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MASTER IN ENVIRONMENT AND SMART ENERGY MANAGEMENT

MASTER'S FINAL PROJECT

# ENERGY EFFICIENCY SOLUTIONS AND LIFE CYCLE ANALYSIS IN AN AUTOMOTIVE PLANT

Author: Marcos Roa Escobar

Director: María del Mar Cledera Castro

Director: Carlos Morales Polo

Madrid

June of 2021

I declare, under my responsibility, that the Project presented with the title ENERGY EFFICIENCY SOLUTIONS AND LIFE CYCLE ANALYSIS IN AN AUTOMOTIVE PLANT in the ETS of Engineering - ICAI Pontificial University of Comillas in the academic course 2020/2021. It is my own, original and unpublished and it has not been previously submitted for other purposes. The Project is not plagiarism of another, neither totally nor partially and the information that has been taken of other documents is duly referenced.

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SOLUCIONES DE EFICIENCIE ENERGÉTICA Y ANÁLISIS DE CICLO DE VIDA EN UNA PLANTA DE AUTOMOCIÓN

**Autor: Roa Escobar, Marcos.**

Director: Morales Polo, Carlos.

Directora: Cledera Castro, María del Mar.

**Entidad Colaboradora: ICAI – Universidad Pontificia Comillas – Cátedra de Transición Energética.**

# RESUMEN DEL PROYECTO

## 1. Introducción y Metodología

En este proyecto se proponen y dimensionan una serie de mejoras tecnológicas para reducir el impacto medioambiental de una fábrica de coches en Madrid. Concretamente se implantarán unos colectores solares de tubo de vacío para aportar calor a los sistemas de climatización de la empresa, unos paneles de concentración solar tipo Fresnel para aportar energía al proceso de pintura y unas bombas de calor para, de nuevo, aportar calor al proceso de pintura. Estas bombas en particular, reutilizarán calores residuales de la propia fábrica, mejorando su eficiencia y disminuyendo sus pérdidas.

De forma paralela, se realizará un Análisis de Ciclo de Vida en el que se evaluará el impacto de está empresa en diferentes indicadores medioambientales (eutrofización, calentamiento global, destrucción de la capa de ozono, acidificación de los océanos…) utilizando la herramienta de SimaPro. Este ACV se centrará exclusivamente en los procesos de chapa, pintura y montaje de la fábrica, y será llevado a cabo 2 veces. La primera, previamente a la instalación de las mejoras tecnológicas, y la segunda, una vez estas mejoras hayan sido ya implementadas, con el fin de comparar ambos resultados y estudiar la reducción del impacto (en especial la reducción de la emisión de gases de efecto invernadero) que pueden suponer

Cabe destacar por último, que además del dimensionado de las bombas y la tecnología solar, se lleva acabo un estudio de viabilidad económica de ambas partes, en el que se evalúa, entre otras cosas, la inversión inicial que habría que llevar a cabo, su periodo de retorno, y si realmente merece la pena realizar esta inversión y reducir las emisiones de la fábrica.

## 2. Resultados.

### 2.1. Colector solar de tubo de vacío

Esta tecnología sería utilizada para alimentar los sistemas de calefacción de la fábrica. Para ello se utilizó la herramienta de POLYSUN. Tras una serie de iteraciones y de decisiones técnicas, buscando siempre adaptarse a las necesidades de la fábrica y obteniendo la mayor eficiencia al menor coste, se obtuvieron los siguientes resultados.

**Overview solar thermal energy (annual values)**

| | |
|---|---|
| Collector area | 18.4 m² |
| Solar fraction total | 50.3% |
| Total annual field yield | 5,348.4 kWh |
| Collector field yield relating to gross area | 291.3 kWh/m²/Year |
| Collector field yield relating to aperture area | 454.6 kWh/m²/Year |
| Max. fuel savings | 566 m³(gas): [Natural gas H] |
| Max. energy savings | 5,942.6 kWh |
| Max. reduction in CO2 emissions | 1,376 kg |

*Figura 1. Resumen resultados del colector solar de tubo de vacío*

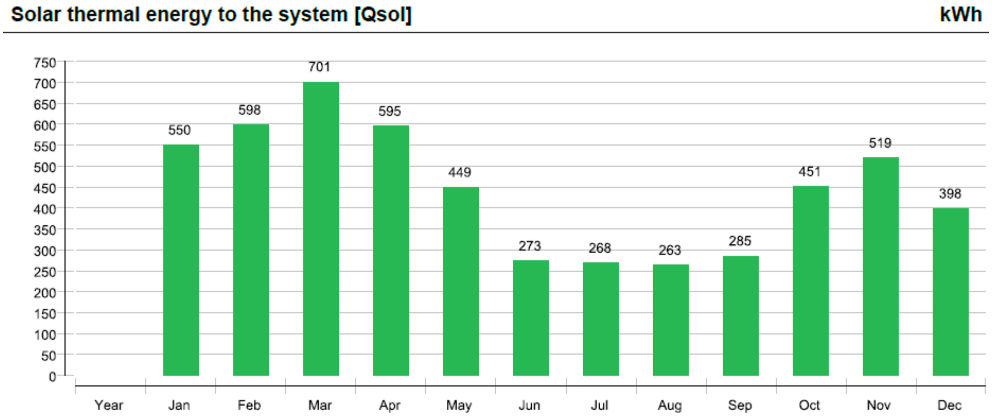


*Figura 2. Aportación solar por meses al sistema*

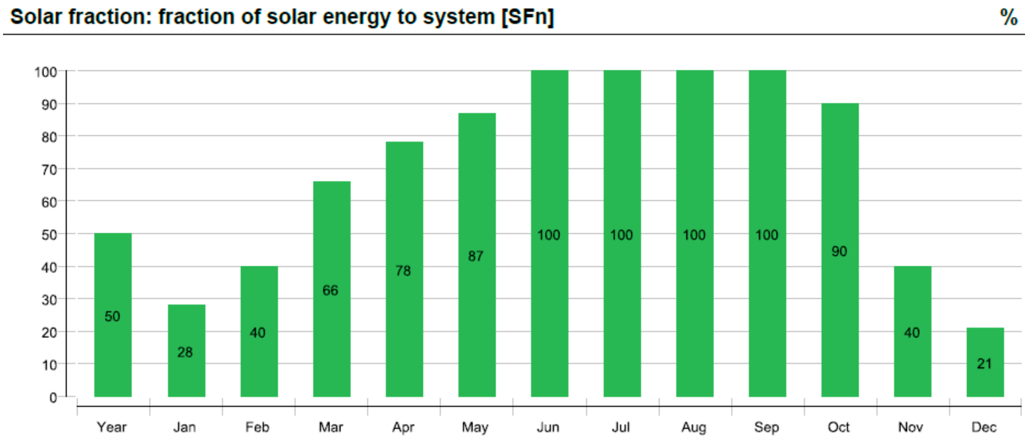


*Figura 3. Porcentaje de energía solar que se aporta al sistema, por meses*

Como era de esperar cuando menos energía se aporta es en los meses de verano, siendo el 100% de esta, de tipo solar. Esto es debido a que en estos meses es cuando más se puede aprovechar este tipo de energía, sin embargo es cuando no se necesitan los sistemas de calefacción.

## 2.2. Energía solar térmica de concentración

Esta tecnología se utiliza para aportar el calor necesario a los procesos de pintura. El dimensionamiento se realizó con la herramienta RESSSPI y se obtuvieron los siguientes resultados

**Resumen de resultados**

| | | |
|---|---|---|
| **Ahorro solar año 1:** 141002 €/año | **% Ahorro combustible:** 20.4% | |
| **Factura actual:** 553050.0 €/año | **Coste combustible actual:** 0.0 €/kWh | |
| **Inversión:** 1684805.8 € | **TIR:** 10.4 % | **Retorno:** Año 11 |
| **Campo solar:** 6336 $m^2$ | **Producción energía:** 3618786.6 kWh/año | **CO2 evitado:** 723.8 Ton/año |

*Figura 4. Resumen de resultados de la energía solar térmica de concentración*

## 2.3. Bombas de calor

Tras una evaluación se concluyó que se utilizarían 3 bombas para reutilizar el calor de cierto focos emisores de la fábrica que presentaban características similares. Las bombas serían adquiridas directamente a los fabricadores sin necesidad de dimensionar bombas propias, por lo que se procedió a la evaluación económica, obteniendo los siguientes resultados.

| Resultados Técnicos | | |
|---|---|---|
| Ahorro de gas | 1710 | kW |
| CO2 Evitado | 1102 | Ton/año |
| CO2 emitido por el uso de las bombas | -500,803 | Ton/año |
| CO2 evitado neto | 601,197 | Ton/año |

*Figura 5. Resultados técnicos*

| Resultados Económicos | | |
|---|---|---|
| **VAN** | **447.049,85 €** | **€** |
| **IRR** | **18,16%** | **€** |
| **Periodo Ret.** | **6,41** | **años** |

*Figura 6. Resultados Económicos*

A continuación, una tabla que muestra los días laborables en cada mes, así como los consumos de los hornos de pintura y de la Central Térmica. La última columna muestra el porcentaje de los kW que cubren las bombas con respecto al total de los hornos de pintura.

| Días laborables | Mes | Hornos Pintura | CT - PCI | | % Reducción |
|---|---|---|---|---|---|
| 17 | Enero | 1.745.095 | 2.182.306 | kWh | 26,65% |
| 19 | Febrero | 1.992.222 | 2.248.169 | kWh | 26,09% |
| 18 | Marzo | 1.877.918 | 1.644.304 | kWh | 26,22% |
| 21 | Abril | 2.146.097 | 864.163 | kWh | 26,77% |
| 20 | Mayo | 1.953.799 | 0 | kWh | 28,01% |
| 22 | Junio | 2.216.319 | 0 | kWh | 27,16% |
| 16 | Julio | 1.595.193 | 0 | kWh | 27,44% |
| 12 | Agosto | 1.266.973 | 0 | kWh | 25,91% |
| 22 | Septiembre | 2.381.964 | 0 | kWh | 25,27% |
| 15 | Octubre | 1.539.678 | 11.723 | kWh | 26,65% |
| 20 | Noviembre | 2.106.669 | 2.120.859 | kWh | 25,97% |
| 14 | Diciembre | 1.492.795 | 1.708.857 | kWh | 25,66% |

*Figura 7. Porcentaje de reducción de consumo de gas con las bombas en serie [Fuente propia]*

## 2.4. Análisis de ciclo de vida.

El proceso que más se vio afectado por la implementación de las tecnologías fue el de la pintura, en la siguiente imagen se puede ver el consumo total de energía en este proceso, así como el reparto de las diferentes fuentes de aportación energética, antes y después de la implementación. Como se puede ver en los diagramas de Pareto, el consumo total pasa de 3,15 GJ por coche, a tan solo 2,6 GJ. Y el porcentaje de energías renovables en el mix, aumenta de cerca del 3% a un 12%

del total. Esto es el resultado de combinar la energía solar, con la reutilización de calores que hacen las bombas de calor.

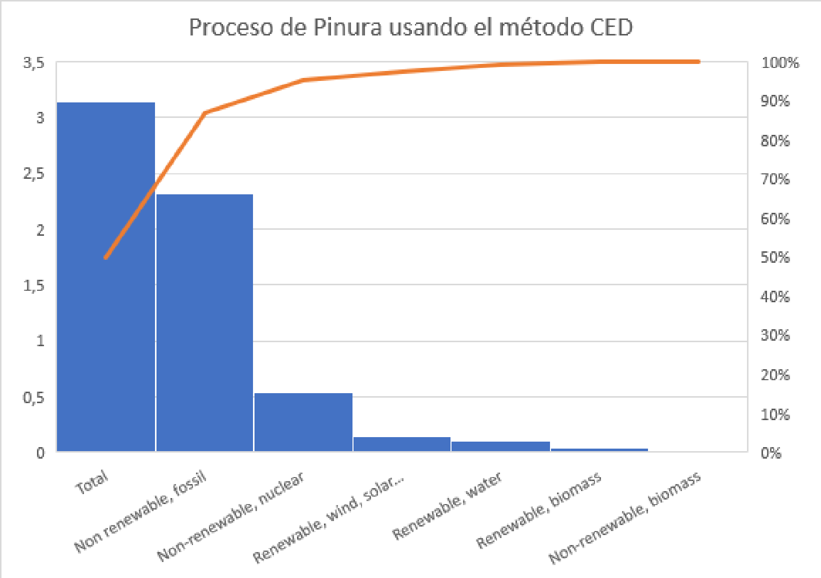


*Figura 8. Consumo energético proceso de pintura sin mejoras tecnológicas*

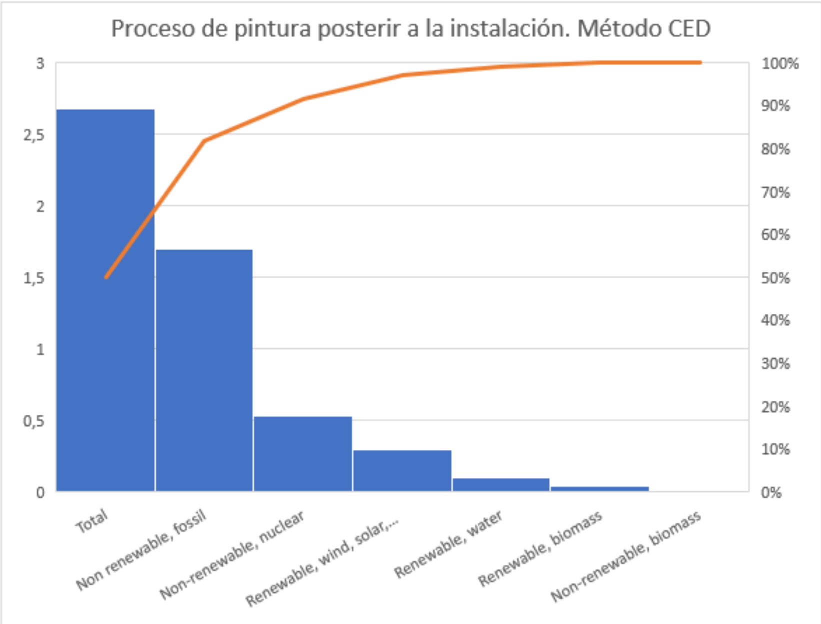


*Figura 9. Consumo energético proceso de pintura con mejoras tecnológicas*

Por último, se va a ver la reducción en la emisión de gases de efecto invernadero. La instalación de los colectores solares SOLATOM [1], supone una reducción de las emisiones de CO2 de 723.8 Ton/año. Y el uso de las bombas, evita que se emitan a la atmosfera 600.9 Ton/año de este mismo gas (esto sería la resta del CO2 evitado al reducir el consumo de gas, menos el CO2 generado al alimentar las bombas con electricidad)

Con todo ello, se reduce en un total de 1324,7 Ton/año las emisiones de CO2 (y esto solo en la zona de los hornos de pintura, no se está teniendo en cuenta los colectores solares de tubo de vacío que se utilizarán para la climatización)

De acuerdo con la Generalitat de Catalunya Comisión Interdepartamental del Cambio Climático, el factor de emisión del gas natural es de 2,15 kg de CO2/Nm3 [2] y según GASNAM [3], la densidad del mismo es de 0,743 kg/ Nm3, es decir, se producen 2,9 kg de CO2, por cada kg consumido de Gas Natural. Por lo que si se consumen 24 kg de Gas Natural por cada coche producido, y en un año estándar se producen 82.000 coches, esta fábrica consume 1,968 millones de kg de Gas natural al año, lo que implica unas emisiones de 5.707,2 toneladas de CO2 al año.

Por lo tanto.

$$\frac{1324.7}{5707.2} = \mathbf{23,21}\%$$

La implementación de estas medidas supone una reducción de las emisiones totales de un 23,21%. Una mejora significativa que acercará a esta empresa a los objetivos de sostenibilidad de la agenda 2030, que le permitirá seguir realizando su actividad a la vez que protegen el medio ambiente y que sin duda les dará una publicidad positiva con respecto a posibles clientes interesados en sus coches.

# 3. Conclusiones.

A continuación se recogen algunas de las conclusiones que se han ido obteniendo a lo largo de la realización del proyecto.

- La fabricación de un vehículo supone un porcentaje muy pequeño de su impacto medioambiental de ciclo de vida. Dentro del proceso de fabricación, a su vez, la parte de pintura, es otra pequeña parte, y dentro de esta parte de pintura, se ha conseguido reducir las emisiones de gases de efecto invernadero en un 23%, lo cual, a nivel global de todo el ciclo de vida de un vehículo, supondrá una muy pequeña mejora.
- Existen la posibilidad de aumentar el tamaño de las mejoras en el futuro. La fábrica dispone de una parcela enorme donde podrían implantarse más paneles solares, además, se desperdician numerosos focos de calor que se podrían aprovechar para alimentar otras partes del proceso de fabricación de coches o para aclimatar diferentes zonas de la fábrica.
- La inversión inicial para conseguir esta mejora es importante. Las energías renovables como la solar, actualmente tienen un precio elevado que hace que algunos proyecto sean inviables, sin embargo, solo mediante la inversión en este sector y el desarrollo de proyectos como este, se conseguirá reducir los precios de las energías renovables y ampliar su viabilidad y su implementación.
- Con todo, esta fábrica obtendrá muy buenas conclusiones de este proyecto. Mejorará su imagen de cara al público, lo que le aportará un nuevo abanico de clientes que motivados por el compromiso medioambiental de la empresa, no dudará en adquirir sus productos. Y por último, y más importante, su aportación

ayudará a acerca a la sociedad a la tan ansiada transición energética, haciendo de este mundo un lugar mejor, más seguro y más limpio.

- Con respecto al análisis de ciclo de vida, es una potente herramienta que ayuda a clarificar los diferentes impactos que tiene un producto o un proceso a lo largo de su vida útil, sin embargo, a la hora de analizar un proceso, puede resultar una herramienta limitada, puesto que el alcance puede ser complicado de establecer, o no lo suficientemente grande como para tener en cuenta todos los factores. Esta herramienta puede resultar más útil por lo tanto en productos en vez de en procesos, por la mayor facilidad de definir el alcance.
- Con respecto a las tecnologías solares cabe destacar su enorme potencial. Queda mucho que mejorar en este sector en cuanto a eficiencia y es verdad que es un tipo de energía que se ve neutralizada si las condiciones climáticas no son favorables, pero su potencial es enorme, y con la investigación adecuada, podrían lograrse números mucho más impresionantes y ahorros de electricidad mucho más atractivos.

# 4. Referencias


[1] «SolatomCSP». https://www.solatom.com/ (accedido may 02, 2021).

[2] Generalitat de Catalunya, Comisión Interdepartamental, y del Cambio Climático, «GUÍA PRÁCTICA PARA EL CÁLCULO DE EMISIONES DE GASES DE EFECTO INVERNADERO (GEI)». mar. 2011. [En línea]. Disponible en: http://www.caib.es/sacmicrofront/archivopub.do?ctrl=MCRST234ZI97531&id=97531

[3] GASNAM y SEDIGAS, «Tabla Equivalencias gas natural». [En línea]. Disponible en: http://gasnam.es/wp-content/uploads/2016/02/Tabla_equivalencias_GASNAM_SEDIGAS.pdf

ENERGY EFFICIENCY SOLUTIONS AND LIFE CYCLE ANALYSIS IN AN AUTOMOTIVE PLANT

**Author: Roa Escobar, Marcos.**

Director: Morales Polo, Carlos.

Director: Cledera Castro, María del Mar.

**Collaborating Entity: ICAI - Pontifical University of Comillas - Chair of Energy Transition.**

# PROJECT ABSTRACT

## 1. Introduction and Methodology

In this project, a series of technological improvements are proposed and dimensioned to reduce the environmental impact of a car manufacturer in Madrid. Specifically, some vacuum tube solar collectors will be installed to provide heat to the company's air conditioning systems, also, Fresnel-type solar concentration panels will be installed to provide energy to the painting process and heat pumps to, again, provide heat to the same process. These pumps will reuse residual heat from the factory itself, improving its efficiency and reducing its losses.

Parallel to this, a Life Cycle Analysis will be carried out, in which it will be measured the impact of this company's activities, on different environmental indicators (eutrophication, global warming, destruction of the ozone layer, ocean acidification ...) using the SimaPro software. This LCA will focus exclusively on the sheet metal, painting, and assembly processes of the factory, and it will be carried out 2 times. The first time, it will be carried out prior to the installation of the technological improvements, and the second time, once these improvements have already been implemented. The objective is to compare both results and study the reduction of the impact (especially the reduction of greenhouse gas emissions) that these improvements bring.

Finally, it should be noted that in addition to the sizing of the pumps and solar technology, an economic feasibility study is carried out on both parties, which evaluates, among other things, the initial investment that would have to be carried out, its payback period, and if it is really worthy to make this investment and reduce the factory emissions.

## 2. Results.

### 2.1. Vacuum tube solar collector

This technology would be used to power the factory's heating systems. For this, the POLYSUN tool was used. After a series of iterations and technical decisions, always seeking to adapt to the needs of the factory and obtaining the highest efficiency at the lowest cost, the following results were obtained.

| Overview solar thermal energy (annual values) | |
|---|---|
| Collector area | 18.4 m² |
| Solar fraction total | 50.3% |
| Total annual field yield | 5,348.4 kWh |
| Collector field yield relating to gross area | 291.3 kWh/m²/Year |
| Collector field yield relating to aperture area | 454.6 kWh/m²/Year |
| Max. fuel savings | 566 m³(gas): [Natural gas H] |
| Max. energy savings | 5,942.6 kWh |
| Max. reduction in CO2 emissions | 1,376 kg |

*Figure 1. Summary results of the vacuum tube solar collector*

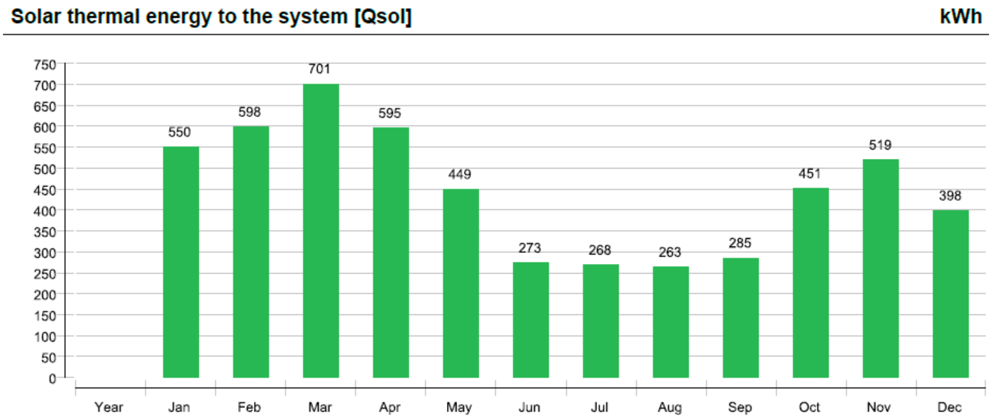


*Figure 2. Solar contribution for months to the system*

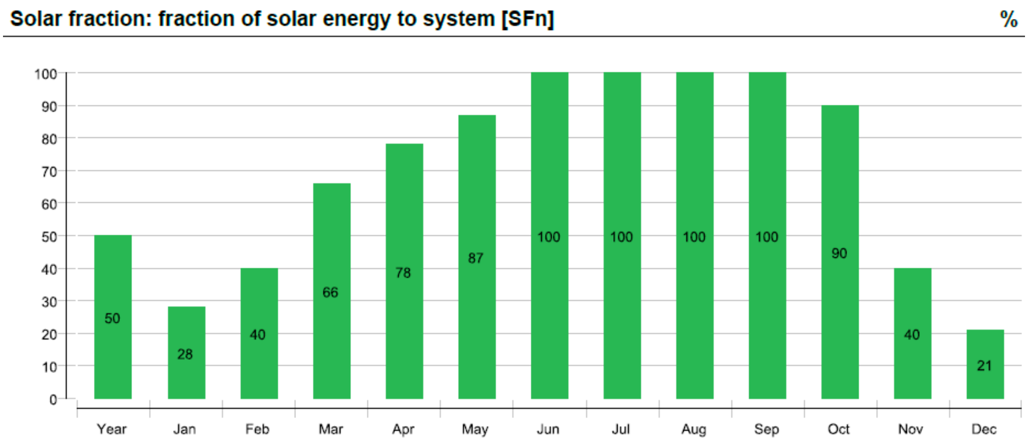


*Figure 3. Percentage of solar energy to the system, by months*

As expected, when less energy is provided is in the summer months, 100% of which is solar. This is because in these months it is when this type of energy can be used the most, however it is when heating systems are not needed.

