

## Financial viability and environmental aspects in the selection of energy sources for sanitary hot water (SHW) and heated swimming pools

## Viabilidad financiera y aspectos ambientales en la selección de fuentes de energía para agua caliente sanitaria (ACS) y piscinas climatizadas

LONGARELA-ARES, Angeles†\*

*Universidade da Coruña, Regulation Research Group, Economy and Finance (GREFIN), Department of Business, Faculty of Economics and Business, Elviña, 15071 La Coruna, Spain.*

ID 1<sup>st</sup> Author: Angeles, Longarela-Ares / ORC ID: 0000-0003-0488-4950

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### Abstract

Sustainability and energy efficiency are topics of great interest, especially in the sports facilities management sector, due to the high energy costs. One of the most relevant costs is derived from the consumption of Sanitary Hot Water (SHW) and swimming pool. The objective of this work is to study new ways to manage and reduce these costs through the valuation of the use of traditional and renewable energy sources and the necessary investment to contribute to the promotion of a more sustainable vision of business management. Four alternative energy installations (Natural Gas, Biomass, Solar Thermal Combined with Natural Gas or Biomass) are proposed, it is verified which is more suitable in terms of financial viability and one of them is selected. For this purpose, we start from a hypothetical business-case and a 20-year forecast of the energy consumption, the costs and initial investment of each alternative is made; viability analysis are performed with the Net Present Value (NPV) and the obtained results are compared. The conclusion is that the most appropriate solution, from a financial point of view, for sports centers similar to the business-case and with the considered circumstances, is the installation of Biomass, an option that, in addition, can be considered respectful with the environment.

**Sanitary Hot Water, Renewable Energies, Sports Facilities, Financial Evaluation, Business Sustainability**

### Resumen

La sostenibilidad y la eficiencia energética son temas de gran interés, especialmente en el sector de gestión de instalaciones deportivas, debido a que presentan elevados costes energéticos. Uno de los costes más relevantes es el derivado del consumo de Agua Caliente Sanitaria (ACS) y piscina. Este trabajo tiene como objetivo estudiar nuevas formas para gestionar y reducir estos costes a través de la valoración del uso de fuentes de energía tradicionales y renovables y de la inversión necesaria para contribuir al fomento de una visión más sostenible de la gestión empresarial. Se proponen cuatro alternativas de instalación energética (Gas Natural, Biomasa, Solar Térmica combinada con Gas Natural o con Biomasa), se comprueba cual es más adecuada en términos de viabilidad financiera y se selecciona una de ellas. Para ello se parte de una hipotética empresa-caso y se hace una previsión a 20 años de los consumos energéticos y de los costes y desembolso inicial para cada alternativa; se realizan análisis de viabilidad con el Valor Actual Neto (VAN) y se comparan los resultados. Se concluye que la solución más adecuada, desde un punto de vista financiero, para centros deportivos similares a la empresa-caso y con las circunstancias consideradas, es la instalación de Biomasa, una opción que, además, puede ser considerada respetuosa con el medio ambiente.

**Agua Caliente Sanitaria, Energías Renovables, Instalaciones Deportivas, Evaluación Financiera, Sostenibilidad Empresarial**

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\* Correspondence to Author (email: angeles.maria.longarela.ares@udc.es)

† Researcher contributing first author.

## 1. Introduction

In recent years, energy prices have been subject to a gradual increase that has caused companies to consume energy from a marginal item in Their cost structure to a considerable part (ATECYR, 2011). This has led them to Rethink Their management, without losing the advantages it grants (higher productivity and quality) Because business Efforts Have Been traditionally based on the overall efficiency of Processes neglecting consumption, something the current economic Necessary Given situation.

In sports facilities, energy consumption is one of the Most Important items of the company's expenses, Representing the Sanitary Hot Water (SHW) and the heating of the pool water (Pool), 25% of the total energy consumption (Ministry of Economics and Technological Innovation, 2005). This makes its management look demeanor if it is not accompanied by appropriate thermal conditions in showers and heated pools (Municipal Sports Foundation, 2011). The choice of a suitable energy installation can allow the company to reduce its consumption, making it more competitive in costs, improving its efficiency and contributing to a business model that is respectful of the environment and more sustainable, Which will have a better brand image and will grant a competitive and differentiating advantage.

These questions make interesting the study of the selection of a SHW installation and pool water heating, and therefore it was chosen as the subject of this work.

What is intended is to make a comparison of four alternatives of ACS and pool facilities: a conventional installation of Natural Gas (non-renewable energy), a Biomass installation (renewable energy based on the consumption of organic fuel, such as pellets) and two Solar Thermal installations (combined with each of the first alternatives, giving rise to two hybrid installations). The objective is to select the most appropriate for a sports center considering the financial evaluation of the various alternatives and commenting on the impacts and environmental aspects of each of them.

The work is structured as Follows: section 2 presents the state of the art and description of the business-case; Section 3 shows the methodology; Section 4 sets out the results; Section 5 comments on the conclusions; Section 6 collects the bibliography used and Appendix 1 collects some of the tables With the data and calculations made, which for reasons of space, and to facilitate reading, could not be incorporated into the text

## 2. State of the art and description of the company-case

### 2.1. State of the art

Sports facilities are characterized by special energy needs different from those of any other type of business. This peculiarity is due to its high loads of heat and electricity consumed (Artuso & Santiangeli, 2008) since they are usually used by a large number of people who consume resources, mainly water and energy.

Applying measures that, in addition to reducing consumption, reduce the environmental impact, such as the installation of SHW systems and heating of pool water with clean energy, will mean responsible action that, if it is also feasible and economically viable, can be applied to other types of environments or sports centers. In Addition, the construction and rehabilitation of These sports facilities is a good opportunity for the introduction of environmental criteria, especially in terms of energy efficiency, with the impact That These types of Measures Have on the economic expenses of the facilities operation (Fraguas Herrero, 2010).

It becomes interesting to value the installation of innovative equipment, with high energy efficiency; maintain these equipment regularly and change them depending on the performance evolution and provide energy supply systems such as active or passive solar energy, wind engines, heat pumps, etc. (Fraguas Herrero, 2010). Likewise, regulations Have Been established, Such as document HE4 of the Technical Building Code (CTE), Which Encourage the use of clean energy in new buildings, When the main source of energy is not renewable (Natural Gas), of such that there must be a minimum solar contribution to SHW and pool water heating.

Some of these projects to be evaluated by companies, and which represent an important decision that will have an impact on their future costs, are investment projects in energy facilities. Probably, The most used decision rule to choose The most efficient alternative Among the different projects, to ASSESS and analyze the viability from a financial point of view is the net present value (NPV) or the present value of the benefits less the present value of the costs used by economists to defend the adoption of Energy Efficiency Measures by Individuals and Organizations (Galan Gonzalez Leal & Varela, 1999; Dhavale & Sarkis, 2015).

Nikolaidis, Chatzis & Poullikkas (2018) performed a life cycle cost analysis, a NPV analysis and an uncertainty analysis to assess the impact of intermittent renewable energy sources. In order to obtain the components of the NPV, they considered that the general expenses of an electrical energy storage facility include the investment costs or initial cost of the project or installation, the operation and maintenance costs.

Chakrabarty and Islam (2011) and Palit, Malhotra and Kumar (2011) also consider similar VPN components as those of Nikolaidis, Chatzis & Poullikkas (2018), although Chakrabarty and Islam (2011) complement their study with an eco-efficiency analysis and Palit, Malhotra and Kumar (2011) approach it from the perspective that if the present value of the cost (CPV) of an energy project based on biomass gasifiers (BGPP) is less than or at least equal to the present value of the benefits accrued by the Project Implementation Agency (PIA) of the electricity sale (BPV) throughout the life of the project, this will be financially viable.

There are several studies in esta area. Some authors focus on a specific type of energy that usually includes some energy considered renewable and analyze the viability of Said project. This is the case of authors: such as Brittany (2007), Which Focuses on the financial valuation of a biomass installation, Condori Yucra (2010) and Corral (2011) That focus on solar installation, or Noguera (2011) That Focuses in analyzing a project, which combines several types of energy: solar thermal, geothermal and biomass.

On the other hand, other authors choose to compare several alternatives that allow selecting among different types of energy the most appropriate for a given case. This is what Martínez Sánchez (2011) and Moreno (2012), which focus, respectively, on comparing a microgeneration system of thermal energy and electricity with conventional systems and a diesel installation with a biomass installation to consider replace it. O Chakrabarty & Islam (2011) who Carried out a financial feasibility analysis of domestic Solar Systems with six case studies, comparing previous expenditures on conventional energy sources before implementing the system.

In any case, the procedure is similar defining in the first place the Characteristics of the building or place Where the installation to be EVALUATED is going to be Implemented, making calculations of a technical nature and, subsequently, of a financial nature, Such as the NPV, to ASSESS the installation, and exposing the Appropriate conclusions in view of the results.

There are both real case studies (Chakrabarty & Islam, 2011; Corral, 2011), Where the feasibility analysis will be used to determine Whether to Maintain or change the Existing facility, Such as business-case studies Arising from academic projects, business projects not Carried out yet or studies that are based on real data of buildings, swimming pools or sports centers that can serve as a base (Noguera, 2011), Where analyzing the feasibility will be used to choose what type of installation to perform. Some studies focus on urban buildings (Martínez Sánchez, 2011; Moreno, 2012), homes (Chakrabarty & Islam, 2011) transferable to the sports field and others in sports centers or swimming pools (Cloquell, Artacho and Santamarina, 2009; Condori Yucra, 2010; Corral, 2011; Noguera, 2011).

Regarding environmental aspects, projects related to energy facilities can generate costs borne by Also society, called external costs, external effects or externalities (Delacámara, 2008; European Investment Bank, 2013). These externalities can influence When selecting a type of SHW installation or another. In the case study, for example, using the solar energy or a renewable energy source will reduce negative flows by reducing consumption and Avoiding costs.

However, a financial analysis does not include the external effects. Usually, the presence of the resource generates economic agents other than its owner and/or user, that is, on society (Delacámara, 2008). With this in mind, not only financial but environmental issues also would come into play.

