VILNIAUS GEDIMINAS TECHNICAL UNIVERSITY

FACULTY OF ENVIRONMENTAL ENGINEERING

DEPARTMENT OF BUILDING ENERGETICS

Manuel Belmonte Hernández

SOLAR HEAT USE FOR HOT WATER AND HEATING PREPARATION IN A RESIDENTIAL BUILDING

Final Thesis

Vilnius, 2013

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Academic supervisor Assoc. prof. Kęstutis Valančius

Student Manuel Belmonte Hernández

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0. Resumen en español

0.1. Objetivo del proyecto

El presente proyecto fue realizado y defendido por su autor Manuel Belmonte Hernández en la Vilnius (Lituania) en la universidad 'Vilniaus Gediminos Technical University' bajo la tutela de la coordinadora Rasa Stukeite y el tutor Kestukis Valancius, durante el curso escolar 2012/2013.

La posesión de una parcela con condiciones adecuadas para la instalación solar en Ávila motivó al autor de este proyecto a realizar un análisis de la viabilidad económica de su implantación, valorando también la reducción del impacto medioambiental que esto acarrearía.

La instalación solar está diseñada para abastecer la demanda de ACS parte del aire acondicionado en verano y calefacción en invierno, de las 20 casas unifamiliares. Las viviendas se distribuyen en 4 filas de 7 casas adosadas, entre ellos dos calles que separan los bloques. La sala de calderas se encuentra en el extremo de las calles y centrada con respecto a las filas de casas.

El objetivo del presente Proyecto Fin de Carrera es analizar las ventajas y beneficios, así como los inconvenientes que supone el uso de la tecnología solar para aplicaciones de agua caliente sanitaria (ACS).

Se estudiará la demanda de ACS, la climatización en verano y la calefacción en invierno, combinando elementos de tecnología solar y convencional (caldera auxiliar).

Se debe analizar también la viabilidad económica, así como la eficiencia de nuestro sistema y el impacto medioambiental.

0.2. Introducción

El sol es la fuente vital de la vida. Satisfacer todas las necesidades futuras de energía con la energía solar es técnicamente imposible, pero es necesario el desarrollo de esta tecnología y la reducción de costes para que este inmenso recurso sea capaz de proporcionar una porción significativa de la energía de las necesidades mundiales de forma fiable y con un coste aceptable.

A lo largo de la historia humana, la energía del Sol se ha utilizado con fines domésticos del hogar como cocinar y calentar. Como la energía del sol está en todas partes y la posibilidad de utilizarla de manera eficaz hace que la energía solar tenga un fuerte peso en la elección popular.

La energía del Sol incide sobre la tierra es la fuente intrínseca de como muchas formas de energía renovable (como el viento, térmica oceánica y bioenergía) y toda la energía fósil.

La energía solar así como la eólica, la biomasa, la energía de las olas o maremotriz, cuenta forman parte de la energía renovable, pero sólo una parte de la energía solar está siendo utilizado. La industria solar se comenzó a desarrollar durante los años 1980, pero los combustibles fósiles redujeron el crecimiento de la industria solar en el año 1990 ya que el costo de los combustibles fósiles sigue siendo bajo. Sin embargo, en 2000 el mercado mundial para la energía solar tuvo un rápido crecimiento debido al aumento del costo, las preocupaciones por el clima mundial y también la mejora de las tecnologías en sí y la reducción de los costos de la energía solar.

La energía desempeña un papel vital en la vida de hoy. Nuestro trabajo, el ocio, nuestro bienestar social, económico y físico bienestar depende de un suministro suficiente de energía. Sin embargo, lo damos por hecho y ahora tenemos una demanda mundial de energía alarmante. Los combustibles fósiles utilizados tradicionalmente como el petróleo son limitados.

Se debe hacer un esfuerzo por hacerlos más sostenibles para evitar el impacto negativo del cambio climático global, el creciente riesgo de interrupciones en el suministro, la volatilidad de precios y la contaminación del aire que están asociados con el sistema de energía de hoy en día. Esto requiere de acciones inmediatas para y para aumentar la eficiencia energética de las formas de producción de energía y promover las fuentes de energía limpia como las energías renovable y evitar las masivas emisiones de gases contaminantes de los combustibles alternativos para el transporte que incrementan el efecto invernadero.

0.3. Descripcion del sistema de agua caliente sanitaria

Sistema de captación, formado por los captadores solares homologados, encargados de transformar la radiación solar incidente en energía térmica de un fluido de trabajo. Rendimiento mínimo 40%. Conexión en serie o paralelo según zonas climáticas.

Sistema de acumulación, formado por uno o varios depósitos, recubiertos de material aislante, que almacenan el agua caliente hasta que se precisa su uso.

Sistema hidráulico, formado por circuitos de captación (primario) y de consumo (secundario) independientes, constituido por tuberías, válvulas, bombas, vasos de expansión, etc…, que se encarga de establecer el movimiento del fluido caliente.

Sistema de intercambio de calor, separando los dos fluidos anteriores (primario y secundario) a través de los propios depósitos o con un intercambiador específico. Realiza la transferencia de energía térmica desde el primario al agua caliente que se consume.

Sistema de regulación y control, formado por determinados automatismos para el aprovechamiento máximo de la energía solar así como para evitar situaciones de riesgo para la instalación.

Sistema energético auxiliar, centralizado o individual, formado por equipos convencionales de ACS para cubrir eventualmente el 100% de las necesidades.

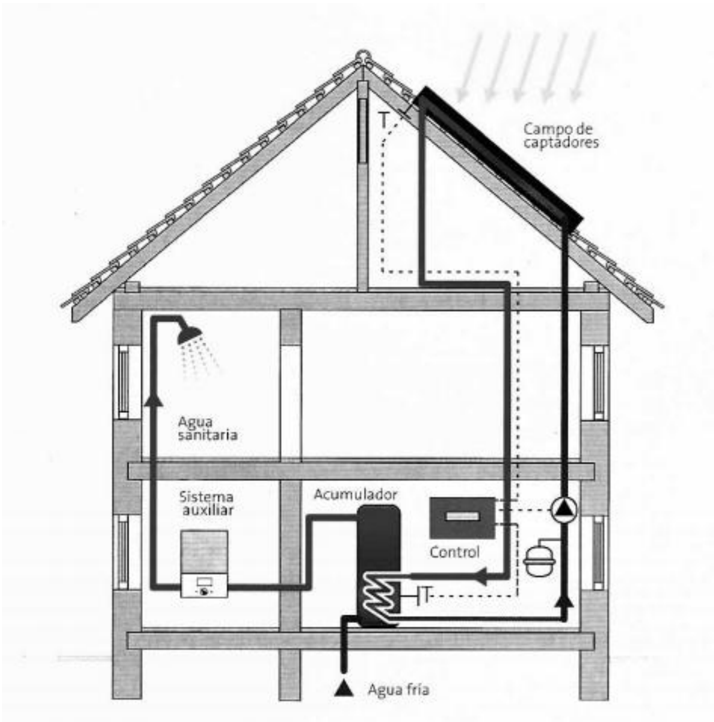


Figura 0.0: Instalación solar de circulación forzada y circuito indirecto.

Sistema de captación, formado por los captadores solares homologados, encargados de transformar la radiación solar incidente en energía térmica de un fluido de trabajo. Rendimiento mínimo 40%. Conexión en serie o paralelo según zonas climáticas.

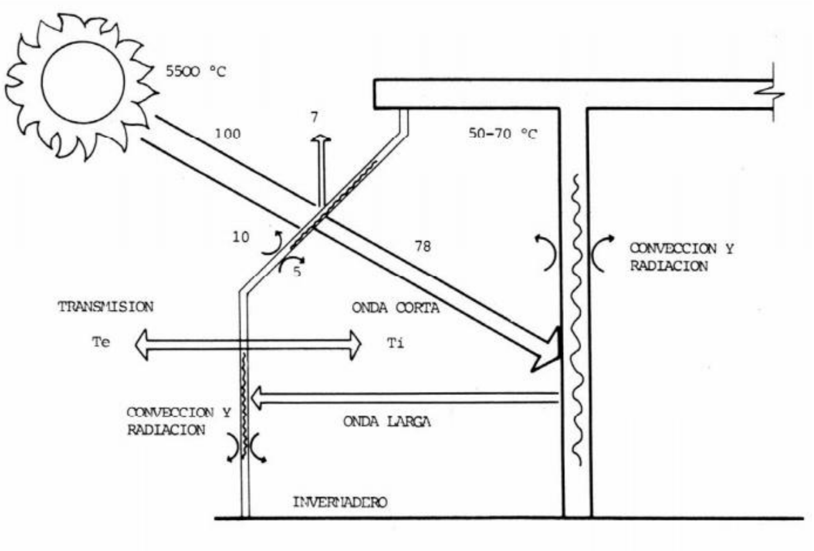


Figura 0.1: Principio de funcionamiento de un captador solar plano.

0.4. Condiciones de diseño.

Para el cálculo de cargas térmicas se tienen condiciones iniciales de las Reglas de calefacción del edificio en los edificios (RITE). En la tabla se puede ver los valores de invierno y verano. En este proyecto se utilizará como temperatura seca cubierta 21 º C y que la humedad relativa del 40%.

Para la estimación de las condiciones externas en invierno requieren saber, básicamente, dos variables: temperatura seca y la humedad relativa.

De acuerdo con esta demanda al día, a la zona de irradiación donde se encuentra el edificio, la zona IV, se explica en la sección: Descripción de la construcción, y la fuente de energía auxiliar, general (gas natural), se explica en la sección: Introducción, El objetivo del proyecto.

La cobertura mínima permitida para este proyecto es de 60%. Esto significa que el 60% de la demanda total de agua caliente al año tiene que ser calentado por la energía solar, es el mismo que, por ejemplo, que el 60% de la energía utilizada para calentar el agua tiene que ser proporcionada por un sistema solar. La cobertura real puede calcular con el método f-chart. Después, esta verdadera cobertura se compara con el mínimo uno, y lo real tiene que ser mayor que el mínimo para el cumplimiento de la regulación.

0.5. Método de cálculo y resultados.

" PRODUCCIÓN DE AGUA CALIENTE DE LA ENERGÍA SOLAR MEDIANTE CTE DB-HE-4"

Captación cálculos de área para la producción de agua caliente sanitaria, con el fin de cumplir con la contribución marcada por la fracción solar mínima establecida en el CTE.

Características de consumo de datos.

La tipología es viviendas unifamiliares. Cada edificio cuenta con 20 viviendas de 5 habitaciones, para los que el CTE ofrece 7 personas por hogar. Con lo que nos encontramos con un número de 140 personas.Con un consumo previsto de 22 litros por persona. La temperatura de uso previsto es de 60 ° C.

Consumo total = 3.080 litros por día.

DATOS DE LAS CARACTERISTICAS DEL CONSUMO.

Viviendas unifamiliares 20 viviendas con 5 dormitorios, según CTE 7 personas por vivienda. Con un consumo de 20 litros por persona.

Temperatura de utilización = 60 ºC. **Consumo total de 2800 litros por día.**

DATOS GEOGRÁFICOS	Provincia: AVILA	Latitud de cálculo: 41º	Zona Climática : IV

Los porcentajes de utilización a lo largo del año previstos son:

	ENE	FEB	MAR	ABR	MAY	JUN	Jul	AGO	SEP	OCT	NOV	DIC
% de ocupación:	100	100	100	100	100	100	100	100	100	100	100	100

CÁLCULO DE LA DEMANDA DE ENERGIA

	ENE	FEB	MAR	ABR	MAY	JUN	Jul	AGO	SEP	OCT	NOV	DIC
Deman. Ener. [KWh]:	5.639	5.002	5.336	4.969	5.034	4.775	4.833	4.934	4.872	5.135	5.164	5.639
									Total demanda energética anual:			61.332 KWh

DATOS DEL CAPTADOR SELECCIONADO		**Modelo: BUDERUS CPC 12 V2**	
Factor de eficiencia óptica = 0,644	Coeficiente global de pérdidas = 0,749 W/(m2·ºC)	Área Útil = 2,57 m2.	Dimensiones: 1,390 m x 2,06 m.

Constantes consideradas en el cálculo

Factor corrector conjunto captador-intercambiador 0.95	Modificador del ángulo de incidencia 1.15	Temperatura mímima ACS 45º

RESULTADOS DEL SISTEMA SELLECIONADOS

Número de Captadores: 15	**Área Útil de captación: 38.55 m2.**	**Volumen de acumulación ACS: 2730 l**

Inclinación: 35 º	Desorientación con el sur:15 º

PERDIDAS DEL SISTEMA

Caso General	Por inclinación. (optima 40º) =-0,26%	Por desorientación Sur: 0,79%	Por sombras 0 %

CALCULO DE LA PRODUCCIÓN ENERGÉTICA DEL SISTEMA

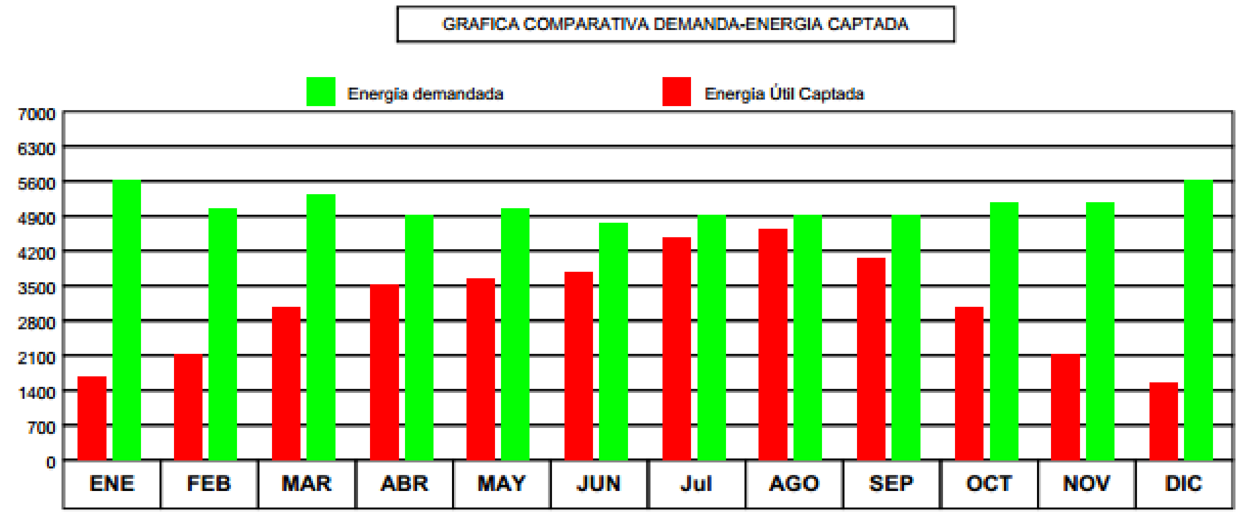
	ENE	FEB	MAR	ABR	MAY	JUN	Jul	AGO	SEP	OCT	NOV
EU=f*DE:	1.722	2.154	3.107	3.448	3.590	3.769	4.481	4.668	3.999	3.011	2.033
									Total producción energética útil anual:		37.569 KWh

RESULTADOS	E. Demandada:	E. Producida:	Factor F anual aportado de: 61%
EXIGENCIAS DEL CTE			
Zona climática tipo: IV	Sistema de energía de apoyo tipo: General: gasóleo, propano, gas natural, u otras		Contribución Solar Mínima: 60%
CUMPLE LAS EXIGENCIAS DEL CTE			

EXIGENCIAS DEL CTE Respecto al límite de pérdidas	Orien. e incl.	Sombras	Total
Pérdida permitidas en CTE. Caso General	10%	10%	15%
Pérdida en el proyecto	0,53%	0,00%	0,53%
CUMPLE LAS EXIGENCIAS DEL CTE			

CÁLCULO ENERGÉTICO												
	ENE	FEB	MAR	ABR	MAY	JUN	Jul	AGO	SEP	OCT	NOV	
% ENERGIA APORTADA:	31%	43%	58%	69%	71%	79%	93%	95%	82%	59%	39%	28%

Cumple la condición del CTE, no existe ningún mes que se produzca más del 110% de la energía demandada.Cumple la condición del CTE, no existen 3 meses consecutivos que se produzca más de un 100% de la energía demandada.