## 2.2. Concentrating solar thermal energy

This technology is used to provide the necessary heat to the painting processes. The sizing was carried out with the RESSSPI tool, and after a series of iterations, always seeking the objective of supplying 20% of the demand, with the least investment and the fastest payback period, the following results were obtained.

**Resumen de resultados**

**Ahorro solar año 1:** 141002 €/año

**Factura actual:** 553050.0 €/año

**Inversión:** 1684805.8 €

**Campo solar:** 6336 $m^2$

**% Ahorro combustible:** 20.4%

**Coste combustible actual:** 0.0 €/kWh

**TIR:** 10.4 %

**Producción energía:** 3618786.6 kWh/año

**Retorno:** Año 11

**CO2 evitado:** 723.8 Ton/año

*Figure 4. Concentration solar thermal energy results summary*

For more details about the results, consult the project report.

## 2.3. Heat pumps

After an evaluation, it was concluded that 3 pumps would be used to reuse the heat from certain emitting sources in the factory that had similar characteristics. The pumps would be purchased directly from the manufacturers without the need to size their own pumps, for which the economic evaluation was carried out, obtaining the following results.

| Technical Results | | |
|---|---|---|
| Gas saving | 1710 | kW |
| CO2 Avoided | 1102 | Ton / year |
| CO2 emitted by the use of the pumps | -500.803 | Ton / year |
| Net avoided CO2 | 601,197 | Ton / year |

*Figure 5. Technical results*

| Economic results | | |
|---|---|---|
| **GO** | **€ 447,049.85** | **€** |
| **IRR** | **18.16%** | **€** |
| **Period Ret.** | **6.41** | **years** |

*Figure 6. Economic results*

Below is a table that shows the working days in each month, as well as the consumption of the paint ovens and the Thermal Power Plant. The last column shows the percentage of kW that the pumps cover with respect to the total paint ovens.

| Work days | Month | Paint Ovens | CT - PCI | | % Reduction |
|---|---|---|---|---|---|
| 17 | January | 1,745,095 | 2,182,306 | kWh | 26.65% |
| 19 | February | 1,992,222 | 2,248,169 | kWh | 26.09% |
| 18 | March | 1,877,918 | 1,644,304 | kWh | 26.22% |
| 21 | April | 2,146,097 | 864,163 | kWh | 26.77% |
| 20 | May | 1,953,799 | 0 | kWh | 28.01% |
| 22 | June | 2,216,319 | 0 | kWh | 27.16% |
| 16 | July | 1,595,193 | 0 | kWh | 27.44% |
| 12 | August | 1,266,973 | 0 | kWh | 25.91% |
| 22 | September | 2,381,964 | 0 | kWh | 25.27% |
| 15 | October | 1,539,678 | 11,723 | kWh | 26.65% |
| 20 | November | 2,106,669 | 2,120,859 | kWh | 25.97% |
| 14 | December | 1,492,795 | 1,708,857 | kWh | 25.66% |

*Figure 7. Gas consumption reduction percentage with series pumps [Own source]*

## 2.4. Life cycle analysis.

The process that was most affected by the implementation of the technologies was that of painting, in the following image you can see the total energy consumption in this process, as well as the distribution of the different sources of energy input, before and after of the implementation. As can be seen in the Pareto diagrams, the total consumption goes from 3.15 GJ per car, to only 2.6 GJ. And the percentage of renewable energies in the mix increases from about 3% to 12% of the total. This is the result of combining solar energy with the reuse of heat that heat pumps do.

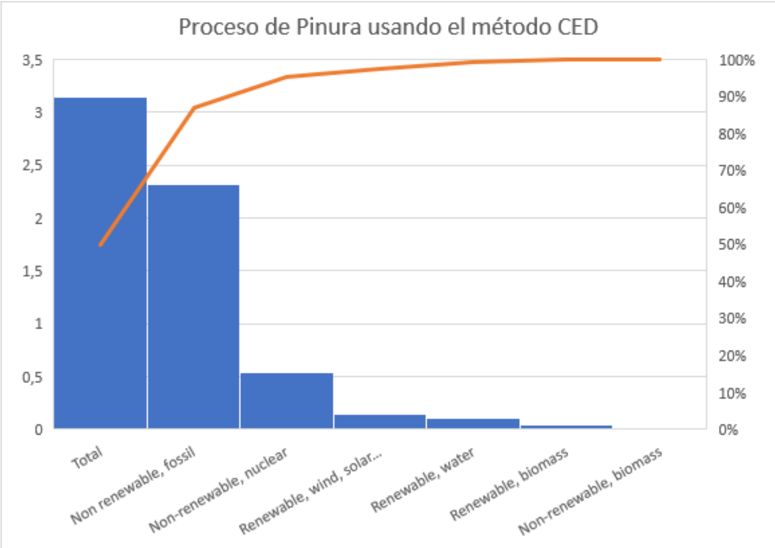


*Figure 8. Energy consumption painting process without technological improvements*


*Figure 9. Energy consumption painting process with technological improvements*

Finally, the reduction in the emission of greenhouse gases will be seen. The installation of SOLATOM solar collectors[1], supposes a reduction of $CO_2$ emissions of 723.8 Ton / year. And the use of the pumps prevents 600.9 Ton / year of this same gas from being emitted into the atmosphere (this would be the subtraction of the $CO_2$ avoided by reducing gas consumption, minus the $CO_2$ generated by feeding the pumps with electricity)

With all this, $CO_2$ emissions are reduced by a total of 1,324.7 Ton / year (and this only in the area of the painting ovens, the vacuum tube solar collectors that will be used for air conditioning)

According to the Generalitat de Catalunya Interdepartmental Climate Change Commission, the natural gas emission factor is 2.15 kg of $CO_2$ / $Nm^3$[2] and according to GASNAM [3], its density is 0.743 kg / $Nm^3$, that is, 2.9 kg of $CO_2$ are produced for each kg of Natural Gas consumed. Therefore, if 24 kg of Natural Gas are consumed for each car produced, and 82,000 cars are produced in a standard year, this factory consumes 1,968 million kg of Natural Gas per year, which implies emissions of 5,707.2 tons of $CO_2$ per year.

Therefore.

$$\frac{1324.7}{5707.2} = \mathbf{23{,}21}\%$$

The implementation of these measures implies a reduction in total emissions of 23.21%. A significant improvement that will bring this company closer to the sustainability objectives of the 2030 agenda, which will allow it to continue carrying out its activity while protecting the environment and which will undoubtedly give them positive publicity with respect to potential customers interested in their cars.

## 3. Conclusions.

Below are some of the conclusions that have been obtained throughout the project.

- Building a vehicle accounts for a very small percentage of its life cycle environmental impact. Within the manufacturing process, in turn, the paint part is another small part, and within this paint part, it has been possible to reduce greenhouse gas emissions by 23%, which, globally over the entire life cycle of a vehicle, it will be a very small improvement.
- There is a possibility to increase the size of the improvements in the future. The factory has a huge plot where more solar panels could be installed, in addition, numerous heat sources are wasted that could be used to power other parts of the car manufacturing process or to acclimatize different areas of the factory.
- The initial investment to achieve this improvement is important. Renewable energies such as solar, currently have a high price that makes some projects unviable, however, only through investment in this sector and the development of projects like this, will it be possible to reduce the prices of renewable energies and expand their feasibility and its implementation.
- All in all, this factory will obtain very good conclusions from this project. It will improve its image with the public, which will bring them a new range of customers who, motivated by the company's environmental commitment, will not hesitate to purchase their products. And finally, and most important, their contribution will

help bring society closer to the long-awaited energy transition, making this world a better, safer, and cleaner place.

- Regarding the life cycle analysis, it is a powerful tool that helps to clarify the different impacts that a product or a process has throughout its useful life, however, when analyzing a process, it can be a tool limited, as the scope may be difficult to establish, or not large enough to take all factors into account. This tool may therefore be more useful in products rather than in processes, due to the ease of defining the scope.
- Regarding the solar technologies, their enormous potential should be highlighted. There is much to improve in this sector in terms of efficiency and it is true that it is a type of energy that is neutralized if the climatic conditions are not favorable, but its potential is enormous, and with the proper research, much more impressive numbers could be achieved. and much more attractive electricity savings.

# 4. References

[1] «SolatomCSP». https://www.solatom.com/ (accedido may 02, 2021).
[2] Generalitat de Catalunya, Comisión Interdepartamental, y del Cambio Climático, «GUÍA PRÁCTICA PARA EL CÁLCULO DE EMISIONES DE GASES DE EFECTO INVERNADERO (GEI)». mar. 2011. [En línea]. Disponible en: http://www.caib.es/sacmicrofront/archivopub.do?ctrl=MCRST234ZI97531&id=97531
[3] GASNAM y SEDIGAS, «Tabla Equivalencias gas natural». [En línea]. Disponible en: http://gasnam.es/wp-content/uploads/2016/02/Tabla_equivalencias_GASNAM_SEDIGAS.pdf

*Master Thesis*

# Energy efficiency solutions and life cycle analysis in an automotive plant

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**Abstract:** In this project, a series of technological improvements are proposed and dimensioned to reduce the environmental impact of a car manufacturer in Madrid. Specifically, some vacuum tube solar collectors will be installed to provide heat to the company's air conditioning systems, also, Fresnel-type solar concentration panels will be installed to provide energy to the painting process and heat pumps to, again, provide heat to the same process. These pumps will reuse residual heat from the factory itself, improving its efficiency and reducing its losses.

Parallel to this, a Life Cycle Analysis will be carried out, in which it will be measured the impact of this company's activities, on different environmental indicators (eutrophication, global warming, destruction of the ozone layer, ocean acidification ...) using the SimaPro software. This LCA will focus exclusively on the sheet metal, painting, and assembly processes of the factory, and it will be carried out 2 times. The first time, it will be carried out prior to the installation of the technological improvements, and the second time, once these improvements have already been implemented. The objective is to compare both results and study the reduction of the impact (especially the reduction of greenhouse gas emissions) that these improvements bring.

Finally, it should be noted that in addition to the sizing of the pumps and solar technology, an economic feasibility study is carried out on both parties, which evaluates, among other things, the initial investment that would have to be carried out, its payback period, and if it is really worthy to make this investment and reduce the factory emissions.

**Keywords:** environment, life cycle analysis, solar energy, heat pump, green gas emissions, CO2, energy efficiency, thermo solar.

## 1. Introduction

This project is carried out through ICAI's Energy Transition Chair, in order to improve energy efficiency and reduce the environmental impact of a car factory in Spain, for which a series of technological improvements will be implemented in the factory, and the reduction of the consumption of energy and fossil fuels will be evaluated.

The factory processes that will be affected by these improvements are sheet metal, painting and assembly, and the project will be divided into the following stages:

- A life cycle analysis to study the environmental impact. One will be done prior to the installation of the technologies (not included in this project), and another later, with the technologies already implemented, in order to study the reduction of greenhouse gas emissions.
- The sizing and implementation of a series of self-consumption measures based on solar energy. These technological measures will be vacuum tube solar collectors and Fresnel-type technology (concentrating solar thermal energy). In addition to sizing and implementation, an economic analysis will be carried out to study its viability.

- A study to implement heat pumps that provide heat to the painting process of vehicles by reusing residual heat from certain sources in the factory itself. An economic evaluation will be carried out as well.

Life Cycle Analysis is a term that is coined based on Sustainability, so it is important to establish a definition of Sustainability to be able to talk about Life Cycle Analysis.

The term "Sustainability" was coined in the Brundtland report in 1987 by Dr. Gro Harlem Brundtland. In said report, Sustainable Development is defined as follows. “Sustainable development is one that allows meeting the needs of present generations without compromising the possibilities of future generations to meet their own needs. The three pillars that are related in Sustainable Development are the economy, the environment and society. The purpose of their relationship is that there is an economic and social development that respects the environment ” [1]

Life cycle analysis arises in order to help achieve this idea of sustainability, since it is a design tool that investigates and evaluates the environmental impact produced by a service or product throughout its existence. This includes the processes of raw material extraction, manufacturing, production, distribution, and its end of life (recycling, reuse, recovery, disposal ...).

An LCA (from English “Life Cycle Assessment”, and form that will be used to abbreviate Life Cycle Analysis from here on) consists of a series of mandatory phases. They are as follows: [2]

<u>Objective</u>

Answer questions like: Why is the study being done? What questions should it answer? Who is it done for?

<u>Definition of scope</u>

- Definition of the Functional Unit
- Scope of the system: what processes / activities are considered within the product life cycle.
- Select the evaluation parameter: choose the impact of the evaluation.
- Select the limits (temporal and geographical), as well as the level of technological development.
- Select perspective:
  - Consequential: consequence of substituting one alternative for another.
  - Attributional: Study the impact associated with the activity under evaluation.
- Critical review (yes / no): if it is necessary for public communication.

<u>Inventory analysis</u>

Build an inventory of processes according to the definition of goal and scope and collect data of physical flows. These flows can be of the type of:

- Inputs: Materials, resources, other products
- Outputs: Emissions, products, waste ...

Most of these processes are included in the database of the program in which the LCA is carried out, in the case of this final master project, that program is SimaPro. Even so, new processes can always be added.

The result of this section is the Life Cycle Inventory. A flow list of quantifiable items, associated with the functional unit.

<u>Impact assessment of the life cycle</u>

Based on the Life Cycle Inventory, the impact assessment translates the physical flows of the system into environmental impacts, using scientific environmental models.

According to ISO 14040 [3],this section consists of 5 phases that are:

1) Selection of the impact categories chosen in the scope with their associated indicator and model, capable of translating elementary flows into quantified environmental impacts.
2) Classification of the elemental flows of the inventory, assigning them to the impact category to which they contribute.
3) Characterization. Quantification of the contribution of the process.
4) Standardization. Express these impacts in common magnitudes to facilitate comparison.
5) Weighting. Give a unique value as a result of the evaluation.

<u>Interpretation</u>

The results are interpreted in order to answer the questions proposed in the objectives. In this section it is necessary to indicate the limits of the project and the assumptions made

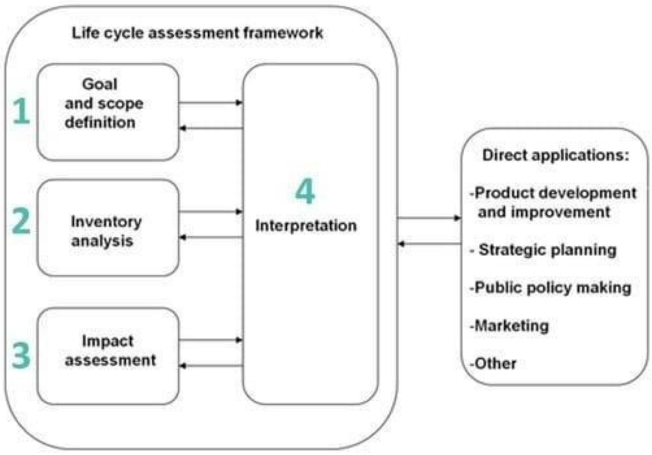



**Figure 1** LCA phases [4]

## 2. State of the Art

### <u>2.1. Vacuum tube solar collector</u>

The vacuum tube solar collector is a type of solar collector whose energy source is solar thermal. It is made up of linear collectors arranged in parallel and housed in vacuum glass tubes. These tubes are connected perpendicular to a mast that conducts the heat transfer fluid (generally water). Usually, the tubes are more efficient on cold, windy, or cloudy days, to keep them cool so that they do not have failures or malfunctions due to excessive heat.

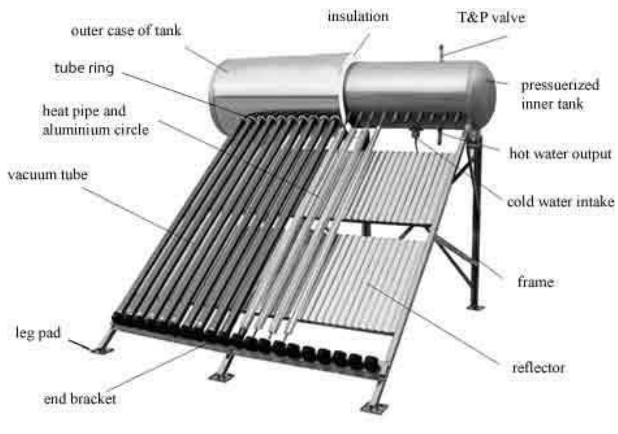



**Figure 2**. Schematic of a vacuum tube solar collector.*[5]*

They have certain advantages over flat collectors, for example, the reduction of convection losses in vacuum tubes, being insulated, is reduced by around 5%. And as there are many tubes, this means savings of up to 35%

There are two types of systems depending on the circuit arrangement. Direct (open loop) or indirect (closed loop)[6].

In direct loop systems, the working fluid circulates through the collector and storage tank without heat exchange, and water is used as the working fluid. This type of circuit is used in regions where there are no freezing problems.

In indirect circuit systems, there is a heat exchange and an intermediate fluid with low freezing points is used. This type of system is designed for regions with cold climates, in addition, by not using water in the entire circuit, calcification and corrosion are prevented.

In this project, the direct type of circuit will be used.

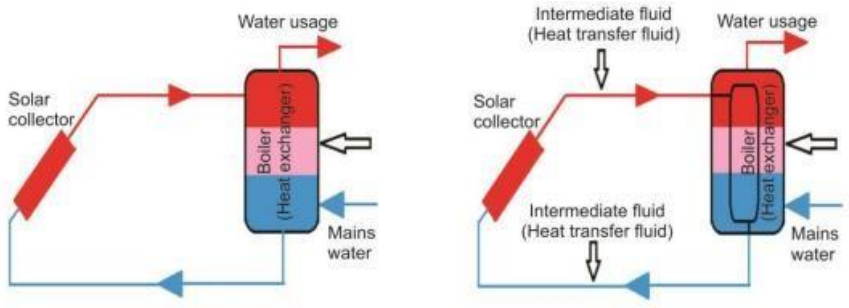



**Figure 3.** Comparison of direct and indirect systems.*[7]*

## 2.2. Concentrating solar thermal energy

Concentrated Solar Power (CSP) is based on the concept of using solar radiation to produce air or water at high temperatures, which it can be later used to generate electricity, or as heat input to other processes. It uses mirrors to concentrate the sun's rays on a small surface on which to circulate the substance to be heated.[8]

There are currently four types of concentration technologies. [9]

- Parabolic dish systems
- Parabolic trough collector
- Fresnel linear reflector
- Solar power towers

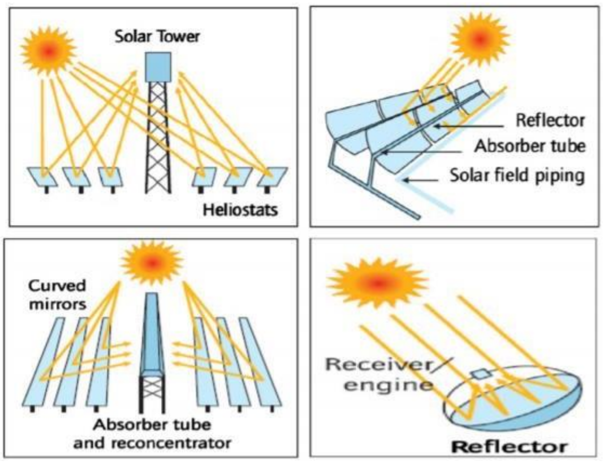



**Figure 4.** Types of concentrating solar technologies*[10]*

This project will use linear Fresnel reflectors. This type of technology is manufactured with many strips of thin and flat mirrors that concentrate the sunlight on some tubes through which the fluid to be heated circulates.

## 2.3 Heat pumps

A heat pump is a thermodynamic machine formed by a classic refrigeration circuit (expansion and compression systems, evaporator, and condenser) from which the heat transferred by the condenser is used (generally hot water that comes out of it, although it can also be air) from the cold source absorbed by the evaporator (generally water from a river or well). In the following image it can be seen the classic cycle of operation of a heat pump.[11]

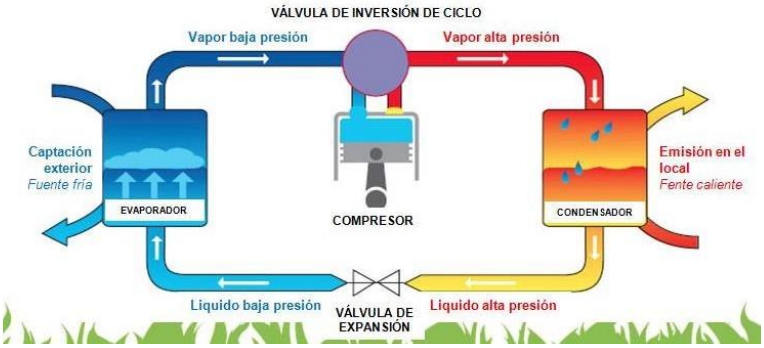



**Figure 5.** Operation diagram of a heat pump[12]

During the evaporation process, energy is withdrawn from the environment in the form of heat. This heat is absorbed by the refrigerant fluid, which goes from a liquid to a gaseous state, with this change of state occurring at constant pressure.

The compressor serves to compress the refrigerant fluid (now in a vapor state), even liquefying it and conducting it to the condenser where it completely liquefies releasing the previously absorbed heat (Qc)

In the condensation phase, the energy is released to the medium to be heated, be it domestic, industrial, or commercial.

At the condenser outlet, the fluid is directed towards the expansion system, generally a valve or capillary tube, where the expansion takes place, turning into humid vapor. This vapor returns to the evaporator at a pressure lower than that of liquefaction where, to evaporate its liquid fraction, it must absorb a quantity of heat from the medium (Qo)

The total heat transferred will be equal to the heat absorbed plus the mechanical work of the compressor.

One of the factors that makes heat pumps such an efficient and interesting system is the fact that the amount of energy consumed to run the compressor (usually an electric motor) is, in general, much smaller than the energy detached by the condenser.

<u>Life cycle analysis.</u>

The history of life cycle analysis studies is relatively recent. The (perhaps) first LCA in history occurred in 1963, performed by Harold Smith on the production of chemicals. Shortly after, the famous Coca Cola company, carried out its own study to find the best container for its drink. In 1989, the first software for life cycle analysis, GaBi, appeared and the following year SimaPro was developed. That same year the term Life Cycle Analysis was coined, and it is from there that all the standards that regulate this kind of studies begin to appear today. ISO 14040 (1997), ISO 14041 (1998), ISO 14042 (2000)...

Since the LCA studies were established, numerous libraries and databases have appeared that have facilitated the appearance of projects of this type.

However, carrying out the study of a fleet of vehicles has always been very complicated, it requires too much detail, therefore an alternative method is used to model the production of a vehicle, and that is to use a standard vehicle [13]. Some important agents in the automotive sector have published the list of components of some of their vehicles, for example, the LCI (life cycle inventory) of the Volkswagen Golf A4, published by the company itself and available at[14], a full life cycle inventory list is provided on the materials used to produce the Volkswagen car. And studies and articles have already been carried out based on this database created by Volkswagen[15].

Actually, the manufacturing process of a vehicle represents less than 1% of its life cycle impact, but the transport sector and the industrial sector are two of the main greenhouse gas emitters. [16], a project aimed at reducing fossil fuel consumption, will help achieve the goals of the 2030 agenda and make this world a better place.

## 3. Objectives

The objective of this project is to carry out a life cycle analysis study of the processes that occur in the PSA factory, evaluate their impact and possible points for improvement. Once its weaknesses are known, technological improvements will be implemented in order to improve efficiency and reduce the environmental impact of its procedures. Subsequently, the life cycle analysis would be carried out again with the improvements already applied in order to compare with the initial data and have empirical samples of the consequences of the applied improvements. In order to achieve this goal, the following milestones will be pursued.