To make more complete decisions, externalities should be duly quantified and taken into account in the analyzes, counting them as costs of the decision if their impact is negative or as benefits thereof, if it is positive. It could be considered, for example, that externalities in facilities that use renewable energy sources above the mandatory percentage would have a positive impact as the reduction of pollution is greater, or that the reduction in fuel consumption or the use of the solar energy sources, would lead to avoided costs in the generation of energy, while maintaining the possibility of fully covering the demand (Delacámara, 2008).

The European Investment Bank (2013) to evaluate the costs and benefits for society, it considers that is necessary to take into account externalities and such, for this, they must be added together with the operation and maintenance costs. This requires an estimate of the volume of externality (for example, tons of greenhouse gas emissions per year) and an appropriate unit price, or a marginal estimate of external cost. Although it may be difficult to estimate, the European Investment Bank (2013) has made valuations in euros of some externalities in the sectors in which it operates and considers them a negative flow when calculating the NPV.

Infrastructure Sustainability Council of Australia (ISCA) (2016) starts from the fact that the cost-benefit analysis (CBA) is a financial analysis process to calculate the net costs and benefits of the options expressed in monetary units and that the results can be expressed, among other forms, with the net present value (NPV). From there, the complete economic analysis (CEA) is a tool that allows expanding the CBA by including externalities in the evaluation and calculating the net benefits (benefits minus costs) of the options expressed in monetary units.

However, in the private sector the cost-benefit analysis and the NPV do not usually include externalities. When evaluating some investment projects, in part, due to the lack of relevant data and the limited time, but also due to the little emphasis on the external effects (Karmokolias, 1996). This makes incorporating externalities into the financial feasibility analyzes can be complicated by the difficulty to be valued monetarily, in some cases being considered as intangible effects (Delacámara, 2008); other environmental effects do not lend themselves easily to quantification due to their nature (Karmokolias, 1996) and, although significant progress has been made in refining the estimates of values and methods to integrate them into the analysis, it is still necessary to expand the range of externalities considered, not only harmful emissions, but also others such as loss of biodiversity and ecosystem services (European Investment Bank, 2013).

Taking into account the considerations mentioned, this work will focus on the financial evaluation of various alternatives for an ACS installation and heated pool, without considering externalities and environmental costs at the empirical level. However, the environmental aspects and impacts of each alternative will be discussed by describing the level of pollution and CO<sub>2</sub> emissions of the different alternatives based on the investment decision in traditional or renewable energy projects.

## 2.2. Business-case description

In the present study, a hypothetical business-case is used, which have the following characteristics: construction of 3,984 m<sup>2</sup> (not counting the fuel silo, if applicable) located in Lugo. It consists of several units, on two floors, and special attention will be given to those involved in the management of SHW and pool water, listed in table 1 below:

	Sheet of water	Height	Pool volume	Glass surface (walls and floor)
Indoor pool or Pool 1	312.5 m <sup>2</sup>	1.5 m high at the front	625 m <sup>3</sup>	462,50 m <sup>2</sup>
		2.5 m high at the rear Average height of 2 m		
Splash Pool Indoor - Pool 2	70 m <sup>2</sup>	1.2 m average height	84 m <sup>3</sup>	104 m <sup>2</sup>
Changing rooms	318 m <sup>2</sup> for users and monitors With showers, toilets and sinks) and auxiliary services (12 m <sup>2</sup> With toilets and sinks).			

**Table 1** Dependencies involved in the management of hot water and pool water

Source: *Self made*

Company profile-event is geared to be a market leader. The sports center begins to be built in year 0, opens its doors at 21 months of beginning to be built, that is, on October 1 of year 1 and Year 2 it is the first full year of operation and considered as the base year. The monthly inflow for a total of 12,476 uses / month, according to forecasts for year 2, based on guidance from professionals. It is based on the characteristics of a sports center with a wide range of courses and supervised activities, taught at various times to a maximum of people per session, and free activities (swimming pool, fitness, paddle, tennis ...).

Uses are considered not sales, because, for example, a person enrolled in a course of 2 days per week is considered as a single sale, but as 8 uses per month. For courses and supervised activities, applications were set at 40% of the maximum number of people per session that could come to be, because in the first years of operation it is usually the common influx and for free activities are directly estimated the number was directly estimated of monthly uses, in accordance with the guidelines of sports center managers (table 2.1 APPENDIX 1). In the case of number of subscribers (sales, no use) is expected up to 5,000 customers as a stop, growing from 2,000 subscribers (40% of 5,000) is in year 2 50% for year 3 , 33% for 4, 15% for 5 and 5% to 6 reaching 4,817 subscribers.

### 3. Methodology

The methodology for performing this study is divided into three phases:

- Calculate power in kilowatts (kW) that is required to have the facility for hot water and pool water heating and annual energy consumption in kilowatt hours (kWh).
- Investment, initial or installation costs and operation and maintenance costs of each type of installation.
- NPV calculation of each type of installation.

In addition, relevant environmental aspects of the alternatives considered, such as the estimated CO<sub>2</sub> emissions for each type of SHW installation and heated pool valued at work, will be discussed.

Since the study focuses primarily on a financial level, not on an assessment of environmental costs or impact of emissions, were considered only economic variables such as prices and investment costs or initial and installation costs, operating costs and maintenance costs of each type of installation in the financial analysis and were complemented with appropriate justifications according to which some alternatives are considered more sustainable than others, based on their CO<sub>2</sub> emissions and environmental aspects.

To determine the power and energy consumption, the formulas of power and energy contained in Albarracín, Sanabria and Maíllo (2007), the "Technical Guide Hot Water Central" ATECYR (2011) and expert technical advice were used. Likewise, information on similar academic works was obtained and the procedure used in these, or any of its steps, was followed for the different sections (Britain, 2007; Cloquell, Artacho and Santamarina, 2009; Condori Yucra, 2010, Corral, 2011; Noguera, 2011; Martínez Sánchez, 2011; Moreno (2012), Also, it was used an energy efficiency manual by Escobar (2009) and an audit by Creara (2011), studies that also served as guidance for financial analysis, in addition to Chakrabarty and Islam (2011), Palit, Malhotra and Kumar (2011 ) and Nikolaidis, Chatzis and Poullikkas (2018), to determine the components of the NPV.

All calculations were made based on year 2, as it is the first full year of operation of the sports center, except for the NPV calculation for which a 20-year forecast is applied. Although in the future the number of clients increases, energy facilities should be based on the most conservative and the early data, as if estimates are met they can always be increased. Data used were obtained from various sources are discussed in detail below, together with the methodology used in each phase.

Traditionally assessing the viability of projects has been carried out based on financial aspects. However, at present, it is important to assess how well a project is able not only to generate profit or be viable, but also to reduce negative impacts on the environment, and see how they can take into account the issues and environmental costs.

To determine the environmental impacts and CO<sub>2</sub> emissions data were applied and indications and formulations of the Practical Guide for calculating emissions of greenhouse gases (ghgs) by the Generalitat de Catalunya (2011) and IDAE (2019) were followed in the stage of energy consumption, as well as the method to value economically CO<sub>2</sub> emissions from European Investment Bank (2013).

### **3.1. Methodology for calculating power and energy consumption**

To determine the thermal power and energy consumption, on the one hand, it was calculated the consumption of liters of SHW and thermal energy demand which will involve the locker room and on the other hand, the power and energy demand of swimming pools, since in each case will be obtained differently. The power for hot water, hot water consumed for health services (showers and toilets, mainly) was calculated from daily water consumption, which is given by the daily influx of people to the center and liters each person consumes. The daily influx is determined from the monthly influx. Since it varies every month, especially in summer, due to the seasonality of use of sports centers, guidance influx rates were established, taking 12. 476 uses as the months in which the monthly inflow level is 100% of the expected (Table 2.2 Appendix 1).

Subsequently, the monthly uses were added to know the annual ones and, from these, the average monthly and daily uses (345 people/day) were obtained.

In respect of pools, they consume hot water due to 2 main causes: constitute the first time the pool glass is filled and the heat losses of the glass due to five factors: evaporation, radiation, convection, transmission and water renewal. This will mean having to use hot water to maintain the temperature at the appropriate levels (between 24 °c and 30 °c, according to the RITE Wellness and Health Requirement IT 1.1). A temperature of 28°c was chosen for pool 1 and 30°c for 2, because according to the RITE and orientations of real sports centers, pool 2 if used by babies, senior citizens and pregnant women, should have a higher temperature.

Energy consumption will be given in kilowatt hours (kwh). On the one hand, we have the energy consumption of SHW and, on the other hand, those of swimming pools. The annual energy consumption (kwh) shall be calculated by the product of the installed power (kw) for the hours that power is expected to be used annually.

### **3.2. Methodology for calculating investment costs or initial installation, energy costs and maintenance costs**

Once the power to be installed was calculated, the installation costs were determined for each alternative (Natural Gas, Biomass and Solar combined with Natural Gas or Biomass), based on estimates of professionals and catalogs of boilers and solar panels such as Vaillant rate catalog or the Herz price generator.

The facilities are adapted to document HE4 of the Technical Building Code (CTE) which, since 2006, establishes that, in new buildings, when the main source of energy is not renewable (Natural Gas), there must be a minimum solar contribution to SHW and pool. In SHW this contribution will depend on the solar zone (Lugo is Zone II) and the hot water consumer (between 5,000 and 10,000 liters / day) that will be 40% of the energy demanded for SHW. For swimming pool heating it will depend on the solar zone and will be 30% of the energy demanded for swimming pools.

To determine the number of solar panels required, the required contribution will be calculated according to the percentages mentioned, the heat exchanger savings will be taken into account and the auropro3.0.1 program of Vaillant will be used to calculate the number of solar panels needed for SHW and pool.

In addition, it will be taken into account in the cost of facilities the subsidies for renewable energy projects of INEGA 2018, which for the Biomass boiler is € 360 / kw of installed power, with a 50% maximum aid percentage, and for Solar Thermal energy installations, for the non-mandatory part of the CTE and being combined with conventional energies, of € 1500 / kw with a 50% maximum aid percentage.

