Energy Systems Report

(Solar Thermal Energy)

# Chapter 1 – Technology description and Impacts

Solar thermal energy (STE) is the usage of solar irradiance to generate heat. It may be used to heat drinking water or rooms, for cooking, to generate electricity, for industrial processes and even for cooling with the help of absorption chillers.

As early as 214 BC Archimedes of Syracuse used a concave mirror to boil water. About a thousand years later, in the 1890s Clarence M. Kemp claimed the first patent on a solar thermal system (STS). After the second World War STS were ousted by fossil fuels, but the market restarted to grow in the 70s and has now one of the highest potentials to impact the fight against climate change.

The simplest usage of STE is a black painted box to absorb solar irradiance. The market uses much more sophisticated systems. In general, they are made up of the solar absorber, which transfers the heat to a heat transfer medium, which can be water, oil, air or salt. The medium will be then be stored in a tank, because mostly the heat is needed when the sun is not shining.

In warmer areas, systems are usually designed after the thermosiphon or gravity principle. The storage is placed slightly above the collectors. Due to the higher density of colder water the system cycle is kept running by the sun. Here STS have to potential to cover the whole demand for hot water.

Systems in colder areas are called forced-circulation systems. A pump is used to keep the cycle running. Freezing of the system is prevented by adding of antifreeze. Therefore, a heat exchanger and a second cycle are needed for the drinking water.

There are two main types of collectors. Flat plate collectors are the most common ones. Inside the collectors are tubes which transfer the heat to the water flowing threw them. Vacuum Tube collectors (VTC) are made of tubes in an evacuated environment, which reduces heating losses drastically. Inside the tubes an easily evaporative medium, like methanol, is stored. Due to a certain minimal tilt of the collectors the medium will evaporate when the sun is shining and will transfer its heat threw a heat exchanger to another medium, then it will condensate again and drip back down to be reheated again. VTCs are generally more efficient than other types but are much more expensive as well.

# Chapter 2 – Solar Resource, demand and system output

With the data provided by the teacher (45 liters of water per person per day, with a water temperature of 60ºC, as well as average temperatures for each season of the year), we started by calculating our demand parameters.

## Chapter 2.1 – Houses (demand and output)

Since each house has 2,5 people, we get the volume of water needed each day per house (V­­­­­h):

The volume per year (Vy) is therefore:

|  |  |  |  |
| --- | --- | --- | --- |
| Season | Water Temp [°C] | Q [Wh/P\*d] | Q [Wh/H\*d] |
| Spring | 15,00 | 2,35x103 | 5,88x103 |
| Summer | 20,00 | 2,09x103 | 5,23x103 |
| Fall | 15,00 | 2,35x103 | 5,88x103 |
| Winter | 10,00 | 2,61x103 | 6,54x103 |

Table 1

On table 1 we have the values for the energy we need to supply in order to meet the required water heating, for each season. The last row of the table, the relevant one, was calculated using the following equation:

Where = 45 [l]; ; .

|  |  |
| --- | --- |
| **Month** | **Solar Share [%]** |
| Jan | 35,8% |
| Feb | 35,3% |
| Mar | 58,3% |
| Apr | 88,2% |
| May | 88,7% |
| Jun | 141,6% |
| Jul | 150,0% |
| Aug | 124,4% |
| Sep | 89,2% |
| Oct | 62,1% |
| Nov | 38,4% |
| Dec | 24,8% |

Table 2

On table 2 we can see the solar share for each month, which means the percentage of the demand that we can meet. The values above 100% mean that the excess energy will be wasted, can be stored or used for other purposes, while the values below that threshold indicate that we require another source of energy (could be electricity, for example) to meet the deficit. These percentages are calculated through dividing the output of our system by the demand, for each month.

Figure 1 – House system production and demand

Looking at the figure above, we can have a clearer idea of the relation between the demand, solar irradiation available and the actual production of our system (for houses), through the installation of 2 square meters of panels for each house.

## Chapter 2.2 – Industry (Tourism) demand and output

By consultation of the book “Quaschning, V. (2015). Regenerative Energiesysteme (9th Edition). Munich, Germany: Carl Hanser Publishing Company”, we were able to project a small industry of tourism consisting of 3 hotels and 1 hostel and arrived at a total value of water demand, in liters per year, of 1,32x107l. Many more values were calculated by consultation of this book and will be referenced as such as they appear.

Another of these assumptions calculated through the book is the total energy demand per year, with a value of 6,08x105 [kWh/year].

|  |  |
| --- | --- |
| **Month** | **Solar Share [%]** |
| Jan | 24,35% |
| Feb | 32,04% |
| Mar | 52,86% |
| Apr | 80,01% |
| May | 80,41% |
| Jun | 128,42% |
| Jul | 136,06% |
| Aug | 112,81% |
| Sep | 80,91% |
| Okt | 56,36% |
| Nov | 34,84% |
| Dec | 22,53% |

Table 3

The table above follows the logic of table 2 but applied to the industry. On the figure below, we can see the irradiation, demand and system production for tourism.

Table 4 - Tourism system production and demand

# Chapter 3 – Proposed Systems and Costs

In this section you can find the costs associated with the system, the available energy per square meter in the island, and the final price per kWh. We chose both for the house and tourism systems a Vacuum Tube Collector type, with 2m2 for each house and a total of 588m2 for the whole tourism industry. The houses storage is 225 liters, and the tourism 4,34x105 liters. The storage is calculated by multiplying the water demand per person times the number of people per house, and the same for the hotels/hostel.

|  |  |
| --- | --- |
| **Per Home** |  |
| Total System Cost [€] | 2,54x103 |
| Total Annual Cost [€/y] | 1,27x102 |
| Total Energy Cost [€/kWh] | 0,078 |
| Energy per m2 [kWh/m2] per year | 8,13x102 |
| System Cost per m2 [€/m2] | 1,27x103 |

Table 5

Table 5 shows the system cost for each house (initial investment plus the maintenance for its 20-year lifespan), the annual cost is the total cost divided by the lifespan (20years). The cost of the kWh is 78 cents and we can also see the system cost per square meter (dividing the total cost by the installed area of panels, which is 2 square meter).

|  |  |
| --- | --- |
| **Tourism** |  |
| Total System Cost [€] | 1,74x106 |
| Total Annual Cost [€/y] | 8,71x104 |
| Total Energy Cost [€/kWh] | 0,19 |
| Energy per m2 [kWh/m2] per year | 7,75x102 |
| System Cost per m2 [€/m2] | 2,96x103 |

Table 6

Table 6 is the same application of Table 5, but for Tourism, with an installed panel area of 588 m2.

The area of the panels for both situations was calculated through:

For the mentioned calculations in this chapter, a value of 75% for solar share, an average system efficiency of 50% and a total lifespan of 20 years were assumed.

By adding the costs of both house and tourism systems, we can express the total costs for the island, which are shown in table 7.

|  |  |
| --- | --- |
| **Island** |  |
| Total System Cost [€] | 5,25E+07 |
| Total Annual Cost [€/y] | 2,62E+06 |

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