows an example of a ST system circulator [9].

Figure 2.6 - Example of a Grundfos HTF circulator

2.1.7. Auxiliary units

Another important component in a domestic water heating system, is the auxiliary unit which responsible for granting heat to the stored water whenever the solar panels are uncapable of heating it until the desired temperature. In situations where solar radiation is not high or has a short time span, it is imperative to have an alternative way of heating water. An auxiliary unit may consist of a simple resistance inside the water tank or of a boiler, that can be fed by gas (natural, butane or propane) or fuel oil, the latter being less common due to environmental reasons.

These systems despite being important to grant hot water at a desired temperature, lead to an increase of the overall costs of systems since they require energy acquisition. The correct system implementation for a certain location may maximize the heat output from the Sun, diminishing the use of auxiliary units.

2.2. Solar photovoltaic water heating systems

Another system capable of heating domestic water using solar energy is a solar photovoltaic (PV) system. In this case, a PV panel is utilized to produce electricity which is then used to feed a resistive heating element that increases water temperature by releasing heat. The components usually encountered in these systems are:

- Photovoltaic panel: generates electricity from solar radiation.
- DC Resistive element: generates heat to increase water temperature.
- Storage tank: stores hot water for when it is not being used.
- Auxiliary AC heating element: provides electricity whenever the panels cannot meet the electricity demand.

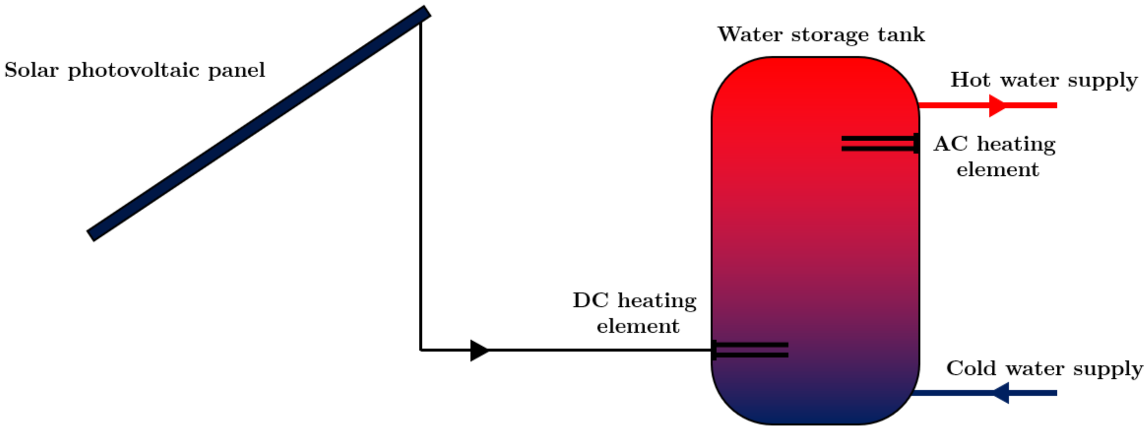


Figure 2.7 - Simplified schematic of a photovoltaic solar water heating system

Some of the aforementioned items (storage tank and auxiliary unit) have been described in sections 2.1.5 and 2.1.7 and will not be mentioned within the next pages since they are common to photovoltaic and solar thermal systems.

2.2.1. Photovoltaic panels

Electricity production from solar radiation, requires a photovoltaic panel. PV panels (Figure 2.8) produce electricity by collecting energy from high-energy photons and transfer it to free electrons in a semiconductor material inside the panel, generating direct current (DC) [13, p. 75]. These panels are built of different cells connected together in a circuit and are capable of providing power within the range of 80 to 400 watts [11, p. 439], meaning a PV system is usually combined of multiple panels, in order to produce the necessary power to feed a domestic household and all its electrical necessities.

Photovoltaic panels have become more frequent in domestic households due to the increase on their efficiency in most recent years and because of the decrease on the overall cost of acquisition or the price per watt of installed power. Nowadays, solar modules have a cost of less than one euro per watt-peak (€/Wp) meaning that a photovoltaic panel is currently cheaper than a solar thermal panel.

These panels are usually divided in two main types: monocrystalline and polycrystalline. Monocrystalline photovoltaic panels usually offer a higher efficiency, in the range of 13% to 19% but are usually more difficult to produce and thus more expensive than the alternative polycrystalline panels which offer a lower maximum efficiency (around 14%) but are cheaper and easier to manufacture [13, p. 78].

In a domestic water heating system, a photovoltaic panel would be responsible for producing electricity to power a resistive element that would heat up water to a desired temperature. Considering the size of the tank and the power output needed to fulfil that task the number and power of the PV panels should be carefully chosen to prevent shortage of power. Oversizing a system can be an option which assures electricity generation and could, potentially, lead to electricity sales to the grid but has a higher initial cost that could lead to a system that is not economically viable.

Figure 2.8 - Monocrystalline and polycrystalline photovoltaic panels [18]

2.3. Solar energy

The most important variable when determining the viability of a solar water heating system is the amount of solar radiation exposure. To have an efficient and productive system one must not only choose the correct system setup for a certain household but also to analyse the amount of solar energy available in the location in which it is being installed.

Only a small amount of all the solar radiation that reaches the Earth's atmosphere is available at the surface of the planet because most of it is scattered, reflected out to space, and absorbed by the atmosphere. Out of the amount of solar radiation that enters our atmosphere, some of it is scattered and the rest reaches the surface directly. The scattered radiation is also called *diffuse* radiation, and only a small amount of it reaches the surface of the planet. The other part that comes directly through the atmosphere is called *direct* or *beam radiation*. This solar energy that reaches the Earth's surface is called insolation. All in all, the total solar radiation depends on the thickness of the ozone layer, the distance travelled through the atmosphere, the amount of particles in the air and the extent of the cloud cover [8, p. 95].

Insolation also depends on the time of day, day of the year and on a location's latitude. These three main aspects determine the number of hours of a location's exposure to sunlight during a day and the orientation of the sunlight.

When considering a DHW system, one must know an important variable called incidence angle of solar radiation in a solar panel. The incidence angle, or angle of incidence, is the angle measured between an incoming beam of radiation and an imaginary perpendicular line to a surface [13, p. 219]. The lower the incidence angle, the higher is the insolation of a given location which means that the maximum power output of a solar panel should be at noon which is when the sun is at its highest point.

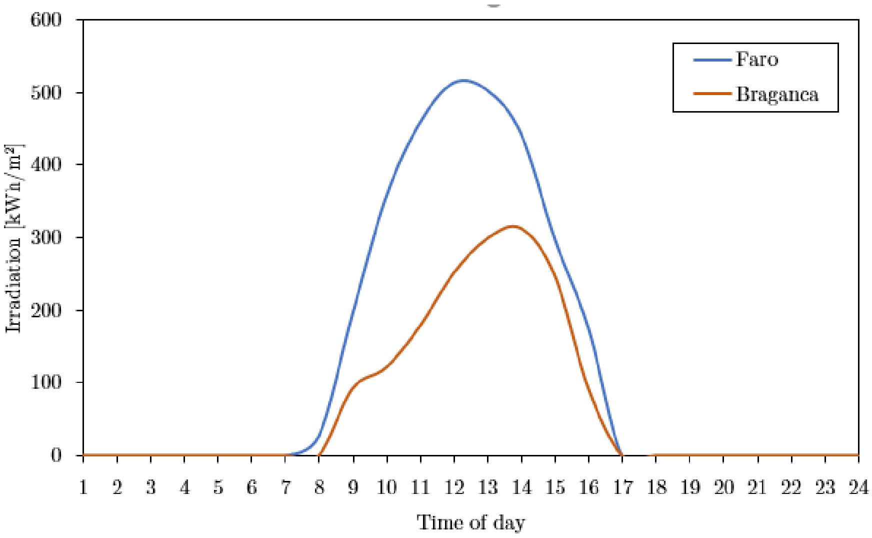


Figure 2.9 - Distribution of solar irradiation in a day in January for two different locations [19]

Another important aspect in these systems is the panel's tilt angle, which is the angle between a panel's plane and the horizontal. The correct tilt angle should be the one that maximizes the quantity of solar rays that hit the plane of the panel. This means that the correct position is the one where the solar rays make a 90° angle with the panel's surface. In real life, the tilt angle that is equivalent to the latitude of its location should serve the power collection needs all year round [13, p. 14].

The collector orientation is also a very important variable when installing a system's panel, but it is usually an easy decision. The panel should always face the middle of the sun's daily path within ±15° East or West of true South, and not magnetic South plus, for a DHW system, facing the panels to the West should maximize its performance since ambient temperatures are usually higher in the afternoon [13, pp. 14–17].

The amount of solar irradiation in Earth's surface has been largely studied and, therefore, is widely available in many kinds of resources. Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) maps are a very good tool to determine the amount of solar energy available at a certain location. These maps provide an average value that can usually lead to a reliable estimation of the long-term system performance. Figures 2.10 and 2.11 show GHI and DNI maps for Portugal, respectively [20].

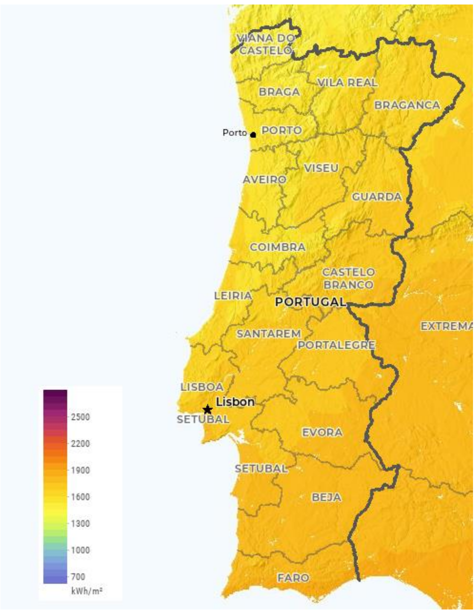


Figure 2.10 - GHI map for Portugal

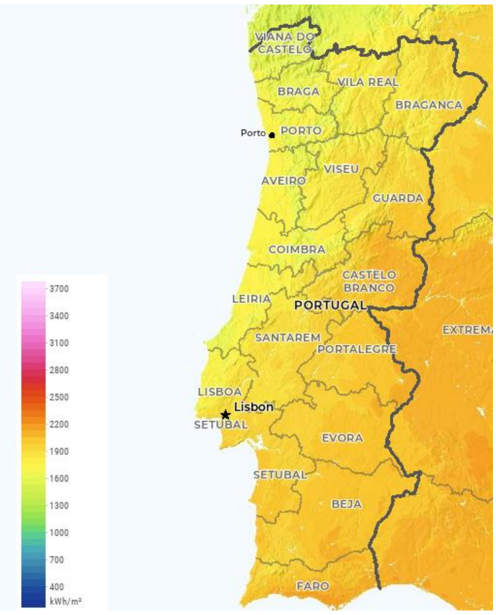


Figure 2.11 - DNI map for Portugal

2.4. Water consumption profile

When considering a domestic solar water heating system and its dimension, besides the environmental conditions, one must account for the hot water needs for the households where it is being installed. The amount of hot water demand over a certain period (days, weeks, or months) varies from person to person, and is not a constant variable throughout a month or year.

To better determine hot water demand, the most frequent approach is to consider average values for a few frequent tasks (manual dish washing, showering, bathing, or cooking) and then, depending on the size of the family, determine the overall household hot water needs. Depending on the number of individuals in a house, then we can estimate the water consumption profile throughout the day and then extrapolate it for a month or year. An example of a daily water consumption profile is shown in Figure 2.12 and was extracted from one of the yearly profiles used in this work.

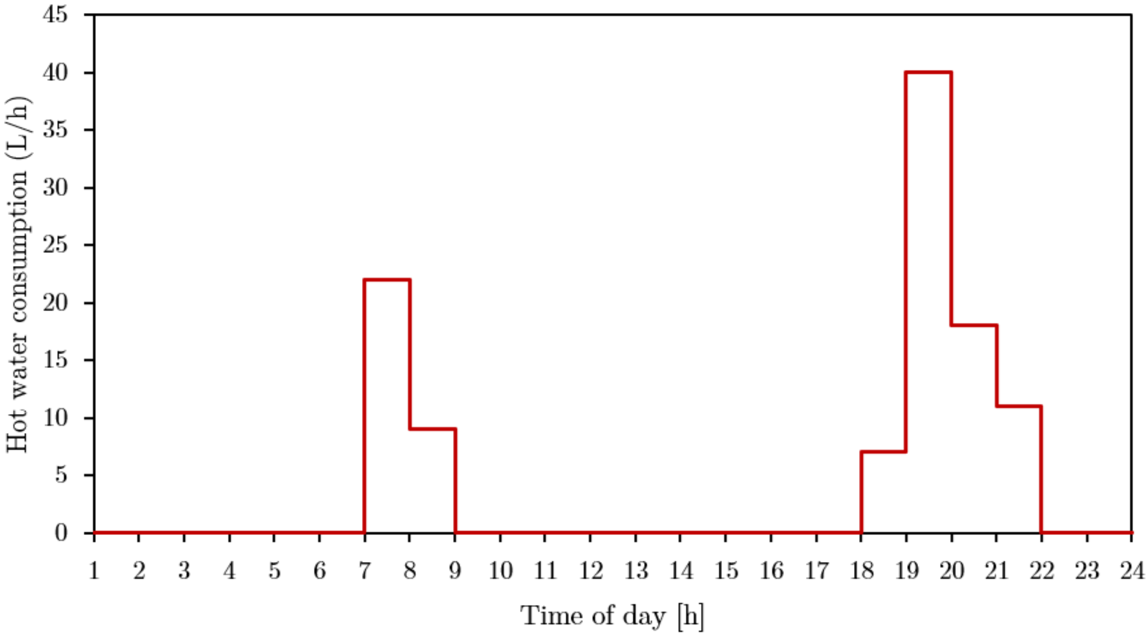


Figure 2.12 - Example of a daily domestic hot water load profile (Source: DHW profile)

The amount of water consumption directly affects the number of solar panels that should be installed also the size of the storage tanks, for instance. It also affects the amount of energy that needs to be purchased to cover the lack of solar radiation, since a greater water consumption requires more power to heat water which increases the overall cost.

2.5. Energy cost

When assessing the economic viability of the installation of a SWHS, one must also consider the price of heating water with a conventional system. Electric and gas water heaters can be the most affordable systems if the price of electricity and gas is sufficiently low that the big initial investment in a new system becomes unattractive from the economic point of view. In some countries, natural gas and electricity are cheap enough to rival the environmentally friendly alternatives. For instance, in locations with a low average ambient temperature and low solar radiation exposure, the conventional systems can be cheaper because of the higher initial investment of solar alternatives suitable to colder climates or the lower amount of available solar radiation to produce electricity which can increase the overall cost of heating domestic water. Despite all this, solar water heating systems have the tendency of becoming cheaper and more efficient in the future, which should lead to an increase in their economic attractiveness even in places where electricity and gas are low.

3. State of the art

3.1. Introduction

Economic viability is, in most cases, the most important factor when evaluating a project. A study conducted within the scope of "The FROnT project", aimed to identify end-users' decision making factors for heating and cooling systems within the European landscape. The most important criteria for respondents was the total economic savings with 84%, and the initial investment was the third with 75% of responses followed by maintenance with 71% [21, p. 10]. This means that, out of the 4 most important criteria for European users, 3 are directly associated with economic factors.

Today, an engineer must have the tools to not only provide an insight on the technical viability of a project but also to understand if it is the best solution from the economic standpoint, when compared to other alternatives. Engineering economics is defined as a science that deals with quantitative analysis useful for selecting the best alternative from several technically viable ones [22, p. 3]. Despite existing many techniques to evaluate the economic viability of projects, these "predictions" may be incorrect. This uncertainty should be considered when analysing a project, and this can be covered with a sensitivity analysis that takes some important variables and varies them in a likely range. To sum up, one can say that the economic viability of a project is associated with its overall costs, how it compares with other technically viable options from the economic point of view and with the degree of certainty of the overall analysis.

In this chapter, a review on the state of the art of economic analyses of solar domestic water heating systems will be present, bearing in mind the most important indicators when assessing the economic viability of these systems. This review considered recent work in this topic in order to have up-to-date conclusions instead of some that could not be applied to the current economic conditions.

3.2. Literature review

The economic analysis of domestic water heating systems has been largely studied in the past years, to correctly assess the best solutions for a given application. Even though solar energy is free, these systems usually have a big initial cost which, depending on the operating conditions and costs, may or may not compromise its economic viability. Also, the type of application (residential, commercial, etc.) usually determines the economic criterion more suitable for the said application. For residential/domestic applications, the metric that is more frequently found is the Payback Period (PP). The Net Present Value (NPV) and the Internal Rate of Return (IRR) are also indicators that can be used by some residential users [23, p. 7]. Another indicator that has been used in the last few years in domestic solar thermal systems is the Levelized Cost of Heat (LCoH), which is derived from the Levelized Cost of Energy (LCoE). To know the best solution for a given application, comparative analyses are conducted, considering different systems under the same conditions.

Michael and Selvarasan [24], compared a solar PV/T water heating system with a solar PV system and a FPC solar water heating system from the economic and environmental standpoint. It consisted of an experimental analysis of the three off-grid roof-mounted systems in Chennai, India, with the same aperture area (2 m^2) and catered to the needs of residential consumers. The flat plate collector had a thermal efficiency of 57,98% and the PV/T collector had a thermal efficiency of 30,16%. The PV panel and the PV/T panel had an electrical efficiency of 10,98% and 11,44%, respectively. From the cost point of view, the PV/T system was the most expensive, followed by the FPC system and the cheapest was the PV system. The overall annual useful thermal energy was higher in the PV/T system, then came the solar thermal system and the photovoltaic one had the least amount of useful thermal energy. Though, the previous order was not present in the economic analysis, where the ST system had the advantage, in the Simple Payback Period (SPP), Return on Investment (ROI), Benefit to Cost (B/C) ratio, IRR and Unit Cost of Energy (UCE), which should be associated with the lower initial costs. The PV/T system was the most attractive when it came to the NPV.

Experimental studies can provide a high degree of accuracy when studying economic indicators but are limited when it comes to versatility. The results are usually used to calibrate a simulation model that can study the same system in different conditions. Kalogirou et al. [25] successfully validated a new TRNSYS type (Type 99) for thermosiphon solar thermal collector systems, which proved to be more reliable (lower deviations from the empirical values) than the existing Type 45a. The system was then simulated for DHW production, in a small residential unit with a demand of 100 litres per day, in three weather zones (Freiburg, Naples and Larnaca). A parametric analysis was conducted to find the design configuration with the lowest SPP by varying some important parameters such as collector slope, tank volume, solar collector area, and others. Amongst other conclusions, the study managed to verify that the SPP is shorter with the decrease in the latitude (Larnaca < Naples < Freiburg) and that in Freiburg the SPP is mostly affected by the heat storage tank volume and in Naples and Larnaca the said economic metric is mostly influenced by the solar collector area. The only economic metric that was analysed in this paper was the SPP which is very easy to understand and to calculate but, does not consider the time value of money. Therefore, the analysis of the Discounted Payback Period (DPP) or other economic indicator could provide a more accurate assessment of future outcome of investments.

Panangiotidou, Aye and Rismanchi [26] compared 5 solar driven water heating systems for residential buildings in urban Greek areas (Heraklion, Athens, Thessaloniki and Florina). The chosen systems were an electric water heater (Baseline), a PV with electric heater backup (S1), a ST (FPC) also with electric heater assistance (S2), a PV/T again with electric heater (S3) and a PV with a heat-pump backup system (S4). The analysis considered approximately a daily hot water demand of 150 litres for each household which had 3 occupants. There were also considered to be shower and sinks water draw-offs, with a flow rate of 479 L/hour and 6 minutes duration and 161 L/hour and 1-minute duration, respectively. Both cases had 3 daily events. All the systems were modelled and simulated in TRNSYS, and an economic assessment was conducted along with a sensitivity analysis for the discount rate. The results were similar in all 4 cities, S2 and S3 had the most attractive NPV values, the latter being best in hotter climates (Athens and Heraklion) and the former more suitable for colder climates (Thessaloniki and Florina). S1 and the baseline case were not viable mainly due to the high electricity consumption which increases overall costs. S4 was not also viable due to higher electricity consumption (for the heat-pump) and initial costs. This study only considered electricity fed backup systems which is good from the environmental standpoint but could be worse from the economic standpoint when compared with a natural gas backup boiler, since this energy source usually has a lower cost per kWh. Another conclusion was that results attained could be applied on other Mediterranean locations with similar latitude values which receive similar solar radiation. Other economic indicators (PP and IRR) could have been studied since they can give a simple insight on the economic viability of the system to the residential consumer.

Louvet et al. [27] also led a comparative economic analysis of different (solar thermal vs conventional) household water heating solutions in five different European countries: Austria, Denmark, France, Germany and Switzerland. The economic indicator chosen was the Levelized Cost of Heat (LCoH), which had a formula developed in the scope of the IEA-Task 54. Different software was applied in each country according to the habits of each location, which leads to a lot of caution when directly comparing LCoH values of different countries. Single-family houses (SFH) and multi-family houses (MFH) were studied for each country, with statistically suitable number of occupants. The solar systems studied were active and had a glazed FPC, a storage tank and an auxiliary boiler, with different characteristics depending on the country. LCoH values for MFH were always lower than for SFH in each country. This study also concluded that solar technology for water heating purposes has higher a potential in countries where the fossil fuel costs are higher (e.g., Denmark) when compared to countries with lower prices (e.g., France). Excluding VAT and subsidies, only one solar system (in Austrian MFH) showed a lower LCoH value when compared with its conventional alternative. In France, the LCoH of a solar assisted system was the lowest of the five countries, but still was higher than the LCoH of a conventional system due to the competitive prices of natural gas. With the addition of VAT (which increases energy prices) and subsidies (which decrease initial costs of investments), the results could be very different. This aspect along with studying other countries (which was suggested by the authors), could be worth investigating.

Ben Taher et al. [28] studied the economic and environmental performance of solar thermal systems (forced-circulation, with FPC and ETC) in Moroccan residential buildings. The two systems were simulated using TRNSYS and MATLAB for a whole year, considering a typical meteorological year in 6 different zones. The economic analysis assessed the NPV, B/C ratio and PP (simple and discounted). A Life Cycle Cost (LCC) analysis was also applied to determine the overall costs of each system in every location in a 20-year life span, with different backup systems (butane, propane, and electricity). The ETC system proved to be the best in all zones, with a higher NPV and B/C ratio, lower PP and the lowest LCC for every type of auxiliary energy source. This outcome might have been led by the higher efficiency of the evacuated tube collector (87,42%) when compared with the flat plate one

(56,63%), and the lower initial cost. The lowest LCC was with butane boosting, mainly since this gas is subsidized by the government. Electricity was the most expensive out of all three options. Despite being in a lower latitude, the shortest payback period achieved was 10 years for the ETC system in Errachidia, which has a hot desert climate. This might be due to the initial investment considered (5600$ for FPC and 5000$ for ETC), which are higher than in some other countries. From the environmental standpoint, the ETC also provided the highest CO_2 emissions reduction, which might have happened because of being less dependent on auxiliary energy. This study assumed an occupation of 4 to 5 people per household and a daily hot water demand of 240 litres per day at 45°C.

Herrando and Markides [29] compared Hybrid PV/T systems with a PV alternative for domestic water heating and power production in the UK, a location located in a higher latitude than most of the studies in this field. Colder locations have the benefit of reducing the impact of the efficiency decrease of photovoltaic panels due to high operating temperatures but typically have lower amount of available solar radiation. A parametric study varying the fraction of the panel's surface covered by PV cells and the water flow rate was conducted to determine the best configuration regarding these two aspects. Thus, 5 PV/T systems were studied with 100% (2), 80% (1) and 60% (2) PV fraction. In 100% and 60% systems, one was optimized for better electrical output (higher water flow rate) and the other was optimized for better thermal output (lower flow rate). The 80% system was simulated at intermediate conditions. These systems were studied for a 3-bedroom terraced housed in London, with 4 occupants. The main takeaways are that the PV system has a lower DPP and NPV (total cumulative cost of the system over a 20-year timespan) than all PV/T systems, mainly due to the higher PV/T costs (incentives can be applied but do not change the outcome). Still, the results show that PV/T systems have a lot of potential to lower emissions and the primary energy consumption. The best PV/T solution was the one which fully covered the solar panel with PV cells and had a low water flow rate, thanks to the low temperatures usually reached in London. This configuration should be different in climates with very different conditions.

Gagliano et al. [30] evaluated the performances of solar systems while fulfilling Europe's average annual domestic thermal energy demand (1000 kWh per person) and annual electrical energy demand (3000 kWh). This study compared PV/T with PV-only and PV+ST systems in 3 European cities with different climate conditions (Freiburg, Split and Catania), sized to fulfil the whole electric demand based on the average possible electric production of PV panels in each location (8 panels for Catania and Split and 12 panels in Freiburg). TRNSYS was the software selected to simulate these systems. The first part of the analysis concluded that on average the efficiency of the panels (PV and PV/T) was higher the coldest location (Freiburg), due to the lower ambient temperature. For PV panels, Freiburg produced the highest amount of energy followed by Catania and then Split. For PV/T systems, Catania had the biggest amount of electrical energy produced, then came Freiburg and lastly Split. PV/T installations also produced more electric energy than

PV mainly due to the cooling effect of water in the panels, which reduced the efficiency loss with temperature (β). When it comes to thermal energy, PV/T produced 50%, 44% and 25% of the necessities in Catania, Split and Freiburg, respectively. The second part of the analysis had the intent of calculating the performance of systems with both PV and ST panels combined and compare them with the systems studied in the first part. The overall result was that PV/T systems had the best performance again, but PV+ST system proved to be very competitive with a small percentage of ST panels (10 to 20%) from the overall energy production and primary energy reduction standpoints. Finally, an economic analysis was made to compare all systems considered in the paper. The initial costs were higher in Freiburg due to the necessity of having a bigger panel area to fulfil the necessities, and the PV systems were cheaper followed by the ST systems. In the three cities, the PV+ST systems' economic viability decreases with the increase in the solar thermal percentage. In Split, PV/T systems have no economic viability mainly due to the low primary energy costs. Overall, PV systems have the best economic benefits (more revenue) due to high electricity prices and the low technology cost. Despite this, if thermal energy production is needed, PV/T systems have the advantage despite the higher initial cost.

Choosing the best solution for a given case can also be done via a decision-making tool, based on multiple criteria and their importance. Casanovas-Rubio and Armengou [31] used this approach to create an assessment tool to select the optimal solution for a domestic water heating system considering economic, environmental and social factors which was then tested in a case study. The first stage consisted in finding the most relevant aspects and then defining them as indicators. Then two surveys were conducted to determine a statistically correct weight for each indicator based on panellists' opinion. The economic indicators had a higher weight, but solar systems should be preferred to conventional alternatives due to environmental reasons despite having a higher cost. Then, multiplying the weight with the indicator an index would be obtained. The lower the index, the best the alternative. Two flat plate and three evacuated tube collector systems were considered combined with two types of conventional backup system (gas and electricity powered). The conventional systems were also studied alone despite this not being allowed by current legislation in Barcelona, which totalled 12 different systems. According with Barcelona's local laws, the methodology was studied for a changing room designed for 100 people, with a 1000 litres demand per day at a reference temperature of 60°C. The results showed that the gas-powered conventional system was the cheapest due to low gas prices, and then followed the solar + gas systems. Acquisition, installation, and maintenance costs make the solar alternative more expensive. The FPC solar systems also had a lower impact index than the ETC alternatives. When it comes to CO_2 emissions, the solar systems had a similar index when compared to each other, and both had a lower quantity of emissions than the conventional ones. Considering all the factors, the natural gas-fed boiler had again the lowest impact. Lastly, two sensitivity analyses were conducted, the first changed the weights increasing the importance of energy consumption and CO_2 emissions and turned one of the

FPC systems with gas backup into the best solution while the second one changed the reference by which the indicator index was calculated, and it led to a similar conclusion. These analyses also confirmed the idea that FPC systems are in general better than ETC systems. Expanding this methodology to the average consumer and its tendencies can lead to a very good understanding of the market needs and trends and to a correct assessment of the best solution to a given case.

Axaopoulos and Fylladitakis [32] evaluated the performance and the economics of hybrid PV/T systems and compared the results with conventional alternatives for domestic hot water production (electricity, gas and oil). The system, simulated in TRNSYS, consisted of a flat-plate PV/T collector, an inverter to convert DC power from the photovoltaic modulo to AC power, a 300 L storage tank with an immersed heat exchanger, a pump, a diverter, and a tee piece to mix hot and cold water. The panel area was different for all the locations (5,68m^2 for Athens, 12,78m^2 for Munich and 24.14m^2 for Dundee) with the goal of producing the same amount of heat which also leads to a different amount of electricity generated. The working fluid was a water/glycol mixture (60%-40%) that flowed through the system whenever the temperature at the collector outlet exceeded the bottom tank temperature by 5°C. The daily water load was considered to be of 200L at 50°C. The efficiency of the auxiliary heaters was of 100% for electricity and 91% for oil and gas. The economic analysis evaluated the net present value (NPV) of this technology in the cities of Athens, Munich and Dundee which have different economic conditions and was coupled with a sensitivity analysis for the discount rate. The project lifetime was of 20 years. The results showed that from the yearly heat production standpoint, the best results were for the system in the city with the most amount of available solar irradiation which is Athens, followed by Munich and Dundee. The total yearly electricity production results showed a reversed order, with Dundee producing more than Munich and Athens, due to the higher amount of photovoltaic panel area but the electricity per m^2 was higher in Athens, since there is a smaller collector area, followed by Munich. The most efficient system was located in Athens, and the least efficient was the one simulated in Dundee. From the economic standpoint, the highest NPV was for Athens followed by Munich and Dundee. This technology was economically viable to substitute all heating alternatives in Athens but, in Munich only the replacement of electricity was proved to be acceptable and in Dundee there was no economically viable case. This conclusion is mainly due to the lower prices of electricity, oil, and gas in Dundee where the bigger initial investment due to a higher collector area cannot compete with the energy prices. The sensitivity analysis proved that the replacement of a heating oil water heater would become viable at a reduction of more than 60% of the discount rate and the replacement of a natural gas water heater would not be economically viable this way. For Dundee, the sensitivity analysis showed that a higher than 10% reduction on the discount rate would turn a PV/T system more viable than an electricity fed water heater but would never be more advantageous than the other alternatives.

Matuska and Sourek [33] compared a solar domestic water heating system with solar thermal panels and with photovoltaic panels. There were three systems simulated in TRNSYS: a PV system with MPPT, a PV system without MPPT and a ST system. Each system had the goal of producing hot water at 55°C with a daily hot water load of 160 litres. The system was simulated under the climate conditions of Prague. All systems were coupled with a 200L storage tank. The PV system had a maximum power of a 2 kW_p from 8 polycrystalline solar panels with a total area of 13,2 m^2 connected in series to a DC resistive element inside the storage tank. The ST system consisted of two flat-plate collectors with a total area of 4,5 m^2 with the task of heating a HTF that circulated between the panels and an immersed heat exchanger located inside the tank. The auxiliary heating necessities were calculated from the tank outlet temperature and the necessary DHW temperature. The results showed that the PV system with MPPT mode on yielded more electricity production leading to a lower dependence on auxiliary energy. The solar thermal system had the best results, being capable of fulfilling 61% of the total energy necessities while the alternatives were only capable of having a solar fraction of 48% and 29% for the PV systems with MPPT on and off, respectively. The authors also conducted an economic evaluation of the said systems for a timeframe of 20 years in order to assess their viability from this point of view and compared it with a conventional grid connected water heating system. The price of electricity (0,10€, inflated at a rate of 5% yearly) contributed to the conclusion that the solar systems took nearly 15 years and more than 15 years for the ST and the PV systems, respectively, to match the total costs of a conventional system. This showed that the solar thermal alternative is still more competitive than other alternatives using photovoltaic panels. One can also conclude that the price of electricity can also determine the economic viability of these projects since a conventional system powered by a low electricity tariff can be cheaper in the short term than a solar water heating system but, in the long term, the solar alternatives are more attractive.

4. Methodology

The purpose of this work is to conduct a comparative analysis of different solar domestic hot water production systems mainly from the economic standpoint but also looking at the energy production, efficiency, and environmental benefits of each system. To do so, the chosen strategy consisted of the following main steps:

- Choose the most relevant solar water heating systems and configurations.
- Determine the case studies that should be analysed considering different hot water load profiles and different locations.
- Develop three TRNSYS models, one for each system, and validate these with experimental or simulated data from other studies.
- Conduct a parametric study associated with the storage capacity of the tanks and number of ST/PV panels in order to determine the performance of different configurations under different conditions.
- Ascertain the costs of the different systems configurations and conduct an economic analysis on the results obtained along with a sensitivity analysis considering the most relevant variables.
- Compare the results of each system from the performance, economic and environmental standpoints and determine the best alternative for different hot water consumption profiles and locations.

At the end of this analysis, one should be able to correctly determine the best water heating solution and configuration for a given case from the economic, energy production and environmental standpoints.

4.1. System description

The first stage of this work consisted of selecting the domestic hot water production systems and their characteristics in order to compare them. The first one is a baseline/reference system consisting of a conventional electric water heater (S1). The second system (S2) is a ST water heating system and S3 is a PV solar water heating system.

The baseline/reference system is a conventional electric water heater, an equipment that is present in millions of households worldwide. This system consists of a water storage tank with an immersed resistive element connected to the electrical grid and are usually available in different capacities and have different heating power. The bigger the power of the resistance, the faster is the heating process which makes hot water available in a short time span. On the contrary, the bigger the capacity of the equipment, the longer it takes to reach its setpoint temperature. The capacity was chosen in order to fulfil the amount of hot water needed for each type of load profile and considering the lower cost per litre of stored water. Normally, the higher the storage capacity, the lower is the cost per volume of stored water so, a 200L system was chosen as a reference. The characteristics of the simulated system are present in Table 4.1.

Table 4.1 - Description of the reference system (S1)

Capacity	200 L
Power of heating source	2200 W
Heating efficiency	100%
Maximum operating temperature	65°C
Height	1570 mm

S2 consists of a solar water heating system with a solar thermal FPC connected to a storage tank via a heat exchanger located inside the latter. This system is characterized as an indirect forced circulation system since a pump transports a heat transfer fluid in the closed primary circuit between the collector and the storage tank. Inside the storage tank, there is an electrical 2000W AC resistance, connected to the electrical grid, to assist whenever necessary. The temperature inside the tank is controlled by a thermostat responsible for activating/deactivating the resistance and by a controller with the function of activating/deactivating the pump. The characteristics of the main components involved in this system is available in Table 4.2 [34].

Table 4.2 - Description of the solar thermal system (S2)

FPC total area	2.65 m^2
FPC aperture area	2.47 m^2
Optical efficiency	0.808
Linear heat loss coefficient	3.334 $W \cdot (m^{-2} \cdot K^{-2})$
Quadratic heat loss coefficient	0.02 $W \cdot (m^{-2} \cdot K^{-2})$
Incidence angle modifier (IAM)	0.95
Nominal flow rate	138 L/h
Storage tank capacity	200 L
Storage tank height	1320 mm
Maximum operating temperature	90 °C
Auxiliary heating element	2000 W
Circulation pump power	45 W

The solar water heating system with photovoltaic panels (S3), consists of an arrangement of polycrystalline PV panels directly connected in parallel to a DC resistive heating element located inside the storage tank. The goal is to produce electricity to feed this resistance directly and therefore produce hot water whenever there is solar radiation available. Despite not being a commercially available solution, this arrangement can provide good results if the system and its components are chosen correctly. To compensate for the eventual lack of solar radiation, a secondary heating element (connected to the grid) is located inside the storage tank. The main heating element (DC) that is connected to the panels should be correctly dimensioned according to the characteristics of the PV array, namely the maximum power of the system. To connect a PV system directly to a DC resistive element, one must consider two important variables: the maximum power point voltage (V_{MPP}) and the maximum system power which is equivalent to the sum of the power of all the panels involved in the system (P_{max}). The V_{MPP} and P_{max} of the PV system should not be higher than the voltage and power of the DC heating element due to safety reasons and to prevent wasting electricity since the heating element is rated for a certain power and higher a P_{max} will not prove to be beneficial. The resistance of the heating element should also be higher than the resistance associated with the PV array. With all this in mind, a 48V DC heating element rated for 1500W was considered. This element can be connected to the different configurations of PV system considered in this work.

Table 4.3 - Description of the photovoltaic system (S3)

PV panel area	1.94 m^2
Maximum power point voltage (V_{MPP})	37.3 V
Maximum power point current (I_{MPP})	8.98 A
Maximum panel power (P_{max})	335 W
Open circuit voltage (V_{OC})	46.3 V
Short circuit current (I_{SC})	9.35 A
DC resistance power	1500 W
AC resistance power	2000 W
Storage tank capacity	200 L
Maximum operating temperature	90°C

4.2. Case studies

When conducting an analysis and comparison of different systems for domestic hot water, choosing only one case to portray reality is usually not enough so, with that in mind, different cases were chosen in order to have broad range of results that can fit many real-world cases. The cases will consist in having different number of consumers for all the solar water heating systems and in separate locations.

The average Portuguese household has the size of 2,5 people and in Europe 47% and 40% of households with children have of 3 or 4 persons, respectively [35]. Given these facts, the case studies will consist of 2, 3 and 4 occupant households. A total volume of 50 litres per occupant was considered, meaning three different load profiles were created: 100, 150 and 200 litre daily water consumption. -

Another important factor when assessing the economic viability of solar water heating systems is their location. Two different locations within the Portuguese territory were chosen in order to produce a wider range of results and conclusions. The chosen locations were the cities of Bragança and Faro. (Figure 4.1). The chosen orientation and slope of the panels was the same for every configuration analysed in this work. The chosen azimuth/orientation of the panels was of 0° (South) and the slope of the panels was of 38°.

Table 4.4 - Description of the photovoltaic system (S3)

ST/PV panels slope	38°
Azimuth/Orientation	0° (South)

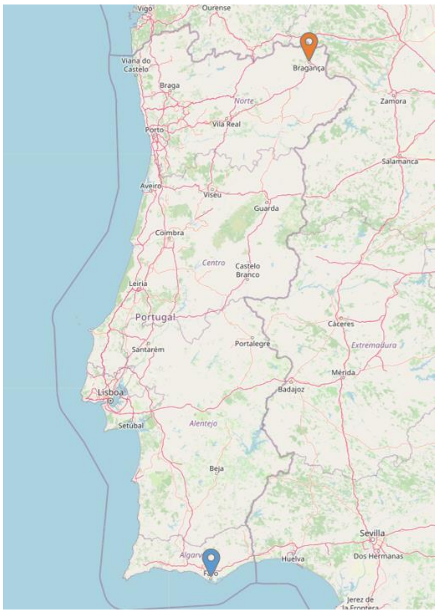
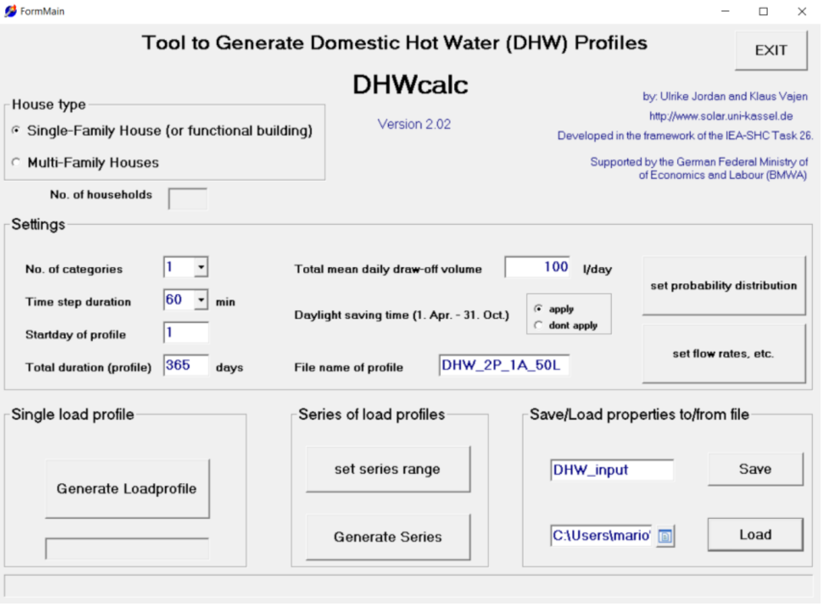


Figure 4.1 – Chosen locations for the analysis of the systems.

After determining the average daily water consumption, the next phase was to generate a suitable water load profile. To that end, the software DHWcalc was used to generate a domestic hot water profile for each case. This tool allows the user to generate a profile with the necessary characteristics such as total duration, mean water draw-off volumes, probabilities during the weekdays or weekends, among others. This approach also allows a certain degree of variability to the daily profiles making it more realistic when compared to a constant daily hot water load. The output generated by this software is a text file containing the flow rates of each time step which can be directly read by the chosen simulation software.



FormMain

Tool to Generate Domestic Hot Water (DHW) Profiles

DHWcalc

Version 2.02

by: Ulrike Jordan and Klaus Vajen
http://www.solar.uni-kassel.de
Developed in the framework of the IEA-SHC Task 26.
Supported by the German Federal Ministry of of Economics and Labour (BMWA)

House type
● Single-Family House (or functional building)
○ Multi-Family Houses
No. of households

Settings
No. of categories: 1
Time step duration: 60 min
Startday of profile: 1
Total duration (profile): 365 days
Total mean daily draw-off volume: 100 l/day
Daylight saving time (1. Apr. - 31. Oct.): ● apply ○ dont apply
File name of profile: DHW_2P_1A_50L

Single load profile

Series of load profiles

Save/Load properties to/from file
DHW_input
C:\Users\mario'

Figure 4.2 - Layout of the DHW profile generator (DHWcalc)

The water consumption profile will directly influence the performance of the water heating systems since these require solar energy to produce hot water and the timing of the water draw-offs will influence the amount of energy needed to fulfil the hot water demand. Three water consumption profiles were created to account for the previously mentioned number of users (2, 3 and 4-person households). The time span that was chosen was one year, or 8760 hours, which means that 365 different daily hot water load profiles were simulated. The three hot water consumption profiles did not consider periods such as holidays where the amount of hot water that is usually consumed is lower. The daily distribution of the volume of water consumed is present in Table 4.5.