From the energy consumption data with fuel prices biomass set by the IDAE (Institute for Saving and Energy Diversification), prices of Natural Gas Endesa (2018) for consumptions between 100,000 kwh / year and 3 gwh / year with Rate 3.4. Recommended by Endesa professionals and document HE4 Building Technical Code for solar panels, the annual energy cost of each type of installation is determined.

To determine the energy cost of "Natural Gas" annual energy consumption savings exchanger was used, minus the mandatory minimum solar contribution, since this contribution is free. When installing a condensing boiler must be noted that the yield is 104%, so that with each kwh produced will be covered 1.04 kwh and therefore consumption will be covered with less energy production ( $\text{Production} = \text{Consumption} / \text{Performance}$ ). The production result obtained was multiplied by the price of the most economical Natural Gas in the market for consumption between 100,000 kwh / year and 3 gwh / year with the rate 3.4. (Endesa, 2018), taking into account the monthly fixed term.

For the cost of consumption of "biomass", the price of wood pellets in bulk (one of the fuels of this type of boiler) in € / kwh with an average price of the A1 certified pellet in bulk is € 0.0366 / kwh and uncertified pellet bulk € 0.0352 / kwh, according to the IDAE liberalized energy prices report (2017-2018) and professionals in the sector.

The average of both is 0.0359 € / kwh. It was multiplied by the production of energy needed to cover annual energy consumption with savings of discounted exchanger (production will be greater than consumption, since it has a Biomass boiler with a yield of 93% that covers 0.93 kwh for each kwh produced).

For installations with voluntary solar contribution, the corresponding solar contribution was subtracted from the annual energy consumption with exchanger savings. In the case of the "Solar combined with Natural Gas" installation, the energy costs were determined as indicated for installation "Natural Gas", and for "Solar Biomass" installation, as in the case of installation "Biomass".

And, based on estimates of professionals in the sector, maintenance costs were calculated. There are common maintenance costs for any of the alternatives analyzed. On the one hand, there are the mechanical maintenance costs related to monthly preventive operations of checking the energy equipment (12h / month), of daily operations of temperature control of the deposits and pool (2h / day), and of corrective operations for assistance or unforeseen events (200h per year) and, on the other hand, chemical maintenance costs, performed by an approved laboratory, such as legionella and PH analysis of SHW and swimming pool (€ 6,000). The first ones will be given by the cost / hour of the necessary personnel and by the hours that are in the center and the second ones have a fixed price. Moreover, in the biomass installation there will have to be a person in charge of removing the ashes from the fuel weekly (52 hours per year) and a monitoring plan will be carried out in the thermal solar installation (cleaning of panels and control of collectors and circuits) and maintenance of the collection, accumulation and exchange systems, hydraulic circuit and electrical system.

### 3.3. Methodology for feasibility analysis (NPV)

Depending on the results, it made a comparison of the alternatives, paying particular attention to costs and initial investment, and financial viability of each option was studied using an NPV analysis.

For the calculation of the NPV, a time horizon equal to the useful life of the facilities was established, 20 years, setting as down payment the cost of the installation (with subsidy) and as cash flows the annual energy costs added to the costs of maintenance. Being disbursement flows will be negative and therefore the result of NPV too, so that one with a higher NPV will be proposed as a more adequate installation, despite being all negative.

To make temporary projections of 20 years the increase in the influx of people to SHW was taken into account. In year 1 the flow is the fourth part of year 2, the center being open for only a quarter. Since the flow 2 increases by 50%, 33%, 15% and 5% in years 3, 4, 5 and 6, respectively, with the same ACS consumption being maintained since it will vary in these proportions. The pool will consume the same every year, except for losses the first year, to work only during the opening three months since October, will be the fourth of the year 2. The first cup filling is made in October and the following filled year in December. Other years are filled alternately. After the first filling of swimming pools in October of the opening year 1, and of the filling of the year 2 calculation base, the entire pools will be emptied only when repairs are required, and only a part is usually emptied for minor repairs. As the company of this study is a quality benchmark and to anticipate possible repairs, it was considered a commissioning every two years.

The NPV formula is shown in table 9 of Appendix 1. The effect of inflation has not been considered, since when applying a rate  $g$  multiplying the price of each year  $n$  by  $(1 + g)^n$ , in the formula of the NPV the discount factor  $(1 + g)^{-n}$  must be added, and the same result would be obtained as without an inflation rate (Garrido, 2001). The WACC (Weighted Average Cost of Capital) is considered a discount rate, based on an estimate of the total cost of building a sports center with the characteristics of the business-case and from the costs of debt according to orientations of experts of the sector of management of sports facilities and advisers of banking entities. Upgrading to a discount rate of 8.40% WACC offers the same conclusions as to consider inflation at 3% and upgrade to a rate of 11, 65% (taking into account the effect of inflation,  $(1 + 0.084) * (1 + 0.03)$ ).

This WACC value is appropriate, used in studies of similar nature in which for an energy project to be carried out in the company can be used as the discount rate WACC of this (Noguera, 2011).

### 3.4. Methodology for calculating environmental impacts and CO2 emissions

The analysis of external costs and environmental externalities means greater transparency in the management, more information about the activities to be analyzed and less discretion of some decisions. The literature on the economic valuation of environmental external costs, agrees on the need to match two unequal but consistent methodological approaches: the approach path impact and life cycle analysis (LCA) and although sometimes not easy to estimate externalities by technical ignorance or lack of means, in any case, it is good to reflect on them (Linares Llamas, 2002. European Investment Bank, 2013; Infrastructure Sustainability Council of Australia (ISCA), 2016).

For energy the life cycle analysis (LCA) comprises the extraction of fuel, transport, preparation, construction, operation and decommissioning of generation, energy transmission and management of waste produced. All these steps have environmental consequences, higher or lower depending on the type of energy.

In the case of natural gas, emissions from extraction, transport and generation, occupation of land, noise and pollutant discharges are generated. In the case of biomass it produces emissions in the cultivation, collection, transportation and generation, waste, residues and occupation of terrain and in the case of solar energy it generates solid waste such as heavy metals in its generation and land occupation and visual impact, however, it does not generate CO2 emissions (Linares Llamas, 2002).

In addition, for economic evaluation of externalities, there are various applicable methods to quantify in monetary terms damage, such as the "top-down" method Hohmeyer (1988), using aggregate data emission and impacts to estimate external costs of certain contaminants.



Approach "bottom-up" using specific values for each unit of production or energy demand (Bernow & Marron, 1990; Ottinger et al., 1991; Pearce et al., 1992); damage function, a succession of steps following the impact from the activity that generates it until the damage that occurs independently for each activity and impact considered; a methodology applied by the European Commission (1995, 1999) for the externe project ( Linares Llamas, 2002) or as the European Investment Bank (2013) that estimates the volume of an externality and an appropriate unit price, or a marginal estimate of external cost.

In the consumption stage, which this study focuses on, natural gas is a fuel that contributes to increasing CO<sub>2</sub> emissions. The Practical Guide for the calculation of greenhouse gas (GHG) emissions (Generalitat de Catalunya, 2011) involves the emission of 2.15 kg CO<sub>2</sub> / Nm<sup>3</sup> of natural gas.

Biomass is a fuel with emissions considered practically neutral (Generalitat de Catalunya, 2011), a zero-emission factor will be applied (t CO<sub>2</sub> / TJ Nm<sup>3</sup>).

Solar energy means less CO<sub>2</sub> emissions, covering part of the need to produce energy with other non-renewable sources and is considered to have zero emissions.

In this paper, to analyze the environmental impact, it has chosen to focus on CO<sub>2</sub> emissions at the consumption stage only since when it comes to incorporating the valuation of externalities in an economic or financial analysis there are usually several difficulties. Some difficulties may be of a technical nature, related to the risk of incurring double counting of securities, ie incorporate two or more times the same welfare loss, then overestimating the externality, and can be complementary and competitive features for the same resource (Turner et al., 2003) or problems with the scale data, since in order to analyze economically externalities, it may be used estimations obtained for similar analysis, in other places or circumstances, and that could mean not transferring the results properly to context of the analysis being developed (Delacámara, 2008).

To determine CO<sub>2</sub> emissions at the consumption stage, the following considerations were taken into account:

- Natural gas, according to the Practical Guide for calculating emissions of greenhouse gases (GHGs) (Generalitat de Catalunya, 2011) involves the issuance of 2.15 kg CO<sub>2</sub> / Nm<sup>3</sup> of natural gas.
- Biomass is a fuel with emissions considered practically you neutral (Generalitat de Catalunya, 2011), are subject to a zero emission factor (t CO<sub>2</sub> / TJ Nm<sup>3</sup>).
- Solar energy means less CO<sub>2</sub> emissions, covering part of the need to produce energy with other non-renewable sources.

In addition, according to the European Investment Bank (2013), CO<sub>2</sub> emissions could be economically valued in EUR / t CO<sub>2</sub>e. The European Investment Bank (2013) makes a central estimate of the damage associated with an emission in 2010 of 25 euros per tonne of carbon dioxide equivalent, plus a high and low estimate of 40 euros and 10, respectively (all measured in constant euros of 2006). Reflecting a common finding that the marginal damages of emissions increases as a function of atmospheric carbon concentrations, annual "adders" are applied after 2010, ie, an absolute increase in value per year (measured in prices constant 2006). Therefore, an issue in 2017, the year of the study, according to the central estimate would be equal to 25+ (2017-2010) = 32 (Euro 2006). Thus reducing the consumption of natural gas and bet on hybrid systems combining solar energy, beyond legally binding, or betting on biomass installations, you can assume greater sustainability for the business-case and a positive impact on the consumption stage for the environment.

## 4. Results

### 4.1. Results of power and energy consumption

#### Power

Table 3 summarizes the powers necessary for hot water and pool and the power to be installed is collected and then explained as calculated.