1) Obtain empirical data from the factory. Periodic visits will be made to the facilities to obtain some first-hand data.
2) Carry out a life cycle analysis with this data using the SimaPro tool (this part of the project is not included in this paper)
3) Study the results and propose improvements where it is most optimal. With this data obtained, it will be studied where their processes are less efficient or there are greater waste of both energy and materials.
4) Propose and dimension the chosen technological measures and carry out an economic evaluation. In the event that these proposals do not meet the proposed objectives, or exceed the established budget, the transition will be made until the balance is found between reducing consumption and emissions, but always within the economic framework.
5) Apply these improvements. Based on the data, technological improvements will be proposed to improve the performance of the processes under study.
6) Carry out another study of the environmental impact with the improvements applied. Again using the SimaPro tool.
7) Compare the data from both studies and draw conclusions. This will help the company to have empirical evidence of both environmental and economic improvements with the new processes and will serve as an example for other companies to apply these measures and reduce their environmental impact.

## 4. Resources used

### 4.1 SimaPro

There are different softwares for the generation of life cycle analysis studies. Among them is OpenLCA, SimaPro or GaBi [17]. The choice of one program or another is very important depending on the functions and databases wanted. Due to the demands of this project, it was decided to use the SimaPro tool.

SimaPro

**Figure 6.** SimaPro logo

SimaPro [18] is a software with more than 30 years in the market and with a presence in more than 80 countries. Companies apply it in different areas such as sustainability reports, product design, water and carbon footprint measurement ... With SimaPro it is possible to:

• Easily model and analyze complex lifecycles in a systematic and transparent way.

• Measure the environmental impact of different products and services at all stages of the life cycle.

• Identify critical points in each link in the supply chain, from the extraction of raw materials to manufacturing, distribution, use and disposal.

SimaPro makes use of a large number of databases to analyze processes or materials, among which are (Agri-footprint, ELCD, ecoinvent, EXIOBASE, Environmental Footprint databes ...)

### 4.2. Engineering Equation Solver (EES)

EES is a software for the calculation of a set of algebraic equations. This program is capable of efficiently solving a hundred coupled nonlinear algebraic equations, as well as differential equations. The program was developed at the University of Wisconsin-Madison. The program also incorporates thermophysical functions, which is interesting in this project for the calculation of heat pumps.

### 4.3. Polysun

Polysun is a high-end software oriented to the planning, design and optimization of energy production systems [19]. In the case of this project, it will be used to size the vacuum tubes that will replace natural gas in the production of heat. Through this program, the consumption and the installation to be dimensioned will be simulated.

**Figure 7.** Polysun logo

### 4.4. Ressspi

Ressspi is an open source software for the simulation of solar installations and applications. Ressspi is an online calculator, developed in Python 3, developed to establish a common framework in the benchmarking of solar concentration technologies. It is capable of estimating both energy production and financial aspects, in addition, it is very flexible in its simulation and has great power despite being a free program. [20]

**Figure 8**. RESSSPI logo

In this project, it will be used to size the concentration collectors (linear concentration solar thermal collectors, Fresnel type, provided by the company SOLATUM, the same company that develops the Ressspi software).

### 4.5. PVSyst

PVSyst is a simulation software used globally and in numerous studies and real projects, for the dimensioning and optimization of renewable energy generation systems (wind and solar). [21]

**Figure 9.** PVSyst logo

It will be used in this project as a complement to the two previous programs and to simulate the global process that includes both the vacuum tubes and the concentration collectors.

## 5. Results

This section will be divided into subsections according to the different parts of the project.

### 5.1. Vacuum tube solar collector

This technology would be used to power the factory's heating systems. For this, the POLYSUN tool was used. After a series of iterations and technical decisions, always seeking to adapt to the needs of the factory and obtaining the highest efficiency at the lowest cost, the following results were obtained.

**Overview solar thermal energy (annual values)**

| | |
|---|---|
| Collector area | 18.4 m² |
| Solar fraction total | 50.3% |
| Total annual field yield | 5,348.4 kWh |
| Collector field yield relating to gross area | 291.3 kWh/m²/Year |
| Collector field yield relating to aperture area | 454.6 kWh/m²/Year |
| Max. fuel savings | 566 m³(gas): [Natural gas H] |
| Max. energy savings | 5,942.6 kWh |
| Max. reduction in CO2 emissions | 1,376 kg |

**Figure 10**. Summary results of the vacuum tube solar collector

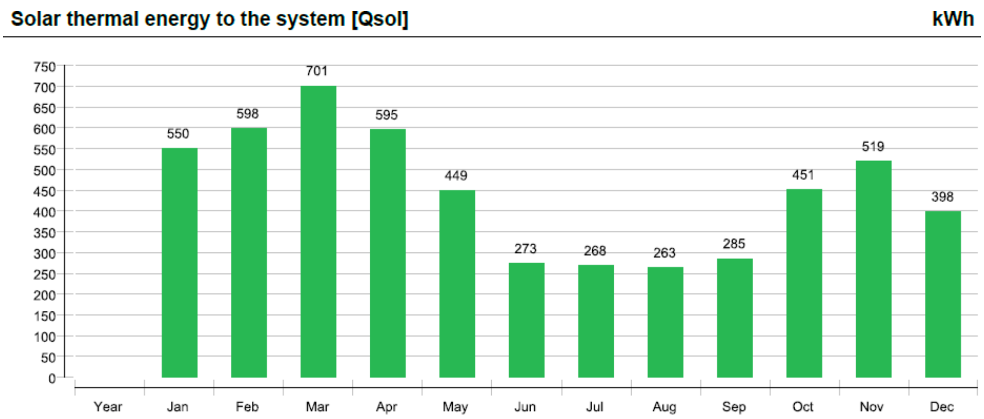



**Figure 11**. Solar contribution by months to the system

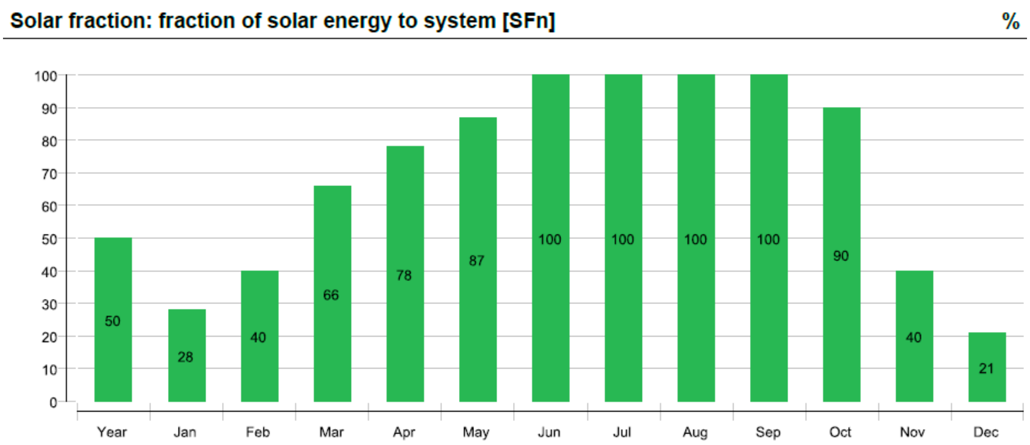



**Figure 12.** Percentage of solar energy to the system, by months

As expected, when less energy is provided is in the summer months, 100% of which is solar. This is because in these months it is when this type of energy can be used the most, however it is when heating systems are not needed.

## 5.2. Concentrating solar thermal energy

This technology is used to provide the necessary heat to the painting processes. The sizing was carried out with the RESSSPI tool, and after a series of iterations, always seeking the objective of supplying 20% of the demand, with the least investment and the fastest payback period, the following results were obtained.

| | | |
|---|---|---|
| Solar savings on first year | 141.002 | €/year |
| Current Invoice | 553.050 | €/year |
| Initial Investment | 1.684.805 | € |
| Solar Field | 6.336 | $m^2$ |
| %Fuel Saving | 20,4 | % |
| IRR | 10,4 | % |
| Energy Production | 3.618.786,6 | kWh/year |
| Payback Period | 11 | Years |
| CO2 avoided | 723,6 | Ton/year |

**Figure 13**. Concentration solar thermal energy results summary

5.3. Heat pumps

After an evaluation, it was concluded that 3 pumps would be used to reuse the heat from certain emitting sources in the factory that had similar characteristics. The pumps would be purchased directly from the manufacturers without the need to size their own pumps, for which the economic evaluation was carried out, obtaining the following results.

| Technical Results | | |
|---|---|---|
| Gas saving | 1710 | kW |
| CO2 Avoided | 1102 | Ton / year |
| CO2 emitted by the use of the pumps | -500.803 | Ton / year |
| Net avoided CO2 | 601,197 | Ton / year |

**Figure 14.** Technical results

| Economic results | | |
|---|---|---|
| **GO** | **€ 447,049.85** | **€** |
| **IRR** | **18.16%** | **€** |
| **Period Ret.** | **6.41** | **years** |

**Figure 15**. Economic results

Below, a table that shows the working days in each month, as well as the consumption of the paint ovens and the Thermal Power Plant. The last column shows the percentage of kW that the pumps cover with respect to the total paint ovens.

| Work days | Month | Paint Ovens | CT - PCI | Unit | % Reduction |
|---|---|---|---|---|---|
| 17 | January | 1,745,095 | 2,182,306 | kWh | 26.65% |
| 19 | February | 1,992,222 | 2,248,169 | kWh | 26.09% |
| 18 | March | 1,877,918 | 1,644,304 | kWh | 26.22% |
| 21 | April | 2,146,097 | 864,163 | kWh | 26.77% |
| 20 | May | 1,953,799 | 0 | kWh | 28.01% |
| 22 | June | 2,216,319 | 0 | kWh | 27.16% |
| 16 | July | 1,595,193 | 0 | kWh | 27.44% |
| 12 | August | 1,266,973 | 0 | kWh | 25.91% |
| 22 | September | 2,381,964 | 0 | kWh | 25.27% |
| 15 | October | 1,539,678 | 11,723 | kWh | 26.65% |
| 20 | November | 2,106,669 | 2,120,859 | kWh | 25.97% |
| 14 | December | 1,492,795 | 1,708,857 | kWh | 25.66% |

**Figure 16**. Gas consumption reduction percentage with series pumps [Own source]

5.4. Life cycle analysis.

The last section of the results section is the life cycle analysis. In this section, a study of the environmental impact of the car factory will be carried out, and it will be compared with a study prior to the implementation of the technological measures that has been exposed in this work.

For this, the SimaPro tool will be used, which will evaluate the adverse effects of this industrial activity on different environmental indicators (eutrophication, ocean acidification, damage to the ozone layer, greenhouse effect ...), paying special attention to the emission of greenhouse gases. greenhouse effect (to the reduction of these with respect to previous values).

A life cycle analysis (LCA) has a specific structure that must be followed whenever a study of this type is carried out. This structure has already been specified in the part of section 1. Introduction and continues below.


**Figure 17.** Partes de estudio de un LCA *[22]*

5.4.1. Objective and Scope definition

The main objective of this project is to carry out an environmental impact study on some of the processes that take place in a Spanish car factory, specifically, it will focus on the painting, sheet metal and assembly processes. Their impact will be evaluated first. Once its weaknesses are known (part carried out prior to this project), technological improvements (previous sections) will be implemented in order to improve efficiency and reduce the environmental impact of these procedures. Subsequently, the life cycle analysis would be carried out again with the improvements already applied in order to compare with the initial data and have empirical samples of the consequences of the applied improvements.

The results of this study should answer questions like. How big is the carbon footprint of this company? What can they do to reduce it? Are these new technologies a significant improvement? What part of the environment is most affected by the factory? Has the implementation of these technological improvements been worth it? ...

The applicants for this study are the PSA Factory, as well as the professors involved in the Cátedra de Transición Energética (Cátedra de Transición Energética)

This project will have some limitations. As has been established, it will only be focused on the sheet metal, painting and assembly processes, and this part of the life cycle of a car represents less than 1% of the total environmental impact that the car has if the method of "From the cradle to the grave"[23]. Therefore, the reduction of the impact will not be as significant as if it were focused on the use of a car, which is the part of its life where it has the most significant impact but, as already seen, the transport sector is one of the major contributors to global greenhouse gas emissions [24], closely followed by industrial activity, so this project contributes to reducing the environmental impact of two of the largest sectors that pollute the most, and any initiative, for Small though it is, it helps to achieve the sustainable development goals and to have a cleaner planet.

This project will not evaluate anything related to raw material suppliers, the scope is limited to the factory's own processes. This option remains as a possible point of improvement. Look for more sustainable suppliers, or raise awareness among existing ones and pressure them to carry out more respectful practices with the environment.

On the other hand, although the impact of materials, such as paint or sheet metal, will be studied, the improvements that will be proposed will be limited exclusively to reducing energy consumption, as has already been seen, by means of solar collectors, vacuum tubes and fuel pumps. hot.

The functional unit is therefore to measure the environmental impact of these three processes in the production of a single car.

5.4.2. Inventory Analysis

The inventory of materials and processes is divided into the parts of painting, sheet metal and assembly. Technological measures have only been set aside for the part of the painting process, so only the improvement in the impact in this area will be studied.

The paint part in turn has numerous threads, which have been classified into

- Cataphoresis and degreasing effluents
- TTS Green
- Base B0
- Cataphoresis
- Lacquers and Varnish
- Putties
- Final baking.

Below are some screenshots of the analysis inventory. These images have been contributed by Pablo Gómez Sánchez de Rojas, since his Final Degree Project consists of the environmental study of the life cycle impact prior to the installation of the technological measures that have been developed here, and this project includes post-implementation impact improvement study. It is impossible to reference Pablo's project since it is being carried out simultaneously with it.

The images present a summary of the materials and processes of each of the 3 stages, as well as their quantities. As can be seen, the one with the highest level of detail is the painting stage, since, as already mentioned, it is the part under study.

| Producto | Cantidad | Ud. | Proyecto |
|---|---|---|---|
| Water, completely softened {RoW}\| market for water, completely softened \| Cut-off, U | 622,34 | kg | Ecoinvent 3 - allocati |
| Electricity, low voltage {ES}\| market for \| Cut-off, U | 120 | kWh | Ecoinvent 3 - allocati |
| Sodium hydroxide, without water, in 50% solution state {GLO}\| market for \| Cut-off, U | 0,1648 | kg | Ecoinvent 3 - allocati |
| Hydrochloric acid, without water, in 30% solution state {RER}\| market for \| Cut-off, U | 0,1625 | kg | Ecoinvent 3 - allocati |
| Sulfuric acid {RER}\| production \| Cut-off, U | 0,05466 | kg | Ecoinvent 3 - allocati |
| Lime, hydrated, packed {RER}\| market for lime, hydrated, packed \| Cut-off, U | 0,043 | kg | Ecoinvent 3 - allocati |
| Aluminium sulfate, powder {RoW}\| market for aluminium sulfate, powder \| Cut-off, U | 0,02733 | kg | Ecoinvent 3 - allocati |
| Non-ionic surfactant {GLO}\| non-ionic surfactant production, fatty acid derivate \| Cut-off, U | 0,085 | kg | Ecoinvent 3 - allocati |
| Sodium borates {GLO}\| market for \| Cut-off, U | 0,732 | kg | Ecoinvent 3 - allocati |
| Ammonium chloride {GLO}\| amination of chlorosilane \| Cut-off, U | 0,311 | kg | Ecoinvent 3 - allocati |
| Hexamethyldisilazane {GLO}\| amination of chlorosilane \| Cut-off, U | 0,127 | kg | Ecoinvent 3 - allocati |
| Manganese {GLO}\| market for \| Cut-off, U | 0,065 | kg | Ecoinvent 3 - allocati |
| Water, deionised {Europe without Switzerland}\| water production, deionised \| Cut-off, U | 147,29 | kg | Ecoinvent 3 - allocati |
| Diethylene glycol {GLO}\| market for \| Cut-off, U | 0,000182 | kg | Ecoinvent 3 - allocati |
| Polyester resin, unsaturated {GLO}\| market for \| Cut-off, U | 0,1362 | kg | Ecoinvent 3 - allocati |
| Rutile, 95% titanium dioxide {GLO}\| rutile production, synthetic, 95% titanium dioxide \| Cut | 0,1817 | kg | Ecoinvent 3 - allocati |
| Barite {RER}\| production \| Cut-off, U | 0,1784 | kg | Ecoinvent 3 - allocati |
| Carbon black {GLO}\| production \| Cut-off, U | 0,16225 | kg | Ecoinvent 3 - allocati |
| Melamine formaldehyde resin {RER}\| production \| Cut-off, U | 0,0649 | kg | Ecoinvent 3 - allocati |
| Polyurethane, flexible foam {RoW}\| market for polyurethane, flexible foam \| Cut-off, U | 0,2596 | kg | Ecoinvent 3 - allocati |
| Solvent, organic {GLO}\| production \| Cut-off, U | 0,07788 | kg | Ecoinvent 3 - allocati |
| Compressed air, 1200 kPa gauge {RER}\| market for compressed air, 1200 kPa gauge \| Cut- | 300 | m3 | Ecoinvent 3 - allocati |
| Cationic resin {RER}\| market for cationic resin \| Cut-off, U | 0,4558 | kg | Ecoinvent 3 - allocati |
| Barium sulfide {GLO}\| barium sulfide production \| Cut-off, U | 0,2194 | kg | Ecoinvent 3 - allocati |
| Solvent, organic {GLO}\| production \| Cut-off, U | 0,0844 | kg | Ecoinvent 3 - allocati |
| Polyvinylchloride, bulk polymerised {RER}\| polyvinylchloride production, bulk polymerisati | 2,28259 | kg | Ecoinvent 3 - allocati |
| Acrylic varnish, without water, in 87.5% solution state {RER}\| acrylic varnish production, prc | 1,7036 | kg | Ecoinvent 3 - allocati |
| Coating powder {GLO}\| market for \| Cut-off, U | 1,7036 | kg | Ecoinvent 3 - allocati |
| Natural gas, from medium pressure network (0.1-1 bar), at service station {GLO}\| market fc | 24 | kg | Ecoinvent 3 - allocati |

**Figure 18.** Inventory analysis of the painting process analysis [SimaPro Report]

| Producto | Cantidad | Ud. | Proyecto |
|---|---|---|---|
| Electricity, low voltage {ES}\| market for \| Cut-off, U | 38,07 | kWh | Ecoinvent 3 - allocati |
| Water, completely softened {RoW}\| market for water, completely softened \| Cut-off, U | 67,94 | kg | Ecoinvent 3 - allocati |

**Figure 19.** Inventory analysis in mounting process analysis [SimaPro Report]

| Producto | Cantidad | Ud. | Proyecto |
|---|---|---|---|
| Polyester-complexed starch biopolymer {GLO}\| market for \| Cut-off, U | 2,2825 | kg | Ecoinvent 3 - allocati |
| Steel, low-alloyed {GLO}\| market for \| Cut-off, U | 295 | kg | Ecoinvent 3 - allocati |
| Welding, arc, steel {RER}\| processing \| Cut-off, U | 10 | m | Ecoinvent 3 - allocati |
| Water, completely softened {RoW}\| market for water, completely softened \| Cut-off, U | 250,13 | kg | Ecoinvent 3 - allocati |
| Electricity, low voltage {ES}\| market for \| Cut-off, U | 86,79 | kWh | Ecoinvent 3 - allocati |

**Figure 20.** Sheet metal process inventory analysis [SimaPro Report]

Those represented here are the data prior to the installation of the technological improvements. After this installation, gas consumption per vehicle will be substantially reduced, as well as general energy consumption in all processes.

#### 5.4.3. Life Cycle Impact Assessment (LCIA)

Two methods are going to be used int this study.

**CML-IA baseline** is a LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in The Netherlands.

The CML-IA (baseline) method elaborates the problem-oriented (midpoint) approach. The CML Guide provides a list of impact assessment categories grouped into:

A: Obligatory impact categories (Category indicators used in most LCAs)
B: Additional impact categories (operational indicators exist, but are not often included in LCA studies)
C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA)

In case several methods are available for obligatory impact categories a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem-oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.

Only baseline indicators are available in the CML method in SimaPro (based on CML Excel spreadsheet with characterization and normalization factors). In general, these indicators do not deviate from the ones in the spreadsheet. In case the spreadsheet contained synonyms of substance names already available in the substance list of the SimaPro database, the existing names are used. A distinction is made for emissions to agricultural soil and industrial soil. Emissions to agricultural soil are made clear by placing 'agricultural' in the column 'sub compartment' while emissions to industrial soil are blank. Emissions to seawater are indicated with 'ocean', while emissions to fresh water are blank (it is assumed that all emissions to water in existing process records are emissions to fresh water).

Depletion of abiotic resources

Two impact categories: Abiotic depletion (elements, ultimate reserves) and abiotic depletion (fossil fuels)

Abiotic depletion (elements, ultimate reserves) is related to extraction of minerals due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals (kg antimony equivalents/kg extraction) based on concentration reserves and rate of deaccumulation. Abiotic depletion of fossil fuels is related to the Lower Heating Value (LHV) expressed in MJ per kg of m3 fossil fuel. The reason for taking the LHV is that fossil fuels are considered to be fully substitutable.

Global warming

The characterization model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterization factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide equivalent/kg emission.

Ozone layer depletion (steady state)

The characterization model is developed by the World Meteorological Organization (WMO) and defines ozone depletion potential of different gases (kg CFC-11 equivalent/ kg emission).

Human toxicity (HTP inf), Freshwater aquatic ecotoxicity (FAETP inf), Marine aquatic ecotoxicology (MAETP inf) and Terrestrial ecotoxicity (TETP inf)

Characterization factors, expressed as Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/ kg emission.

Photochemical oxidation (high NOx)

The model is developed by Jenkin & Hayman and Derwent and defines photochemical oxidation expressed in kg ethylene equivalents per kg emission.

Acidification (incl. fate, average Europe total, A&B)

Acidification potential expressed in kg SO2 equivalents per kg emission. Model is developed by Huijbregts.

Eutrophication (fate not included)

Eutrophication potential developed by Heijungs et al and expressed in kg PO4 equivalents per kg emission.

For further information see the database manual.

The other method is CED

**Cumulative Energy Demand (CED)** is based on the method published by ecoinvent version 2.0 and expanded by PRé Consultants for raw materials available in the SimaPro 7 database. The method is based on higher heating values (HHV).

Frischknecht R., Jungbluth N., et.al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, www.ecoinvent.ch

Wood is not included in this methodology due to the frequent use of wood as feedstock in Simapro.

Normalization: it is not a part of this method.

Weighting: Each impact category is given the weighting factor 1.

For more information see the Database manual.

5.4.4. Results and interpretation

The results of the different processes prior to the installation of the technological improvements are set out below. With regard to the sheet metal and assembly processes, they will only be included once, since technological improvements have been focused on the painting process.

PLATE and MOUNTING

In the following Pareto diagram, using the CED method, it can be seen how the largest source of energy supply is non-renewable (fossil fuels) followed by renewable biomass.

