# Modeling a Solar Energy System for Required Heat and Electricity of a House

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*Abstract:* - In attaining sustainable development, energy efficiency processes and sustainable energy resources play an important role. The use of renewable energies offers a wide range of benefits and low $CO_2$-emision. A sustainable energy system may be regarded as a cost-efficient, reliable, and environmentally friendly energy system that effectively utilizes local resources and networks. The purpose of this project is to examine the feasibility and efficiency of using solar energy in a house. Energy and thermal analyzes were evaluated, for a house using a concentrating solar system with TEG modules. The concentrator is composed of a Fresnel lens that focuses sunlight onto a plate of aluminium alloy coated with low emissivity paint, the absorber. From there the heat is transferred to the hot side of the module and part of it is transformed into electricity. The module transfers the remaining thermal energy to a water-cooling system. Therefore the concentrating system enables the harvest of electrical energy as well as thermal energy.

*Key-Words:* - renewable energy (RE), solar energy, TEG modules, photovoltaic, Seebeck module, parabolic mirrors.

## 1 Introduction

Renewable energies are increasingly present in today because they fulfill a growing concern for the environment, and they represent inexhaustible sources of clean energy that may lead to the liberation of monopoly of oil economy. It is normal to say that solar energy is renewable, ever though the sun is not renewable.

Sun is a source of perpetual energy. It is said that power would have a perpetual existence for more than ten million years. (Nuclear energy is also considered perpetual).

The more it advances in this field of new technologies, as well as mass production, the cost of implementing a solar power system will fall and investment in this type of equipment will become more attractive.

Solar radiation reaching the earth surface is 6.33 $10^7$ W/m$^2$ and about 51% absorbed by land and oceans, with 6% lost as radiation to space that atmosphere reflects, 20% reflected by the clouds, 4% reflected by the earth surface 16% absorbed by the atmosphere and 3% absorbed by the clouds [1].

Around the world population consumes 14 TW of energy per year, of which 4.5 TW are derived from fossil fuels (oil), 2.7 TW are derived from gas, 2.9 TW from coal and 1.2 TW derived from biomass [2]. One hour of sunlight is equivalent to all the energy we use on a year around the world [3]. The use of solar energy has been used all over the world and can be done in several ways: solar, photovoltaic, thermoelectric (steam turbine, Stirling engine or thermoelectric generators - TEG), and thermal (water heating), or new concepts such as artificial photosynthesis [4].

## 2 Advantages and Disadvantages of Using Solar Energy

The solar energy is free, although there is a cost in the implementation and equipment to convert solar energy into electricity and/or heat. The solar energy

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is perpetual and does not cause pollution. However, the associated equipment and manufacturing process may have some associated pollutions.
Because there are certain geographical areas where the intensity of sunlight reaching the ground is small, or because of climate issues (like cloudy sky), this technology sometimes can be compromised.
Now the prices of equipment to capture and conversion the solar energy are still very expensive, although in future that could change. Also, a solar power station occupies large areas of land, changing the landscape, fauna and flora.

## 3 Case Study for an Average Size House

The purpose of this project was the development and assessment a simple solar concentrating system, in order to obtain both electricity and heat. Fresnel lenses were preferred for the concentration system, instead of parabolic mirrors, because they are an economical solution and offer a smaller set of clutter, less susceptible to strong winds.
The house was considered as a home for 4 people, with all the required appliances, such as electric devices (fridge, washing machine, air conditioning, TV, PC, lights, microwave, etc.) and central heating and water heater. Data on climate conditions is used in the modelling.
For the electricity production we used a Seebek module RS code 6937116, which can withstand a high temperature and has the following specifications (Table 1).The results shown in this paper were carry out on Edp web page [1].