	Installed power (kW)
SHW power	71.05
Power evaporation	63.22
Power radiation	6.62
Convection power	0.00
Power per transmission	13.91
Renewing water power	29.53
Commissioning power pool	196.89
<b>Total</b>	<b>381.23</b>
(Power evaporation + renewal + radiation)	-99.37
<b>Total installed</b>	<b>281.85</b>

**Table 3** Power installed

Source: Self made

First, the thermal power needed for the production of SHW was determined by finding the one hand consumption liters of water and the thermal energy demand which will provide the locker and on the other, demand for pools, since power in kw is obtained differently.

Knowing, therefore, that a month come to the center 345 people / day and each person consumes 21 liters of water at 60 ° C (according to the document HE4 "Power Saver" CTE) would consumption SHW of 7,245 liters / day. Therefore, 1 SHW tank of 2,500 liters of capacity will be installed and a time of 2 hours will be considered each time the tank is filled, leaving a necessary power to heat the water at 60°C of 71.05 kw (Albarracín, Sanabria and Maíllo, 2007; ATECYR, 2011). As in the base year it is forecast consumption of 7,245 liters and the tank is 2,500 liters if the boiler works 6 hours / day for SHW will produce 7,500 liters in total and, therefore, to 7,245 liters will work 5.8 hours / day. In the event that would increase the flow to the center, if the same percentages apply subscriber growth,

As for the pools, the consumed hot water comes from 2 main causes: constitute the first time the pool is filled and the heat losses from the pool vessel. The heat losses of the pool vessels were calculated (Albarracín, Sanabria and Maíllo, 2007; ATECYR, 2011) adding a necessary power of 113.28 kw and, after filling the pool glasses for the first time, the power to cover the set-up to be consumed each time, for repairs, the pools have to be refilled, it adds a power of 196.89 kw.

The total power required would be 381.23 kw (table 3), considering the commissioning, the renewal of the water and the losses power due to evaporation or radiation (Albarracín, Sanabria and Maíllo, 2007; ATECYR, 2011). If one takes into account the punctual use of the commissioning power of the pool and, thinking that when it is produced, the renewal power of the water is already covered and there are practically no losses due to evaporation or radiation, a boiler would be installed to covering a power equal to 281.85 kw. The choice is, therefore, a boiler of 300 kw.

### Energy consumption

In terms of energy consumption, on the one hand, if we consider that the SHW power is 71.05 kw and 5.8 hours a day working in year 2 (calculation basis) a daily demand of 412 kwh will occur and, as the center will be open 365 days a year, there will be an energy demand of 150,309.12 kwh per year. On the other hand, pools work the following hours:

- Renovation and transmission (24 hours a day, 365 days a year) and radiation (24 hours a day, 362 days a year, 3 days of setting up the pool vessel) are discounted.
- Commissioning: at the end of year 2 a pool filling, as it is the basis of calculation. Year 1 is the initial warming, and the other years, from 2 \*, one will be filled and no.
- Evaporation: only the hours that the center is open (4,888 hours) minus 72 hours of commissioning are considered, because at that time the water will not evaporate, the pools will be covered with a thermal blanket the rest of the hours that the center is not open.

In this way, 907,001.17 kwh would be consumed in the base year (table 4 and table 4.1 complete Appendix 1).

	Installed power (kW)	Total working hours /year	Energy consumption (kWh) annually
<b>Total evaporation power</b>	63.22	4816	304,486.95
<b>Total radiation power</b>	6.62	8,688	57476.09
<b>Convection power</b>	0		
<b>Total power per transmission</b>	13.91	8,760	121,834.08
<b>Total renovation Water power</b>	29.53	8,760	258,718.57
<b>ACS power</b>	71.05	2,115.54	150,309.12
<b>Total system capacity made</b>	196.89	72	14176.36
<b>Total</b>			907,001.17
<b>Saving heat exchanger (Table 4.1)</b>			136,586.72
<b>Total consumed energy with saving exchanger</b>			770,414.45

**Table 4** Summary of power, operating hours and consumed energy in the base year calculation

Source: Self made

To save part of this consumption can be installed heat exchangers that can recover energy from water renewal pools, saving 136,586.72 kwh, being

An annual consumption of 770,414.45 kwh. These consumption will be affected by the performance

Boilers, requiring produce more or less kwh of which will be consumed, depending on whether performance is above or below 100% (Energy production = Consumption / Boiler Performance).

Based on the data obtained so far, the cost of each type of installation, the cost of consumption of each of them and the cost of maintenance will be sized and estimated, to make the financial assessment.

#### 4.2. Results of installation or investment costs, energy or operational costs and maintenance costs

##### Installation or investment costs

Investment costs or installation required to implement each alternative were estimated according to the mentioned methodology.

Based on estimates of industry professionals and catalogs of boilers and solar panels such as the Vaillant catalog or the Herz price generator. A summary of the necessary initial investment or installation costs for each type of alternative listed in Table 5 and detailed estimates are shown in table 5.1

<b>Natural gas (with contribution Solar Required according CTE)</b>	
Natural gas	30971
Solar	93896
<b>Total</b>	<b>124867</b>
<b>Biomass</b>	
Total biomass	113635
Grant Inega	56,818
<b>Total</b>	<b>56,818</b>
<b>Natural gas Solar Voluntary Contribution (plus Required)</b>	
Total Natural Gas	30971
Total Solar	180322
<b>Total</b>	<b>211293</b>
Grant Inega	60,000
<b>Total</b>	<b>151293</b>
<b>Biomass Solar voluntary contribution (equal to mandatory GN)</b>	
Biomass	110135
Solar	93896
<b>Total Solar Biomass</b>	<b>204031</b>
Grant Inega	60,000
<b>Total with Grant Inega</b>	<b>144031</b>

**Table 5** Investment cost or initial cost of each type of facility (€)

Source: Self made

40% of the annual energy demand for Solar Thermal ACS are 60,123.65 kWh and 30% of the annual energy demand for Solar Thermal Pools:

To determine the number of solar panels needed the minimum contribution required by the specified percentages are calculated which are 227,007.61 kWh, but saving heat exchanger are reduced to 90420.89 kWh. With the AuroPro3.0.1 program. Vaillant was calculated that 32 panels for hot water and 97 are needed for pools.

Since heat exchangers are installed in the pools, the document can be reduced HE4 considered mandatory solar minimum thereof, from 30% to 12.37%, and panels 97 to 40, representing a total of 72 solar, with ACS panels.

In addition, taken into account in the cost of facilities, subsidies for renewable energy projects of INEGA (Table 6), which for biomass boilers are of 310 € / kW of installed capacity, with 50% of project cost maximum support (56,818 € maximum) and energy facilities Solar Thermal, for non-mandatory part of the CTE and being combined with conventional energy, 1500 € / kW, with 50% of the project cost and 60,000 € for project maximum support (105,647 and 102,016 € € is 50% in the case of solar thermal systems with more than the minimum required solar panels and maximum subsidized € 60,000).

<b>Biomass subsidy/grant</b>	
<b>Maximum power assistance</b>	<b>Maximum support per project</b>
310 € / kW - (P / 4) for additional power P of 40 kW <P ≤ 440 kW with automatic feeding and accumulation volume fuel V ≥ 250 liters and V <1,000 liters and 50 € / kW if system automatic cleaning exchanger	The aid intensity will be 50%.  The maximum amount of aid per project will be € 60,000.
<b>Solar Thermal Grant</b>	
<b>Maximum power assistance</b>	<b>Maximum support per project</b>
1500 € / kW	The aid intensity will be 50%. The maximum amount of aid per project will be € 60,000.

**Table 6** INEGA subsidies for renewable energy  
Source: Self made

Installation alternatives contemplated are therefore:

- Natural Gas facility that will comply A Natural Gas facility installation that will comply with the mandatory solar minimum including 71 panels and will not have any subsidy.
- An installation exclusively of Biomass, with a subsidy of € 56,818.
- A solar installation combined with Natural Gas, with solar input higher than the mandatory one (51% to SHW and 31% to swimming pool), 142 panels, 71 volunteers, with a subsidy of € 60,000.
- And a Solar installation combined with Biomass in which the minimum amount required for conventional energy will be taken as a voluntary solar contribution, with a subsidy of € 60,000.

According to the installation costs (table 5 and table 5.1 Appendix 1) without taking into account the subsidies, the installation that requires a smaller investment is the “Biomass” installation (€ 113,635) followed by “Natural Gas” (€ 124,867), “Solar combined with Biomass” (€ 204,031) and “Solar combined with Natural Gas” (€ 211,293).

If there is no obligation for the CTE to install a minimum of solar panels when conventional energy is used, the “Natural Gas” installation would be the one that would have the lowest investment costs (€ 30,971), but this option has not been realizable since 2006.

Taking into account subsidies, the “Biomass” installation would continue to have the lowest price (€ 56,818) and the Solar combined with other energies could be interesting, since its cost is reduced by almost a third of the value without subsidy and they are the alternatives with the highest solar input. In principle, if we only based the analysis on the cost of the investment (CAPEX or Capital Expenditure), the most economical installation would be the “Biomass”.

However, it should be seen if it compensates for a larger investment depending on whether in the long term it allows reducing the costs of energy consumption and even other operating expenses (OPEX or Operational Expenditure), for example, the annual maintenance of facilities, before settling on one considering only the investment. In this case, they consider disbursements arising from operating expenses.

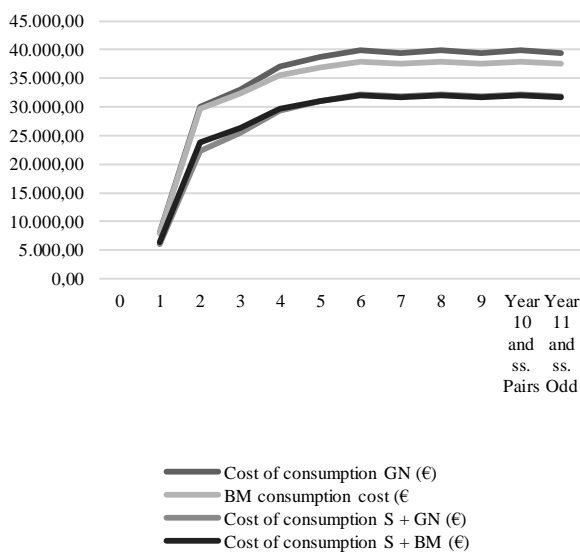
### Energy costs

To determine energy costs indicated methodology was followed. These costs for the base year calculation, are shown in Table 7 and Table 7.1 of Annex 1 of more detailed and disaggregated form. Accordingly, the facility would consume less "Solar with Natural Gas", with a cost of € 22,327.87 in the base year, very close to the running costs of the "Solar Biomass" installation.