0.6. Análisis de resultados

La demanda de energía es casi constante, la pequeña variación que tiene es debido a mes tienen diferente número de días. La energía solar incidente por mes es superior a la demanda de energía durante los ocho meses centrales del año. Y cuanto mayor sea la energía incidente es, la cobertura solar es mayor, y mayor será la energía útil es tomada. Como es lógico, cuando la energía solar incidente es menor que la demanda de energía, la cobertura solar y en la adicción a la energía útil adoptado tiene valores muy bajos.

Si se encontró un método para aumentar la irradiación solar, también se incrementará la cobertura solar, ya que ambas poseen características similares.

La cobertura solar durante julio, agosto y septiembre está en torno al 90%, y más del 80% en mayo y junio, valores muy altos. Por eso, se puede predecir que el consumo de energía y el coste del combustible van a ser muy pequeños.

- COSTES DE LA INSTALACIÓN

El costo de inversión es el costo inicial total de la instalación incluye elementos e instalación. Los precios de los elementos han sido tomados de otros proyectos, por lo tanto, estos precios son bastante fiables.

Hay tres elementos principales, los que se han estudiado y calculado cuidadosamente. Además, hay algunos elementos secundarios, tales como tuberías, soportes de fijación y posicionamiento, sistemas de control, etc. El costo de todos estos elementos secundarios se considera que es el quince por ciento de los tres principales elementos de coste. Y el costo de la instalación es el cinco por ciento de los tres principales elementos de coste. Estos porcentajes se han verificado en muchos proyectos anteriores.

La inversión inicial de la instalación asciende a 29.774 **€**. Este coste se paga a todos los propietarios del edificio, entonces este costo será entre los 20 edificios individuales que componen el total. Por lo tanto el costo por chalet de siete habitantes será 1.488,7 **€**.

- COMBUSTIBLE, ENERGÍA Y DINERO AHORRADO.

Para calcular la energía auxiliar de la caldera, el volumen de combustible necesario para obtener esta energía, y el dinero que cuesta este combustible sin tener en cuenta el sistema solar se han realizado cálculos similares a el apartado anterior. En este caso toda la demanda de energía está cubierto por la caldera de gas natural. Y el segundo cálculo, se han obtenido los mismos parámetros, pero esta vez teniendo en cuenta el sistema solar. Por lo tanto, la energía cubierta por el combustible en este caso es la parte que el sistema solar no puede suministrar.

$$\textit{Consumo de energía antes de la reforma} = \frac{67.465\ (\frac{KWh}{year})}{3,6\ (\frac{MJ}{KWh})} = 18.740\ (\frac{KWh}{year})$$

$$\textit{Consumo de después de la reforma} = \frac{26.864\ (\frac{KWh}{year})}{3,6\ (\frac{MJ}{KWh})} = 7.462\ (\frac{KWh}{year})$$

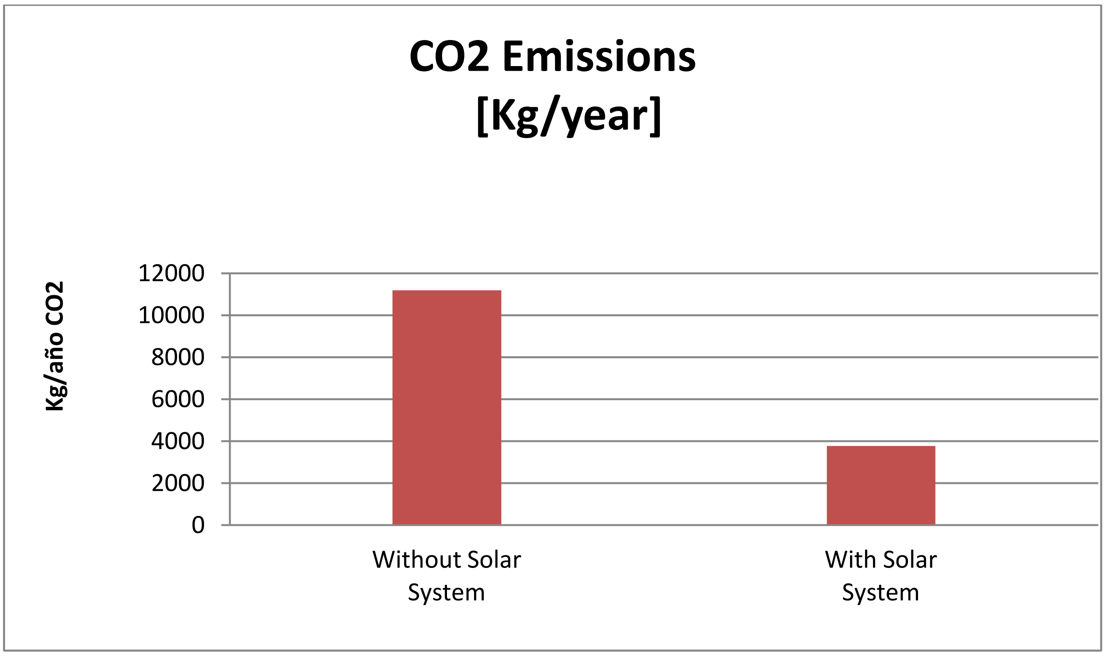
Reducción de potencia $= 11.278\ (\frac{KWh}{year})$

La reducción del precio es un poco más bajo que los otros dos. Esto sucede debido a que el precio del gas natural tiene una parte del precio que es constante, y éste no se reduce. A continuación, la reducción es menor debido a que sólo la parte variable relacionada con el consumo se reduce.

Estas tres variables dependen directamente, por lo que la evolución a lo largo del año es la misma para todos ellos. Y la relación entre los dos cálculos es también la misma para los tres parámetros. Luego, basta representan sólo una, la energía caldera auxiliar, por ejemplo, y muestra los resultados numéricos de los tres.

- REDUCCIÓN DE CO2.

El CO2 se produce por la combustión de gas natural, y son directamente proporcionales. Se puede observar en la distribución, que es la misma para el consumo de volumen de gas natural se ha mencionado en la parte anterior. El porcentaje de reducción de las emisiones también va a ser el mismo.



- PAYBACK

La recuperación de la inversión es ligeramente alta, similar a la del período de la vida prevista de la mayor parte de los elementos de la instalación, entre veinte y veinte cinco años. Tiene que ser mirada desde un enfoque positivo. La instalación es obligatoria, no hay decisión sobre la instalación o no, entonces es un muy buen resultado si todos los costos iniciales se recuperan durante el periodo de vida de la instalación. Y tal vez algunos beneficios se obtendrán en los últimos años.

Aún más, se sabe que el gas natural está aumentando su precio año por año. Si su precio sigue aumentando el dinero ahorrar al año también aumentará y el período de recuperación de la inversión se reducirá, haciendo el sistema más rentable.

0.7. Conclusiones

Todo el planeta ahora está sufriendo las consecuencias de su propio desarrollo. El calentamiento global, debido al efecto invernadero y el agujero de la capa de ozono de la Antártida están aumentando y supone un problema muy grave para el medio ambiente y el desarrollo del mundo. La humanidad tiene que evolucionar hacia una vida mejor , pero siempre sin dejar de lado el cuidado del planeta en el que viven .

El objetivo de esta tesis es calcular el tamaño y el equipamiento necesario para un sistema de calefacción solar de agua. La instalación de este sistema es seguido por unas pocas consecuencias que son necesarios para conocer y cuantificar de antemano . Estas consecuencias pueden ser vistos desde diferentes puntos de vista , las dos principales son el ambiental y el económico.

Por un lado , en el aspecto ambiental , que tiene que ser considerado la reducción de la energía producida por los combustibles fósiles . Esto es equivalente a una reducción del consumo de combustibles fósiles , lo que significa también una reducción en las emisiones de gases de efecto invernadero , como el dióxido de carbono , metano, óxido nitroso y así sucesivamente . Vale la pena mencionar que el sistema calculará en esta tesis hace una muy buena contribución al medio ambiente. La demanda de energía tradicional, por tanto, el consumo de gas natural, se han reducido un 60,18 %. Esto significa una reducción de 40.601 KWh / año y 3.776 m3 / año, respectivamente. Esta reducción del consumo de combustible evita la emisión de 7.417,9 Kg CO_2/año.

Por otro lado, en la forma económica , la cantidad de dinero ahorrado para este edificio es bastante importante . Hoy en día en España, la instalación de sistemas de agua caliente sanitaria mediante energía solar es obligatoria en edificios nuevos y renovados. Por lo tanto, no es una elección acerca de la instalación o no. Dos parámetros económicos tienen que ser calculado , el primero es el costo de la inversión inicial, y el segundo es el periodo de recuperación . En este proyecto los dos parámetros tienen un valor aceptable.

El primero de ellos, el costo de inversión inicial alcanza la cantidad de 29.774 € . Esta cantidad tiene que ser pagado entre todos los pisos del edificio, por lo que cada propietario de un piso debe pagar 1.488,7 € . Por último, la recuperación de la inversión se obtiene es 20,56 años . Esta vez es aproximadamente igual al período de la vida de la instalación , entre 20 y 25 años . Teniendo en cuenta el incremento en el precio del gas natural año tras año, el periodo de recuperación podría reducirse considerablemente. Por lo tanto, es muy posible que no sólo el dinero de la inversión inicial de volver, pero también podría ser beneficios adicionales durante estos últimos años de la vida de la instalación.

A veces, con el fin de conseguir un mejor entorno para la vida , los beneficios económicos deben ser considerados como secundarios. Los resultados globales del proyecto muestran que las instalaciones térmicas solares son atractivas para el consumidor y muy positivas para el medio ambiente.

Uno de los inconvenientes en el desarrollo de este tipo de proyectos es que no se dispone de los equipos y tecnología necesarios. No obstante, conviene destacar la importancia de la ayuda recibida por la Comunidad de Madrid y el IDAE , que si no fuera así, la amortización de la instalación se producen en 25 años, al final de la vida útil de los mismos , lo que haría que deje de ser interesante para el usuario . Por consiguiente, es esencial que no sólo por una parte facilitar las instituciones y las subvenciones, sino que también proporcionan información suficiente para lograr la sensibilización de los

1. Introduction

1.1. PERSONAL MOTIVATION

From the beginning of his studies, the student author of this project have been interested by continuing reports concerning the problematic derived from pollution generated by fossil fuel use for obtaining energy, this essential element for the human development, as well as to the different actions to alleviate the aforementioned problematic, are being carried out, both globally, with initiatives such as the Kyoto Protocol, and territorial levels, by various administrations of each country promulgating regulations that directly or indirectly aspects can contribute to reduce pollution from the use of such fuels, as is the case with the Technical Building Code (CTE), issued by the Ministry of Housing for the purpose of achieving some buildings more efficient from an environmental perspective.

Consistent with the discussion in the previous paragraph, parallel also been interested in the possibilities offered by modern technologies, in order to clean energy generation through the use of alternative sources of production.

This attitude staff related to the problematic of contamination, the chance to contribute to finding solutions to it by the use of the new possibilities offered by science and technology, and considering that Spain, according to EPIA balances (European Photovoltaic Industry Association) and DBK (Spanish company specializing in the preparation of studies and business analysis), is a world leader in solar energy , it still depends heavily on fossil fuels, the author of the project decided to focus their studies on aspects of engineering related to this matter.

Consequently, interest in deepening these issues is the main cause and personal motivation for the choice of the subject matter of the final project, which intends to translate the knowledge gained throughout the university.

1.2. ABSTRACT

One way to reduce CO_2 emissions, help to the global sustainable development and reduce the global warming is the use of clean and renewable energies. One of them is the solar energy, in fact this is one of the natural sources with more energetic potential. Due to this several prestigious entities and governments are

promoting and improving the development and use of this kind of energy. For example, the Spanish government approved a law in March of 2006, named "Código Técnico de la Edificación". This regulation is mandatory, and set the minimum quality requirements that residential buildings must have. One of them forces that new and renovated buildings have to produce part the energy demand for heating water by means of a solar thermal system.

The project is going to be carried out in an old building which is being renovated. The aim of this thesis is to design and calculate the installation of a solar system for covering part of the sanitary hot water in a residential building placed in Ávila, Spain.

The calculation includes dimension the system, to select the components and to obtain the solar annual coverage. After this, check that the obtained solar annual coverage is greater than the minimum one set by the law. The obtained results are the energy, fuel and money saves, as well as the initial investment and the payback of the installation.

1.3. THE AIM OF THE PROJECT.

The aim of this Thesis is to highlight the advantages and benefits of the use of existing solar technology for domestic applications, especially hot water (DHW), in view of the current legislation, the economic viability and environmental impact.

So the end of the installation you will be designing is intended to meet the demand for ACS, and also get in the common areas of housing the air conditioning in summer and heating in winter, combining elements of conventional solar technology.

One of the important aspects taken into account when addressing the project is economic, in that the amortization of costs, based on the savings it brings, should be attractive for the consumer.

In the elaboration of the project has followed a methodology based on the development of the different phases as listed below:

The 1st Phase: Obtaining weather data related to air temperature, relative humidity, wind speed and direction, radiation on the inclined plane, etc.., the place where to place the buildings in which the project was developed.

The 2nd Phase: Definition and analysis of the characteristics of the buildings, to determine the requirements demanded by them and DHW demand housing assembly.

The 3rd Phase: Calculation of thermal loads in buildings and losses in the manifolds for the effect of wind, solar radiation…

The 4th Phase: In view of the data obtained in Phase 1, 2 and 3, determination of the optimal number of collectors, through the energy and mass balances, and thus calculate annual solar coverage.

The 5th Stage: Designing the water accumulation tank, the pump power required to overcome friction losses of the installation and the other components.

The 6th Phase: Environmental impact study and calculation of the amortization of the facility.

2.Overview

2.1.GLOBAL MARKET

Today, the world's energy supply is based mainly on non-renewable sources of energy: oil, coal, natural gas and uranium, which together cover about 82% of the global primary energy requirements. The remaining 18% is divided into approximately 2/3 biomass and 1/3 hydropower. Clearly a less well developed yet abundant resource is solar energy and in an era of increasing concerns over climate change and energy security it makes sense for society to invest now to let the sun be a major energy provider for residential water and space heating in the future.

SWH markets around the world vary considerably from country to country, in terms of policy and legal framework, technologies, products, systems, services, industry scale and structure, market prices and economic conditions, promotion mechanisms and distribution channels and building integration maturity.

2.2.GLOBAL SOLAR THERMAL MARKET

Globally the solar water heater sector has tended to be a mainly localized sector where local producers provide their products and services to the local communities or domestic market. As such, the products and the ways these are integrated or mounted to buildings vary considerably from country to country. Due to the increasing maturity of the technology, more reliable and better quality products and increased public awareness, the popularity of solar heating systems has been expanding in recent years. Increasingly this has lead to cross border supply and increasing standardization.