Table 4.5 - Daily distribution of hot water consumption

Time interval	Volume in each interval (%)
22:00 to 6:30	0
6:30 to 7:30	15
7:30 to 12:00	5
12:00 to 13:00	0
13:00 to 18:00	10
18:00 to 22:00	70

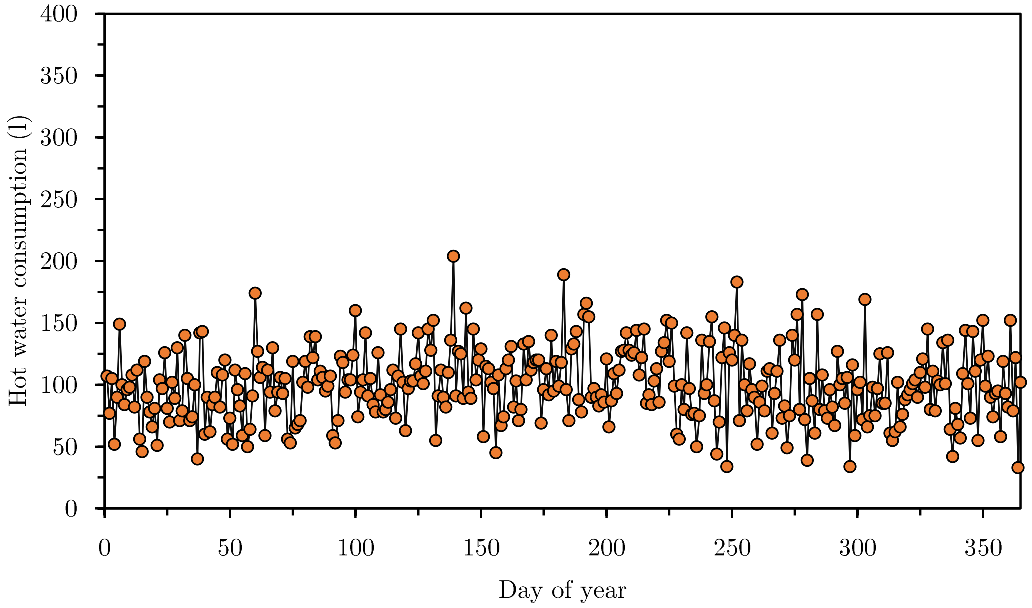


Figure 4.3 - Annual distribution of the DHW load for a 2-person household

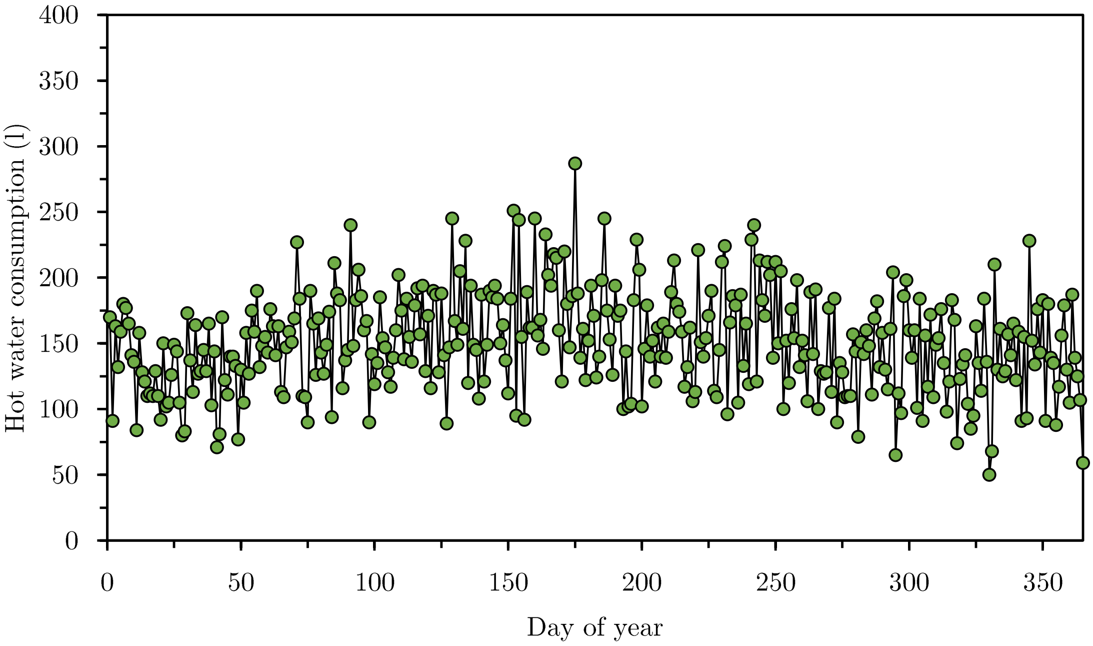


Figure 4.4 - Annual distribution of the DHW load for a 3-person household

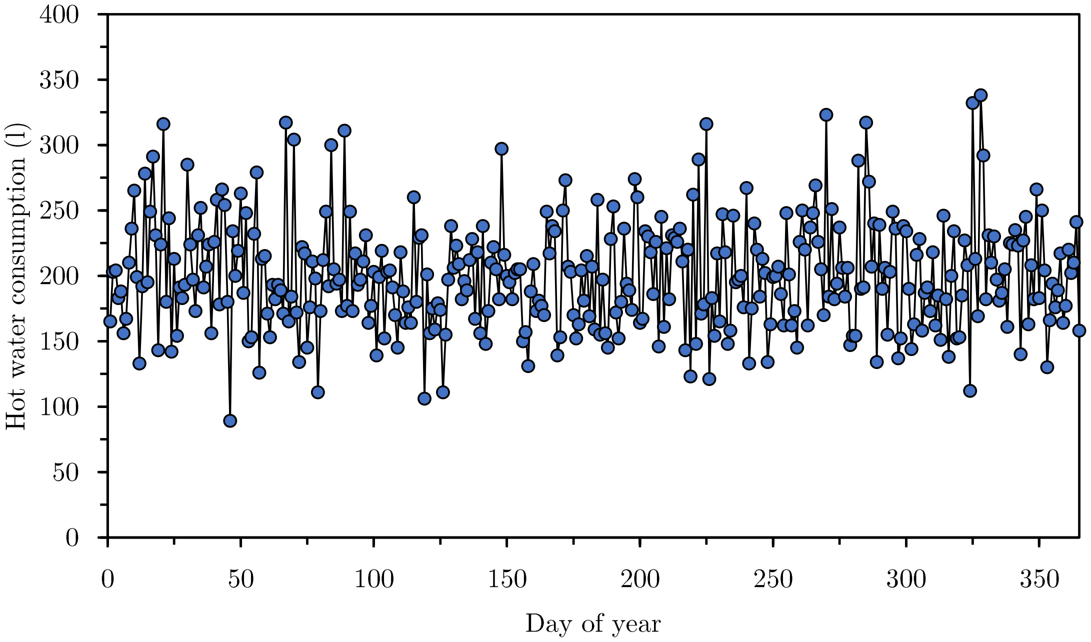


Figure 4.5 - Annual distribution of the DHW load for a 4-person household

The daily hot water consumption volumes for a 2-person, 3-person and 4-person household is evident in Figure 4.3, Figure 4.4, and Figure 4.5, respectively. These profiles show some degree of randomness within the total daily water load values, as was expected, but the average is the same as the predetermined daily water consumption of 100, 150 and 200 litres for each case.

4.3. System modelling

The economic evaluation of solar water heating systems depends heavily on knowing the performance of said systems with a good degree of accuracy. The key values are the amount of energy that SWHS can produce and the necessary amount of energy that an auxiliary system must add in order to fulfil all the necessities. To assess the performance of solar water heating systems, empirical or simulated results can be utilised.

Experimental analyses have the advantage of giving real-world results which can easily be trusted in order to perform an economic analysis, provided all the equipment is working flawlessly and there are no malfunctions. When an experimental analysis cannot be executed, the performance of SWHS can be studied using a simulation tool that tries to mimic real-world conditions in order to correctly depict the behaviour of the systems. Simulation tools have the advantage of being more versatile, allowing the user to vary the simulation conditions and systems' characteristics. Despite this advantage, simulated values usually have a degree of uncertainty that affects the results and can compromise any conclusions of further analyses that need the said results, as can happen with an economic analysis.

4.3.1. Simulation software

The simulation tool used to simulate every water heating system was TRNSYS or Transient System Simulation Tool. TRNSYS is one of the most flexible energy simulation programs used to simulate transient systems, while being more focused on analysing the performance of electrical and thermal systems. This program divides systems into various individual components (types) that can be connected in order to make up a whole system. Each component has its own inputs and outputs that can be edited so that a system can easily be customized according to the user's necessities. Another advantage is that TRNSYS can simulate a system during the necessary duration, which allows the user to have results for a short or long-time span according to its objectives. This software has a Simulation Studio with a graphical interface (Figure 4.6) which simplifies the user's task and makes it more intuitive. Given the previously referred aspects, it is easy to conclude that TRNSYS is a great tool to simulate energy systems, solar water heating systems in this case.

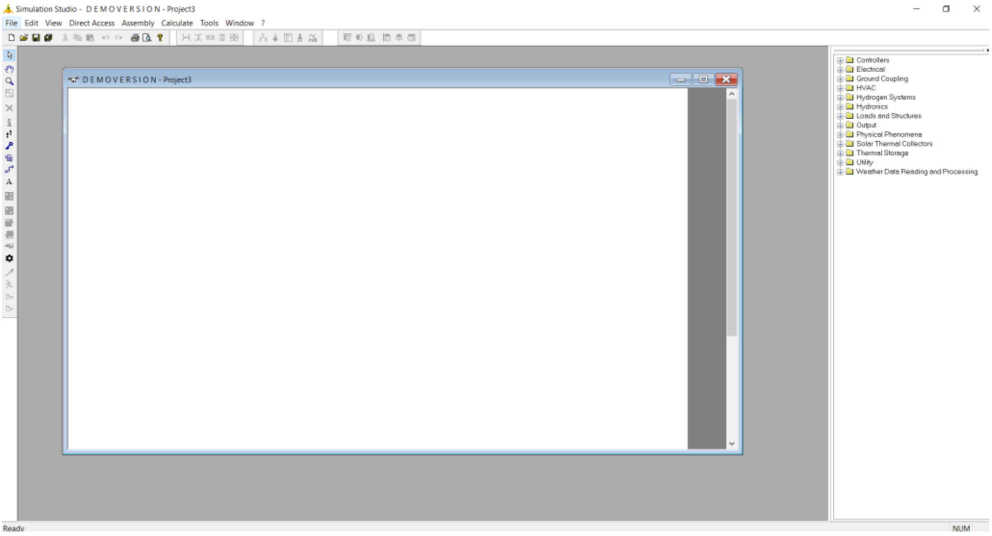


Figure 4.6 - Layout of the graphical interface of TRNSYS software

4.3.2. Models

As was mentioned previously, this economic analysis will consider four different water heating systems (one conventional and two solar systems). This means that 3 different models had to be built in the TRNSYS Simulation Studio.

The first system that was modelled was a conventional electric water heater. The storage tank was modelled using Type 158, which has the capability of adding auxiliary heating sources. In this case, the auxiliary heater was modelled using TESS Type 1226 connected to the auxiliary heater input in the storage tank. The maximum temperature simulated inside the storage tank was controlled by a thermostat (Type 106) that sends the heating control signal to the resistance whenever the temperature in the top of the tank is lower than 60°C with a dead band of 3°C. The load profile data was stored in a .txt file and was read by Type 9a data reader. The tank outlet temperature is also controlled by a tempering valve limiting the DHW temperature to 45°C.

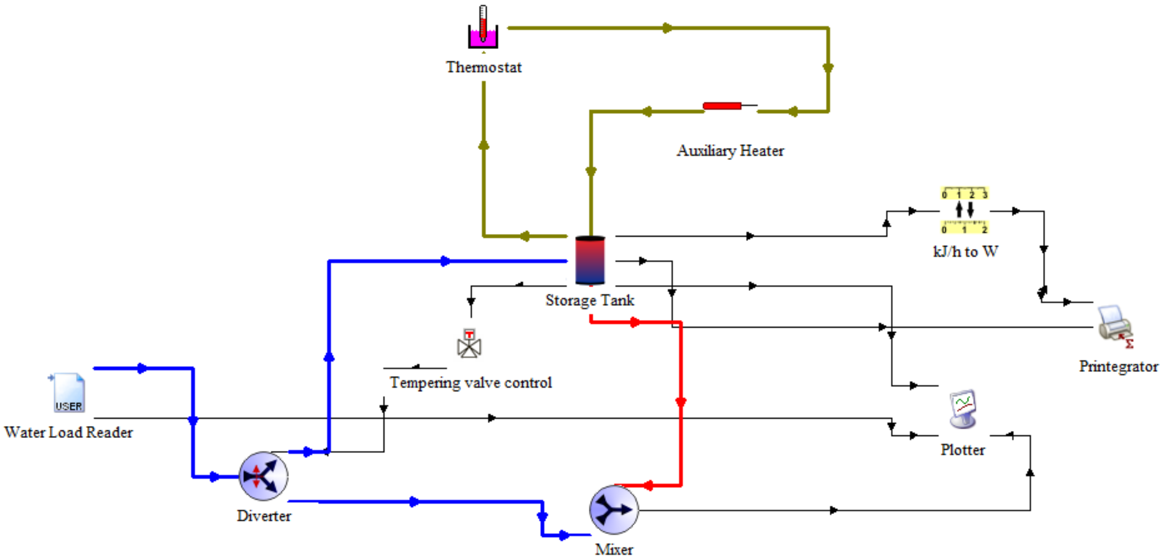


Figure 4.7 - Layout of the TRNSYS simulation model built for S1.

S2 was built by connecting a solar collector (Type 1b) to a storage tank by means of a heat exchanger. The storage tank Type 156 had an immersed heat exchanger connected to the solar collector outlet on the “hot side” and to a pump on the “cold side”. The pump modelled by Type 114 was linked with a controller (Type 165) that sent a signal to turn it on whenever the temperature at the collector outlet was 10°C higher than the temperature at the bottom of the tank and off when the HTF at the outlet was 2°C higher than the temperature at the bottom of the tank. The setpoint temperature for the thermostat was set at 60°C, meaning the resistance would not turn on if the temperature were higher than the chosen value. Since the storage tank had a maximum operating temperature of 90°C, the controller responsible for activating or deactivating the pump was set to allow a maximum temperature of 85°C. The water load was again read from a .txt file by Type 9 component. The results, as with S1, were integrated and written in an external file.

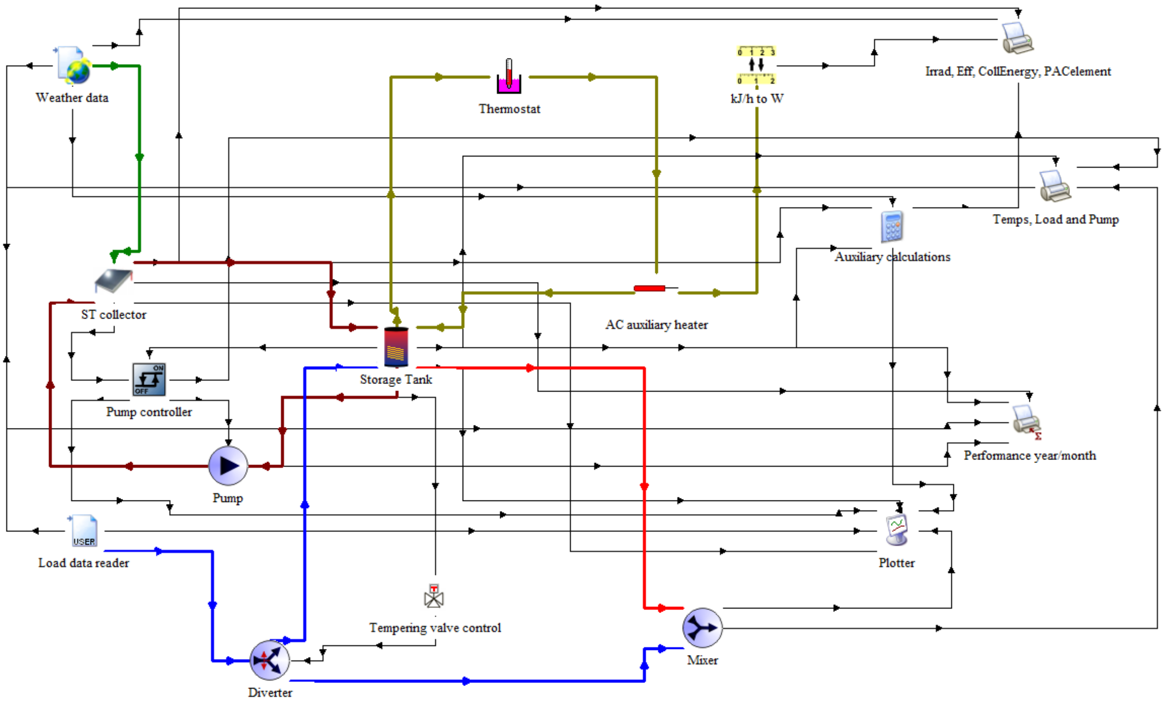


Figure 4.8 - Layout of the TRNSYS simulation model built for S2.

The third hot water solar system was built by a storage tank (Type 158) with two auxiliary heating elements (Type 1226). The solar photovoltaic panels (Type 103) were directly connected to one of the heating elements, powering a DC resistance. The storage tank also had an AC resistance connected to the grid in order to compensate for the lack of heating capacity by the DC heating element. There are two thermostats in this model, one to control the heating signal for the AC resistance, turning it on whenever the temperature at the top of the tank was under the setpoint of 60°C and the other thermostat to control the DC resistance, turning it on whenever the temperature fell below 85°C which was the chosen maximum temperature allowed inside the tank. This way, the use of the DC resistance can be maximized while keeping the system within its temperature limitations. As in the aforementioned models, the results were integrated and written in external files for posterior processing. The layout of the system can be observed in Figure 4.9.

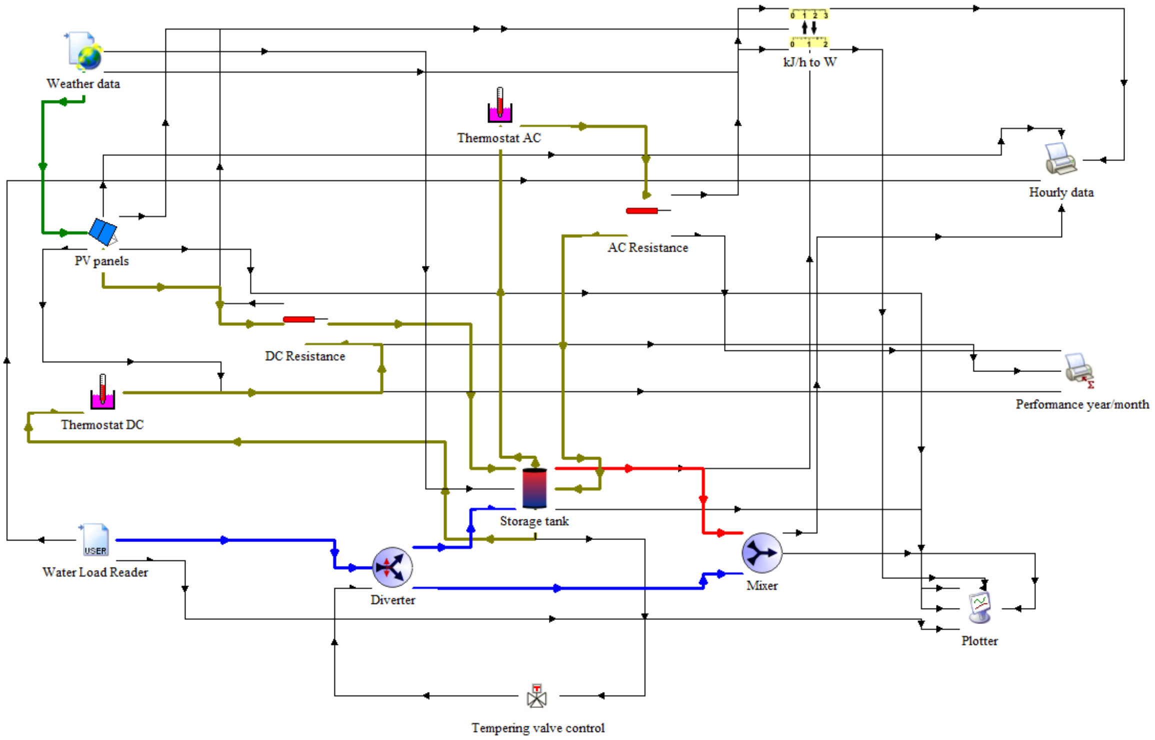


Figure 4.9 - Layout of the TRNSYS simulation model built for S3.

4.4. Model validation

Today, despite simulation results being quite accurate if all the components are correctly defined, it is important to always verify them and validate them with a trustworthy source. Without the validation of the models involved in this analysis, the margin of error might be big, and it may lead to incorrect posterior conclusions and analyses.

Given the fact that experimental evaluations of the selected systems for this analysis are not able to be conducted, the models involved in this analysis were validated by resorting to results from other authors in which the same or very similar systems were analysed while being subjected to similar conditions. Since not all systems were analysed experimentally in the literature, some validations will be made by comparing simulation results. In order to correctly compare the models built for this economic analysis, the characteristics of all the components were adjusted in order to replicate the systems available in the literature so that the outcomes are as close as possible.

An important aspect when comparing solar water heating systems is the weather data in which these perform or are simulated. For all models built for this economic analysis, the weather data was extracted from a typical meteorological year (TMY) generator available online in the European Commission's Science Hub [19], which means that there may be some discrepancies between the results from the literature and the simulations that were conducted in this analysis since some were analysed empirically and others were simulated. All models that were simulated using weather data in EnergyPlus format (.epw file) for every location involved in this analysis.

The data used for comparison was extracted directly from the sources mentioned below whenever available numerically. When the results were shown graphically, these were extracted by using an online tool called WebPlotDigitizer [36] as accurately as possible in order to reduce the uncertainty associated with this process.

4.4.1. Reference system (S1)

For the baseline system (S1), we have an electric water heater constituted by a water storage tank and an auxiliary heater in the form of a resistive element located inside the tank. A similar system was simulated using TRNSYS by Panangiotidou, Aye and Rismanchi [26, in four different locations and quantifying the total electricity consumption by the conventional system. The output of the simulations by the authors was used to compare the electric water heater model built for this economic analysis. The volume of the tank was of 200 litres with a total auxiliary power of 7200 watt divided by two elements as in the reference system in the literature. The heating setpoint was 60°C and the total daily hot water consumption for all locations was 150 L at a temperature of 40°C. Since the power of the auxiliary heater that is intended to be simulated is of 2000W, the same TRNSYS model was simulated with the aforementioned value and also compared with the reference case.

Table 4.6 shows similar values for all three cases. The results are very consistent with the reference values with differences ranging between 5.6% and 0.1% for the 7200W system and between 4.3% and 0.3% for the 2000W system. Considering the small deviations between the reference case and the simulated values, the TRNSYS model for S1 can be assumed to be valid and able to be utilized in the economic analysis.

Table 4.6 – Energy consumed for the simulated cases and reference case.

Location	Reference (kWh)	7200W	2000W
Heraklion	1666.8	1765.3 (+5.6%)	1740.8 (+4.3%)
Athens	1719.7	1738.8 (+1.1%)	1768.8 (+2.8%)
Thessaloniki	1776.3	1778.4 (+0.1%)	1781.2 (+0.3%)

4.4.2. Solar thermal system (S2)

S2 is a solar thermal water heating system with a flat-plate collector (FPC) producing hot water to a storage tank also with an immersed auxiliary heating element. The heat was transferred to the stored water by means of a heat exchanger inside the tank. The HTF was a water/glycol mixture. To evaluate the accuracy of the TRNSYS model for this system, two different sets of data were considered. The first one was from the study conducted by Matuska and Sourek [37], where a similar system was studied but without an auxiliary heater. The authors studied the performance of a solar thermal system experimentally in the city of Ziar and Hronom, Slovakia with a total of two flat-plate collectors with a combined area of 3.56 m^2, with an orientation of 15° towards East (from South) and a slope of 45°, connected to a 200 L storage tank. The daily water load was 200 L at a temperature of 45°C, and an inlet water temperate of 10°C.

The total annual heat gains are very similar when comparing experimental and simulated values, with the empirical annual total being of 1544 kWh and the simulated annual total being 1539 kWh, which is a difference of -0.32% as shown in Table 4.7. Regarding the monthly values, a divergence was found in some months which is caused by the different weather data used in the simulation when compared with the experimental weather conditions.

Table 4.7 – Validation results for S2 in Slovakia

Month	Simulated case (kWh)	Reference experimental case (kWh)
January	38	29
February	91	72
March	84	155
April	152	172
May	158	181
June	167	220
July	241	197
August	207	147
September	160	154
October	148	134
November	42	47
December	52	36
Total	1539 (-0.3%)	1544

Another study by Matuska and Sourek [33], analysed a similar system to the previously mentioned one in TRNSYS but this time using a 2000W resistive element inside the water tank as is the goal of this work. The solar collector area was 4.5m^2 again with a 200 L storage tank. The daily water load in this analysis was 160L at a temperature of 55°C and the location that was chosen was the city of Prague.

Table 4.8 shows similar values, with the total solar gains being 1675 kWh and 1691 kWh for the literature and the simulated values, respectively, which is a difference of 0,93%. The total auxiliary energy necessities were 1090 kWh for the reference case and 1130 kWh for the simulated case which results in a difference of 3.69%. The contrast between the monthly numbers of energy production for the reference case and simulated case should be due to differences in the weather data, as predicted.

Table 4.8 – Validation results for S2 in Prague

Month	Simulated case (kWh)	Reference case (kWh)
January	23	43
February	83	90
March	185	139
April	200	182
May	147	204
June	225	190
July	175	205
August	194	209
September	185	174
October	148	143
November	66	67
December	61	30
Total	1691 (+0,93%)	1675

4.4.3. Photovoltaic system (S3)

The third system that was studied was a photovoltaic water heating system, which uses electrical energy generated by PV panels to power a DC resistive element inside the storage tank. Inside the storage tank there is also an AC auxiliary resistance connected to the grid in order to provide the necessary backup energy. This solution is not too common in the literature so the amount of available information to be compared with the TRNSYS model is not as big as with other kinds of solar water heating systems. The validation considered a 200L daily hot water load consumed at a temperature of 45°C.

To validate the model built in TRNSYS, data from the previously mentioned study by Matuska and Sourek was used [37], in which a similar system was studied with TRNSYS. The authors simulated the system in different locations, varying the total power of the PV system from 0.5 kW_p to 2 kW_p. The power of the PV modules was of 250 watts for the simulation. The authors calculated the annual specific heat gains per m^2 for the power interval, and these values were used as a comparison for the results obtained by the TRNSYS models built for this analysis. Figure 4.10 and Figure 4.11 show a direct comparison of the reference results and the simulated values for the cities of Istanbul, and Prague, respectively. The results show very similar values in most cases, with the biggest difference being for the 2kWp system in Istanbul. Despite having some discrepancies, the simulated values show in most cases a picture that is quite like the values available in the literature.

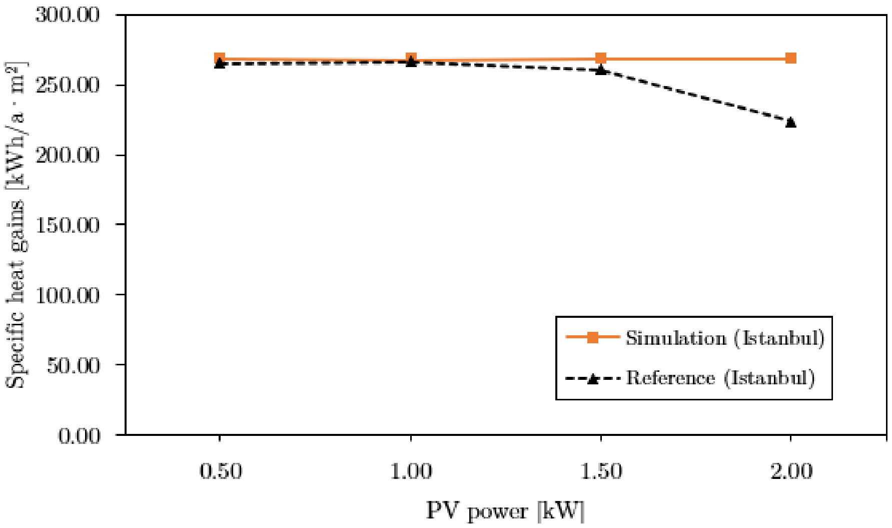


Figure 4.10 - Comparison between the reference case and simulated model in Istanbul

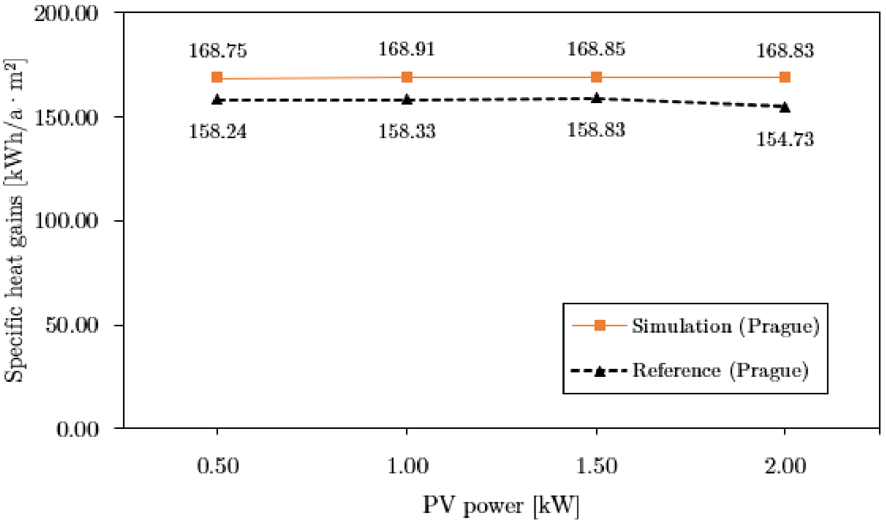


Figure 4.11 - Comparison between the reference case and simulated model in Prague

In the study used as a reference in the previously mentioned comparison, the authors also assessed the energy production for a 2 kW_p system in other European locations under the same conditions. As such, the model built for this economic analysis was compared with the results obtained in the article in terms of electricity production per kW_p of PV power. The comparison is evident in Table 4.9, and it is noticeable that the simulation results are very similar in some cities and have some gaps in others. Again, these differences may be due to discrepancies between the weather data used in the literature and in this validation.

Table 4.9 – Validation results for S3 in different European locations

Month	Simulated case (kWh)	Reference case (kWh)	Difference (%)
Prague	1061.43	1080.50	+2
Athens	1717.44	1903.50	+11
Stockholm	1154.79	998.50	-14
Milan	1316.95	1451.50	+10
Zurich	1189.19	1235.50	+4
Madrid	1855.04	1706.50	-8
Genova	1631.45	1445.50	-11
Bordeaux	1422.60	1378.00	-3
Istanbul	1783.78	1582.00	-11

4.5. Parametric analysis

The performance of solar water heating systems is also dependent on design variables related with the dimension of the components involved or other geometric aspects. Parameters like the area of solar thermal and photovoltaic panels or the volume of a water storage tank can have a significant effect on the performance of these systems. This reality advocates for the necessity of determining the optimal solution by varying different parameters in order to maximize the performance or minimize the overall costs of the system.

In order to find the optimal solution from the techno-economic perspective, a parametric analysis on the three systems involved was conducted. This analysis consisted of varying the following parameters: storage tank volume and solar thermal/photovoltaic panel area. For S1, the electric water heater volume was studied for a 100L, 150L and 200L capacity. For S2, the ST panel area was varied by changing the number of solar thermal panels from 1 to 3 panels which is equal to varying the area from 2.47 to 7.41m^2. Increasing the maximum number of panels would not prove to be beneficial from the economic view since, for typical domestic hot water applications and considering the daily hot water profiles analysed in this work, these are the most common values. The volume of the storage tank was also varied in order to determine the best solar collector area and storage tank volume combination, considering capacities of 200L, 250L and 300L. For S3, the total installed power of this system was the main constraint because the power of the PV system should be correlated with the power of the resistive element as mentioned in section 4.1. Therefore, the system was studied for 3 (5.82 m^2), 4 (7.76 m^2) and 5 (9.70 m^2) PV panels which is equivalent to a total maximum power of 1.005 kW$_p$, 1.34 kW$_p$ and 1.675 kW$_p$. The parametric analysis for S3 also analysed the volume of the storage tank in the same range as chosen for S2.

4.6. Energy analysis

Before conducting an economic analysis, it is crucial to evaluate the thermal and electrical performance of solar water heating systems. This is the goal of the previously mentioned simulation tool, with which the major parameters can be directly calculated during the simulations of all the systems involved under all the chosen conditions.

The efficiency of SWHS is one of the key parameters to be calculated because it translates how effective the system is at using the available solar energy and turning it into thermal or electric energy, depending on the type of system. Considering that in this work there are systems who have the goal of producing thermal, electric energy or both, the way efficiency is calculated is not the same for each case.

For solar thermal panels (FPC), the collector efficiency (η_{ST}) is calculated by dividing the useful energy gained (Q_u) by the total energy input which is given by the total collector area (A_{st}) multiplied by the global solar irradiance at the collector plane (G_t) [8, p. 222].

$$\eta_{ST} = \frac{Q_u}{A_{st} \times G_t} \tag{4.1}$$

When it comes to photovoltaic panels, the efficiency is determined in a similar manner, with the only difference being the replacement of Q_u by the total power (P) being produced by a panel or a PV system, as shown in Equation 4.2.

$$\eta_{PV} = \frac{P_{pv}}{A_{pv} \times G_t} \tag{4.2}$$

Solar water heating systems require an auxiliary heating source (electricity or gas) in order to fulfil the hot water demand since the amount of heat produced with the sun is not always sufficient. This means that only a fraction of the total necessary energy is from the sun, therefore one can determine the solar contribution to the hot water production, also called solar fraction (f). The solar fraction is given by the total energy necessary (solar and auxiliary) subtracted by the auxiliary energy portion, divided by the total energy necessary. This is equivalent to saying that it is given by the quotient between the solar energy delivered (Q_s) and the total energy required (Q_{total}) [8, p. 583].

$$f = \frac{Q_s}{Q_{total}} = \frac{Q_{total} - Q_{aux}}{Q_{total}} = \frac{Q_s}{Q_s + Q_{aux}} \tag{4.3}$$

4.7. Economic analysis

Nowadays, every investor intends to have a return on their investment and this behaviour is becoming more present in “normal” consumers, who tend to give a lot of importance to the cost efficiency of their investments/purchases. This makes economic analyses of projects very important because these can determine the acceptance or rejection of said projects and give an estimate of the returns an investor can expect. The most suitable economic indicators must be chosen in order to correctly depict the results and to ease the user’s/investor’s comprehension of the situation.

The main goal of this work is to execute an economic analysis to every solar water heating system in order to compare them in similar conditions to know which has the most advantages from the economic standpoint. Several economic metrics can be chosen to reach the necessary conclusions, as the state of the art reveals, and it is imperative and obvious that all systems are evaluated under the same indicators.

4.7.1. Economic indicators

Solar domestic water heating systems can be easily "predictable" when it comes to their return on investment. The bigger the investment, the slower is the return. Also, very rarely do these systems give immediate return on investment, meaning that SWHS usually take a few years to give the investor some profit. It can be particularly important when there is not an immediately available sum of money to purchase these systems, which means that a loan may be necessary. This, depending on the available interest rates of bank loans, can directly affect the economic viability of these systems. It is important to give the investor a good picture on the future outcome of its investment and there are a few economic indicators that can precisely do that. The chosen economic indicators for this work were the following: Payback Period (PP, the Net Present Value (NPV), the Internal Rate of Return (IRR) and the Levelized Cost of Heat (LCoH).

The Payback Period (PP) is the required period an investment takes to become profitable, or the total amount of savings generated is the same as the initial investment amount. In this case, it is the necessary number or days, months or years of savings that are necessary in order to match the solar water heating system investment. This economic metric can be calculated by two different ways: the Simple Payback Period (SPP) and the Discounted Payback Period (DPP).

$$\mathrm{SPP} = \frac{\mathrm{C} - \mathrm{I}}{\mathrm{S} - \mathrm{O\&M}} \tag{4.4}$$

$$\mathrm{SPP} = \mathrm{N} + \frac{\mathrm{CCF_N}}{\mathrm{CF_{N+1}}} \tag{4.5}$$

The SPP is only suitable for simple, quick, and superficial economic analyses since it does not consider the time value of money. As shown in Equation 4.4, it divides the investment cost (C) subtracted by any eventual incentives by the government or other entities (I) by the estimated annual savings (S) subtracted by the annual cost of operation and maintenance (O&M), assuming the values remain constant in the project lifetime. Whenever the cash flows are not constant throughout the year, one can use Equation4.5 to calculate the SPP, where N is the year of the last negative cumulative cash flow (CCF), and CF is the cash flow the following year.

The DPP can be used to attain a similar result but considering the time value of money. The DPP is calculated by adding the year (N) where the last negative cumulative discounted cash flow occurs to the quotient between the last negative cumulative discounted cash flow (CDCF) and the discounted cash flow (DCF) the year after. Equation 4.6 summarizes the description of DPP.

$$\mathrm{DPP} = \mathrm{N} + \frac{\mathrm{CDCF_N}}{\mathrm{DCF_{N+1}}} \tag{4.6}$$

The economic viability of investments can also be done by calculating the net present value (NPV). This indicator is a good tool for comparing different projects or alternatives as it evaluates the cash flows of a project in its lifetime. The NPV is calculated by adding all the discounted cash flows over the project's lifetime, at a certain discount rate (d), as shown in Equation 4.7 If the value obtained is greater than 0 then the project is economically attractive, if NPV is equal to 0 then the investment has no benefits or drawbacks and the investor should be indifferent between investing or not doing so, and if NPV is lower than 0 then the project is not viable.

$$\mathrm{NPV} = \sum_{\mathrm{n}=0}^{\mathrm{N}} \frac{\mathrm{CF}}{(1+\mathrm{d})^{\mathrm{n}}} \tag{4.7}$$

The internal rate of return (IRR) is another economic metric that can be utilised to evaluate the attractiveness of SWHS investments. It is the discount rate at which the NPV is equal to zero meaning these two indicators are correlated. This economic indicator is usually compared with the discount rate in order to determine if the project is viable or not. If the IRR is greater than the discount rate, then the investment is worthwhile. The internal rate of return can be determined using trial-and-error by varying the discount rate until we reach the goal of a null NPV, process that can be done using a spreadsheet program.

$$\mathrm{NPV} = 0 \equiv \sum_{\mathrm{n}=0}^{\mathrm{N}} \frac{\mathrm{CF}}{(1+\mathrm{IRR})^{\mathrm{n}}} = 0 \tag{4.8}$$

Another economic indicator for these types of projects is the levelized cost of heat (LCoH). The LCoH is an indicator based on the levelized cost of energy that is more frequent in projects of electrical nature. It has the goal of determining the cost of producing heat with a solar system during its lifetime. This indicator can also be used to compare different types of systems and choose the most attractive one. In this case, the system with the lowest value of LCoH is the most attractive one since it means that costs less money to produce heat. The LCoH is calculated using the following expression [38],

$$\mathrm{LCoH} = \frac{\mathrm{C} - \mathrm{I} + \sum_{\mathrm{n}=1}^{\mathrm{N}} \frac{\mathrm{O\&M_n}}{(1+\mathrm{d})^{\mathrm{n}}}}{\sum_{\mathrm{n}=1}^{\mathrm{N}} \frac{\mathrm{E_n}}{(1+\mathrm{d})^{\mathrm{n}}}} \tag{4.9}$$

where $\mathrm{E_n}$ is the total energy savings by the solar system, which remains constant throughout the period of analysis for solar thermal panels and reduces by 0.5% for the systems with a photovoltaic element (S3). The degradation of photovoltaic panels is caused by climate conditions in the most part. Examples are the UV exposure that can lead to discoloration of the solar cells and extreme temperature differences can affect the soldered connections in the panel, reducing power and efficiency of the panel [39]. Operation and maintenance costs are assumed to be constant in the period of analysis.

For this economic analysis other parameters must be predetermined in order to have accurate and realistic results. The discount rate (d) has been mentioned and is a very important parameter and can determine that economic viability of a project. Usually, for risky investments a high value of d is used in order to minimize risk and a low discount rate can be used to less risky projects. Solar water heating systems are usually a low-risk investment because their technology is already proven and very rarely do they pose a high risk from the economic standpoint, albeit some issues like oversizing a system or malfunctions might affect the performance and viability of these systems. Given these facts and considering the typical values used in these types of projects, the chosen discount rate was 5% [40, p. 44].

Another variable that can also affect the outcome of an economic analysis is the price of electric energy. As was mentioned in section 2.6, a low cost of energy for reference or conventional systems (electricity or gas) might make the investment on a solar system more costly long term than the alternative. Nevertheless, in most countries, energy prices tend to increase, and this may also increase the attractiveness of renewable energy systems. During the last year, this trend has reversed and the prices of electricity in most European countries has decreased. In Portugal, the mean price variation of electricity for domestic users has been -1% between 2015 and 2020 (Source: INE/PORDATA). Given the uncertainty the prices of electricity, the chosen value for the inflation of electricity prices was of 0%.

4.7.2. Sensitivity analysis

As was mentioned previously, the values obtained for some economic indicators might be affected by some variables such as the discount rate or the energy prices. Due to this fact, the results obtained when conducting an economic analysis should bear in mind that for different conditions there will be different outcomes. Therefore, a sensitivity analysis should be conducted in order to analyse how the results vary when modifying certain variables.

In this case, a variation of the discount rate and the electricity prices is relevant in order to assess the outcome of the economic analysis under different conditions. Electricity prices for domestic consumers in European countries vary from around 0,10€ to 0,28€, which means a variation of -51% to +34% when compared with the price in Portugal. This way, the sensitivity analysis for electricity prices will be conducted approximately within this range.

4.7.3. Equipment costs

The chosen economic indicators show that for every investment the initial cost has a lot of weight when determining the economic viability. If technology prices are too high and the total savings are too low, the investment might not be viable. The good news is that for solar water heating systems, the prices have been decreasing in the last years meaning they are becoming much more attractive and easier to acquire. In Table 4.6, the prices of the chosen solar water heating systems can be observed.

For S1, the price was taken from an online source with the average price from different suppliers in Portugal. The prices of the different configurations for S2 were extracted from a catalogue which contained the cost of a solar thermal water heating system including all the necessary equipment for a forced circulation system [34]. Not all chosen configurations had a pre-determined price so, the available prices were edited by adding the cost of additional ST panels, replacing a 200L tank for a 300L tank and adding the necessary heating element. The cost of a system with the characteristics of S3 is hard to define since these are usually not available commercially so, the prices of all configurations were determined by adding the cost of each PV panel to the cost of a storage tank and the cost of two heating elements (DC and AC). It is not common to find water storage tanks with two heating elements so, to simplify the analysis and to make S3 comparable with S2, it was assumed that the storage tank in S3 was the same as the one in S2 from the technical and economic standpoints. The cost of all the different systems studied in the economic analysis are present in Table 4.10, where “1 STP – 200L” means a system with 1 ST panel and a 200L tank and “3 PVP – 200L” means a system with 3 PV panels and a 200L tank.

Table 4.10 - Initial investment of the chosen water heating systems

S1		S2		S3	
Description	Cost (€)	Description	Cost (€)	Description	Cost (€)
100L	160.00	1 STP – 200 L	2189.00	3 PVP – 200 L	1225.60
		1 STP – 300 L	2394.90	3 PVP – 300 L	1360.60
150L	240.00	2 STP – 200 L	2554.70	4 PVP – 200 L	1374.60
		2 STP – 300 L	2689.70	4 PVP – 300 L	1509.60
200L	286.00	3 STP – 200 L	3010.70	5 PVP – 200 L	1523.60
		3 STP – 300 L	3145.70	5 PVP – 300 L	1658.60

The total cost of a SWHS is not limited to the initial investment and others costs mainly associated with operation and maintenance must be considered when conducting an economic analysis. For these kinds of systems, the yearly maintenance cost can be considered to be 1% of the initial investment [8, p. 704]. Other operation costs, also called parasitic costs, must be contemplated. For the systems involved in this analysis, operation costs are usually associated with the electricity consumed to power a pump or pumps necessary to transport the working fluid between the collector and the heat exchanger located inside the storage tank.

Table 4.11 - Assumed values for other important economic variables.

Maintenance costs	1% of the total initial cost
Residual value	0 €
Incentives or grants	0 €

In some analyses, the residual value of the solar water heating system at the end of a project's lifetime can be considered. The residual value, or salvage value is the price at which the components can be sold at the end of their lifetime for scrap or recycling, for instance. This can have a positive effect on the outcome of an economic analysis but, in this case, the residual value of the considered SWHS is assumed to be zero at the end of the analysis period.

The price of a solar water heating system can also be reduced if the government or other entities can give consumers an incentive or grant that covers a percentage of the total cost of the system. These measures have the goal or promoting the reduction of electricity consumption, promote an efficient energy use and meeting environmental goals to combat climate change. Obviously, this can also have a positive effect on the economic viability of a project and reduce its risk. Despite this reality, it is assumed that all the systems involved in this work do not consider any incentives that can reduce their overall cost.

4.8. Environmental analysis

Another important aspect when considering the installation of solar water heating systems is their environmental impact. Considering that the main goal is the reduction of the quantity of electricity purchased from the grid which may be produced with a significant amount of CO_2 emissions, these systems have a positive effect on the reduction of GHG (greenhouse gas) emissions. With the growing concerns on the important of the reduction of greenhouse gases in the atmosphere, it is also important to quantify the benefits of these systems on the environment. Although important, these impacts are becoming less relevant and will continue to decrease due to the increasing amount of "green" energy that is produced worldwide which contributes greatly on the reduction of the specific emissions per kWh of electricity produced.

For this evaluation, along with the total reduction of electricity consumption from the grid by each system, it is important to know the average CO_2 emissions per kWh of electricity produced in the location chosen for the case studies. In Portugal, the specific emissions considered in this environmental analysis was of 216 g/kWh [41, p. 100].

With the specific emissions along with the total energy necessary from the auxiliary source to cover the hot water necessities, we can determine the total reduction of greenhouse gas emissions by the studied solar water heating systems. A direct comparison between the four chosen systems will be present in section 5.3.