	<b>Natural gas</b>
<b>Annual Natural Gas Cost</b>	<b>29,966.30 €</b>
	<b>Biomass</b>
<b>Annual cost Biomass</b>	<b>29,739.65 €</b>
	<b>Solar combined</b>
	<b>Solar with Natural Gas</b>
<b>Annual cost Solar + Natural Gas (€)</b>	<b>22,327.87 €</b>
	<b>Solar Biomass</b>
<b>Solar + Biomass annual cost (€)</b>	<b>23,854.95 €</b>

**Table 7** Energy costs of each type of facility  
Source: Self made

This is due to the fact that the solar contribution is high, exceeding the mandatory minimum, and that the Natural Gas condensing boilers have a higher yield than those of Biomass. The installation with the highest consumption costs is “Natural Gas” (€ 29,966.30) because the mandatory solar contribution does not mean considerable savings, followed by the installation of biomass (€ 29,739.65), which despite being the most energy must produce has a cheaper fuel than natural gas, so it might be interesting, knowing that over the years the influx of people will increase and, therefore, the energy to be produced. Therefore, although in terms of installation costs, “Biomass” would be the option with the lowest investment, at the level of consumption costs, for this company, the most appropriate would be the “Solar with Natural Gas” installation, if its high installation costs are amortized (figure 1). This will be seen in the NPV analysis.



**Graphic 1** Consumption costs of each type of facility (€)  
Source: Self made

**Maintenance costs**

They were calculated according to the methodology discussed. There are, on the one hand, common costs for any of the alternatives analyzed, some of which, such as costs of mechanical maintenance, daily operations temperature control of deposits and pool and corrective operations for assistance or unforeseen will be given by the cost / hour of the necessary personnel and for the hours that they are in the center and on the other hand, chemical maintenance costs, have a fixed price.

A major in the installation of biomass will have to be a person in charge of removing the fuel ashes weekly and it will be carried out in the thermal solar a monitoring plan (cleaning of panels and control of collectors and circuits) and maintenance of the accumulation and exchange systems, hydraulic circuit and electrical system that were estimated at 1.400 € / year for installation "Natural Gas" and 2.775 € / year for "Solar with Natural Gas" on the grounds that the maintenance cost of solar panels is 8.3 € / m2 installation (25 € / h would mean 56 and 111 hours per year, respectively). The overall maintenance costs are shown in Table 8 and shown in Table 8.1 of Annex 1

	<b>Natural gas (NG)</b>	<b>Biomass (BM)</b>	<b>Solar + GN</b>	<b>Solar + BM</b>
<b>Annual maintenance</b>	33,650	33,550	35,025	34,950

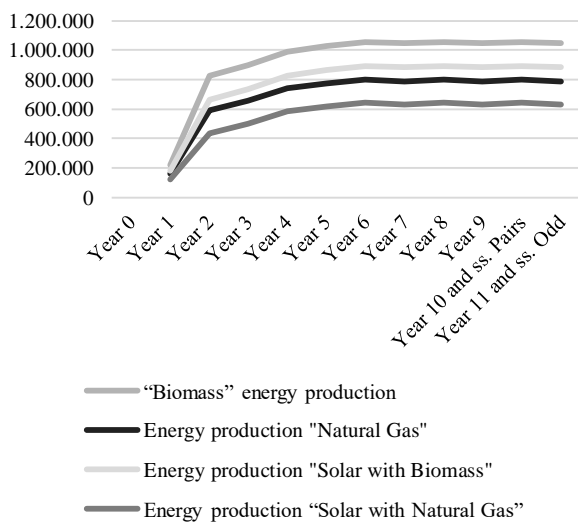
**Table 8** Maintenance costs of each type of installation base year (€)  
Source: Self made

According to these costs, the “Solar with Natural Gas” installation is the one with highest maintenance costs, compared to “Biomass”, the most economical. It remains to be seen whether the increased investment and maintenance costs of the "Solar with Natural Gas" installation are assumable to compensate with lower consumption cost.

**4.3. VAN analysis**

To estimate the VPN, the commented methodology and the formula included in table 9 Appendix 1 First, before applying the NPV, energy consumption (kwh) and the production of energy required was estimated to cover the claimed consumption depending on the performance of each type of installation.

During a time horizon of 20 years as the average useful life of the facilities (Figure 2 and table 10 Appendix 1), applying the percentages of growth for SHW discussed in the methodology (50% year 3, year 33% 4 15% 5% 5 year year 6). From year 6, the consumption of SHW number of users, and to make visual tables, columns 12 to 20 were removed, and put “10 and following (ss ) pairs” and “11 and following (ss)”, understanding that there would be the same consumption alternately.



**Graphic 2** Energy production of each type of installation (kWh)  
Source: Self made

After the first filling swimming pools in October of 1 (opening) and filling of year 2 (calculation basis) only complete pools will be emptied when required repairs, and is usually emptied only a portion for minor repairs. As the business-case is a benchmark of quality and to anticipate potential repairs it was considered a commissioning every two years. The years when the pools are not empty, should take into account evaporation losses and radiation 72 hours excluded in the years that emptied itself. The annual energy consumption results are those listed in table 10 Appendix 1, ranging between € 203,127 and a maximum of 982,194 in the 20 years considered. They suppose an increasing consumption until year 6, from which there will be only small declines in the years when the pools are not emptied.

Based on the above data, and taking into account the performance of each type of boiler, energy producing and energy costs for each type of installation were calculated.

By adding the maintenance costs (equal for all years), the total annual costs of each installation were obtained. The total and disaggregated costs are shown in Tables 10.1 (Natural Gas), 10.2 (Biomass), 10.3 (Solar with Natural Gas) and 10.4 (Solar with Biomass) of Appendix 1.

From the initial investment and total costs, all negative as disbursements, the updated cash flows were obtained at 8.40% (discount rate according to the WACC formula). And by adding the discounted cash flows of each installation, the npvs of each of them were obtained. And by adding the discounted cash flows of each facility the NPV of each were obtained. In Tables 10.1, 10.2, 10.3 and 10.4 APPENDIX 1 all cash flows data that serve as the basis for calculations of VPN and Table 11 below, the results are collected.

	Value (€)
NPV Natural Gas	755,418.55
NPV Biomass	672,403.49
Solar NPV with Natural Gas	726,471.05
NPV Solar Biomass	719,968.79

**Table 11** NPV values  
Source: Self made

As shown in the above table, the NPV of greater value is the installation "Biomass" (€ 672,403.49). Therefore, this type of installation will be the most convenient and profitable for the company. It is because, although "Biomass" has a low energy consumption slightly lower than "Natural Gas" and higher than the installations with voluntary solar contribution ("Solar with Natural Gas" and "Solar with Biomass"), these energy costs are compensated with an initial investment and with lower maintenance costs than other types of installation, due in large part to subsidies that considerably reduce their installation costs (Table 10.2 Appendix 1). Even if a higher pellet cost (€ 0.0366 / kwh of the certified category A1 was used instead of the € 0.0359 / kwh used as the average price) and gave a higher energy cost in the base year (30,319 , € 54 versus € 29,737.2), the NPV would remain the highest (-678,623.1 €), compensating to spend a little more on the cost of producing energy than investing a very large amount in hybrid solar installations, since which will mean lower consumption and lower cash flows (tables 10.3 and 10.4 Appendix 1) but not enough to make the initial outlay better than "Biomass".

The VPN closest to that of “Biomass” is that of “Solar with Biomass”. Keep in mind that this installation has higher cash flows and therefore less costs, a difference that will be reduced over time, as it will increase the consumption of SHW with the influx of people, so that the difference will be reduced, and it presents a higher initial outlay and higher maintenance costs (table 10.4 APPENDIX 1). The way to finance the installation, except for subsidies, was not taken into account in the VPN analysis in order to see the VPN of the project itself.

#### 4.4. Environmental impact

As mentioned, and according to the criteria of the Practical Guide for calculating emissions of greenhouse gases (ghgs) (Generalitat de Catalunya, 2011), it is considered that biomass and solar energy does not produce CO<sub>2</sub> emissions at their stage of consumption, or they are hardly significant. However, natural gas does (2.15 kg / Nm<sup>3</sup> emissions of CO<sub>2</sub>, considering that each represents 1 kwh Nm<sup>3</sup> / 10.65 kwh (Generalitat de Catalunya, 2011)). Therefore, the most sustainable installations would be those that use biomass (exclusively or combined with solar energy), followed by installations that use natural gas (combined with more solar energy than the mandatory or compulsory).

The implementation of the “Biomass” installation, the most appropriate for the business-case according to the financial feasibility analysis, is a neutral issue and, as can be seen in table 12 of APPENDIX 1, when opting for the installation “ Biomass ”against“ Natural Gas with Solar ”, it is avoided to emit between 24,131.28 kg and 129,463, 92 kg of CO<sub>2</sub> per year (minimum and maximum estimates) a and against the installation“ Natural Gas” it is avoided to emit between 32,031.77 and 161,065.48 kg kg of CO<sub>2</sub> per year (minimum and maximum estimates). It is seen, therefore, that the installation "Biomass" pollutes less.

If CO<sub>2</sub> emissions are valued economically according to the European Investment Bank (2013) method with a central estimate of the associated damage, it is obtained that they would be equal to 25 + (2018 - 2010) = € 33 / t CO<sub>2</sub>.

Knowing this, the external environmental costs could be calculated by multiplying this figure by the CO<sub>2</sub> emissions obtained in Table 13. As it has been seen, only the installations with Natural Gas will suppose emissions in the consumption stage, therefore, they will be the only ones that add external costs and the only ones that suffer modifications in their VPN that will suppose more negative flows (tables 14.1 and 14.2 of Appendix 1). According to this, the NPV of the “Natural Gas” and “Solar with Natural Gas” installation will be more negative and will continue to be lower than those of “Biomass” and “Solar with Biomass” (table 14). The installation chosen according to these NPV would continue to be “Biomass”.