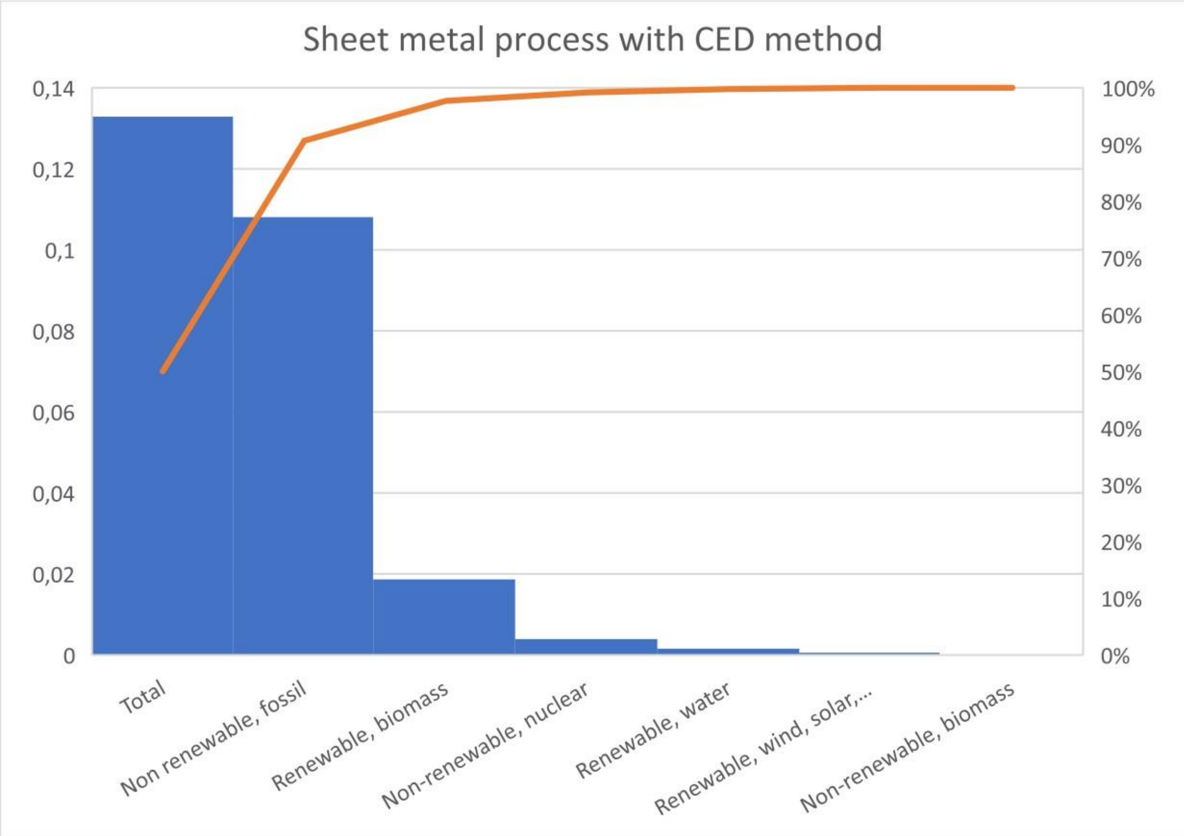



**Figure 21.** Energy consumption of the sheet metal process [Own source]

Something similar occurs in the assembly process, where the greatest energy contribution comes from fossil fuels, followed by nuclear and thirdly from renewable energies such as solar or wind. This was to be expected since the Spanish energy mix has percentages similar to those that can be found in these graphs.

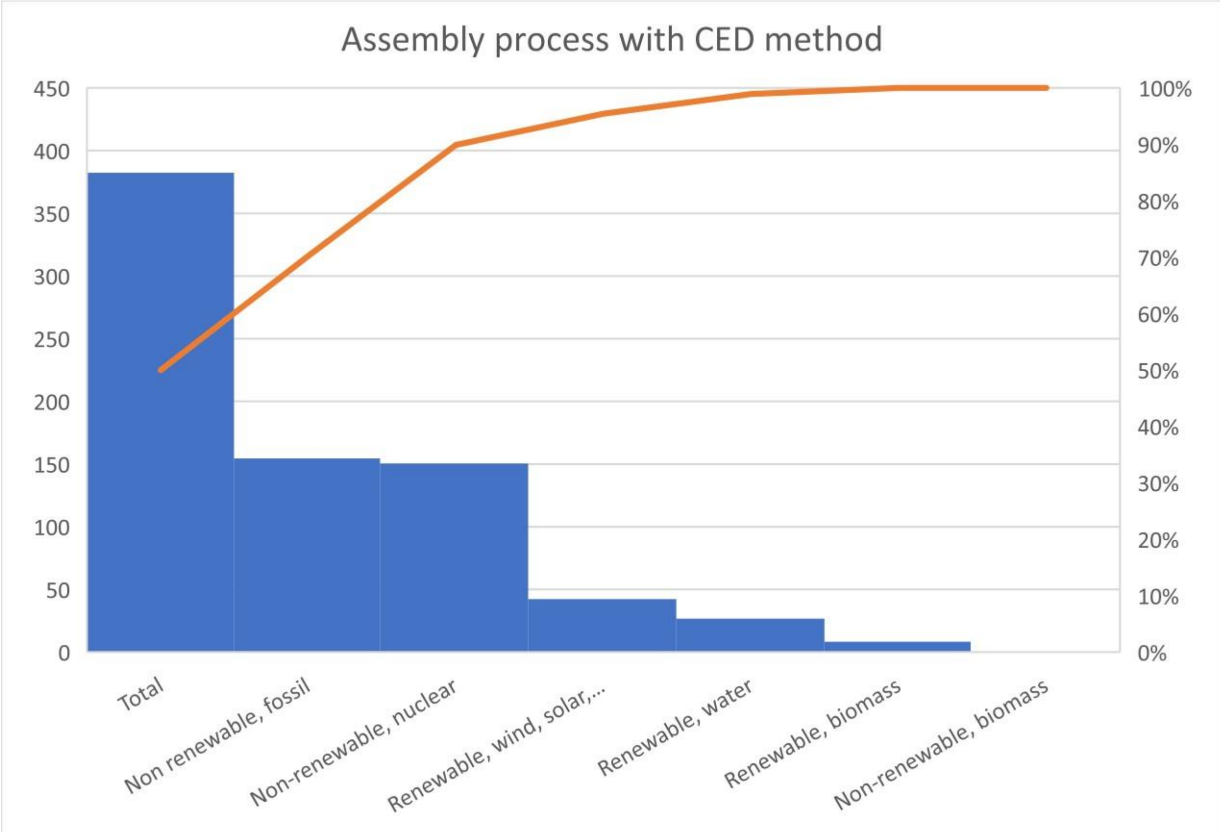



**Figure 22.** Energy consumption in the Assembly process [Own source]

Using now the CML-IA baseline method, it can be seen in which environmental indicators these processes have a greater impact, the worst being marine aquatic ecotoxicity, followed by fresh water ecotoxicity and, thirdly, human toxicity. It must be taken into account that these analyzes focus on the complete life cycle and, most of the pollutants, always end up in some body of water when they are absorbed and precipitated by raindrops or carried away by the flow of rivers or rivers. of groundwater, from its source of emission to the sea, the ocean or a lake. In the following pages it can be found the two graphs with the results.

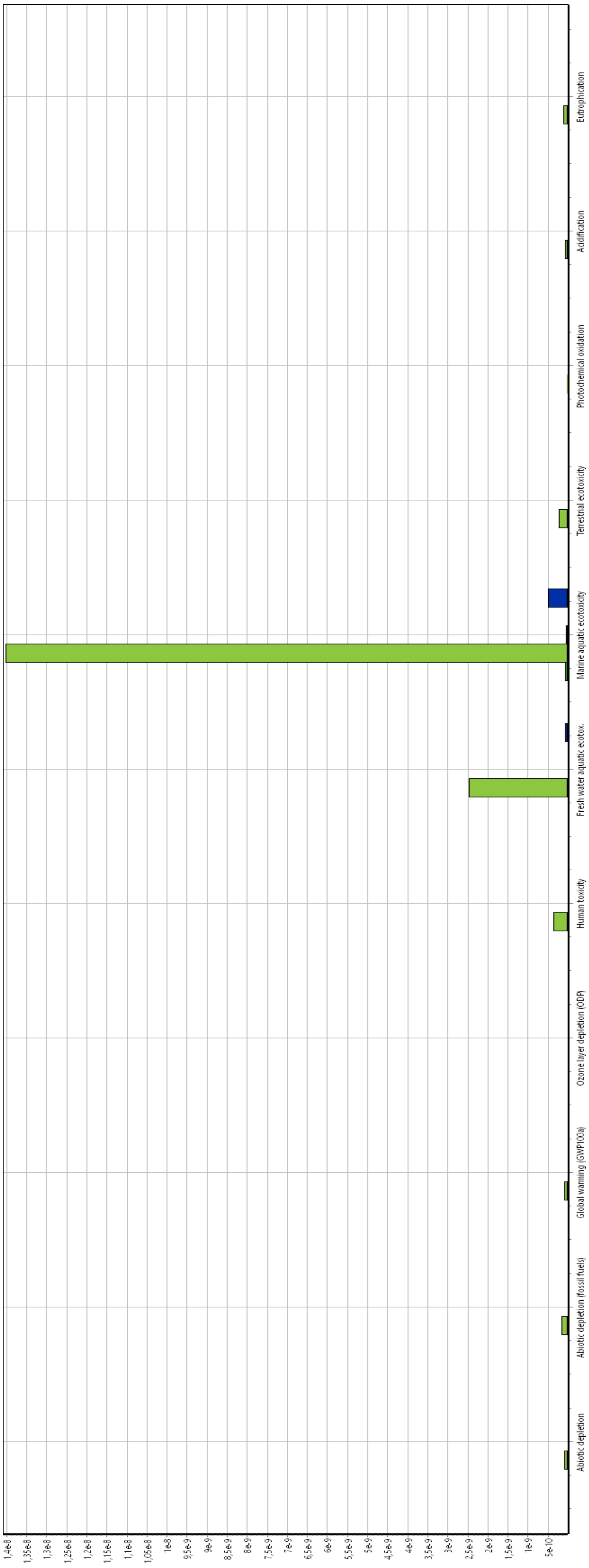
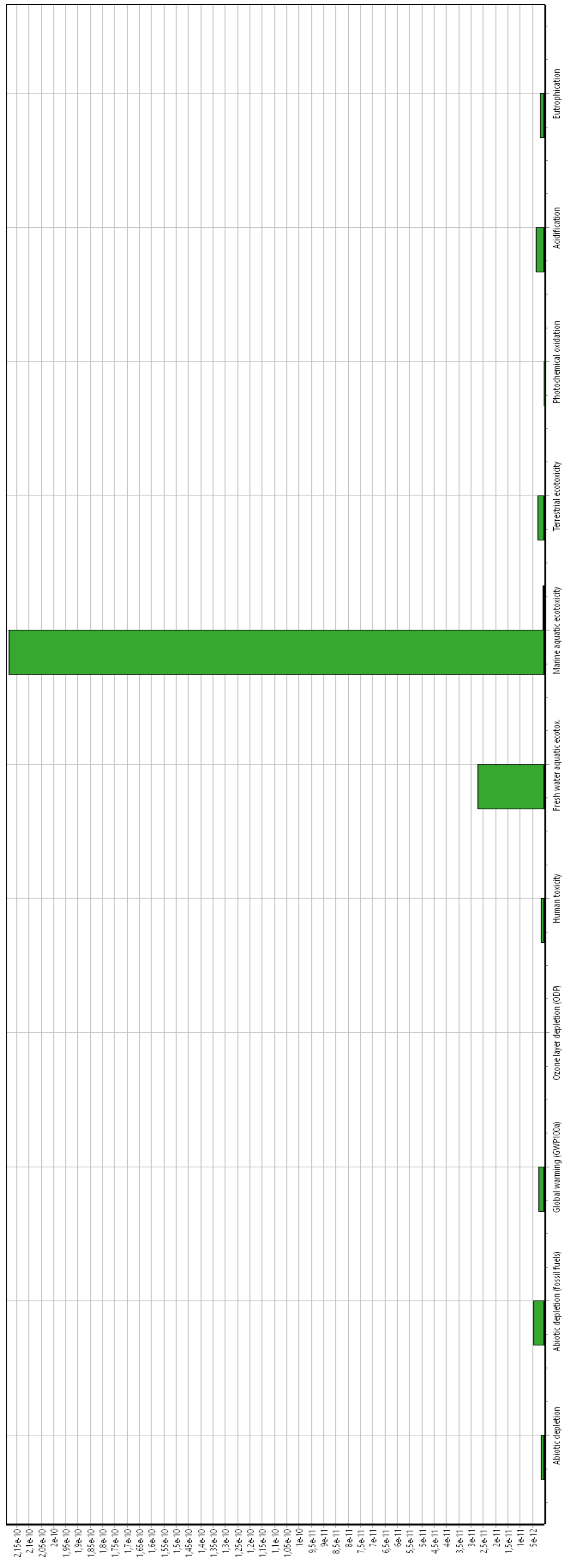



**Figure *23.*** *Results of the sheet metal process with the CML-IA baseline method [SimaPro Report*




534

**Figure *24*.** Results of the assembly process with the CML-IA baseline method [SimaPro Report] 535

<u>PAINTING</u>

First, the data prior to the installation of the technological improvements will be analyzed and then the data once installed. Once both results have been shown, a comparison will be made between them focused exclusively on the emission of greenhouse gases.

Below the CED method

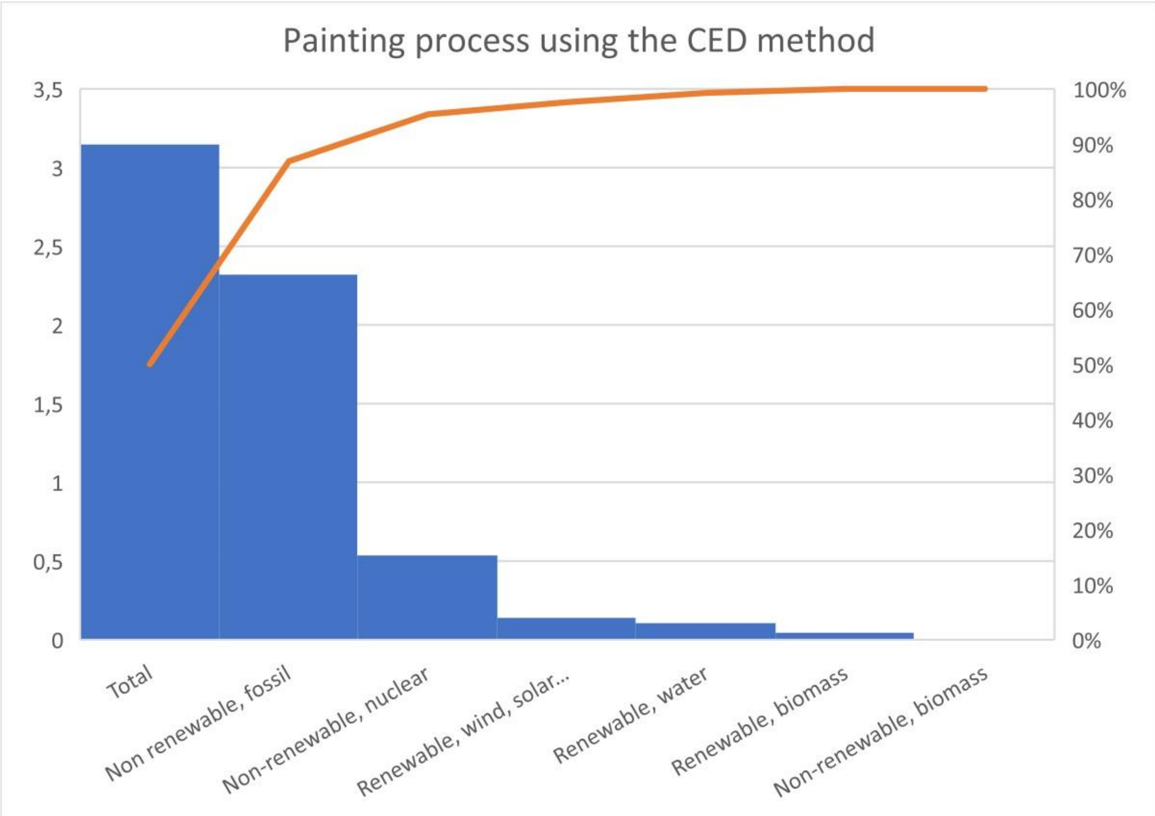
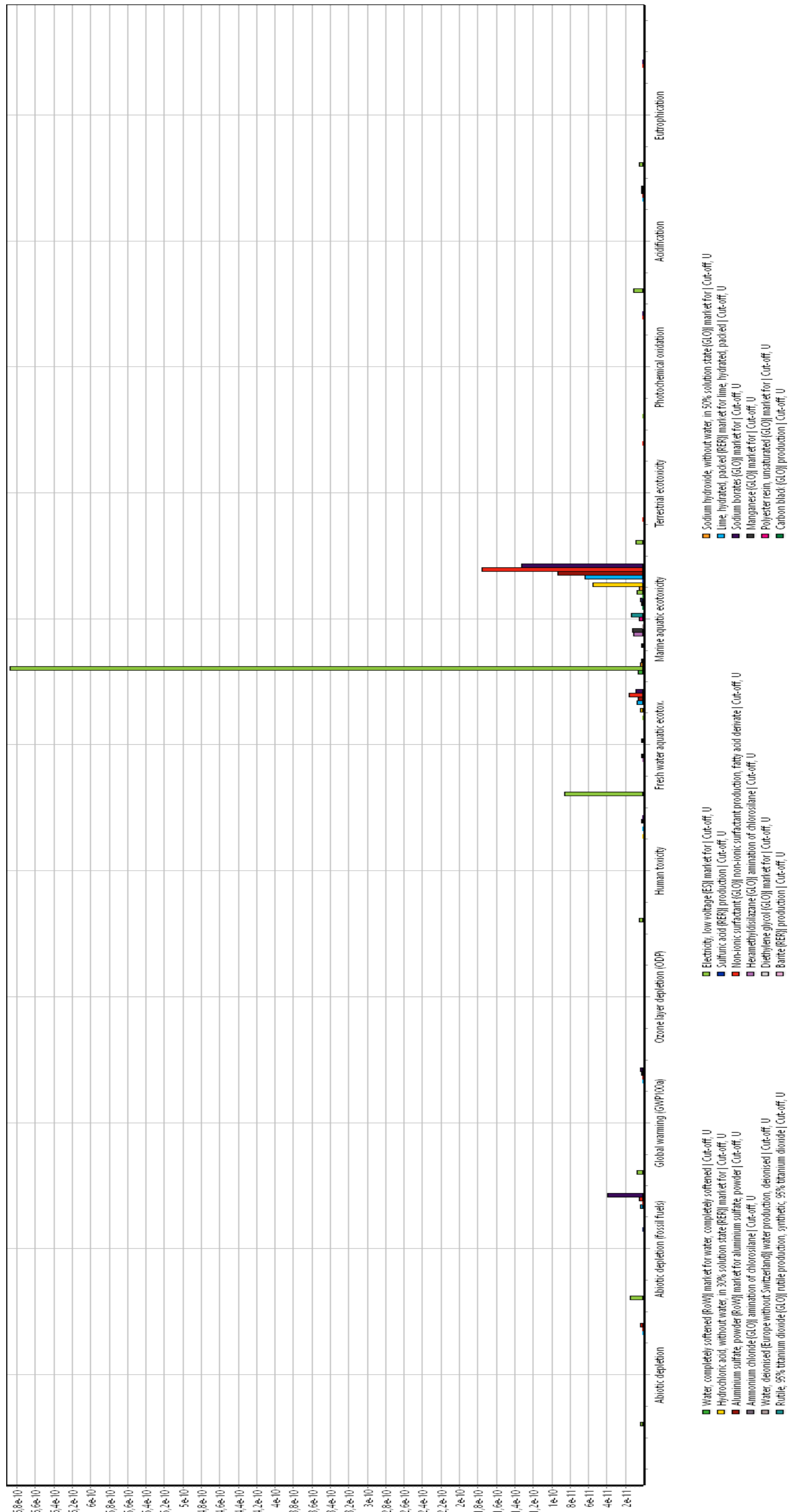



**Figure *25*.** Energy consumption of the painting process [Own source]

The greatest energy contribution comes from fossil fuels.

If the results are now analyzed using the CML-IA baseline method, it can be seen that, as in the previous cases, marine ecotoxicity is where it has a greater impact.




549

**Figure 26.** Results of the painting process with the CML-IA baseline method [SimaPro Report] 550

Below are the results after the technological improvements here dimensioned. First with the CED method. For its calculation, it was necessary to calculate what percentage of natural gas was avoided using the sum of the solar panels and the use of heat pumps. Taking into account the previous results, it can be seen that this sum implies a reduction of 45% of the total, that is, it goes from consuming 24kg of natural gas per vehicle, to consuming only 13kg. To this, it must be added the energy production provided by solar panels. Heat pumps use residual heat to work, so overall, the process consumes less energy, and the percentages of the energy supplied corresponding to renewable sources, increases. In the Figure below, the final results.

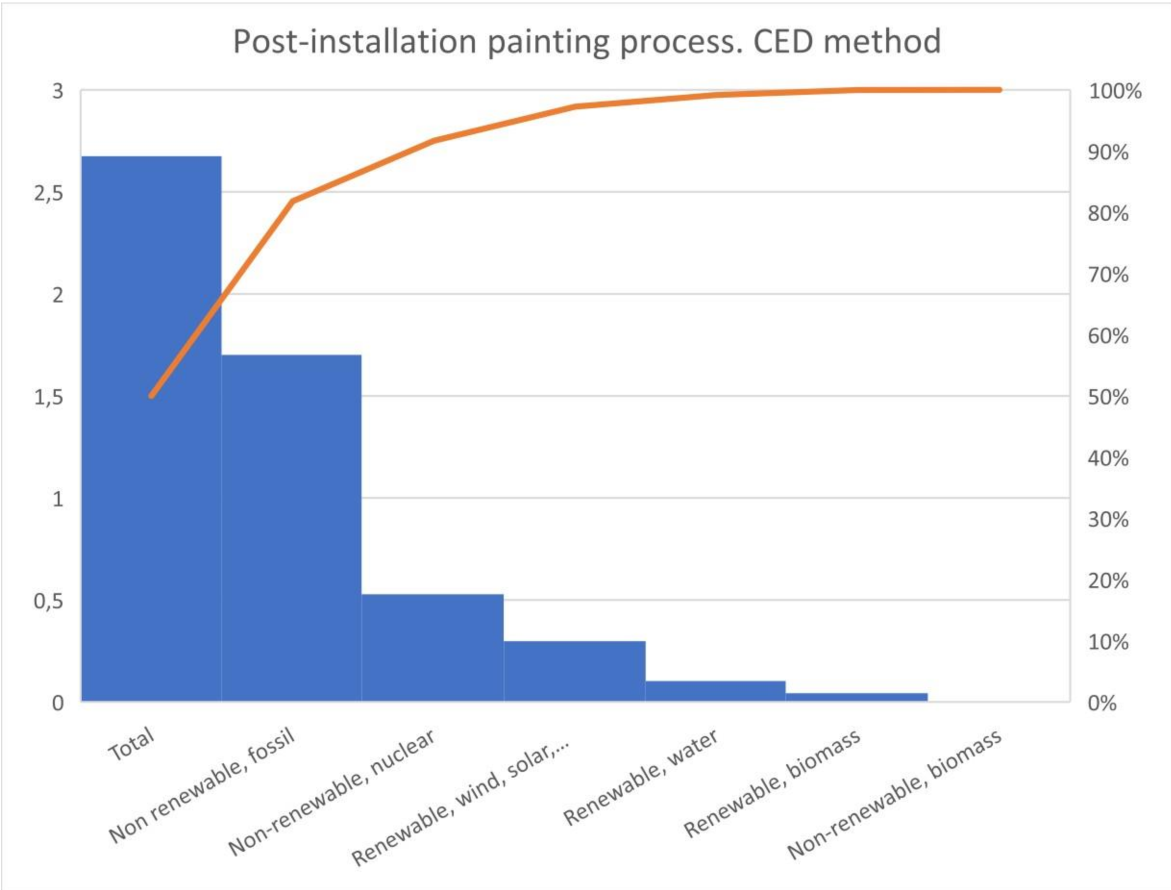



**Figure 27.** Energy consumption of the painting process with technological improvements [Own source]

As expected, total consumption has dropped from 3.2 GJ per year to just 2.67 GJ. In addition, the percentage of solar use has increased from just 3% to a total of almost 12%. Significant improvements, although it continues to be in third place in terms of global energy transport.

Using the CML-IA baseline method, the results are practically negligible, since when studying the life cycle impact, improvements of this type do not imply a significant change in the global. The overall impact will decrease in all sections, but marine ecotoxicity will remain the worst stop, followed by fresh water ecotoxicity as in previous cases.

The corresponding graph is included below.