5. Results

In this chapter, all the results that were obtained in the energy, economic and environmental analysis of the three water heating systems will be present, together with a discussion of the numbers that were achieved and the comparison between all chosen cases.

5.1. Energy analysis result

After simulating all systems under the chosen conditions, the first stage of analysis was a comparison of the performance of all systems from the energy production and consumption standpoints. S2, which had solar thermal panels produced thermal energy and consumed electric energy while S3 produced and consumed electric energy. Therefore, a comparison between the systems must consider that one system produced thermal energy and the other produces electric energy. The baseline case (S1) consumed electricity exclusively in order to produce hot water.

An important aspect to consider is the total area of ST panels and PV panels in system 2 and 3, respectively. The total area for each configuration of S2 and S3 is present in Table 5.1.

Table 5.1 - Area for different number of STP and PVP panels

System	Area (m^2)
1 STP	2.47
2 STP	4.94
3 STP	7.41
3 PVP	5.82
4 PVP	7.76
5 PVP	9.70

5.1.1. Electric water heater

The first part of the analysis consisted in analysing the performance of a typical electric water heater (S1) to produce and provide hot water under three different water load scenarios and to serve as a reference case to the solar alternatives.

Table 5.2 - Electricity consumption for different electric water heaters

System capacity	Electricity consumption (kWh)		
	100L (2P) load	150L (3P) load	200L (4P) load
100L	1488.00	2132.25	2582.25
150L	1538.75	2182.75	2774.00
200L	1582.00	2225.75	2866.00

The results showed an expected increase in electricity consumption as the volume and DHW load increases. Analysing the amount of electricity spent to heat a litre of consumed DHW, by dividing the amount of electricity by the total daily hot water load, determines that the system with a capacity of 100L of hot water needs less energy than the other alternatives as shown in Table 5.3. With this aspect in consideration, the 100L electric water heating system served as the reference system in this comparative analysis.

Table 5.3 - Electricity consumption per litre of hot water for one year

System capacity	Electricity consumption per litre of consumed water (kWh/L)		
	100L (2P) load	150L (3P) load	200L (4P) load
100L	14.88	14.22	12.91
150L	15.39	14.55	13.87
200L	15.82	14.84	14.33

5.1.2. Solar thermal water heating system (S2)

In this study, a parametric analysis was conducted on all systems in order to determine the influence of different design specifications on the performance results. For S2, a variation of the number of ST panels and the volume of the storage tank was analysed leading to 9 different configurations. These configurations were also analysed under two different locations (Bragança and Faro).

The results of the analysis showed that the amount of thermal energy produced by the solar panels depends on the characteristics of the system and on the DHW profile, as expected. The numbers show that increasing the number of ST panels had a greater impact on the production of thermal energy than increasing the capacity of the storage tank. Another conclusion is that the same system can produce more hot water when it is not limited by a smaller daily hot water consumption profile since the system only turns the HTF pump when necessary. The consumption of electricity increases with the increase in the DHW load and decreases with the increase of the number of ST panels and storage tank capacity. The results obtained for S2 in Bragança are present in Table 5.4.

Table 5.4 - Energy produced and electricity consumed for S2 in Bragança.

System	Energy produced (kWh_{th}) and electricity consumed (kWh)					
	100L (2P) load		150L (3P) load		200L (4P) load	
	Produced	Consumed	Produced	Consumed	Produced	Consumed
1 STP - 200L	1153.53	346.83	1517.47	747.00	1685.16	1315.17
1 STP - 250L	1170.04	333.36	1544.01	725.22	1723.60	1305.93
1 STP - 300L	1182.28	321.58	1557.45	718.12	1747.60	1298.87
2 STP - 200L	1266.20	193.02	1761.63	437.35	2103.98	815.80
2 STP - 250L	1287.29	172.09	1801.33	395.89	2151.59	786.65
2 STP - 300L	1299.41	157.32	1822.96	376.59	2188.66	756.41
3 STP - 200L	1296.47	146.25	1851.75	322.16	2253.13	640.64
3 STP - 250L	1314.76	124.97	1877.20	294.08	2309.84	592.07
3 STP - 300L	1326.54	113.43	1892.64	280.96	2348.36	559.20

For the climate conditions of Faro, an increase on the thermal energy production by the same systems is evident which is due to the increase in the total solar irradiation available in this location when compared with Bragança. Faro also has a slightly hotter average ambient temperature than Bragança during the year, which also contributes to less losses to the environment. This also led to a decrease on the consumption of electricity by all systems as expected. Judging by the results in Table 5.5, one can see that in Faro the difference between the thermal energy produced by the system with one ST panel and the system with three ST panels is smaller than in Bragança for the same DHW profile. This means that in hotter climates and under these hot water profiles, the ST systems are very much affected by the DHW profile. The studied configurations cannot take full advantage of the higher temperatures because most of the hot water consumption occurs in the morning or in the evening leading to the conclusion that more ST panels is not always the best solution.

Table 5.5 - Energy produced and electricity consumed for S2 in Faro.

System	Energy produced (kWh_{th}) and electricity consumed (kWh)					
	100L (2P) load		150L (3P) load		200L (4P) load	
	Produced	Consumed	Produced	Consumed	Produced	Consumed
1 STP - 200L	1316.63	172.88	1804.80	471.01	2018.66	1025.88
1 STP – 250L	1330.15	160.73	1831.61	456.39	2063.54	1006.31
1 STP – 300L	1344.78	147.30	1846.40	450.90	2085.80	999.40
2 STP - 200L	1363.57	83.84	1984.33	191.98	2499.82	410.38
2 STP – 250L	1373.96	74.08	2007.34	169.51	2556.28	355.20
2 STP – 300L	1377.13	72.41	2028.99	147.02	2594.08	318.01
3 STP - 200L	1368.27	63.87	2014.18	140.79	2585.01	289.14
3 STP – 250L	1373.28	57.16	2035.09	117.99	2623.41	245.51
3 STP – 300L	1378.75	51.57	2049.81	100.42	2666.19	202.59

Table 5.6 - Energy produced per unit of area for S2 in Bragança and Faro.

System	Thermal energy produced per m^2 ($\text{kWh}_{\text{th}}/m^2$)					
	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
1 STP - 200L	467.01	614.36	682.25	533.05	730.69	817.27
1 STP – 250L	473.70	625.11	697.81	538.52	741.54	835.44
1 STP – 300L	478.66	630.55	707.53	544.45	747.53	844.45
2 STP - 200L	256.32	356.61	425.91	276.03	401.69	506.04
2 STP – 250L	260.59	364.64	435.54	278.13	406.34	517.47
2 STP – 300L	263.04	369.02	443.05	278.77	410.73	525.12
3 STP - 200L	174.96	249.90	304.07	184.65	271.82	348.85
3 STP – 250L	177.43	253.33	311.72	185.33	274.64	354.04
3 STP – 300L	179.02	255.42	316.92	186.07	276.63	359.81

The results present at Table 5.6 show that increasing the number of panels reduces the amount of thermal energy produced by m^2. These numbers also show that the increase of the storage tank volume along with the increase in the DHW consumption has a positive effect in this metric.

Another important aspect when analysing the performance of a solar thermal system is its efficiency. The results for the average yearly amount of converted solar energy of the studied configurations are present in Table 5.7. The numbers show that increasing the number of solar panels decreases the overall efficiency of the system while the increase of the storage tank volume increases the efficiency but in a very small amount. It is also evident that for a higher consumption of hot water, the efficiency of the system increases as well, which is expected since in these cases the amount of energy produced is higher.

Table 5.7 – Average monthly percentage of available solar energy converted for S2.

System	Average percentage of energy converted (%)					
	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
1 STP - 200L	34.21	42.58	47.09	49.84	68.33	76.42
1 STP - 250L	34.69	43.32	48.19	50.36	69.34	78.12
1 STP - 300L	35.02	43.67	48.85	50.91	69.90	78.96
2 STP - 200L	19.83	26.23	31.44	25.81	37.56	47.32
2 STP - 250L	20.23	26.99	32.30	26.01	38.00	48.39
2 STP - 300L	20.55	27.37	32.89	26.07	38.41	49.10
3 STP - 200L	13.69	18.80	23.23	17.27	25.42	32.62
3 STP - 250L	13.96	19.12	23.99	17.33	25.68	33.11
3 STP - 300L	14.17	19.40	24.50	17.40	25.87	33.65

Table 5.8 - Average monthly solar fraction for S2 in Bragança and Faro

System	Average yearly system solar fraction (%)					
	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
1 STP - 200L	80.92	69.20	58.63	94.06	84.10	69.55
1 STP – 250L	81.93	70.26	59.46	94.89	84.82	70.48
1 STP – 300L	82.65	70.68	59.94	95.78	85.10	70.85
2 STP - 200L	90.42	82.28	74.85	98.26	95.04	89.24
2 STP – 250L	91.80	84.23	76.16	98.86	95.96	91.13
2 STP – 300L	92.85	85.14	77.30	98.86	96.92	92.37
3 STP - 200L	93.05	87.40	80.49	98.93	96.75	92.85
3 STP – 250L	94.52	88.67	82.31	99.28	97.66	94.29
3 STP – 300L	95.34	89.27	83.50	99.50	98.32	95.70

The solar fraction for the studied configurations of S2 in Bragança and Faro show that it increases with the size of the system and decreases with the increase in the hot water load profile. This agrees with the results from the energy production and electricity consumption from the grid, which shows that with a higher hot water demand comes a higher consumption of electricity to maintain the temperature of the stored water at the temperature setpoint.

To sum up, this analysis allows us to make the following conclusions:

- The performance of a solar water heating system with ST panels is very good as expected, greatly reducing the amount of energy purchased from the grid to produce hot water which is the main goal.
- Increasing the number of solar thermal panels also increases the amount of thermal energy produced by the system and has a higher impact than the increase of the storage tank volume in the overall performance of the systems.
- The increase of the number of ST panels does not make the system more efficient in these conditions since it is limited by the DHW load profile. The increase in the hot water storage capacity has a very small positive effect on the overall efficiency of the system.
- The studied system is more efficient in a warmer location than in a colder one, since on the former there is a higher amount of solar energy available to be converted to thermal energy.

5.1.3. Photovoltaic water heating system (S3)

The strategy used to analyse the performance of S2 was applied on the analysis of S3, varying the storage tank volume and the total power of the system adding more PV panels. These configurations were also analysed in the same locations as the solar thermal system.

The results showed that for this system, the electricity production was slightly higher for the smallest system when compared with the smallest ST system. This study also shows that the biggest PV system cannot produce as much electricity as the biggest ST system despite having a higher total panel area. This is easily explained by the lower efficiency of PV panels when compared with ST panels. Another conclusion is that the consumption of electricity from the grid is much lower than in ST systems. This should be due to the increase in production of electricity on the colder season of the year since PV panels are not negatively affected by a low ambient temperature. The results for the city of Bragança are present in Table 5.9.

Table 5.9 – Electric energy produced and consumed for S3 in Bragança.

System	Electricity produced and consumed (kWh)					
	100L (2P) load		150L (3P) load		200L (4P) load	
	Produced	Consumed	Produced	Consumed	Produced	Consumed
3 PVP - 200L	1199.73	100.00	1579.64	390.00	1724.28	895.00
3 PVP - 250L	1217.07	83.50	1606.05	365.75	1734.29	905.75
3 PVP - 300 L	1224.46	77.25	1627.13	346.50	1737.56	915.00
4 PVP - 200 L	1243.15	50.25	1738.56	213.50	2009.74	592.25
4 PVP - 250 L	1250.16	44.00	1752.20	203.00	2026.68	587.25
4 PVP - 300 L	1259.47	35.00	1762.75	195.50	2027.45	598.25
5 PVP - 200 L	1262.61	27.50	1795.28	148.25	2167.40	426.25
5 PVP - 250 L	1268.50	22.75	1817.18	128.25	2182.63	421.00
5 PVP - 300 L	1272.51	19.75	1830.76	117.50	2208.57	403.00

The same trend was found for the analysis of S3 in Faro. As expected, the total electricity produced increased, and the consumption of electricity from the grid decreased. A curious outcome is that the effect of adding a bigger storage tank does not translate in a higher electricity production by the PV panels as happens with S2. The results obtained for S3 in Faro are presented in Table 5.10.

Table 5.10 – Electric energy produced and consumed for S3 in Faro.

System	Electricity produced and consumed (kWh)					
	100L (2P) load		150L (3P) load		200L (4P) load	
	Produced	Consumed	Produced	Consumed	Produced	Consumed
3 PVP - 200L	1268.51	29.75	1778.71	181.00	1957.84	676.50
3 PVP - 250L	1274.85	23.75	1802.23	163.25	1968.07	682.00
3 PVP - 300 L	1286.24	12.75	1820.26	149.00	1968.15	692.25
4 PVP - 200 L	1280.46	10.00	1859.98	85.50	2293.76	310.00
4 PVP - 250 L	1283.53	8.00	1878.81	72.50	2327.12	283.00
4 PVP - 300 L	1286.31	7.25	1894.86	58.00	2341.38	276.25
5 PVP - 200 L	1282.87	7.75	1895.09	43.00	2407.89	179.25
5 PVP - 250 L	1288.37	5.00	1915.29	26.50	2441.56	148.75
5 PVP - 300 L	1378.75	51.57	2049.81	100.42	2666.19	202.59

The electricity production per unit of area decreased for S3 (Table 5.11) when compared with S2 (Table 5.6), which is expected since all the configurations had higher panel areas than the solar thermal systems. This means that for the same area, a PV system produces less electricity to produced hot water than a ST system. This may have direct implications when the area available for installing the panels is not high but, considering the areas involved in this study, there should not be a big difficulty installing any of the configuration in a typical household.

Table 5.11 - Energy produced per unit of area for S3 in Bragança and Faro

System	Electricity produced per m^2 (kWh/m^2)					
	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
3 PVP - 200L	206.10	271.37	296.21	217.92	305.56	336.34
3 PVP - 250L	209.08	275.90	297.93	219.01	309.61	338.10
3 PVP - 300 L	210.35	279.53	298.50	220.96	312.70	338.11
4 PVP - 200 L	160.17	224.00	258.94	164.98	239.64	295.53
4 PVP - 250 L	161.07	225.76	261.12	165.37	242.07	299.83
4 PVP - 300 L	162.27	227.12	261.22	165.73	244.14	301.67
5 PVP - 200 L	130.14	185.05	223.40	132.23	195.33	248.19
5 PVP - 250 L	130.75	187.30	224.97	132.80	197.42	251.66
5 PVP - 300 L	131.16	188.70	227.65	132.53	198.09	253.89

The percentage of solar energy converted of all the PV system configurations that were analysed in this study were lower than for the ST system analysis. This is also normal because photovoltaic panels have a much lower efficiency than solar thermal panels. As expected, the efficiency is higher where there is more solar energy available to be converted to electricity. Again, the increase in the volume of the storage tank does not lead to a big increase in the overall efficiency of the system as was the case of S2.

Table 5.12 - Average monthly percentage of available solar energy converted for S3.

System	Average percentage of energy converted (%)					
	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
3 PVP - 200L	16.04	19.66	21.18	17.75	24.39	26.56
3 PVP - 250L	16.40	20.09	21.29	17.88	24.70	26.64
3 PVP - 300 L	16.58	20.36	21.31	18.08	24.93	26.64
4 PVP - 200 L	12.77	16.91	19.37	13.45	19.17	24.39
4 PVP - 250 L	12.91	17.03	19.49	13.48	19.46	24.76
4 PVP - 300 L	13.01	17.22	19.47	13.55	19.69	24.91
5 PVP - 200 L	10.49	14.22	17.32	10.79	15.65	20.87
5 PVP - 250 L	10.54	14.49	17.51	10.86	15.89	21.19
5 PVP - 300 L	10.60	14.58	17.75	10.84	15.90	21.40

The results for the solar fraction of the studied configurations of S3 show that it increases with the size of the system and decreases with the increase in the daily hot water necessities. With a higher hot water demand, comes a higher consumption of electricity from the grid to keep the stored water at the setpoint temperature.

Table 5.13 - Average monthly solar fraction for S3 in Bragança and Faro

System	Solar fraction (%)					
	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
3 PVP - 200L	92.15	79.10	65.97	97.76	90.83	74.46
3 PVP - 250L	93.50	80.45	65.92	98.19	91.69	74.43
3 PVP - 300L	94.08	81.51	65.79	99.07	92.49	74.13
4 PVP - 200L	96.10	88.41	77.51	99.23	95.59	88.17
4 PVP - 250L	96.70	88.99	77.92	99.41	96.29	89.24
4 PVP - 300L	97.45	89.48	77.68	99.47	97.05	89.52
5 PVP - 200L	97.89	91.94	83.83	99.40	97.75	93.09
5 PVP - 250L	98.29	93.07	84.21	99.63	98.64	94.28
5 PVP - 300L	98.55	93.67	84.96	99.57	98.80	94.87

For a 4-person household, the solar fraction can be as much as 85% for a system with 5 PV panels and a 300L storage tank. The smallest solar fraction also comes for a 4-person DHW demand, but for a configuration with 3 PV panels and a 200L tank, as expected.

One important aspect to mention about this kind of system, is that the PV system only transfers electric energy to the DC resistance whenever it is necessary. This means that during the day, if the desired temperature setpoint is reached, no power will be transferred. Therefore, as it stands, all the power produced by the PV system, whenever electricity is not needed in the tank, is wasted. There is potential to convert that power into AC power using an inverter and “injecting” as much electricity into the household as possible during the day and/or selling the excess energy to the grid. This possibility was not analysed in this study, but this may reduce the payback period of these systems since it would lead to a reduction of the total household energy bill. This would be affected by the price of the inverter as well. For a 5 PV panel system with a 200L tank and a 4-person household in Faro, an excess of approximately 857 kWh of electricity was produced. The excess electricity heavily depends on the total installed power and on the daily how water consumption profile.

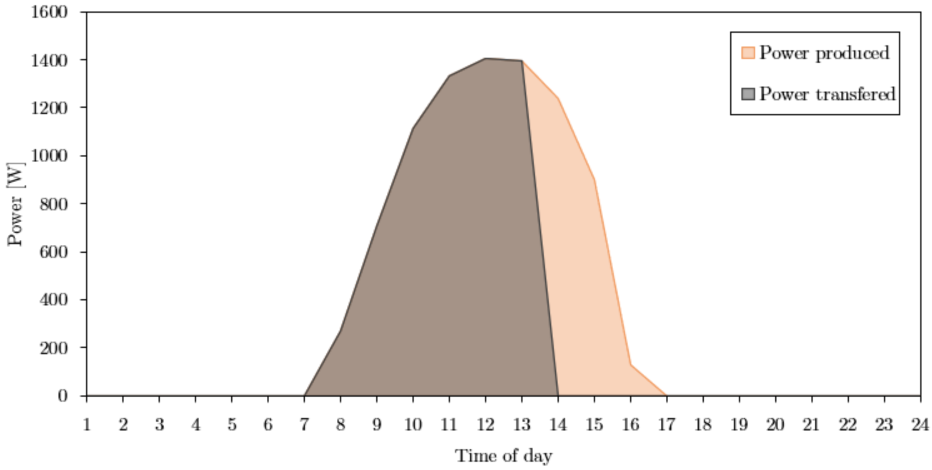


Figure 5.1 – Power produced and transferred to the resistance during a day.

For a more in-depth evaluation, all the results from the performance analysis of the systems involved are present at Appendix A.

Considering all the results obtained, some conclusions can be made on the performance of S3 under the chosen conditions:

- A photovoltaic panel can be a good mean of producing domestic hot water, since these lead to a considerable decrease in electricity consumption from the grid.
- The increase in the number of PV panels increases the electricity output of the system but does not increase the efficiency of the system while still producing more electricity overall.
- The most important component in a system such as the one studied in this work is the solar PV panel because increasing the number of PV panels leads to a bigger increase in the amount of electricity produced than the increase of the capacity of the storage tank.
- In order to produce the same amount of energy as a solar thermal panel, a PV system requires a higher total area of panels when compared with a ST alternative.
- A system such as this one can compete with a solar thermal system for the conditions analysed in this work, from the performance standpoint.

5.2. Economic analysis results

The main objective of this work is to conduct a comparative economic analysis on three systems capable of producing domestic hot water, with particular interest in the systems that use solar energy to reach that goal in a more economic manner. To assess the economic results of the systems involved in this analysis, different economic metrics were selected as was mentioned in section 4.7.1. The baseline economic variables were set at 5% for the discount rate and 0,212€ for the price of electricity, which is the average price household consumers paid for electricity, **including taxes**. Despite being analysed in the parametric analysis to assess their performance, the economic analysis did not consider the configurations with a 250L storage tank since this capacity is not usually available commercially. The chosen period of analysis was of 25 years, which is in line with the maximum lifetime of solar thermal and solar photovoltaic panels.

5.2.1. Economic analysis of S1

The first part of the economic analysis of the systems involved in this work, looked at the overall costs of operating an electric water heater as a means of producing DHW. As expected, these systems are not cost efficient despite having a low initial cost. Since these require electricity to produce hot water and do not rely on any form of renewable energy source, the lifetime costs are quite high despite being very efficient from the electricity to thermal energy conversion standpoint.

The system used as a reference case, was studied under 3 different DHW load profiles, and the total electricity consumption for these three conditions were of approximately 1488, 2132 and 2582 kWh for a 2-person, 3-person and 4-person household, respectively. This leads to an annual cost of approximately 317, 457 and 552 euros. Table 5.14 summarizes the total costs of having a 100L electric water heater producing domestic hot water.

Table 5.14 - Economic analysis of S1 under 3 DHW profiles for 0.212€/kWh

DHW profile	Initial investment (€)	Yearly cost (€)	Total cost for 25 years (€)
100L (2P)	160.00	317.06	8086.40
150L (3P)		456.50	11540.92
200L (4P)		551.91	13925.92

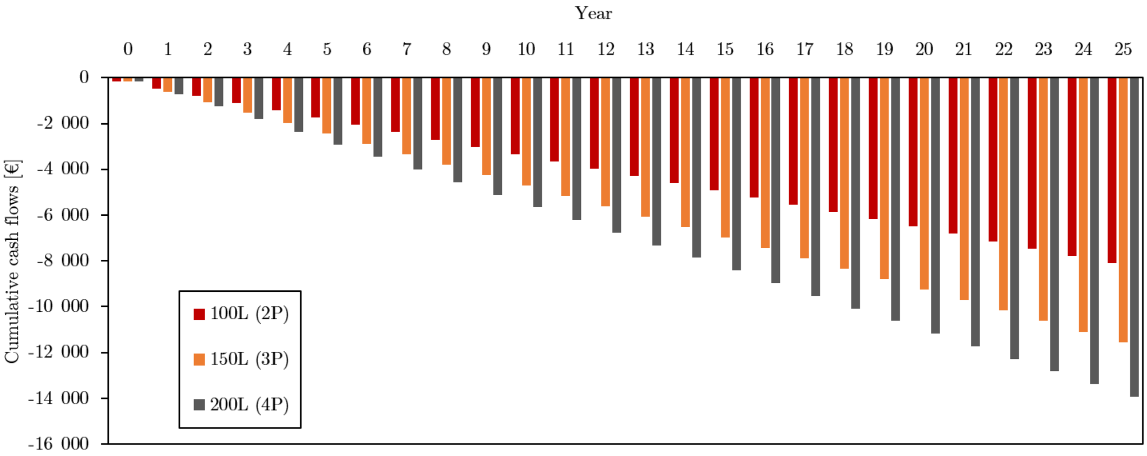


Figure 5.2 - Cumulative cash flows for S1 with a 0.212€/kWh cost of electricity

Despite having a very low initial investment, systems such as S1 are not cost effective when looking at the long-term picture. These numbers consider a static price for electricity over the whole period of analysis which is not very likely to happen since prices vary from year to year. Only with very low prices for electricity do these systems become more competitive when compared with solar alternatives. For an electricity price of 0.106€/kWh, which is close to the lowest price practiced in the EU, the costs of producing hot water with an electric water heater are greatly reduced turning a system such as the one analysed more competitive with SWHS.

Table 5.15 - Economic analysis of S1 under 3 DHW profiles for 0.106€/kWh

DHW profile	Initial investment (€)	Yearly cost (€)	Total cost (25 years) (€)
100L (2P)	160.00	170.55	4143.20
150L (3P)		241.65	5890.46
200L (4P)		309.52	7082.96

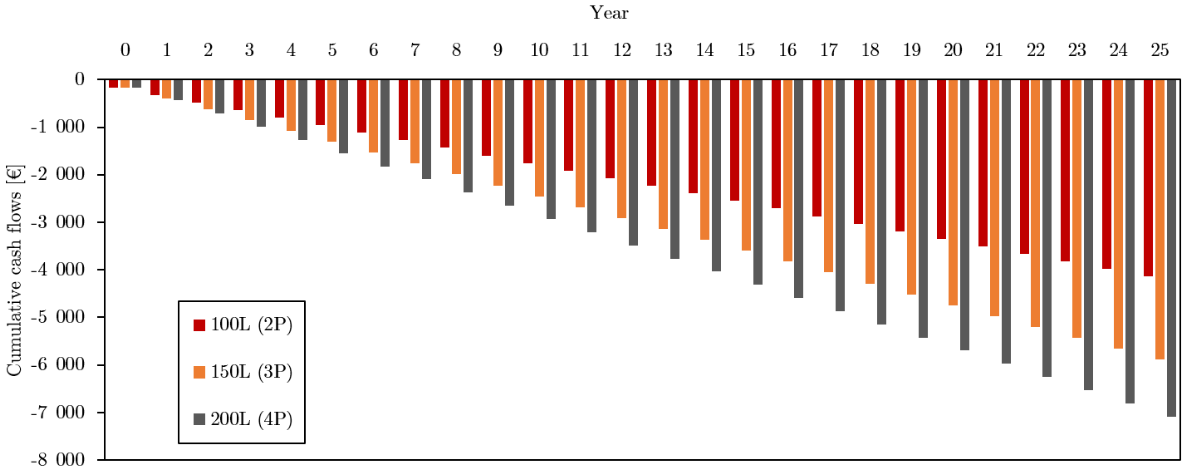


Figure 5.3 - Cumulative cash flows for S1 with a 0,106€/kWh cost of electricity

5.2.2. Economic analysis of S2

The economic analysis of S2 showed that choosing the most cost-effective solar thermal system is not as linear as sometimes expected. This system was analysed for two locations and the conclusions were that the best solution from the economic standpoint is not the same for both Bragança and Faro and depends on the DHW profile. The criterion was chosen to decide the best option from the economic standpoint was the NPV, meaning the system with the highest NPV would be the option.

The results shown in Table 5.16 reveal that in Bragança the system with the best NPV is the system with 2 solar thermal panels and a 200L storage tank. A "bigger" system is not as attractive as the aforementioned option since the costs increase with a higher number of panels and higher water storage capacity and, in this case, the daily hot water load is of only 100L. As expected, the payback periods (discounted and simple) increase with the increase in the costs of the system. It is also clear that the cost of producing hot water is significantly lower for solar systems, with an estimated 0,14€ per kWh. An IRR of 9% also confirms the attractiveness of investing in such a system.

Table 5.16 - Economic analysis of S2 for a DHW profile of 100L in Bragança

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	9	899.38	14.2	10.0	0.16
1 STP - 300 L	8	820.82	15.1	10.4	0.16
2 STP - 200 L	8	942.76	14.8	10.3	0.15
2 STP - 300 L	8	895.41	15.4	10.6	0.14
3 STP - 200 L	7	562.22	18.5	11.9	0.15
3 STP - 300 L	7	506.28	19.1	12.1	0.14

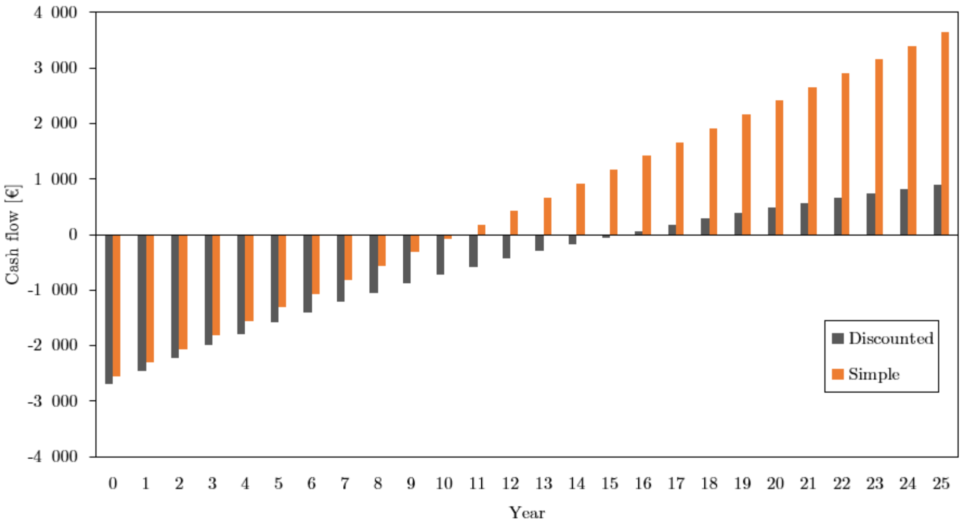


Figure 5.4 - Discounted and simple cash flows for the best configuration of S2 in Bragança considering a 100L daily load.

For Faro (Table 5.17), it is observable that the most cost-effective solution is the system with 1 ST panel and a 300L storage tank. The overall picture shows more attractive values for the economic indicators when compared with Bragança which is expected given the higher amount of solar energy available in this location. Again, oversized systems when considering a low daily hot water demand prove to be not as cost-effective as “smaller” systems.

Table 5.17 - Economic analysis of S2 for a DHW profile of 100L in Faro

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	10	1335.56	12.0	8.88	0.145
1 STP - 300 L	10	1341.54	12.1	8.94	0.143
2 STP - 200 L	10	1268.98	13.0	9.42	0.137
2 STP - 300 L	9	1149.08	14.0	9.88	0.137
3 STP - 200 L	8	808.36	16.6	11.11	0.138
3 STP - 300 L	7	691.11	17.7	11.56	0.137

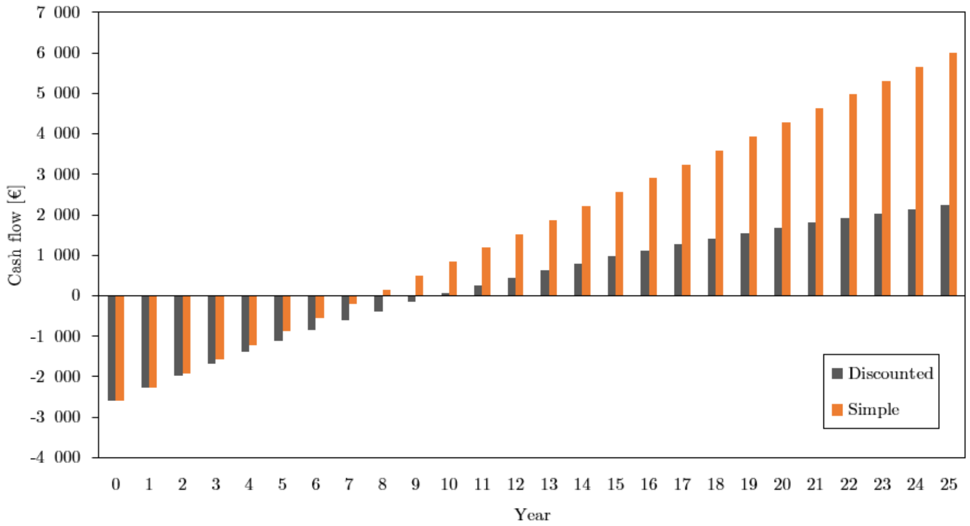


Figure 5.5 - Discounted and simple cashflows for the best configuration of S2 in Bragança considering a 150L daily load.

When assessing the same configuration but under a different DHW profile, the results change. As shown in Table 5.18, for Bragança and with a 150L hot water daily demand, the best system is the one with 2 solar thermal panels and a 300L storage tank whereas for a 100L DHW profile the best system was the second one (1 STP - 300 L). An increase in the attractiveness of the systems is also evident since a higher demand of hot water can also take advantage of the benefits of these systems. As in the previous results, the addition of extra storage capacity does not always prove to be beneficial since it leads to only marginal gains when compared with an additional number STP's. For the last two configurations, increasing the storage tank capacity decreases the NPV of the system. Another curious conclusion is that the DPP and SPP do not necessarily increase with the increase in the price of the system as was the case when analysing the first DHW profile.

Table 5.18 - Economic analysis of S2 for a DHW profile of 150L in Bragança

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	12	1628.67	10.6	8.1	0.14
1 STP - 300 L	11	1644.55	10.7	8.1	0.14
2 STP - 200 L	13	2221.26	9.5	7.4	0.12
2 STP - 300 L	13	2248.80	9.7	7.6	0.11
3 STP - 200 L	11	2045.18	11.0	8.3	0.11
3 STP - 300 L	11	2014.27	11.4	8.5	0.11

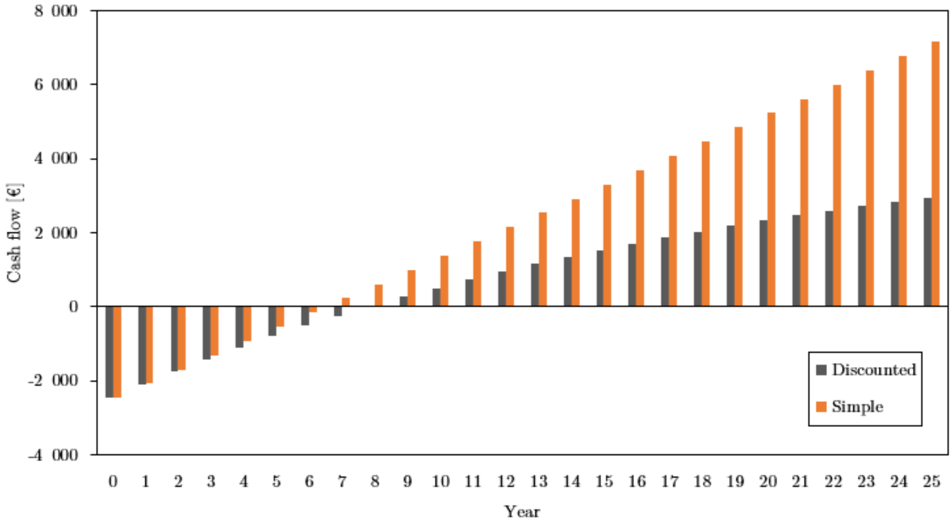


Figure 5.6 - Discounted and simple cash flow for the best configuration of S2 in Faro considering a 150L daily load.

Analysing the results obtained for the city of Faro (Table 5.19), we can once again observe an increase in the overall attractiveness of the systems. In this case, the best configuration is the system with two solar thermal panels and a 200L storage tank. Again, the DPP and SPP decrease for the systems with two STP's. It is also evident a decrease in the LCoH when having a higher demand of hot water. This is due to the increase in the energy savings associated with having higher demands. A low demand of hot water limits the collector's energy output.

Table 5.19 - Economic analysis of S2 for a DHW profile of 150L in Faro

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	15	2453.33	8.3	6.65	0.118
1 STP - 300 L	14	2442.98	8.4	6.74	0.117
2 STP - 200 L	15	2954.43	7.9	6.42	0.102
2 STP - 300 L	15	2934.73	8.3	6.63	0.100
3 STP - 200 L	13	2587.12	9.6	7.48	0.101
3 STP - 300 L	12	2614.59	9.8	7.60	0.099

Evaluating the results available in Table 5.20 for a 200L DHW daily load in Bragança, once again the results are different from the previous profiles. In this case, the best system is the one with 3 STP's and a 300L tank. These numbers show that the higher the daily hot water demand, the more cost-effective the systems become. This configuration under these conditions of capable of producing hot water at less than half of the price of a typical electric water heater. This analysis also shows that increasing the size of the system does not necessarily improve the economic attractiveness if a different metric is considered. As shown in Table 5.19, the systems with the most attractive IRR, DPP and SPP are the ones with two solar thermal panels whereas for the LCoH, the best systems are the ones with three STP's. This is mostly due to the increase in price and a not so big increase in thermal energy production.

Table 5.20 - Economic analysis of S2 for a DHW profile of 200L in Bragança

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	10	1275.61	12.1	8.9	0.15
1 STP - 300 L	10	1253.87	12.3	9.0	0.15
2 STP - 200 L	13	2435.08	9.0	7.1	0.11
2 STP - 300 L	13	2458.50	9.2	7.3	0.11
3 STP - 200 L	12	2438.17	9.9	7.7	0.10
3 STP - 300 L	12	2527.48	10.0	7.7	0.10

For the city of Faro, the results follow the same trend as in the previous DHW profiles. The system with the highest NPV is the one with two solar thermal panels and a 300L tank. As expected, this configuration has the highest NPV of all the studied solar thermal configurations and one of the lower payback periods. In these conditions, adding an extra solar thermal panel also does not prove to be beneficial because it leads to an increase in the payback periods, decrease in the net present value and internal rate of return.

Table 5.21 - Economic analysis of S2 for a DHW profile of 200L in Faro

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	13	2139.98	9.03	7.13	0.127
1 STP - 300 L	13	2148.66	9.14	7.20	0.126
2 STP - 200 L	17	3646.43	6.87	5.69	0.093
2 STP - 300 L	17	3768.40	6.97	5.76	0.090
3 STP - 200 L	15	3488.41	7.95	6.43	0.090
3 STP - 300 L	15	3592.99	8.03	6.48	0.087

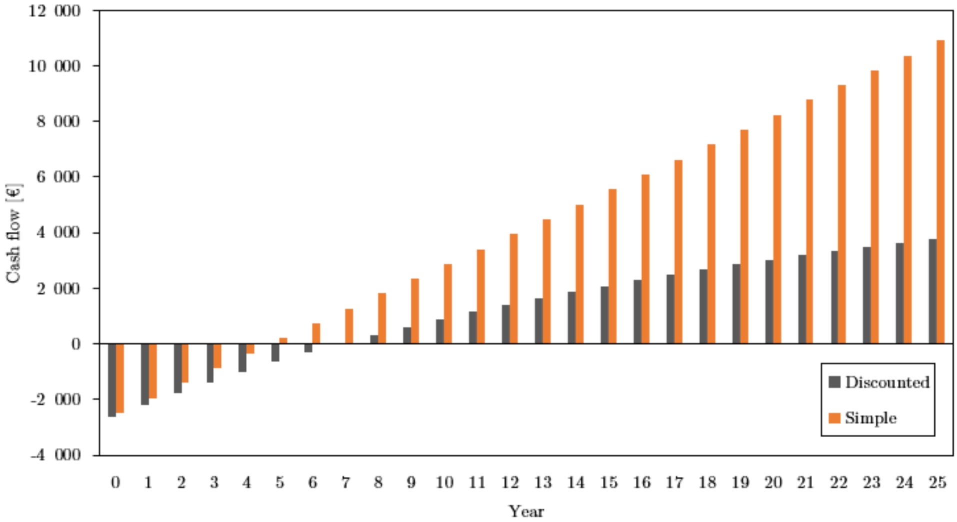


Figure 5.7 - Discounted and simple cash flows for the best configuration of S2 in Faro considering a 200L daily load.

To recap, a few important conclusions can be made of the economic analysis of different configurations of solar thermal systems for DHW production:

- Increasing the "size" of the system does not necessarily improve its economic viability.
- The economic performance depends not only on the characteristics of the system, but mostly depends on the climate conditions and DHW load profile.
- Varying the size of a system has different impacts in different economic metrics, despite all depending on the cost of the system.
- When compared with an electric water heater (S1), producing hot water with a system such as S2 can almost cost only a third of the price.

5.2.3. Economic analysis of S3

The economic analysis of S3 was conducted along the same lines as S2, studying different configurations and assessing their economic viability. When considering the performance results present in section 5.1 and the overall cost of the configurations, we could predict encouraging results from the economic standpoint.

Observing the results obtained for S3 in Bragança and for a DHW profile of 100 daily litres, we can easily conclude that the configuration analysed are very attractive from the economic standpoint. When comparing these numbers with the ones obtained for S2, under the same conditions, we can see that a system such as S3 can easily beat any configuration of S2. This reality is mainly due to the lower overall cost of a photovoltaic system when compared with a solar thermal system. Another important conclusion made is that increasing the size of the system leads to a decrease of the attractiveness of these systems when considering any economic metric. This fact is mainly due to the daily hot water demand since for DHW profiles with low daily consumption we can never take full advantage of these systems, hence why properly sizing a solar system is very important. The best configuration for the aforementioned case was a system with three PV panels and a 200L storage tank as shown in Table 5.22.

Table 5.22 - Economic analysis of S3 for a DHW profile of 100L in Bragança

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200 L	23	2734.66	5.0	4.35	0.067
3 PVP - 300 L	21	2651.85	5.6	4.77	0.066
4 PVP - 200 L	21	2720.39	5.5	4.72	0.065
4 PVP - 300 L	19	2637.58	6.1	5.13	0.064
5 PVP - 200 L	19	2621.60	6.1	5.18	0.064
5 PVP - 300 L	17	2491.84	6.8	5.63	0.064

As expected, changing the climate conditions to a warmer climate (Faro) increases the economic attractiveness of these systems. The best configuration was once again the one with three PV panels and a 200L storage tank. The LCoE (Levelized Cost of Energy) for these kinds of systems is much lower than the ones obtained for S2 due to the decrease in the cost of the system but also due to the decrease in operational costs. The values vary similarly for each configuration, mainly due to the inexistence of operational costs associated with a pump, as occurs with S2. PV system do not require a pump to circulate a HTF fluid which consumes electricity and increases costs. The maintenance costs of PV systems are also lower than for ST systems because the former have less components that require periodic inspections or replacement.

Table 5.23 - Economic analysis of S3 for a DHW profile of 100L in Faro

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200 L	24	2954.56	4.74	4.13	0.063
3 PVP - 300 L	22	2853.75	5.29	4.55	0.063
4 PVP - 200 L	22	2846.38	5.35	4.59	0.063
4 PVP - 300 L	20	2700.96	5.97	5.05	0.063
5 PVP - 200 L	19	2683.42	6.04	5.10	0.063
5 PVP - 300 L	18	2534.88	6.70	5.57	0.063

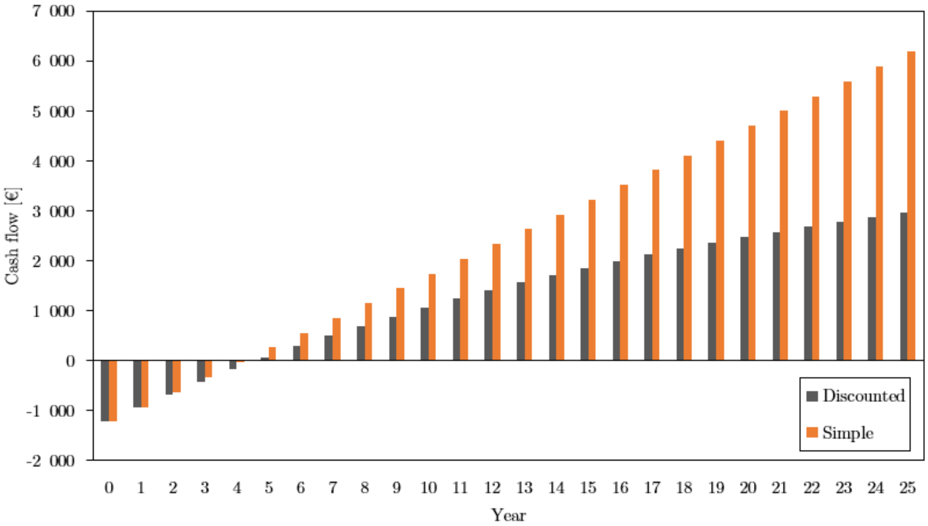


Figure 5.8 - Discounted and simple cash flow for the best configuration of S3 in Faro considering a 100L daily load.

Increasing the daily hot water demand also increases the attractiveness of these systems as was the case with S2. For a 150L daily hot water demand, the best configuration is the one with 4 photovoltaic panels and a 300L tank (Table 5.24).

Table 5.24 - Economic analysis of S3 for a DHW profile of 150L in Bragança

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200 L	29	3751.87	3.9	3.44	0.053
3 PVP - 300 L	28	3734.01	4.1	3.73	0.052
4 PVP - 200 L	28	4134.35	3.9	3.50	0.049
4 PVP - 300 L	27	4184.57	4.2	3.72	0.047
5 PVP - 200 L	26	4168.60	4.3	3.76	0.047
5 PVP - 300 L	25	4110.82	4.6	4.04	0.047

As was the case for other configurations, the increase in available solar energy leads to an increase in the economic viability of the studied systems. For a 150L hot water demand in Faro, the best solution is the system with 4 PV panels and a 200L storage tank.