	Value (€)
NPV Natural Gas	-799,717.13
NPV Biomass	672,403.49
Solar NPV with Natural Gas	761549.2
NPV Solar Biomass	719,968.79

**Table 14** NPV values of external costs emCO<sub>2</sub> issions  
Source: Self made

The implementation of the “Biomass” installation will mean environmental advantages for the business-case such as:

- Optimal implementation of Corporate Social Responsibility (CSR), and to be aware for the proper performance of their activities
- A competitive advantage oriented towards sustainable development by following an environmentally friendly energy management
- Reducing pollutant emissions as fuels such as natural gas are composed of different harmful gases and by opting for biomass, less pollution is created.

However, despite this study focuses on emissions and environmental impact of the consumption stage, you should be aware that the environmental impact goes beyond and encompasses the entire life cycle of the fuel or power source (LCA) to be used. So, taking the account the whole life cycle, biomass could have some negative impact on the environment and be more sustainable hybrid installation "Solar with biomasa".

## Conclusions

Based on the above, and the present case, it could be concluded that the "biomass" installation is the most appropriate because:

- It has the highest NPV of options analyzed.
- Although the costs of energy consumption of hybrid installations "Solar with Natural Gas" and "Solar Biomass" are lower than those of "biomass", the high investments required by these installations are not offset by their costs of energy consumption or maintenance costs.

The study was based mainly on financial issues and environmental impacts in the consumption stage. Between "Biomass" exclusively or "Solar Biomass", the first option is the best financially, because, even if it has a higher consumption, it would be compensated with the reduced investment that it requires in front of a hybrid installation. Therefore, the "Biomass" installation would be the chosen one, since it requires less initial outlay than the other installations and, in addition, has reduced maintenance costs.

For future studies would be interesting to note if under different circumstances, such as other characteristics of the subsidies, applying another type of analysis, including risk factors or uncertainties or considering alternative installation of hot water and pool heating, the option of "biomass" would remain the most appropriate or optimal. Some methods to include risk considerations in the analysis could be to add a risk factor in the discount rate or to quantify the uncertainty through sensitivity analysis to present a range of possible outcomes varying assumptions of risk (Galán, Gonzalez Leal & Varela, 1999).

At the environmental level, the consumption stage in which it has based the study, "Biomass" would also be the option chosen. However, it might be interesting to note the benefits of the hybrid system, combining two sources of renewable energy: solar and biomass.

In principle, both have less harmful emissions for the environment than the "Natural Gas" and "Solar with Natural Gas" installations but we see that "Biomass" has a greater need to produce more kwh of energy, not covered by solar contribution (table 12 Appendix 1).

In addition, although emissions at the consumption stage are neutral, they are not in the rest of the life cycle of the energy source therefore it could also be interesting to apply and study the usefulness of operational improvements in managing demand hot water needed to reduce consumption and analyze the environmental impact not only taking into account the emissions generated in the consumption phase, but throughout the life cycle because, in that case, the alternative choice might be different. A more sustainable option in this regard, which incorporates all externalities and environmental impact, despite assuming a higher investment cost, could be the "Solar with Biomass" alternative because with the solar contribution the saving in energy use would reduce the impact environmental, preserving non-renewable resources, avoiding the generation of more energy, not requiring the consumption of so many pellets and reducing the carbon footprint.

In short, implementing installations in which renewable energy and sustainability prevail will help companies to differentiate themselves, as actions that affect their corporate social responsibility associated with the conservation of the environment, taking into account not only growth and economic savings but also the social and environmental impact (Martí, 2012). Betting on energy such as biomass, solar or combined in hybrid systems, can be positive since it contributes to greater long-term economic savings and lower emissions in the energy consumption stage, but we must move forward to take into account not only economic and environmental aspects impact on the consumption stage, but in general

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## Appendix 1

Swimming courses	Sessions / week	Users / session	User / month
Type 1	29	5	580
type 2	18	10	720
type 3	12	240	960
type 4	40	8	1280
Total	107		3,540
<b>40% Year 2</b>			<b>1,416</b>
Racket courses	Grades 1 h /week	Users / course	User / month
Tennis	8	two	64
paddle	12	4	192
Total	twenty	6	256
<b>40% Year 2</b>			<b>102</b>
Arts courses	Sessions / week	users	users
marial		/session	/month
Total	twenty-one	twenty	1680
<b>40% Year 2</b>			<b>672</b>
		<b>User / month</b>	
Tracks		<b>158</b>	
		<b>User / month</b>	
Free admission		<b>10</b>	
		<b>User / month</b>	
Swimming pool		<b>1,200</b>	
		<b>User / month</b>	
fitness		<b>5,300</b>	
Guided activities	Weekly sessions 1 h	users /session	users / Month
room 1	16	17	1,088
room 2	37	17	2,516
room 3	40	17	2,720
room 4	40	17	2,720
Total			9,044
<b>40% Year 2</b>			<b>3617.6</b>
<b>Total Monthly Uses</b>			<b>12,476</b>

**Table 2.1** Monthly Inflow in Year 2 with 40% coverage of the maximum number of people and 100% of the inflow to the center.

Source: Self made

Year 2	Uses / Month	January	February	March	April	May	June
<b>Influx to the Sports Center</b>	<b>100%</b>	<b>80%</b>	<b>90%</b>	<b>90%</b>	<b>100%</b>	<b>100%</b>	<b>90%</b>
<i>courses</i>	2,190	1,752	1,971	1,971	2,190	2,190	1,971
<i>Tracks</i>	158	126	142	142	158	158	142
<i>Free admission</i>	10	8	9	9	10	10	9
<i>Swimming pool</i>	1,200	960	1,080	1,080	1,200	1,200	1,080
<i>fitness</i>	5,300	4,240	4,770	4,770	5,300	5,300	4,770
<i>Rooms</i>	3,618	2,894	3,256	3,256	3,618	3,618	3,256
<b>TOTAL (Users)</b>	<b>12,476</b>	<b>9,981</b>	<b>11,228</b>	<b>11,228</b>	<b>12,476</b>	<b>12,476</b>	<b>11,228</b>
Year 2	Uses / month	July	August	September	October	November	December
<b>Influx to the Sports Center</b>	<b>100%</b>	<b>70%</b>	<b>40%</b>	<b>80%</b>	<b>90%</b>	<b>100%</b>	<b>80%</b>
<i>courses</i>	2,190	1,533	876	1,752	1,971	2,190	1,752
<i>Tracks</i>	158	111	63	126	142	158	126
<i>Free admission</i>	10	7	4	8	9	10	8
<i>Swimming pool</i>	1,200	840	480	960	1,080	1,200	960
<i>fitness</i>	5,300	3,710	2,120	4,240	4,770	5,300	4,240
<i>Rooms</i>	3,618	2,533	1,447	2,894	3,256	3,618	2,894
<b>TOTAL (Users)</b>	<b>12,476</b>	<b>8,733</b>	<b>4,990</b>	<b>9,981</b>	<b>11,228</b>	<b>12,476</b>	<b>9,981</b>

**Table 2.2** Monthly Inflow Year 2 as percentages of affluence center

Source: Self made

	Installed power (kW)	Operating hours per day	Days a year	Total hours / year	Energy consumption (kWh) annually
<b>Total evaporation power</b>	<b>63.22</b>			<b>4816</b>	<b>304,486.95</b>
<i>pool 1</i>	44.66	-	-	4816	215,060.72
<i>pool 2</i>	18.57			4816	89426.23
<b>Total radiation power</b>	<b>6.62</b>	<b>24</b>	<b>362</b>	<b>8,688</b>	<b>57476.09</b>
<i>pool 1</i>	5.38	24	362	8,688	46751.63
<i>pool 2</i>	1.23	24	362	8,688	10724.46
<b>Convection power</b>	<b>0</b>	<b>-</b>	<b>-</b>		
<b>Total power per transmission</b>	<b>13.91</b>	<b>24</b>	<b>365</b>	<b>8,760</b>	<b>121,834.08</b>
<i>pool 1</i>	11.1	24	365	8,760	97236.00
<i>pool 2</i>	2.81	24	365	8,760	24598.08
<b>Total renovation Water power</b>	<b>29.53</b>	<b>24</b>	<b>365</b>	<b>8,760</b>	<b>258,718.57</b>
<i>pool 1</i>	25.68	24	365	8,760	224,931.25
<i>pool 2</i>	3.86	24	365	8,760	33787.32
<b>ACS power</b>	<b>71.05</b>	<b>5.8</b>	<b>365</b>	<b>2,115.54</b>	<b>150,309.12</b>
<b>Total system capacity made</b>	<b>196.89</b>			<b>72</b>	<b>14176.36</b>
<i>pool 1</i>	171.18			72	12325.00
<i>pool 2</i>	25.71			72	1,851.36
<b>TOTAL</b>					<b>907,001.17</b>
<i>Saving heat exchanger (Table 46.1)</i>					<b>136,586.72</b>
<b>TOTAL saving exchanger</b>					<b>770,414.45</b>

(\*) Note: For calculations used the unrounded values of the powers.