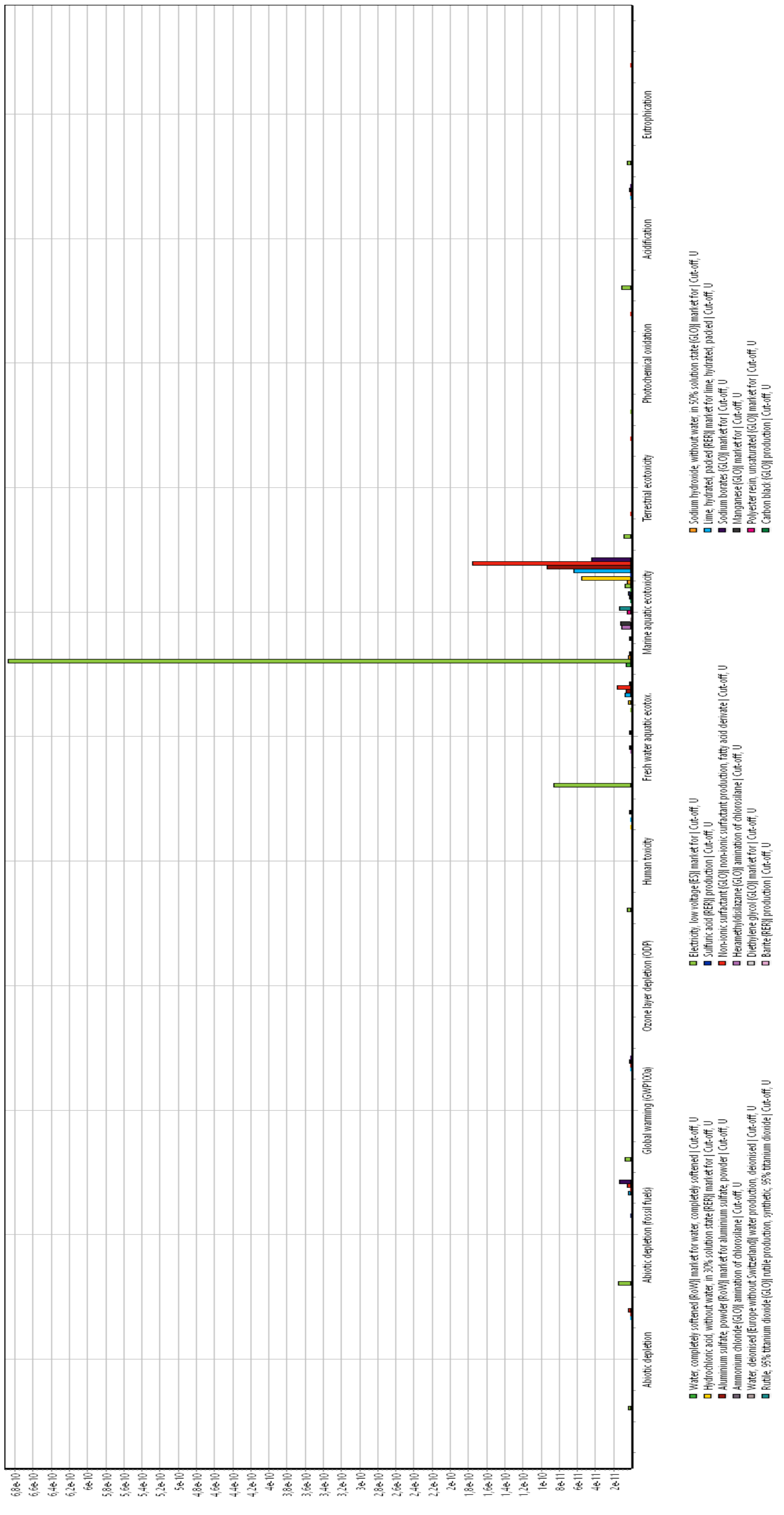



**Figure 28.** Results of the painting process with the CML-IA baseline method

and the improvements installed [SimaPro Report]

Finally, the reduction in the emission of greenhouse gases will be seen. The installation of SOLATOM solar collectors [25], represents a reduction in CO2 emissions of 723.8 Ton / year. And the use of the pumps prevents 600.9 Ton / year of this same gas from being emitted into the atmosphere (this would be the subtraction of the CO2 avoided by reducing gas consumption, minus the CO2 generated by feeding the pumps with electricity)

With all this, CO2 emissions are reduced by a total of 1,324.7 Ton / year (and this only in the area of the painting ovens, the vacuum tube solar collectors that will be used for air conditioning)

According to the Generalitat de Catalunya Interdepartmental Climate Change Commission, the emission factor of natural gas is 2.15 kg of CO2 / Nm3 [26] and according to GASNAM [27], its density is 0.743 kg / Nm3 , that is, 2.9 kg of CO2 are produced for each kg of Natural Gas consumed. Therefore, if 24 kg of Natural Gas are consumed for each car produced, and 82,000 cars are produced in a standard year, this factory consumes 1,968 million kg of Natural Gas per year, which implies emissions of 5,707.2 tons of CO2 per year.

Therefore.

$$\frac{1324.7}{5707.2} = \mathbf{23,21}\%$$

The implementation of these measures implies a reduction in total emissions of 23.21%. A significant improvement that will bring this company closer to the sustainability objectives of the 2030 agenda, which will allow it to continue carrying out its activity while protecting the environment and which will undoubtedly give them positive publicity with respect to potential customers interested in their cars.

## 6. Conclusions

Below are some of the conclusions that have been obtained throughout the project. Some of these deductions have already been collected in previous sections of the project and may be repeated in this section.

- Building a vehicle accounts for a very small percentage of its life cycle environmental impact. Within the manufacturing process, in turn, the painting part is another small part, and within this painting part, it has been possible to reduce greenhouse gas emissions by 23%, which, globally over the entire life cycle of a vehicle, it will be a very small improvement.
- There is the possibility of increasing the size of the improvements in the future. The factory has a huge plot where more solar panels could be installed, in addition, numerous heat sources are wasted that could be used to power other parts of the car manufacturing process or to acclimatize different areas of the factory.
- The initial investment to achieve this improvement is important. Renewable energies such as solar, currently have a high price that makes some projects unviable, however, only through investment in this sector and the development of projects like this, will it be possible to reduce the prices of renewable energies and expand their feasibility and its implementation.
- All in all, this factory will obtain very good conclusions from this project, it will have to make a significant initial investment, but as it has been seen, in less than 10 years it will have recovered the investment and will be making profit. In addition, it will improve their image to the public, which will bring a new range of customers who, motivated by the company's environmental commitment, will not hesitate to purchase their products. And last, and most importantly, This contribution will help bring society closer to the long-awaited energy transition, making this world a better, safer and cleaner place.
- With respect to the life cycle analysis, it is a powerful tool that helps to clarify the different impacts that a product or a process has throughout its useful life, however, when analyzing a process, it can be a Limited tool, since the scope can be difficult to establish, or not large enough to take into account all factors. This tool may therefore be more useful in products rather than in processes, due to the ease of defining the scope.
- With regard to the solar technologies, it is worth highlighting their enormous potential. There is much to improve in this sector in terms of efficiency and it is true that it is a type of energy that is neutralized if the climatic conditions are not favorable, but its

potential is enormous, and with the proper research, much more impressive numbers could be achieved. and much more attractive electricity savings.

## 7. Sustainable Development Goals

The Sustainable Development Goals are a set of global goals, developed by world leaders on September 25, 2015 that seek to eradicate poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda [28]. Each objective has specific goals that must be achieved in the next 15 years. Below are the 17 SDGs.


**Figure 29.** Sustainable Development Goals *[29]*

As already noted above, the ultimate goal of this work is the preservation of the environment through the optimization of processes in a car factory, in order to reduce its emissions and energy waste, and thus mitigate the impact of this productive activity throughout its life cycle. Therefore, the objectives that this project helps to achieve will be listed below and the reasons for this will be explained.
The following objectives are directly met:

9) Industry, innovation, and infrastructure.
By applying the new measures that will be proposed, an innovation is inevitably taking place in the infrastructure of this company, in addition, it is an innovation in search not only of economic savings, but also of the reduction of the environmental impact of said industry.

12) Responsible consumption and production
The purpose of the project is to help this company reduce its energy consumption and reduce its waste by analyzing the life cycle of its processes, which will lead to more responsible consumption and more efficient production, with less waste.
By carrying out this project, the impacts in different environmental areas that this company produces in its industrial activity will be considerably reduced. Therefore, it is necessary to talk about those SDGs that are met indirectly. This project protects natural ecosystems by reducing emissions of harmful substances and is committed to sustainable and environmentally friendly cities, so the following objectives could also be taken into account:
11) Sustainable cities and communities
13) Climate action
14) Underwater life
15) Life of terrestrial ecosystems.

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## 9. Annexes

1) Heat Pump 61XWH03 85-75 + 33-28ºC
2) Heat Pump 61XWH03 85-75 + 40-35ºC
3) Heat Pump 61XWH05 85-75 + 33-28ºC
4) Heat Pump 61XWH05 85-75 + 40-35ºC
5) Catalog “Focos”
6) Dimensioning of Fresnels
7) Simulation of heat pumps in EES
8) Plan of the spotlights
9) Sizing of the vacuum tube collectors in POLYSUN

# Informe de rendimiento (a carga total)

Nombre del proyecto:

Preparado por: Angel Cancela **24/02/2021**

## Bomba de calor agua-agua

## 61XWHHZE03

IOM

PSD

Brochure

### Información sobre rendimiento

| | | |
|---|---|---|
| Potencia calorífica | **376** | kW |
| Eficacia de calefacción (C.O.P.) | **2,96** | kW/kW |
| *Eficacia de calefacción (Coeficiente COP bruto) no certificado ** | ***2,98*** | *kW/kW* |
| Capacidad frigorífica al origen | **257** | kW |
| Potencia absorbida por la unidad | **127** | kW |

### Información del evaporador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **28,0** | °C |
| Temperatura de entrada | **33,0** | °C |
| Caudal de fluido | **12,4** | l/s |
| Pérdida de carga total | **18** | kPa |

### Información del condensador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **85,0** | °C |
| Temperatura de entrada | **75,0** | °C |
| Caudal de fluido | **9,2** | l/s |
| Pérdida de carga total | **15** | kPa |

### Información acerca del equipo

| | | |
|---|---|---|
| Lugar de fabricación | **Montluel, France** | |
| Tipo de refrigerante | **R1234ze(E)** | |
| Potencia mínima | **50** | % |
| Número de circuito refrigerante | **1** | |
| Peso de funcionamiento/envío | **2251/2132** | kg |
| Dimensiones del equipo (la x an x al) | **2724/981/1594** | mm |

### Información eléctrica

| | | |
|---|---|---|
| Tensión de la unidad | **400(+/-10%)-3-50** | V-Ph-Hz |
| Potencia en modo de espera | **0,100** | kW |
| Factor de potencia | **0,89** | |

| Amps (Un 400V) | CKT A |
|---|---|
| In (A):<br>Intensidad máxima | 241 |
| Id (A):<br>Corriente de arranque (max. Direct) | 1210 |
| Id/In | 5,0 |

### Información acústica

| | | |
|---|---|---|
| Nivel de potencia sonora (LwA) | **93** | dB(A) |
| Nivel de presión sonora a 10 m (LpA) | **76** | dB(A) |

### Opciones instaladas y accesorios

*: sin caída de presión del intercambiador

Todos los rendimientos son conformes con la norma EN 14511-3:2018. Nivel de potencia sonora de conformidad con ISO 9614-1.

CARRIER participates in the ECP program for Liquid Chilling Packages and Hydronic Heat Pumps.
Check ongoing validity of certificate:www.eurovent-certification.com.
Outside the scope of AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages Certification Program, but is rated in accordance with AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI).

# Informe de rendimiento (a carga total)

Nombre del proyecto:

Preparado por: Angel Cancela **24/02/2021**

## Bomba de calor agua-agua

## 61XWHHZE03

IOM

PSD

Brochure

### Información sobre rendimiento

| | | |
|---|---|---|
| Potencia calorífica | **438** | kW |
| Eficacia de calefacción (C.O.P.) | **3,33** | kW/kW |
| *Eficacia de calefacción (Coeficiente COP bruto) no certificado ** | ***3,36*** | *kW/kW* |
| Capacidad frigorífica al origen | **316** | kW |
| Potencia absorbida por la unidad | **131** | kW |

### Información del evaporador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **35,0** | °C |
| Temperatura de entrada | **40,0** | °C |
| Caudal de fluido | **15,2** | l/s |
| Pérdida de carga total | **24** | kPa |

### Información del condensador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **85,0** | °C |
| Temperatura de entrada | **75,0** | °C |
| Caudal de fluido | **10,7** | l/s |
| Pérdida de carga total | **15** | kPa |

### Información acerca del equipo

| | | |
|---|---|---|
| Lugar de fabricación | **Montluel, France** | |
| Tipo de refrigerante | **R1234ze(E)** | |
| Potencia mínima | **50** | % |
| Número de circuito refrigerante | **1** | |
| Peso de funcionamiento/envío | **2251/2132** | kg |
| Dimensiones del equipo (la x an x al) | **2724/981/1594** | mm |

### Información eléctrica

| | | |
|---|---|---|
| Tensión de la unidad | **400(+/-10%)-3-50** | V-Ph-Hz |
| Potencia en modo de espera | **0,100** | kW |
| Factor de potencia | **0,89** | |

| Amps (Un 400V) | CKT A |
|---|---|
| In (A):<br>Intensidad máxima | 241 |
| Id (A):<br>Corriente de arranque (max. Direct) | 1210 |
| Id/In | 5,0 |

### Información acústica

| | | |
|---|---|---|
| Nivel de potencia sonora (LwA) | **93** | dB(A) |
| Nivel de presión sonora a 10 m (LpA) | **76** | dB(A) |

### Opciones instaladas y accesorios

*: sin caída de presión del intercambiador

Todos los rendimientos son conformes con la norma EN 14511-3:2018. Nivel de potencia sonora de conformidad con ISO 9614-1.

CARRIER participates in the ECP program for Liquid Chilling Packages and Hydronic Heat Pumps.
Check ongoing validity of certificate:www.eurovent-certification.com.
Outside the scope of AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages Certification Program, but is rated in accordance with AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI).

# Informe de rendimiento (a carga total)

Nombre del proyecto:

Preparado por: Angel Cancela

**24/02/2021**

## Bomba de calor agua-agua

## 61XWHHZE05

IOM

PSD

Brochure

### Información sobre rendimiento

| | | |
|---|---|---|
| Potencia calorífica | **612** | kW |
| Eficacia de calefacción (C.O.P.) | **3,03** | kW/kW |
| *Eficacia de calefacción (Coeficiente COP bruto) no certificado ** | ***3,05*** | *kW/kW* |
| Capacidad frigorífica al origen | **423** | kW |
| Potencia absorbida por la unidad | **202** | kW |

### Información del evaporador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **28,0** | °C |
| Temperatura de entrada | **33,0** | °C |
| Caudal de fluido | **20,3** | l/s |
| Pérdida de carga total | **20** | kPa |

### Información del condensador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **85,0** | °C |
| Temperatura de entrada | **75,0** | °C |
| Caudal de fluido | **15,0** | l/s |
| Pérdida de carga total | **15** | kPa |

### Información acerca del equipo

| | | |
|---|---|---|
| Lugar de fabricación | **Montluel, France** | |
| Tipo de refrigerante | **R1234ze(E)** | |
| Potencia mínima | **50** | % |
| Número de circuito refrigerante | **1** | |
| Peso de funcionamiento/envío | **3230/3012** | kg |
| Dimensiones del equipo (la x an x al) | **3059/1041/1745** | mm |

### Información eléctrica

| | | |
|---|---|---|
| Tensión de la unidad | **400(+/-10%)-3-50** | V-Ph-Hz |
| Potencia en modo de espera | **0,100** | kW |
| Factor de potencia | **0,89** | |

| Amps (Un 400V) | CKT A |
|---|---|
| In (A):<br>Intensidad máxima | 360 |
| Id (A):<br>Corriente de arranque (max. Direct) | 1828 |
| Id/In | 5,1 |

### Información acústica

| | | |
|---|---|---|
| Nivel de potencia sonora (LwA) | **97** | dB(A) |
| Nivel de presión sonora a 10 m (LpA) | **80** | dB(A) |

### Opciones instaladas y accesorios

*: sin caída de presión del intercambiador

Todos los rendimientos son conformes con la norma EN 14511-3:2018. Nivel de potencia sonora de conformidad con ISO 9614-1.

CARRIER participates in the ECP program for Liquid Chilling Packages and Hydronic Heat Pumps.
Check ongoing validity of certificate:www.eurovent-certification.com.
Outside the scope of AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages Certification Program, but is rated in accordance with AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI).

# Informe de rendimiento (a carga total)

Nombre del proyecto:

Preparado por: Angel Cancela

**24/02/2021**

## Bomba de calor agua-agua

## 61XWHHZE05

IOM

PSD

Brochure

### Información sobre rendimiento

| | | |
|---|---|---|
| Potencia calorífica | **707** | kW |
| Eficacia de calefacción (C.O.P.) | **3,39** | kW/kW |
| *Eficacia de calefacción (Coeficiente COP bruto) no certificado ** | ***3,42*** | *kW/kW* |
| Capacidad frigorífica al origen | **514** | kW |
| Potencia absorbida por la unidad | **208** | kW |

### Información del evaporador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **35,0** | °C |
| Temperatura de entrada | **40,0** | °C |
| Caudal de fluido | **24,8** | l/s |
| Pérdida de carga total | **27** | kPa |

### Información del condensador

| | | |
|---|---|---|
| Tipo de fluido | **Agua dulce** | |
| Factor de suciedad | **0,000** | (sqm-K)/kW |
| Número de pasos | **2** | |
| Temperatura de salida | **85,0** | °C |
| Temperatura de entrada | **75,0** | °C |
| Caudal de fluido | **17,3** | l/s |
| Pérdida de carga total | **15** | kPa |

### Información acerca del equipo

| | | |
|---|---|---|
| Lugar de fabricación | **Montluel, France** | |
| Tipo de refrigerante | **R1234ze(E)** | |
| Potencia mínima | **50** | % |
| Número de circuito refrigerante | **1** | |
| Peso de funcionamiento/envío | **3230/3012** | kg |
| Dimensiones del equipo (la x an x al) | **3059/1041/1745** | mm |

### Información eléctrica

| | | |
|---|---|---|
| Tensión de la unidad | **400(+/-10%)-3-50** | V-Ph-Hz |
| Potencia en modo de espera | **0,100** | kW |
| Factor de potencia | **0,89** | |

| Amps (Un 400V) | CKT A |
|---|---|
| In (A):<br>Intensidad máxima | 360 |
| Id (A):<br>Corriente de arranque (max. Direct) | 1828 |
| Id/In | 5,1 |

### Información acústica

| | | |
|---|---|---|
| Nivel de potencia sonora (LwA) | **97** | dB(A) |
| Nivel de presión sonora a 10 m (LpA) | **80** | dB(A) |

### Opciones instaladas y accesorios

*: sin caída de presión del intercambiador

Todos los rendimientos son conformes con la norma EN 14511-3:2018. Nivel de potencia sonora de conformidad con ISO 9614-1.

CARRIER participates in the ECP program for Liquid Chilling Packages and Hydronic Heat Pumps.
Check ongoing validity of certificate:www.eurovent-certification.com.
Outside the scope of AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages Certification Program, but is rated in accordance with AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI).

# Catálogo Focos de Proceso

| ID FOCO | | CAPCA | | Potencia térmica (KW t) | Sistemático S/N | Sistema depuración | Ubicación | Aplicación | Nueva identif. Mant. Pint. | Observaciones |
|---|---|---|---|---|---|---|---|---|---|---|
| | | GRUPO | CÖDIGO | | | | | | | |
| 3P | Horno de masillas (entrada) | C | 03 03 26 36 | 1.799 | S | NO | MASILLAS | Secado carrocerías | EM.M-5 | |
| 5P | Horno de masillas (salida) | C | 03 03 26 36 | 1.799 | S | NO | MASILLAS | | EM.M-6 | Antigua "Y griega" |
| 7P | Enfriador horno de masillas | C | 03 03 26 36 | 1.799 | S | NO | MASILLAS | | | Sin codificar por mantenimiento |
| 9P | Cabina aplicac.B0 2º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | Acondiciona-miento temperatura cabina | CA.M-8 | |
| 10P | Cabina aplicac.B0 3º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-9 | |
| 11P | Cabina aplicac.B0 4º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-10 | |
| 13P | Cabina aplicac.B0 2º Extractor dcho. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-2 | |
| 14P | Cabina aplicac.B0 3º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-3 | |
| 15P | Cabina aplicac.B0 4º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-4 | |
| 16P | Cabina aplicac.B0 5º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-5 | |
| 17P | Cabina aplicac.B0 6º Extractor dcho. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | B0 | | CA.M-6 | |
| 19P | Extractor Túnel Ventilado B0 | C | 06 01 01 03 (1) | - | S | NO | B0 | | EA.M-18 | |
| 29P | Cabina lacas (entrada) | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | Acondiciona-miento temperatura cabina | CL.M-38 | Extractor DRYSYS |
| 30P | Cabina de lacas 1º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-11 | |
| 31P | Cabina de lacas 2º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-12 | |
| 32P | Cabina de lacas 3º Extractor izdo. | | | | | | LACAS | | CL.M-13 | Al equipo de oxidación térmica (foco 84P) |
| 33P | Cabina de lacas 4º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-14 | |
| 34P | Cabina de lacas 5º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-15 | |
| 35P | Cabina de lacas 6º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-16 | |
| 36P | Cabina de lacas 7º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-17 | |
| 37P | Cabina de lacas 8º Extractor izdo. | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-18 | |
| 38P | Cabina de lacas 9º Extractor izdo. | | | | | | LACAS | | CL.M-19 | Al equipo de oxidación térmica (foco 84P) |
| 39P | Cabina de lacas 1º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-2 | |
| 40P | Cabina de lacas 2º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-3 | |
| 41P | Cabina de lacas 3º Extractor dcho | | | | | | LACAS | | CL.M-4 | Al equipo de oxidación térmica (foco 84P) |
| 42P | Cabina de lacas 4º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-5 | |
| 43P | Cabina de lacas 5º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-6 | |
| 44P | Cabina de lacas 6º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-7 | |
| 45P | Cabina de lacas 7º Extractor dcho | C | 06 01 01 03 (1) | - | S | Cajones de lavado | LACAS | | CL.M-8 | |
| 46P | Cabina de lacas 8º Extractor dcho | | | | | | LACAS | | CL.M-9 | Al equipo de oxidación térmica (foco 84P) |
| 48P | SAS salida cabina de lacas | | | | | | LACAS | Secado carrocerías | EL.M-24 | Al equipo de oxidación térmica (foco 84P) |
| 49P | Horno secado lacas (enfriador) | C | 03 03 26 36 | 3.840 | S | NO | LACAS | | EL.M-40 | |
| 51P | Horno extracción (entrada) | | | | | | LACAS | | EL.M-28 | Al equipo de oxidación térmica (foco 84P) |
| 55P | Horno extracción (salida) | C | 03 03 26 36 | 3.840 | S | NO | LACAS | | EL.M-37 | |
| 56P | Cuba cataforesis | B | 04 03 08 08 | - | S | NO | CATAFORESIS | Acondiciona-miento temperatura cuba | CC.M-82 | |
| 57P | Extracción horno de cataforesis | C | 03 03 26 36 | 2.871 | N | NO | CATAFORESIS | Secado carrocerías | EC.M-40 | Extractor de enfriado rápido (sólo funciona cuando tiene que enfriar el horno en fin de semana o por avería cadena -func. discontinuo-). Sólo funciona el viernes noche (4 h/semana). |
| 59P | Enfriador horno cataforesis | C | 06 01 01 03 (1) | 2.871 | S | NO | CATAFORESIS | | EC.M-50 | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 60P | Incinerador cataforesis II | C | 03 03 26 36 | 1.100 | S | INCINERACIÖN | CATAFORESIS | Incineración COV's | EC.M-12 | Quemador Q-3 |
| 62P | Incinerador cataforesis I | C | 03 03 26 36 | 1.595 | S | INCINERACIÓN | CATAFORESIS | Incineración COV's | EC.M-90 | Quemador Q-1 |
| 63P | Nuevos Boxes retoques | C | 06 01 01 03 (1) | - | S | NO | RETOQUES | Acondic. temperatura boxes | | Reutilización canalización foco 63P por eliminación línea Hospital (mar.13) e instalación nuevos boxes de retoques (4). Nueva denominación equipo. |
| 70P | ~~Estufa retoques montaje (I)~~ Cabina preparación pinturas y limpieza de pistolas z. retoques | - | 06 01 01 04 | - | N | NO | MONTAJE | Secado carrocerías | ~~ERM.L1~~ | Antiguo foco eliminado por mejora proceso retoques. Se ha aprovechado el foco existente para hacer la extracción de la cabina de preparación de pinturas y limpieza pistolas (func. < 1 h/día) |
| 71P | Extracción GA circulating (sala mezclas) | - | 06 01 01 01 | - | S | NO | CIRCULATING | Acondic. temperatura sala | SB.1 | |
| 72P | Cabina retoques montaje (I) | - | 06 01 01 04 | - | S | FILTROS DE PANELES | MONTAJE | Acondiciona-miento temperatura cabina | CRM.L1 | Sólo funciona cuando hay vehículos que retocar |
| 73P | Cabina retoques montaje (II) | - | 06 01 01 04 | - | S | FILTROS DE PANELES | MONTAJE | | CRM.L2 | Sólo funciona cuando hay vehículos que retocar |
| 74P | Extracción antiguos boxes 1 | C | 06 01 01 03 (1) | - | S | NO | RETOQUES | Acondic. temperatura boxes | | Modificación identificación equipo por eliminación línea hospital en marzo 2013. |
| 75P | Extracción cortina entrada TTS | B | 04 02 10 05 | - | S | NO | TTS | Acondiciona-miento temperatura | | Sin codificar por mantenimiento |
| 81P | Grupo radiación horno cataforesis 1 | C | 03 03 26 36 | 2.871 | S | NO | CATAFORESIS | Secado carrocerías | EC.M-100 | 1ª zona suelo radiante (recircula) |
| 82P | Grupo radiación horno cataforesis 2 | C | 03 03 26 36 | 2.871 | S | NO | CATAFORESIS | | EC.M-400 | 2ª zona suelo radiante (recircula) |
| 83P | Extracción antiguos boxes 2 | C | 06 01 01 03 (1) | - | S | NO | RETOQUES | Acondic. temperatura boxes | | Modificación identificación equipo por eliminación línea hospital en marzo 2013. |
| 84P | Oxidador térmico regenerativo | C | 03 01 06 02 | 2.930 | S | OXIDACIÓN TÉRMICA REGENERATIVA (2) | LACAS | Incineración COV's | | Oxidación de: 32P, 38P, 41P, 46P, 48P y 51P |
| 85P | Enfriador Cataforesis 1 | C | 03 03 26 36 | 2.871 | N | NO | CATAFORESIS | Secado carrocerías | | Sólo funcionan con T ambiente elevada (func. discontinuo< 5%). Sólo func. 1/3 tiempo periodo jun-jul |
| 86P | Enfriador Cataforesis 2 | C | 03 03 26 36 | 2.871 | N | NO | CATAFORESIS | | | |
| 87P | Desengrase TTS | B | 04 02 10 05 | - | N | NO | TTS | Acondiciona-miento temperatura | | Antiguo equipo impulsor de aire. Sólo funciona en caso de avería del transportador aéreo del TTS (1 o 2 veces al año) |
| 88P | Lavado 1 TTS | B | 04 02 10 05 | - | N | NO | TTS | | | Antiguo equipo impulsor de aire. Sólo funciona en caso de temperatura elevada (1-2 veces al año durante unas horas). |
| 61C | Lavadora (GEFCO) | C | 03 01 03 03 | 1.750 | S | NO | GEFCO | Secado bacs | | |
| 76C | Caldera ASC Baños TTS 1 | C | 03 01 03 03 | 755 | S | NO | SALA CALDERAS TTS | Calentamiento baños TTS | | |
| 77C | Caldera ASC Baños TTS 2 | C | 03 01 03 03 | 755 | S | NO | | | | |
| 78C | Caldera ASC Baños TTS 3 | C | 03 01 03 03 | 755 | S | NO | | | | |
| 79C | Caldera ASC 1 (Central Térmica) | B | 03 01 03 02 | 2.500 | S | NO | CENTRAL TÉRMICA | Calefacción naves | | |
| 80C | Caldera ASC 2 (Central Térmica) | B | 03 01 03 02 | 2.500 | S | NO | | | | |
| 81C | Caldera ASC 3 (Central Térmica) | B | 03 01 03 02 | 2.500 | S | NO | | | | |
| 82C | Caldera ASC 4 (Central Térmica) | B | 03 01 03 02 | 2.500 | S | NO | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |

| Nº | MODIFICACIÓN | FECHA | PILOTO |
|---|---|---|---|
| 1 | Creación documento | 21/01/00 | J.L. Vizcano |
| 2 | Eliminación antigua cabina de retoques | 01/09/01 | J.L. Vizcano |
| 3 | Instalación nueva cabina de retoques en Acabado (4 nuevos focos) | 31/05/02 | J.L. Vizcano |
| 4 | Nueva codificación del documento | 10/10/02 | J.L. Vizcano |
| 5 | Inclusión de tres focos no inventariados hasta la fecha ( 1 TTS y 2 en ceras ) | 31/03/04 | J.L. Vizcano |
| 6 | Actualización catálogo focos (envío dossier AAI a la C.A.M.) | 17/08/07 | J.L. Vizcano |
| 7 | Rectificación catálogo focos definitivo (envío correo electrónico a la C.A.M.) | 20/08/07 | J.L. Vizcano |
| 8 | Catálogo focos pintura revisados por mantenimiento | 01/04/08 | J.L. Vizcano |
| 9 | Catálogo focos Resolución de 15/04/2008 AAI (expediente AAI-2023/05) | 31/05/08 | J.L. Vizcano |
| 10 | Actualización catálogo focos (revisión por mantenimiento -> tiempos funcionamiento focos discontinuos) | 30/03/09 | J.L. Vizcano |
| 11 | Actualización catálogo focos (revisión por mantenimiento -> tiempos funcionamiento focos discontinuos) | 28/09/12 | J.L. Vizcano |
| 12 | Eliminación línea Hospital en marzo 2013, siendo remplazada por 4 nuevos boxes de pintura. | 27/03/13 | J.L. Vizcano |
| 13 | Catálogo focos Resolución de 20/02/2014 Modificación de Oficio AAI (expediente ACIC-MO-AAI-2023/14) | 31/03/14 | J.L. Vizcano |
| 14 | Catálogo focos Resolución de 25/11/2014 Modificación no sustancial AAI (expediente ACIC-MF1-AAI-2023/14) | 28/11/14 | J.L. Vizcano |
| 15 | Modificación potencia quemadores focos 76C, 77C y 78C (la anterior correspondía a la caldera) tras verificación GEI 2014 | 06/03/15 | J.L. Vizcano |
| 16 | Inclusión 5 columnas nuevas en el documento (Grupo CAPCA, Código CAPCA, Potencia Térmica, Sistemático y Sistema de depuración) | 01/07/15 | J.L. Vizcano |
| 17 | Eliminación focos 18P, 21P, 22P, 23P, 24P, 25P y 27P (horno aprestos) e instalación quemador (407 KW) en Horno masillas por implantación gama compacta pintura. Cambio denominación "Cabina aprestos" por "Cabina aplicación B0" (id. Id.) | 17/08/15 | J.L. Vizcano |
| 18 | Eliminación Focos 76P (extracción vestíbulo zona blanca) y 77P (extracción máq. plumas lacas) por implantación gama compacta pintura (eliminación zona blanca y máq. plumas) | 20/10/16 | J.L. Vizcano |
| 19 | Eliminación Foco 61P (campana extractora horno cataforesis) por mejoras realizadas en el proceso de cataforesis. | 20/10/16 | J.L. Vizcano |
| 20 | Eliminación foco 80P (Túnel de tratamiento de superficies) por mejoras en proceso TTS (no es necesario el proceso secado carrocerías). | 20/10/16 | J.L. Vizcano |
| 21 | Nuevos focos 87P (Desengrase TTS) y 88P (Lavado 1 TTS) por mejoras en el proceso del TTS (cambio funcionamiento equipos, pasando de "impulsores de aire" a extractores) | 20/10/16 | J.L. Vizcano |
| 22 | Cambio denominación foco 70P de "Estufa retoques montaje (I)" a "Cabina preparación pinturas y limpieza de pistolas z. retoques" | 31/08/18 | J.L. Vizcano |
| 23 | Cambio foco 88P de sistemático a no sistemático por mejoras en el proceso | 31/08/18 | |

I.PMA92.03 del 08/15

(1) En el momento en el que el titular tuviera constancia, a partir de los datos de los planes de gestión de disolventes, de que la capacidad de consumo de disolventes de la línea asociada a dicho foco supera las 200 toneladas/año o los 150 Kg/h, deberá comunicarlo a la Consejería de Medio Ambiente y Ordenación del Territorio para la revisión del código asignado a estos focos.

(2) En funcionamiento únicamente del 15 de junio al 15 de septiembre, siempre y cuando las emisiones de COV's asociadas a ese foco no superen los 5 Kg/veh. En caso contrario, el sistema de oxidación térmica regenerativa deberá estar en funcionamiento

# Catálogo Focos de Calefacción

| ID FOCO | | CAPCA | | Potencia Térmica (KW t) | Sistemático S/N | Sistema depuración | Ubicación | Aplicación | Observaciones |
|---|---|---|---|---|---|---|---|---|---|
| | | GRUPO | CÓDIGO | | | | | | |
| 69C | Caldera nº1 EGO | - | 03 01 03 03 | 1.750 | S | NO | EGO | Agua caliente | |
| 70C | Caldera nº2 EGO | - | 03 01 03 03 | 1.750 | S | NO | EGO | Agua caliente | |
| 75C | Grupo de aporte T.I.I. | - | 03 01 03 03 | 1.396 | S | NO | Techo Cofre | Aire caliente | |
| 19C | Generador Liescotherm (178) | - | 03 01 03 03 | 349 | S | NO | GEFCO | Aire caliente | |
| 17C | Generador Liescotherm (177) | - | 03 01 03 03 | 640 | S | NO | Parque | Aire caliente | |
| 18C | Generador Liescotherm (175) | - | 03 01 03 03 | 640 | S | NO | Parque | Aire caliente | |
| 62C | Generador Liescotherm (147) | - | 03 01 03 03 | 640 | S | NO | Acolchados | Aire caliente | Zona proveedor Plastic Omnium |
| 28C | Generador Liescotherm (30) | - | 03 01 03 03 | 640 | S | NO | Mecánica (PR) | Aire caliente | |
| 24C | Generador Liescotherm (36) | - | 03 01 03 03 | 640 | S | NO | Mecanica (PR) | Aire caliente | |
| 83C | Caldera Ferroli | - | 03 01 03 03 | 351 | S | NO | Clínica y Comed. | Agua caliente | |
| 68C | Caldera Saunier Duval | - | 03 01 03 03 | 39 | S | NO | Clínica | Agua caliente | Agua caliente en Clínica (antes en Cocina) |
| 41C | Secadora Zanussi n1 | - | 03 01 03 03 | 48 | S | NO | CEE | Secado | |
| 42C | Secadora Zanussi nº2 | - | 03 01 03 03 | 48 | S | NO | CEE | Secado | |
| 16C | Generador Liescotherm (143) | - | 03 01 03 03 | 137 | S | NO | Mecanica (PR) | Aire caliente | |
| 33C | Generador Liescotherm (152) | - | 03 01 03 03 | 640 | S | NO | Mecanica (PR) | Aire caliente | |
| 15C | Generador Liescotherm (27) | - | 03 01 03 03 | 640 | S | NO | Mecanica (PR) | Aire caliente | |
| 85C | Caldera vestuario Chapa-Norte | - | 03 01 03 03 | 200 | S | NO | Chapa-Norte | Agua caliente | |
| 86C | Calentador Junkers | - | 03 01 03 03 | 48 | S | NO | Cocina | Agua caliente | |
| 87C | Tubo radiante GSR300 nº1 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 88C | Tubo radiante GSR300 nº2 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 89C | Tubo radiante GSR300 nº3 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 90C | Tubo radiante GSR300 nº4 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 91C | Tubo radiante GSR300 nº5 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 92C | Tubo radiante GSR300 nº6 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 93C | Tubo radiante GSR300 nº7 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 94C | Tubo radiante GSR300 nº8 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 95C | Tubo radiante GSR300 nº9 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 96C | Tubo radiante GSR300 nº10 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 97C | Tubo radiante GSR300 nº11 | - | 03 01 03 03 | 349 | S | NO | Mecánica (PR) | Aire caliente | |
| 98C | Tubo radiante GSR200 nº1 | - | 03 01 03 03 | 233 | S | NO | Mecánica (PR) | Aire caliente | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 99C | Tubo radiante GSR200 nº2 | - | 03 01 03 03 | 233 | S | NO | Mecánica (PR) | Aire caliente | |
| 100C | Tubo radiante GSR200 nº3 | - | 03 01 03 03 | 233 | S | NO | Mecánica (PR) | Aire caliente | |
| 101C | Tubo radiante GSR100 nº1 | - | 03 01 03 03 | 116 | S | NO | Mecánica (PR) | Aire caliente | |
| 102C | Generador PKA060N nº1 | | 03 01 03 03 | 86 | S | NO | CEE | Aire caliente | |
| 103C | Generador PKA060N nº2 | | 03 01 03 03 | 86 | S | NO | CEE | Aire caliente | |
| 104C | Generador PKA060N nº3 | | 03 01 03 03 | 86 | S | NO | CEE | Aire caliente | |
| 105C | Generador MM-090-H | | 03 01 03 03 | 90 | S | NO | CEE | Aire caliente | |
| 106C | Generador Tervotherm PKE-120H | | 03 01 03 03 | 137 | S | NO | Acolchados | Aire caliente | Zona proveedor Maviva |
| 107C | Generador Tervotherm PKE-060H nº 1 | | 03 01 03 03 | 86 | S | NO | Acolchados | Aire caliente | Zona proveedor Plastic Omnium |
| 108C | Generador Tervotherm PKE-060H nº 2 | | 03 01 03 03 | 86 | S | NO | Acolchados | Aire caliente | Zona proveedor Plastic Omnium |

| **Nº** | **MODIFICACIÓN** | **FECHA** | **PILOTO** |
|---|---|---|---|
| 1 | Creación documento | 21/01/00 | J.L. Vizcano |
| 2 | Modificaciones climatización en P. Mecánica y Bout d'Usine | 30/04/01 | J.L. Vizcano |
| 3 | Instalación nuevo quemador en grupo aporte Cataforesis | 31/08/01 | J.L. Vizcano |
| 4 | Instalación nuevas cabinas retoques pintura en Acabado | 31/05/02 | J.L. Vizcano |
| 5 | Nueva codificación del documento | 10/10/02 | J.L. Vizcano |
| 6 | Actualización catálogo focos | 31/03/04 | J.L. Vizcano |
| 7 | Actualización catálogo focos (envío dossier AAI a la C.A.M.) | 17/08/07 | J.L. Vizcano |
| 8 | Catálogo focos Resolución de 15/04/2008 AAI (expediente AAI-2023/05) | 31/05/08 | J.L. Vizcano |
| 9 | Eliminación focos 1C, 2C, 3C y 4C e inclusión focos 79C, 80C, 81C y 82C por resolución de la C.A.M. de fecha 18/11/2009 de Modificación No Sustancial | 14/12/09 | J.L. Vizcano |
| 10 | Eliminación focos 46C y 47C en marzo 2013. Sustituidos por aerotermos eléctricos. | 27/03/13 | J.L. Vizcano |
| 11 | Revisión y actualización (ubicación y observaciones) focos 45C y 83C para actualización inventario focos de nuestra AAI. | 21/01/14 | J.L. Vizcano |
| 12 | Eliminación focos no canalizados (pantallas de infrarrojos, grupos de aporte de aire y tubos radiantes) para actualización inventario focos de nuestra AAI | 21/01/14 | J.L. Vizcano |
| 13 | Inclusión 5 columnas nuevas en el documento (Grupo CAPCA, Código CAPCA, Potencia Térmica, Sistemático y Sistema de depuración) | 01/07/15 | J.L. Vizcano |
| 14 | Eliminación focos por proyecto compactado actividad Centro (transfer V. Motor y Suspensiones de Mecánica a Carrocerías). | 17/08/15 | J.L. Vizcano |
| 15 | Eliminación focos 48C (horno secado fosfatado 1) y 49C (horno secado fosfatado 2) por mejoras en el proceso del TTS (no es necesario el proceso secado) | 20/10/16 | J.L. Vizcano |
| 16 | Nuevos focos 85C por instalación caldera calefacción en el vestuario Chapa-Norte y 86C (calentador agua cocina) | 20/10/16 | J.L. Vizcano |
| 17 | Revisión y actualización nuevos focos de combustión para calefacción en antigua nave Mecánica por ampliación actividad de PR (piezas de recambio):<br>- eliminación focos 25C, 26C, 31C y 84C;<br>- puesta en marcha de antiguos focos eliminados en 2015: 6C, 33C y 15C (correspondientes proyecto compactado actividad del Centro)<br>- nuevos focos: 11 tubos radiantes de 300 Mcal7h (87C a 97C), 3 tubos radiantes de 200 Mcal/h (98C a 100C) y 1 tubo radiante de 100 Mcal/h (101C) | 20/10/16 | J.L. Vizcano |
| 18 | Nuevos focos en CEE y nave Acolchados: 102C a 108C | 26/01/2018 | J.L. Vizcano |
| 19 | Eliminación focos 52C y 53C de la nave de Post-Venta. Sustituidos por climatizadores con bomba de calor. | 31/08/2018 | J.L. Vizcano |
| 20 | Eliminación focos 63C, 64C, 65C y 66C por demolición nave fundición. | 31/01/2019 | J.L. Vizcano |
| 21 | Traslado foco 62 C de la nave de fundición al parque de proveedores (Plastic Omnium depósitos) | 31/01/2019 | J.L. Vizcano |
| 22 | Eliminación foco 40C de la entreplanta utillaje. Sustituido por climatizadores con bomba de calor | 30/04/2018 | J.L. Vizcano |

ICAI

# Resultados de la simulación

## Resumen de resultados

**Ahorro solar año 1:** 141002 €/año**% Ahorro combustible:** 20.4%

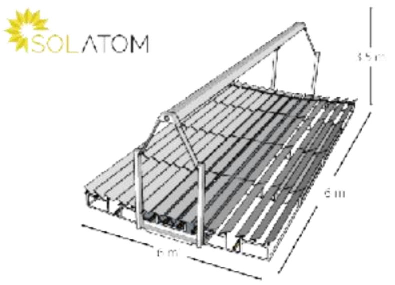
**Factura actual:** 553050.0 €/año**Coste combustible actual:** 0.0 €/kWh

**Inversión:** 1684805.8 € **TIR:** 10.4 % **Retorno:** Año 11

**Campo solar:** 6336 $m^2$ **Producción energía:** 3618786.6 kWh/año **CO2 evitado:** 723.8 Ton/año

## Instalación solar

La instalación solar está formada por un número determinado de colectores, agrupados en filas. En las filas los colectores se unen enserie. Las series se conectan en paralelo. El número de colectores por fila se ha diseñado para que en una fila se alcance el salto detemperatura de diseño(**10.0 °C**). El número de filas depende de la demanda de energía de la industria.

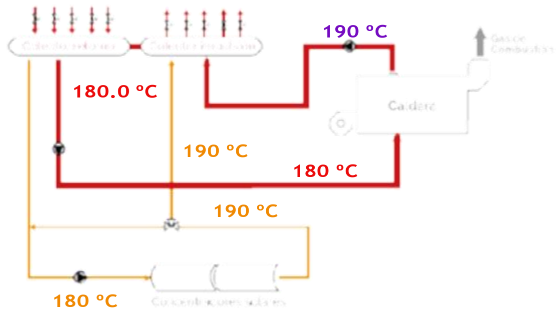



**Colector simulado:** SOLATOM *[Ref:www.solatom.com]*
**Tipo de óptica:** Fresnel lineal
**Peso del captador:** 900 kg/módulo (25kg/$m^2$)

**Número de colectores:** 240 (Superficie total 9504.0 $m^2$)
**Disposición :** (20x12) 20 filas con 12 colectores cada uno
**Tipo de ubicación:** clean_ground
**Cimentación:** No necesario

**Monitorización de datos:** Incluido on-line los primeros 4 años
**Mantenimiento requerido:** Incluido los primeros 4 año(s). Es recomendable limpiar los espejos mensualmente.

## Esquema de integración




**Esquema de integración:** "SL_L_P"
*[Ref: IEA SHC Task 49 - Integration Guideline - Feb 2015]*

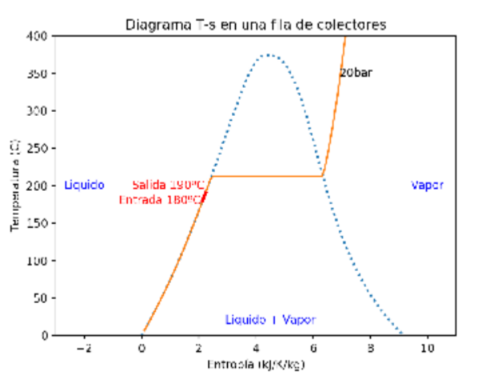
**Descripción:** La conexión del sistema solar se realiza en paralelo a la caldera. El sistema solar calienta el fluido a la misma temperatura que lo hace la caldera, por lo que la conexión se realiza directamente al colector de impulsión.

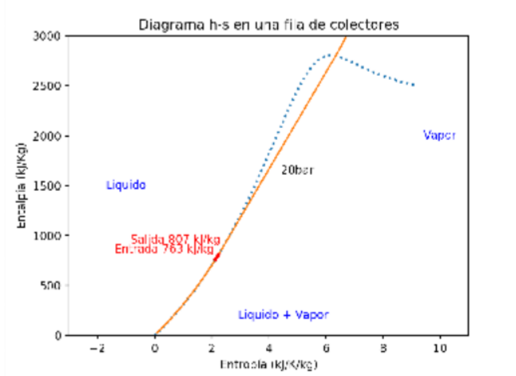
**Almacenamiento:** No
**Volumen del almacenamiento:** 0 litros
**Capacidad del almacenamiento:** 0 kWh
**Temperatura del almacenamiento:** 0 °C

**Valores de caudal por seride 12 colectores**
**Promedio:** 2.0 kg/s **Max:** 4.3 kg/s **Rango:** 4.0 kg/s **Std:** 0.9 kg/s
**Valores de acudal principal**
**Promedio:** 40.3 kg/s **Max:** 85.4 kg/s **Rango:** 79.1 kg/s **Std:** 18.4 kg/s

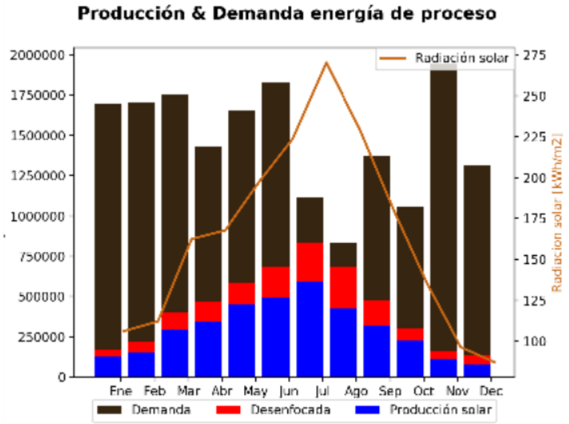
## Propiedades del fluido en diseño: water

**Descripción:** Todo el circuito está en fáse líquida, no existe evaporación. A la entrada del sistema solar entra fluido líquido a **180 °C** . El campo solar calienta el fluido hasta una temperatura de **190 °C** , correspondiente a la temperatura de salida de la caldera. Dado que la temperatura de salida del campo solar es la misma que la salida de caldera, el campo solar se puede conectar directamente a la red de distribución de la fábrica.