2.3.BUILDING INTEGRATION

From this 'definition' we see that there are several aspects to building integration. We distinguish five aspects:

. 1) Appearance: The way in which the solar heating system affects the aesthetics of a building. A collector can be visible as an 'add-on' or integrated in the building design.

. 2) Building structure: Solar collectors are appropriately installed and have an appropriate lifetime to ensure that the functions of load bearing and water proofing of the building are not affected. Furthermore the abilities of the system and structure to resist strong wind, heavy snow, hail, and other environmental factors should also be ensured.

. 3) The technical installation in the building: Solar circulation piping and water supply piping are reasonably distributed, i.e. length of hot water pipes are as short as possible, pass-holes for pipes in the building are prepared in advance. The design of the whole heating system is adapted to the solar heating system and the design is well matched. Space heating systems can be considered a further form of integration of the solar heating system with the whole heating installation.

. 4) Building regulations: If a solar heating system is part of a building it should fulfill all the existing building codes and certificates that exists for residential buildings. In some cases building integration is difficult, because existing regulations are not adapted to SWH- systems and a strict interpretation of the building code does not allow a SWH-system to be integrated in the building. The government can improve the building regulations to allow building integrated SWH-systems of even enforce the installation of SWH-systems.

. 5) Building process: For the best solution, the integration of solar heating into the building should be considered early in the building or the renovation design process, as this gives the best opportunities for well integrated solutions and lower costs.

2.4.MARKET BARRIERS, WAYS THE MARKET PLAYERS ARE OVERCOMING THEM

The markets for solar water heaters are different around the world, but the barriers for sustained and higher market growth are quite similar. They are comparable to the barriers found for other consumer goods and can be summarized as the ‘four A’s’:

- Acceptable (quality, ease of installation / maintenance and performance): barriers exist if the system quality does not meet expectations and the systems are not simple to install and maintain. Furthermore lack of knowledge and concerns about performance restrains buyers from purchasing the system.

- Affordable: the initial investment can be higher relative to other technology choices and lead to a longer payback time.

- Available: in some countries it is difficult to buy a system, as it is hard to find a reliable supplier and installer. The trend is especially true in the consumer market, as users are not prepared to make a lot of effort to buy products.

- Awareness: Consumer awareness about the Solar Water Heating option means that there is little end user demand on developers to ‘pull the market’ and this lack of knowledge acts as a barrier to market development. The manufacturer is of course the main stakeholder in overcoming these barriers. His role is to make the system acceptable (high quality, easy to install) and affordable. He can also work on the marketing of his systems and improve the awareness and the availability of the systems. In some markets this role is played by the installer. For new buildings more stakeholders are involved.

2.5. OUTLOOK

Solar water heating, as a key application of renewable energy, is considered as one of the alternatives in helping to reach national targets and international commitments on renewable energy and reductions in CO_2-emissions in a number of industrialized countries. Solar water heaters are also considered in a number of countries, including China, as an economical solution for providing domestic hot water to households. It is expected that the market for solar water heating will continue to grow worldwide, with a tendency to a more constant growth rate in most countries. As the market grows, correct integration into buildings will become more and more important.

2.6.QUALITY OF INSTALLATION OF SOLAR WATER HEATERS

Installing a solar water heater is not extremely difficult. However, it is a new technology that requires some extra attention to detail or actions. Small mistakes in installation can strongly influence the performance or the lifetime of the solar water heater.

The primary approach to increase the quality of installation is to organize courses for installers. Secondly, large sales campaigns should only accept or promote the services of qualified installers who can show that they are able to correctly install solar water heaters. A third option is to provide the buyers of solar water heaters with technical checklists that enable them to check whether their solar thermal system has been correctly installed. A fourth approach is to include gauges or indication lights that give a warning on major malfunctions, so that major problems can be detected. Another variation to this approach is to include performance-monitoring equipment with the solar water heaters. However a disadvantage of performance-monitoring is that it takes some knowledge and effort to be able to tell whether the system yield is as high as it should.

Global Status of Solar Thermal Technologies and Building Integration

The increase in the use of solar collectors for domestic hot water preparation since the early eighties has shown that SWH systems have developed to a mature and reliable technology. A broad variety of solar domestic-hot-water systems have been developed and adjusted to the needs and meteorological conditions around the world. Simple thermosiphon systems are mainly used in low latitudes without frost during the cold season. More advanced pumped systems are in use mainly in higher latitudes due to the lower outdoor air temperatures and frost in wintertime. Large collective installations with seasonal energy storage are not yet widely used.

From a building integrated perspective, there are a large number of examples to be found around the world of projects where special attention was given to the integration of solar heating products into buildings. Beside the technical and economical reasons there is clearly an increasing trend to consider the aesthetical reasons for building integration of solar hot water systems.

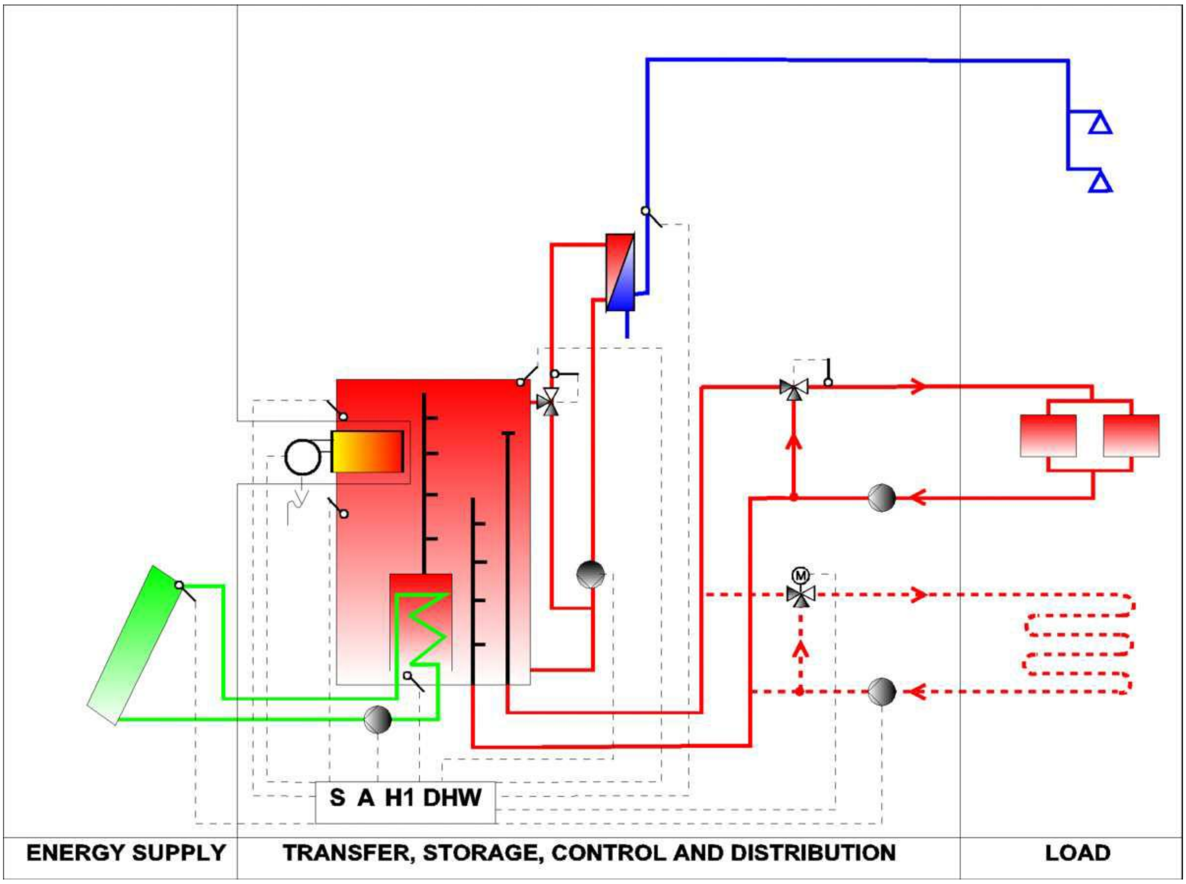


Figure 1: Hydraulic scheme of a solar combi-system.

3. Weather data

3.1.STATISTICAL STUDY OF WEATHER DATA

Initially, a basic aspect of the work is the knowledge of meteorological data for those variables that occur in different months of the year, at the place of location of the construction project under development, are essential because the same condition as all other parameters of the installation to project.

To this end, it has to be noted that the data in question, have been taken from the records of the meteorological station, is located in Navarrevisca (Ávila), the town where is located our project.

In this season have been recorded, the data for those variables that for the realization of the project are considered necessary and which are:

1) dry air temperature 2) Velocity Wind 3) Relative humidity 4) Wind Direction

As for the time period of the data used were those recorded during the years 2009, 2010, 2011 and 2012 measurements taken every 10 minutes in the meteorological station mentioned before. That is, the 144 daily measurements made within 24 hours of each day.

Given the fact that data from the indicated variables have different values as a function of time of year it was taken, it proceeded to carry out the operations indicated later, in order to obtain more homogeneous media parameters.

With regard to the first three variables have been calculated the average of the temperature levels of the m / s of wind and moisture content, respectively, of each month. To do this, we take all the data for each variable in each of the months, and averaging each of the 144 intervals of 10 minutes there every day, we got a day "type" for each month of the year.

With respect to the radiation on the horizontal plane, the way of proceeding is similar to the above except for the fact that, due to movement of the earth, only have solar radiation in a strip of the day.

With respect to the wind direction, the calculation is somewhat more complicated since it is a qualitative data.

The data captured by the meteorological station are measured in degrees and this precludes the option to average them.

To analyze it we must use COUNT function of Microsoft Excel. Thanks to it, how to evaluate cumulative counters will be created, so that, in each of the intervals of 10 minutes, increases by one the counter whose circular band, is matched by the wind direction at the time. Possible approaches to take the cardinal points: North, South, East and West.

Initial data.

This chapter will show the raw data available to us:

- Location and description of housing
- Demand for ACS with the help of the Technical Building Code.

3.2. LOCATION AND DESCRIPTION OF HOUSING

All the homes are located in the town of Navarrevisca, Ávila in the coordinates.

Altitude: 1135 m Latitude: 40 ° 21'59 .99" or North Longitude: 52'59 .99" or West

Navarrevisca is a town of Spain, in the province of Ávila, autonomous community of Castilla y León. It lies 49 kilometers from the provincial capital to which the Judicial belongs. It has an area of 39.99 km ², with a population of 376 inhabitants and a density of 9.40 inhabitants / km ².

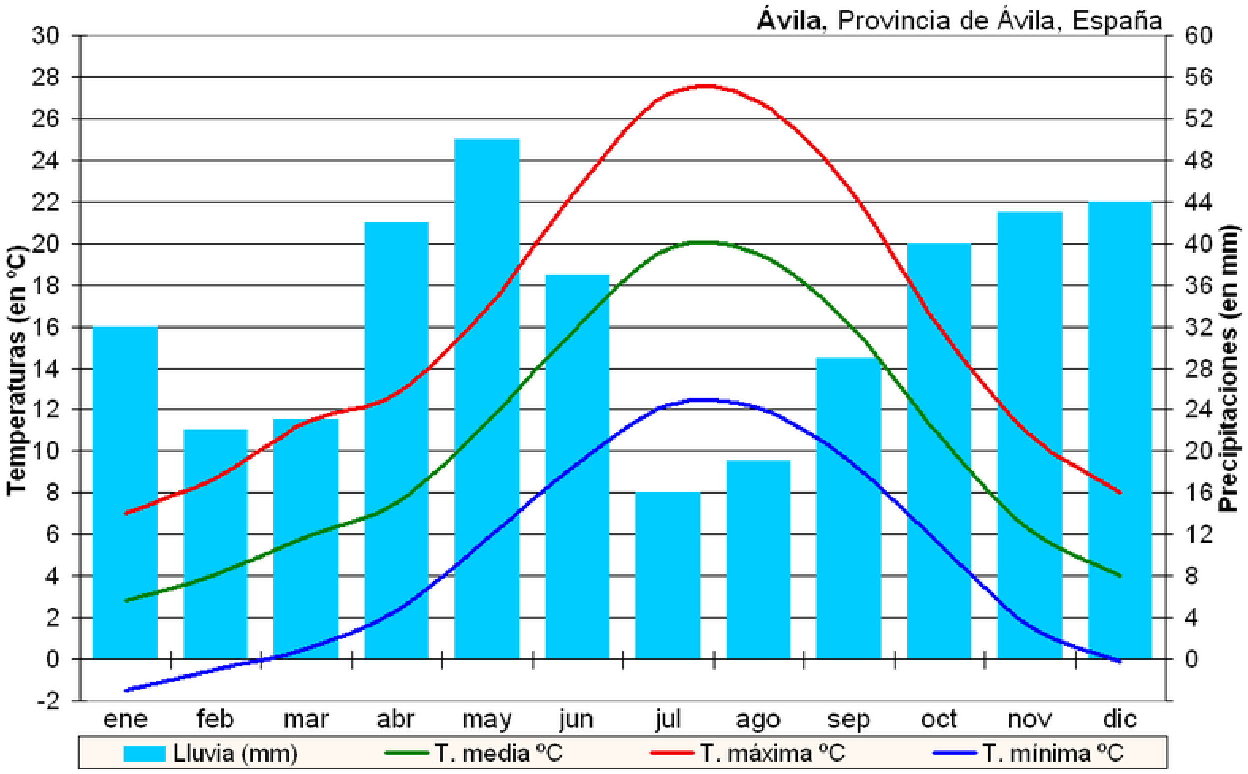


Figure 2: Initial data.

Average climatic parameters Observatory of Avila (1981-2010)

Month	Jan	Feb	Mars	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Registered maximum temperature (° C)	19.6	19.8	22.6	25.4	30.6	34.8	37.6	37.4	35.4	29.2	22.4	19.0	37.6
Maximum daily temperature (° C)	7.6	9.4	12.6	14.3	18.5	24.6	28.5	27.9	23.4	16.9	11.2	8.4	17.0
Average daily temperature (° C)	3.0	4.3	6.7	8.5	12.5	17.4	20.6	20.2	16.5	11.4	6.4	4.0	11.0
Daily minimum temperature (° C)	-1.6	-0.8	0.8	2.7	6.4	10.2	12.6	12.4	9.6	5.9	1.7	-0.4	5.0
Registered minimum temperature (° C)	-16.0	-12.0	-13.2	-8.6	-4.6	-1.0	1.0	1.4	-3.0	-5.4	-14.0	-13.4	-16.0
Total rainfall (mm)	33.6	23.7	22.9	39.6	55.4	33.2	12.0	18.8	30.0	52.9	48.4	41.7	415.6
Days of precipitation (≥ 1 mm)	6	5	4	8	9	5	2	3	4	8	7	7	67
Snowy days (≥)	5	4	2	2	0	0	0	0	0	0	2	3	20
Hours of sunshine	131	154	212	223	253	313	353	322	244	182	131	117	2636
Humidity (%)	78	72	63	63	59	51	43	45	56	69	78	63	66

Table 1: Hydraulic Average climatic parameters.

The solar installation is designed to supply the demand for ACS part of air conditioning in summer and heating in winter, of the 20 houses. The houses are distributed in 4 rows of 5 terraced houses, including two streets forming. The boiler room will be located at the end of the streets and centered with respect to the rows of chalets.