**Table 4.1** Power, operating hours per day, days per year and energy consumed in the base year calculation

<b>Natural gas (with contribution Solar Required according CTE)</b>			
You	Concept	€ / ud.	Total
<i>one</i>	300 kW boiler	17,000	17,000
<i>32</i>	Solar panels for ACS minimum	778	24,896
<i>39</i>	Minimum Solar panels for pool	778	30342
<i>36</i>	Support for 2 panels	109	3,924
<i>two</i>	Accumulator 2500 liters	5,772	11,544
<i>one</i>	Accumulator 1500 liters	4,362	4,362
<i>one</i>	Heat exchangers water-water	2,049	2,049
<i>one</i>	hydraulic equipment	6,000	6,000
<i>one</i>	Electric material	4,500	4,500
<i>one</i>	Isolating material	4000	4000
<i>one</i>	Labor and commissioning	12,000	12,000
<i>one</i>	Transportation to work	4,250	4,250
	Natural gas		30971
	Solar		93896
	<b>Total</b>		<b>124867</b>
<b>Biomass</b>			
You	Concept	€ / ud.	Total
<i>one</i>	300 kW boiler	55510	55510
<i>one</i>	Accumulator 2500 liters	5,772	5,772
<i>one</i>	Fuel storage silo	17,500	17,500
<i>one</i>	Heat exchangers water-water	2,049	2,049
<i>one</i>	hydraulic equipment	4,628	4,628
<i>one</i>	Electric material	2500	2,500
<i>one</i>	Gas cleaning system with insulation	7153	7,153
<i>one</i>	Power system	5563	5,563
<i>one</i>	Automatic discharge device ash and ash deposit	5160	5,160
<i>one</i>	Construction and commissioning	6000	6,000
<i>one</i>	Transportation to work	1800	1,800
	Total biomass		113635
	Grant Inega		56,818
	<b>Total</b>		<b>56,818</b>
<b>Natural gas Solar Voluntary Contribution (plus Required)</b>			
You	Concept	€ / ud.	Total
<i>40</i>	Solar panels for ACS	778	31,120
<i>102</i>	Solar panels for pool	778	79356
<i>71</i>	Support for 2 panels	109	7,739
<i>one</i>	300 kw Natural gas boiler	17,000	17,000
<i>3</i>	Accumulator 2500 liters	5,772	17,316
<i>one</i>	Accumulator 300 liters	1,363	1,363
<i>one</i>	Heat exchangers water-water	2,049	2,049
<i>one</i>	hydraulic equipment	10,800	10,800
<i>one</i>	Electric material	8,100	8,100
<i>one</i>	Isolating material	7,200	7,200
<i>one</i>	Labor and commissioning	21,600	21,600
<i>one</i>	Transportation to work	7,650	7,650
	Total Natural Gas		30971
	Total Solar		180322
	<b>Total</b>		<b>211293</b>
	grant Inega		60,000
	<b>Total</b>		<b>151293</b>
<b>Biomass Solar voluntary contribution (equal to mandatory GN)</b>			
You	Concept	€ / ud.	Total
<i>71</i>	Solar panels for ACS	778	55238
<i>36</i>	Support for two panels	109	3,924
<i>one</i>	300 kw Biomass boiler Policombustible	55510	55510
<i>two</i>	Accumulator 2500 liters	5,772	11,544
<i>one</i>	Accumulator 1500 liters	4,362	4,362
<i>one</i>	Fuel storage silo	14,000	14,000
<i>one</i>	Heat exchangers water-water	2,049	2,049
<i>one</i>	Gas cleaning system with insulation	7,153	7,153
<i>one</i>	Power system	5,563	5,563
<i>one</i>	Automatic discharge device ash and ash deposit	5,160	5,160
<i>one</i>	hydraulic equipment	9,428	9,428
<i>one</i>	Electric material	6,100	6,100
<i>one</i>	Isolating material	3,200	3,200
<i>one</i>	Construction and commissioning	15,600	15,600
<i>one</i>	Transportation to work	5,200	5,200
	biomass		110135
	Solar		93896
	<b>TOTAL Biomass</b>		<b>204031</b>
	grant Inega		60,000
	<b>TOTAL with Grant Inega</b>		<b>144031</b>

**Table 5** Cost of each type of installation

	Natural gas
Annual energy consumption SAVINGS exchanger (kWh)	770,414.45
Solar minimum mandatory contribution to ACS (40%) and pools (12%) (kWh)	152,444.87
boiler Natural gas consumption (kWh)	617,969.58
to produce actual boiler efficiency 104% energy (kWh)	594,201.52
Price Natural Gas (€ / kWh)	0.048796
fixed monthly cost	80.97
Annual Natural Gas Cost	29,966.30 €
	biomass
Annual energy consumption savings exchanger (kWh)	770,414.45
Energy to produce 93% boiler efficiency (kWh)	828,402.63
Pellets Bulk price (€ / kWh)	0.0359
Annual cost Biomass	29,739.65 €
	Solar combined
Annual energy consumption savings exchanger (kWh)	770,414.45
	Solar with Natural Gas
Solar Mandatory contribution to ACS (40%) and Pool (12%) (kWh)	152,444.87
Solar Voluntary contribution to ACS (10%) and Pool (20%) (kWh)	162,799.49
Boiler Natural gas consumption (kWh)	455,170.09
To produce actual boiler efficiency 104% energy	437,663.55
Price Natural Gas (€ / kWh)	0.048796
fixed monthly cost	80.97
Annual cost Solar + Natural Gas (€)	22,327.87 €
	Solar Biomass
Solar Voluntary contribution to ACS (40%) and swimming pool (30%) (kWh)	152,444.87
Biomass boiler consumption (kWh)	617,969.58
to produce actual boiler efficiency 93% energy	664,483.42
Pellets Bulk price (€ / kWh)	0.0359
Solar + Biomass annual cost (€)	23,854.95 €

Table 7.1 Energy costs of each type of facility

	Natural gas (NG)	Biomass (NM)	Solar + GN	Solar + BM
Annual maintenance	33,650.00 €	33,550 €	35,025	34,950

Concept	Working h / year	€ / h	€ per year
Monthly Preventative operations	120	25	3,000
Daily operations	730	25	18,250
Corrective operations	200	25	5,000
Common mechanical maintenance (1)	1050	25	26,250
Maintenance Chemical (2)			6,000
Biomass weekly Ash Removal (3)	52	25	1,300
Thermal Solar: Maintenance panels (4)	56	25	1400
Thermal Solar: Maintenance panels (5)	111	25	2,775

Maintenance cost of Natural Gas: (1) + (2) + (4)  
 Biomass maintenance cost: (1) + (2) + (3)  
 Maintenance Cost Solar Natural Gas: (1) + (2) + (5)  
 Solar maintenance cost Biomass: (1) + (2) + (3) + (4)

Table 8.1 Maintenance costs of each type of installation base year

$$VAN = \sum_{t=1}^n \frac{V_t}{(1+k)^t} - I_0$$

Where

Vt: Cash Flow represents in each period t.  
 I0: The value of the initial investment outlay (year 0)  
 Nt: the number of periods considered.  
 K: Is the discount rate = 8.40% = WACC (Weighted Average Cost of Capital)

$$WACC(cpp) = K_e \frac{CAA}{CAA + D} + K_d(1 - T) \frac{D}{CAA + D}$$

Where:

WACC: 8.40%

Ke: Rate opportunity cost of shareholders (must be greater than Kd)

CAA: Capital contributed by shareholders for the establishment of sports center

D: outstanding indebtedness

kd: Cost of financial debt (having various types was a weighted average)

T: Tax rate

CAA	2,340,000 €	.5526	CAA / (CAA + D)
D	1,894,635 €	.4474	D / (D + CAA)
T	0.25	0.0604 (1)	Ke * CAA / (CAA + D)
Ke	10.93%	0.0236 (2)	Kd * (D / D + CAA) * (1-T)
kd	7.03%	8.40%	(1) + (2) = WACC

Table 9 Formula NPV and WACC

	Energy production "Solar with Natural Gas" (Yield 104%) = (3) / 1.04	Energy consumption / year with higher solar contribution CTE (3)	Energy production "Solar Biomass" (yield 0.93%) = (2) / 0.93	Energy production "Natural Gas" (Rendimiento 04%) = (2) / 1.04	Energy consumption / year solar contribution CTE (2)	Energy production "Biomass" (Yield 93%) = (1) / 0.93	Energy consumption / year (1)	year 0
	119534	124316	177436	158669	165015	218416	203127	Year 1
	437663	455170	664483	594201	617969	828402	770414	year 2
	501131	521176	735458	657669	683976	899377	836421	year 3
	581469	604727	825298	738007	767527	989217	919972	year 4
	615922	640559	863827	772460	803359	1027746	955804	year 5
	641298	666950	892204	797836	829749	1056123	982,194.00	year 6
	632502	657802	882367	789040	820601	1046286	973046	year 7
	641298	666950	892204	797836	829749	1056123	982194	year 8
	632502	657802	882367	789040	820601	1046286	973046	year 9
	641298	666950	892204	797836	829749	1056123	982194	Year 10 et seq. pairs
	632502	657802	882367	789040	820,601.60	1046286	973046	Year 11 et seq. Impares

**Table 10** Summary of energy consumption (kWh) for each type of installation and cash flows to calculate the NPV

= Cash flows (7) * (1 + WACC) ^ n - (year)	Cash Flow GN = (7) = (4) + (5) + (6)	initial outlay (6)	Maintenance costs (€) (5)	Monthly Fixed Cost (€) (3)			Energy consumption per year (kWh) (1)
				Consumption cost (€) = (4) = (1) * (2) + (3) months a year *	Natural Gas Cost (€ / kWh) (2)	Energy consumption per year (kWh) (1)	
124867	124867	124867					0
15127.10	16397.80		8,412.50	7,985.30		158669	one
54138.90	63616.30		33650.00	29966.30		594201	two
52375.00	66713.30		33650.00	33063.30		657669	3
51155.60	70633.40		33650.00	36983.40		738007	4
48314.80	72314.60		33650.00	38664.60	0,048796	772461	5
45334.00	73552.80		33650.00	39902.80	80,97	797836	6
41577.00	73123.60		33650.00	39473.60		789040	7
38580.30	73552.80		33650.00	39902.80		797836	8
35383.00	73123.60		33650.00	39473.60		789040	9
32832.70	73552.80		33650.00	39902.80		797836	Year 10 et seq. pairs
30111.70	73123.60		33650.00	39473.60		789040	Year 11 et seq. Impares

**Table 10.1** Summary of total costs (€) broken down for installation of Natural Gas and cash flows to calculate the NPV