## Producción solar durante un año




**Fichero meteorológico:** "Madrid.dat" (Meteonorm v.7)
**Energía solar en la ubicación:** 1968.0 kWh/año

**Producción solar anual bruta:** 5125834.5 kWh
**Producción solar anual suministrada:** 3618786.6 kWh
**Porcentaje global de utilización:** 70.59897506862977 %

**Demanda anual de energía de la industria:** 17697600.0 kWh
**% entre energía solar brutay demanda total:** 29.0%
**% entre energía solar suministraday demanda total:** 20.4%
**Producción anual por módulo:** 21357.6 kWh

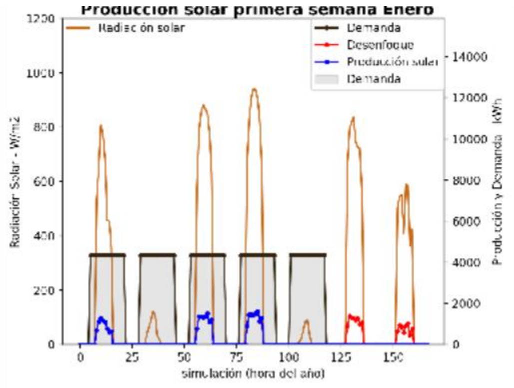
Producción solar en kWh por mes:

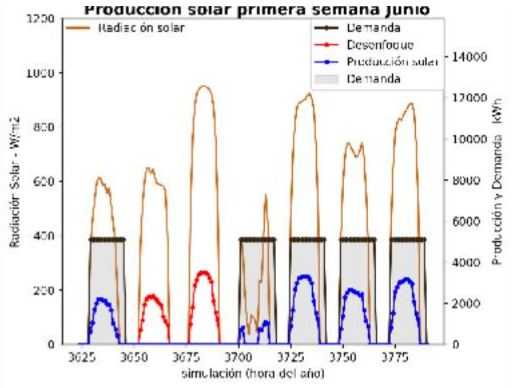
| Mes | Producción | Razón | Mes | Producción | Razón | Mes | Producción | Razón |
|---|---|---|---|---|---|---|---|---|
| Ene | 169813.4 | 7.4% | Feb | 223020.7 | 9.0% | Mar | 400108.4 | 16.9% |
| Abr | 469385.3 | 24.2% | May | 587124.1 | 27.4% | Jun | 685692.4 | 26.9% |
| Jul | 833387.0 | 53.4% | Ago | 686684.9 | 51.6% | Sep | 473674.1 | 22.9% |
| Oct | 300314.6 | 21.7% | Nov | 163997.9 | 5.7% | Dic | 132631.6 | 5.7% |

## Detalle de la producción solar en invierno y verano

Las gráficas mostradas a continuación representan el comportamiento de la instalación solar durante la primera semana de Enero (que corresponde al rango de horas 0 y 167 del año) y la primera de Junio(que corresponde al rango de horas 3620 y 3791 del año).

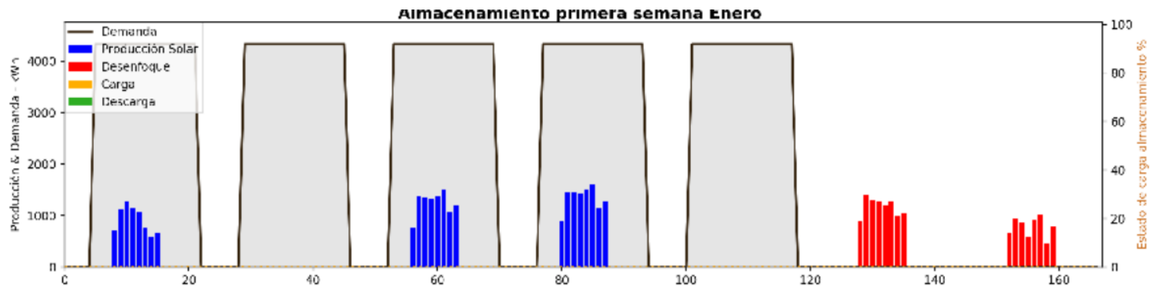
El esquema hidraúlico seleccionado no dispone de almacenamiento. En este caso, si la **energía solar producida** es mayor que la **demanda de la industria**, esa energía sobrante no puede ser utilizada. Las **columnas azules** representan la energía útil que finalmente se suministra a la industria. Cuando hay un exceso de energía, el sistema solar se **desenfoca** automáticamente.

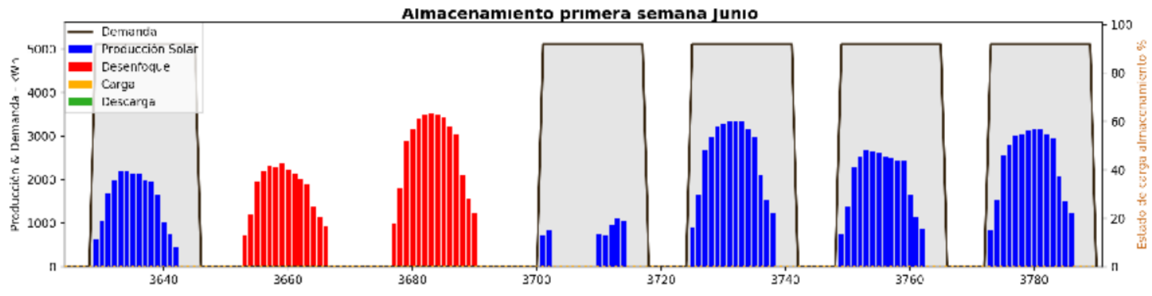



## Detalle del almacenamiento en las semanas de invierno y verano

**"Carga" - Energía solar que se almacena en el depósito en un año:** 0 kWh
**"Descarga" - Energía almacenada que se suministra a la industria en un año:** 0 kWh
**"Desenfoque" - Energía solar que no puede almacenarse ni puede consumirse en un año:** 1507047.9 kWh
**Porcentaje global de utilización:** 70.6 %
**Porcentaje de desenfoque:** 29.4 % (Porcentaje de energía desenfocada)
**Incremento de energía por almacenamiento:** 0 % (Incremento respecto a la opción sin almacenamiento)



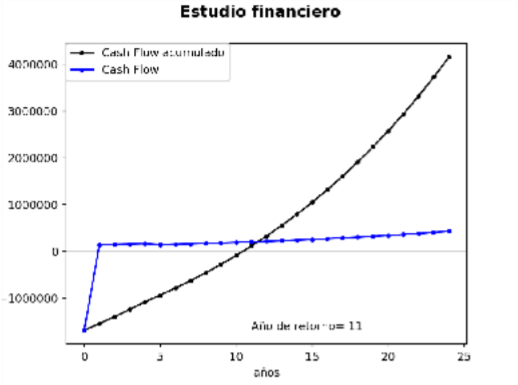
## Resultados económicos

**Modelo de negocio:** turnkey**Inversión total:** 1684805.8 €**Retorno:** Año 11

**TIR:** 10.4 % **TIR en 10 años:** -3.4 %

**Ahorro anual por coste de $CO_2$:** 27915.320051526654 €

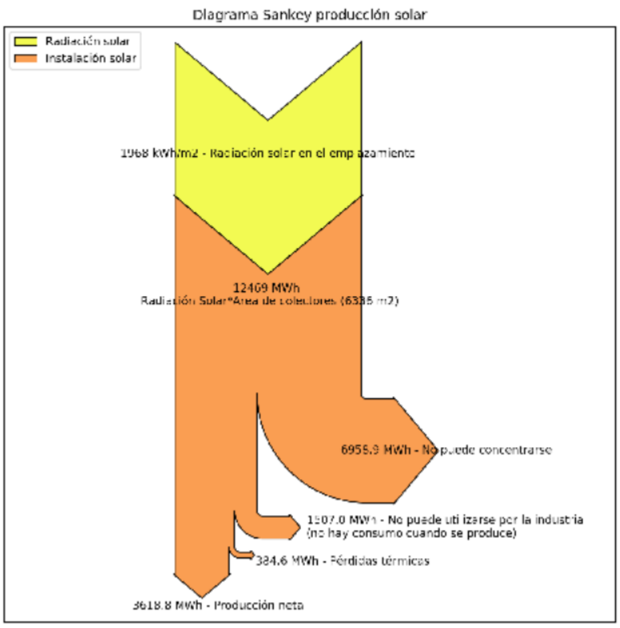
| Año | Cash Flow acumulado | Ahorro solar + emisiones CO2 + Mantenimiento | Factura energética industria |
|---|---|---|---|
| Año 0 | (1684805) € | 0 € | 553050.0 € |
| Año 1 | (1543803) € | 141002 € | 553050.0 € |
| Año 2 | (1396015) € | 147788 € | 586233.0 € |
| Año 3 | (1241035) € | 154980 € | 621407.0 € |
| Año 4 | (1078432) € | 162604 € | 658691.4 € |
| Año 5 | (936546) € | 141885 € | 698212.9 € |
| Año 6 | (786095) € | 150451 € | 740105.7 € |
| Año 7 | (626563) € | 159532 € | 784512.0 € |
| Año 8 | (457407) € | 169156 € | 831582.7 € |
| Año 9 | (278048) € | 179359 € | 881477.7 € |
| Año 10 | (87875) € | 190174 € | 934366.3 € |
| Año 11 | 113762 € | 201637 € | 990428.3 € |
| Año 12 | 327550 € | 213788 € | 1049854.0 € |
| Año 13 | 554219 € | 226669 € | 1112845.3 € |
| Año 14 | 794541 € | 240322 € | 1179616.0 € |
| Año 15 | 1049335 € | 254794 € | 1250392.9 € |
| Año 16 | 1319470 € | 270135 € | 1325416.5 € |
| Año 17 | 1605866 € | 286396 € | 1404941.5 € |
| Año 18 | 1909499 € | 303633 € | 1489238.0 € |
| Año 19 | 2231404 € | 321904 € | 1578592.3 € |




*Inversión inicial:*
- Precio instalación por m2: 265.9100136020784 € [ref: www.solatom.com]
- La inversión incluye: colectores, instalación de conexión, control y adquisición de datos y el mantenimiento inicial de la planta.
- La inversión **no** incluye: Transporte, refuerzos de cubierta (si fueran necesarios)

*Hipótesis tenidas en cuenta durante el estudio económico::*
- El ahorro mostrado tiene en cuenta un coste anual de mantenimiento y monitorización de 28800.0 €
- Precio por tonelada de CO2:38.6 € [Ref: Ind]. Rendimiento de caldera: 80% [Ref: Ind]. Incremento anual del precio de combustible fósil: 3.5 % [Ref: Forecast to 2022 IEA]. Incremento anual del IPC: 2.5 % [Ref: National Institute of Statistics].

## Diagrama de la producción energética del sistema




**Distribución de la producción de energía ANUAL en el sistema:**

**1) Radiación solar:** 1968.0 kWh/m$^2$
*La radiación solar es la energía disponible en la ubicación seleccionada que llega desde el sol .*

**2) Energía sobre superficie:** 12469.3 MWh
*Radiación solar que puede ser reflejada por los espejos*

**-> 2.1) Energía no concentrada:** 6958.9 MWh/año
*Radiación que geométricamente no puede concentrarse en elreceptor y por tanto se pierde*

**-> 2.2) Energía no utilizada:** 1507.0 MWh
*Radiación solar que llega al receptor pero no puede ser utilizadapor la industria (ya que no existe almacenamiento o la industria no necesita energía cuando hay producción solar)*

**-> 2.3) Energía perdida al ambiente:** 384.6 MWh
*Pérdidas térmicas del sistema al ambiente*

**3) Energía transmitida a la industria:** 3618.8 MWh
*Energía solar que finalmente se suministra a la industria*

ReSPI

## Datos de entrada estudio energético Ressspi

### Datos de la industria - 2021-05-02

**Nombre:** dfh **Empresa:** gdh

**Sector:**

### Datos financieros

**Combustible actual:** NG **Precio:** 0.0 €/kWh

**Modelo de negocio:** turnkey

### Sistema solar

**Localización:** Madrid**Superficie disponible:** 17000 m**Tipo de terreno:** clean_ground

**Orientación:** NS**Inclinación:** flat **Sombras:** free

**Distancia a la red:** 17000 m

### Proceso térmico -

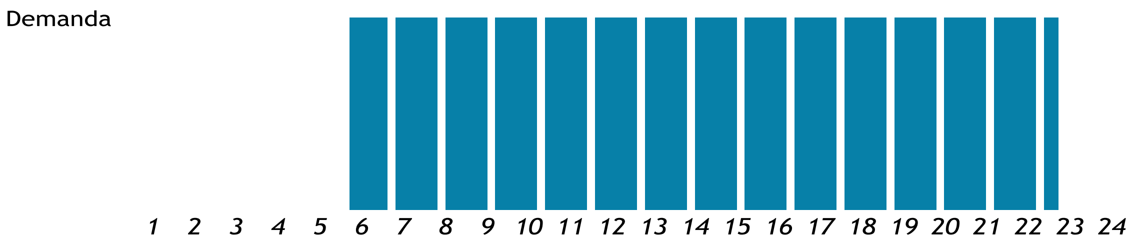
**Temp. salida de caldera:** 190.0**Temp. entrada a caldera:** 180.0 °C

**Fluido:** water **Presión:** 20 bar**Tipo de integración:** SL_L_P

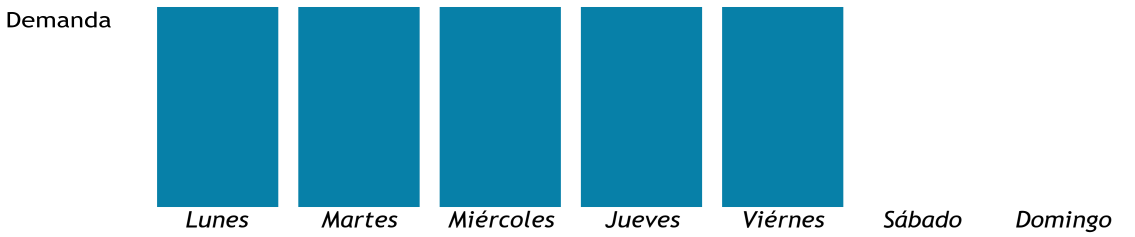
### Consumo energético

**Consumo anual de energía:** 17697600.0 kWh

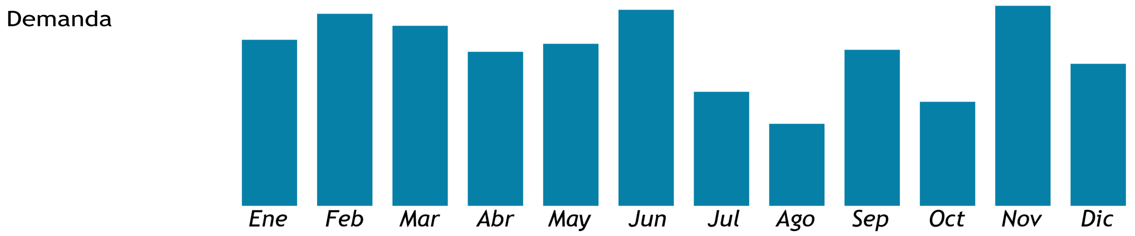
### Perfil de consumo diario: -




### Perdil de consumo semanal:




### Perfil de consumo anual:



```
$UnitSystem SI bar C mole kJ

"Funciones económicas"
Subprogram npv(INV; wacc; r_g; r_e; r_CO2; N; T_g; T_e; T_CO2; E; AG; CO2E: VAN)

k_g = (1+r_g)/(1+wacc)
k_e = (1+r_e)/(1+wacc)
k_CO2 = (1+r_CO2)/(1+wacc)

f_SIGMAg = f_sigma(k_g; N)
f_SIGMAe = f_sigma(k_e; N)
f_SIGMACO2 = f_sigma(k_CO2; N)

VAN = AG*T_g*f_SIGMAg - E*T_e*f_SIGMAe + CO2E*T_CO2*f_SIGMACO2 - INV
End

 Subprogram payback(INV; wacc; r_g; r_e; r_CO2; N; T_g; T_e; T_CO2; E; AG; CO2E: PR)

k_g = (1+r_g)/(1+wacc)
k_e = (1+r_e)/(1+wacc)
k_CO2 = (1+r_CO2)/(1+wacc)

f_SIGMAg = f_sigma(k_g; PR)
f_SIGMAe = f_sigma(k_e; PR)
f_SIGMACO2 = f_sigma(k_CO2; PR)

VAN = 0
VAN = AG*T_g*f_SIGMAg - E*T_e*f_SIGMAe + CO2E*T_CO2*f_SIGMACO2 - INV
End

Subprogram irr(INV; wacc; r_g; r_e; r_CO2; N; T_g; T_e; T_CO2; E; AG; CO2E: TIR)

k_g = (1+r_g)/(1+TIR)
k_e = (1+r_e)/(1+TIR)
k_CO2 = (1+r_CO2)/(1+TIR)

f_SIGMAg = f_sigma(k_g; N)
f_SIGMAe = f_sigma(k_e; N)
f_SIGMACO2 = f_sigma(k_CO2; N)

VAN = 0
VAN = AG*T_g*f_SIGMAg - E*T_e*f_SIGMAe + CO2E*T_CO2*f_SIGMACO2 - INV
End


Function f_sigma(k; N)
if((k<1,01) and (k>0,99)) Then
    f_sigma = N
Else
    f_sigma = k*(1-k^N)/(1-k)
Endif
End

Function f_amort(wacc; N)
if((wacc<0,01) and (wacc>0)) Then
    f_amort = 1/N
Else
    f_amort = wacc*(1+wacc)^N/((1+wacc)^N-1)
Endif
End



"DATOS"
h_bar_fCH4 = enthalpy(CH4; T=25)
h_bar_fCO2 = enthalpy(CO2; T=25)
h_bar_fH2O = enthalpy(H2O; T=25)
```

```
C_bar_pO2 = (enthalpy(O2; T=185)-enthalpy(O2; T=25))/(185-25)
C_bar_pN2 = (enthalpy(N2; T=185)-enthalpy(N2; T=25))/(185-25)
C_bar_pCO2 = (enthalpy(CO2; T=185)-enthalpy(CO2; T=25))/(185-25)
C_bar_pH2O = (enthalpy(H2O; T=185)-enthalpy(H2O; T=25))/(185-25)

f_CO2 = 201,53 "g CO2/kWh-PCS" {b*44000*3600/abs(h_bar_comb) el valor de 201,53 está tomado de "https://www.miteco.gob.es/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/factores_emision_tcm30-479095.pdf" }


T_g = 24,56*1,11
T_e = 86,40
T_CO2 = 35
r_g = 0,023
r_e = 0,025
r_CO2 = 0,08
wacc = 0,05
N = 15
H = 180*16
INV = 2*105407,72 + 91953,32

"Estequiometría"
{ CH4 + a*(1+lambda)*(O2 + 3,76 N2) -> b CO2 + c H2O + d (1+lambda) N2 + a lambda O2 }

1 = b
4 = 2*c
2*a = 2*b + c
2*3,76*a = 2*d
h_bar_comb = b*h_bar_fCO2 + c*h_bar_fH2O - h_bar_fCH4

"Condición de partida: lambda_0; n_dot_f0"
a*(1+lambda_0)*(C_bar_pO2+3,76*C_bar_pN2)*(25-25) = h_bar_comb + (b*C_bar_pCO2 + c*C_bar_pH2O + d*(1+lambda_0)*C_bar_pN2 + a*lambda_0*C_bar_pO2)*(185-25)

"Condición de ahorro: lambda; n_dot_f"
a*(1+lambda)*(C_bar_pO2+3,76*C_bar_pN2)*(75-25) = h_bar_comb + (b*C_bar_pCO2 + c*C_bar_pH2O + d*(1+lambda)*C_bar_pN2 + a*lambda*C_bar_pO2)*(185-25)

"Prestaciones"
Q_dot_con = 612 + 438 + (475/514)*707
Q_dot_con = n_dot_f*a*(1+lambda)*(C_bar_pO2+3,76*C_bar_pN2)*(75-25)

n_dot_f0*(b + c + d*(1+lambda_0) + a*lambda_0) = n_dot_f*(b + c + d*(1+lambda) + a*lambda)
Q_dot_gas0 = n_dot_f0*abs(h_bar_comb)
Q_dot_gas = n_dot_f*abs(h_bar_comb)
Q_dot_gasAHORRADO = Q_dot_gas0 - Q_dot_gas
CO2Egas = Q_dot_gasAHORRADO*H*1,11*f_CO2/1e6
CO2Eelec = - (E*331/1000)
CO2E = CO2Egas + CO2Eelec

AG = (Q_dot_gasAHORRADO/1000)*H
E = ((202 + 131 + 208*(475/514))/1000)*H


Call npv(INV; wacc; r_g; r_e; r_CO2; N; T_g; T_e; T_CO2; E; AG; CO2Egas: VAN)
Call payback(INV; wacc; r_g; r_e; r_CO2; N; T_g; T_e; T_CO2; E; AG; CO2Egas: PR)
Call irr(INV; wacc; r_g; r_e; r_CO2; N; T_g; T_e; T_CO2; E; AG; CO2Egas: TIR)
```

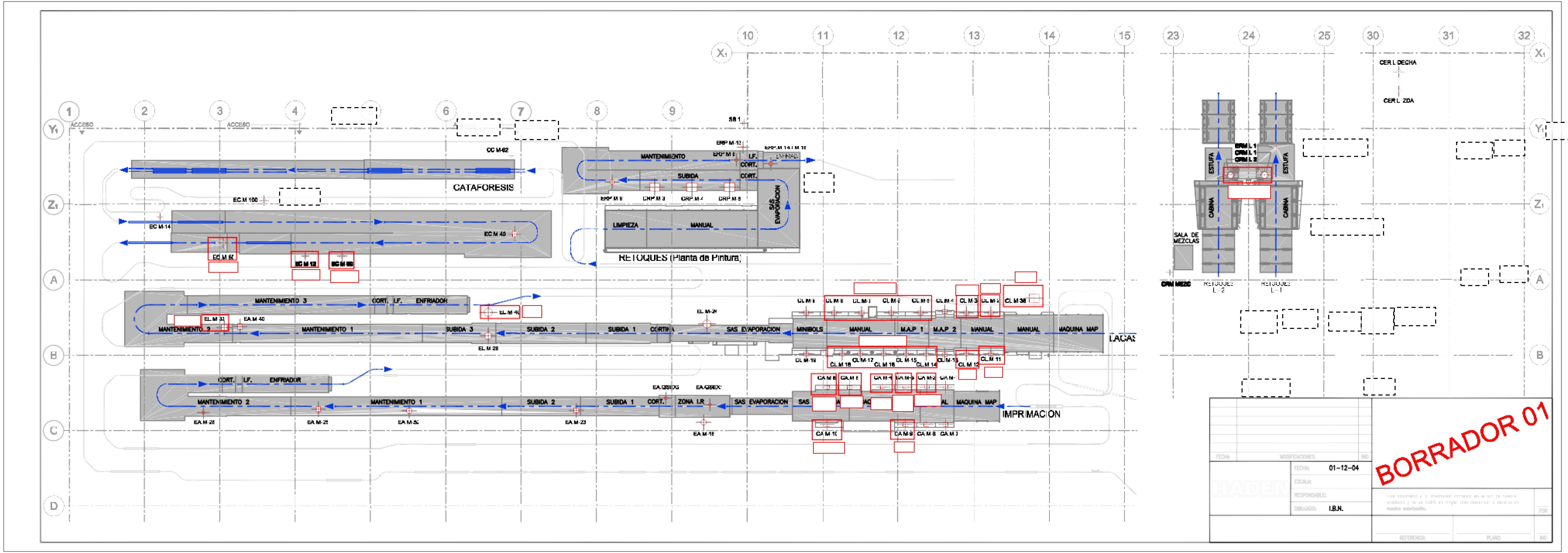
SOLUTION

**Unit Settings: SI C bar kJ molar deg**

a = 2
AG = 4925 [MWh]
b = 1
c = 2

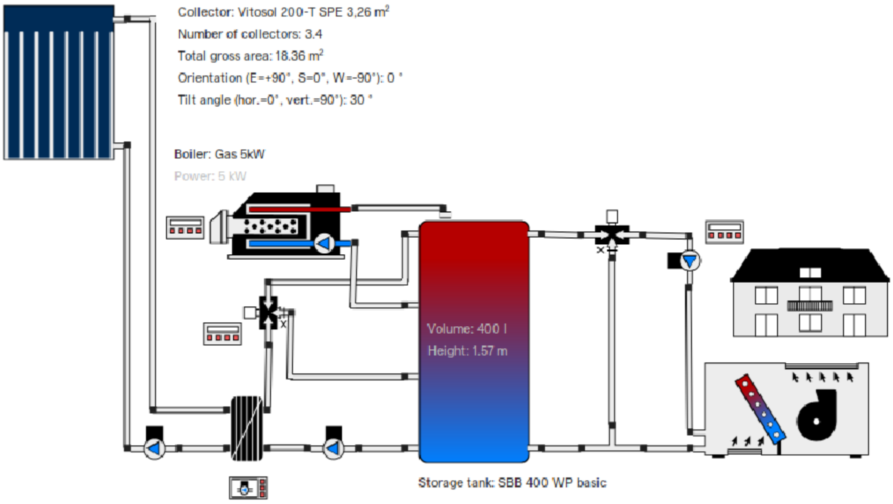
CO2E = 600,9 [ton/año]
CO2Eelec = -500,7
CO2Egas = 1102
$\overline{C}_{pCO2}$ = 40,44 [kJ/kmol-K]
$\overline{C}_{pH2O}$ = 34,11 [kJ/kmol-K]
$\overline{C}_{pN2}$ = 29,21 [kJ/kmol-K]
$\overline{C}_{pO2}$ = 30,03 [kJ/kmol-K]
d = 7,52
E = 1513 [MWh]
$f_{CO2}$ = 201,5 [g/kWh]
H = 2880 [h]
$\overline{h}_{comb}$ = -802513 [kJ/kmol]
$\overline{h}_{fCH4}$ = -74595 [kJ/kmol]
$\overline{h}_{fCO2}$ = -393486 [kJ/kmol]
$\overline{h}_{fH2O}$ = -241811 [kJ/kmol]
INV = 302769 [€]
$\lambda$ = 24,83
$\lambda_0$ = 16,76
N = 15 [años]
$\dot{n}_f$ = 0,004715 [kmol/s]
$\dot{n}_{f0}$ = 0,006846 [kmol/s]
PR = 6,673 [años]
$\dot{Q}_{con}$ = 1703 [kW]
$\dot{Q}_{gas}$ = 3784 [kW]
$\dot{Q}_{gas0}$ = 5494 [kW]
$\dot{Q}_{gasAHORRADO}$ = 1710 [kW]
$r_{CO2}$ = 0,08 [p.u.]
$r_e$ = 0,025 [p.u.]
$r_g$ = 0,023 [p.u.]
TIR = 0,1896 [p.u.]
$T_{CO2}$ = 35 [€/ton]
$T_e$ = 86,4 [€/MWhe]
$T_g$ = 27,26 [€/MWht-PCS]
VAN = 447036 [€]
wacc = 0,05 [p.u.]