Table 5.25 - Economic analysis of S3 for a DHW profile of 150L in Faro

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200 L	33	4406.08	3.40	3.05	0.047
3 PVP - 300 L	30	4352.22	3.76	3.35	0.047
4 PVP - 200 L	31	4535.02	3.67	3.27	0.045
4 PVP - 300 L	28	4467.07	4.01	3.56	0.045
5 PVP - 200 L	28	4498.05	4.02	3.56	0.045
5 PVP - 300 L	26	4405.06	4.39	3.85	0.045

Lastly, for a daily hot water demand of 200 litres, the results also prove to be very attractive. The payback periods, LCoE for these systems are much lower than the ones for S2 while the IRR and NPV increases, as expected. The best configuration for Bragança was a system with 4 PV panels and a 300L storage tank while in Faro, the most attractive was the one with 5 PV panels and a 200L storage tank as shown in Table 5.26 and Table 5.27. Again, the results show that properly sizing a system is very important since the results are not linear, as sometimes assumed. In Appendix B, detailed information on the economic analysis of all the systems and configurations in each location and DHW load profile is present.

Table 5.26 - Economic analysis of S3 for a DHW profile of 200L in Bragança

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200 L	28	3515.68	4.02	3.56	0.056
3 PVP - 300 L	29	3299.05	4.13	4.02	0.057
4 PVP - 200 L	29	4293.35	3.79	3.37	0.047
4 PVP - 300 L	29	4658.94	3.85	3.42	0.044
5 PVP - 200 L	29	4642.96	3.89	3.45	0.044
5 PVP - 300 L	27	4561.71	4.23	3.73	0.043

Table 5.27 - Economic analysis of S3 for a DHW profile of 200L in Faro

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200 L	32	4199.63	3.50	3.13	0.049
3 PVP - 300 L	28	3996.31	3.97	3.52	0.050
4 PVP - 200 L	34	5176.85	3.26	2.94	0.041
4 PVP - 300 L	31	5128.47	3.57	3.19	0.041
5 PVP - 200 L	32	5416.12	3.44	3.08	0.039
5 PVP - 300 L	30	5404.52	3.70	3.30	0.038

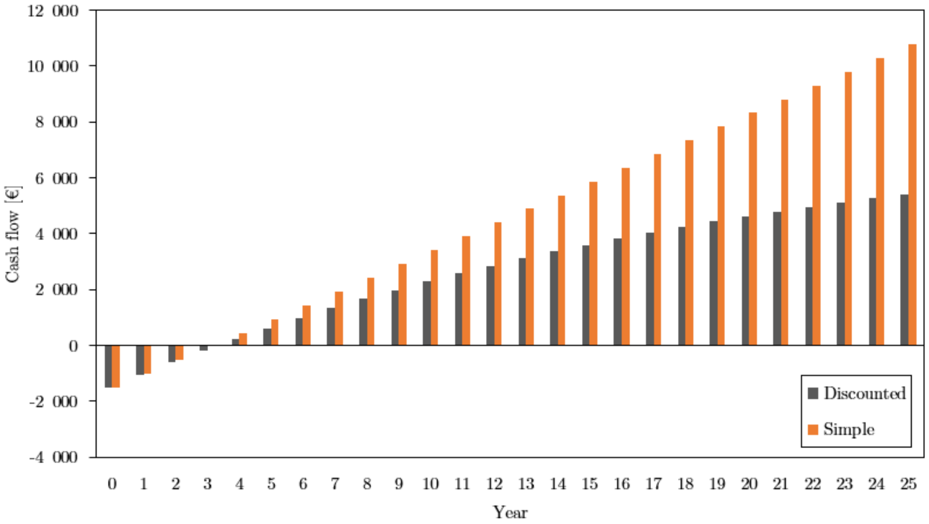


Figure 5.9 - Discounted and simple cash flows for the best configuration of S3 in Faro considering a 200L daily load.

Once again, some of the same conclusions can be made of the results obtained:

- Increasing the size of the system does not always prove to be more beneficial from the economic standpoint.
- The best configuration for a given economic metric is not necessarily the best one for another economic metric.
- Systems such as S3 can be capable of producing hot water at a lower overall cost than solar thermal systems.
- Despite being very competitive, PV systems require more available area in order to produce the same amount of energy due to their lower efficiency converting solar energy to electricity.

5.2.4. Sensitivity analysis

After analyzing the economic viability of all the configurations involved, a sensitivity analysis was conducted to assess the effect of the price of electricity and the value of the discount rate on the economic results. For that matter, the price of electricity was changed within a range of -50% to +50% when compared with the original number (0.212€) and the discount rate was varied from 4% to 8%. This analysis focused on the configurations of S2 and S3 with the highest NPV out of all the possibilities but, some exceptions are made to illustrate the negative effect that a low price of electricity and a high value for the discount rate have in certain conditions.

For S2, the configuration with the highest NPV was the one with 2 ST panels and a 300L for a 200L daily hot water demand and in the climate conditions of Faro. On the reference conditions of 0.212€/kWh for electricity and a 5% discount rate, this configuration has a NPV of 3768€, an IRR of 17%, a SPP and DPP of 5.8 and 7 years respectively, and a LCoH of 0.09€/kWh. For S3, the best configuration was the system with 5 PV panels and a 200L tank for a 200L daily hot water demand and in Faro. It had a NPV of 5416€, an IRR of 32%, a SPP and DPP of 3.1 and 3.4 years respectively, and a LCoE of 0.04€/kWh.

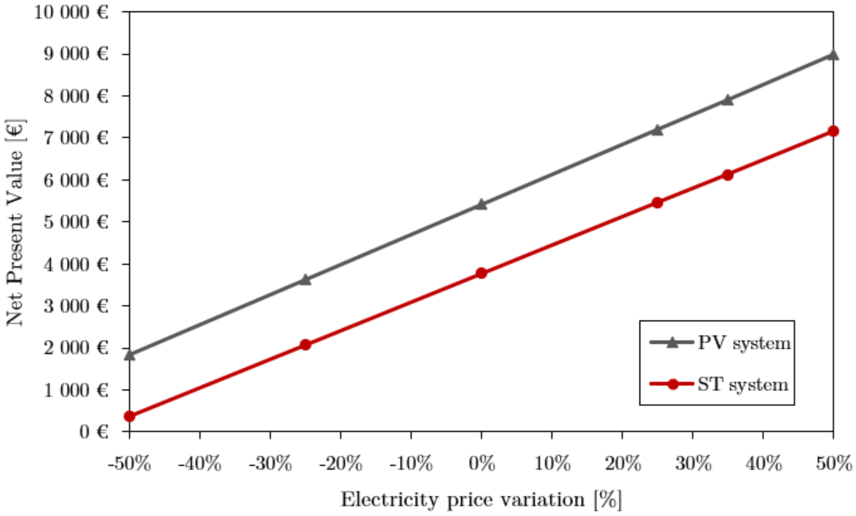


Figure 5.10 - Effect of the price of electricity on the NPV

The price of electricity has a great impact on the economic viability of a project, as was mentioned previously. A low price for electricity turns a solar system into a much less attractive investment because it means the potential monetary savings are lower. A 50% reduction on the cost of electricity would reduce the NPV from 5416€ to approximately 1839€ for the considered S3 configuration (PV) and from 3768€ to approximately 386€ for the considered S2 configuration. On the contrary, a 50% increase on the cost of electricity would increase the NPV to 8993€ in the first case, and to 7151€ on the second case (Figure 5.10).

These results were for the best-case scenario from all the configurations of S2 which means that, for less attractive systems, a low price for electricity may turn the investment much less viable. To illustrate this reality, the studied configurations for S2 in the city of Bragança and for a 100L daily hot water demand were considered. As shown in Figure 5.11, low prices of electricity make some configurations not as viable since these have a negative NPV. Some caution must be utilized if these systems are to be considered as not viable, because conventional systems such as an electric water heater are still much more costly to operate in the long run when compared with solar systems with slightly negative NPVs. Determining whether a system is viable or not, can depend on the investor's views, goals, and financial necessities.

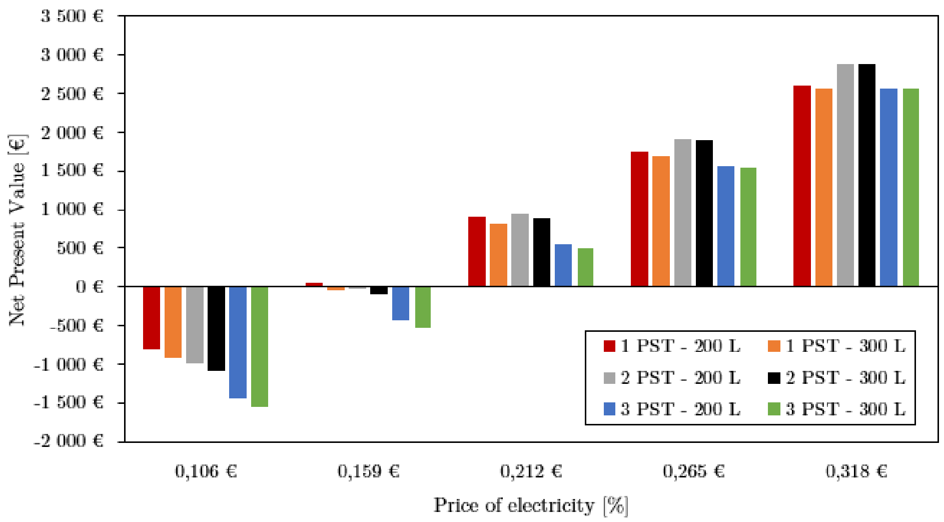


Figure 5.11 – Effect of the price of electricity on the NPV for S2 and a 100L load profile

The NPV is not the only economic metric affected by the cost of electricity. The payback periods (DPP and SPP) are also influenced by the cost of electricity. Opposite to the NPV, the payback periods decrease with the increase in the cost of electricity which is expected since the total yearly cash flow and discounted cash flow increase as well. As shown in Figure 5.12, the SPP and DPP do not depend on the cost of electricity in a linear fashion, with the cost of electricity having a bigger impact on the payback period for low prices when compared with higher ones. This occurs because with low prices of electricity come low cash flows therefore, the ratio between the initial investment and the cash flows increases. Increasing the cash flows means the investment is paid faster, but the ratio between the investment (constant value) and the cash flow (variable value) is lower, consequently the SPP and DPP are less affected by higher electricity prices.

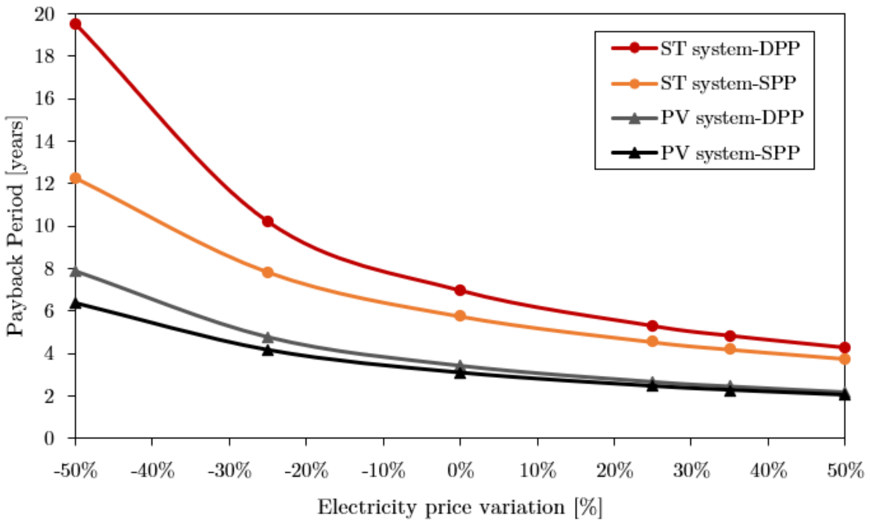


Figure 5.12 - Effect of the price of electricity on the DPP and SPP

The internal rate of return is also affected by the variation in the cost of electricity with a similar behavior to that of the NPV. The values increase with the increase in the price, and vice-versa. A 50% increase in the price of electricity can lead to an IRR of 49% for the PV system and 26% for the ST system (Figure 5.13).

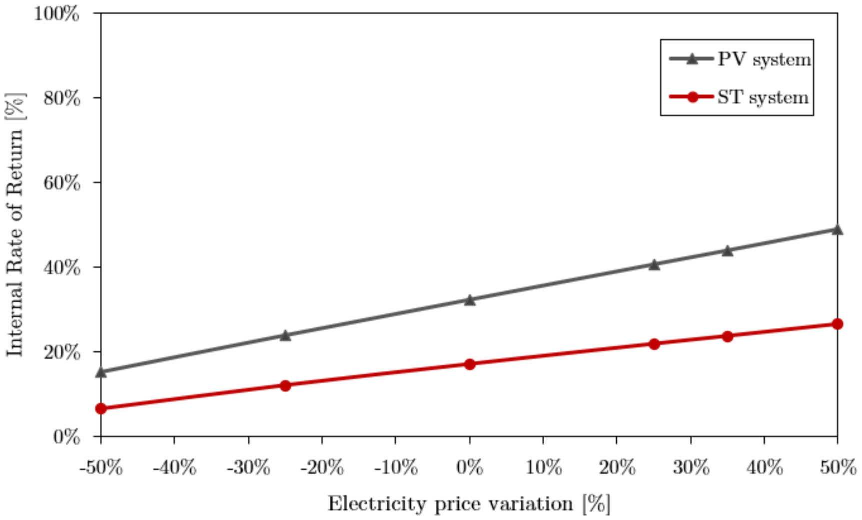


Figure 5.13 - Effect of the price of electricity on the IRR

The discount rate is also an aspect that has a lot of importance when studying the viability of investments. Depending on its value, this rate can have a big impact on the cash flows of a project and consequently on its economic viability. Usually, low discount rates are used in low-risk investments, and high discount rates on high-risk ones but, the discount rate can also be used to make a more "pessimistic" analysis, artificially increasing the risk of a project.

The increase of the discount rate lowers the attractiveness of the investment as shown in Figure 5.14 but, given that these types of investments are very low-risk and have reasonable payback periods, even a more pessimistic analysis cannot make such an investment not viable. For the two studied cases, it is apparent that at an 8% discount rate the projects are still much more interesting than the alternative conventional systems.

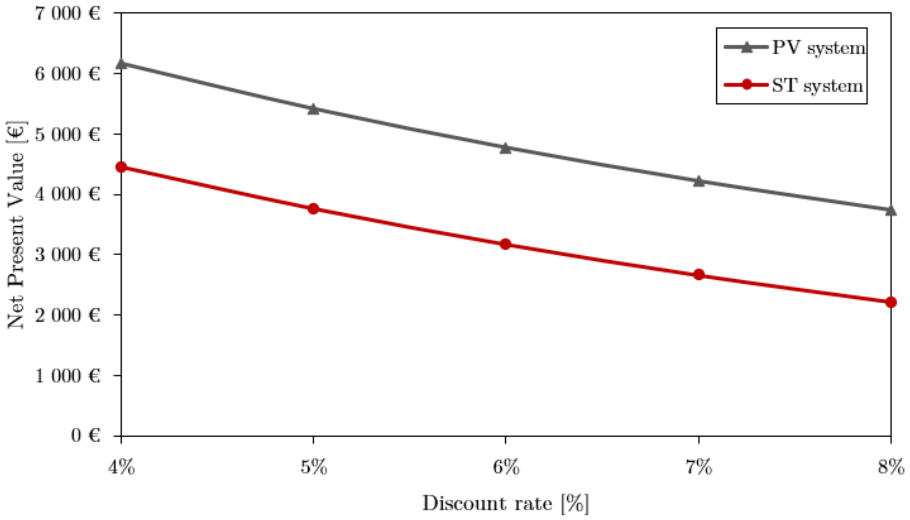


Figure 5.14 - Effect of the discount rate on the NPV

Out of all the configurations involved in this analysis, only for a 100L daily hot water demand in the city of Bragança, some of the variations of S2 had a negative NPV which deems them much less viable at discount rate of 8% (Figure 5.15).

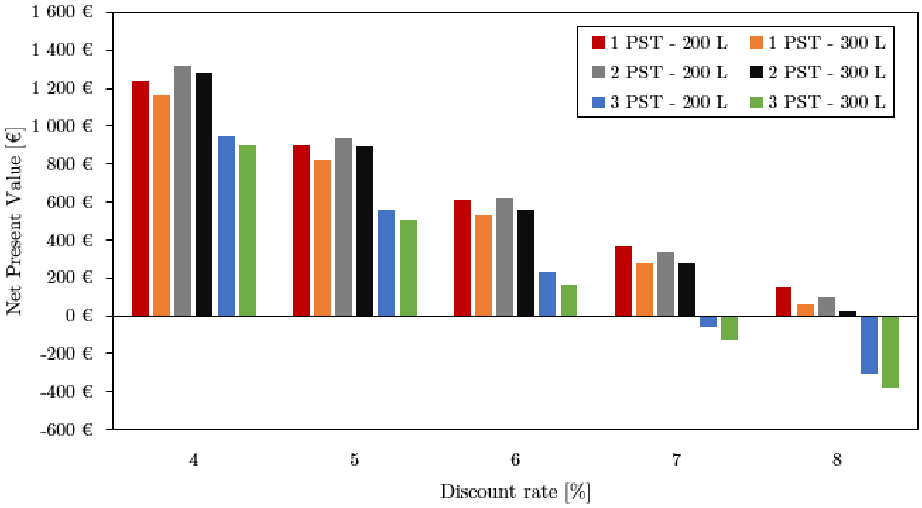


Figure 5.15 - Effect of the discount rate on the NPV for S2 and a 100L load profile

Varying the discount rate has little impact on the DPP, because it depends on the discounted cash flows. The discounted payback period does not change too much when increasing or decreasing the discount rate, reaching only a maximum of 8 years and 3.7 years for the ST system and the PV system, respectively, for an 8% rate (Figure 5.16).

At last, the effect of the discount rate on the LCoH and LCoE was also assessed (Figure 5.17), and the results show that for an 8% discount rate, the LCoH for the ST system increases to 0.11€/kWh and the LCoE for the PV system increases to 0.05€/kWh. This increase is justified by the decrease on the cashflows provoked by the increase in the discount rate.

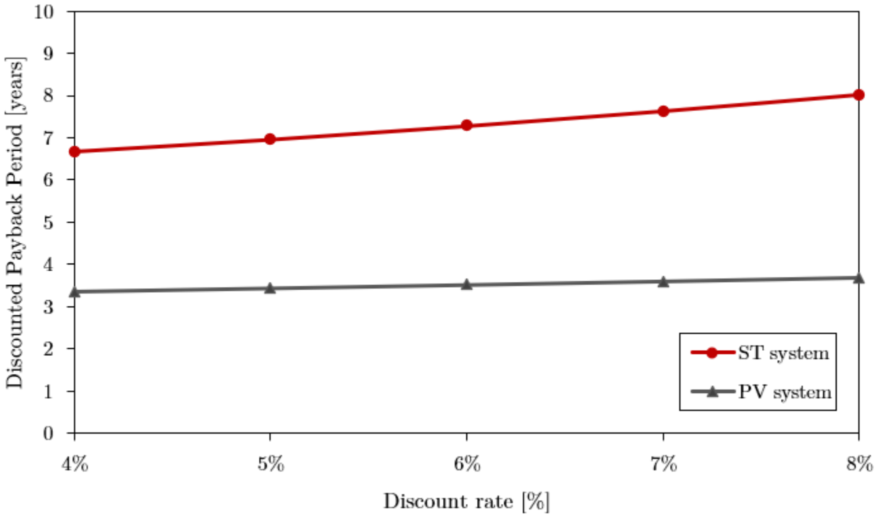


Figure 5.16 - Effect of the discount rate on the DPP

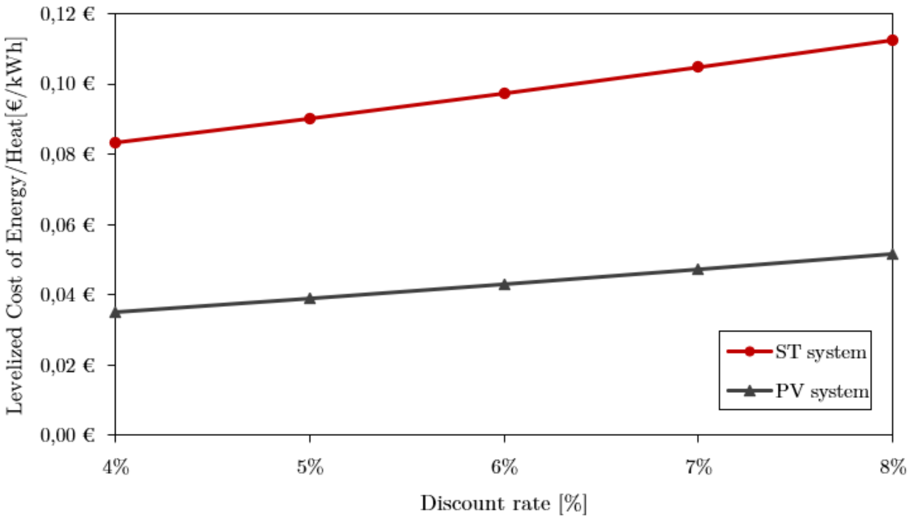


Figure 5.17 - Effect of the discount rate on the LCoH and LCoE

In short, the sensitivity analysis showed that depending on the value of some economic variables such as the discount rate or the cost of electricity, the economic attractiveness of projects can be increase or decrease. A more detailed description of the effect of the price of electricity and the discount rate on all the systems involved in this analysis is present at Appendix C.

Some very important conclusions can be made from the sensitivity analysis that was conducted:

- The price of electricity has a great impact on the economic metric chosen for this comparative economic analysis, especially on the NPV, IRR and DPP and SPP of the investments.
- For very low electricity prices, the investment in SWHS become much less attractive, reaching negative values for NPV in some conditions.
- The price of electricity has a higher impact on the economic viability of these kinds of systems.
- The discount rate has a smaller impact than the price of electricity but, for certain conditions, a high rate can lead to a negative NPV and high payback periods.

5.2.5. Effect of inflation of electricity prices

Another important reality when performing an economic analysis such as the one in this work, is the variation of the price of electricity over the years. As mentioned in section 4.7.1, the price of electricity can increase or decrease from year to year, depending on many political and economic events. Therefore, this variable was assumed to be constant throughout the period of analysis. However, a brief analysis on the effect of a 1% increase of the price of electricity every year was made during this work, and the results are present in this section.

Figure 5.18 shows the differences in the NPV of the configurations of S2 for a 2-person household in the city of Faro, and it is evident that the values increase but the best configuration does not change. Figure 5.19 shows the NPV variation for the configurations of S3 in Bragança also for a 2-person household, and the increase in the NPV of the different configurations as well as a change in the configuration with the highest NPV are also noticeable. The detailed results of this analysis are present in Appendix D.

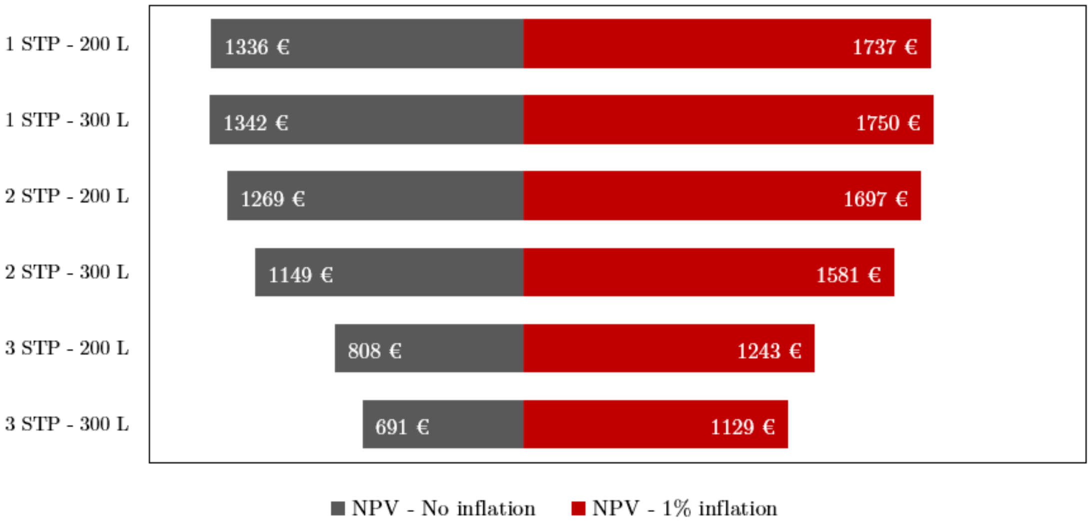


Figure 5.18 - Comparison for the NPV of S2 with no inflation and a 1% yearly inflation on the cost of electricity

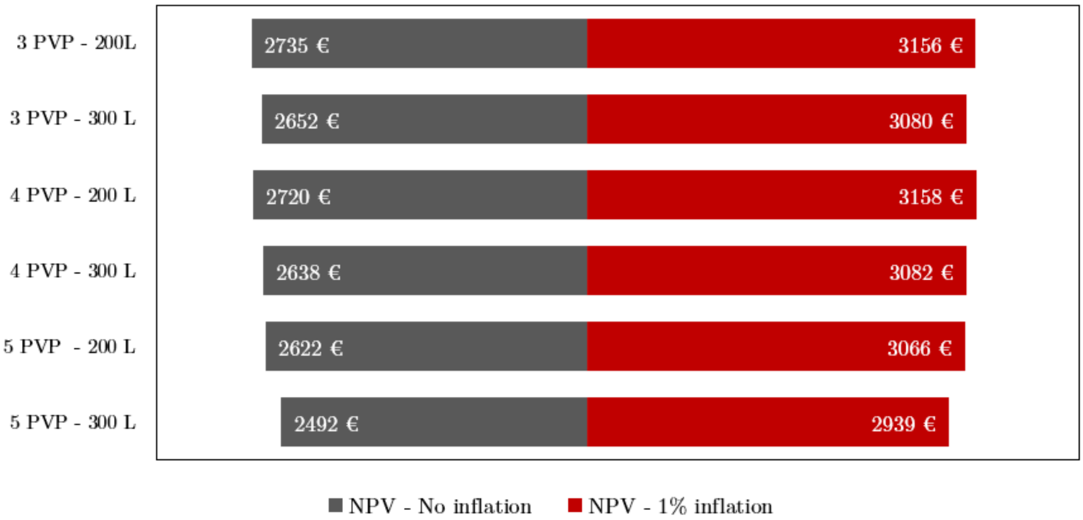


Figure 5.19 - Comparison for the NPV of S3 with no inflation and a 1% yearly inflation on the cost of electricity

Since the increase on the price of electricity increases the economic viability of these systems as was shown previously, the same was expected from this study. The results precisely show that, with an increase of the values for the NPV and IRR and a decrease of the payback periods. Only for two cases did the 1% inflation of the prices change the best PV configuration (highest NPV) from all the alternatives: PV system (S3), for a 100L and a 200L daily hot water load in Bragança and Faro, respectively. Additionally, for all the configurations of S2, the results for the best configurations remained the same.

5.3. Environmental analysis result

The last part of this work consisted in performing a comparison of the environmental benefits of the different configurations that were studied, more specifically the reduction in CO_2 emissions. The mass of carbon dioxide was calculated from the total energy savings of the systems when compared with the reference case. The total CO_2 reduction was for the total period of analysis (25 years).

For S2, in Bragança, the total reduction of CO_2 emissions can reach a value of 109 tCO_2 for a system with 3 ST panels and a 300L storage tank for a period of 25 years. The lowest reduction is of 62 tCO_2 for the system with the lowest amount of savings, as shown in Figure 5.20. For Faro (Figure 5.21), we can see an increase in the total reduction in CO_2 emissions as expected, because in its weather conditions the total energy saved is greater.

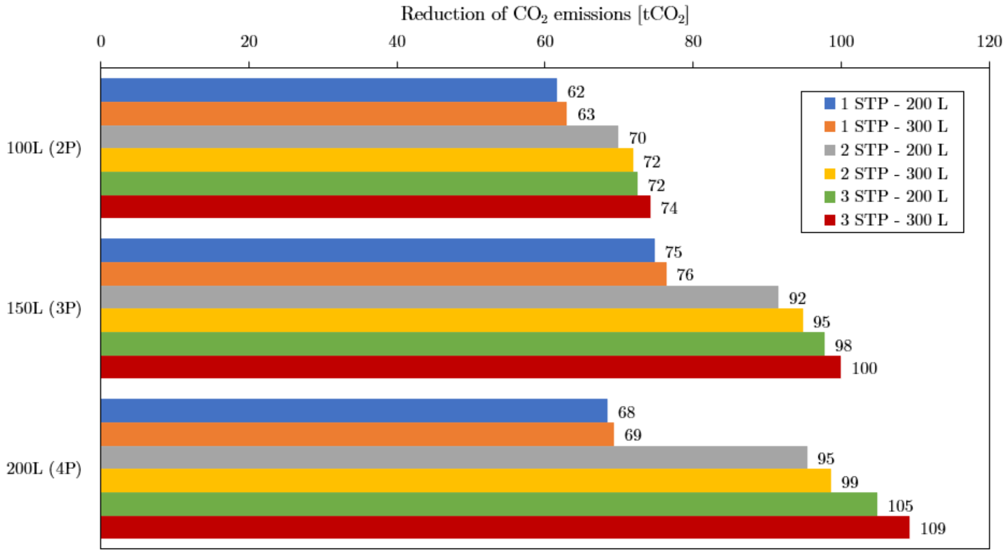


Figure 5.20 - Reduction of CO2 emissions for S2 in Bragança

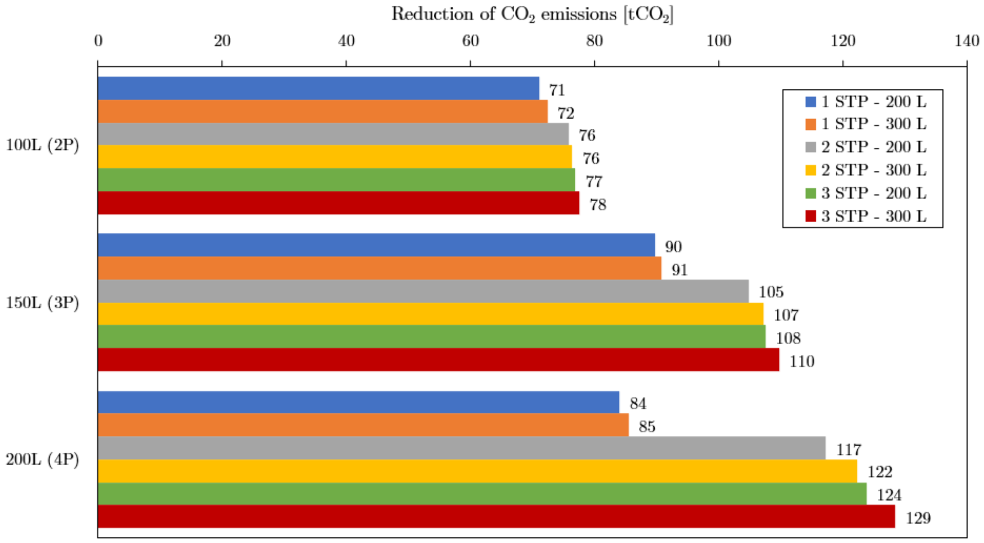


Figure 5.21 - Reduction of CO2 emissions for S2 in Faro

For S3, in Bragança, we can observe an increase in the total reduction of CO_2 emissions for every case. The smallest amount of CO_2 prevented of getting into the atmosphere is of 75 tCO_2 and the greatest is of 116 tCO_2, for a system with 3 PV panels and a 200L tank and a system with 5 PV panels and a 300L tank, respectively (Figure 5.22). For Faro, the total amount of CO_2 prevented from being released to the atmosphere increases, with a maximum value of 132 tCO_2 for a system with 5 PV panels and a 300L tank, under a daily hot water demand of 200 litres (Figure 5.23) over a 25-year timespan.

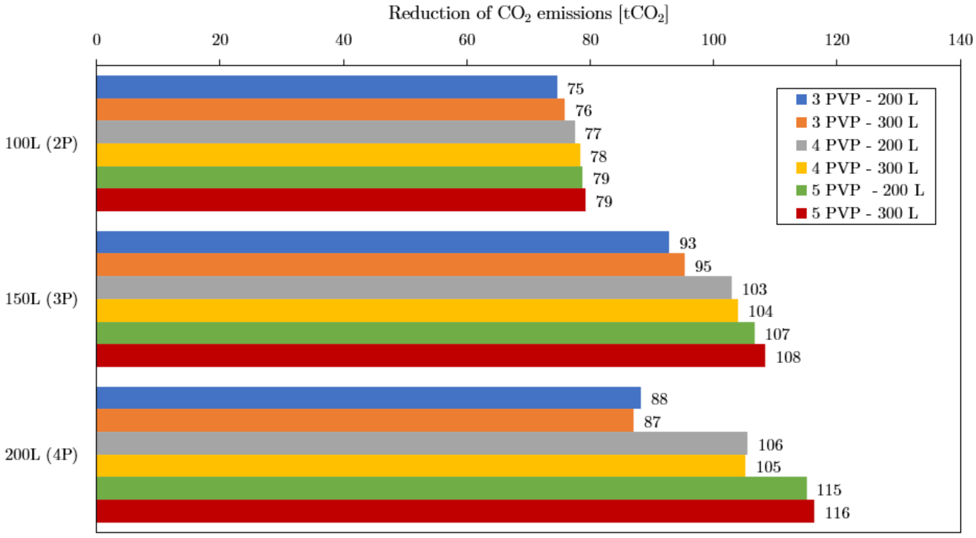


Figure 5.22 - Reduction of CO2 emissions for S3 in Bragança

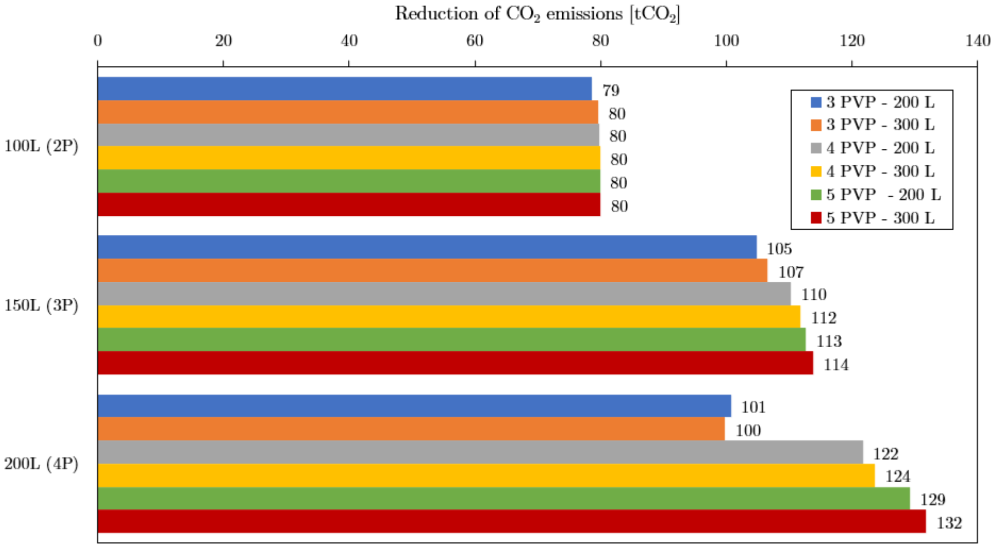


Figure 5.23 - Reduction of CO2 emissions for S3 in Faro

Considering the results obtained, we can easily confirm the positive impact of solar systems on the environmental conditions. Over the course of the lifetime of these systems, the total reduction of GHG emissions is quite substantial, making them a good mean of preserving the environment, assuming these results are multiplied by millions of households.

6. Conclusion

This Master's dissertation conducted an economic analysis on solar water heating systems for domestic purposes, to assess the best configurations for SWHS under different conditions, namely the location and DHW profile but also under different economic conditions. Two different solar systems were considered and compared with a conventional system, from the performance and economic standpoints. In-depth economic analyses of these systems are not common since most real-life studies are very basic and rarely rely on different economic metrics to determine the economic viability of such projects. This work performed an economic analysis counting on different indicators to have a very solid foundation and to show that choosing a SWHS is not a linear task.

In essence, solar water heating systems proved to be much better than the conventional systems, as was expected, despite the latter being much more affordable to acquire up-front. Solar thermal systems (S2) are a proven technology, that is capable of heavily reducing the total costs of producing hot water for domestic and non-domestic applications, and this reality was once again confirmed in this work. Despite having a hefty initial cost, depending on the configuration that is chosen, ST systems have acceptable economic results for most use cases. The attractiveness of these systems is proportional to the DHW demand, which means that when there are not sufficient daily hot water necessities, these systems may take a long time to return the initial investment and lifetime maintenance. The main negative aspect of these systems is the higher initial cost, when compared with a PV system leading to slightly less attractive economic results, but the additional operation and maintenance costs also contribute to this reality.

This work also studied the economic viability of a photovoltaic water heating system (S3), which is not a system usually available commercially but that, in theory, can yield great results. The analysis concluded that such a system, on the chosen case studies, can be very competitive against a ST system mainly due to the much lower initial investment cost. There are some questions regarding the technical viability of such a system, in particular the need for extra components that can increase the overall cost of the system but, given the economic results obtained, it is evident that these systems will be viable even considering a slight price increase. The main drawback of such a system is the additional area necessary to install the PV panels because these required more space to produce an equivalent amount of energy to that of an equivalent solar thermal system.

A sensitivity analysis was done to determine the effect of different economic variables (price of electricity and discount rate) on the viability of the systems. The results showed that the price of electricity can have a big impact on the viability of these kinds of investments because they are always compared with a conventional alternative that needs electricity to produce hot water. If electricity prices are low, a big investment on SWHS can be less attractive economically because it yields fewer annual savings. The increase of the price of electricity has the opposite outcome, as expected. The results confirmed that the act of choosing a solar hot water system is not linear, which means that oversizing a system may be less attractive than choosing the correct configuration for a given hot water necessity.

From the environmental standpoint, SWHS are also capable of reducing the amount of CO_2 sent to the atmosphere by a huge amount, when compared with conventional systems. One aspect that should be mentioned is that in the future the total amount of CO_2 released to the environment by means of electricity production is going to diminish thanks to renewable energy systems, that do not require fossil fuels to produce electricity. This will lead to a decrease in the environmental benefits of SWHS.

The main objectives of this dissertation were attained, showing that the act of investing in a solar water heating system to replace a conventional alternative is not as obvious and it is sometimes thought to be. The performance and economic viability depend on various important aspects such as the domestic hot water needs, location, and economic conditions. The studied SWHS proved to be more economically attractive than a conventional electric water heater as expected, even when considering less favourable economic conditions.

On a final note, future work could explore different locations in order to determine the viability of a system such as S3 specially in colder climates where a solar thermal system suffers from cold temperatures. There is room for involving different solar hot water systems in these analyses, such as solar thermal systems with evacuated-tube collectors which are more suitable for colder climates or PV/T systems than are able of producing heat and electricity at the same time. A comparison between solar systems and an equivalent DHW heat-pump system would also be interesting to conduct. In order to correctly assess the techno-economic viability of a system such as S3, conducting an experimental study would be a great way of doing so, comparing the experimental results obtained in Portuguese climate conditions with simulated ones. Studying different economic conditions, such as a negative inflation for electricity prices or a variable inflation over the period of analysis is also an idea to consider in future studies. Lastly, there is room for analysing different DHW profiles, varying the hourly distribution of hot water demand which can have a big impact on the performance of the systems and consequently on the economic results.