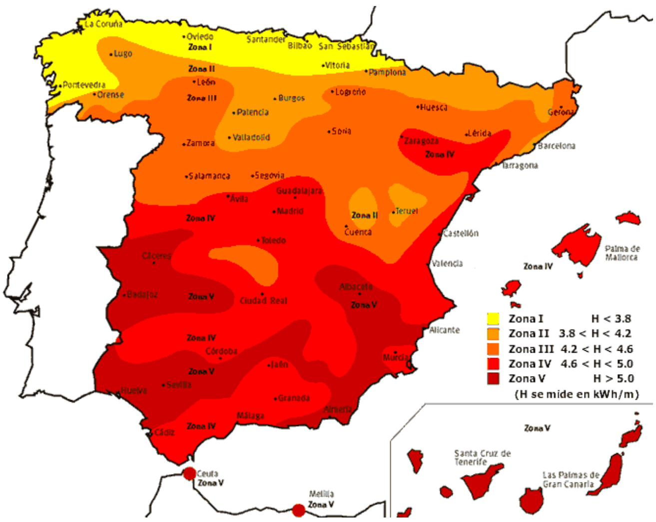


Figure 3: Irradiation Zone Map of Spain.

Each detached house has a garage and a small garden behind the main entrance.

The chalets set orientation is north-south, very suitable for placement of flat solar collectors, as indicated in subsequent chapters. The inclination of the roof is 35 ° above the horizontal.

3.3. HWS DEMAND

The main data necessary to begin calculating the optimum collector area of the installation is the HWS demand due to all people who presumably live in the houses.

3.3.1. Load calculation of monthly consumer media.

For the analysis of the needs of HWS have followed the instructions given by the Ordinance of the Community of Castilla y León supporting us at all times on the instructions of the Technical Building Code (CTE), according to the which requires:

- 22 liters per person and day
- Supply Temperature 60ºC

We will need to determine the number of inhabitants of the installation. This will come determined by the number of bedrooms contained in each chalet. Noting the table provided by the CTE, it is determined that each house will have a minimum of 6 people occupancy as the number of bedrooms in each chalet is 5.

Once you know the HWS consumption, it is necessary to apply this monthly correlations to obtain a value that approximates closer to reality, since due to the high summer temperatures and low winter is logical that the consumption of HWS decreases in the former case and increase in the second.

3.4. SOLAR MINIMUM PAYMENT CONTRIBUTIONS

The Minimum Solar contribution expresses the relation between the amount of energy obtained from the sun minimum required by CTE and total energy demand. Technical Building Code offers specific values for each region of Spain as a function of geographical area and DHW demand per day.

The town of Navarrevisca is located in the climatic zone IV and HWS demand amounts to total building 3.696 liters per day. Entering in the table we see that the technical code requires at least a 60% solar contribution of hot water, this value is an average of monthly values.

Besides the Technical Building Code (CTE) provides that the basic sizing of a facility, should be done in a way that meets the following restrictions:

• Not to exceed more than 100% DHW demand for 3 consecutive months.

• In any month of the year the energy produced by the solar installation could exceed 110% of the hot water demand.

4. Description of the sanitary hot water system.

The main purpose of the system is to provide of hot water to a residential building by using solar energy. We are able to understand with the help of the diagram shown in the following picture.

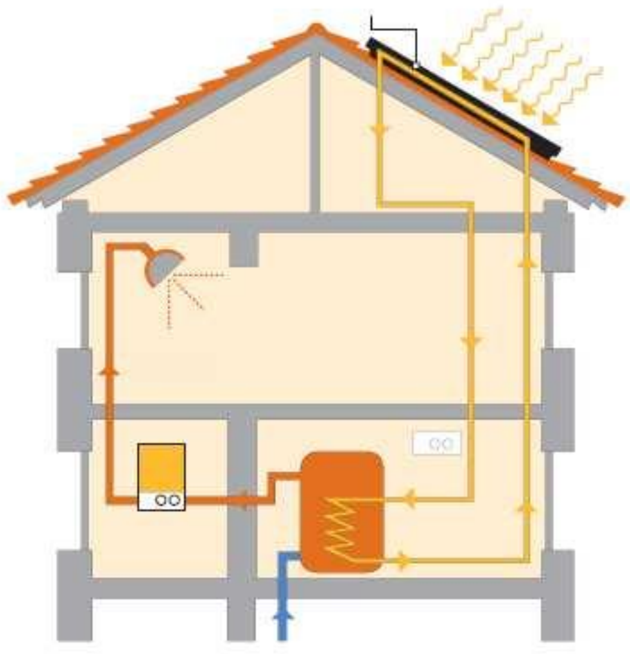


Figure 4: Sanitary Hot Water System Diagram.

With this diagram is possible understand the case of the project. Although this diagram does not represent the real one which is going to be installed, the main working process is the same than the real one. It is recommendable to have a look for the right comprehension of the process.

The current heating and domestic hot water systems of buildings serve to meet the demands of interior heating comfort and a supply of domestic hot water (DHW) that is suitable. In turn, they allow for a rational use of energy, for both financial and environmental reasons. The current respective regulations in force set forth the design and installation of efficient heating and DHW systems, as well as suitable maintenance that ensures that the systems and all their parts retain their initial performance and properties. Within this context, the installer of heating and domestic hot water systems is a professional specialised in the carrying out of different jobs related to the installation and maintenance of heating and DHW systems in buildings, those of industrial as well as domestic use.

First, the solar energy in form of radiation is absorbed by the solar panels and transferred to the heat-transfer fluid. Then, this heat-transfer fluid flows inside the firstly circuit pipes and the fluid yields it is energy in form of heat to the cold water storage in the accumulator, the heat-transmission is done across the interior coil pipe. The water will be used for the human consumption. The water is stored till it is need in some supply point. When the hot water is needed it leaves the accumulator and goes through the auxiliary natural gas boiler. Now, the control system measures the temperature of the accumulator exit water, and switch on the auxiliary boiler if the water temperature is not high enough, under 60 ^{o}C, or keep the auxiliary boiler off if the water temperature is right, 60 ^{o}C. Finally, the water flows inside the deliver pipes until the supply point.

4.1. DESCRIPTION IN DETAIL OF THE MAIN ELEMENTS

Now, once that the system's work process has been told, the main elements of the installation are going to be explained in detail.

4.1.1. Solar Panel, Flat Plate Collector

The type of solar panel selected for the project is a flat plane collector systems. Solar collectors gather the sun's energy, transform its radiation into heat, then, it transfers that heat to water, solar fluid, or air. The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. There are several types of solar collectors:

- Flat-plate collectors
    - Evacuated-tube collectors
    - Integral collector-storage systems Residential and commercial building applications that require temperatures below 200°F typically use flat-plate collectors, whereas those requiring temperatures higher than 200°F use evacuated-tube collectors." "Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector and then flows to the house. Solar pool heating also uses liquid flat-plate collector technology, but the collectors are typically

"Solar collectors are the key component of active solar-heating unglazed as in figure below."

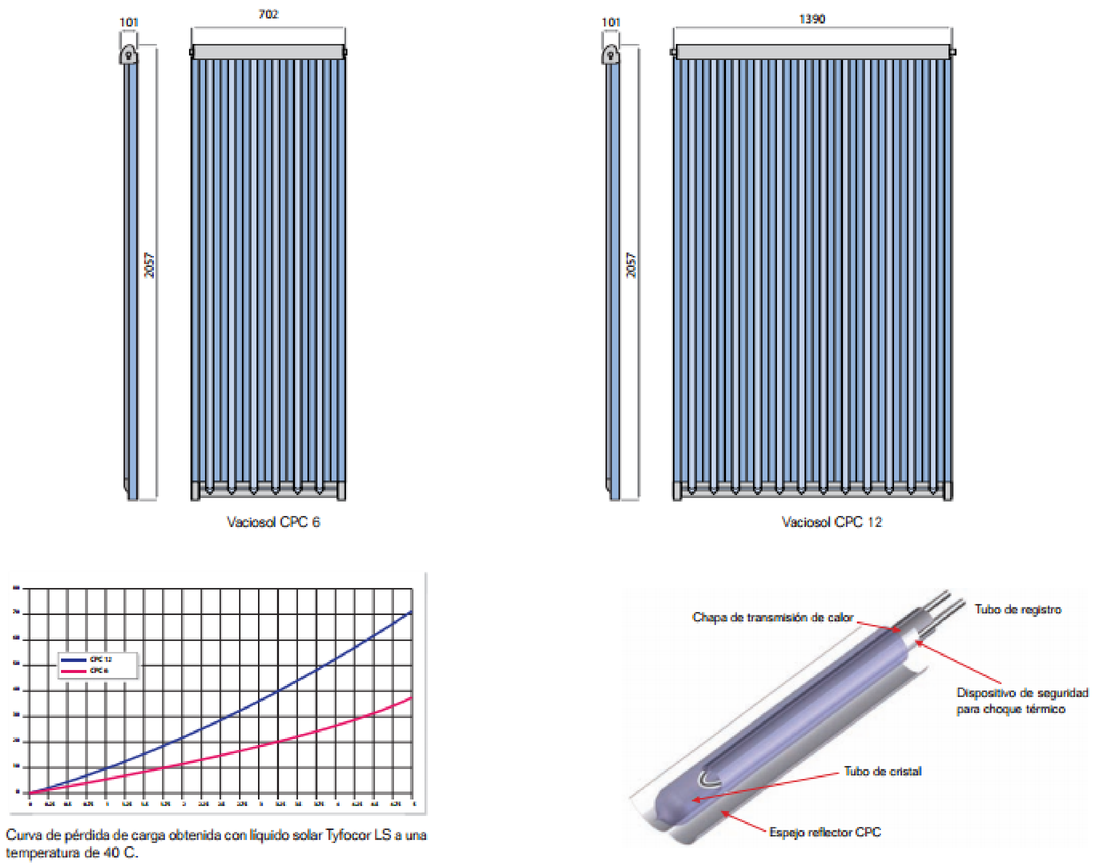


Figure 5:Solar Panel, Flat Plate Collector.

The flat plane collector selected for our project is BUDERUS V2 CPC 6 . For achieving the minimum coverage set by the CTE, the absorbent surface needed is 43,52 m^2 , equivalent to 34 solar panels.

Heating is the business for which solar energy is best suited. Solar heating requires almost no energy transformation, so it has a very high efficiency. Heat energy can be stored in a liquid, such as water, or in a packed bed. A packed bed is a container filled with small objects that can hold heat (such as stones) with air space between them. Heat energy is also often stored in phase-changer or heat-of-fusion units. These devices will utilize a chemical that changes phase from solid to liquid at a temperature that can be produced by the solar collector. The energy of the collector is used to change the chemical to its liquid phase, and is as a result stored in the chemical itself. It can be tapped later by allowing the chemical to revert to its solid form. Solar energy is frequently used in residential homes to heat water. This is an easy application, as the desired end result (hot water) is the storage facility. A hot water tank is filled with hot water during the day, and drained as needed. This application is a very simple adjustment from the normal fossil fuel water heaters.The heat-transfer fluid used in this project is Tyfocor L, from Tyfo.

4.1.2. Heat-Transfer Fluid.

Heat-transfer fluids carry heat through solar collectors and a heat exchanger to the heat storage tanks in solar water heating systems. When selecting a heat-transfer fluid, you and your solar heating contractor should consider the following criteria:

- Coefficient of expansion – the fractional change in length (or sometimes in volume, when specified) of a material for a unit change in temperature
- Viscosity – resistance of a liquid to sheer forces (and hence to flow)
- Thermal capacity – the ability of matter to store heat
- Freezing point – the temperature below which a liquid turns into a solid
- Boiling point – the temperature at which a liquid boils
- Flash point – the lowest temperature at which the vapor above a liquid can be ignited in air.

For example, in a cold climate, solar water heating systems require fluids with low freezing points. Fluids exposed to high temperatures, as in a desert climate, should have a high boiling point. Viscosity and thermal capacity determine the amount of pumping energy required. A fluid with low viscosity and high specific heat is easier to pump, because it is less resistant to flow and transfers more heat. Other properties that help determine the effectiveness of a fluid are its corrosiveness and stability.

4.1.3. Accumulator.

Just like the other renewable sources, solar energy is not constantly available. As a consequence, accumulation systems are extremely important for the evolution and development of technologies.
The energy produced by thermo-solar plants does not have to be limited to sunny hours nor have to be hampered by clouds. For this reason, two techniques have been tested. They also allow a better use of the installation and therefore a lower cost for the production of electric energy:

- Accumulation of thermal energy: the heat is used to warm a medium from which, on a specific moment, heat is extracted to produce electric energy. These devices are quite cheap, highly efficient and allow to keep the installation working during peak periods and night hours. They also have the advantage to eliminate, in many cases, fluctuations due to clouds.

The accumulator selected for this project is Vitocell 100V 1.100 liters, of the Viessmann Company. It would be installed three of these accumulators, because the storage volume needed is 3.080 liters.

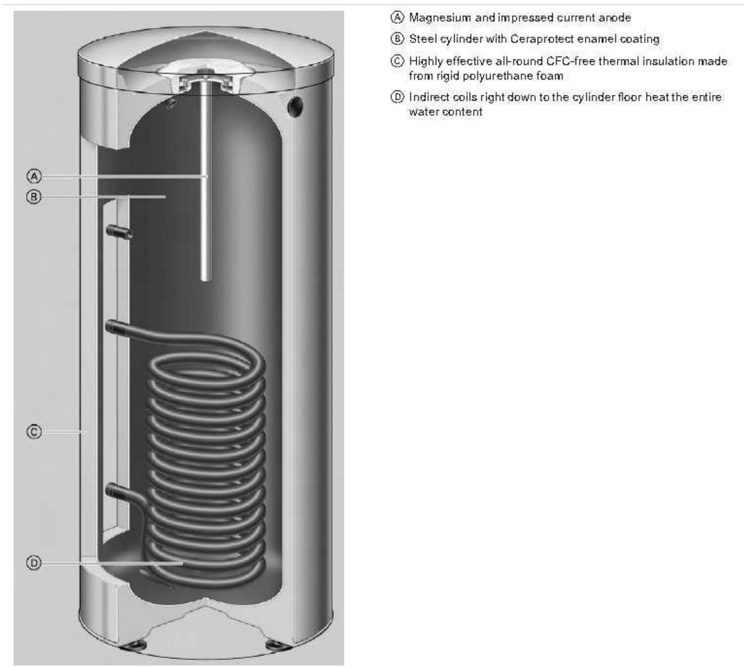


Figure 6 : Viessmann, Vitocell 100V Design and Structure.

4.1.4. Auxiliary Natural Gas Boiler

"A boiler is a device for generating steam for power, processing, or heating purposes or for producing hot water for heating purposes or hot water supply. Heat from an external combustion source is transmitted to a fluid contained within the tubes in the boiler shell. This fluid is delivered to an end-use at a desired pressure, temperature, and quality."

The purpose of the auxiliary gas boiler is to heat the water when the solar energy is not enough to heat it till the demand temperature.

It should be considered the next: first one is the power of the boiler. We select the power according to the heat energy demand predicted, more powerful is the boiler as bigger the installation. The efficiency is the second characteristic wich will determine the fuel consumption that depends on the heat demand. It is include the thermal insulation in order to do not have loses of heat, and good heat transfer fuel-water. Finally, it is important to consider not only its prices also the availability in the region of fuel used. The most common fuels for gas boilers are natural gas, propane gas (GLP), kerosene, coal and electricity.

The auxiliary gas boiler selected for our project is Vitogas 200F, of the Viessmann Company. This model works with natural gas and its power is from 10 KW to 70 KW, in our installation it only will work until 29 KW. The design, the structure and the components can be seen in the following picture.