30 potential unit problems were detected.


CATAFORESIS
RETOQUES (Planta de Pintura)
MANTENIMIENTO
SUBIDA
CORT.
LIMPIEZA
MANUAL
S/S EVAPORACION
MANTENIMIENTO 3
CORT.
I.F.
ENFRIADOR
MANTENIMIENTO 2
MANTENIMIENTO 1
SUBIDA 3
SUBIDA 2
SUBIDA 1
SAS EVAPORACION
MINIBOLS
MANUAL
M.A.P 1
M.A.P 2
MAQUINA MAP
LACAS
ZONA I.R.
SAS
IMPRIMACION
SALA DE MEZCLAS
ESTUFA
CABINA
RETOQUES L-2
RETOQUES L-1
ACCESO
FECHA:
01-12-04
ESCALA:
RESPONSABLE:
DIBUJADO:
I.B.N.
REFERENCIA
PLANO
BORRADOR 01

# Professional Report

**Psa_v2** **FINAL**




## Location of the system

Spain
MADRID
Longitude: -3.71 °
Latitude: 40.41 °
Elevation: 608 m

## This report has been created by:

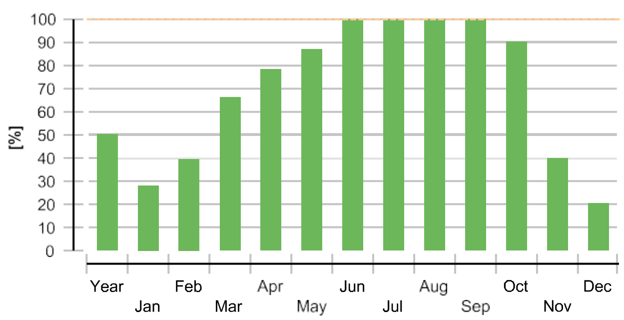
## System overview (annual values)

| | |
|---|---|
| Total fuel and/or electricity consumption of the system [Etot] | 6,592 kWh |
| Total electricity consumption [Ecs] | 152 kWh |
| Total gas consumption [Egas] | 6,440 kWh |
| Total energy consumption [Quse] | 7,560 kWh |
| System performance [(Quse+Einv) / (Eaux+Epar)] | 1.15 |
| Primary energy factor | 0.97 |
| Comfort demand | Energy demand covered |

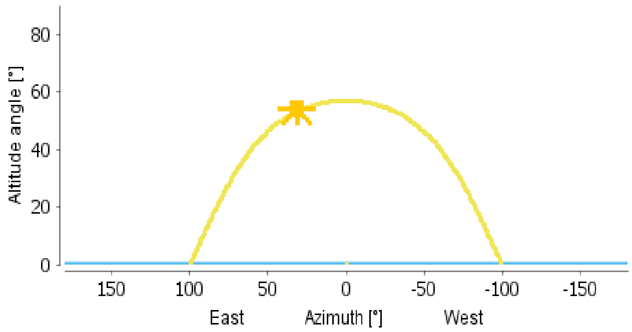
## Overview solar thermal energy (annual values)

| | |
|---|---|
| Collector area | 18.4 m² |
| Solar fraction total | 50.3% |
| Total annual field yield | 5,348.4 kWh |
| Collector field yield relating to gross area | 291.3 kWh/m²/Year |
| Collector field yield relating to aperture area | 454.6 kWh/m²/Year |
| Max. fuel savings | 566 m³(gas): [Natural gas H] |
| Max. energy savings | 5,942.6 kWh |
| Max. reduction in CO2 emissions | 1,376 kg |

### Solar fraction: fraction of solar energy to system [SFn]




### Horizon line




## Meteorological data-Overview

| | |
|---|---|
| Average outdoor temperature | 15.6 °C |
| Global irradiation, annual sum | 1,642 kWh/m² |
| Diffuse irradiation, annual sum | 581 kWh/m² |

## Component overview (annual values)

| **Boiler** | **Gas 5kW** | |
|---|---|---|
| Power | kW | 5 |
| Total efficiency | % | 82 |
| Energy from/to the system [Qaux] | kWh | 5,282 |
| Fuel and electricity consumption [Eaux] | kWh | 6,440 |
| Fuel consumption of the back-up boiler [Baux] | m³(gas) | 613 |
| Energy savings solar thermal | kWh | 5,943 |
| CO2 savings solar thermal | kg | 1,376 |
| Fuel savings solar thermal | m³(gas) | 566 |
| Exhaust fumes losses [Qex] | kWh | 644 |

# Professional Report

| Collector | Vitosol 200-T SPE 3,26 m² | |
|---|---|---|
| Data Source | | TÜV Rheinland |
| Number of collectors | | 3.4 |
| Number of arrays | | 4 |
| Total gross area | m² | 18.36 |
| Total aperture area | m² | 11.764 |
| Total absorber area | m² | 11.76 |
| Tilt angle (hor.=0°, vert.=90°) | ° | 30 |
| Orientation (E=+90°, S=0°, W=-90°) | ° | 0 |
| Collector field yield [Qsol] | kWh | 5,348 |
| Irradiation onto collector area [Esol] | kWh | 22,147 |
| Collector efficiency [Qsol / Esol] | % | 24.1 |
| Direct irradiation after IAM | kWh | 14,244 |
| Diffuse irradiation after IAM | kWh | 6,712 |
| **Building** | **-** | |
| Heating setpoint temperature | °C | 20 |
| Heating energy demand excluding DHW [Qdem] | kWh | 7,600 |
| Useful heat gain | kWh | 11,400 |
| Total energy losses | kWh | 19,000 |

| Fan coil | NUESTRO | |
|---|---|---|
| Nominal heating power | W | 2,500 |
| Nominal hot water inlet temperature | °C | 85 |
| Nominal hot water return temperature | °C | 75 |
| Net energy from/to heating/cooling modules | kWh | 7,558 |

| External heat exchanger Solar loop | huge | |
|---|---|---|
| Transfer capacity | W/K | 30,000 |

| Pump Heating loop | Eco, medium | |
|---|---|---|
| Circuit pressure drop | bar | 0.001 |
| Flow rate | l/h | 321 |
| Fuel and electricity consumption [Epar] | kWh | 86.6 |

| Pump Solar loop | Eco, medium | |
|---|---|---|
| Circuit pressure drop | bar | 0.003 |
| Flow rate | l/h | 176 |
| Fuel and electricity consumption [Epar] | kWh | 32.8 |

| Pump Transfer circuit | Eco, medium | |
|---|---|---|
| Circuit pressure drop | bar | 0.001 |
| Flow rate | l/h | 176 |
| Fuel and electricity consumption [Epar] | kWh | 32.8 |

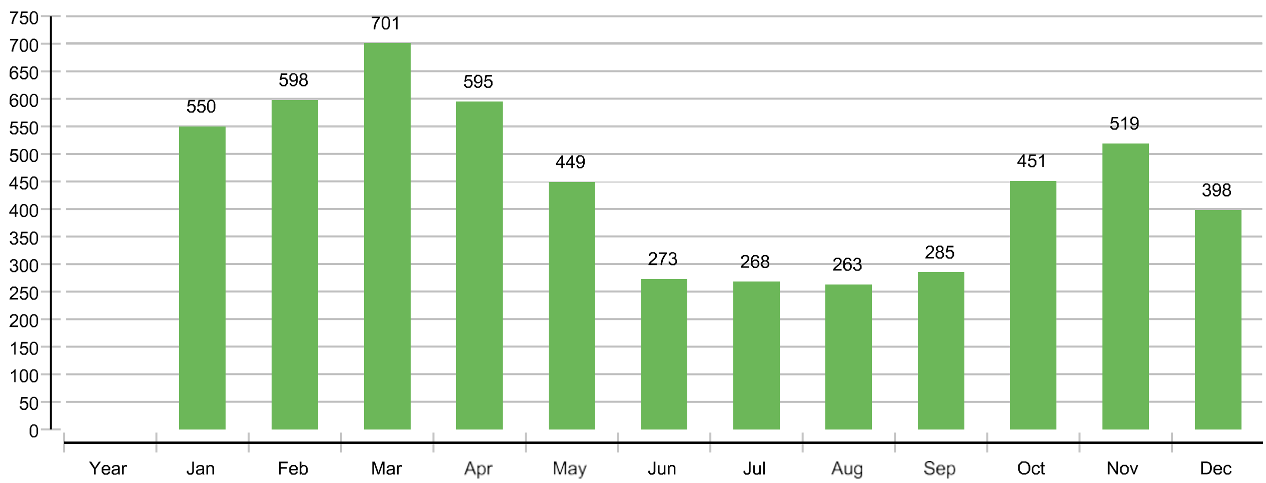
# Professional Report

| Storage tank Buffer tank | SBB 400 WP basic | |
|---|---|---|
| Volume | l | 400 |
| Height | m | 1.57 |
| Material | | Enameled steel |
| Insulation | | Rigid PU foam |
| Thickness of insulation | mm | 50 |
| Heat loss [Qhl] | kWh | 820 |
| Connection losses | kWh | 352 |

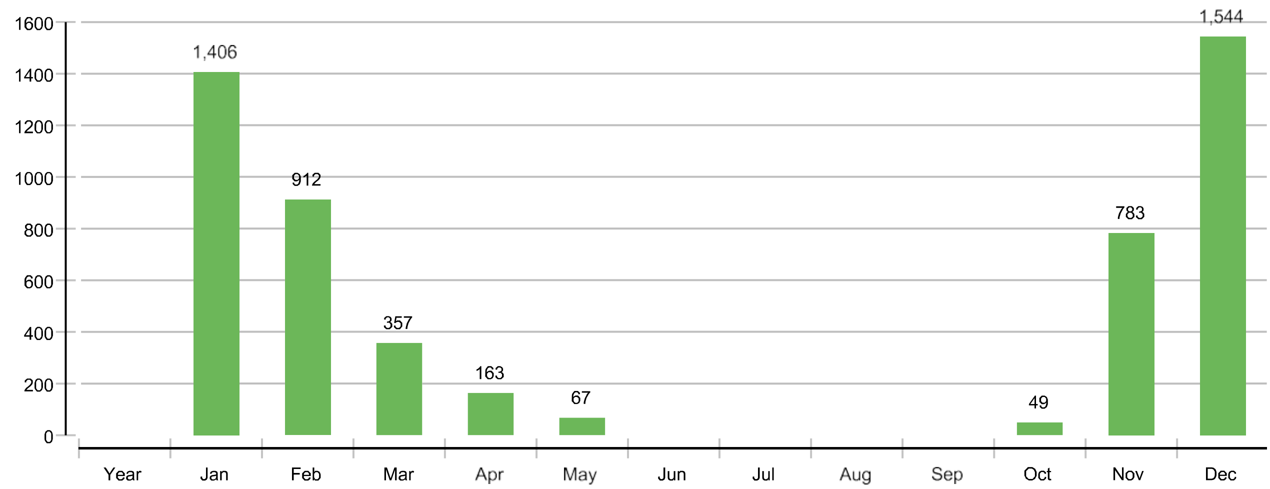
## Loop

| Solar loop | | |
|---|---|---|
| Fluid mixture | | Propylene mixture |
| Fluid concentration | % | 33.3 |
| Fluid domains volume | l | 32.1 |
| Pressure on top of the circuit | bar | 4 |

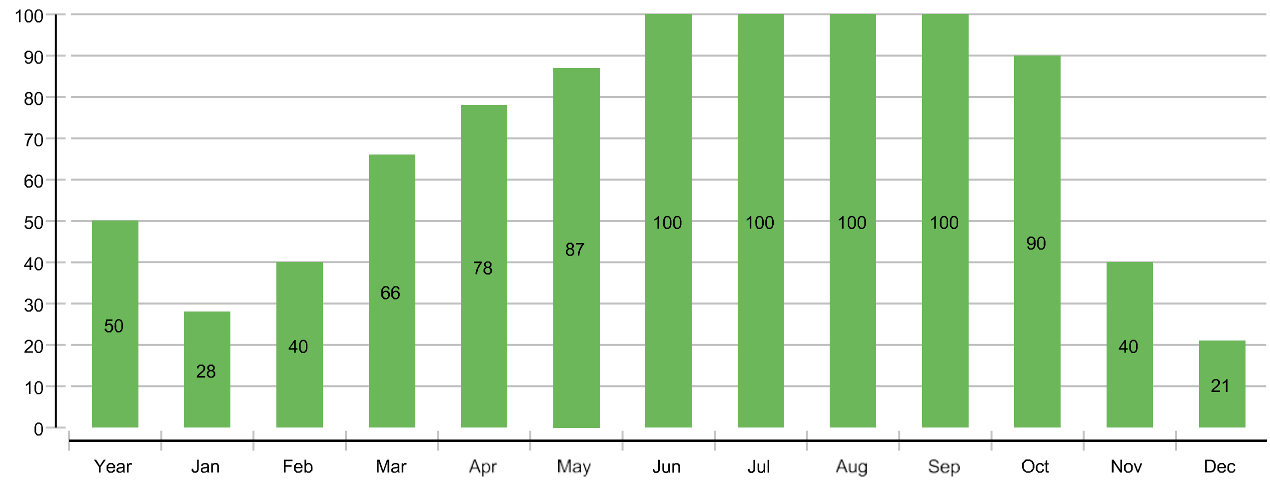
**Solar thermal energy to the system [Qsol]** **kWh**



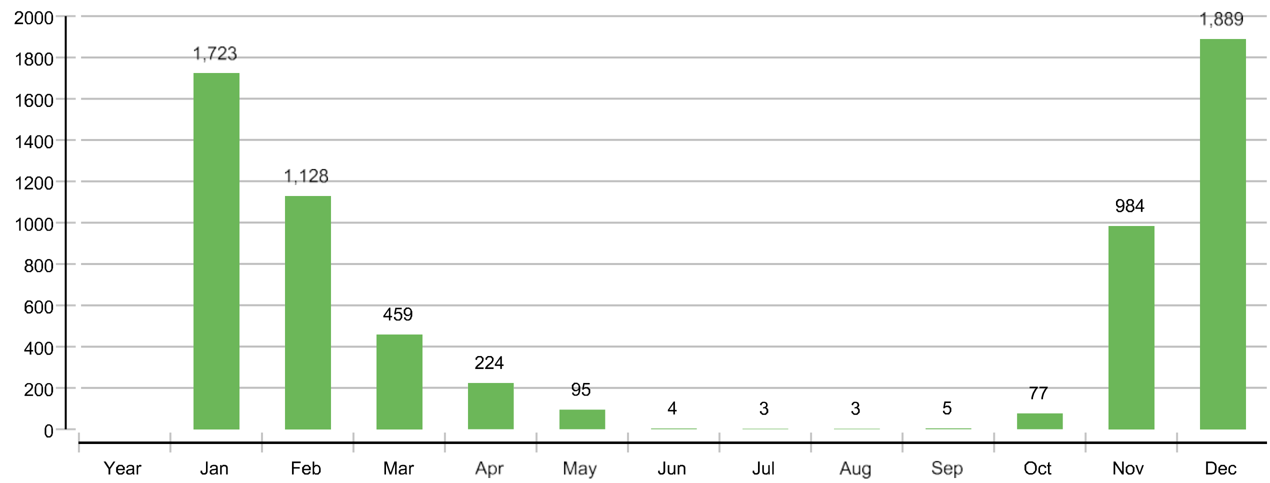
## Heat generator energy to the system (solar thermal energy not included) [Qaux] kWh




## Solar fraction: fraction of solar energy to system [SFn] %

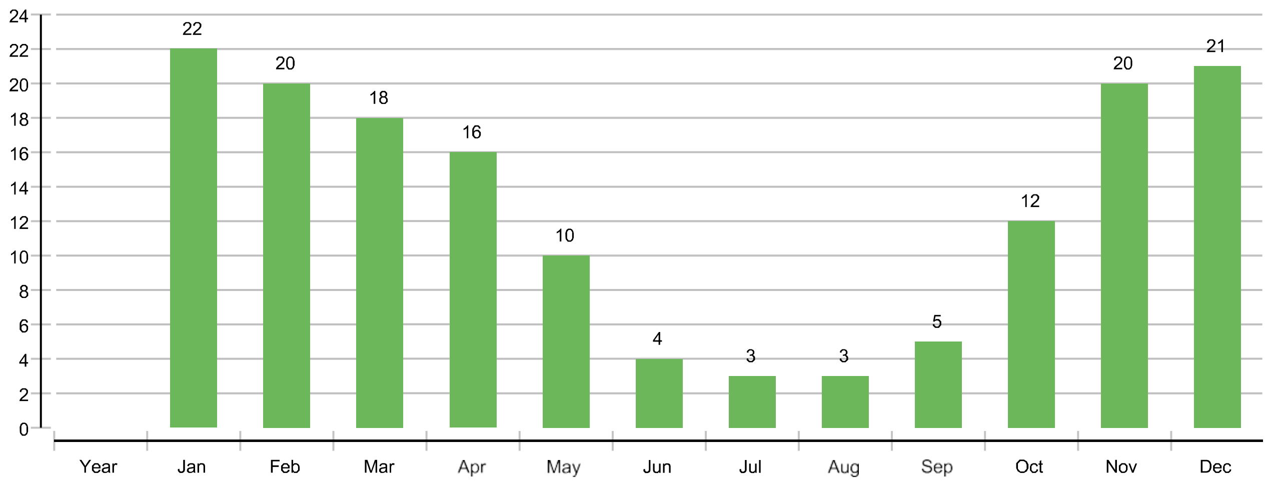



## Total fuel and/or electricity consumption of the system [Etot] kWh



# Professional Report

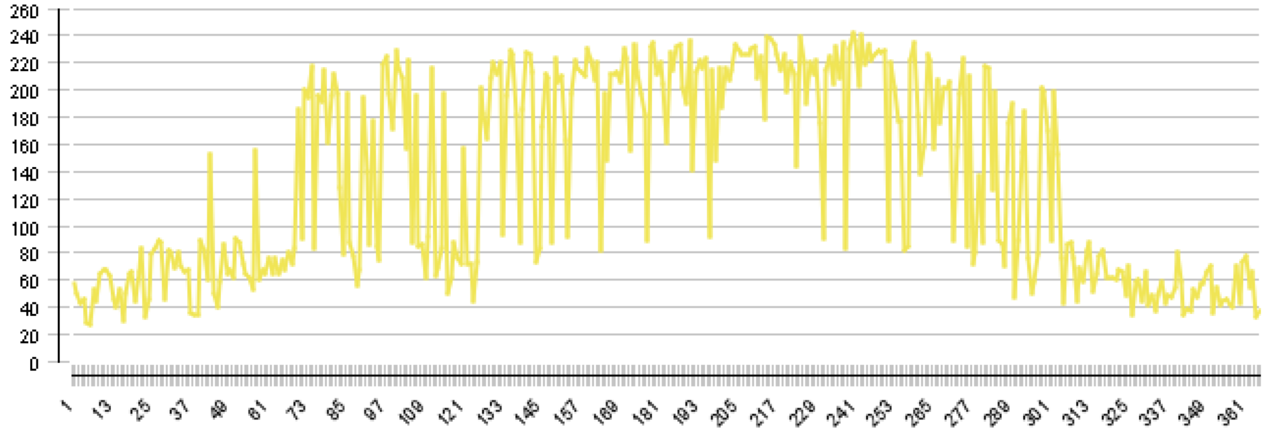
**Total electricity consumption [Ecs]** kWh




| | Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Solar thermal energy to the system [Qsol]** | | | | | | | | | | | | | |
| kWh | 5348 | 550 | 598 | 701 | 595 | 449 | 273 | 268 | 263 | 285 | 451 | 519 | 398 |
| **Heat generator energy to the system (solar thermal energy not included) [Qaux]** | | | | | | | | | | | | | |
| kWh | 5282 | 1406 | 912 | 357 | 163 | 67 | 0 | 0 | 0 | 0 | 49 | 783 | 1544 |
| **Heat generator fuel and electricity consumption [Eaux]** | | | | | | | | | | | | | |
| kWh | 6440 | 1702 | 1109 | 441 | 208 | 85 | 0 | 0 | 0 | 0 | 65 | 963 | 1868 |
| **Solar fraction: fraction of solar energy to system [SFn]** | | | | | | | | | | | | | |
| % | 50.3 | 28.1 | 39.6 | 66.2 | 78.5 | 87 | 100 | 100 | 100 | 100 | 90.2 | 39.8 | 20.5 |
| **Total fuel and/or electricity consumption of the system [Etot]** | | | | | | | | | | | | | |
| kWh | 6592 | 1723 | 1128 | 459 | 224 | 95 | 4 | 3 | 3 | 5 | 77 | 984 | 1889 |
| **Irradiation onto collector area [Esol]** | | | | | | | | | | | | | |
| kWh | 22147 | 1245 | 1348 | 2028 | 1999 | 2270 | 2399 | 2548 | 2471 | 2087 | 1658 | 1170 | 925 |
| **Electricity consumption of pumps [Epar]** | | | | | | | | | | | | | |
| kWh | 152.3 | 21.7 | 19.7 | 18.1 | 15.5 | 10.2 | 3.6 | 3 | 2.9 | 4.7 | 11.7 | 20.4 | 20.8 |
| **Total energy consumption [Quse]** | | | | | | | | | | | | | |
| kWh | 7560 | 1704 | 1276 | 771 | 505 | 227 | 10 | 0 | 0 | 25 | 240 | 1091 | 1711 |
| **Heat loss to indoor room (including heat generator losses) [Qint]** | | | | | | | | | | | | | |
| kWh | 2971 | 337 | 278 | 255 | 229 | 221 | 206 | 212 | 209 | 203 | 217 | 268 | 337 |
| **Heat loss to surroundings (without collector losses) [Qext]** | | | | | | | | | | | | | |
| kWh | 764 | 58 | 63 | 79 | 76 | 72 | 61 | 58 | 58 | 62 | 71 | 58 | 48 |
| **Total electricity consumption [Ecs]** | | | | | | | | | | | | | |
| kWh | 152 | 22 | 20 | 18 | 16 | 10 | 4 | 3 | 3 | 5 | 12 | 20 | 21 |

## Collector

### Daily maximum temperature [ °C]



## Energy flow diagram (annual balance)