$= \text{Cash flows } (6) * (1 + \text{WACC})^n - (\text{year})$	Cash Flow BM = (6) = (3) + (4) + (5)	initial outlay (5)	Maintenance costs (€) (4)	Consumption cost (€) = (1) * (2)	pellets cost (€ / kwh) (2)	Energy consumption per year (kWh) (1)
56818	56818	56.818			0	0
14971.10	16228.60		8,387.50	7,841.10	0.0359	218416
53861	63289.70		33550.00	29739.70	0.0359	828402
51687	65837.70		33550.00	32287.70	0.0359	899377
50018.20	69062.90		33550.00	35512.90	0.0359	989217
47066.30	70446.10		33550.00	36896.10	0.0359	1027746
44047.00	71464.80		33550.00	37914.80	0.0359	1056123
40433.00	71111.70		33550.00	37561.70	0.0359	1046286
37485.00	71464.80		33550.00	37914.80	0.0359	1056123
34409.40	71111.70		33550.00	37561.70	0.0359	1046286
31900.60	71465		33550.00	37914.80	0.0359	1056123
29283	71111.70		33,550	37561.70	0.0359	1046286

**Table 10.2** Summary of total costs (€) for installation of biomass breakdown and cash flows to calculate the NPV

$= \text{Cash flows } (7) * (1 + \text{WACC})^n - (\text{year})$	Cash Flow S + GN = (7) = (4) + (5) + (6)	initial outlay (6)	Maintenance costs (€) (5)	Consumption cost (€) = (4) = (1) * (2) + (3) months a year *	Months a year	Monthly Fixed Cost (€) (3)	Natural Gas Cost (€ / kwh) (2)	Energy consumption per year (kWh) (1)
151293	151293	151293	0				0	0
13682.60	14832.00		8,756	6,075.70	3	80.97		119534.5
48808.60	57352.90		35,025	22327.90	12	80.97		437663.6
47457.80	60449.90		35,025	25424.90	12	80.97		501131.5
46619	64370		35,025	29345.00	12	80.97		581468.9
44130	66051.20		35,025	31026.20	12	80.97		615922.8
41473	67289		35,025	32264.40	12	80.97	0.048796	641298.1
38015	66860		35,025	31835.20	12	80.97		632502.0
35294.90	67289.40		35,025	32264.40	12	80.97		641298.1
32352.20	66860.20		35,025	31835.20	12	80.97		632502.0
30036	67289		35,025	32,264	12	80.97		641298.1
27532.50	66860.20		35,025	31835.20	12	80.97		632502.0

**Table 10.3** Summary of total costs (€) disaggregated Solar Installation with Natural Gas and cash flows to calculate the NPV

$= \text{Cash flows (6)} * (I) + \text{WACC} * (year)$	$\text{Cash Flow S} + \text{BM} = (6)$	$\text{initial outlay (5)}$	$\text{Maintenance costs (4)}$	$\text{Consumption cost (3)} = (I) * (2)$	$\text{pellets cost (€ / kWh) (2)}$	$\text{Energy consumption per year (kWh) (1)}$
144031	144031	144031			0.0366	0
13936.80	15107.50		8,737.50	6,370.00	0.0359	one
50044.40	58805.00		34950.00	23855.00	0.0359	two
48166.80	61353.00		34950.00	26403.00	0.0359	3
46770.20	64578.20		34950.00	29628.20	0.0359	4
44070.00	65961.40		34950.00	31011.40	0.0359	5
41282.90	66980.10		34950.00	32030.10	0.0359	6
37883.10	66627.00		34950.00	31677.00	0.0359	7
32239.40	66627.00		34950.00	32030.10	0.0359	8
29898.80	66980.10		34950.00	31677.00	0.0359	9
27436.50	66627.00		34950.00	32030.10	0.0359	Year 10 et seq. pairs
				31677.00	0.0359	Year 11 et seq. Impaires

**Table 10.4** Summary of total costs (€) broken down for installation of Solar Biomass and cash flows to calculate the NPV

$\text{CO}_2 \text{ emissions kg (2.15 kg / Nm}^3\text{) for "Solar with Natural Gas"}$	$\text{Natural gas m}^3\text{/year "Solar with Natural Gas" solar contribution greater than CTE = Nm}^3\text{/10.65 kWh}$	$\text{Energy production "Solar Biomass" (Yield 10.9% solar contribution greater than CTE kWh) (2)}$	$\text{Em kgCO}_2 \text{issions "Solar Biomass" (Zero emission factor)}$	$\text{Energy production "Solar Biomass" (Yield 0.93% solar contribution CTE)}$	$\text{CO}_2 \text{ emissions kg (2.15 kg / Nm}^3\text{) for "Natural Gas"}$	$\text{Natural gas m}^3\text{/year "Natural Gas" solar contribution kWh CTE = (1) * 1 Nm}^3\text{/10.65 kWh}$	$\text{Energy production "Natural Gas" (Rendimiento 10.4% kWh) (1)}$	$\text{Em kgCO}_2 \text{issions "Biomass" (Zero emission factor)}$	$\text{Energy production "Biomass" (93% yield)}$
2413.28	11223.85	119534	0	177436	32031.77	14898.5	158669	0	year 0
88354.50	41095.12	437663	0	664483	119956	55793.52	594201	0	Year 1
101,167.29	47054.55	501131	0	735458	132,768.86	61752.95	657669	0	year 2
117,385.76	54598.03	581469	0	825298	148,987.33	69296.43	738007	0	year 3
124,341.06	57833.05	615922	0	863827	155,942.63	72531.45	772460	0	year 4
129,463.92	60215.77	641298	0	892204	161,065.48	74914.17	797836	0	year 5
127,688.20	59389.86	632502	0	882367	159,289.76	74088.26	789040	0	year 6
129,463.92	60215.77	641298	0	892204	161,065.48	74914.17	797836	0	year 7
127,688.20	59389.86	632502	0	882367	159,289.76	74088.26	789040	0	year 8
129,463.92	60215.77	641298	0	892204	161,065.48	74914.18	797836	0	year 9
127,688.20	59389.86	632502	0	882367	159,289.76	74088.26	789040	0	Year 10 et seq. pairs
									Year 11 et seq. Impaires

**Table 12** Consumos energy (kWh) estimated for each type of installation based on what is necessary to produce and CO2 emissions generated



	€ Economic value of CO2 emissions $t^* = 25 + 18 \text{ EUR} / t$ "Solar with Natural Gas"	CO2 emissions kg (2-15) kg / (Nm3) for "Solar with Natural Gas"	€ Economic value of CO2 emissions $t^* = 25 + 18 \text{ EUR} / t$ "Natural Gas"	CO2 emissions kg (2-15) kg / (Nm3) for "Natural Gas"	year 0
	-796.33	2413.28	1,057.05	32031.77	Year 1
	2,915.70	88354.50	3,958.55	1199.56	year 2
	3,338.52	101,167.29	4,381.37	132,768.86	year 3
	3,873.73	117,385.76	4,916.58	148,987.33	year 4
	4,103.25	124,341.06	5,146.11	155,942.63	year 5
	4,272.31	129,463.92	5,315.16	161,065.48	year 6
	4,213.71	127,688.20	5,256.56	159,289.76	year 7
	4,272.31	129,463.92	5,315.16	161,065.48	year 8
	4,213.71	127,688.20	5,256.56	159,289.76	year 9
	4,272.31	129,463.92	5,315.16	161,065.48	Year 10 et seq. pairs
	4,213.71	127,688.20	5,256.56	159,289.76	Year 11 et seq. Impares

**Table 13** Economic value (€) CO2 emissions at the consumption stage (external costs)

	They are "Natural Gas" external costs CO2	Discounted cash flow = (3) $*(1 + \text{WACC})^{-n} \cdot (\text{year})$	Cash Flow GN = (1) + (2) = (3)	Discounted cash flow = (2) $*(1 + \text{WACC})^{-n} \cdot (\text{year})$	Cash Flow GN (2)	CO2 external costs (€) (1)
799717.1	124867	124867	124867	124867	124867	0
	1610226	1610226	1745485	15127.10	16397.80	one
	5750777	5750777	6757485	54138.90	63616.30	two
	5581478	5581478	7109467	52375.00	66713.30	3
	5471636	5471636	7554998	51155.60	70633.40	4
	5175294	5175294	7746071	48314.80	72314.60	5
	4860992	4860992	7886796	45334.00	73552.80	6
	4456575	4456575	7838016	41577.00	73123.60	7
	4136817	4136817	7886796	38580.30	73552.80	8
	3792649	3792649	7838016	35383.00	73123.60	9
	3520528	3520528	7886796	32832.70	73552.80	10
	3227632	3227632	7838016	30111.70	73123.60	eleven

**Table 14.1** Total cost (€) for installation "Natural Gas" cash flows to calculate the NPV and NPV taking into account the external costs of CO2 emissions at the consumption stage

<i>They are "Natural Gas" external costs CO2</i>	<i>Discounted cash flow = (3) * (I + WACC)<sup>t</sup> - (year)</i>	<i>Cash Flow GN = (I) + (2) = (3)</i>	<i>Discounted cash flow = (2) * (I + WACC)<sup>t</sup> - (year)</i>	<i>Cash Flow GN (2)</i>	<i>CO2 external costs (G) (I)</i>
<b>761,549.20</b>	151,293.00	151293	151293	151293	<b>0</b>
	14417.28	15628	13682.60	14832.00	<b>one</b> -796.33
	51289.98	60269	48808.60	57352.90	<b>two</b> 2,915.70
	50078.81	63788	47457.80	60449.90	<b>3</b> 3,338.52
	49424.88	68244	46619	64370	<b>4</b> 3,873.73
	46871.50	70154	44130	66051.20	<b>5</b> 4,103.25
	44106.50	71561	41473	67289	<b>6</b> 4,272.31
	40411.41	71074	38015	66860	<b>7</b> 4,213.71
	37535.87	71562	35294.90	67289.40	<b>8</b> 4,272.31
	34391.15	71074	32352.20	66860.20	<b>9</b> 4,213.71
	31943.72	71561	30036	67289	<b>10</b> 4,272.31
	29267.67	71074	27532.50	66860.20	<b>eleven</b> 4,213.71

**Table 14.2** Total cost (€) for installation "Solar with Natural Gas" cash flows to calculate the NPV and NPV taking into account the external costs of CO2 emissions at the consumption stage