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Appendix A – Performance data and results of all simulations

Table A.1 – Monthly electricity consumption for the parametric study on S1

	Electricity consumption (kWh)								
Month	100L(2P) load			150L (3P) load			200L (4P) load		
	100L	150L	200L	100L	150L	200L	100L	150L	200L
January	119,25	125,25	129,00	162,50	168,50	171,50	224,00	246,00	258,50
February	101,50	106,00	111,25	147,25	149,50	156,25	203,75	219,00	226,25
March	128,50	133,25	134,50	181,00	186,00	188,75	223,50	236,25	242,00
April	120,50	124,00	128,75	186,75	189,00	192,00	208,25	221,25	227,25
May	140,00	145,00	148,00	193,50	199,75	203,00	212,50	229,50	237,00
June	124,75	129,00	131,25	206,00	208,75	213,00	206,00	220,00	225,75
July	143,50	146,00	151,50	191,75	196,75	199,50	218,50	235,00	243,50
August	130,75	135,25	137,25	188,75	193,50	197,25	218,75	232,75	241,50
September	118,25	122,50	127,50	181,75	185,75	188,25	215,75	232,00	239,50
October	123,00	126,00	131,00	170,50	173,00	178,00	220,75	237,50	245,50
November	116,50	122,00	123,50	154,25	160,00	162,75	211,75	229,75	237,50
December	121,50	124,50	128,50	168,25	172,25	175,50	218,75	235,00	241,75
Total	1488,00	1538,75	1582,00	2132,25	2182,75	2225,75	2582,25	2774,00	2866,00

Table A.2 – Monthly thermal energy production for S2 in Bragança for 100L profile

Thermal energy production (kWh_{th})									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	61.38	62.08	62.26	77.44	79.76	82.39	85.15	91.00	93.54
February	59.58	60.78	60.68	79.03	80.90	84.01	82.14	83.98	88.11
March	95.45	97.48	100.13	103.65	107.15	107.24	104.21	105.53	108.16
April	108.22	111.22	112.93	106.67	113.46	113.03	113.82	111.82	111.78
May	113.02	115.46	116.84	129.96	130.13	129.48	130.54	135.75	137.38
June	116.58	120.25	123.02	115.20	113.25	114.28	113.76	113.35	112.98
July	134.14	133.48	131.59	131.31	134.28	134.91	133.59	133.30	133.30
August	121.04	122.01	125.13	122.96	121.40	120.85	122.61	122.80	123.24
September	104.10	104.30	103.79	108.78	112.44	111.96	108.89	110.38	109.98
October	94.77	95.84	97.07	106.94	106.99	110.87	110.27	113.90	113.78
November	77.60	79.18	80.51	96.42	96.15	96.78	98.29	99.38	97.04
December	67.66	67.97	68.33	87.83	91.39	93.62	93.21	93.57	97.24
Total	1153.53	1170.04	1182.28	1266.20	1287.29	1299.41	1296.47	1314.76	1326.54

Table A.3 - Monthly electricity consumption for S2 in Bragança for 100L profile

Electricity consumption (kWh)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	59.00	59.75	60.75	45.00	44.75	43.75	37.75	35.25	35.75
February	38.25	38.00	39.00	15.00	14.75	14.00	9.75	8.00	4.50

March	34.25	32.75	30.25	21.00	13.25	13.25	16.25	15.00	12.00
April	3.00	0.00	0.00	1.50	0.00	0.00	1.25	0.00	0.00
May	19.50	17.50	16.00	7.75	5.50	4.50	3.50	1.75	0.00
June	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	3.00	1.75	0.00	1.25	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	4.00	2.00	1.50	2.00	0.00	0.00	1.75	0.00	0.00
October	23.25	22.50	20.25	7.25	7.75	4.00	3.75	0.00	0.00
November	28.75	27.50	25.75	5.25	5.50	3.25	1.75	0.00	0.00
December	52.25	51.50	48.50	28.00	22.50	17.50	20.75	17.00	15.00
Total	266.25	253.25	242.00	134.00	114.00	100.25	96.50	77.00	67.25

Table A.4 – Monthly thermal energy production for S2 in Bragança for 150L profile

Thermal energy production (kWh$_{th}$)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	68.52	69.09	69.51	93.93	97.47	99.57	105.98	107.92	110.20
February	67.02	68.53	68.40	99.31	103.75	105.28	115.85	118.45	123.13
March	118.29	119.37	121.07	136.18	141.69	147.23	141.99	146.76	143.58
April	140.36	143.85	145.37	158.06	162.13	165.39	162.82	168.90	175.01
May	146.28	151.29	153.91	174.95	180.21	182.01	186.59	189.23	185.27
June	165.32	169.07	170.12	199.59	202.49	204.96	203.79	203.76	202.15
July	185.09	187.34	188.58	184.36	185.24	180.03	184.36	184.50	185.56
August	185.65	186.29	188.34	186.01	186.21	191.58	186.81	186.50	186.60
September	163.83	166.33	166.19	172.96	171.42	171.47	174.42	176.18	177.69
October	110.37	113.22	115.44	132.72	139.40	142.00	142.80	140.72	146.59
November	92.94	94.69	94.85	113.38	118.73	119.28	127.52	134.86	131.78
December	73.80	74.93	75.68	110.18	112.59	114.16	118.82	119.40	125.07
Total	1517.47	1544.01	1557.45	1761.63	1801.33	1822.96	1851.75	1877.20	1892.64

Table A.5 – Monthly electricity consumption for S2 in Bragança for 150L profile

Electricity consumption (kWh)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	98.50	99.75	101.25	72.75	71.50	72.75	62.75	64.00	63.75
February	84.50	81.75	82.25	49.25	45.25	42.25	30.25	28.00	24.50
March	73.25	74.50	73.75	50.75	47.00	43.50	42.00	36.25	36.00
April	43.50	39.50	38.00	20.25	16.25	12.50	14.50	9.00	10.25
May	50.25	46.50	43.75	21.25	15.00	12.25	9.75	6.75	8.75
June	49.25	47.00	46.50	5.75	3.50	2.25	0.00	0.00	0.00
July	5.50	4.25	4.50	1.50	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	16.25	13.00	10.50	5.75	5.75	4.00	3.75	2.25	0.00
October	58.75	55.25	54.00	33.00	27.75	28.00	19.75	18.50	13.00
November	63.50	62.00	61.25	34.75	29.00	26.25	19.25	15.00	17.25
December	98.50	96.75	97.75	62.75	57.25	57.25	50.75	47.50	43.25
Total	641.75	620.25	613.50	357.75	318.25	301.00	252.75	227.25	216.75

Table A.6 – Monthly thermal energy production for S2 in Bragança for 200L profile

Thermal energy production (kWh$_{th}$)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	75.38	77.20	78.20	117.29	121.36	124.05	138.50	146.25	150.05
February	72.52	74.25	75.25	113.94	117.11	119.12	135.15	142.76	147.54
March	125.82	129.03	131.85	169.78	174.87	184.74	178.95	185.16	194.41
April	155.80	160.72	162.65	187.66	192.61	196.94	194.51	201.15	204.88
May	158.09	162.95	164.77	196.29	202.29	206.25	209.33	212.97	215.98
June	169.10	171.82	173.63	213.50	216.69	220.55	215.71	220.37	220.19
July	206.02	209.60	211.59	227.32	230.02	230.95	228.40	229.84	229.99
August	225.40	229.87	233.99	233.43	227.68	230.10	231.62	231.97	232.41
September	186.59	190.52	194.30	207.24	216.09	216.16	220.13	222.35	223.03
October	127.44	130.40	132.31	168.93	177.32	180.96	188.12	192.90	200.66
November	104.13	106.58	107.34	146.55	149.21	150.20	167.89	173.65	175.66
December	78.86	80.67	81.72	122.05	126.35	128.63	144.82	150.48	153.56
Total	1685.16	1723.60	1747.60	2103.98	2151.59	2188.66	2253.13	2309.84	2348.36

Table A.7 – Monthly electricity consumption for S2 in Bragança for 200L profile

Electricity consumption (kWh)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	178.25	183.25	185.25	136.75	139.50	140.25	117.00	115.50	115.25
February	157.00	157.25	158.50	116.00	114.75	113.25	91.75	86.25	83.50
March	124.25	123.25	121.25	79.00	77.75	70.75	67.25	62.00	54.00
April	69.00	66.50	66.25	28.00	22.50	18.50	22.50	16.50	12.00
May	81.75	78.00	76.75	37.00	30.50	24.50	21.25	15.00	12.00
June	61.75	59.00	58.50	8.25	6.25	5.25	3.50	0.00	0.00
July	36.75	35.50	34.00	6.50	3.50	2.25	3.50	2.00	1.75
August	12.00	10.25	8.75	0.00	3.00	0.00	2.00	0.00	0.00
September	55.75	52.25	50.50	29.50	23.50	21.75	17.75	16.25	14.50
October	122.50	121.25	119.25	73.75	68.75	66.25	50.75	46.50	41.00
November	136.25	137.00	137.25	88.50	86.25	85.25	65.75	60.75	57.50
December	164.75	167.00	167.00	121.50	120.50	119.75	97.25	93.00	91.50
Total	1200.00	1190.50	1183.25	724.75	696.75	667.75	560.25	513.75	483.00

Table A.8 – Monthly thermal energy production for S2 in Faro for 100L profile

Thermal energy production (kWh$_{th}$)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	109.21	111.09	110.78	112.14	114.99	115.65	112.63	115.05	117.43
February	94.13	94.81	100.48	93.02	92.35	91.71	92.47	87.58	89.74
March	92.81	95.05	95.21	105.89	108.87	110.78	111.22	118.68	118.07
April	102.46	104.71	106.66	115.41	117.42	118.25	115.73	116.79	116.67
May	128.38	131.43	134.68	131.12	131.86	132.88	130.20	130.12	128.29
June	113.38	113.65	113.97	115.02	114.68	114.25	115.20	115.04	119.16

July	133.85	134.41	134.35	131.55	132.16	127.91	131.65	131.83	129.32
August	122.38	122.74	122.42	122.83	122.18	126.61	122.99	123.05	119.48
September	103.08	104.17	103.90	104.72	105.82	103.58	105.12	104.47	111.23
October	112.62	114.03	115.78	116.42	115.12	116.68	117.97	117.83	116.46
November	102.62	99.81	99.20	105.40	105.49	105.93	103.58	103.83	104.02
December	101.70	104.24	107.34	110.06	113.00	112.92	109.50	109.02	108.88
Total	1316.63	1330.15	1344.78	1363.57	1373.96	1377.13	1368.27	1373.28	1378.75

Table A.9 – Monthly electricity consumption for S2 in Faro for 100L profile

Electricity consumption (kWh)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	5.00	6.25	9.00	5.00	6.25	7.50	5.00	6.25	7.50
February	5.00	3.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00
March	22.25	21.25	15.75	9.25	5.25	3.50	5.00	2.00	0.00
April	16.75	14.00	14.50	4.50	2.75	3.50	1.25	0.00	0.00
May	11.25	9.25	6.00	2.25	2.25	2.25	2.25	2.50	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	3.25	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
November	4.25	3.25	2.00	0.00	0.00	0.00	0.00	0.00	0.00
December	15.75	13.50	11.25	3.50	0.00	0.00	1.75	0.00	0.00
Total	83.50	72.25	59.75	24.50	16.50	16.75	15.25	10.75	7.50

Table A.10 – Monthly thermal energy production for S2 in Faro for 150L profile

Thermal energy production (kWh$_{th}$)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	140.06	143.92	144.85	153.51	156.65	159.42	154.96	157.81	159.78
February	134.09	136.38	137.02	142.12	145.07	144.10	141.78	143.16	143.00
March	116.27	117.37	118.70	146.82	148.83	151.51	153.69	155.03	160.81
April	129.64	130.08	132.13	163.09	167.67	169.59	170.22	177.15	180.88
May	166.26	168.06	169.45	181.97	186.88	184.94	183.15	184.56	187.34
June	177.12	179.44	180.91	201.09	202.47	205.71	203.56	203.24	202.61
July	186.05	189.82	190.90	183.45	183.50	186.27	183.57	183.88	184.03
August	184.35	186.41	187.25	185.37	186.98	186.71	185.71	186.75	186.57
September	155.10	158.50	160.56	165.68	167.50	165.83	171.06	168.49	166.03
October	158.23	159.34	161.29	163.58	164.77	167.80	166.21	168.27	169.23
November	132.67	134.62	135.26	151.18	148.80	149.82	148.51	148.62	148.33
December	124.96	127.67	128.08	146.48	148.23	157.30	151.76	158.13	161.20
Total	1804.80	1831.61	1846.40	1984.33	2007.34	2028.99	2014.18	2035.09	2049.81

Table A.11 – Monthly electricity consumption for S2 in Faro for 150L profile

Electricity consumption (kWh)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	23.00	22.75	24.25	5.00	6.25	7.50	5.00	6.25	7.50
February	18.50	17.75	18.00	3.00	0.00	0.00	1.75	0.00	0.00
March	63.75	63.00	61.00	27.75	23.50	19.00	20.25	16.75	8.50
April	62.75	61.75	60.50	28.25	24.00	23.50	19.50	14.50	12.75
May	33.50	32.25	33.25	9.50	6.75	5.50	6.50	4.75	2.50
June	36.00	35.00	34.25	3.00	1.50	0.00	0.00	0.00	0.00
July	4.25	3.00	3.50	0.00	0.00	0.00	0.00	0.00	0.00
August	3.25	2.50	1.75	1.75	0.00	0.00	1.50	0.00	0.00
September	22.75	18.00	17.75	6.00	1.25	2.25	1.25	1.75	2.25
October	6.25	6.75	3.75	1.75	4.25	0.00	0.00	0.00	0.00
November	22.75	21.50	21.00	0.00	0.00	0.00	0.00	0.00	0.00
December	47.75	46.25	46.75	19.50	18.25	8.25	12.75	5.50	2.25
Total	344.50	330.50	325.75	105.50	85.75	66.00	68.50	49.50	35.75

Table A.12 – Monthly thermal energy production for S2 in Faro for 200L profile

Thermal energy production (kWh_{th})									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	158.70	162.50	164.06	223.09	232.47	235.80	237.89	241.16	246.53
February	150.40	154.37	156.04	196.66	201.34	207.94	203.09	211.57	216.26
March	126.14	128.40	129.66	170.48	178.56	182.85	185.66	190.11	191.88
April	137.80	139.30	141.56	180.78	187.21	194.13	195.48	199.73	206.99
May	174.88	178.90	180.59	213.14	218.58	222.06	216.22	221.97	223.23
June	180.18	183.38	185.02	216.27	218.33	217.30	220.60	220.37	220.20
July	210.96	215.61	217.35	228.70	230.09	230.20	227.98	227.74	227.47
August	217.61	221.87	225.97	229.72	232.15	233.31	227.69	228.97	234.17
September	176.55	181.05	181.89	209.97	211.00	214.77	212.11	214.51	218.14
October	200.39	207.96	210.86	231.38	237.29	241.69	235.74	235.34	240.77
November	148.44	151.04	152.60	205.27	208.28	210.20	216.03	218.89	224.46
December	136.61	139.15	140.20	194.36	200.99	203.84	206.53	213.05	216.09
Total	2018.66	2063.54	2085.80	2499.82	2556.28	2594.08	2585.01	2623.41	2666.19

Table A.13 – Monthly electricity consumption for S2 in Faro for 200L profile

Electricity consumption (kWh)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	105.25	104.75	105.00	30.25	24.00	22.50	10.25	9.50	7.50
February	80.50	79.00	78.75	30.25	26.25	21.75	23.00	14.00	9.50
March	121.75	120.50	120.00	68.00	59.75	54.00	51.00	44.75	41.25
April	93.00	93.75	91.75	48.00	42.25	36.00	32.25	30.50	25.75
May	63.50	60.50	61.50	16.50	12.50	11.00	10.75	5.00	3.75

June	51.75	49.75	48.75	4.50	0.00	0.00	0.00	0.00	0.00
July	30.00	28.00	27.75	0.00	0.00	0.00	0.00	0.00	0.00
August	25.50	23.50	22.25	4.75	2.25	1.75	6.75	5.50	0.00
September	65.75	63.50	59.50	22.50	19.00	12.25	19.25	13.25	7.25
October	45.50	40.75	42.00	6.50	2.25	0.00	3.75	6.25	0.00
November	95.50	94.50	94.50	28.25	24.25	21.00	15.75	12.75	8.50
December	109.75	109.50	109.25	44.25	38.50	36.00	26.75	18.00	16.75
Total	887.75	868.00	861.00	303.75	251.00	216.25	199.50	159.50	120.25

Table A.14 – Monthly efficiency for S2 in Bragança for 100L profile

100L (2P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	46.6%	47.1%	47.3%	29.4%	30.3%	31.3%	21.5%	23.0%	23.7%
February	39.9%	40.7%	40.6%	26.5%	27.1%	28.1%	18.3%	18.7%	19.7%
March	33.9%	34.7%	35.6%	18.4%	19.1%	19.1%	12.4%	12.5%	12.8%
April	27.0%	27.8%	28.2%	13.3%	14.2%	14.1%	9.5%	9.3%	9.3%
May	23.8%	24.4%	24.7%	13.7%	13.7%	13.7%	9.2%	9.5%	9.7%
June	21.9%	22.6%	23.1%	10.8%	10.7%	10.7%	7.1%	7.1%	7.1%
July	23.6%	23.5%	23.2%	11.6%	11.8%	11.9%	7.8%	7.8%	7.8%
August	22.3%	22.5%	23.1%	11.3%	11.2%	11.2%	7.5%	7.6%	7.6%
September	27.4%	27.5%	27.4%	14.3%	14.8%	14.8%	9.6%	9.7%	9.7%
October	41.3%	41.7%	42.3%	23.3%	23.3%	24.1%	16.0%	16.5%	16.5%
November	47.3%	48.3%	49.1%	29.4%	29.3%	29.5%	20.0%	20.2%	19.7%
December	55.3%	55.5%	55.8%	35.9%	37.3%	38.2%	25.4%	25.5%	26.5%
Average	34.2%	34.7%	35.0%	19.8%	20.2%	20.6%	13.7%	14.0%	14.2%

150L (3P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	-	52.4%	52.8%	35.7%	37.0%	37.8%	26.8%	27.3%	27.9%
February	44.9%	45.9%	45.8%	33.3%	34.7%	35.3%	25.9%	26.4%	27.5%
March	42.1%	42.5%	43.1%	24.2%	25.2%	26.2%	16.8%	17.4%	17.0%
April	35.1%	35.9%	36.3%	19.7%	20.2%	20.6%	13.6%	14.1%	14.6%
May	30.9%	31.9%	32.5%	18.5%	19.0%	19.2%	13.1%	13.3%	13.0%
June	31.1%	31.8%	32.0%	18.8%	19.0%	19.3%	12.8%	12.8%	12.7%
July	32.6%	33.0%	33.2%	16.2%	16.3%	15.8%	10.8%	10.8%	10.9%
August	34.3%	34.4%	34.8%	17.2%	17.2%	17.7%	11.5%	11.5%	11.5%
September	43.2%	43.8%	43.8%	22.8%	22.6%	22.6%	15.3%	15.5%	15.6%
October	48.0%	49.3%	50.2%	28.9%	30.3%	30.9%	20.7%	20.4%	21.3%
November	56.7%	57.7%	57.8%	34.6%	36.2%	36.4%	25.9%	27.4%	26.8%
December	60.3%	61.2%	61.8%	45.0%	46.0%	46.6%	32.4%	32.5%	34.1%
Average	42.6%	43.3%	43.7%	26.2%	27.0%	27.4%	18.8%	19.1%	19.4%

200L (4P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	57.2%	58.6%	59.4%	44.5%	46.1%	47.1%	35.0%	37.0%	38.0%
February	48.6%	49.7%	50.4%	38.2%	39.2%	39.9%	30.2%	31.9%	32.9%

March	44.8%	45.9%	46.9%	30.2%	31.1%	32.9%	21.2%	22.0%	23.0%
April	38.9%	40.1%	40.6%	23.4%	24.0%	24.6%	16.2%	16.7%	17.1%
May	33.4%	34.4%	34.8%	20.7%	21.3%	21.8%	14.7%	15.0%	15.2%
June	31.8%	32.3%	32.7%	20.1%	20.4%	20.7%	13.5%	13.8%	13.8%
July	36.3%	36.9%	37.3%	20.0%	20.2%	20.3%	13.4%	13.5%	13.5%
August	41.6%	42.4%	43.2%	21.5%	21.0%	21.2%	14.3%	14.3%	14.3%
September	49.2%	50.2%	51.2%	27.3%	28.5%	28.5%	19.3%	19.5%	19.6%
October	55.5%	56.8%	57.6%	36.8%	38.6%	39.4%	27.3%	28.0%	29.1%
November	63.5%	65.0%	65.4%	44.7%	45.5%	45.8%	34.1%	35.3%	35.7%
December	64.4%	65.9%	66.8%	49.9%	51.6%	52.5%	39.4%	41.0%	41.8%
Average	47.1%	48.2%	48.8%	31.4%	32.3%	32.9%	23.2%	24.0%	24.5%

Table A.15 – Monthly efficiency for S2 in Faro

					100L (2P)				
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	49.6%	50.5%	50.3%	25.5%	26.1%	26.3%	17.1%	17.4%	17.8%
February	42.8%	43.1%	45.6%	21.1%	21.0%	20.8%	14.0%	13.3%	13.6%
March	42.2%	43.2%	43.3%	24.1%	24.7%	25.2%	16.8%	18.0%	17.9%
April	46.5%	47.6%	48.5%	26.2%	26.7%	26.9%	17.5%	17.7%	17.7%
May	58.3%	59.7%	61.2%	29.8%	30.0%	30.2%	19.7%	19.7%	19.4%
June	51.5%	51.6%	51.8%	26.1%	26.1%	26.0%	17.4%	17.4%	18.0%
July	60.8%	61.1%	61.0%	29.9%	30.0%	29.1%	19.9%	20.0%	19.6%
August	55.6%	55.8%	55.6%	27.9%	27.8%	28.8%	18.6%	18.6%	18.1%
September	46.8%	47.3%	47.2%	23.8%	24.0%	23.5%	15.9%	15.8%	16.8%
October	51.2%	51.8%	52.6%	26.4%	26.1%	26.5%	17.9%	17.8%	17.6%
November	46.6%	45.3%	45.1%	23.9%	24.0%	24.1%	15.7%	15.7%	15.8%
December	46.2%	47.4%	48.8%	25.0%	25.7%	25.6%	16.6%	16.5%	16.5%
Average	49.8%	50.4%	50.9%	25.8%	26.0%	26.1%	17.3%	17.3%	17.4%

					150L (3P)				
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	63.6%	65.4%	65.8%	34.9%	35.6%	36.2%	23.5%	23.9%	24.2%
February	60.9%	62.0%	62.2%	32.3%	33.0%	32.7%	21.5%	21.7%	21.7%
March	52.8%	53.3%	53.9%	33.3%	33.8%	34.4%	23.3%	23.5%	24.4%
April	58.9%	59.1%	60.0%	37.0%	38.1%	38.5%	25.8%	26.8%	27.4%
May	75.5%	76.3%	77.0%	41.3%	42.4%	42.0%	27.7%	27.9%	28.4%
June	80.5%	81.5%	82.2%	45.7%	46.0%	46.7%	30.8%	30.8%	30.7%
July	84.5%	86.2%	86.7%	41.7%	41.7%	42.3%	27.8%	27.8%	27.9%
August	83.7%	84.7%	85.1%	42.1%	42.5%	42.4%	28.1%	28.3%	28.3%
September	70.5%	72.0%	72.9%	37.6%	38.0%	37.7%	25.9%	25.5%	25.1%
October	71.9%	72.4%	73.3%	37.2%	37.4%	38.1%	25.2%	25.5%	25.6%
November	60.3%	61.2%	61.4%	34.3%	33.8%	34.0%	22.5%	22.5%	22.5%
December	56.8%	58.0%	58.2%	33.3%	33.7%	35.7%	23.0%	23.9%	24.4%
Average	68.3%	69.3%	69.9%	37.6%	38.0%	38.4%	25.4%	25.7%	25.9%

					200L (4P)				
Month	1 STP	1 STP	1 STP	2 STP	2 STP	2 STP	3 STP	3 STP	3 STP

	200L	250L	300L	200L	250L	300 L	200 L	250 L	300 L
January	72.1%	73.8%	74.5%	50.7%	52.8%	53.6%	36.0%	36.5%	37.3%
February	68.3%	70.1%	70.9%	44.7%	45.7%	47.2%	30.8%	32.0%	32.7%
March	57.3%	58.3%	58.9%	38.7%	40.6%	41.5%	28.1%	28.8%	29.1%
April	62.6%	63.3%	64.3%	41.1%	42.5%	44.1%	29.6%	30.2%	31.3%
May	79.4%	81.3%	82.0%	48.4%	49.6%	50.4%	32.7%	33.6%	33.8%
June	81.9%	83.3%	84.1%	49.1%	49.6%	49.4%	33.4%	33.4%	33.3%
July	95.8%	98.0%	98.7%	51.9%	52.3%	52.3%	34.5%	34.5%	34.4%
August	98.9%	100.8%	102.7%	52.2%	52.7%	53.0%	34.5%	34.7%	35.5%
September	80.2%	82.3%	82.6%	47.7%	47.9%	48.8%	32.1%	32.5%	33.0%
October	91.0%	94.5%	95.8%	52.6%	53.9%	54.9%	35.7%	35.6%	36.5%
November	67.4%	68.6%	69.3%	46.6%	47.3%	47.7%	32.7%	33.1%	34.0%
December	62.1%	63.2%	63.7%	44.1%	45.7%	46.3%	31.3%	32.3%	32.7%
Average	76.4%	78.1%	79.0%	47.3%	48.4%	49.1%	32.6%	33.1%	33.6%

Table A.16 – Pump electricity consumption for S2 in Bragança

Pump electricity consumption (kWh)						
System	Bragança			Faro		
	100L (2P)	150L (3P)	200L (4P)	100L (2P)	150L (3P)	200L (4P)
1 STP - 200L	80.58	105.25	115.17	89.38	126.51	138.13
1 STP – 250L	80.11	104.97	115.43	88.48	125.89	138.31
1 STP – 300L	79.58	104.62	115.62	87.55	125.15	138.40
2 STP - 200L	59.02	79.60	91.05	59.34	86.48	106.63
2 STP – 250L	58.09	77.64	89.90	57.58	83.76	104.20
2 STP – 300L	57.07	75.59	88.66	55.66	81.02	101.76
3 STP - 200L	49.75	69.41	80.39	48.62	72.29	89.64
3 STP – 250L	47.97	66.83	78.32	46.41	68.49	86.01
3 STP – 300L	46.18	64.21	76.20	44.07	64.67	82.34

Table A.17 – Monthly electricity production for S3 in Bragança for 100L profile

Electricity production (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	76.64	77.78	80.10	87.78	89.39	91.90	95.57	97.78	99.30
February	75.69	76.63	73.35	82.81	83.46	84.21	88.84	84.83	84.16
March	99.18	105.38	110.21	102.33	103.93	105.83	107.75	113.77	115.01
April	107.69	102.83	102.93	107.77	107.58	107.50	104.47	100.72	100.61
May	117.49	119.69	118.43	120.08	120.18	123.71	122.11	126.20	126.96
June	107.16	104.93	109.29	108.96	103.07	103.03	107.07	107.48	107.28
July	123.70	128.09	124.97	122.39	125.33	123.90	123.68	123.51	123.46
August	113.13	112.51	109.33	114.82	117.06	118.96	114.69	109.85	113.07
September	104.70	105.27	108.06	103.45	103.47	103.34	102.73	107.86	99.18
October	100.39	100.29	97.88	103.33	103.99	104.46	105.16	105.39	111.05
November	89.12	94.51	96.47	93.76	93.50	93.17	93.58	93.30	93.42
December	84.85	89.16	93.46	95.67	99.20	99.48	96.97	97.80	99.00
Total	1199.73	1217.07	1224.46	1243.15	1250.16	1259.47	1262.61	1268.50	1272.51

Table A.18 – Monthly electricity consumption for S3 in Bragança for 100L profile

Electricity consumption (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	34.50	35.25	37.25	23.50	25.25	26.25	12.75	14.25	16.25
February	12.00	11.25	11.25	5.00	2.75	1.00	0.00	0.00	0.00
March	10.75	9.75	6.75	5.75	6.00	5.00	3.75	2.50	1.25
April	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	6.50	4.75	6.25	2.75	4.00	0.00	2.25	0.75	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	2.25	0.75	0.00	1.25	0.50	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	1.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00
October	6.25	6.50	6.25	1.50	0.50	0.00	0.50	0.00	0.00
November	5.50	2.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
December	21.00	13.25	9.50	10.00	5.00	2.75	7.75	5.25	2.25
Total	100.00	83.50	77.25	50.25	44.00	35.00	27.50	22.75	19.75

Table A.19 – Monthly electricity production for S3 in Bragança for 150L profile

Electricity production (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	82.73	87.24	88.92	99.14	99.57	103.41	109.67	111.53	113.48
February	84.38	85.06	85.06	107.87	105.65	105.31	119.41	122.62	116.58
March	128.55	128.53	130.32	143.05	145.35	148.46	143.65	148.49	153.21
April	146.03	148.35	150.26	153.79	159.80	156.38	158.36	161.84	166.69
May	160.89	158.76	165.00	172.32	172.57	176.40	174.21	177.85	176.38
June	177.37	181.56	183.32	190.68	191.12	192.35	191.95	189.14	188.72
July	169.44	171.37	173.24	172.28	171.29	170.84	172.12	171.13	173.54
August	169.47	170.34	172.82	173.20	170.51	173.67	173.83	174.22	174.03
September	159.27	162.22	158.93	162.21	168.81	162.48	164.71	165.00	166.40
October	110.92	114.81	117.00	125.82	130.34	131.71	137.62	133.87	138.94
November	97.13	104.35	108.80	124.63	119.90	119.95	127.53	135.09	133.29
December	93.46	93.46	93.46	113.56	117.29	121.79	122.22	126.39	129.51
Total	1579.64	1606.05	1627.13	1738.56	1752.20	1762.75	1795.28	1817.18	1830.76

Table A.20 – Monthly electricity consumption for S3 in Bragança for 150L profile

Electricity consumption (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	68.75	66.50	68.00	54.25	57.25	56.50	43.25	44.75	46.25
February	50.25	48.75	47.00	25.75	26.75	25.25	15.25	12.00	12.25
March	45.50	46.50	45.00	28.00	27.25	26.75	25.25	19.75	15.50
April	24.50	22.75	20.75	10.25	7.50	7.75	5.00	1.75	6.25
May	18.50	21.00	14.50	9.00	5.75	5.00	2.50	2.50	1.25
June	16.25	13.25	15.25	0.00	1.00	0.00	1.00	1.00	0.00

July	5.00	2.00	0.50	0.00	0.00	1.50	0.00	1.00	0.00
August	2.25	1.25	0.00	0.75	0.00	0.00	0.75	0.00	0.00
September	9.00	5.00	4.00	4.00	0.75	0.75	1.50	1.75	0.00
October	44.75	41.00	39.00	25.25	23.50	26.25	11.50	13.25	8.00
November	42.00	35.25	30.00	14.75	14.75	12.75	9.75	4.00	3.75
December	63.25	62.50	62.50	41.50	38.50	33.00	32.50	26.50	24.25
Total	390.00	365.75	346.50	213.50	203.00	195.50	148.25	128.25	117.50

Table A.21 – Monthly electricity production for S3 in Bragança for 200L profile

Electricity production (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	88.92	88.92	88.92	118.56	118.56	118.56	140.48	142.37	143.42
February	85.06	85.06	85.06	113.42	113.42	113.42	136.72	141.36	141.77
March	137.18	138.95	138.95	167.50	171.66	169.27	184.12	183.72	190.00
April	163.72	166.55	167.88	178.53	185.24	188.68	184.96	193.25	188.11
May	169.90	167.88	168.03	194.34	195.74	191.74	206.10	206.38	210.44
June	179.90	181.52	183.32	201.77	206.07	208.46	205.66	204.27	201.15
July	195.76	195.76	195.76	212.59	211.49	214.49	211.49	211.69	214.08
August	206.28	208.68	208.68	216.64	214.84	211.51	216.78	212.64	218.78
September	169.70	171.16	171.16	189.66	190.83	194.76	201.87	207.57	205.90
October	122.76	124.72	124.72	149.55	154.47	153.85	165.88	161.18	169.55
November	111.63	111.63	111.63	142.57	139.76	138.11	165.44	166.12	173.13
December	93.46	93.46	93.46	124.61	124.61	124.61	147.88	152.10	152.24
Total	1724.28	1734.29	1737.56	2009.74	2026.68	2027.45	2167.40	2182.63	2208.57

Table A.22 – Monthly electricity consumption for S3 in Bragança for 200L profile

Electricity consumption (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	139.25	145.00	148.25	111.50	115.75	120.25	92.75	94.00	96.00
February	121.50	124.50	126.25	94.25	97.25	97.50	70.50	70.00	70.75
March	89.75	89.00	89.50	59.50	56.75	60.00	40.50	41.75	37.25
April	44.25	42.50	42.00	22.50	19.75	19.25	13.50	8.25	10.00
May	43.75	46.50	46.00	21.75	15.25	17.50	9.00	5.25	5.75
June	29.00	30.00	30.75	3.25	0.00	0.00	0.00	1.00	0.25
July	25.75	25.25	23.50	4.00	4.75	3.00	3.00	2.50	2.25
August	13.75	12.00	13.25	1.50	3.75	2.00	1.25	3.00	1.25
September	52.50	52.00	53.00	29.75	27.00	26.75	17.75	13.00	11.75
October	102.75	102.00	103.00	75.75	73.50	76.00	56.50	60.00	52.75
November	105.75	107.75	108.75	73.00	75.25	76.50	50.00	53.25	45.00
December	127.00	129.25	130.75	95.50	98.25	99.50	71.50	69.00	70.00
Total	895.00	905.75	915.00	592.25	587.25	598.25	426.25	421.00	403.00

Table A.23 – Monthly electricity production for S3 in Faro for 100L profile

Electricity production (kWh)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	105.01	106.17	109.48	102.76	106.28	108.99	102.58	107.18	109.67
February	83.36	87.33	81.77	88.35	83.41	86.72	88.09	83.87	85.87
March	100.11	95.56	103.99	104.19	111.77	107.46	106.91	108.80	106.49
April	110.05	111.32	112.80	108.08	107.04	107.42	103.79	108.99	105.58
May	120.05	122.30	124.34	123.71	122.48	123.81	127.55	120.07	127.54
June	105.98	105.45	105.48	107.88	107.87	107.72	106.58	111.35	106.72
July	124.48	123.52	123.33	124.06	120.14	118.74	123.16	123.64	123.52
August	114.60	114.30	111.53	113.60	117.90	119.23	114.59	111.91	109.49
September	99.14	102.03	102.71	101.94	100.39	98.18	101.39	102.48	102.61
October	104.22	106.26	105.89	106.25	107.74	109.55	106.97	103.86	109.13
November	101.64	100.18	99.82	94.15	94.34	97.55	96.66	101.45	97.67
December	99.89	100.44	105.10	105.48	104.18	100.95	104.60	104.77	101.47
Total	1268.51	1274.85	1286.24	1280.46	1283.53	1286.31	1282.87	1288.37	1285.74

Table A.24 – Monthly electricity consumption for S3 in Faro for 100L profile

	Electricity consumption (kWh)								
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	4.25	5.50	6.50	4.25	5.00	6.00	4.25	5.00	6.00
February	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March	9.25	9.50	4.25	4.25	1.00	1.25	2.00	0.00	0.00
April	0.50	1.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00
May	6.25	3.75	1.25	0.00	1.50	0.00	0.00	0.00	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	0.75	0.00	0.00	0.75	0.00	0.00	0.50	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
November	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00
December	6.50	4.00	0.00	0.75	0.50	0.00	0.50	0.00	0.00
Total	29.75	23.75	12.75	10.00	8.00	7.25	7.75	5.00	6.00

Table A.25 – Monthly electricity production for S3 in Faro for 150L profile

	Electricity production (kWh)								
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	141.53	142.44	143.79	143.47	145.87	147.83	144.68	147.38	149.29
February	126.73	128.59	128.55	131.63	132.44	133.33	132.78	133.09	127.05
March	121.65	125.32	125.32	135.65	137.22	139.98	149.61	153.78	160.00
April	147.46	147.62	146.96	159.58	163.59	165.15	167.20	168.47	171.45
May	161.88	164.81	172.24	169.84	173.68	170.63	172.13	172.78	176.89
June	183.65	187.78	184.08	191.62	189.42	194.04	192.06	193.53	189.86

July	172.29	171.08	169.00	171.49	173.64	172.58	172.20	171.94	171.43
August	167.90	171.03	179.78	173.81	173.68	176.69	173.39	174.60	175.05
September	149.36	151.79	152.73	156.46	153.10	151.51	158.16	157.95	158.57
October	149.80	153.39	155.32	149.41	154.95	155.30	151.73	154.32	154.54
November	130.11	129.79	133.89	141.40	135.12	137.51	137.49	135.48	137.43
December	126.35	128.60	128.60	135.63	146.09	150.31	143.65	151.97	150.28
Total	1778.71	1802.23	1820.26	1859.98	1878.81	1894.86	1895.09	1915.29	1921.84

Table A.26 – Monthly electricity consumption for S3 in Faro for 150L profile

	Electricity consumption (kWh)								
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	7.75	9.50	11.50	4.00	4.75	6.50	4.00	4.75	6.00
February	6.00	6.00	3.75	3.50	2.25	0.00	0.50	0.00	0.00
March	45.50	39.25	40.25	26.50	25.50	20.75	12.25	7.00	5.00
April	27.75	28.75	29.25	15.75	13.00	13.50	6.00	6.75	6.00
May	14.50	13.75	13.25	3.75	4.25	3.25	0.75	0.50	0.00
June	12.25	8.25	6.50	2.75	0.00	0.00	1.00	0.00	0.75
July	1.50	1.75	1.75	0.75	0.00	0.00	0.00	0.00	0.00
August	6.00	4.00	0.00	1.75	0.00	0.00	2.00	0.00	0.00
September	14.75	10.25	7.25	5.00	8.00	6.50	2.75	1.25	0.75
October	5.75	2.75	1.00	2.25	0.75	1.25	3.00	0.50	0.00
November	8.75	10.00	5.00	0.75	0.50	0.00	1.50	0.00	0.00
December	30.50	29.00	29.50	18.75	13.50	6.25	9.25	5.75	5.00
Total	181.00	163.25	149.00	85.50	72.50	58.00	43.00	26.50	23.50

Table A.27 – Monthly electricity production for S3 in Faro for 200L profile

	Electric energy production (kWh)								
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	153.07	153.07	153.07	201.55	204.09	204.09	221.03	225.66	226.04
February	144.29	144.29	144.29	180.30	180.63	182.38	191.76	195.10	201.68
March	125.32	125.32	125.32	155.39	161.22	164.55	173.58	180.06	173.04
April	153.44	153.44	153.44	178.72	184.89	178.62	192.13	195.40	199.62
May	181.33	184.24	184.32	200.45	203.45	203.73	206.31	209.92	209.55
June	187.17	190.69	190.69	202.55	202.74	203.45	206.01	207.41	204.75
July	208.16	208.40	208.40	213.49	212.87	213.84	209.55	211.50	213.05
August	201.46	203.63	203.63	212.17	212.09	214.59	213.15	213.56	219.60
September	160.38	160.38	160.38	188.62	192.94	198.80	193.52	197.81	201.74
October	179.40	180.79	180.79	215.02	221.37	225.56	216.21	215.39	222.38
November	135.23	135.23	135.23	176.97	179.97	180.30	194.46	195.46	195.10
December	128.60	128.60	128.60	168.52	170.88	171.47	190.17	194.28	196.62
Total	1957.84	1968.07	1968.15	2293.76	2327.12	2341.38	2407.89	2441.56	2463.15

Table A.28 – Monthly electricity consumption (kWh) for S3 in Faro for 200L profile

Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	84.25	86.50	87.75	32.75	32.75	35.00	9.25	8.00	8.50
February	67.25	68.50	69.50	30.00	29.50	30.25	16.75	12.75	9.50
March	96.75	97.75	98.50	64.00	60.00	55.25	45.00	37.75	44.00
April	56.75	58.50	59.25	30.75	27.00	34.25	16.00	15.25	13.50
May	33.50	31.50	32.00	12.00	8.75	11.50	4.75	0.75	2.00
June	20.50	17.75	18.75	3.25	3.00	1.25	2.00	0.00	0.00
July	11.25	12.75	14.00	0.75	0.00	0.00	2.25	0.00	0.00
August	21.25	19.50	20.50	7.50	9.25	8.00	5.50	5.00	0.75
September	59.00	61.00	61.50	28.25	21.75	13.50	22.75	16.00	9.75
October	47.25	46.25	47.75	9.00	4.75	1.50	6.25	8.75	3.25
November	84.25	86.25	86.50	38.75	34.75	34.25	20.25	19.25	18.50
December	94.50	95.75	96.25	53.00	51.50	51.50	28.50	25.25	24.00
Total	676.50	682.00	692.25	310.00	283.00	276.25	179.25	148.75	133.75

Table A.29 – Monthly efficiency for S3 in Bragança

100L (2P)

Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	24.7%	25.1%	25.8%	21.2%	21.6%	22.2%	18.5%	18.9%	19.2%
February	21.5%	21.8%	20.8%	17.7%	17.8%	18.0%	15.2%	14.5%	14.4%
March	15.0%	15.9%	16.6%	11.6%	11.8%	12.0%	9.8%	10.3%	10.4%
April	11.4%	10.9%	10.9%	8.6%	8.6%	8.5%	6.6%	6.4%	6.4%
May	10.5%	10.7%	10.6%	8.1%	8.1%	8.3%	6.6%	6.8%	6.8%
June	8.6%	8.4%	8.7%	6.5%	6.2%	6.2%	5.1%	5.1%	5.1%
July	9.2%	9.6%	9.3%	6.9%	7.0%	6.9%	5.5%	5.5%	5.5%
August	8.9%	8.8%	8.6%	6.7%	6.9%	7.0%	5.4%	5.2%	5.3%
September	11.7%	11.8%	12.1%	8.7%	8.7%	8.7%	6.9%	7.2%	6.7%
October	18.5%	18.5%	18.1%	14.3%	14.4%	14.5%	11.7%	11.7%	12.3%
November	23.1%	24.5%	25.0%	18.2%	18.1%	18.1%	14.5%	14.5%	14.5%
December	29.4%	30.9%	32.4%	24.9%	25.8%	25.9%	20.2%	20.3%	20.6%
Average	16.0%	16.4%	16.6%	12.8%	12.9%	13.0%	10.5%	10.5%	10.6%

150L (3P)

Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	26.7%	28.1%	28.6%	24.0%	24.1%	25.0%	21.2%	21.6%	21.9%
February	24.0%	24.2%	24.2%	23.0%	22.5%	22.4%	20.4%	20.9%	19.9%
March	19.4%	19.4%	19.7%	16.2%	16.5%	16.8%	13.0%	13.4%	13.9%
April	15.5%	15.7%	15.9%	12.2%	12.7%	12.4%	10.1%	10.3%	10.6%
May	14.4%	14.2%	14.8%	11.6%	11.6%	11.8%	9.4%	9.6%	9.5%
June	14.2%	14.5%	14.6%	11.4%	11.4%	11.5%	9.2%	9.1%	9.0%
July	12.7%	12.8%	12.9%	9.7%	9.6%	9.6%	7.7%	7.7%	7.8%
August	13.3%	13.3%	13.5%	10.2%	10.0%	10.2%	8.2%	8.2%	8.2%
September	17.8%	18.1%	17.8%	13.6%	14.2%	13.6%	11.1%	11.1%	11.2%
October	20.5%	21.2%	21.6%	17.4%	18.1%	18.2%	15.3%	14.8%	15.4%

November	25.1%	27.0%	28.2%	24.2%	23.3%	23.3%	19.8%	21.0%	20.7%
December	32.4%	32.4%	32.4%	29.5%	30.5%	31.7%	25.4%	26.3%	26.9%
Average	19.7%	20.1%	20.4%	16.9%	17.0%	17.2%	14.2%	14.5%	14.6%
200L (4P)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	28.6%	28.6%	28.6%	28.6%	28.6%	28.6%	27.2%	27.5%	27.7%
February	24.2%	24.2%	24.2%	24.2%	24.2%	24.2%	23.3%	24.1%	24.2%
March	20.7%	21.0%	21.0%	19.0%	19.4%	19.2%	16.7%	16.6%	17.2%
April	17.4%	17.7%	17.8%	14.2%	14.7%	15.0%	11.8%	12.3%	12.0%
May	15.2%	15.0%	15.0%	13.1%	13.1%	12.9%	11.1%	11.1%	11.3%
June	14.4%	14.5%	14.6%	12.1%	12.3%	12.5%	9.9%	9.8%	9.6%
July	14.6%	14.6%	14.6%	11.9%	11.9%	12.0%	9.5%	9.5%	9.6%
August	16.2%	16.3%	16.3%	12.7%	12.6%	12.4%	10.2%	10.0%	10.3%
September	19.0%	19.1%	19.1%	15.9%	16.0%	16.3%	13.5%	13.9%	13.8%
October	22.7%	23.0%	23.0%	20.7%	21.4%	21.3%	18.4%	17.9%	18.8%
November	28.9%	28.9%	28.9%	27.7%	27.1%	26.8%	25.7%	25.8%	26.9%
December	32.4%	32.4%	32.4%	32.4%	32.4%	32.4%	30.8%	31.6%	31.7%
Average	21.2%	21.3%	21.3%	19.4%	19.5%	19.5%	17.3%	17.5%	17.8%

Table A.30 – Monthly efficiency for S3 in Faro

100L (2P)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	33.8%	34.2%	35.3%	24.8%	25.7%	26.3%	19.8%	20.7%	21.2%
February	23.7%	24.8%	23.2%	18.8%	17.8%	18.5%	15.0%	14.3%	14.6%
March	15.1%	14.4%	15.7%	11.8%	12.7%	12.2%	9.7%	9.9%	9.6%
April	11.7%	11.8%	12.0%	8.6%	8.5%	8.5%	6.6%	6.9%	6.7%
May	10.7%	11.0%	11.1%	8.3%	8.2%	8.3%	6.9%	6.5%	6.9%
June	8.5%	8.4%	8.4%	6.5%	6.5%	6.4%	5.1%	5.3%	5.1%
July	9.3%	9.2%	9.2%	7.0%	6.7%	6.7%	5.5%	5.5%	5.5%
August	9.0%	9.0%	8.7%	6.7%	6.9%	7.0%	5.4%	5.3%	5.1%
September	11.1%	11.4%	11.5%	8.6%	8.4%	8.2%	6.8%	6.9%	6.9%
October	19.3%	19.6%	19.6%	14.7%	14.9%	15.2%	11.9%	11.5%	12.1%
November	26.3%	25.9%	25.8%	18.3%	18.3%	18.9%	15.0%	15.7%	15.2%
December	34.6%	34.8%	36.4%	27.4%	27.1%	26.3%	21.8%	21.8%	21.1%
Average	17.8%	17.9%	18.1%	13.5%	13.5%	13.5%	10.8%	10.9%	10.8%
150L (3P)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	45.6%	45.9%	46.3%	34.7%	35.2%	35.7%	28.0%	28.5%	28.9%
February	36.0%	36.5%	36.5%	28.1%	28.2%	28.4%	22.6%	22.7%	21.7%
March	18.4%	18.9%	18.9%	15.4%	15.5%	15.8%	13.6%	13.9%	14.5%
April	15.6%	15.6%	15.6%	12.7%	13.0%	13.1%	10.6%	10.7%	10.9%
May	14.5%	14.8%	15.4%	11.4%	11.7%	11.5%	9.2%	9.3%	9.5%
June	14.7%	15.0%	14.7%	11.5%	11.3%	11.6%	9.2%	9.3%	9.1%
July	12.9%	12.8%	12.6%	9.6%	9.7%	9.7%	7.7%	7.7%	7.7%

August	13.2%	13.4%	14.1%	10.2%	10.2%	10.4%	8.2%	8.2%	8.2%
September	16.7%	17.0%	17.1%	13.1%	12.8%	12.7%	10.6%	10.6%	10.6%
October	27.7%	28.3%	28.7%	20.7%	21.5%	21.5%	16.8%	17.1%	17.1%
November	33.7%	33.6%	34.6%	27.4%	26.2%	26.7%	21.3%	21.0%	21.3%
December	43.8%	44.6%	44.6%	35.3%	38.0%	39.1%	29.9%	31.6%	31.3%
Average	24.4%	24.7%	24.9%	19.2%	19.5%	19.7%	15.6%	15.9%	15.9%

200L (4P)

Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	49.3%	49.3%	49.3%	48.7%	49.3%	49.3%	42.7%	43.6%	43.7%
February	41.0%	41.0%	41.0%	38.4%	38.5%	38.9%	32.7%	33.3%	34.4%
March	18.9%	18.9%	18.9%	17.6%	18.3%	18.6%	15.7%	16.3%	15.7%
April	16.3%	16.3%	16.3%	14.2%	14.7%	14.2%	12.2%	12.4%	12.7%
May	16.2%	16.5%	16.5%	13.5%	13.7%	13.7%	11.1%	11.3%	11.3%
June	14.9%	15.2%	15.2%	12.1%	12.1%	12.2%	9.9%	9.9%	9.8%
July	15.6%	15.6%	15.6%	12.0%	11.9%	12.0%	9.4%	9.5%	9.6%
August	15.8%	16.0%	16.0%	12.5%	12.5%	12.6%	10.0%	10.0%	10.3%
September	17.9%	17.9%	17.9%	15.8%	16.2%	16.7%	13.0%	13.3%	13.5%
October	33.1%	33.4%	33.4%	29.8%	30.7%	31.3%	24.0%	23.9%	24.6%
November	35.0%	35.0%	35.0%	34.3%	34.9%	35.0%	30.2%	30.3%	30.3%
December	44.6%	44.6%	44.6%	43.8%	44.4%	44.6%	39.6%	40.4%	40.9%
Average	26.6%	26.6%	26.6%	24.4%	24.8%	24.9%	20.9%	21.2%	21.4%

Table A.31 – Monthly solar fraction for S2 in Bragança

100L (2P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	51.0%	51.0%	50.6%	63.2%	64.1%	65.3%	69.3%	72.1%	72.3%
February	60.9%	61.5%	60.9%	84.0%	84.6%	85.7%	89.4%	91.3%	95.1%
March	73.6%	74.9%	76.8%	83.2%	89.0%	89.0%	86.5%	87.6%	90.0%
April	97.3%	100.0%	100.0%	98.6%	100.0%	100.0%	98.9%	100.0%	100.0%
May	85.3%	86.8%	88.0%	94.4%	95.9%	96.6%	97.4%	98.7%	100.0%
June	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	97.8%	98.7%	100.0%	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%
August	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
September	96.3%	98.1%	98.6%	98.2%	100.0%	100.0%	98.4%	100.0%	100.0%
October	80.3%	81.0%	82.7%	93.7%	93.2%	96.5%	96.7%	100.0%	100.0%
November	73.0%	74.2%	75.8%	94.8%	94.6%	96.8%	98.3%	100.0%	100.0%
December	56.4%	56.9%	58.5%	75.8%	80.2%	84.3%	81.8%	84.6%	86.6%
Average	80.9%	81.9%	82.7%	90.4%	91.8%	92.8%	93.1%	94.5%	95.3%

150L (3P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	41.0%	40.9%	40.7%	56.4%	57.7%	57.8%	62.8%	62.8%	63.4%
February	44.2%	45.6%	45.4%	66.8%	69.6%	71.4%	79.3%	80.9%	83.4%
March	61.8%	61.6%	62.1%	72.9%	75.1%	77.2%	77.2%	80.2%	80.0%
April	76.3%	78.5%	79.3%	88.6%	90.9%	93.0%	91.8%	94.9%	94.5%

May	74.4%	76.5%	77.9%	89.2%	92.3%	93.7%	95.0%	96.6%	95.5%
June	77.0%	78.2%	78.5%	97.2%	98.3%	98.9%	100.0%	100.0%	100.0%
July	97.1%	97.8%	97.7%	99.2%	100.0%	100.0%	100.0%	100.0%	100.0%
August	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
September	91.0%	92.8%	94.1%	96.8%	96.8%	97.7%	97.9%	98.7%	100.0%
October	65.3%	67.2%	68.1%	80.1%	83.4%	83.5%	87.8%	88.4%	91.9%
November	59.4%	60.4%	60.8%	76.5%	80.4%	82.0%	86.9%	90.0%	88.4%
December	42.8%	43.6%	43.6%	63.7%	66.3%	66.6%	70.1%	71.5%	74.3%
Average	69.2%	70.3%	70.7%	82.3%	84.2%	85.1%	87.4%	88.7%	89.3%

200L (4P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	29.7%	29.6%	29.7%	46.2%	46.5%	46.9%	54.2%	55.9%	56.6%
February	31.6%	32.1%	32.2%	49.6%	50.5%	51.3%	59.6%	62.3%	63.9%
March	50.3%	51.1%	52.1%	68.2%	69.2%	72.3%	72.7%	74.9%	78.3%
April	69.3%	70.7%	71.1%	87.0%	89.5%	91.4%	89.6%	92.4%	94.5%
May	65.9%	67.6%	68.2%	84.1%	86.9%	89.4%	90.8%	93.4%	94.7%
June	73.3%	74.4%	74.8%	96.3%	97.2%	97.7%	98.4%	100.0%	100.0%
July	84.9%	85.5%	86.2%	97.2%	98.5%	99.0%	98.5%	99.1%	99.2%
August	94.9%	95.7%	96.4%	100.0%	98.7%	100.0%	99.1%	100.0%	100.0%
September	77.0%	78.5%	79.4%	87.5%	90.2%	90.9%	92.5%	93.2%	93.9%
October	51.0%	51.8%	52.6%	69.6%	72.1%	73.2%	78.8%	80.6%	83.0%
November	43.3%	43.8%	43.9%	62.3%	63.4%	63.8%	71.9%	74.1%	75.3%
December	32.4%	32.6%	32.9%	50.1%	51.2%	51.8%	59.8%	61.8%	62.7%
Average	58.6%	59.5%	59.9%	74.9%	76.2%	77.3%	80.5%	82.3%	83.5%

Table A.32 – Monthly solar fraction for S2 in Faro

100L (2P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	95.6%	94.7%	92.5%	95.7%	94.8%	93.9%	95.7%	94.8%	94.0%
February	95.0%	96.9%	98.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
March	80.7%	81.7%	85.8%	92.0%	95.4%	96.9%	95.7%	98.3%	100.0%
April	85.9%	88.2%	88.0%	96.2%	97.7%	97.1%	98.9%	100.0%	100.0%
May	91.9%	93.4%	95.7%	98.3%	98.3%	98.3%	98.3%	98.1%	100.0%
June	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
August	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
September	96.9%	98.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
October	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
November	96.0%	96.8%	98.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
December	86.6%	88.5%	90.5%	96.9%	100.0%	100.0%	98.4%	100.0%	100.0%
Average	94.1%	94.9%	95.8%	98.3%	98.9%	98.9%	98.9%	99.3%	99.5%

150L (3P)

Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L

January	85.9%	86.4%	85.7%	96.8%	96.2%	95.5%	96.9%	96.2%	95.5%
February	87.9%	88.5%	88.4%	97.9%	100.0%	100.0%	98.8%	100.0%	100.0%
March	64.6%	65.1%	66.1%	84.1%	86.4%	88.9%	88.4%	90.2%	95.0%
April	67.4%	67.8%	68.6%	85.2%	87.5%	87.8%	89.7%	92.4%	93.4%
May	83.2%	83.9%	83.6%	95.0%	96.5%	97.1%	96.6%	97.5%	98.7%
June	83.1%	83.7%	84.1%	98.5%	99.3%	100.0%	100.0%	100.0%	100.0%
July	97.8%	98.4%	98.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
August	98.3%	98.7%	99.1%	99.1%	100.0%	100.0%	99.2%	100.0%	100.0%
September	87.2%	89.8%	90.0%	96.5%	99.3%	98.7%	99.3%	99.0%	98.7%
October	96.2%	95.9%	97.7%	98.9%	97.5%	100.0%	100.0%	100.0%	100.0%
November	85.4%	86.2%	86.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
December	72.4%	73.4%	73.3%	88.3%	89.0%	95.0%	92.2%	96.6%	98.6%
Average	84.1%	84.8%	85.1%	95.0%	96.0%	96.9%	96.8%	97.7%	98.3%

200L (4P)									
Month	1 STP 200L	1 STP 250L	1 STP 300L	2 STP 200L	2 STP 250L	2 STP 300 L	3 STP 200 L	3 STP 250 L	3 STP 300 L
January	60.1%	60.8%	61.0%	88.1%	90.6%	91.3%	95.9%	96.2%	97.0%
February	65.1%	66.1%	66.5%	86.7%	88.5%	90.5%	89.8%	93.8%	95.8%
March	50.9%	51.6%	51.9%	71.5%	74.9%	77.2%	78.4%	80.9%	82.3%
April	59.7%	59.8%	60.7%	79.0%	81.6%	84.4%	85.8%	86.8%	88.9%
May	73.4%	74.7%	74.6%	92.8%	94.6%	95.3%	95.3%	97.8%	98.3%
June	77.7%	78.7%	79.1%	98.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	87.5%	88.5%	88.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
August	89.5%	90.4%	91.0%	98.0%	99.0%	99.3%	97.1%	97.7%	100.0%
September	72.9%	74.0%	75.4%	90.3%	91.7%	94.6%	91.7%	94.2%	96.8%
October	81.5%	83.6%	83.4%	97.3%	99.1%	100.0%	98.4%	97.4%	100.0%
November	60.9%	61.5%	61.8%	87.9%	89.6%	90.9%	93.2%	94.5%	96.4%
December	55.5%	56.0%	56.2%	81.5%	83.9%	85.0%	88.5%	92.2%	92.8%
Average	69.6%	70.5%	70.9%	89.2%	91.1%	92.4%	92.9%	94.3%	95.7%

Table A.33 – Monthly solar fraction for S3 in Bragança

100L (2P)									
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	69.0%	68.8%	68.3%	78.9%	78.0%	77.8%	88.2%	87.3%	85.9%
February	86.3%	87.2%	86.7%	94.3%	96.8%	98.8%	100.0%	100.0%	100.0%
March	90.2%	91.5%	94.2%	94.7%	94.5%	95.5%	96.6%	97.8%	98.9%
April	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	94.8%	96.2%	95.0%	97.8%	96.8%	100.0%	98.2%	99.4%	100.0%
June	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	98.2%	99.4%	100.0%	99.0%	99.6%	100.0%	100.0%	100.0%	100.0%
August	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
September	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	100.0%	100.0%
October	94.1%	93.9%	94.0%	98.6%	99.5%	100.0%	99.5%	100.0%	100.0%
November	94.2%	97.9%	100.0%	99.5%	100.0%	100.0%	100.0%	100.0%	100.0%
December	80.2%	87.1%	90.8%	90.5%	95.2%	97.3%	92.6%	94.9%	97.8%
Average	92.1%	93.5%	94.1%	96.1%	96.7%	97.5%	97.9%	98.3%	98.6%

				150L (3P)					
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	54.6%	56.7%	56.7%	64.6%	63.5%	64.7%	71.7%	71.4%	71.0%
February	62.7%	63.6%	64.4%	80.7%	79.8%	80.7%	88.7%	91.1%	90.5%
March	73.9%	73.4%	74.3%	83.6%	84.2%	84.7%	85.0%	88.3%	90.8%
April	85.6%	86.7%	87.9%	93.8%	95.5%	95.3%	96.9%	98.9%	96.4%
May	89.7%	88.3%	91.9%	95.0%	96.8%	97.2%	98.6%	98.6%	99.3%
June	91.6%	93.2%	92.3%	100.0%	99.5%	100.0%	99.5%	99.5%	100.0%
July	97.1%	98.8%	99.7%	100.0%	100.0%	99.1%	100.0%	99.4%	100.0%
August	98.7%	99.3%	100.0%	99.6%	100.0%	100.0%	99.6%	100.0%	100.0%
September	94.7%	97.0%	97.5%	97.6%	99.6%	99.5%	99.1%	99.0%	100.0%
October	71.3%	73.7%	75.0%	83.3%	84.7%	83.4%	92.3%	91.0%	94.6%
November	69.8%	74.7%	78.4%	89.4%	89.0%	90.4%	92.9%	97.1%	97.3%
December	59.6%	59.9%	59.9%	73.2%	75.3%	78.7%	79.0%	82.7%	84.2%
Average	79.1%	80.5%	81.5%	88.4%	89.0%	89.5%	91.9%	93.1%	93.7%

				200L (4P)					
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	39.0%	38.0%	37.5%	51.5%	50.6%	49.6%	60.2%	60.2%	59.9%
February	41.2%	40.6%	40.3%	54.6%	53.8%	53.8%	66.0%	66.9%	66.7%
March	60.5%	61.0%	60.8%	73.8%	75.2%	73.8%	82.0%	81.5%	83.6%
April	78.7%	79.7%	80.0%	88.8%	90.4%	90.7%	93.2%	95.9%	95.0%
May	79.5%	78.3%	78.5%	89.9%	92.8%	91.6%	95.8%	97.5%	97.3%
June	86.1%	85.8%	85.6%	98.4%	100.0%	100.0%	100.0%	99.5%	99.9%
July	88.4%	88.6%	89.3%	98.2%	97.8%	98.6%	98.6%	98.8%	99.0%
August	93.8%	94.6%	94.0%	99.3%	98.3%	99.1%	99.4%	98.6%	99.4%
September	76.4%	76.7%	76.4%	86.4%	87.6%	87.9%	91.9%	94.1%	94.6%
October	54.4%	55.0%	54.8%	66.4%	67.8%	66.9%	74.6%	72.9%	76.3%
November	51.4%	50.9%	50.7%	66.1%	65.0%	64.4%	76.8%	75.7%	79.4%
December	42.4%	42.0%	41.7%	56.6%	55.9%	55.6%	67.4%	68.8%	68.5%
Average	66.0%	65.9%	65.8%	77.5%	77.9%	77.7%	83.8%	84.2%	85.0%

Table A.34 – Monthly solar fraction for S3 in Faro

				100L (2P)					
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	96.1%	95.1%	94.4%	96.0%	95.5%	94.8%	96.0%	95.5%	94.8%
February	98.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
March	91.5%	91.0%	96.1%	96.1%	99.1%	98.9%	98.2%	100.0%	100.0%
April	99.5%	99.1%	99.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
May	95.1%	97.0%	99.0%	100.0%	98.8%	100.0%	100.0%	100.0%	100.0%
June	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
July	99.4%	100.0%	100.0%	99.4%	100.0%	100.0%	99.6%	100.0%	100.0%
August	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
September	98.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
October	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
November	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%	100.0%	100.0%

December	93.9%	96.2%	100.0%	99.3%	99.5%	100.0%	99.5%	100.0%	100.0%
Average	97.8%	98.2%	99.1%	99.2%	99.4%	99.5%	99.4%	99.6%	99.6%
					150L (3P)				
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	94.8%	93.7%	92.6%	97.3%	96.8%	95.8%	97.3%	96.9%	96.1%
February	95.5%	95.5%	97.2%	97.4%	98.3%	100.0%	99.6%	100.0%	100.0%
March	72.8%	76.1%	75.7%	83.7%	84.3%	87.1%	92.4%	95.6%	97.0%
April	84.2%	83.7%	83.4%	91.0%	92.6%	92.4%	96.5%	96.1%	96.6%
May	91.8%	92.3%	92.9%	97.8%	97.6%	98.1%	99.6%	99.7%	100.0%
June	93.7%	95.8%	96.6%	98.6%	100.0%	100.0%	99.5%	100.0%	99.6%
July	99.1%	99.0%	99.0%	99.6%	100.0%	100.0%	100.0%	100.0%	100.0%
August	96.5%	97.7%	100.0%	99.0%	100.0%	100.0%	98.9%	100.0%	100.0%
September	91.0%	93.7%	95.5%	96.9%	95.0%	95.9%	98.3%	99.2%	99.5%
October	96.3%	98.2%	99.4%	98.5%	99.5%	99.2%	98.1%	99.7%	100.0%
November	93.7%	92.8%	96.4%	99.5%	99.6%	100.0%	98.9%	100.0%	100.0%
December	80.6%	81.6%	81.3%	87.9%	91.5%	96.0%	94.0%	96.4%	96.8%
Average	90.8%	91.7%	92.5%	95.6%	96.3%	97.0%	97.8%	98.6%	98.8%
					200L (4P)				
Month	3 PVP 200L	3 PVP 250L	3 PVP 300L	4 PVP 200L	4 PVP 250L	4 PVP 300L	5 PVP 200L	5 PVP 250L	5 PVP 300 L
January	64.5%	63.9%	63.6%	86.0%	86.2%	85.4%	96.0%	96.6%	96.4%
February	68.2%	67.8%	67.5%	85.7%	86.0%	85.8%	92.0%	93.9%	95.5%
March	56.4%	56.2%	56.0%	70.8%	72.9%	74.9%	79.4%	82.7%	79.7%
April	73.0%	72.4%	72.1%	85.3%	87.3%	83.9%	92.3%	92.8%	93.7%
May	84.4%	85.4%	85.2%	94.4%	95.9%	94.7%	97.7%	99.6%	99.1%
June	90.1%	91.5%	91.0%	98.4%	98.5%	99.4%	99.0%	100.0%	100.0%
July	94.9%	94.2%	93.7%	99.6%	100.0%	100.0%	98.9%	100.0%	100.0%
August	90.5%	91.3%	90.9%	96.6%	95.8%	96.4%	97.5%	97.7%	99.7%
September	73.1%	72.4%	72.3%	87.0%	89.9%	93.6%	89.5%	92.5%	95.4%
October	79.2%	79.6%	79.1%	96.0%	97.9%	99.3%	97.2%	96.1%	98.6%
November	61.6%	61.1%	61.0%	82.0%	83.8%	84.0%	90.6%	91.0%	91.3%
December	57.6%	57.3%	57.2%	76.1%	76.8%	76.9%	87.0%	88.5%	89.1%
Average	74.5%	74.4%	74.1%	88.2%	89.2%	89.5%	93.1%	94.3%	94.9%

Table A.35 – Total available solar energy for Faro and Bragança

	Available solar energy [kWh/m^2]	
Month	Faro	Bragança
January	89.12	53.34
February	101.65	60.45
March	109.81	113.82
April	156.54	162.13
May	210.40	191.89
June	235.59	215.23
July	253.70	229.94
August	221.40	219.32
September	151.58	153.59
October	138.50	93.01

November	87.02	66.41
December	73.57	49.55
Total	1828.86	1608.69

Appendix B – Economic analysis results

Table B.1 – Economic analysis of S1 for a 200L capacity and a 100L profile

100L (2P)				
Year	Cash flow (€)	Cumulative Cash flow (€)	O&M (€)	Energy consumed (kWh)
0	-286.00	-286.00	0	0.00
1	-338.24	-624.24	-2.86	-1582.00
2	-338.24	-962.49	-2.86	-1582.00
3	-338.24	-1300.73	-2.86	-1582.00
4	-338.24	-1638.98	-2.86	-1582.00
5	-338.24	-1977.22	-2.86	-1582.00
6	-338.24	-2315.46	-2.86	-1582.00
7	-338.24	-2653.71	-2.86	-1582.00
8	-338.24	-2991.95	-2.86	-1582.00
9	-338.24	-3330.20	-2.86	-1582.00
10	-338.24	-3668.44	-2.86	-1582.00
11	-338.24	-4006.68	-2.86	-1582.00
12	-338.24	-4344.93	-2.86	-1582.00
13	-338.24	-4683.17	-2.86	-1582.00
14	-338.24	-5021.42	-2.86	-1582.00
15	-338.24	-5359.66	-2.86	-1582.00
16	-338.24	-5697.90	-2.86	-1582.00
17	-338.24	-6036.15	-2.86	-1582.00
18	-338.24	-6374.39	-2.86	-1582.00
19	-338.24	-6712.64	-2.86	-1582.00
20	-338.24	-7050.88	-2.86	-1582.00
21	-338.24	-7389.12	-2.86	-1582.00
22	-338.24	-7727.37	-2.86	-1582.00
23	-338.24	-8065.61	-2.86	-1582.00
24	-338.24	-8403.86	-2.86	-1582.00
25	-338.24	-8742.10	-2.86	-1582.00
150L (3P)				
Year	Cash flow (€)	Cumulative Cash flow (€)	O&M (€)	Energy consumed (kWh)
0	-286.00	-286.00	0	0.00
1	-477.58	-763.58	-2.86	-2225.75
2	-477.58	-1241.16	-2.86	-2225.75
3	-477.58	-1718.74	-2.86	-2225.75
4	-477.58	-2196.32	-2.86	-2225.75
5	-477.58	-2673.89	-2.86	-2225.75
6	-477.58	-3151.47	-2.86	-2225.75
7	-477.58	-3629.05	-2.86	-2225.75

8	-477.58	-4106.63	-2.86	-2225.75
9	-477.58	-4584.21	-2.86	-2225.75
10	-477.58	-5061.79	-2.86	-2225.75
11	-477.58	-5539.37	-2.86	-2225.75
12	-477.58	-6016.95	-2.86	-2225.75
13	-477.58	-6494.53	-2.86	-2225.75
14	-477.58	-6972.11	-2.86	-2225.75
15	-477.58	-7449.68	-2.86	-2225.75
16	-477.58	-7927.26	-2.86	-2225.75
17	-477.58	-8404.84	-2.86	-2225.75
18	-477.58	-8882.42	-2.86	-2225.75
19	-477.58	-9360.00	-2.86	-2225.75
20	-477.58	-9837.58	-2.86	-2225.75
21	-477.58	-10315.16	-2.86	-2225.75
22	-477.58	-10792.74	-2.86	-2225.75
23	-477.58	-11270.32	-2.86	-2225.75
24	-477.58	-11747.90	-2.86	-2225.75
25	-477.58	-12225.47	-2.86	-2225.75

200L (4P)

Year	Cash flow (€)	Cumulative Cash flow (€)	O&M (€)	Energy consumed (kWh)
0	-286.00	-286.00	0	0.00
1	-613.31	-899.31	-2.86	-2866.00
2	-613.31	-1512.62	-2.86	-2866.00
3	-613.31	-2125.94	-2.86	-2866.00
4	-613.31	-2739.25	-2.86	-2866.00
5	-613.31	-3352.56	-2.86	-2866.00
6	-613.31	-3965.87	-2.86	-2866.00
7	-613.31	-4579.18	-2.86	-2866.00
8	-613.31	-5192.50	-2.86	-2866.00
9	-613.31	-5805.81	-2.86	-2866.00
10	-613.31	-6419.12	-2.86	-2866.00
11	-613.31	-7032.43	-2.86	-2866.00
12	-613.31	-7645.74	-2.86	-2866.00
13	-613.31	-8259.06	-2.86	-2866.00
14	-613.31	-8872.37	-2.86	-2866.00
15	-613.31	-9485.68	-2.86	-2866.00
16	-613.31	-10098.99	-2.86	-2866.00
17	-613.31	-10712.30	-2.86	-2866.00
18	-613.31	-11325.62	-2.86	-2866.00
19	-613.31	-11938.93	-2.86	-2866.00
20	-613.31	-12552.24	-2.86	-2866.00
21	-613.31	-13165.55	-2.86	-2866.00
22	-613.31	-13778.86	-2.86	-2866.00
23	-613.31	-14392.18	-2.86	-2866.00
24	-613.31	-15005.49	-2.86	-2866.00
25	-613.31	-15618.80	-2.86	-2866.00

Table B.2 – Economic analysis of S2 for a 100L profile in Bragança

Cash flow (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	219.19	223.20	248.15	254.37	253.51	259.12
2	219.19	223.20	248.15	254.37	253.51	259.12
3	219.19	223.20	248.15	254.37	253.51	259.12
4	219.19	223.20	248.15	254.37	253.51	259.12
5	219.19	223.20	248.15	254.37	253.51	259.12
6	219.19	223.20	248.15	254.37	253.51	259.12
7	219.19	223.20	248.15	254.37	253.51	259.12
8	219.19	223.20	248.15	254.37	253.51	259.12
9	219.19	223.20	248.15	254.37	253.51	259.12
10	219.19	223.20	248.15	254.37	253.51	259.12
11	219.19	223.20	248.15	254.37	253.51	259.12
12	219.19	223.20	248.15	254.37	253.51	259.12
13	219.19	223.20	248.15	254.37	253.51	259.12
14	219.19	223.20	248.15	254.37	253.51	259.12
15	219.19	223.20	248.15	254.37	253.51	259.12
16	219.19	223.20	248.15	254.37	253.51	259.12
17	219.19	223.20	248.15	254.37	253.51	259.12
18	219.19	223.20	248.15	254.37	253.51	259.12
19	219.19	223.20	248.15	254.37	253.51	259.12
20	219.19	223.20	248.15	254.37	253.51	259.12
21	219.19	223.20	248.15	254.37	253.51	259.12
22	219.19	223.20	248.15	254.37	253.51	259.12
23	219.19	223.20	248.15	254.37	253.51	259.12
24	219.19	223.20	248.15	254.37	253.51	259.12
25	219.19	223.20	248.15	254.37	253.51	259.12

Present Value (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	208.75	212.57	236.34	242.26	241.44	246.78
2	198.81	202.45	225.08	230.72	229.94	235.03
3	189.35	192.81	214.36	219.74	218.99	223.83
4	180.33	183.62	204.16	209.27	208.56	213.18
5	171.74	174.88	194.43	199.31	198.63	203.02
6	163.56	166.55	185.18	189.82	189.17	193.36
7	155.78	158.62	176.36	180.78	180.16	184.15
8	148.36	151.07	167.96	172.17	171.58	175.38
9	141.29	143.87	159.96	163.97	163.41	167.03
10	134.57	137.02	152.34	156.16	155.63	159.08
11	128.16	130.50	145.09	148.73	148.22	151.50
12	122.05	124.28	138.18	141.64	141.16	144.29

13	116.24	118.37	131.60	134.90	134.44	137.42
14	110.71	112.73	125.33	128.48	128.04	130.87
15	105.44	107.36	119.37	122.36	121.94	124.64
16	100.41	102.25	113.68	116.53	116.13	118.70
17	95.63	97.38	108.27	110.98	110.60	113.05
18	91.08	92.74	103.11	105.70	105.34	107.67
19	86.74	88.33	98.20	100.66	100.32	102.54
20	82.61	84.12	93.53	95.87	95.54	97.66
21	78.68	80.11	89.07	91.30	90.99	93.01
22	74.93	76.30	84.83	86.96	86.66	88.58
23	71.36	72.67	80.79	82.82	82.53	84.36
24	67.96	69.21	76.94	78.87	78.60	80.34
25	64.73	65.91	73.28	75.12	74.86	76.52

Cumulative discounted Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	-1981.15	-2112.33	-2318.36	-2447.44	-2769.26	-2898.92
2	-1782.33	-1909.89	-2093.28	-2216.72	-2539.33	-2663.90
3	-1592.99	-1717.08	-1878.92	-1996.98	-2320.34	-2440.06
4	-1412.66	-1533.46	-1674.76	-1787.71	-2111.78	-2226.88
5	-1240.91	-1358.58	-1480.33	-1588.40	-1913.15	-2023.86
6	-1077.35	-1192.02	-1295.15	-1398.59	-1723.97	-1830.50
7	-921.57	-1033.40	-1118.79	-1217.81	-1543.81	-1646.35
8	-773.21	-882.33	-950.83	-1045.64	-1372.23	-1470.97
9	-631.92	-738.46	-790.87	-881.67	-1208.82	-1303.94
10	-497.36	-601.43	-638.53	-725.51	-1053.18	-1144.87
11	-369.20	-470.94	-493.44	-576.78	-904.96	-993.37
12	-247.14	-346.65	-355.26	-435.14	-763.80	-849.08
13	-130.90	-228.29	-223.65	-300.24	-629.36	-711.67
14	-20.19	-115.56	-98.32	-171.76	-501.32	-580.80
15	85.24	-8.19	21.05	-49.40	-379.38	-456.16
16	185.65	94.05	134.73	67.13	-263.25	-337.45
17	281.29	191.43	243.00	178.11	-152.64	-224.40
18	372.37	284.18	346.11	283.80	-47.30	-116.73
19	459.11	372.50	444.31	384.47	53.02	-14.19
20	541.72	456.62	537.84	480.34	148.56	83.47
21	620.40	536.74	626.91	571.64	239.56	176.48
22	695.33	613.04	711.74	658.60	326.22	265.05
23	766.69	685.71	792.53	741.42	408.75	349.42
24	834.66	754.91	869.48	820.29	487.36	429.76
25	899.38	820.82	942.76	895.41	562.22	506.28

Energy saved (kWh)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-	-	-	-	-	-
1	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
2	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75

3	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
4	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
5	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
6	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
7	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
8	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
9	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
10	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
11	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
12	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
13	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
14	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
15	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
16	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
17	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
18	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
19	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
20	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
21	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
22	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
23	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
24	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75
25	1221.75	1246.00	1354.00	1387.75	1391.50	1420.75

Table B.3 – Economic analysis of S2 for a 150L profile in Bragança

Cash flow (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	270.94	275.71	332.93	344.47	352.80	360.18
2	270.94	275.71	332.93	344.47	352.80	360.18
3	270.94	275.71	332.93	344.47	352.80	360.18
4	270.94	275.71	332.93	344.47	352.80	360.18
5	270.94	275.71	332.93	344.47	352.80	360.18
6	270.94	275.71	332.93	344.47	352.80	360.18
7	270.94	275.71	332.93	344.47	352.80	360.18
8	270.94	275.71	332.93	344.47	352.80	360.18
9	270.94	275.71	332.93	344.47	352.80	360.18
10	270.94	275.71	332.93	344.47	352.80	360.18
11	270.94	275.71	332.93	344.47	352.80	360.18
12	270.94	275.71	332.93	344.47	352.80	360.18
13	270.94	275.71	332.93	344.47	352.80	360.18
14	270.94	275.71	332.93	344.47	352.80	360.18
15	270.94	275.71	332.93	344.47	352.80	360.18
16	270.94	275.71	332.93	344.47	352.80	360.18
17	270.94	275.71	332.93	344.47	352.80	360.18
18	270.94	275.71	332.93	344.47	352.80	360.18

19	270.94	275.71	332.93	344.47	352.80	360.18
20	270.94	275.71	332.93	344.47	352.80	360.18
21	270.94	275.71	332.93	344.47	352.80	360.18
22	270.94	275.71	332.93	344.47	352.80	360.18
23	270.94	275.71	332.93	344.47	352.80	360.18
24	270.94	275.71	332.93	344.47	352.80	360.18
25	270.94	275.71	332.93	344.47	352.80	360.18

Present Value (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	258.04	262.58	317.08	328.06	336.00	343.03
2	245.75	250.08	301.98	312.44	320.00	326.69
3	234.05	238.17	287.60	297.56	304.76	311.14
4	222.90	226.83	273.91	283.39	290.25	296.32
5	212.29	216.03	260.86	269.90	276.42	282.21
6	202.18	205.74	248.44	257.05	263.26	268.77
7	192.55	195.94	236.61	244.81	250.73	255.97
8	183.38	186.61	225.34	233.15	238.79	243.78
9	174.65	177.73	214.61	222.05	227.42	232.18
10	166.33	169.26	204.39	211.47	216.59	221.12
11	158.41	161.20	194.66	201.40	206.27	210.59
12	150.87	153.53	185.39	191.81	196.45	200.56
13	143.68	146.22	176.56	182.68	187.10	191.01
14	136.84	139.25	168.15	173.98	178.19	181.92
15	130.33	132.62	160.15	165.69	169.70	173.25
16	124.12	126.31	152.52	157.80	161.62	165.00
17	118.21	120.29	145.26	150.29	153.92	157.15
18	112.58	114.56	138.34	143.13	146.59	149.66
19	107.22	109.11	131.75	136.32	139.61	142.54
20	102.11	103.91	125.48	129.83	132.96	135.75
21	97.25	98.96	119.50	123.64	126.63	129.28
22	92.62	94.25	113.81	117.76	120.60	123.13
23	88.21	89.76	108.39	112.15	114.86	117.26
24	84.01	85.49	103.23	106.81	109.39	111.68
25	80.01	81.42	98.32	101.72	104.18	106.36

Cumulative discounted Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1931.86	-1978.72	-2154.02	-2278.04	-2591.10	-2719.07
2	-1686.12	-1728.64	-1852.04	-1965.59	-2271.11	-2392.38
3	-1452.07	-1490.47	-1564.44	-1668.03	-1966.35	-2081.24
4	-1229.17	-1263.64	-1290.53	-1384.64	-1676.10	-1784.92
5	-1016.88	-1047.62	-1029.67	-1114.74	-1399.68	-1502.71
6	-814.71	-841.88	-781.23	-857.69	-1136.42	-1233.93
7	-622.16	-645.94	-544.62	-612.88	-885.69	-977.96
8	-438.78	-459.32	-319.27	-379.74	-646.91	-734.18

9	-264.13	-281.60	-104.66	-157.69	-419.49	-502.00
10	-97.80	-112.34	99.73	53.78	-202.91	-280.88
11	60.61	48.87	294.39	255.19	3.37	-70.29
12	211.48	202.39	479.78	447.00	199.82	130.27
13	355.17	348.61	656.35	629.68	386.91	321.28
14	492.01	487.86	824.50	803.66	565.10	503.20
15	622.33	620.48	984.65	969.35	734.80	676.45
16	746.45	746.79	1137.17	1127.16	896.42	841.45
17	864.66	867.08	1282.43	1277.45	1050.34	998.60
18	977.24	981.64	1420.77	1420.58	1196.93	1148.26
19	1084.46	1090.75	1552.52	1556.90	1336.55	1290.80
20	1186.57	1194.66	1678.00	1686.72	1469.51	1426.55
21	1283.82	1293.63	1797.51	1810.37	1596.15	1555.83
22	1376.44	1387.88	1911.32	1928.12	1716.75	1678.96
23	1464.65	1477.64	2019.71	2040.27	1831.61	1796.22
24	1548.66	1563.13	2122.95	2147.08	1941.00	1907.90
25	1628.67	1644.55	2221.26	2248.80	2045.18	2014.27

Energy saved (kWh)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-	-	-	-	-	-
1	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
2	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
3	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
4	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
5	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
6	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
7	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
8	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
9	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
10	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
11	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
12	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
13	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
14	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
15	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
16	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
17	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
18	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
19	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
20	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
21	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
22	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
23	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
24	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50
25	1490.50	1518.75	1774.50	1831.25	1879.50	1915.50

Table B.4 – Economic analysis of S2 for a 200L profile in Bragança

Cash flow (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	245.89	247.99	348.11	359.35	380.68	396.59
2	245.89	247.99	348.11	359.35	380.68	396.59
3	245.89	247.99	348.11	359.35	380.68	396.59
4	245.89	247.99	348.11	359.35	380.68	396.59
5	245.89	247.99	348.11	359.35	380.68	396.59
6	245.89	247.99	348.11	359.35	380.68	396.59
7	245.89	247.99	348.11	359.35	380.68	396.59
8	245.89	247.99	348.11	359.35	380.68	396.59
9	245.89	247.99	348.11	359.35	380.68	396.59
10	245.89	247.99	348.11	359.35	380.68	396.59
11	245.89	247.99	348.11	359.35	380.68	396.59
12	245.89	247.99	348.11	359.35	380.68	396.59
13	245.89	247.99	348.11	359.35	380.68	396.59
14	245.89	247.99	348.11	359.35	380.68	396.59
15	245.89	247.99	348.11	359.35	380.68	396.59
16	245.89	247.99	348.11	359.35	380.68	396.59
17	245.89	247.99	348.11	359.35	380.68	396.59
18	245.89	247.99	348.11	359.35	380.68	396.59
19	245.89	247.99	348.11	359.35	380.68	396.59
20	245.89	247.99	348.11	359.35	380.68	396.59
21	245.89	247.99	348.11	359.35	380.68	396.59
22	245.89	247.99	348.11	359.35	380.68	396.59
23	245.89	247.99	348.11	359.35	380.68	396.59
24	245.89	247.99	348.11	359.35	380.68	396.59
25	245.89	247.99	348.11	359.35	380.68	396.59

Present Value (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	234.18	236.18	331.53	342.23	362.55	377.71
2	223.03	224.94	315.74	325.94	345.29	359.72
3	212.41	214.22	300.71	310.42	328.84	342.59
4	202.29	204.02	286.39	295.63	313.19	326.28
5	192.66	194.31	272.75	281.56	298.27	310.74
6	183.48	185.05	259.76	268.15	284.07	295.94
7	174.75	176.24	247.39	255.38	270.54	281.85
8	166.43	167.85	235.61	243.22	257.66	268.43
9	158.50	159.86	224.39	231.64	245.39	255.65
10	150.95	152.25	213.71	220.61	233.70	243.47
11	143.76	145.00	203.53	210.10	222.58	231.88
12	136.92	138.09	193.84	200.10	211.98	220.84
13	130.40	131.52	184.61	190.57	201.88	210.32
14	124.19	125.25	175.82	181.49	192.27	200.31

15	118.28	119.29	167.44	172.85	183.11	190.77
16	112.64	113.61	159.47	164.62	174.39	181.68
17	107.28	108.20	151.88	156.78	166.09	173.03
18	102.17	103.05	144.64	149.32	158.18	164.79
19	97.31	98.14	137.76	142.21	150.65	156.95
20	92.67	93.47	131.20	135.43	143.47	149.47
21	88.26	89.01	124.95	128.98	136.64	142.35
22	84.06	84.78	119.00	122.84	130.14	135.58
23	80.05	80.74	113.33	116.99	123.94	129.12
24	76.24	76.89	107.94	111.42	118.04	122.97
25	72.61	73.23	102.80	106.12	112.42	117.12

Cumulative discounted Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1955.72	-2005.12	-2139.57	-2263.87	-2564.55	-2684.39
2	-1732.70	-1780.18	-1823.83	-1937.93	-2219.26	-2324.67
3	-1520.29	-1565.96	-1523.12	-1627.51	-1890.42	-1982.08
4	-1318.00	-1361.94	-1236.74	-1331.88	-1577.23	-1655.80
5	-1125.34	-1167.63	-963.99	-1050.32	-1278.96	-1345.05
6	-941.85	-982.57	-704.23	-782.17	-994.89	-1049.11
7	-767.11	-806.33	-456.83	-526.79	-724.35	-767.26
8	-600.68	-638.48	-221.22	-283.57	-466.69	-498.83
9	-442.18	-478.62	3.17	-51.93	-221.30	-243.18
10	-291.23	-326.38	216.88	168.67	12.40	0.30
11	-147.46	-181.38	420.41	378.78	234.98	232.18
12	-10.54	-43.29	614.24	578.87	446.95	453.02
13	119.86	88.22	798.85	769.44	648.84	663.34
14	244.04	213.48	974.67	950.94	841.10	863.65
15	362.32	332.76	1142.11	1123.79	1024.22	1054.41
16	474.96	446.37	1301.58	1288.41	1198.61	1236.10
17	582.24	554.57	1453.46	1445.19	1364.70	1409.13
18	684.41	657.61	1598.11	1594.51	1522.88	1573.92
19	781.72	755.75	1735.86	1736.71	1673.53	1730.87
20	874.39	849.22	1867.06	1872.15	1817.00	1880.34
21	962.65	938.23	1992.01	2001.13	1953.64	2022.70
22	1046.71	1023.01	2111.01	2123.97	2083.78	2158.27
23	1126.76	1103.75	2224.34	2240.97	2207.72	2287.39
24	1203.00	1180.64	2332.28	2352.39	2325.75	2410.36
25	1275.61	1253.87	2435.08	2458.50	2438.17	2527.48

Energy saved (kWh)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-	-	-	-	-	-
1	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
2	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
3	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
4	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25

5	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
6	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
7	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
8	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
9	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
10	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
11	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
12	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
13	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
14	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
15	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
16	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
17	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
18	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
19	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
20	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
21	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
22	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
23	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
24	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25
25	1382.25	1399.00	1857.50	1914.50	2022.00	2099.25

Table B.5 – Cumulative Cash flow (€) for S2 in Bragança

	100L (2P)					
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	-1970.71	-2101.70	-2306.55	-2435.33	-2757.19	-2886.58
2	-1751.52	-1878.51	-2058.39	-2180.96	-2503.69	-2627.47
3	-1532.32	-1655.31	-1810.24	-1926.58	-2250.18	-2368.35
4	-1313.13	-1432.11	-1562.09	-1672.21	-1996.67	-2109.23
5	-1093.94	-1208.92	-1313.93	-1417.84	-1743.16	-1850.12
6	-874.75	-985.72	-1065.78	-1163.47	-1489.66	-1591.00
7	-655.55	-762.52	-817.63	-909.10	-1236.15	-1331.88
8	-436.36	-539.33	-569.47	-654.72	-982.64	-1072.77
9	-217.17	-316.13	-321.32	-400.35	-729.13	-813.65
10	2.02	-92.93	-73.17	-145.98	-475.63	-554.53
11	221.21	130.26	174.99	108.39	-222.12	-295.42
12	440.41	353.46	423.14	362.76	31.39	-36.30
13	659.60	576.66	671.29	617.14	284.90	222.82
14	878.79	799.85	919.45	871.51	538.40	481.93
15	1097.98	1023.05	1167.60	1125.88	791.91	741.05
16	1317.18	1246.25	1415.75	1380.25	1045.42	1000.17
17	1536.37	1469.44	1663.91	1634.63	1298.92	1259.28
18	1755.56	1692.64	1912.06	1889.00	1552.43	1518.40
19	1974.75	1915.84	2160.21	2143.37	1805.94	1777.52
20	2193.94	2139.03	2408.37	2397.74	2059.45	2036.64

21	2413.14	2362.23	2656.52	2652.11	2312.95	2295.75
22	2632.33	2585.43	2904.67	2906.49	2566.46	2554.87
23	2851.52	2808.62	3152.83	3160.86	2819.97	2813.99
24	3070.71	3031.82	3400.98	3415.23	3073.48	3073.10
25	3289.91	3255.02	3649.13	3669.60	3326.98	3332.22

150L (3P)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1918.96	-1965.59	-2138.17	-2261.63	-2574.30	-2701.92
2	-1648.03	-1689.88	-1805.23	-1917.17	-2221.51	-2341.74
3	-1377.09	-1414.17	-1472.30	-1572.70	-1868.71	-1981.56
4	-1106.15	-1138.46	-1139.36	-1228.23	-1515.92	-1621.38
5	-835.22	-862.75	-806.43	-883.76	-1163.12	-1261.20
6	-564.28	-587.04	-473.49	-539.30	-810.33	-901.02
7	-293.34	-311.33	-140.56	-194.83	-457.53	-540.84
8	-22.40	-35.61	192.38	149.64	-104.74	-180.66
9	248.53	240.10	525.31	494.10	248.06	179.53
10	519.47	515.81	858.25	838.57	600.86	539.71
11	790.41	791.52	1191.18	1183.04	953.65	899.89
12	1061.34	1067.23	1524.12	1527.51	1306.45	1260.07
13	1332.28	1342.94	1857.05	1871.97	1659.24	1620.25
14	1603.22	1618.65	2189.99	2216.44	2012.04	1980.43
15	1874.15	1894.36	2522.92	2560.91	2364.83	2340.61
16	2145.09	2170.07	2855.86	2905.37	2717.63	2700.79
17	2416.03	2445.78	3188.79	3249.84	3070.42	3060.97
18	2686.96	2721.49	3521.73	3594.31	3423.22	3421.15
19	2957.90	2997.20	3854.66	3938.78	3776.02	3781.33
20	3228.84	3272.91	4187.59	4283.24	4128.81	4141.51
21	3499.78	3548.62	4520.53	4627.71	4481.61	4501.69
22	3770.71	3824.34	4853.46	4972.18	4834.40	4861.87
23	4041.65	4100.05	5186.40	5316.65	5187.20	5222.05
24	4312.59	4375.76	5519.33	5661.11	5539.99	5582.23
25	4583.52	4651.47	5852.27	6005.58	5892.79	5942.42

200L (3P)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1944.01	-1993.31	-2122.99	-2246.75	-2546.42	-2665.51
2	-1698.13	-1745.32	-1774.89	-1887.41	-2165.74	-2268.91
3	-1452.24	-1497.33	-1426.78	-1528.06	-1785.06	-1872.32
4	-1206.35	-1249.34	-1078.68	-1168.72	-1404.38	-1475.72
5	-960.47	-1001.34	-730.57	-809.37	-1023.71	-1079.13
6	-714.58	-753.35	-382.47	-450.02	-643.03	-682.53
7	-468.69	-505.36	-34.36	-90.68	-262.35	-285.94
8	-222.81	-257.37	313.74	268.67	118.33	110.66
9	23.08	-9.38	661.85	628.01	499.01	507.25
10	268.97	238.61	1009.95	987.36	879.69	903.84