Installation

For the best performance, always follow the manufacturer's installation recommendations for the heat exchanger. Be sure to choose a heat-transfer fluid that is compatible with the type of heat exchanger you will be using. If you want to build your own heat exchanger, be aware that using different metals in heat exchanger construction may cause corrosion. Also, because dissimilar metals have different thermal expansion and contraction characteristics, leaks or cracks may develop. Either of these conditions may reduce the life span of your heat exchanger.

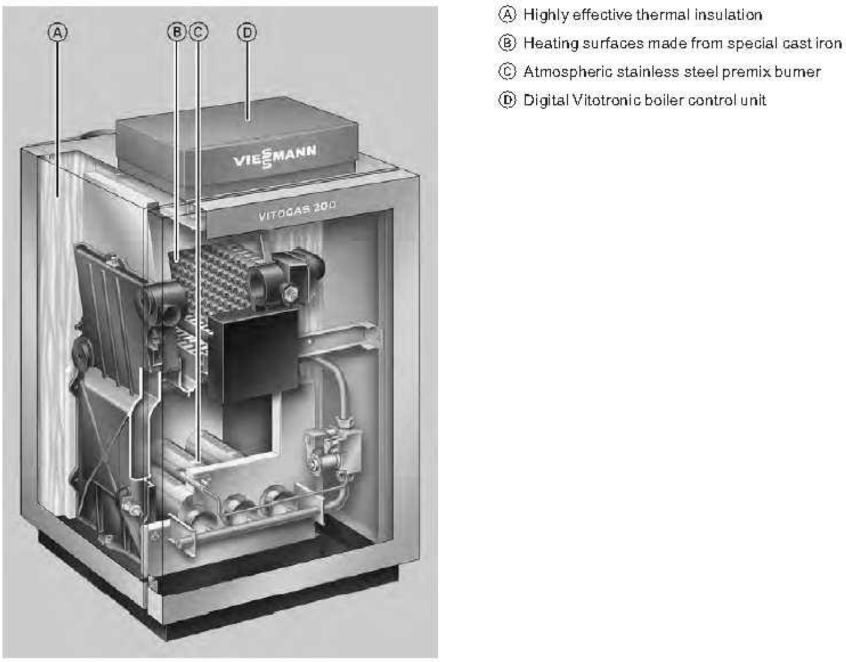


Figure 7: Viessmann, Vitogas 200F Design and Structure.

4.2. THERMAL LOADS.

We proceed to the calculation of the thermal needs of the group of buildings to achieve a comfortable environment to carry out everyday tasks confronting the residents of such housing. This calculation is performed by making a profit and loss balance of heat in the building. They need to know the interior conditions of design, external conditions and characteristics of the building envelope.

Due to the large size of the houses, to the meteorological variables in the area and the limitations of space for collectors, unheated and unheated unviable every room of the chalets.

For this reason, we have chosen to provide air conditioning and heating only the rooms of the house, because it is these common areas and be the rooms that will have higher occupancy expected throughout the day, thus providing more comfort to the maximum number people as possible.

4.2.1. THERMAL LOADS HEATING

The heating system is designed to keep homes at a suitable temperature in those months in which the outside temperature and therefore the interior drops below the limits of comfort.

The heat load of heating is calculated taking into account the losses of the rooms, by driving through all the walls (floors, walls, doors ...) and those lost due both air infiltration, as derived from the ventilation needs.

It is estimated that it will be necessary unheated during the months of November, December, January, February and March, as these months those with lower temperature throughout the year.

It is important to note at this point that the heat load of heating is calculated for the most unfavorable conditions possible, because in this way you can ensure the proper functioning of the facility for any condition outside environment.

5. Conditions of design.

For the calculation of thermal loads are taken initial conditions of the Rules of building heating in buildings (RITE). In the table you can see the values for winter and summer. In this project be used as indoor dry temperature 21ºC and as relative humidity 40%.

Station	Operating Temperature [°C]	Relative humidity [%]
Summer	23 ... 25	45 ... 60
Winter	21 ... 23	40 ... 50

Table 2: Optimal conditions of design.

To estimate the external conditions in winter require to know basically two variables: dry temperature and relative humidity.

For these variables we can use as a basis the average data obtained from experimental data collected in instant weather station.

Number of rooms	1	2	3	4	5	6	7	>7
Number of persons	1,5	3	4	6	7	8	9	Number of rooms

Table 3: Relationship between number of rooms and number of persons, per house.

The irradiation zone where the building is placed is Zone IV, according to the demand per day. CTE sets the minimum solar coverage in the following table:

Tabla 2.1. Contribución solar mínima en %. Caso general

Demanda total de ACS del edificio (l/d)	Zona climática I	II	III	IV	V
50-5.000	30	30	50	60	70
5.000-6.000	30	30	55	65	70
6.000-7.000	30	35	61	70	70
7.000-8.000	30	45	63	70	70
8.000-9.000	30	52	65	70	70
9.000-10.000	30	55	70	70	70
10.000-12.500	30	65	70	70	70
12.500-15.000	30	70	70	70	70
15.000-17.500	35	70	70	70	70
17.500-20.000	45	70	70	70	70
> 20.000	52	70	70	70	70

Table 4: Relationship Minimun Solar Coverage.

The minimum allowed coverage for this project is 60%. It means that the 60% of the total hot water demand per year has to be heated by solar energy. Solar system provides the energy used to heat up water. The real coverage will be calculated with the f-chart method. After, this real coverage will be compared with the minimum one, and the real has to be greater than the minimum in order to compliance the regulation.

6. Calcutations.

''HOT WATER PRODUCTION OF SOLAR ENERGY THROUGH CTE DB-HE-4''

Catchment area calculations for the production of sanitary hot water, in order to meet marked contribution by the solar fraction minimum established in CTE.

DATA CONSUMPTION CHARACTERISTICS.

The building typology is single-family homes.The building has 20 homes with 5 bedrooms, for which the CTE provides 7 people per household. With what we find a number of 140 people.

With an expected consumption of 22 liters per person. The intended use temperature is 60 ° C.

Total consumption = 3080 liters per day.

GEOGRAPHIC DATA	
Province:	*AVILA*
Calculation Latitude:	*41 º*
Climate Zone:	*IV*

The utilization rates throughout the year are planned, we supposed total occupancy during all months because those are unifamiliar buildings for leave:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
%Occupancy	100	100	100	100	100	100	100	100	100	100	100	100

CALCULATION OF ENERGY DEMAND

ENERGY CALCULATION												
	Ene	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days per month	31	28	31	30	31	30	31	31	30	31	30	31
Water consumption [l / day]	3080	3080	3080	3080	3080	3080	3080	3080	3080	3080	3080	3080
T ª. midwater network [°C]	4	5	7	9	10	11	12	11	10	9	7	4
Ta increase [°C]	56	55	53	51	50	49	48	49	50	51	53	56
Ener. Deman. [KWh]	6.202	5.502	5.870	5.466	5.538	5.252	5.316	5.427	5.359	5.649	5.681	6.202

Total annual energy demand: 67.465 KWh

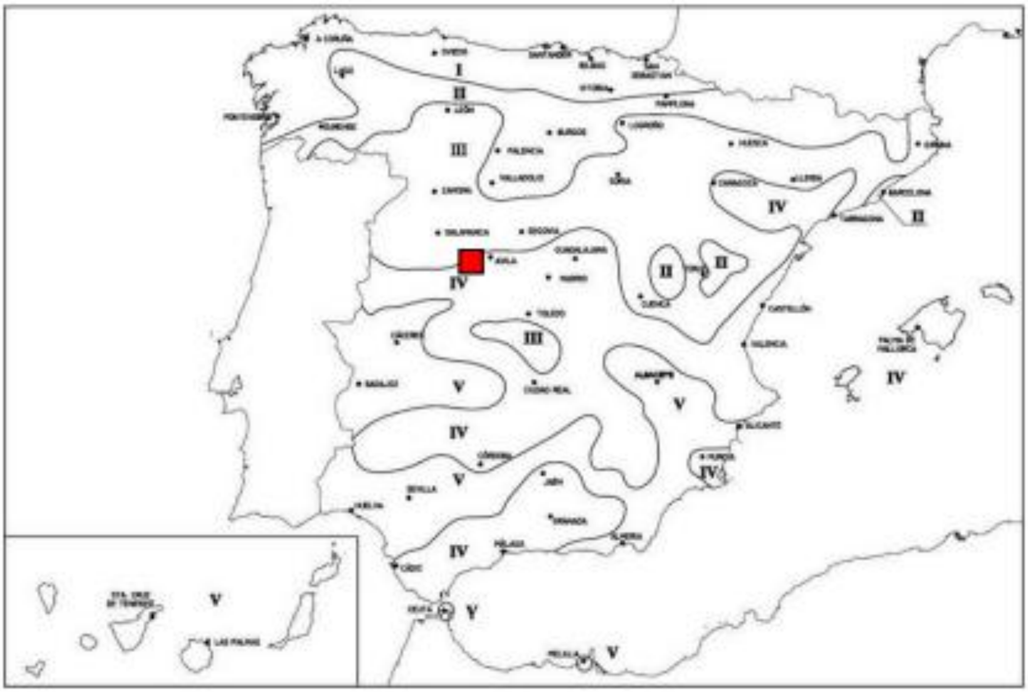


Figure 8 : Irradiation Zone Map of Spain.

SELECTED DATA COLLECTOR		optical efficiency factor	0.644
Model	BUDERUS V2 CPC 6	overall loss coefficient	0.749 W / (m · ° C)
Dimensions:	0,702 m x 2,06 m.	Useful Area	1.28 m².

34 solar panels with a useful area of 43.52 m2 catchment. ACS accumulation volume of 3080 L

Position Data	
Tilt:	35 º
Disorientation to the south:	10 °

General case Losses	
Tilt losses. (optimum 40 °)	-0.26%
Losses disorientation South:	0.35%
Losses shadows	5%

It is calculated the losses for south orientation through the next formula:

$$\text{Losses disorientation South} = 3.5 * 10^{-5} * a^2$$

A calculation is made of the value of losses inclination sensor, different from the optimal (latitude 40 °) from an average weighted tilt loss values compared with the optimum orientation. The inclination data loss on a horizontal surface are taken from the tables of specifications and technical conditions of Low Temperature Facilities IDEA. Contain data in intervals of 5 °, therefore we calculated losses based on the increase.

Considered in the calculation constants	
Correction factor gauge-exchanger assembly	0.95
Incidence angle modifier	1.15
ACS mímima Temperature	45

ENERGY CALCULATION BY THE METHOD F-CHART

	Ene	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rad. horiz. [kWh/m2 · month]:	51,77	70,84	116,25	147,6	167,1	185,7	226,6	217,9	156,6	96,41	57,6	44,64
Coef. K. incl [35 °] lat [41 °]	1,38	1,29	1,18	1,07	0,99	0,96	0,99	1,08	1,22	1,38	1,49	1,47
Rad. inclin. [kWh/m2·mes]	67,63	86,51	129,86	149,5	156,6	168,77	212,38	222,8	180,9	125,95	81,25	62,12
Deman. Ener. [KWh]	6.202	5.502	5.870	5.466	5.538	5.252	5.316	5.427	5.359	5.649	5.681	6.202
Ener. Ac. Cap. [KWh / month]	2.071	2.649	3.976	4.578	4.795	5.167	6.503	6.822	5.538	5.857	2.488	1.902
D1 = EA / DE	0,33	0,48	0,68	0,84	0,87	0,98	1,22	1,26	1,03	0,68	0,44	0,31
K1	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01	1,01
K2	0,77	0,79	0,83	0,86	0,86	0,83	0,81	0,76	0,79	0,83	0,83	0,75
Ener. Per. Cap. [KWh / month]	1.765	1.627	1.819	1.777	1.764	1.584	1.511	1.420	1.497	1.728	1.760	1.711
D2 = EP / DE	0,28	0,30	0,31	0,33	0,32	0,30	0,28	0,26	0,28	0,31	0,31	0,28
f	0,30	0,42	0,57	0,68	0,70	0,78	0,91	0,93	0,81	0,58	0,39	0,28
EU=f*DE	1.853	2.322	3.354	3.726	3.880	4.077	4.854	5.059	4.327	3.251	2.190	1.708

Total annual useful energy production: 40.601 kWh

7. Results.

RESULTS OBTAINED	
Total annual energy demand:	67.465 KWh
Total annual useful energy produccién:	40.601 KWh
Annual F Factor made of:	60%

SITUATION OF CTE	
Climate zone type:	IV
Backup power system type:	General: diesel, propane, natural gas, or other
Solar Contribution Low:	60%

MEET THE DEMANDS OF CTE

Regarding CTE DEMANDS OF limit losses or tilt orientation			
	Orien. and incl.	Shadow.	total
Loss allowed in CTE. General Case	10%	10%	15%
Loss on the project:	0.09%	5.00%	5.09%

MEET THE DEMANDS OF CTE

ENERGY CALCULATION

	Ene	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ener. Deman. [KWh / month]	6.202	5.502	5.870	5.466	5.538	5.252	5.316	5.427	5.359	5.649	5.681	6.202
Ener. Useful cap. [KWh / month]	1.853	2.322	3.354	3.726	3.880	4.077	4.854	5.059	4.327	3.521	2.190	1.708
% ENERGY PROVIDED	30%	42%	57%	68%	70%	78%	91%	93%	81%	58%	39%	28%

The condition of CTE, there is no month to occur more than 110% of the energy demand.

The condition of CTE, there are 3 consecutive months to occur more than 100% of the energy demand.

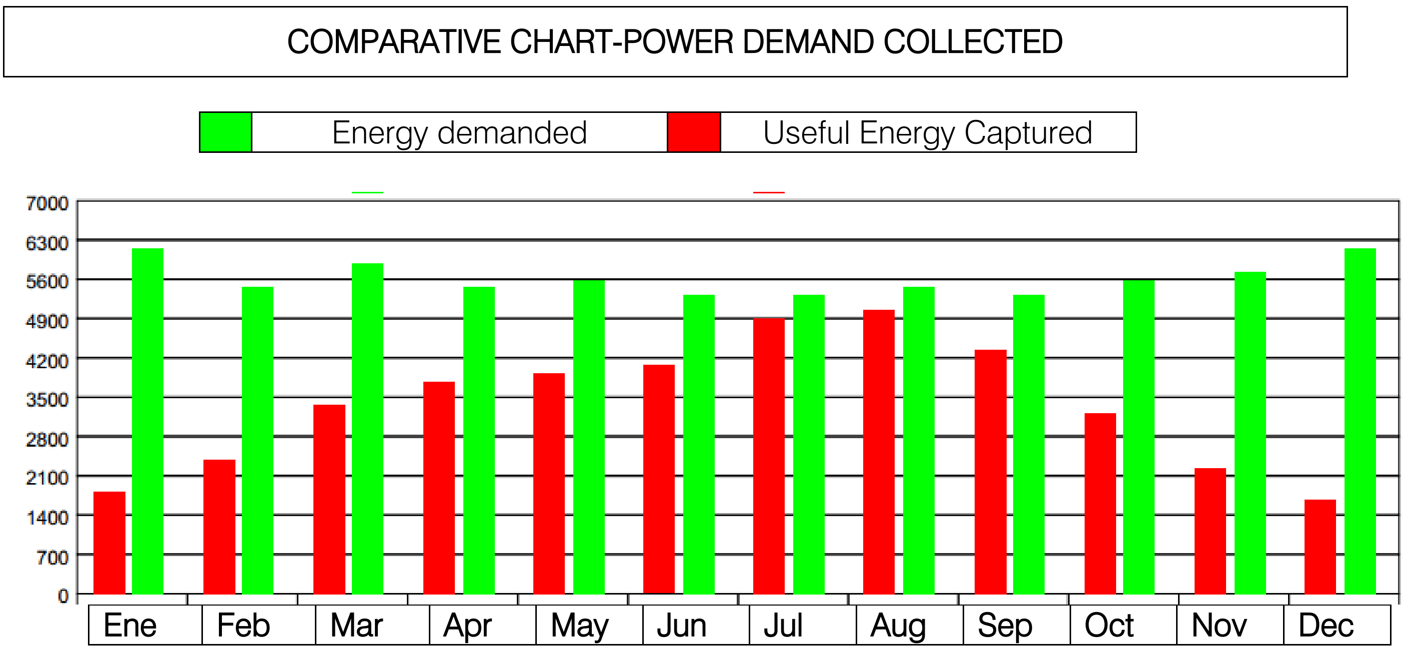


Figure 9: COMPARATIVE CHART-POWER DEMAND COLLECTED

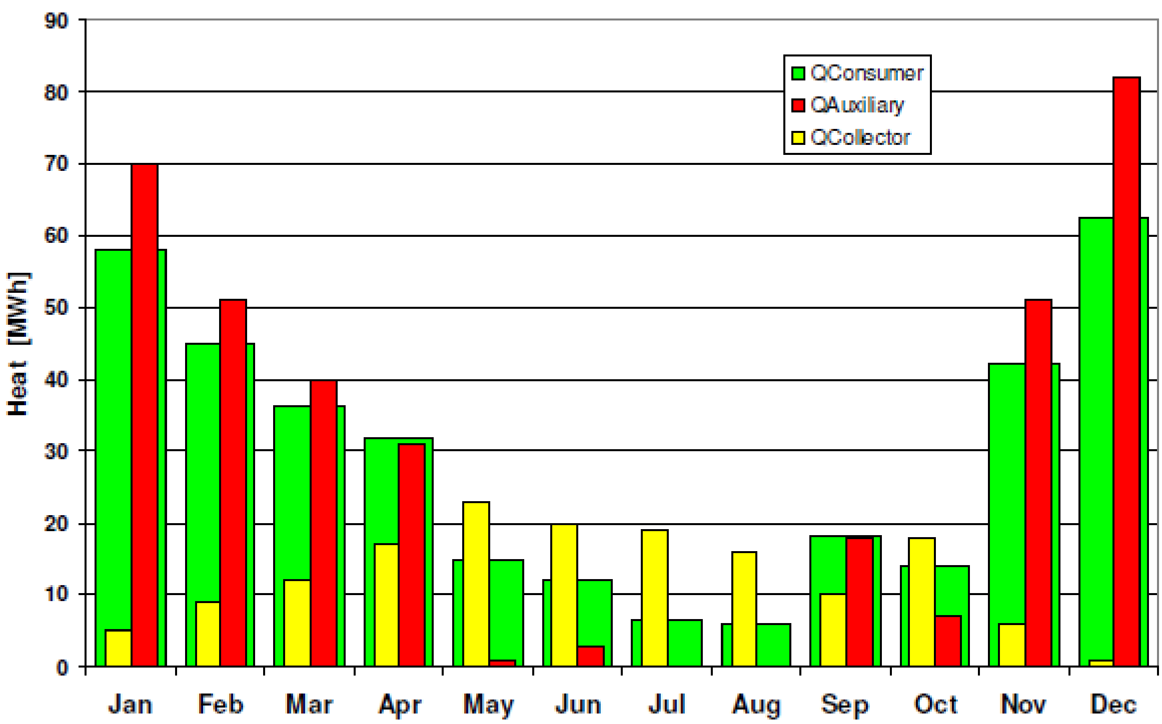
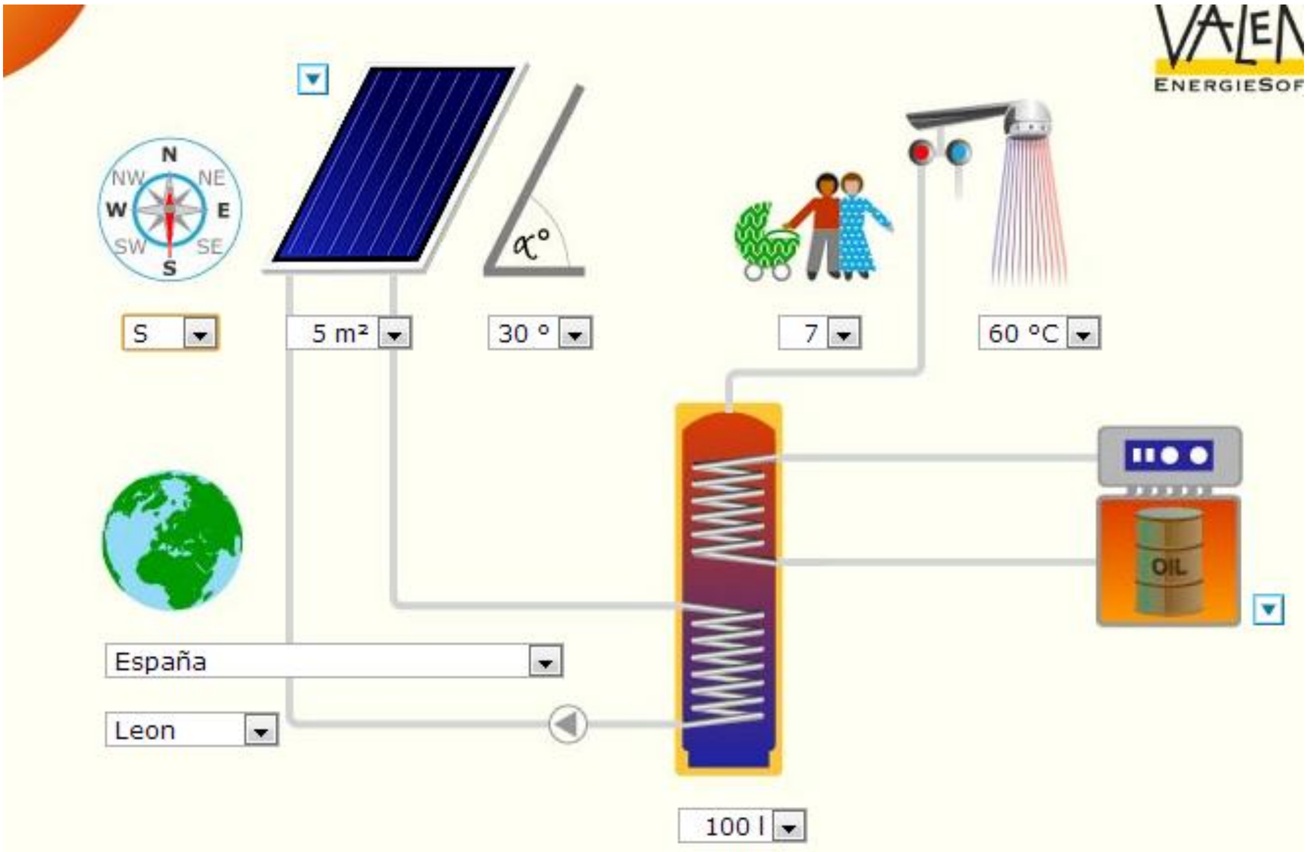


Figure 10: Heat balance 2013 for our project Ávila, Spain.

8.Calculation method.

8.1. ENERGY DEMAND



The water demanded should be heated up till the accumulation temperature, also called demand temperature, this temperature is 60 ºC. The energy needed to increase the water temperature depends on the amount of water and the difference of temperatures between the inlet and the outlet.

The outlet temperature is the demand temperature which has already been fixed and is constant during all the months of the year, 60 ºC. And the inlet temperature is the temperature of the cold water System of Ávila measures in ºC, this temperature varies along the month of the year being lower in winter months and hotter in summer months. The monthly values for the cold water system are obtained from the CTE PC page 50.

Then, the energy demand per month and the power demand per month can be obtained with the next expressions. They are measure in MJ/month and MWh/month, respectively.

$$EDm\left[\frac{MJ}{month}\right] = \frac{HWDm \cdot \rho_{H2O} \cdot (T_{Demand} \cdot T_{CWS}) \cdot c_{p\,H2O}}{1000}$$

$$PDm\left[\frac{MWh}{month}\right] = \frac{EDm}{3600}$$

$\rho H2O$ = Density of water = 0,994 Kg/l

Cp H2O = Specific heat capacity of water = 4,184 KJ/Kg·ºC

Also we calculate the power demand per year and energy demand per year adding those of every month.

These are the total demand of energy and power per year, but the coverage is only the 55% of this amount of energy.

8.2. SOLAR ENERGY

Solar cells do not utilise chemical reactions to produce electric power. They convert sunlight energy into electric current. They do not store energy.
The cell voltage is proportional to the amount of sunlight falling on the cell but is generally less than 0.5 Volts.
The sun's energy reaching the surface of the earth is roughly 1 kilowatt per square metre.
Solar cell conversion efficiencies have improved in recent years to between 20% and 30% but they still only generate 150 W/m^2 in bright sunlight. A reasonable maximum size of a solar array in a typical car would be 3 m^2. In the best case, in bright sunlight, this would generate only 0.5 kW (less than 1 bhp) of power which is not enough to drive a road vehicle or even to charge a reasonable sized battery.
The system works with solar energy, we should quantified this energy for determinate the size of the installation. The more energy absorbed per surface unit, the less surface necessary for obtaining the same amount of energy.

Radiation is the incident solar energy in the absorbent surface of the flat plate collector. Radiation per day can be taken from climatologic stations, the radiation that this stations measure is per day and in horizontal plane. The radiation varies with the inclination of the incident surface, being the maximum when the radiation is perpendicular to the incident surface and is calculated multiplying the horizontal radiation by a correction factor .Correction factors vary along the months of the year because the sun inclination also varies. The value of the horizontal plane radiation in different cities, Ávila in this project, can be obtained from the CTE PC page 100. And the corrections factors for inclined surfaces are also register in the CTE PC pages 102 - 108, depending on the latitude.

It is possible to install the solar panels in horizontal position, but it is not the best option because their efficiency increases when the radiation is perpendicular. The optimal inclination is the value of the latitude of the place, like the CTE suggest that. In our project the inclination is 35º.

The solar energy cross the glass cover of the flat plate collector, producing energy losses. Correction factor is the percentage of energy that the glass cover lets go inside the collector due to the optical performance of the collector. The correction factor is 0.95.

$$G\left[\frac{W}{m^2}\right] = \frac{R_{day}(45^{o}) \cdot 10^{6}\,[J/MJ]}{hd \cdot 60[\min/hour] \cdot 60[seg/\min]}$$

It can be seen that the average radiation increases slightly when the surface is inclined 35º.

8.2.1. Absorbent area and number of collectors

In areas where freezing is a possibility, freeze-tolerance (the capability to freeze repeatedly without cracking) can be achieved by the use of flexible polymers. Silicone rubber pipes have been used for this purpose in UK since 1999. Conventional metal collectors are vulnerable to damage from freezing, so if they are water filled they must be carefully plumbed so they completely drain using gravity before freezing is expected, so that they do not crack. Many metal collectors are installed as part of a sealed heat exchanger system. Rather than having potable water flow directly through the collectors, a mixture of water and antifreeze such as propylene glycol is used. A heat exchange fluid protects against freeze damage down to a locally determined risk temperature that depends on the proportion of propylene glycol in the mixture. The use of glycol lowers the water's heat carrying capacity marginally, while the addition of an extra heat exchanger may lower system performance at low light levels.

Collector and accumulator are very important elements in all solar systems. We should calculate together because the size of the accumulator depends on the collector's size and the size of the collector depends on the efficiency of both.

Solar panel installed BUDERUS V2 CPC 6, of Viessmann Company, it is a flat plate collector. Flat plate collectors have been selected because they work very well in water heater system, today most of the systems use this kind of solar collector.

The collector's efficiency depends on three climatologic variables, cold water system temperature and environment temperature in ^{o}C. Also it is good to know that we do not have 100% efficiency due to several losses in the system, especially on the solar collector.

8.3. NUMBER OF COLLECTORS AND ACCUMULATORS.

Accumulator is also important because is the place where the water is storage. The energy losses in this element are quite difficult to calculate, because they depend on directly on the time the water is storage. This time is almost impossible to know certainly, so the losses have to be assumed. In this project the efficiency of the accumulator will be assumed as 85%.

Once the collector's efficiency and accumulator's efficiency have been obtained, the supplied energy per month (ESm), and the supplied energy per year (ESy) can be calculated. The expressions used to calculate the supplied energies per month and per year are the next ones respectively.

$$\eta_{coll} = \eta_o - k_1 \cdot \frac{T_m - T_e}{G} - k_2 \cdot G \cdot \left(\frac{T_m - T_e}{G} \right)^2$$

Being:

η_o = Optical efficiency of the collector = 0,84

k_1 = Lineal thermal loss correction value = 3,86 W/($m^2 \cdot K$)

k_2 = Square thermal loss correction value = 0,0139 W/($m^2 \cdot K^2$)

T_m [ºC] = Medium temperature of the collector = (T_{out}-T_{in})/2

T_{out} = Outlet water temperature from the collector = 60 ºC

T_{in} [ºC] = Inlet water to the collector = T_{CWS}

The efficiencies of both elements and the supplied energy are shown in the following table. It can be seen that the collector's efficiency has a wide range of work, with a difference of almost 30% between the minimum and the maximum. Although the minimum is 50%, the average efficiency is 66,94%, quite high value, a bit more of two thirds. The minimum efficiency is in January, and it coincidence with the minimum irradiation and with the maximum difference between working and environment temperatures. For against, the maximum efficiency is in August when the irradiation is the maximal and the difference of temperatures is the minimal.

The number of collectors has to be a full number, so the result is round to a greater one, in our case 34 solar panels. In the f-chart method, the real absorbent area (A_{abs}) is used for calculating, and it is obtained multiplying the number of panels by the absorbent area of one.

Now, the size of the solar panels is determined. If the f-chart result sentence that the solar coverage is lower than the minimum set by CTE, the change to improve this result, will be increase the absorbent area

8.3.1. Accumulation volume and number of accumulators

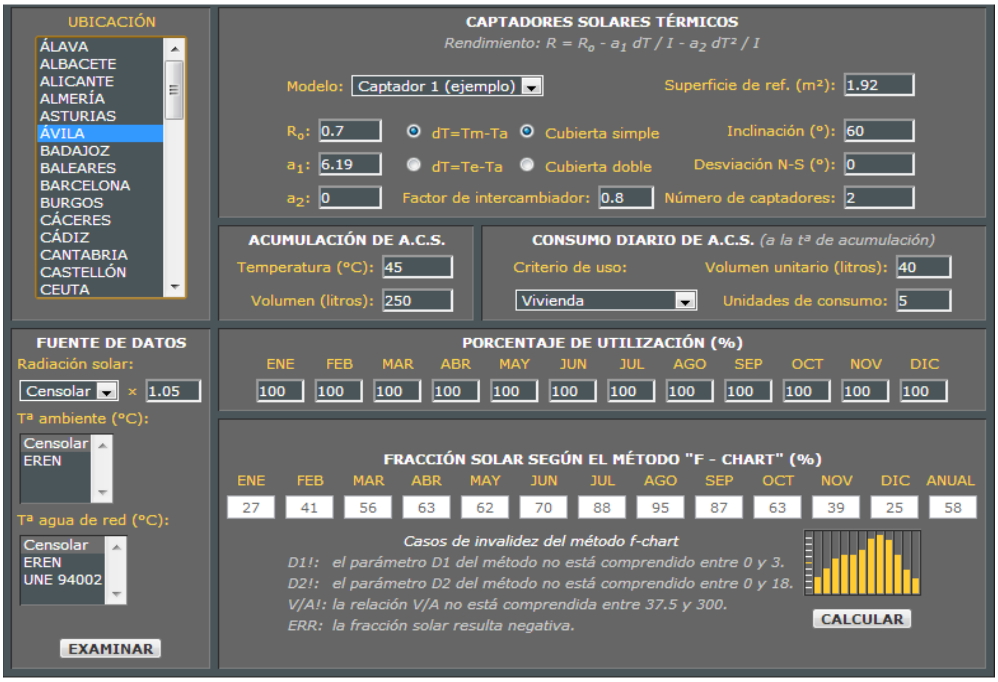
The total accumulation volume also depends on the total absorbent area. This relationship is fixed by the regulation, CTE, and it can be gotten in the page CTE HE 4- 12, $50 < V_{accu} / A_{abs} < 180$.