11	514.85	486.60	1358.06	1346.71	1260.37	1300.44
12	760.74	734.59	1706.16	1706.05	1641.05	1697.03
13	1006.63	982.59	2054.27	2065.40	2021.73	2093.63
14	1252.51	1230.58	2402.37	2424.74	2402.41	2490.22
15	1498.40	1478.57	2750.48	2784.09	2783.08	2886.82
16	1744.29	1726.56	3098.58	3143.44	3163.76	3283.41
17	1990.17	1974.55	3446.69	3502.78	3544.44	3680.00
18	2236.06	2222.54	3794.79	3862.13	3925.12	4076.60
19	2481.95	2470.53	4142.90	4221.47	4305.80	4473.19
20	2727.83	2718.52	4491.00	4580.82	4686.48	4869.79
21	2973.72	2966.51	4839.11	4940.17	5067.16	5266.38
22	3219.61	3214.51	5187.21	5299.51	5447.84	5662.98
23	3465.50	3462.50	5535.32	5658.86	5828.52	6059.57
24	3711.38	3710.49	5883.42	6018.20	6209.20	6456.17
25	3957.27	3958.48	6231.53	6377.55	6589.87	6852.76

Table B.6 – Economic analysis of S2 for a 100L profile in Faro

Cash flow (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2273.50	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	256.07	260.14	271.30	272.37	270.97	272.23
2	256.07	260.14	271.30	272.37	270.97	272.23
3	256.07	260.14	271.30	272.37	270.97	272.23
4	256.07	260.14	271.30	272.37	270.97	272.23
5	256.07	260.14	271.30	272.37	270.97	272.23
6	256.07	260.14	271.30	272.37	270.97	272.23
7	256.07	260.14	271.30	272.37	270.97	272.23
8	256.07	260.14	271.30	272.37	270.97	272.23
9	256.07	260.14	271.30	272.37	270.97	272.23
10	256.07	260.14	271.30	272.37	270.97	272.23
11	256.07	260.14	271.30	272.37	270.97	272.23
12	256.07	260.14	271.30	272.37	270.97	272.23
13	256.07	260.14	271.30	272.37	270.97	272.23
14	256.07	260.14	271.30	272.37	270.97	272.23
15	256.07	260.14	271.30	272.37	270.97	272.23
16	256.07	260.14	271.30	272.37	270.97	272.23
17	256.07	260.14	271.30	272.37	270.97	272.23
18	256.07	260.14	271.30	272.37	270.97	272.23
19	256.07	260.14	271.30	272.37	270.97	272.23
20	256.07	260.14	271.30	272.37	270.97	272.23
21	256.07	260.14	271.30	272.37	270.97	272.23
22	256.07	260.14	271.30	272.37	270.97	272.23
23	256.07	260.14	271.30	272.37	270.97	272.23
24	256.07	260.14	271.30	272.37	270.97	272.23
25	256.07	260.14	271.30	272.37	270.97	272.23
Present Value (€)						

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2273.50	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	243.88	247.75	258.38	259.40	258.07	259.27
2	232.26	235.96	246.08	247.05	245.78	246.92
3	221.20	224.72	234.36	235.28	234.08	235.16
4	210.67	214.02	223.20	224.08	222.93	223.97
5	200.64	203.83	212.57	213.41	212.31	213.30
6	191.08	194.12	202.45	203.25	202.20	203.14
7	181.99	184.88	192.81	193.57	192.57	193.47
8	173.32	176.07	183.63	184.35	183.40	184.26
9	165.07	167.69	174.88	175.57	174.67	175.48
10	157.21	159.71	166.55	167.21	166.35	167.13
11	149.72	152.10	158.62	159.25	158.43	159.17
12	142.59	144.86	151.07	151.67	150.89	151.59
13	135.80	137.96	143.88	144.44	143.70	144.37
14	129.33	131.39	137.02	137.57	136.86	137.50
15	123.17	125.13	130.50	131.02	130.34	130.95
16	117.31	119.17	124.29	124.78	124.14	124.71
17	111.72	113.50	118.37	118.83	118.22	118.77
18	106.40	108.09	112.73	113.18	112.59	113.12
19	101.34	102.95	107.36	107.79	107.23	107.73
20	96.51	98.05	102.25	102.65	102.13	102.60
21	91.91	93.38	97.38	97.77	97.26	97.72
22	87.54	88.93	92.74	93.11	92.63	93.06
23	83.37	84.70	88.33	88.68	88.22	88.63
24	79.40	80.66	84.12	84.45	84.02	84.41
25	75.62	76.82	80.12	80.43	80.02	80.39

Cumulative discounted Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2273.50	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	-2029.62	-2077.15	-2296.32	-2430.30	-2752.63	-2886.43
2	-1797.36	-1841.19	-2050.24	-2183.25	-2506.85	-2639.51
3	-1576.15	-1616.47	-1815.88	-1947.97	-2272.78	-2404.35
4	-1365.48	-1402.45	-1592.69	-1723.89	-2049.85	-2180.38
5	-1164.85	-1198.62	-1380.12	-1510.48	-1837.53	-1967.08
6	-973.76	-1004.50	-1177.67	-1307.23	-1635.33	-1763.94
7	-791.78	-819.62	-984.86	-1113.66	-1442.75	-1570.47
8	-618.46	-643.54	-801.23	-929.31	-1259.35	-1386.21
9	-453.39	-475.85	-626.35	-753.74	-1084.68	-1210.73
10	-296.18	-316.15	-459.80	-586.52	-918.33	-1043.60
11	-146.47	-164.05	-301.18	-427.27	-759.89	-884.44
12	-3.88	-19.19	-150.11	-275.61	-609.01	-732.85
13	131.93	118.77	-6.23	-131.16	-465.30	-588.48
14	261.26	250.16	130.79	6.40	-328.45	-450.98
15	384.43	375.29	261.29	137.42	-198.10	-320.04
16	501.74	494.47	385.58	262.19	-73.97	-195.32

17	613.47	607.97	503.95	381.03	44.26	-76.55
18	719.87	716.06	616.68	494.20	156.85	36.57
19	821.20	819.01	724.04	601.99	264.08	144.30
20	917.72	917.05	826.29	704.64	366.21	246.90
21	1009.63	1010.43	923.67	802.41	463.47	344.61
22	1097.17	1099.36	1016.41	895.52	556.11	437.68
23	1180.54	1184.05	1104.74	984.20	644.33	526.31
24	1259.94	1264.72	1188.86	1068.65	728.35	610.72
25	1335.56	1341.54	1268.98	1149.08	808.36	691.11

Energy saved (kWh)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-	-	-	-	-	-
1	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
2	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
3	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
4	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
5	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
6	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
7	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
8	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
9	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
10	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
11	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
12	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
13	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
14	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
15	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
16	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
17	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
18	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
19	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
20	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
21	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
22	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
23	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
24	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50
25	1404.50	1428.25	1463.50	1471.25	1472.75	1480.50

Table B.7 – Economic analysis of S2 for a 150L profile in Faro

Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	329.45	332.36	384.95	393.14	391.25	402.78
2	329.45	332.36	384.95	393.14	391.25	402.78
3	329.45	332.36	384.95	393.14	391.25	402.78
4	329.45	332.36	384.95	393.14	391.25	402.78

5	329.45	332.36	384.95	393.14	391.25	402.78
6	329.45	332.36	384.95	393.14	391.25	402.78
7	329.45	332.36	384.95	393.14	391.25	402.78
8	329.45	332.36	384.95	393.14	391.25	402.78
9	329.45	332.36	384.95	393.14	391.25	402.78
10	329.45	332.36	384.95	393.14	391.25	402.78
11	329.45	332.36	384.95	393.14	391.25	402.78
12	329.45	332.36	384.95	393.14	391.25	402.78
13	329.45	332.36	384.95	393.14	391.25	402.78
14	329.45	332.36	384.95	393.14	391.25	402.78
15	329.45	332.36	384.95	393.14	391.25	402.78
16	329.45	332.36	384.95	393.14	391.25	402.78
17	329.45	332.36	384.95	393.14	391.25	402.78
18	329.45	332.36	384.95	393.14	391.25	402.78
19	329.45	332.36	384.95	393.14	391.25	402.78
20	329.45	332.36	384.95	393.14	391.25	402.78
21	329.45	332.36	384.95	393.14	391.25	402.78
22	329.45	332.36	384.95	393.14	391.25	402.78
23	329.45	332.36	384.95	393.14	391.25	402.78
24	329.45	332.36	384.95	393.14	391.25	402.78
25	329.45	332.36	384.95	393.14	391.25	402.78

Present Value (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2 189.90	-2 241.30	-2 471.10	-2 606.10	-2 927.10	-3 062.10
1	313.76	316.53	366.62	374.41	372.62	383.60
2	298.82	301.46	349.17	356.59	354.87	365.33
3	284.59	287.11	332.54	339.60	337.97	347.93
4	271.04	273.43	316.70	323.43	321.88	331.36
5	258.13	260.41	301.62	308.03	306.55	315.59
6	245.84	248.01	287.26	293.36	291.95	300.56
7	234.13	236.20	273.58	279.39	278.05	286.24
8	222.98	224.96	260.55	266.09	264.81	272.61
9	212.37	214.24	248.15	253.42	252.20	259.63
10	202.25	204.04	236.33	241.35	240.19	247.27
11	192.62	194.32	225.07	229.86	228.75	235.49
12	183.45	185.07	214.36	218.91	217.86	224.28
13	174.71	176.26	204.15	208.49	207.49	213.60
14	166.39	167.86	194.43	198.56	197.61	203.43
15	158.47	159.87	185.17	189.10	188.20	193.74
16	150.92	152.26	176.35	180.10	179.23	184.52
17	143.74	145.01	167.95	171.52	170.70	175.73
18	136.89	138.10	159.96	163.36	162.57	167.36
19	130.37	131.53	152.34	155.58	154.83	159.39
20	124.17	125.26	145.09	148.17	147.46	151.80
21	118.25	119.30	138.18	141.11	140.44	144.57
22	112.62	113.62	131.60	134.39	133.75	137.69

23	107.26	108.21	125.33	127.99	127.38	131.13
24	102.15	103.05	119.36	121.90	121.31	124.89
25	97.29	98.15	113.68	116.09	115.54	118.94

Cumulative discounted Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1876.14	-1924.77	-2104.48	-2231.69	-2554.48	-2678.50
2	-1577.32	-1623.30	-1755.31	-1875.10	-2199.61	-2313.18
3	-1292.73	-1336.20	-1422.77	-1535.50	-1861.64	-1965.24
4	-1021.69	-1062.76	-1106.07	-1212.06	-1539.76	-1633.88
5	-763.56	-802.35	-804.45	-904.03	-1233.20	-1318.29
6	-517.72	-554.34	-517.19	-610.67	-941.25	-1017.74
7	-283.59	-318.13	-243.61	-331.27	-663.20	-731.49
8	-60.60	-93.18	16.94	-65.18	-398.39	-458.88
9	151.76	121.06	265.09	188.24	-146.18	-199.24
10	354.02	325.10	501.42	429.59	94.01	48.02
11	546.64	519.43	726.49	659.44	322.76	283.52
12	730.09	704.50	940.85	878.36	540.62	507.80
13	904.80	880.76	1145.00	1086.84	748.11	721.40
14	1071.19	1048.62	1339.43	1285.40	945.72	924.83
15	1229.66	1208.49	1524.60	1474.51	1133.91	1118.57
16	1380.59	1360.75	1700.95	1654.61	1313.15	1303.09
17	1524.33	1505.76	1868.90	1826.13	1483.85	1478.82
18	1661.22	1643.86	2028.86	1989.49	1646.42	1646.18
19	1791.59	1775.39	2181.20	2145.07	1801.25	1805.57
20	1915.76	1900.65	2326.28	2293.23	1948.70	1957.37
21	2034.01	2019.95	2464.46	2434.35	2089.14	2101.94
22	2146.63	2133.57	2596.06	2568.74	2222.89	2239.63
23	2253.89	2241.78	2721.39	2696.73	2350.27	2370.77
24	2356.04	2344.83	2840.75	2818.63	2471.58	2495.65
25	2453.33	2442.98	2954.43	2934.73	2587.12	2614.59

Energy saved (kWh)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-	-	-	-	-	-
1	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
2	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
3	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
4	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
5	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
6	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
7	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
8	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
9	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
10	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
11	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
12	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50

13	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
14	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
15	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
16	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
17	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
18	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
19	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
20	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
21	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
22	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
23	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
24	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50
25	1787.75	1806.50	2026.75	2066.25	2063.75	2096.50

Table B.8 – Economic analysis of S2 for a 200L profile in Faro

Cash flow (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	307.22	311.48	434.05	452.29	455.20	472.20
2	307.22	311.48	434.05	452.29	455.20	472.20
3	307.22	311.48	434.05	452.29	455.20	472.20
4	307.22	311.48	434.05	452.29	455.20	472.20
5	307.22	311.48	434.05	452.29	455.20	472.20
6	307.22	311.48	434.05	452.29	455.20	472.20
7	307.22	311.48	434.05	452.29	455.20	472.20
8	307.22	311.48	434.05	452.29	455.20	472.20
9	307.22	311.48	434.05	452.29	455.20	472.20
10	307.22	311.48	434.05	452.29	455.20	472.20
11	307.22	311.48	434.05	452.29	455.20	472.20
12	307.22	311.48	434.05	452.29	455.20	472.20
13	307.22	311.48	434.05	452.29	455.20	472.20
14	307.22	311.48	434.05	452.29	455.20	472.20
15	307.22	311.48	434.05	452.29	455.20	472.20
16	307.22	311.48	434.05	452.29	455.20	472.20
17	307.22	311.48	434.05	452.29	455.20	472.20
18	307.22	311.48	434.05	452.29	455.20	472.20
19	307.22	311.48	434.05	452.29	455.20	472.20
20	307.22	311.48	434.05	452.29	455.20	472.20
21	307.22	311.48	434.05	452.29	455.20	472.20
22	307.22	311.48	434.05	452.29	455.20	472.20
23	307.22	311.48	434.05	452.29	455.20	472.20
24	307.22	311.48	434.05	452.29	455.20	472.20
25	307.22	311.48	434.05	452.29	455.20	472.20
Present Value (€)						
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10

1	292.59	296.65	413.38	430.75	433.52	449.71
2	278.65	282.52	393.70	410.24	412.88	428.29
3	265.38	269.07	374.95	390.70	393.22	407.90
4	252.75	256.25	357.10	372.10	374.49	388.48
5	240.71	244.05	340.09	354.38	356.66	369.98
6	229.25	232.43	323.90	337.50	339.67	352.36
7	218.33	221.36	308.47	321.43	323.50	335.58
8	207.94	210.82	293.78	306.13	308.09	319.60
9	198.03	200.78	279.80	291.55	293.42	304.38
10	188.60	191.22	266.47	277.66	279.45	289.89
11	179.62	182.12	253.78	264.44	266.14	276.08
12	171.07	173.44	241.70	251.85	253.47	262.94
13	162.92	165.18	230.19	239.86	241.40	250.42
14	155.16	157.32	219.23	228.44	229.91	238.49
15	147.78	149.83	208.79	217.56	218.96	227.13
16	140.74	142.69	198.85	207.20	208.53	216.32
17	134.04	135.90	189.38	197.33	198.60	206.02
18	127.65	129.43	180.36	187.93	189.14	196.21
19	121.58	123.26	171.77	178.99	180.14	186.86
20	115.79	117.39	163.59	170.46	171.56	177.97
21	110.27	111.80	155.80	162.34	163.39	169.49
22	105.02	106.48	148.38	154.61	155.61	161.42
23	100.02	101.41	141.32	147.25	148.20	153.73
24	95.26	96.58	134.59	140.24	141.14	146.41
25	90.72	91.98	128.18	133.56	134.42	139.44

Cumulative discounted Cash flow (€)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1897.31	-1944.65	-2057.72	-2175.35	-2493.58	-2612.39
2	-1618.66	-1662.13	-1664.02	-1765.11	-2080.70	-2184.10
3	-1353.27	-1393.07	-1289.06	-1374.41	-1687.49	-1776.20
4	-1100.53	-1136.81	-931.97	-1002.31	-1313.00	-1387.72
5	-859.82	-892.76	-591.87	-647.94	-956.34	-1017.74
6	-630.57	-660.33	-267.98	-310.43	-616.66	-665.38
7	-412.23	-438.97	40.50	11.00	-293.16	-329.80
8	-204.30	-228.15	334.28	317.12	14.93	-10.20
9	-6.26	-27.37	614.08	608.67	308.35	294.18
10	182.34	163.85	880.55	886.34	587.81	584.07
11	361.96	345.97	1134.33	1150.78	853.95	860.15
12	533.03	519.41	1376.03	1402.63	1107.42	1123.08
13	695.96	684.60	1606.22	1642.49	1348.82	1373.50
14	851.12	841.91	1825.44	1870.92	1578.72	1611.99
15	998.90	991.74	2034.23	2088.48	1797.68	1839.12
16	1139.64	1134.43	2233.08	2295.68	2006.21	2055.44
17	1273.67	1270.33	2422.45	2493.01	2204.81	2261.46
18	1401.33	1399.76	2602.81	2680.94	2393.96	2457.67
19	1522.90	1523.02	2774.58	2859.93	2574.09	2644.53

20	1638.69	1640.41	2938.17	3030.39	2745.65	2822.50
21	1748.96	1752.21	3093.97	3192.74	2909.04	2991.99
22	1853.98	1858.69	3242.35	3347.35	3064.65	3153.41
23	1954.01	1960.10	3383.67	3494.60	3212.85	3307.14
24	2049.26	2056.68	3518.26	3634.84	3353.99	3453.55
25	2139.98	2148.66	3646.43	3768.40	3488.41	3592.99
			Energy saved (kWh)			
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-	-	-	-	-	-
1	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
2	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
3	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
4	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
5	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
6	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
7	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
8	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
9	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
10	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
11	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
12	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
13	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
14	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
15	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
16	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
17	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
18	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
19	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
20	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
21	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
22	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
23	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
24	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00
25	1694.50	1721.25	2278.50	2366.00	2382.75	2462.00

Table B.9 – Cumulative Cash flow (€) for S2 in Faro

			100L (2P)			
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2273.50	-2324.90	-2554.70	-2689.70	-3010.70	-3145.70
1	-2017.43	-2064.76	-2283.40	-2417.33	-2739.73	-2873.47
2	-1761.36	-1804.61	-2012.10	-2144.96	-2468.76	-2601.24
3	-1505.29	-1544.47	-1740.80	-1872.59	-2197.78	-2329.01
4	-1249.21	-1284.33	-1469.50	-1600.22	-1926.81	-2056.78
5	-993.14	-1024.19	-1198.20	-1327.84	-1655.84	-1784.55
6	-737.07	-764.04	-926.90	-1055.47	-1384.87	-1512.31
7	-481.00	-503.90	-655.60	-783.10	-1113.90	-1240.08

8	-224.93	-243.76	-384.31	-510.73	-842.92	-967.85
9	31.14	16.38	-113.01	-238.36	-571.95	-695.62
10	287.21	276.53	158.29	34.01	-300.98	-423.39
11	543.28	536.67	429.59	306.38	-30.01	-151.16
12	799.36	796.81	700.89	578.75	240.96	121.07
13	1055.43	1056.96	972.19	851.12	511.94	393.30
14	1311.50	1317.10	1243.49	1123.49	782.91	665.53
15	1567.57	1577.24	1514.79	1395.87	1053.88	937.76
16	1823.64	1837.38	1786.09	1668.24	1324.85	1210.00
17	2079.71	2097.53	2057.39	1940.61	1595.82	1482.23
18	2335.78	2357.67	2328.69	2212.98	1866.80	1754.46
19	2591.86	2617.81	2599.99	2485.35	2137.77	2026.69
20	2847.93	2877.95	2871.29	2757.72	2408.74	2298.92
21	3104.00	3138.10	3142.59	3030.09	2679.71	2571.15
22	3360.07	3398.24	3413.88	3302.46	2950.68	2843.38
23	3616.14	3658.38	3685.18	3574.83	3221.66	3115.61
24	3872.21	3918.53	3956.48	3847.20	3492.63	3387.84
25	4128.28	4178.67	4227.78	4119.58	3763.60	3660.07

150L (3P)

Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1860.45	-1908.94	-2086.15	-2212.96	-2535.85	-2659.32
2	-1531.00	-1576.58	-1701.19	-1819.83	-2144.61	-2256.55
3	-1201.55	-1244.22	-1316.24	-1426.69	-1753.36	-1853.77
4	-872.11	-911.86	-931.28	-1033.56	-1362.11	-1451.00
5	-542.66	-579.49	-546.33	-640.42	-970.86	-1048.22
6	-213.21	-247.13	-161.37	-247.29	-579.62	-645.45
7	116.24	85.23	223.58	145.85	-188.37	-242.67
8	445.69	417.59	608.54	538.98	202.88	160.10
9	775.14	749.95	993.49	932.12	594.12	562.88
10	1104.59	1082.31	1378.44	1325.25	985.37	965.65
11	1434.04	1414.67	1763.40	1718.39	1376.62	1368.43
12	1763.48	1747.03	2148.35	2111.52	1767.87	1771.20
13	2092.93	2079.39	2533.31	2504.66	2159.11	2173.98
14	2422.38	2411.75	2918.26	2897.79	2550.36	2576.75
15	2751.83	2744.12	3303.22	3290.93	2941.61	2979.53
16	3081.28	3076.48	3688.17	3684.06	3332.85	3382.31
17	3410.73	3408.84	4073.13	4077.20	3724.10	3785.08
18	3740.18	3741.20	4458.08	4470.33	4115.35	4187.86
19	4069.62	4073.56	4843.04	4863.47	4506.60	4590.63
20	4399.07	4405.92	5227.99	5256.60	4897.84	4993.41
21	4728.52	4738.28	5612.94	5649.74	5289.09	5396.18
22	5057.97	5070.64	5997.90	6042.87	5680.34	5798.96
23	5387.42	5403.00	6382.85	6436.01	6071.58	6201.73
24	5716.87	5735.37	6767.81	6829.15	6462.83	6604.51
25	6046.32	6067.73	7152.76	7222.28	6854.08	7007.28

			200L (3P)			
Year	1 STP 200L	1 STP 300L	2 STP 200L	2 STP 300L	3 STP 200L	3 STP 300L
0	-2189.90	-2241.30	-2471.10	-2606.10	-2927.10	-3062.10
1	-1882.68	-1929.82	-2037.05	-2153.81	-2471.90	-2589.90
2	-1575.47	-1618.34	-1602.99	-1701.53	-2016.71	-2117.71
3	-1268.25	-1306.86	-1168.94	-1249.24	-1561.51	-1645.51
4	-961.04	-995.39	-734.88	-796.95	-1106.31	-1173.32
5	-653.82	-683.91	-300.83	-344.67	-651.12	-701.12
6	-346.60	-372.43	133.22	107.62	-195.92	-228.93
7	-39.39	-60.95	567.28	559.91	259.27	243.27
8	267.83	250.53	1001.33	1012.19	714.47	715.46
9	575.04	562.01	1435.39	1464.48	1169.67	1187.66
10	882.26	873.49	1869.44	1916.77	1624.86	1659.85
11	1189.48	1184.96	2303.49	2369.05	2080.06	2132.05
12	1496.69	1496.44	2737.55	2821.34	2535.26	2604.24
13	1803.91	1807.92	3171.60	3273.63	2990.45	3076.44
14	2111.12	2119.40	3605.66	3725.91	3445.65	3548.63
15	2418.34	2430.88	4039.71	4178.20	3900.84	4020.83
16	2725.56	2742.36	4473.76	4630.49	4356.04	4493.02
17	3032.77	3053.83	4907.82	5082.77	4811.24	4965.22
18	3339.99	3365.31	5341.87	5535.06	5266.43	5437.41
19	3647.20	3676.79	5775.93	5987.35	5721.63	5909.61
20	3954.42	3988.27	6209.98	6439.63	6176.83	6381.80
21	4261.64	4299.75	6644.03	6891.92	6632.02	6854.00
22	4568.85	4611.23	7078.09	7344.21	7087.22	7326.19
23	4876.07	4922.71	7512.14	7796.49	7542.42	7798.39
24	5183.28	5234.18	7946.19	8248.78	7997.61	8270.58
25	5490.50	5545.66	8380.25	8701.07	8452.81	8742.78

Table B.10 – Economic analysis of S3 for a 100L profile in Bragança

			Cash flow (€)			
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	282.00	285.47	291.06	294.53	294.39	294.68
2	284.84	288.38	294.05	297.60	297.46	297.77
3	287.70	291.32	297.07	300.69	300.55	300.90
4	290.59	294.28	300.13	303.82	303.68	304.05
5	293.51	297.28	303.21	306.98	306.84	307.23
6	296.45	300.30	306.33	310.17	310.03	310.45
7	299.43	303.35	309.47	313.39	313.25	313.70
8	302.43	306.43	312.64	316.65	316.51	316.98
9	305.46	309.54	315.85	319.93	319.79	320.29
10	308.52	312.69	319.09	323.25	323.11	323.64
11	311.61	315.86	322.36	326.60	326.46	327.02
12	314.74	319.06	325.66	329.99	329.85	330.43
13	317.89	322.30	328.99	333.40	333.26	333.88

14	321.07	325.56	332.36	336.86	336.72	337.36
15	324.28	328.86	335.76	340.34	340.20	340.87
16	327.52	332.19	339.19	343.86	343.72	344.42
17	330.79	335.55	342.66	347.42	347.28	348.01
18	334.10	338.95	346.16	351.01	350.87	351.63
19	337.44	342.37	349.70	354.63	354.49	355.29
20	340.80	345.83	353.27	358.30	358.16	358.98
21	344.21	349.33	356.87	362.00	361.86	362.71
22	347.64	352.86	360.51	365.73	365.59	366.48
23	351.11	356.42	364.19	369.50	369.36	370.28
24	354.61	360.02	367.90	373.31	373.17	374.12
25	358.14	363.65	371.65	377.16	377.02	378.01

Present Value

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	268.57	271.88	277.20	280.50	280.37	280.65
2	258.35	261.57	266.71	269.93	269.80	270.09
3	248.52	251.65	256.62	259.75	259.63	259.93
4	239.07	242.11	246.92	249.96	249.84	250.14
5	229.97	232.92	237.57	240.53	240.42	240.73
6	221.22	224.09	228.58	231.45	231.35	231.66
7	212.80	215.59	219.93	222.72	222.62	222.94
8	204.70	207.41	211.61	214.32	214.22	214.54
9	196.90	199.54	203.60	206.23	206.14	206.46
10	189.41	191.96	195.89	198.45	198.36	198.69
11	182.19	184.68	188.48	190.96	190.88	191.20
12	175.26	177.67	181.34	183.75	183.67	184.00
13	168.58	170.92	174.47	176.81	176.74	177.06
14	162.16	164.43	167.86	170.14	170.06	170.39
15	155.98	158.19	161.51	163.71	163.64	163.97
16	150.04	152.18	155.39	157.53	157.46	157.78
17	144.32	146.40	149.50	151.58	151.52	151.84
18	138.82	140.84	143.84	145.85	145.79	146.11
19	133.53	135.49	138.39	140.34	140.29	140.60
20	128.45	130.34	133.14	135.04	134.99	135.30
21	123.55	125.39	128.10	129.94	129.89	130.19
22	118.84	120.62	123.24	125.02	124.98	125.28
23	114.31	116.04	118.57	120.30	120.25	120.55
24	109.95	111.63	114.07	115.75	115.71	116.00
25	105.76	107.39	109.75	111.38	111.33	111.63

Cumulative discounted Cash flow (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-957.03	-1088.72	-1097.40	-1229.10	-1243.23	-1377.95
2	-698.67	-827.15	-830.69	-959.17	-973.43	-1107.86
3	-450.15	-575.50	-574.07	-699.42	-713.80	-847.93

4	-211.08	-333.39	-327.15	-449.46	-463.96	-597.79
5	18.89	-100.47	-89.57	-208.93	-223.54	-357.06
6	240.11	123.62	139.01	22.52	7.81	-125.40
7	452.90	339.20	358.94	245.24	230.43	97.54
8	657.60	546.61	570.55	459.56	444.66	312.08
9	854.50	746.14	774.15	665.79	650.80	518.55
10	1043.91	938.11	970.05	864.24	849.16	717.23
11	1226.11	1122.78	1158.52	1055.20	1040.04	908.43
12	1401.36	1300.45	1339.86	1238.95	1223.71	1092.43
13	1569.94	1471.37	1514.33	1415.76	1400.44	1269.49
14	1732.10	1635.80	1682.20	1585.89	1570.51	1439.88
15	1888.09	1793.99	1843.70	1749.60	1734.15	1603.84
16	2038.13	1946.17	1999.09	1907.13	1891.61	1761.63
17	2182.45	2092.57	2148.59	2058.71	2043.13	1913.46
18	2321.28	2233.41	2292.43	2204.56	2188.92	2059.57
19	2454.81	2368.90	2430.82	2344.90	2329.21	2200.17
20	2583.26	2499.24	2563.96	2479.94	2464.19	2335.47
21	2706.81	2624.63	2692.06	2609.87	2594.08	2465.66
22	2825.65	2745.25	2815.30	2734.90	2719.06	2590.94
23	2939.96	2861.29	2933.87	2855.20	2839.31	2711.49
24	3049.91	2972.92	3047.94	2970.95	2955.02	2827.50
25	3155.67	3080.31	3157.69	3082.33	3066.35	2939.12

Energy saved (kWh)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-	-	-	-	-	-
1	1388.00	1410.75	1437.75	1453.00	1460.50	1468.25
2	1387.50	1410.36	1437.50	1452.82	1460.36	1468.15
3	1387.00	1409.98	1437.25	1452.65	1460.22	1468.05
4	1386.50	1409.59	1437.00	1452.47	1460.09	1467.95
5	1386.00	1409.20	1436.74	1452.30	1459.95	1467.85
6	1385.50	1408.82	1436.49	1452.12	1459.81	1467.76
7	1385.00	1408.43	1436.24	1451.95	1459.67	1467.66
8	1384.50	1408.05	1435.99	1451.77	1459.54	1467.56
9	1384.00	1407.66	1435.74	1451.60	1459.40	1467.46
10	1383.50	1407.27	1435.49	1451.42	1459.26	1467.36
11	1383.00	1406.89	1435.24	1451.25	1459.12	1467.26
12	1382.50	1406.50	1434.99	1451.07	1458.99	1467.16
13	1382.00	1406.11	1434.73	1450.90	1458.85	1467.06
14	1381.50	1405.73	1434.48	1450.72	1458.71	1466.97
15	1381.00	1405.34	1434.23	1450.55	1458.57	1466.87
16	1380.50	1404.96	1433.98	1450.37	1458.44	1466.77
17	1380.00	1404.57	1433.73	1450.20	1458.30	1466.67
18	1379.50	1404.18	1433.48	1450.02	1458.16	1466.57
19	1379.00	1403.80	1433.23	1449.85	1458.02	1466.47
20	1378.50	1403.41	1432.98	1449.67	1457.89	1466.37
21	1378.00	1403.02	1432.72	1449.50	1457.75	1466.27
22	1377.50	1402.64	1432.47	1449.32	1457.61	1466.18

23	1377.00	1402.25	1432.22	1449.15	1457.47	1466.08
24	1376.50	1401.87	1431.97	1448.97	1457.34	1465.98
25	1376.00	1401.48	1431.72	1448.80	1457.20	1465.88

Table B.11 – Economic analysis of S3 for a 150L profile in Bragança

			Cash flow (€)			
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	357.10	364.97	393.03	405.51	405.37	410.54
2	360.38	368.39	396.87	409.56	409.42	414.69
3	363.68	371.83	400.74	413.65	413.51	418.87
4	367.02	375.31	404.66	417.77	417.63	423.10
5	370.38	378.82	408.60	421.94	421.80	427.37
6	373.77	382.35	412.59	426.14	426.00	431.67
7	377.19	385.92	416.61	430.39	430.25	436.02
8	380.64	389.53	420.67	434.67	434.53	440.42
9	384.12	393.16	424.77	439.00	438.86	444.85
10	387.64	396.82	428.91	443.37	443.23	449.33
11	391.18	400.52	433.09	447.78	447.64	453.85
12	394.75	404.26	437.30	452.23	452.09	458.42
13	398.35	408.02	441.56	456.73	456.59	463.03
14	401.99	411.82	445.85	461.27	461.13	467.68
15	405.66	415.65	450.19	465.85	465.71	472.38
16	409.36	419.52	454.57	470.48	470.34	477.13
17	413.09	423.42	458.98	475.15	475.01	481.92
18	416.85	427.35	463.44	479.87	479.73	486.75
19	420.65	431.32	467.94	484.63	484.49	491.64
20	424.48	435.33	472.49	489.44	489.30	496.57
21	428.34	439.37	477.07	494.29	494.15	501.55
22	432.24	443.45	481.70	499.19	499.05	506.58
23	436.17	447.56	486.38	504.14	504.00	511.66
24	440.13	451.71	491.09	509.13	508.99	516.78
25	444.13	455.90	495.85	514.18	514.04	521.96

			Present Value (€)			
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	340.10	374.31	374.31	386.20	386.07	390.99
2	326.87	359.97	359.97	371.48	371.36	376.13
3	314.16	321.20	346.18	357.32	357.20	361.84
4	301.94	308.77	332.91	343.70	343.59	348.08
5	290.20	296.81	320.15	330.60	330.49	334.85
6	278.91	285.32	307.88	317.99	317.89	322.12
7	268.06	274.27	296.08	305.87	305.77	309.87
8	257.63	263.65	284.73	294.20	294.11	298.09
9	247.61	253.43	273.81	282.98	282.89	286.76
10	237.97	243.62	263.31	272.19	272.10	275.85

11	228.71	234.18	253.22	261.81	261.73	265.36
12	219.81	225.10	243.51	251.82	251.74	255.26
13	211.26	216.38	234.17	242.21	242.14	245.55
14	203.03	208.00	225.19	232.97	232.90	236.21
15	195.13	199.93	216.55	224.08	224.02	227.22
16	187.53	192.19	208.24	215.53	215.47	218.58
17	180.23	184.74	200.25	207.31	207.25	210.26
18	173.21	177.57	192.57	199.40	199.34	202.26
19	166.46	170.69	185.18	191.78	191.73	194.56
20	159.98	164.07	178.08	184.46	184.41	187.15
21	153.75	157.71	171.24	177.42	177.37	180.03
22	147.76	151.59	164.67	170.65	170.60	173.17
23	142.00	145.71	158.35	164.13	164.09	166.58
24	136.47	140.06	152.27	157.87	157.82	160.24
25	131.15	134.63	146.43	151.84	151.80	154.14

Cumulative discounted Cash flow (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-885.50	-986.29	-1000.29	-1123.40	-1137.53	-1267.61
2	-558.63	-626.32	-640.32	-751.92	-766.18	-891.48
3	-244.47	-305.11	-294.14	-394.59	-408.97	-529.64
4	57.47	3.66	38.77	-50.89	-65.39	-181.55
5	347.68	300.47	358.92	279.71	265.10	153.30
6	626.59	585.79	666.80	597.70	582.99	475.42
7	894.65	860.06	962.88	903.57	888.76	785.29
8	1152.28	1123.70	1247.61	1197.77	1182.87	1083.39
9	1399.89	1377.14	1521.42	1480.76	1465.76	1370.14
10	1637.87	1620.75	1784.74	1752.95	1737.87	1645.99
11	1866.58	1854.93	2037.95	2014.75	1999.59	1911.35
12	2086.39	2080.03	2281.46	2266.58	2251.33	2166.61
13	2297.65	2296.42	2515.63	2508.79	2493.47	2412.17
14	2500.68	2504.41	2740.81	2741.76	2726.38	2648.38
15	2695.81	2704.35	2957.36	2965.85	2950.39	2875.60
16	2883.34	2896.53	3165.61	3181.38	3165.86	3094.18
17	3063.57	3081.27	3365.86	3388.69	3373.11	3304.44
18	3236.78	3258.84	3558.43	3588.08	3572.44	3506.69
19	3403.25	3429.53	3743.61	3779.86	3764.17	3701.25
20	3563.23	3593.60	3921.69	3964.33	3948.58	3888.40
21	3716.98	3751.31	4092.93	4141.75	4125.96	4068.43
22	3864.74	3902.90	4257.60	4312.40	4296.56	4241.61
23	4006.74	4048.61	4415.95	4476.53	4460.64	4408.19
24	4143.21	4188.67	4568.22	4634.40	4618.47	4568.42
25	4274.37	4323.30	4714.65	4786.24	4770.26	4722.56

Energy saved (kWh)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-	-	-	-	-	-

1	1742.25	1785.75	1918.75	1936.75	1984.00	2014.75
2	1740.30	1784.02	1917.68	1935.77	1983.26	2014.16
3	1738.35	1782.28	1916.61	1934.79	1982.52	2013.57
4	1736.40	1780.55	1915.55	1933.82	1981.78	2012.99
5	1734.45	1778.82	1914.48	1932.84	1981.03	2012.40
6	1732.50	1777.09	1913.41	1931.86	1980.29	2011.81
7	1730.55	1775.35	1912.34	1930.88	1979.55	2011.22
8	1728.60	1773.62	1911.28	1929.91	1978.81	2010.64
9	1726.65	1771.89	1910.21	1928.93	1978.07	2010.05
10	1724.70	1770.16	1909.14	1927.95	1977.33	2009.46
11	1722.75	1768.42	1908.07	1926.97	1976.59	2008.87
12	1720.80	1766.69	1907.01	1926.00	1975.85	2008.29
13	1718.85	1764.96	1905.94	1925.02	1975.10	2007.70
14	1716.90	1763.23	1904.87	1924.04	1974.36	2007.11
15	1714.95	1761.49	1903.80	1923.06	1973.62	2006.52
16	1713.00	1759.76	1902.74	1922.09	1972.88	2005.94
17	1711.05	1758.03	1901.67	1921.11	1972.14	2005.35
18	1709.10	1756.30	1900.60	1920.13	1971.40	2004.76
19	1707.15	1754.56	1899.53	1919.15	1970.66	2004.17
20	1705.20	1752.83	1898.47	1918.18	1969.92	2003.59
21	1703.25	1751.10	1897.40	1917.20	1969.17	2003.00
22	1701.30	1749.37	1896.33	1916.22	1968.43	2002.41
23	1699.35	1747.63	1895.26	1915.24	1967.69	2001.82
24	1697.40	1745.90	1894.20	1914.27	1966.95	2001.24
25	1695.45	1744.17	1893.13	1913.29	1966.21	2000.65

Table B.12 – Economic analysis of S3 for a 200L profile in Bragança

	Cash flow (€)					
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	345.44	339.85	408.13	441.98	441.84	445.41
2	348.06	342.41	411.72	446.09	445.95	449.60
3	350.70	344.98	415.33	450.24	450.10	453.83
4	353.35	347.56	418.98	454.43	454.29	458.09
5	356.02	350.17	422.65	458.65	458.51	462.40
6	358.70	352.78	426.36	462.92	462.78	466.74
7	361.40	355.42	430.09	467.22	467.08	471.12
8	364.12	358.07	433.85	471.56	471.42	475.54
9	366.86	360.74	437.65	475.93	475.79	479.99
10	369.61	363.42	441.48	480.35	480.21	484.49
11	372.38	366.12	445.34	484.80	484.66	489.03
12	375.17	368.83	449.23	489.30	489.16	493.61
13	377.98	371.56	453.15	493.83	493.69	498.23
14	380.80	374.31	457.10	498.41	498.27	502.89
15	383.64	377.08	461.09	503.03	502.89	507.60
16	386.50	379.86	465.11	507.68	507.54	512.34

17	389.37	382.65	469.16	512.38	512.24	517.13
18	392.27	385.47	473.25	517.12	516.98	521.96
19	395.18	388.30	477.37	521.90	521.76	526.84
20	398.10	391.15	481.52	526.73	526.59	531.76
21	401.05	394.01	485.71	531.59	531.45	536.72
22	404.01	396.89	489.93	536.50	536.36	541.72
23	407.00	399.79	494.18	541.46	541.32	546.78
24	410.00	402.70	498.47	546.45	546.31	551.87
25	413.01	405.63	502.80	551.50	551.36	557.01

Present Value (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	328.99	388.70	388.70	420.93	420.80	424.20
2	315.70	373.44	373.44	404.62	404.49	407.80
3	302.94	298.00	358.78	388.94	388.81	392.04
4	290.70	285.94	344.69	373.86	373.74	376.87
5	278.95	274.36	331.16	359.37	359.26	362.30
6	267.67	263.25	318.15	345.44	345.33	348.29
7	256.84	252.59	305.66	332.04	331.94	334.81
8	246.45	242.35	293.65	319.17	319.07	321.86
9	236.48	232.53	282.11	306.79	306.70	309.41
10	226.91	223.11	271.03	294.89	294.81	297.44
11	217.73	214.06	260.38	283.46	283.37	285.93
12	208.91	205.38	250.15	272.46	272.38	274.86
13	200.45	197.05	240.32	261.89	261.82	264.22
14	192.33	189.05	230.87	251.73	251.66	254.00
15	184.54	181.38	221.79	241.96	241.90	244.16
16	177.06	174.02	213.07	232.58	232.51	234.71
17	169.88	166.95	204.69	223.55	223.49	225.62
18	162.99	160.17	196.64	214.87	214.82	216.89
19	156.38	153.66	188.91	206.53	206.48	208.49
20	150.04	147.42	181.48	198.52	198.46	200.41
21	143.95	141.43	174.34	190.81	190.76	192.65
22	138.11	135.68	167.48	183.40	183.36	185.19
23	132.51	130.16	160.89	176.28	176.24	178.01
24	127.13	124.87	154.56	169.44	169.39	171.12
25	121.96	119.78	148.48	162.86	162.82	164.49

Cumulative discounted Cash flow (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-896.61	-971.90	-985.90	-1088.67	-1102.80	-1234.40
2	-580.91	-598.46	-612.46	-684.05	-698.31	-826.59
3	-277.96	-300.46	-253.68	-295.12	-309.50	-434.56
4	12.74	-14.51	91.01	78.74	64.25	-57.68
5	291.68	259.85	422.17	438.11	423.50	304.62
6	559.35	523.10	740.32	783.55	768.83	652.90

7	816.19	775.69	1045.98	1115.59	1100.78	987.72
8	1062.65	1018.05	1339.63	1434.76	1419.85	1309.58
9	1299.13	1250.58	1621.75	1741.55	1726.55	1618.99
10	1526.04	1473.69	1892.77	2036.44	2021.36	1916.42
11	1743.77	1687.75	2153.15	2319.89	2304.73	2202.35
12	1952.68	1893.13	2403.30	2592.36	2577.11	2477.21
13	2153.13	2090.17	2643.62	2854.25	2838.93	2741.44
14	2345.46	2279.23	2874.48	3105.98	3090.59	2995.43
15	2529.99	2460.61	3096.28	3347.94	3332.49	3239.59
16	2707.05	2634.62	3309.35	3580.52	3565.00	3474.30
17	2876.93	2801.57	3514.04	3804.07	3788.49	3699.93
18	3039.93	2961.74	3710.69	4018.94	4003.30	3916.81
19	3196.31	3115.41	3899.60	4225.47	4209.78	4125.30
20	3346.35	3262.82	4081.08	4423.99	4408.25	4325.72
21	3490.31	3404.25	4255.42	4614.80	4599.01	4518.37
22	3628.42	3539.93	4422.90	4798.21	4782.36	4703.55
23	3760.93	3670.09	4583.80	4974.49	4958.60	4881.57
24	3888.05	3794.95	4738.36	5143.93	5127.99	5052.69
25	4010.02	3914.74	4886.83	5306.78	5290.81	5217.18

Energy saved (kWh)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-	-	-	-	-	-
1	1687.25	1667.25	1990.00	1984.00	2156.00	2179.25
2	1682.77	1662.67	1987.04	1981.01	2153.87	2177.23
3	1678.30	1658.10	1984.08	1978.02	2151.74	2175.22
4	1673.82	1653.52	1981.12	1975.03	2149.61	2173.20
5	1669.35	1648.95	1978.15	1972.03	2147.47	2171.19
6	1664.87	1644.37	1975.19	1969.04	2145.34	2169.17
7	1660.40	1639.80	1972.23	1966.05	2143.21	2167.16
8	1655.92	1635.22	1969.27	1963.06	2141.08	2165.14
9	1651.45	1630.65	1966.31	1960.07	2138.95	2163.13
10	1646.97	1626.07	1963.35	1957.08	2136.82	2161.11
11	1642.50	1621.50	1960.39	1954.09	2134.69	2159.10
12	1638.02	1616.92	1957.43	1951.10	2132.56	2157.08
13	1633.55	1612.35	1954.46	1948.10	2130.42	2155.07
14	1629.07	1607.77	1951.50	1945.11	2128.29	2153.05
15	1624.60	1603.20	1948.54	1942.12	2126.16	2151.04
16	1620.12	1598.62	1945.58	1939.13	2124.03	2149.02
17	1615.65	1594.05	1942.62	1936.14	2121.90	2147.01
18	1611.17	1589.47	1939.66	1933.15	2119.77	2144.99
19	1606.70	1584.90	1936.70	1930.16	2117.64	2142.98
20	1602.22	1580.32	1933.74	1927.17	2115.51	2140.96
21	1597.75	1575.75	1930.77	1924.17	2113.37	2138.95
22	1593.27	1571.17	1927.81	1921.18	2111.24	2136.93
23	1588.80	1566.60	1924.85	1918.19	2109.11	2134.92
24	1584.32	1562.02	1921.89	1915.20	2106.98	2132.90