The selected one for this project is 90, due to the building is not very big and with the accumulation volume gotten will be enough to satisfier the necessities of residents. After, this volume has to be converted in the equivalent number of accumulators. The model of the accumulator selected, Vitocell 100V, has capacity for 1000 liters. The process to calculate them is similar to the one for the collectors. As this accumulation volume depends on the absorbent surface, if the absorbent surface changes because the f-char result is not correct, the accumulation volume will change.

8.4. F-CHART CALCULATION.

The way of calculating by this method is just follow the equations step by step. On internet we are able to see several softwares for calculate these monthly fractions.

We can see the next picture software of censolar.com:



The f- chart result is obtained with the next expression.

Where D1 and D2 are two dimensionless parameters of calculation and can be obtained with these expressions.

$$f = 1{,}029*D1 - 0{,}065*D2 - 0{,}245*D1^2 + 0{,}0018*D2^2 + 0{,}0215*D1^3$$

Where D1 and D2 are two dimensionless parameters of calculation and can be obtained with these expressions.

$$D1 = \frac{Absorbed\ energy\ by\ the\ captator\ per\ month\ (\frac{MJ}{month})}{Energy\ demand\ per\ month\ (\frac{MJ}{month})}$$

$$D2 = \frac{Lost\ energy\ in\ the\ captator\ per\ month\ (\frac{MJ}{month})}{Energy\ demand\ per\ month\ (\frac{MJ}{month})}$$

8.5. AUXILIARY NATURAL GAS BOILER POWER.

Finally, the last element that has to be dimensioned is the auxiliary boiler.

The power of the auxiliary boiler has to be calculated as if it was the only energy source of the building. It is the same than say that it has to be calculated with the energy demand (ED), and not with the part of the energy that is not covered with solar energy. The reason of that is because the auxiliary boiler needs to have power enough to cover the whole demand if the solar system breaks down.

In order to get a suitable power, neither very big nor small, it is assumed that the whole demand of energy per day becomes exhausted during twelve hours in a uniform way. The chosen time for calculating is only twelve hours because there are a lot time when there is not hot water consume, for example during the night.

With this the minimum boiler power per day is obtained for each month, and the selected one has to be maximum of all of them.

9. Analysis of results.

Here the final numbers of the project are going to be obtained and analysed. First a short summary of the energies and efficiencies of the system is going to be explain. After the energy, fuel and money saves. Later analysis of reduction of CO_2 emissions. The initial investment of the installation will be calculated too. And finally the payback period of the project.

9.1. SUMMARY OF THE FORMS OF ENERGY AND EFFICIENCIES OF THE SYSTEM

In the next graph we can see the comparation of those two parameters, collector efficiency and solar coverage. The energies that it is interesting to compare are the irradiation received, the energy demand and the solar energy produced.

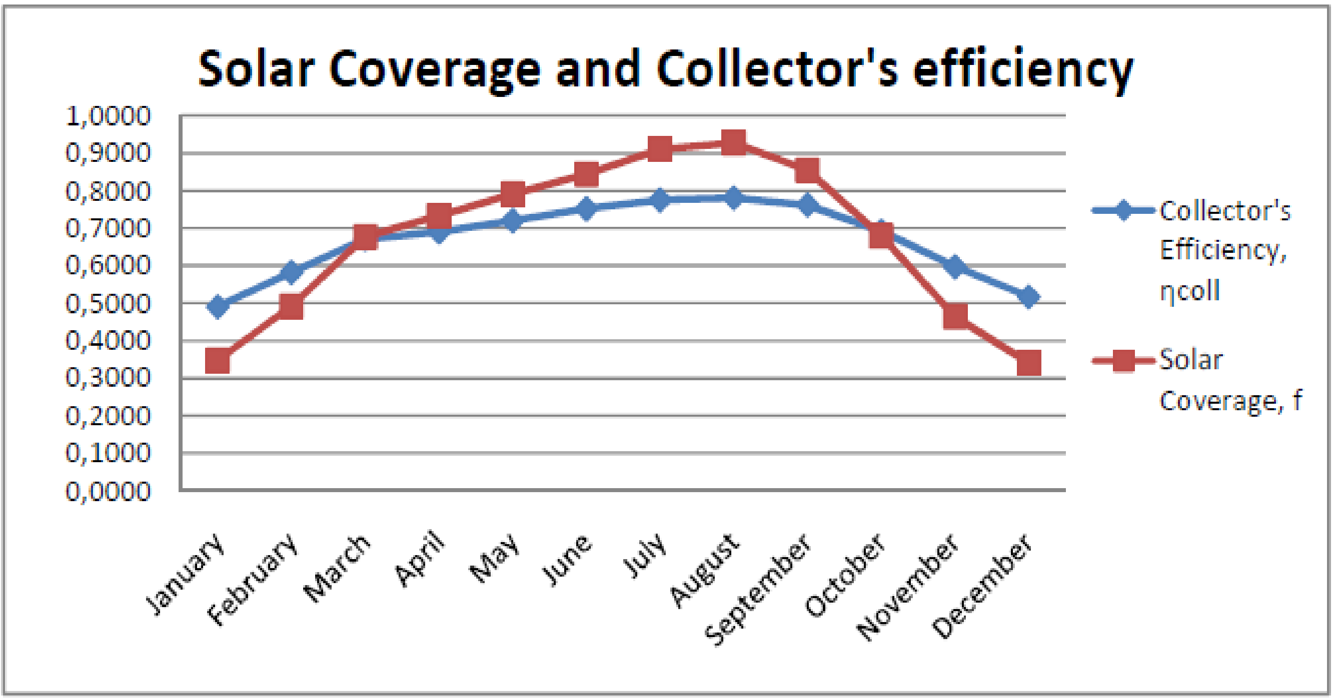


Figure 11 : Solar Coverage and Collector's efficiency..

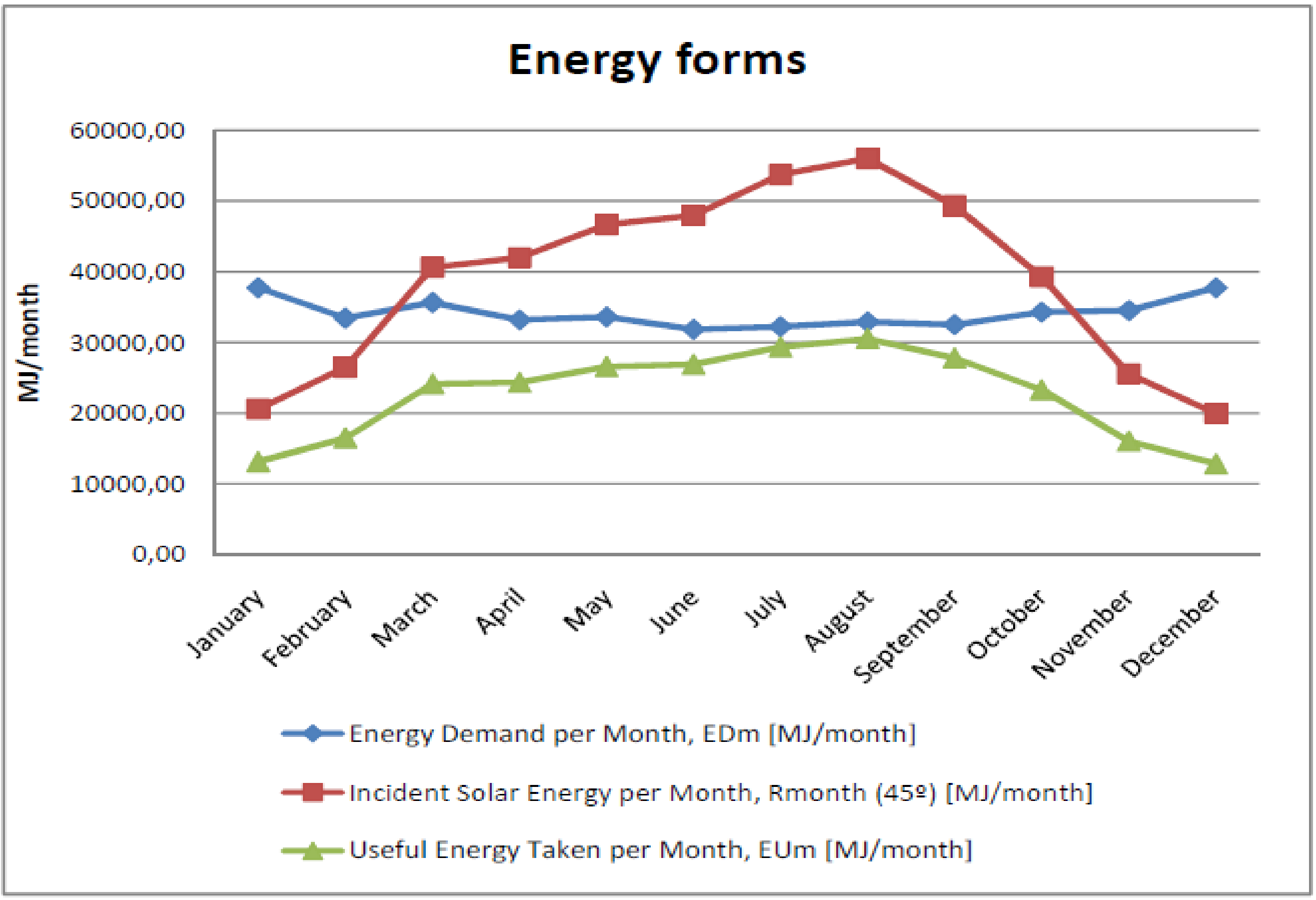


Figure 12 : Energy forms.

The incident solar energy per month is superior to the energy demand during the eight middle months of the year. The energy demand remains constant, the small variation that it has is due to months have different days. And the higher the incident energy is, the higher solar coverage is, and the higher the useful energy taken is. When incident solar energy is lower than demand energy, the solar coverage and the useful energy taken have very low values.

The solar coverage has is similar to the incident energy. The solar coverage will also be increased if it was found some method for increasing the solar irradiation,

The solar coverage during July, August and September is close to 90%, and more than 75% in May and June. Then it can be predicted that the fuel cost are and the energy consumption going to be very small.

9.2. ENERGY, FUEL AND MONEY SAVES.

Alternative fuels that can help to reduce vehicle emissions are available now, with more on the horizon. But their contribution to reducing carbon dioxide can vary widely - we explain the issues.

In summary:

- Biodiesel can be used at a 5% blend in existing diesel engines with no need for modification, but using higher blends could affect your vehicle warranty.
- Bioethanol is produced by the fermentation of starch, sugar and cellulose plants; a 5% blend in petrol can be used in existing petrol vehicles with no modifications.
- Biogas is produced when organic materials are broken down by a microbiological activity to produce methane.
- Liquefied petroleum gas (LPG) is suitable for smaller vehicles such as cars and light vans that have high mileage or operate predominantly in city centres.
- Hydrogen is currently only used in prototype vehicles. It may be used as a fuel in a modified petrol engine or indirectly to power a fuel cell in an electric vehicle.
- Natural gas is an option for goods vehicles with depot-based refuelling sites.

To calculate the saves, have been done calculations of the fuel volume necessary to obtain this energy, the auxiliary boiler energy and the money that costs this fuel without solar system. Energy demand is covered by the natural gas boiler. Energy covered by fuel is the part that the solar system can not supply.

These three variables are directly dependent, so the evolution along the year is the same for all of them. And the relation between the two calculations is also the same for the three parameters. Then, it is enough represent only one, auxiliary boiler energy for example, and shown the numerical results of the three.

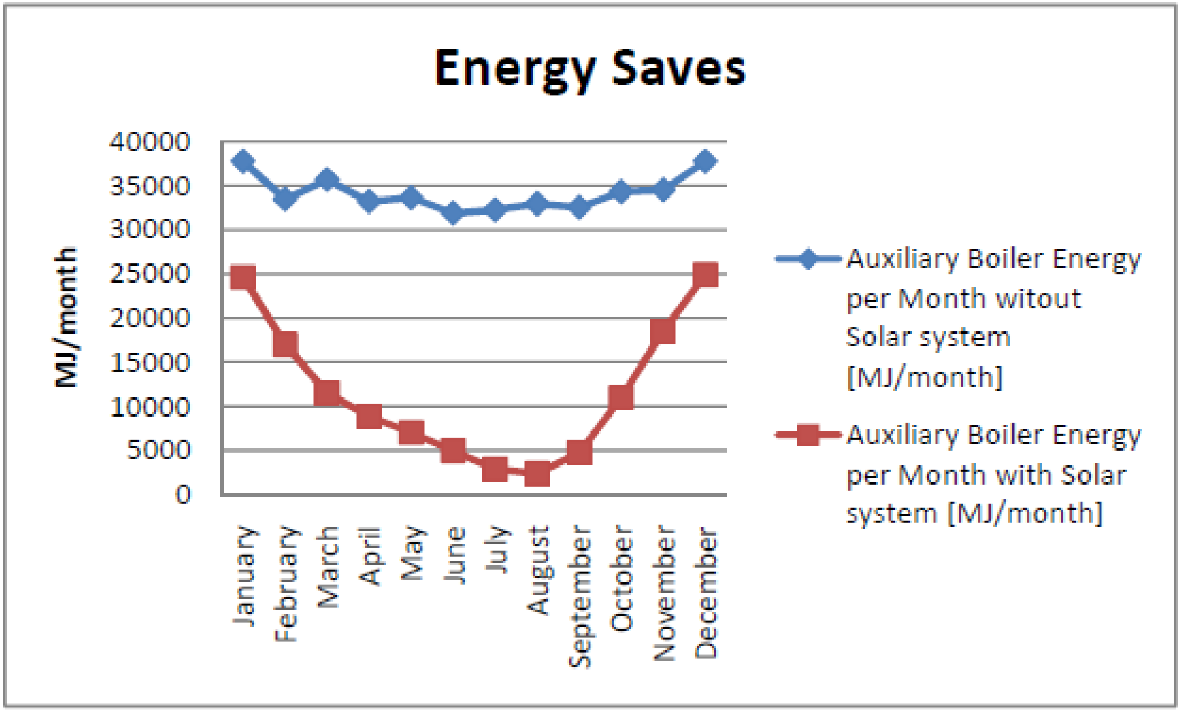


Figure 13 : Auxiliary boiler demand without and with Solar system.

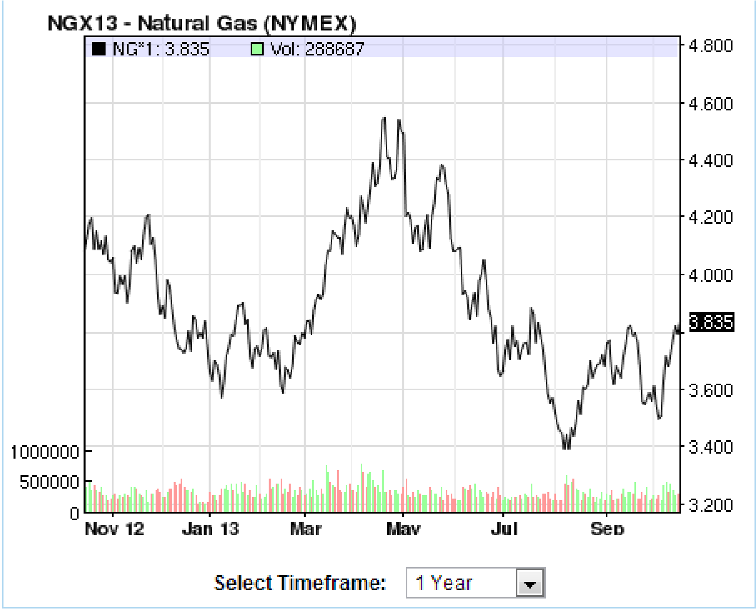
ANEXO

Precios de la tarifa de suministro de último recurso de gas natural

	Nivel de consumo de referencia	Término fijo Tf_i €/cliente/mes	Término variable Tv_i cent/kWh
T.1	Consumo inferior o igual 5.000 kWh/año	2,65	5,909427
T.2	Consumo superior a 5.000 kWh/año e inferior o igual a 50.000 kWh/año	5,72	5,145527
T.3	Consumo superior a 50.000 kWh/año e inferior o igual a 100.000 kWh/año	44,17	4,203727
T.4	Consumo superior a 100.000 kWh/año	65,77	3,936027

Figure 14: Natural gas prices in Spain.

Price of natural gas.



The price of energy in the EU depends on a range of different supply and demand conditions, including the geopolitical situation, import diversification, network costs, environmental protection costs, severe weather conditions, or levels of excise and taxation.

ENERGY CALCULATION												
	Ene	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ener. Deman. [KWh / month]	6.202	5.502	5.870	5.466	5.538	5.252	5.316	5.427	5.359	5.649	5.681	6.202
Ener. Useful cap. [KWh / month]	1.853	2.322	3.354	3.726	3.880	4.077	4.854	5.059	4.327	3.521	2.190	1.708
% ENERGY PROVIDED	30%	42%	57%	68%	70%	78%	91%	93%	81%	58%	39%	28%

Total annual energy demand: 67.465 KWh

Total annual useful energy production: 40.601 kWh

In the table it can be checked that the auxiliary boiler energy and natural gas volume are directly dependent due to the reduction percentage is the same. It should be mentioned too, that the reduction percentage is quite high, more than two thirds.

$$\textit{Power consumtion before the reform} = \frac{67.465\ (\frac{KWh}{year})}{3{,}6\ (\frac{MJ}{KWh})} = 18.740\ (\frac{KWh}{year})$$

$$\textit{Power consumtion after the reform} = \frac{26.864\ (\frac{KWh}{year})}{3{,}6\ (\frac{MJ}{KWh})} = 7.462\ (\frac{KWh}{year})$$

$$\textit{Power reduction} = 11.278\ (\frac{KWh}{year})$$

The reduction of the money is a bit lower than the other two. It happens because the natural gas price has one part of the price that is constant, and this one is not reduced. Then the reduction is less because only the variable part related to the consumption is reduced.

9.3. CO_2 EMISSIONS REDUCTION

The CO_2 analysis is something really important nowadays. Our society is facing a global warming due to the CO_2 emissions and the authorities are doing a special effort to reduce them. For this reason, the CO_2 emissions resulting of all the industrial processes should be studied. At the same time, all the technologies that are avoiding these emissions should be developed and improves, and the most of them are also supported by different entities and governments.

The natural gas composition influences in the CO_2 generation. It is composed by 90 - 95 % of methane, 5 - 8 % of ethane, and the rest < 2 - 3 % of other gases.

Therefore, one mol of natural gas will produce one mol of CO_2, what is the same than one liter of CO_2 for one liter of natural gas. The volume of natural gas necessary with and without solar system has already been calculated.

The CO_2 is liberated to the atmosphere, in that moment the gas is in a thermodynamic state between normal conditions, 1 atmosphere and 25 °C, and standard conditions, 1 atmosphere and 0 °C. One mol of gas in normal conditions occupies a volume of 24,43 liters, and one mol in standard conditions occupies a volume of 22,38 liters. The difference will be despicable between choosing one or the other one. Maybe the final condition would be closer to the standard one because during the cold months is when the natural gas demand is bigger. Then, it will be assumed that one mol of CO_2 occupy 22,4 liters when it is liberated to the atmosphere.

The CO_2 is produced by the natural gas combustion, and they are directly proportional. It can be noticed in the distribution, that is the same to the natural gas volume consumption mentioned in the previous part. The reduction percentage of emissions is also going to be the same.

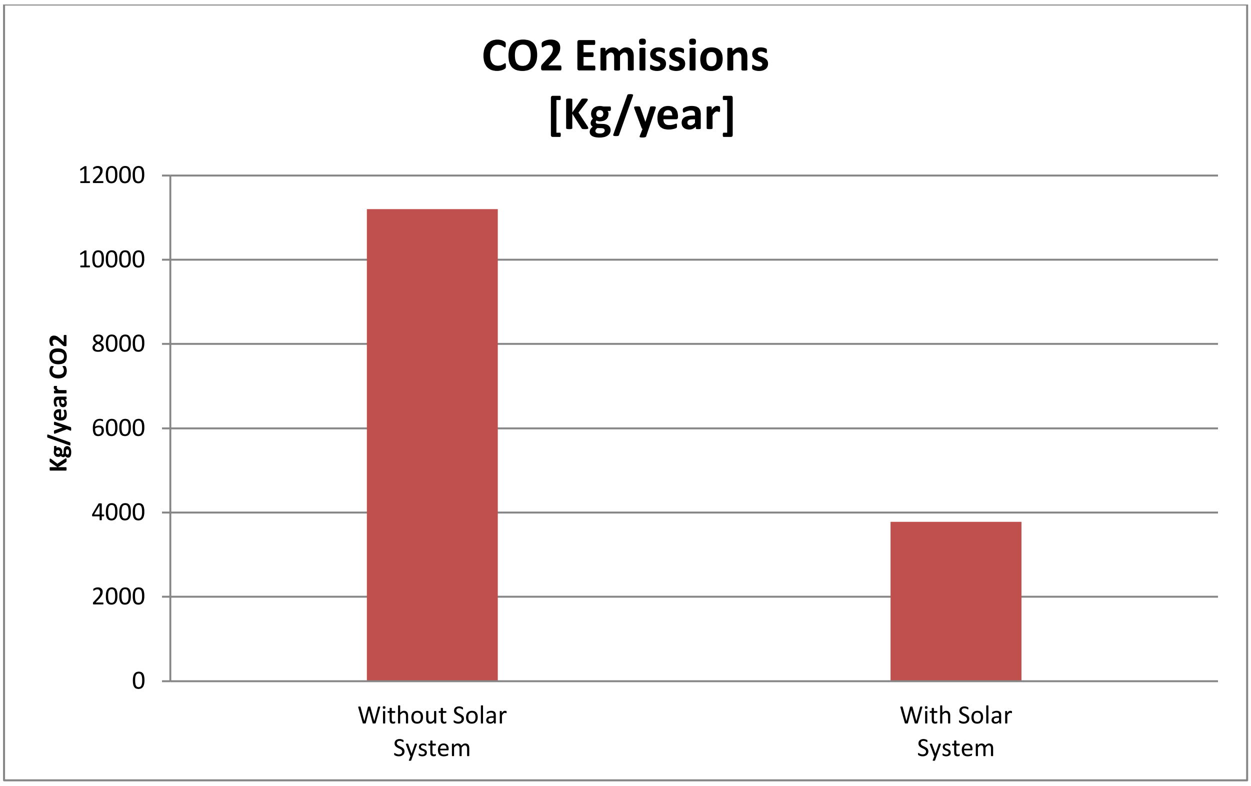


Figure 15 : CO2 emissions reduction.

	CO2 Emissions [Kg/year]
Without Solar System	11199,27
With Solar System	3781,37

Table 5: CO2 emissions.

This reduction is very high, 7.417,9 Kg CO_2/year, and has to be a point of bearing in mind at the moment of taking the final decision about the installation of the solar system.

9.4. COST OF THE INSTALLATION.

Solar water heating systems usually cost more to purchase and install than conventional water heating systems. However, a solar water heater can usually save you money in the long run.

How much money you save depends on the following:

- The amount of hot water you use
- Your system's performance
- Your geographic location and solar resource
- Available financing and incentives
- The cost of conventional fuels (natural gas, oil, and electricity)
- The cost of the fuel you use for your backup water heating system, if you have one.

On average, if you install a solar water heater, your water heating bills should drop 50%–80%. Also, because the sun is free, you're protected from future fuel shortages and price hikes.

DETERMINING ENERGY EFFICIENCY OF A SOLAR WATER HEATER

Use the *solar energy factor* (SEF) and *solar fraction*(SF) to determine a solar water heater's energy efficiency.

The solar energy factor is defined as the energy delivered by the system divided by the electrical or gas energy put into the system. The higher the number, the more energy efficient. Solar energy factors range from 1.0 to 11. Systems with solar energy factors of 2 or 3 are the most common.

Another solar water heater performance metric is the solar fraction. The solar fraction is the portion of the total conventional hot water heating load (delivered energy and tank standby losses). The higher the solar fraction, the greater the solar contribution to water heating, which reduces the energy required by the backup water heater. The solar fraction varies from 0 to 1.0. Typical solar factors are 0.5–0.75.

Don't choose a solar water heating system based solely on its energy efficiency. When selecting a solar water heater, it's also important to consider size and overall cost.

CALCULATING ANNUAL OPERATING COST

Before purchasing a solar water heating system, estimate the annual operating costs and compare several systems. This will help you determine the energy savings and payback period of investing in a more energy-efficient system, which will probably have a higher purchase price.

The investment cost is the total initial cost of the installation including elements and installation. The prices of the elements have been taken from other projects, hence these prices are quite reliable.

There are three main elements, the ones that have been carefully studied and calculated. Besides, there are some secondary elements, such as pipes, supports of fixation and positioning, control systems, and so on.

The cost of all these secondary elements is considered to be the fifteen per cent of the three main elements cost. And the cost of the installation is the five per cent of the three main elements cost. These percentages have been verified in many previous projects. We can see the total cost in the next table.

	Without Solar System	*With Solar System*	*Reduction*	*Reduction Percentage [%]*
Auxiliary Boiler Energy [KWh /year]	*67.465*	*26.824*	*40.601*	*60,18*
Natural Gas Volume [m3/year]	*6.275*	*2.498*	*3.776*	*60,18*
Money [€/year]	*836.8*	*434,59*	*402,21*	*48,06*

Table 6: Numerical results for the energy, fuel and money saves.

	Unitary cost [€ / unit]	Number of Units [unit]	Element cost [€]
Soalr panel: BUDERUS V2 CPC 6	570	34	19.380
Accumulator: Vitocell 100V	1.800	3	5.400
Natural Gas Boiler: Vitogas 200F	1.110	1	1.110
Secondary elements (15% of the three main elements cost)			2.589
nstallation (5% of the three main elements cost)			1.295
Total Installation Cost			29.774

Table 7: Initial investment for the installation of the system.

The initial investment of the installation ascends to 29.774 €. This cost is being paid for all the owners of the building, then this cost should be divided into the 20 individual buildings which composed the total. Therefore the cost per chalet of seven habitants will be 1.488,7 €.

9.5. PAYBACK

The length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions. Calculated as:

Payback Period = Cost of Project / Annual Cash Inflows

The way to calculate is it is very easy and the result show how many years are necessary to amortize the installation. The expression to calculate the payback is the next one.

$$\text{Payback} = \frac{\mathit{Initial\ money\ invested}\ (€)}{\mathit{annual\ money\ saves}\ (€/\text{year})} = \frac{29.774\ \ €.}{1.447{,}96(€/\text{year})} = 20{,}56\ \mathit{years}$$

The payback is similar to the predicted life period of the most of the elements of the installation, between twenty and twenty five years. The installation is mandatory, there is not choice about install or not, then it is a very good result if all the initial costs are recovered during the life period of the installation.

Even more, it is known that natural gas is increasing its price year by year. If its price continues increasing the money save per year will also increase and the payback period will be reduced, making the system more profitable.

10. Conclusions

The whole planet is suffering now the consequences of its own development. The global warming, due to greenhouse effect, and the Antarctic ozone layer hole are increasing and suppose a very grievous problem for the environment and the development of the world. The humanity has to evolve towards a better life, but always without neglecting the care of the planet in which they live.

The aim of this thesis is calculate the size and the necessary equipment for a solar water heating system. The installation of this system is followed by a few consequences that are necessary to know and quantify in advance. These consequences can be looked from different points of view, the two principal ones are the environmental and the economical.

On one hand, in the environmental aspect, it has to be considered the reduction of energy produced by fossils fuels. This is equivalent to a reduction of fossils fuels consumption, which also means a reduction in the greenhouse gases emissions, like carbon dioxide, methane nitrous oxide and so on. It is worth mentioning that the system calculated in this thesis makes a really good contribution to the environment. The traditional energy demand, and as a consequence the natural gas consumption, have been reduced a 60,18%. It means a reduction of *40.601* KWh/year and 3.776 m3 /year respectively. This reduction of fuel consumption avoids the emission of 7.417,9 Kg CO_2/year.

On the other hand, in the economical way, the amount of saved money for this building is quite important. Nowadays in Spain, the installation of Sanitary Hot Water Systems by means of solar energy is mandatory in new and renovated buildings. So, there is not choice about installing it or not. Two economical parameters have to be calculated, the first one is the initial investment cost, and the second one is the payback period. In this project both parameters have an acceptable value.

The first one, the initial investment cost reaches the quantity of 29.774 €. This amount has to be paid between all the flats of the building, so each owner of a flat should pay 1.488,7 €. Finally, the payback obtained is 20,56 years. This time is approximately equal to the life's period of the installation, between 20 and 25 years. Considering the increment in the price of natural gas year by year, the payback period could be considerably reduced. Hence, it is quite possible that not only the initial investment money come back, but also could be additional profits during these last years of the installation's life.

Sometimes, in order to get a better environment for our life, the economical profits should be considered as a secondary factor.The overall results of the project show that the facilities solar thermal are attractive for the consumer and very positive for the environment.

One of the drawbacks in the development of this type of projects are in that, as innovative solutions are not available the necessary equipment adapted to these uses, an example of this is the machine absorption, as this type of equipment is not normally used for domestic purposes and therefore are not commercialized equipment adapted for this purpose. It should however stress the importance of the grant received by the Community of Madrid and the IDEA, which if it were not, the amortization of the Installation occur in 25 years, the end of the useful life thereof, which would make it ceases to be interesting for the user. Consequently it is essential that not only on the one hand facilitate institutions and subsidies, but also provide sufficient information to achieve consumer awareness of the value of this type of facility.

11. References.

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[9] Relationship between number of rooms and number of persons, per house. *Source: Código Técnico de la Edificación (CTE), Document HE, page 4-4.*

[10] Sanitary Hot Water System Diagram. *Source: Energía Solar Térmica para ACS (Solar Thermal Energy for Sanitary Hot Water) web site, 2008.*

[11] Solar flat plate collector. *Source: U.S. Department of Energy, Section of Energy Efficiency and Renewable Energy.*