25	1579.85	1557.45	1918.93	1912.21	2104.85	2130.89

Table B.13 – Cumulative Cash flow (€) for S3 in Bragança

100L (2P)						
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-943.60	-1075.13	-1083.54	-1215.07	-1229.21	-1363.92
2	-658.76	-786.75	-789.49	-917.47	-931.75	-1066.14
3	-371.07	-495.43	-492.42	-616.78	-631.20	-765.25
4	-80.48	-201.15	-192.29	-312.96	-327.52	-461.20
5	213.03	96.13	110.92	-5.98	-20.68	-153.96
6	509.48	396.43	417.25	304.19	289.35	156.49
7	808.91	699.78	726.72	617.59	602.61	470.19
8	1111.34	1006.21	1039.36	934.23	919.11	787.17
9	1416.80	1315.76	1355.21	1254.17	1238.91	1107.46
10	1725.33	1628.44	1674.30	1577.42	1562.02	1431.10
11	2036.94	1944.30	1996.66	1904.02	1888.48	1758.12
12	2351.68	2263.36	2322.32	2234.00	2218.32	2088.55
13	2669.56	2585.66	2651.31	2567.41	2551.59	2422.42
14	2990.63	2911.22	2983.67	2904.26	2888.30	2759.78
15	3314.91	3240.08	3319.43	3244.61	3228.51	3100.65
16	3642.43	3572.27	3658.62	3588.47	3572.23	3445.08
17	3973.22	3907.82	4001.28	3935.89	3919.51	3793.08
18	4307.32	4246.77	4347.45	4286.89	4270.37	4144.71
19	4644.75	4589.14	4697.14	4641.53	4624.87	4500.00
20	4985.56	4934.98	5050.41	4999.83	4983.03	4858.98
21	5329.76	5284.31	5407.28	5361.82	5344.88	5221.69
22	5677.40	5637.16	5767.79	5727.55	5710.47	5588.17
23	6028.51	5993.58	6131.98	6097.05	6079.83	5958.45
24	6383.12	6353.60	6499.88	6470.37	6453.01	6332.58
25	6741.26	6717.25	6871.53	6847.52	6830.02	6710.58
150L (3P)						
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-868.50	-995.63	-981.57	-1104.09	-1118.23	-1248.06
2	-508.12	-627.24	-584.70	-694.53	-708.81	-833.37
3	-144.44	-255.41	-183.96	-280.88	-295.30	-414.50
4	222.57	119.90	220.70	136.89	122.33	8.60
5	592.95	498.72	629.30	558.82	544.12	435.96
6	966.72	881.07	1041.89	984.97	970.13	867.64
7	1343.91	1267.00	1458.50	1415.35	1400.37	1303.66
8	1724.55	1656.52	1879.17	1850.03	1834.91	1744.08
9	2108.68	2049.68	2303.95	2289.03	2273.77	2188.93
10	2496.31	2446.51	2732.86	2732.40	2717.00	2638.26
11	2887.49	2847.03	3165.94	3180.18	3164.64	3092.11
12	3282.24	3251.29	3603.25	3632.41	3616.73	3550.53

13	3680.60	3659.30	4044.80	4089.14	4073.32	4013.56
14	4082.59	4071.12	4490.66	4550.41	4534.45	4481.24
15	4488.24	4486.77	4940.85	5016.27	5000.17	4953.62
16	4897.60	4906.29	5395.41	5486.75	5470.51	5430.75
17	5310.69	5329.71	5854.40	5961.90	5945.52	5912.67
18	5727.54	5757.06	6317.84	6441.77	6425.25	6399.42
19	6148.19	6188.38	6785.79	6926.40	6909.74	6891.06
20	6572.67	6623.71	7258.27	7415.83	7399.03	7387.63
21	7001.01	7063.08	7735.35	7910.12	7893.18	7889.18
22	7433.25	7506.52	8217.05	8409.31	8392.23	8395.76
23	7869.42	7954.08	8703.43	8913.45	8896.23	8907.41
24	8309.55	8405.79	9194.52	9422.59	9405.23	9424.20
25	8753.68	8861.69	9690.37	9936.76	9919.26	9946.15

200L (3P)						
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-880.16	-1020.75	-966.47	-1067.62	-1081.76	-1213.19
2	-532.10	-678.34	-554.75	-621.53	-635.81	-763.58
3	-181.40	-333.37	-139.41	-171.29	-185.71	-309.75
4	171.94	14.20	279.56	283.14	268.58	148.34
5	527.96	364.36	702.21	741.79	727.09	610.74
6	886.66	717.15	1128.57	1204.71	1189.87	1077.47
7	1248.07	1072.56	1558.66	1671.93	1656.95	1548.59
8	1612.19	1430.63	1992.51	2143.48	2128.36	2024.13
9	1979.05	1791.37	2430.16	2619.41	2604.15	2504.12
10	2348.66	2154.79	2871.64	3099.76	3084.36	2988.61
11	2721.05	2520.90	3316.98	3584.57	3569.03	3477.65
12	3096.22	2889.73	3766.21	4073.87	4058.19	3971.26
13	3474.20	3261.30	4219.36	4567.70	4551.88	4469.49
14	3855.00	3635.61	4676.46	5066.11	5050.15	4972.38
15	4238.64	4012.68	5137.55	5569.14	5553.04	5479.98
16	4625.14	4392.54	5602.67	6076.82	6060.58	5992.32
17	5014.51	4775.19	6071.83	6589.20	6572.82	6509.46
18	5406.77	5160.66	6545.08	7106.32	7089.80	7031.42
19	5801.95	5548.96	7022.45	7628.22	7611.56	7558.26
20	6200.06	5940.11	7503.97	8154.95	8138.15	8090.01
21	6601.11	6334.12	7989.67	8686.54	8669.60	8626.73
22	7005.12	6731.01	8479.60	9223.04	9205.96	9168.46
23	7412.12	7130.79	8973.79	9764.50	9747.28	9715.23
24	7822.11	7533.50	9472.26	10310.95	10293.59	10267.11
25	8235.13	7939.13	9975.06	10862.45	10844.95	10824.12

Table B.14 – Economic analysis of S3 for a 100L profile in Faro

Cash flow (€)						
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60

1	296.89	299.15	299.59	298.82	298.58	297.60
2	296.86	299.13	299.58	298.82	298.57	297.59
3	296.83	299.12	299.57	298.81	298.56	297.59
4	296.80	299.11	299.56	298.80	298.55	297.58
5	296.77	299.09	299.55	298.79	298.54	297.57
6	296.74	299.08	299.54	298.78	298.54	297.57
7	296.70	299.07	299.53	298.78	298.53	297.56
8	296.67	299.05	299.52	298.77	298.52	297.55
9	296.64	299.04	299.51	298.76	298.51	297.55
10	296.61	299.03	299.49	298.75	298.50	297.54
11	296.58	299.01	299.48	298.75	298.49	297.53
12	296.55	299.00	299.47	298.74	298.49	297.53
13	296.51	298.98	299.46	298.73	298.48	297.52
14	296.48	298.97	299.45	298.72	298.47	297.52
15	296.45	298.96	299.44	298.72	298.46	297.51
16	296.42	298.94	299.43	298.71	298.45	297.50
17	296.39	298.93	299.42	298.70	298.45	297.50
18	296.36	298.92	299.41	298.69	298.44	297.49
19	296.33	298.90	299.40	298.68	298.43	297.48
20	296.29	298.89	299.39	298.68	298.42	297.48
21	296.26	298.88	299.38	298.67	298.41	297.47
22	296.23	298.86	299.37	298.66	298.40	297.46
23	296.20	298.85	299.36	298.65	298.40	297.46
24	296.17	298.84	299.35	298.65	298.39	297.45
25	296.14	298.82	299.34	298.64	298.38	297.45

Present Value (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	282.76	284.90	285.32	284.59	284.36	283.43
2	269.26	271.32	271.73	271.03	270.81	269.92
3	256.41	258.39	258.78	258.12	257.91	257.07
4	244.18	246.08	246.45	245.82	245.62	244.82
5	232.52	234.35	234.70	234.11	233.92	233.16
6	221.43	223.18	223.52	222.96	222.77	222.05
7	210.86	212.54	212.87	212.34	212.16	211.47
8	200.80	202.41	202.72	202.22	202.05	201.40
9	191.22	192.76	193.06	192.58	192.42	191.80
10	182.09	183.58	183.86	183.41	183.25	182.66
11	173.40	174.83	175.10	174.67	174.52	173.96
12	165.13	166.49	166.76	166.35	166.21	165.67
13	157.25	158.56	158.81	158.42	158.29	157.78
14	149.74	151.00	151.24	150.88	150.75	150.27
15	142.60	143.80	144.04	143.69	143.57	143.11
16	135.79	136.95	137.17	136.84	136.73	136.29
17	129.31	130.42	130.64	130.32	130.21	129.80
18	123.14	124.21	124.41	124.11	124.01	123.61

19	117.27	118.29	118.48	118.20	118.10	117.72
20	111.67	112.65	112.84	112.57	112.47	112.12
21	106.34	107.28	107.46	107.21	107.11	106.77
22	101.27	102.17	102.34	102.10	102.01	101.69
23	96.43	97.30	97.46	97.23	97.15	96.84
24	91.83	92.66	92.82	92.60	92.52	92.23
25	87.45	88.24	88.39	88.19	88.11	87.84

Cumulative discounted Cash flow (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-942.84	-1075.70	-1089.28	-1225.01	-1239.24	-1375.17
2	-673.58	-804.38	-817.55	-953.97	-968.43	-1105.25
3	-417.17	-545.98	-558.77	-695.85	-710.52	-848.18
4	-172.99	-299.91	-312.32	-450.03	-464.90	-603.36
5	59.53	-65.56	-77.62	-215.92	-230.99	-370.21
6	280.96	157.62	145.90	7.04	-8.21	-148.16
7	491.82	370.16	358.77	219.38	203.94	63.31
8	692.62	572.57	561.49	421.60	405.99	264.71
9	883.84	765.33	754.56	614.18	598.42	456.51
10	1065.93	948.91	938.42	797.59	781.67	639.17
11	1239.33	1123.73	1113.52	972.26	956.20	813.13
12	1404.46	1290.23	1280.28	1138.61	1122.40	978.81
13	1561.71	1448.78	1439.09	1297.03	1280.69	1136.59
14	1711.45	1599.78	1590.33	1447.91	1431.44	1286.86
15	1854.05	1743.59	1734.37	1591.59	1575.01	1429.96
16	1989.85	1880.54	1871.54	1728.44	1711.73	1566.25
17	2119.16	2010.96	2002.18	1858.76	1841.94	1696.05
18	2242.30	2135.17	2126.59	1982.87	1965.95	1819.66
19	2359.57	2253.45	2245.07	2101.07	2084.05	1937.39
20	2471.24	2366.10	2357.91	2213.64	2196.52	2049.50
21	2577.58	2473.38	2465.37	2320.84	2303.63	2156.28
22	2678.84	2575.55	2567.71	2422.94	2405.64	2257.97
23	2775.28	2672.84	2665.17	2520.17	2502.79	2354.81
24	2867.11	2765.50	2757.99	2612.77	2595.31	2447.04
25	2954.56	2853.75	2846.38	2700.96	2683.42	2534.88

Energy saved (kWh)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-	-	-	-	-	-
1	1458.25	1475.25	1478.00	1480.75	1480.25	1482.00
2	1458.10	1475.19	1477.95	1480.71	1480.21	1481.97
3	1457.95	1475.12	1477.90	1480.68	1480.17	1481.94
4	1457.80	1475.06	1477.85	1480.64	1480.13	1481.91
5	1457.65	1474.99	1477.80	1480.60	1480.09	1481.88
6	1457.51	1474.93	1477.75	1480.57	1480.06	1481.85
7	1457.36	1474.87	1477.70	1480.53	1480.02	1481.82
8	1457.21	1474.80	1477.65	1480.50	1479.98	1481.79

9	1457.06	1474.74	1477.60	1480.46	1479.94	1481.76
10	1456.91	1474.68	1477.55	1480.42	1479.90	1481.73
11	1456.76	1474.61	1477.50	1480.39	1479.86	1481.70
12	1456.61	1474.55	1477.45	1480.35	1479.82	1481.67
13	1456.46	1474.48	1477.40	1480.31	1479.78	1481.64
14	1456.32	1474.42	1477.35	1480.28	1479.75	1481.61
15	1456.17	1474.36	1477.30	1480.24	1479.71	1481.58
16	1456.02	1474.29	1477.25	1480.21	1479.67	1481.55
17	1455.87	1474.23	1477.20	1480.17	1479.63	1481.52
18	1455.72	1474.17	1477.15	1480.13	1479.59	1481.49
19	1455.57	1474.10	1477.10	1480.10	1479.55	1481.46
20	1455.42	1474.04	1477.05	1480.06	1479.51	1481.43
21	1455.27	1473.97	1477.00	1480.02	1479.47	1481.40
22	1455.13	1473.91	1476.95	1479.99	1479.44	1481.37
23	1454.98	1473.85	1476.90	1479.95	1479.40	1481.34
24	1454.83	1473.78	1476.85	1479.92	1479.36	1481.31
25	1454.68	1473.72	1476.80	1479.88	1479.32	1481.28

Table B.15 – Economic analysis of S3 for a 150L profile in Faro

	Cash flow (€)					
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	401.41	406.84	420.16	424.64	427.68	430.47
2	401.22	406.69	420.07	424.58	427.64	430.44
3	401.03	406.53	419.98	424.52	427.59	430.42
4	400.83	406.37	419.89	424.46	427.55	430.39
5	400.64	406.21	419.80	424.40	427.50	430.37
6	400.45	406.05	419.71	424.34	427.46	430.34
7	400.26	405.90	419.62	424.28	427.41	430.32
8	400.07	405.74	419.53	424.21	427.37	430.29
9	399.87	405.58	419.44	424.15	427.32	430.27
10	399.68	405.42	419.35	424.09	427.27	430.24
11	399.49	405.26	419.26	424.03	427.23	430.22
12	399.30	405.11	419.17	423.97	427.18	430.19
13	399.11	404.95	419.08	423.91	427.14	430.17
14	398.91	404.79	418.99	423.85	427.09	430.15
15	398.72	404.63	418.90	423.78	427.05	430.12
16	398.53	404.47	418.81	423.72	427.00	430.10
17	398.34	404.32	418.71	423.66	426.96	430.07
18	398.15	404.16	418.62	423.60	426.91	430.05
19	397.96	404.00	418.53	423.54	426.86	430.02
20	397.76	403.84	418.44	423.48	426.82	430.00
21	397.57	403.68	418.35	423.42	426.77	429.97
22	397.38	403.53	418.26	423.35	426.73	429.95
23	397.19	403.37	418.17	423.29	426.68	429.92
24	397.00	403.21	418.08	423.23	426.64	429.90

25	396.80	403.05	417.99	423.17	426.59	429.87

Present Value (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	382.29	387.47	400.16	404.42	407.32	409.97
2	363.92	368.88	381.02	385.11	387.88	390.43
3	346.42	351.17	362.80	366.72	369.37	371.81
4	329.77	334.32	345.45	349.20	351.75	354.09
5	313.91	318.28	328.93	332.53	334.96	337.21
6	298.82	303.00	313.20	316.65	318.98	321.13
7	284.46	288.46	298.22	301.53	303.75	305.82
8	270.78	274.62	283.95	287.13	289.26	291.24
9	257.76	261.44	270.37	273.41	275.45	277.36
10	245.37	248.89	257.44	260.36	262.31	264.13
11	233.57	236.95	245.13	247.92	249.79	251.54
12	222.34	225.58	233.41	236.08	237.87	239.55
13	211.65	214.75	222.25	224.81	226.52	228.13
14	201.48	204.45	211.62	214.07	215.71	217.25
15	191.79	194.63	201.50	203.85	205.42	206.90
16	182.57	185.29	191.86	194.11	195.61	197.03
17	173.79	176.40	182.68	184.84	186.28	187.64
18	165.44	167.94	173.95	176.01	177.39	178.69
19	157.48	159.88	165.63	167.61	168.92	170.17
20	149.91	152.20	157.71	159.60	160.86	162.06
21	142.71	144.90	150.16	151.98	153.19	154.33
22	135.84	137.95	142.98	144.72	145.88	146.98
23	129.31	131.33	136.14	137.81	138.92	139.97
24	123.10	125.02	129.63	131.23	132.29	133.30
25	117.18	119.02	123.43	124.96	125.97	126.94

Cumulative discounted Cash flow (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-843.31	-973.13	-974.44	-1105.18	-1116.28	-1248.63
2	-479.39	-604.26	-593.42	-720.07	-728.40	-858.20
3	-132.97	-253.08	-230.63	-353.35	-359.03	-486.39
4	196.80	81.24	114.82	-4.14	-7.28	-132.31
5	510.71	399.52	443.75	328.38	327.68	204.90
6	809.53	702.52	756.94	645.03	646.65	526.03
7	1093.99	990.98	1055.16	946.56	950.41	831.85
8	1364.77	1265.60	1339.12	1233.68	1239.66	1123.09
9	1622.53	1527.04	1609.49	1507.09	1515.12	1400.45
10	1867.90	1775.93	1866.93	1767.45	1777.43	1664.58
11	2101.47	2012.88	2112.07	2015.37	2027.22	1916.12
12	2323.82	2238.46	2345.47	2251.45	2265.09	2155.67
13	2535.47	2453.21	2567.72	2476.26	2491.61	2383.80
14	2736.95	2657.66	2779.34	2690.33	2707.32	2601.05

15	2928.75	2852.30	2980.83	2894.18	2912.74	2807.94
16	3111.32	3037.59	3172.69	3088.29	3108.35	3004.98
17	3285.11	3213.99	3355.38	3273.13	3294.63	3192.61
18	3450.55	3381.93	3529.32	3449.15	3472.02	3371.31
19	3608.03	3541.80	3694.95	3616.76	3640.95	3541.48
20	3757.95	3694.01	3852.66	3776.36	3801.81	3703.54
21	3900.65	3838.91	4002.82	3928.34	3955.00	3857.88
22	4036.50	3976.85	4145.81	4073.07	4100.88	4004.85
23	4165.81	4108.18	4281.95	4210.88	4239.79	4144.82
24	4288.91	4233.20	4411.58	4342.11	4372.08	4278.12
25	4406.08	4352.22	4535.02	4467.07	4498.05	4405.06
			Energy saved (kWh)			
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-	-	-	-	-	-
1	1951.25	1983.25	2046.75	2074.25	2089.25	2108.75
2	1950.34	1982.50	2046.32	2073.96	2089.03	2108.63
3	1949.44	1981.76	2045.89	2073.67	2088.82	2108.51
4	1948.53	1981.01	2045.47	2073.38	2088.60	2108.40
5	1947.63	1980.27	2045.04	2073.09	2088.39	2108.28
6	1946.72	1979.52	2044.61	2072.80	2088.17	2108.16
7	1945.82	1978.78	2044.18	2072.51	2087.96	2108.04
8	1944.91	1978.03	2043.76	2072.22	2087.74	2107.93
9	1944.01	1977.29	2043.33	2071.93	2087.53	2107.81
10	1943.10	1976.54	2042.90	2071.64	2087.31	2107.69
11	1942.20	1975.80	2042.47	2071.35	2087.10	2107.57
12	1941.29	1975.05	2042.05	2071.06	2086.88	2107.46
13	1940.39	1974.31	2041.62	2070.77	2086.67	2107.34
14	1939.48	1973.56	2041.19	2070.48	2086.45	2107.22
15	1938.58	1972.82	2040.76	2070.19	2086.24	2107.10
16	1937.67	1972.07	2040.34	2069.90	2086.02	2106.99
17	1936.77	1971.33	2039.91	2069.61	2085.81	2106.87
18	1935.86	1970.58	2039.48	2069.32	2085.59	2106.75
19	1934.96	1969.84	2039.05	2069.03	2085.38	2106.63
20	1934.05	1969.09	2038.63	2068.74	2085.16	2106.52
21	1933.15	1968.35	2038.20	2068.45	2084.95	2106.40
22	1932.24	1967.60	2037.77	2068.16	2084.73	2106.28
23	1931.34	1966.86	2037.34	2067.87	2084.52	2106.16
24	1930.43	1966.11	2036.92	2067.58	2084.30	2106.05
25	1929.53	1965.37	2036.49	2067.29	2084.09	2105.93

Table B.16 – Economic analysis of S3 for a 200L profile in Faro

			Cash flow (€)			
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	391.76	387.07	467.97	473.78	494.20	502.50
2	391.05	386.34	467.64	473.48	494.01	502.35

3	390.33	385.61	467.31	473.19	493.82	502.21
4	389.61	384.87	466.99	472.90	493.63	502.07
5	388.89	384.14	466.66	472.60	493.44	501.93
6	388.18	383.41	466.33	472.31	493.25	501.79
7	387.46	382.67	466.00	472.02	493.06	501.65
8	386.74	381.94	465.67	471.73	492.87	501.50
9	386.03	381.20	465.34	471.43	492.68	501.36
10	385.31	380.47	465.01	471.14	492.49	501.22
11	384.59	379.74	464.68	470.85	492.30	501.08
12	383.87	379.00	464.36	470.55	492.11	500.94
13	383.16	378.27	464.03	470.26	491.92	500.79
14	382.44	377.53	463.70	469.97	491.73	500.65
15	381.72	376.80	463.37	469.68	491.54	500.51
16	381.01	376.07	463.04	469.38	491.35	500.37
17	380.29	375.33	462.71	469.09	491.16	500.23
18	379.57	374.60	462.38	468.80	490.97	500.09
19	378.86	373.87	462.06	468.51	490.78	499.94
20	378.14	373.13	461.73	468.21	490.59	499.80
21	377.42	372.40	461.40	467.92	490.40	499.66
22	376.70	371.66	461.07	467.63	490.21	499.52
23	375.99	370.93	460.74	467.33	490.02	499.38
24	375.27	370.20	460.41	467.04	489.83	499.24
25	374.55	369.46	460.08	466.75	489.64	499.09

Present Value (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	373.11	368.64	445.69	451.22	470.67	478.57
2	354.69	350.42	424.17	429.46	448.08	455.65
3	337.18	333.10	403.68	408.76	426.58	433.83
4	320.53	316.64	384.19	389.05	406.11	413.05
5	304.71	300.98	365.64	370.30	386.62	393.27
6	289.66	286.10	347.98	352.45	368.07	374.44
7	275.36	271.96	331.18	335.46	350.41	356.51
8	261.76	258.51	315.18	319.28	333.59	339.44
9	248.84	245.73	299.96	303.89	317.59	323.18
10	236.55	233.58	285.48	289.24	302.35	307.71
11	224.86	222.02	271.69	275.29	287.84	292.97
12	213.76	211.04	258.57	262.02	274.03	278.94
13	203.20	200.60	246.08	249.39	260.88	265.58
14	193.16	190.68	234.20	237.37	248.36	252.86
15	183.62	181.25	222.89	225.92	236.44	240.75
16	174.54	172.28	212.12	215.03	225.09	229.22
17	165.92	163.76	201.88	204.66	214.29	218.25
18	157.72	155.65	192.13	194.80	204.01	207.80
19	149.93	147.95	182.85	185.40	194.22	197.84
20	142.52	140.63	174.02	176.46	184.90	188.37

21	135.47	133.67	165.62	167.96	176.03	179.35
22	128.78	127.05	157.62	159.86	167.58	170.76
23	122.41	120.76	150.00	152.15	159.54	162.58
24	116.36	114.79	142.76	144.81	151.88	154.80
25	110.61	109.10	135.86	137.83	144.59	147.38

Cumulative discounted Cash flow (€)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-852.49	-991.96	-928.91	-1058.38	-1052.93	-1180.03
2	-497.80	-641.54	-504.75	-628.92	-604.85	-724.38
3	-160.62	-308.43	-101.06	-220.16	-178.27	-290.55
4	159.91	8.20	283.13	168.89	227.84	122.50
5	464.62	309.18	648.76	539.19	614.46	515.78
6	754.29	595.29	996.74	891.64	982.53	890.22
7	1029.65	867.24	1327.92	1227.09	1332.94	1246.73
8	1291.41	1125.75	1643.11	1546.37	1666.54	1586.17
9	1540.25	1371.48	1943.07	1850.26	1984.12	1909.35
10	1776.79	1605.06	2228.55	2139.50	2286.47	2217.05
11	2001.66	1827.08	2500.24	2414.80	2574.30	2510.02
12	2215.41	2038.12	2758.81	2676.82	2848.33	2788.96
13	2418.61	2238.73	3004.89	2926.21	3109.21	3054.55
14	2611.77	2429.41	3239.09	3163.58	3357.56	3307.41
15	2795.38	2610.66	3461.98	3389.50	3594.00	3548.16
16	2969.93	2782.94	3674.11	3604.53	3819.09	3777.39
17	3135.85	2946.69	3875.99	3809.19	4033.39	3995.64
18	3293.57	3102.35	4068.12	4003.99	4237.39	4203.43
19	3443.49	3250.30	4250.97	4189.39	4431.61	4401.28
20	3586.01	3390.93	4424.99	4365.86	4616.51	4589.65
21	3721.48	3524.60	4590.61	4533.81	4792.54	4769.00
22	3850.26	3651.65	4748.22	4693.67	4960.11	4939.76
23	3972.67	3772.42	4898.23	4845.82	5119.65	5102.34
24	4089.03	3887.20	5040.99	4990.64	5271.53	5257.14
25	4199.63	3996.31	5176.85	5128.47	5416.12	5404.52

Energy saved (kWh)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-	-	-	-	-	-
1	1905.75	1890.00	2272.25	2306.00	2403.00	2448.50
2	1902.37	1886.54	2270.70	2304.62	2402.10	2447.83
3	1898.98	1883.08	2269.15	2303.24	2401.21	2447.16
4	1895.60	1879.62	2267.60	2301.86	2400.31	2446.49
5	1892.22	1876.15	2266.05	2300.47	2399.41	2445.82
6	1888.84	1872.69	2264.50	2299.09	2398.52	2445.16
7	1885.45	1869.23	2262.95	2297.71	2397.62	2444.49
8	1882.07	1865.77	2261.40	2296.33	2396.73	2443.82
9	1878.69	1862.31	2259.85	2294.95	2395.83	2443.15
10	1875.31	1858.85	2258.30	2293.57	2394.93	2442.48

11	1871.92	1855.39	2256.75	2292.19	2394.04	2441.81
12	1868.54	1851.93	2255.20	2290.81	2393.14	2441.14
13	1865.16	1848.46	2253.65	2289.42	2392.24	2440.47
14	1861.78	1845.00	2252.10	2288.04	2391.35	2439.81
15	1858.39	1841.54	2250.55	2286.66	2390.45	2439.14
16	1855.01	1838.08	2249.00	2285.28	2389.56	2438.47
17	1851.63	1834.62	2247.45	2283.90	2388.66	2437.80
18	1848.25	1831.16	2245.90	2282.52	2387.76	2437.13
19	1844.86	1827.70	2244.35	2281.14	2386.87	2436.46
20	1841.48	1824.24	2242.80	2279.76	2385.97	2435.79
21	1838.10	1820.77	2241.25	2278.37	2385.07	2435.12
22	1834.72	1817.31	2239.70	2276.99	2384.18	2434.46
23	1831.33	1813.85	2238.15	2275.61	2383.28	2433.79
24	1827.95	1810.39	2236.60	2274.23	2382.39	2433.12
25	1824.57	1806.93	2235.05	2272.85	2381.49	2432.45

Table B.17 – Cumulative Cash flow (€) for S3 in Faro

			100L (2P)			
Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-928.71	-1061.45	-1075.01	-1210.78	-1225.02	-1361.00
2	-631.85	-762.32	-775.43	-911.96	-926.45	-1063.41
3	-335.02	-463.20	-475.86	-613.15	-627.89	-765.83
4	-38.22	-164.09	-176.30	-314.35	-329.34	-468.25
5	258.55	135.00	123.24	-15.56	-30.80	-170.67
6	555.28	434.08	422.78	283.22	267.74	126.89
7	851.99	733.15	722.31	582.00	566.27	424.45
8	1148.66	1032.20	1021.82	880.77	864.79	722.01
9	1445.30	1331.24	1321.33	1179.53	1163.30	1019.55
10	1741.91	1630.26	1620.82	1478.28	1461.80	1317.09
11	2038.49	1929.27	1920.31	1777.03	1760.30	1614.63
12	2335.03	2228.27	2219.78	2075.77	2058.78	1912.16
13	2631.55	2527.26	2519.24	2374.50	2357.26	2209.68
14	2928.03	2826.23	2818.70	2673.22	2655.73	2507.19
15	3224.48	3125.19	3118.14	2971.94	2954.19	2804.70
16	3520.90	3424.13	3417.57	3270.65	3252.65	3102.20
17	3817.29	3723.06	3716.99	3569.35	3551.09	3399.70
18	4113.65	4021.98	4016.40	3868.04	3849.53	3697.19
19	4409.97	4320.88	4315.80	4166.72	4147.96	3994.67
20	4706.27	4619.77	4615.19	4465.40	4446.38	4292.15
21	5002.53	4918.65	4914.56	4764.07	4744.79	4589.62
22	5298.76	5217.51	5213.93	5062.73	5043.20	4887.09
23	5594.96	5516.36	5513.29	5361.38	5341.59	5184.54
24	5891.13	5815.20	5812.63	5660.03	5639.98	5482.00
25	6187.26	6114.02	6111.97	5958.67	5938.36	5779.44
			150L (3P)			

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-824.19	-953.76	-954.44	-1084.96	-1095.92	-1228.13
2	-422.97	-547.07	-534.36	-660.37	-668.28	-797.69
3	-21.95	-140.54	-114.38	-235.85	-240.68	-367.27
4	378.88	265.82	305.52	188.61	186.87	63.13
5	779.53	672.04	725.32	613.01	614.37	493.50
6	1179.98	1078.09	1145.03	1037.35	1041.83	923.84
7	1580.23	1483.98	1564.65	1461.62	1469.24	1354.16
8	1980.30	1889.72	1984.18	1885.84	1896.60	1784.45
9	2380.17	2295.30	2403.62	2309.99	2323.92	2214.72
10	2779.86	2700.72	2822.97	2734.08	2751.20	2644.97
11	3179.35	3105.99	3242.23	3158.11	3178.43	3075.19
12	3578.65	3511.09	3661.40	3582.08	3605.61	3505.38
13	3977.75	3916.04	4080.48	4005.99	4032.75	3935.55
14	4376.67	4320.83	4499.46	4429.84	4459.84	4365.70
15	4775.39	4725.46	4918.36	4853.62	4886.89	4795.82
16	5173.92	5129.94	5337.16	5277.34	5313.89	5225.91
17	5572.26	5534.25	5755.88	5701.00	5740.85	5655.99
18	5970.41	5938.41	6174.50	6124.60	6167.76	6086.03
19	6368.36	6342.41	6593.04	6548.14	6594.62	6516.05
20	6766.13	6746.25	7011.48	6971.62	7021.44	6946.05
21	7163.70	7149.94	7429.83	7395.03	7448.21	7376.02
22	7561.08	7553.46	7848.09	7818.39	7874.94	7805.96
23	7958.27	7956.83	8266.27	8241.68	8301.62	8235.88
24	8355.26	8360.04	8684.35	8664.91	8728.26	8665.78
25	8752.07	8763.09	9102.34	9088.08	9154.85	9095.65

200L (3P)

Year	3 PVP 200L	3 PVP 300L	4 PVP 200L	4 PVP 300L	5 PVP 200L	5 PVP 300L
0	-1225.60	-1360.60	-1374.60	-1509.60	-1523.60	-1658.60
1	-833.84	-973.53	-906.63	-1035.82	-1029.40	-1156.10
2	-442.79	-587.19	-438.99	-562.34	-535.39	-653.75
3	-52.46	-201.58	28.33	-89.15	-41.57	-151.54
4	337.15	183.29	495.31	383.75	452.06	350.53
5	726.04	567.43	961.97	856.35	945.50	852.46
6	1114.22	950.84	1428.30	1328.66	1438.75	1354.25
7	1501.68	1333.51	1894.30	1800.68	1931.81	1855.89
8	1888.43	1715.45	2359.97	2272.41	2424.68	2357.40
9	2274.45	2096.65	2825.31	2743.84	2917.36	2858.76
10	2659.76	2477.12	3290.32	3214.98	3409.85	3359.98
11	3044.35	2856.86	3755.01	3685.83	3902.15	3861.06
12	3428.23	3235.86	4219.36	4156.39	4394.26	4361.99
13	3811.39	3614.13	4683.39	4626.65	4886.18	4862.79
14	4193.83	3991.66	5147.09	5096.62	5377.91	5363.44
15	4575.55	4368.46	5610.46	5566.29	5869.45	5863.95
16	4956.56	4744.53	6073.50	6035.68	6360.80	6364.32

17	5336.85	5119.86	6536.22	6504.77	6851.96	6864.55
18	5716.42	5494.46	6998.60	6973.57	7342.93	7364.64
19	6095.27	5868.33	7460.66	7442.07	7833.71	7864.58
20	6473.41	6241.46	7922.39	7910.28	8324.30	8364.38
21	6850.83	6613.86	8383.78	8378.20	8814.70	8864.04
22	7227.54	6985.52	8844.86	8845.83	9304.91	9363.56
23	7603.52	7356.45	9305.60	9313.16	9794.93	9862.94
24	7978.79	7726.65	9766.01	9780.20	10284.76	10362.17
25	8353.35	8096.11	10226.09	10246.95	10774.40	10861.27

Appendix C – Sensitivity analysis results

Table C.1 – Electricity price variation values

Electricity price	Percentage variation
0.106€	-50%
0.159€	-25%
0.212€	0%
0.265€	+25%
0.286€	+35%
0.318€	+50%

Table C.2 – Sensitivity analysis for S2 (200L, 2 STP - 300L) on the price of electricity

Metric	Electricity price variation					
	-50%	-25%	0%	+25%	+35%	+50%
NPV	385.72 €	2077.06 €	3768.40 €	5459.75 €	6129.90 €	7151.09 €
SPP	12.28	7.84	5.76	4.55	4.20	3.76
DPP	19.51	10.21	6.97	5.30	4.84	4.28
IRR	6%	12%	17%	22%	24%	26%
LCoH	0.085 €	0.088 €	0.090 €	0.092 €	0.093 €	0.095 €

Table C.3 – Sensitivity analysis for S2 (200L, 2 STP - 300L) on the discount rate

Metric	Discount rate value				
	4%	5%	6%	7%	8%
NPV	4459.56 €	3768.40 €	3175.64 €	2664.66 €	2221.96 €
SPP	5.76	5.76	5.76	5.76	5.76
DPP	6.68	6.97	7.29	7.64	8.03
IRR	17%	17%	17%	17%	17%
LCoH	0.083 €	0.090 €	0.097 €	0.105 €	0.113 €

Table C.4 – Sensitivity analysis for S3 (200L, 5 PVP - 200L) on the price of electricity

Metric	Electricity price variation					
	-50%	-25%	0%	+25%	+35%	+50%
NPV	1838.89 €	3627.51 €	5416.12 €	7204.74 €	7913.43 €	8993.35 €
SPP	6.37	4.16	3.08	2.45	2.27	2.03
DPP	7.86	4.78	3.44	2.69	2.47	2.20
IRR	15%	24%	32%	41%	44%	49%
LCoE	0.039 €	0.039 €	0.039 €	0.039 €	0.039 €	0.039 €

Table C.5 – Sensitivity analysis for S3 (200L, 5 PVP - 200L) on the discount rate

Metric	Discount rate value				
	4%	5%	6%	7%	8%
NPV	6167.17 €	5416.12 €	4771.90 €	4216.47 €	3735.19 €
SPP	3.08	3.08	3.08	3.08	3.08
DPP	3.36	3.44	3.52	3.60	3.69
IRR	32%	32%	32%	32%	32%
LCoE	0.035 €	0.039 €	0.043 €	0.047 €	0.051 €

Table C.6 - Effect of the cost of electricity on NPV for a 100L profile in Bragança

Metric	Electricity price variation				
	-50%	-25%	0%	+25%	50%
1 PST - 200 L	-805.47 €	46.96 €	899.38 €	1751.81 €	2604.24 €
1 PST - 300 L	-921.77 €	-50.47 €	820.82 €	1692.12 €	2563.41 €
2 PST - 200 L	-991.89 €	-24.57 €	942.76 €	1910.08 €	2877.41 €
2 PST - 300 L	-1092.58 €	-98.59 €	895.41 €	1889.40 €	2883.39 €
3 PST - 200 L	-1442.30 €	-440.04 €	562.22 €	1564.48 €	2566.73 €
3 PST - 300 L	-1547.28 €	-520.50 €	506.28 €	1533.06 €	2559.83 €

Table C.7 – Effect of the discount rate on NPV for a 100L profile in Bragança

Metric	Discount rate value				
	4%	5%	6%	7%	8%
1 PST - 200 L	1234.34 €	899.38 €	612.11 €	364.47 €	149.93 €
1 PST - 300 L	1161.90 €	820.82 €	528.30 €	276.14 €	57.67 €
2 PST - 200 L	1321.97 €	942.76 €	617.53 €	337.17 €	94.28 €
2 PST - 300 L	1284.12 €	895.41 €	562.03 €	274.65 €	25.67 €
3 PST - 200 L	949.61 €	562.22 €	229.97 €	-56.43 €	-304.57 €
3 PST - 300 L	902.24 €	506.28 €	166.68 €	-126.06 €	-379.69 €

Appendix D – Effect of inflation on the price of electricity

Table D.1 – 1% inflation of electricity cost for a 100L DHW profile in Bragança for S2

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	10	1247.37	13.0	9.5	0.17
1 STP - 300 L	9	1176.51	13.8	9.9	0.16
2 STP - 200 L	9	1337.65	13.6	9.8	0.15
2 STP - 300 L	9	1301.19	14.0	10.1	0.15
3 STP - 200 L	8	971.38	16.4	11.2	0.15
3 STP - 300 L	8	925.44	16.9	11.4	0.14

Table D.2 – 1% inflation of electricity cost for a 150L DHW profile in Bragança for S2

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	13	2051.09	10.0	7.8	0.14
1 STP - 300 L	13	2075.78	10.1	7.8	0.14
2 STP - 200 L	14	2738.11	9.0	7.2	0.12
2 STP - 300 L	14	2784.18	9.3	7.3	0.11
3 STP - 200 L	12	2597.16	10.3	8.0	0.11
3 STP - 300 L	12	2578.80	10.7	8.2	0.11

Table D.3 – 1% inflation of electricity cost for a 200L DHW profile in Bragança for S2

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	11	1658.21	11.3	8.6	0.15
1 STP - 300 L	11	1641.42	11.5	8.7	0.15
2 STP - 200 L	15	2973.74	8.6	6.9	0.11
2 STP - 300 L	14	3015.28	8.8	7.0	0.11
3 STP - 200 L	13	3030.25	9.4	7.4	0.11
3 STP - 300 L	13	3144.40	9.5	7.5	0.10

Table D.4 – 1% inflation of electricity price for a 100L DHW profile in Faro for S2

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	11	1736.59	11.2	8.5	0.15
1 STP - 300 L	11	1750.37	11.3	8.6	0.14
2 STP - 200 L	11	1697.17	12.1	9.0	0.14
2 STP - 300 L	10	1580.76	12.9	9.4	0.14
3 STP - 200 L	9	1242.64	15.0	10.5	0.14
3 STP - 300 L	8	1129.14	15.8	10.9	0.14

Table D.5 – 1% inflation of electricity price for a 150L DHW profile in Faro for S2

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	16	2959.92	8.0	6.5	0.12
1 STP - 300 L	15	2955.69	8.1	6.5	0.12
2 STP - 200 L	16	3546.10	7.6	6.2	0.10
2 STP - 300 L	16	3540.11	7.9	6.4	0.10
3 STP - 200 L	14	3194.40	9.1	7.2	0.10
3 STP - 300 L	13	3226.65	9.3	7.4	0.10

Table D.6 – 1% inflation of electricity price for a 200L DHW profile in Faro for S2

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoH (€/kWh)
1 STP - 200 L	14	2614.59	8.6	6.9	0.13
1 STP - 300 L	14	2631.34	8.7	7.0	0.13
2 STP - 200 L	18	4308.73	6.6	5.6	0.09
2 STP - 300 L	18	4458.87	6.7	5.6	0.09
3 STP - 200 L	16	4187.68	7.6	6.3	0.09
3 STP - 300 L	16	4318.65	7.7	6.3	0.09

Table D.7 – 1% inflation of electricity cost for a 100L DHW profile in Bragança for S3

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200L	24	3155.67	4.9	4.3	0.07
3 PVP - 300 L	22	3080.31	5.4	4.7	0.07
4 PVP - 200 L	22	3157.69	5.4	4.6	0.06
4 PVP - 300 L	20	3082.33	5.9	5.0	0.06
5 PVP - 200 L	20	3066.35	6.0	5.1	0.06
5 PVP - 300 L	18	2939.12	6.6	5.5	0.06

Table D.8 – 1% inflation of electricity cost for a 150L DHW profile in Bragança for S3

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200L	30	4274.37	3.8	3.4	0.05
3 PVP - 300 L	30	4270.75	4.0	3.7	0.05
4 PVP - 200 L	30	4714.65	3.9	3.5	0.05
4 PVP - 300 L	28	4786.24	4.2	3.7	0.05
5 PVP - 200 L	28	4770.26	4.2	3.7	0.05
5 PVP - 300 L	26	4722.56	4.5	4.0	0.05

Table D.9 – 1% inflation of electricity cost for a 200L DHW profile in Bragança for S3

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200L	29	4010.02	4.0	3.5	0.06
3 PVP - 300 L	31	3786.84	4.1	4.0	0.06
4 PVP - 200 L	31	4886.83	3.7	3.3	0.05
4 PVP - 300 L	30	5306.78	3.8	3.4	0.04
5 PVP - 200 L	30	5290.81	3.8	3.4	0.04
5 PVP - 300 L	28	5217.18	4.2	3.7	0.04

Table D.10 – 1% inflation of electricity price for a 100L DHW profile in Faro for S3

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200L	25	3398.57	4.6	4.1	0.06
3 PVP - 300 L	23	3303.33	5.2	4.5	0.06
4 PVP - 200 L	23	3296.86	5.2	4.5	0.06
4 PVP - 300 L	21	3152.34	5.8	4.9	0.06
5 PVP - 200 L	20	3134.64	5.9	5.0	0.06
5 PVP - 300 L	19	2986.67	6.5	5.4	0.06

Table D.11 – 1% inflation of electricity price for a 150L DHW profile in Faro for S3

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200L	34	4997.02	3.4	3.0	0.05
3 PVP - 300 L	31	4953.64	3.7	3.3	0.05
4 PVP - 200 L	32	5157.23	3.6	3.2	0.05
4 PVP - 300 L	29	5098.29	3.9	3.5	0.05
5 PVP - 200 L	29	5134.18	4.0	3.5	0.04
5 PVP - 300 L	27	5047.58	4.3	3.8	0.04

Table D.12 – 1% inflation of electricity price for a 200L DHW profile in Faro for S3

System	IRR (%)	NPV (€)	DPP (years)	SPP (years)	LCoE (€/kWh)
3 PVP - 200L	33	4765.52	3.5	3.1	0.05
3 PVP - 300 L	29	4557.04	3.9	3.5	0.05
4 PVP - 200 L	35	5862.77	3.2	2.9	0.04
4 PVP - 300 L	32	5825.44	3.5	3.2	0.04
5 PVP - 200 L	33	6144.86	3.4	3.1	0.04
5 PVP - 300 L	31	6148.16	3.6	3.3	0.04