Table 1 - Specific data about the TEG module

| Dimensions | Width | Height | Depth |
|---|---|---|---|
| | 62 (mm) | 62 (mm) | 6.3 (mm) |
| Max. current | Max. power | Max. temp. | Max. Voltage |
| 1.96 (A) | 9.2 (W) | 250 (°C) | 9.4 (V) |
| Number of pairs: | | N=127 | |

We used the concentrating collector to convert heat into electricity, as we required high temperature (200ºC) on the modules hot surface. The other surface (cold) was cooled by water. Efficiency of this type of modules increases with temperature (Fig.1).

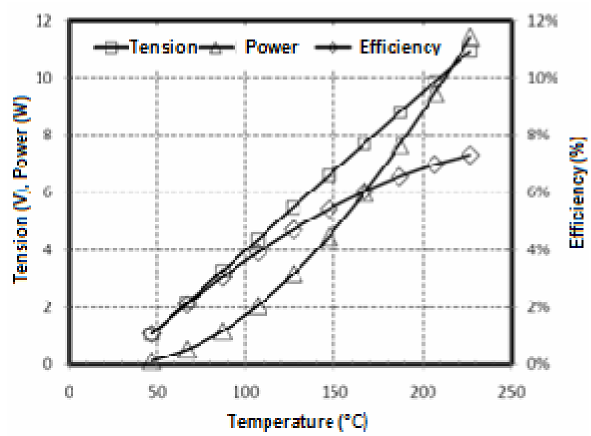


Fig. 1 - Income module Seebek (Antunes, 2011).

So an application should work as closely as possible the maximum temperature that the device supports, in order to get the best performance, as illustrated in Fig. 1.

### 3.1 The Design

The concentration level was determined by the calculation of the TEG surface temperature of 200ºC for average sun energy on of 750W/m². However, when the intensity of the sun is stronger, the temperature may rise above the maximum allowed by the module, and there must be a mechanism to reject this heat. To solve this problem we decided to reduce the energy gain of the sun, by using a collector angle which would not maximize the energy received on the TEG, therefore reducing its temperature. This can be done, taking advantage of the existence of the actuators for positioning solar system, requiring only an additional control algorithm to get the desired effect.

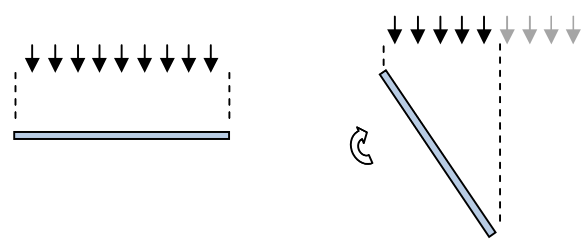

Fig. 2 - Deviation from the collector to reject heat

The idea may be to combine the cooling requirement of the module itself, with the production of hot water. This can be implemented

1- http://www.edp.pt/pt/particulares/bemvindoaedp/Documents/Flash.htm#home

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by decreasing the concentration in the module as shown in Fig. 2. In this figure the position of the TEG is changed, therefore altering the sun concentration. This exposes the water pipe directly to the sun concentrated rays. The system response can be controlled electronically (with the aid of an actuator). As the thermal process is much more efficient than the process of conversion into electricity, the control algorithm should give priority to the needs of electricity.

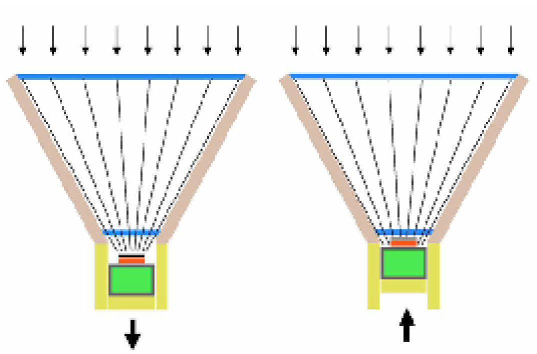

Fig. 3 - System approach to the goal (one part of fluid gets out and other enters)

After a few designs a relatively simple configuration (Fig. 4) was chosen. In this configuration the Fresnel lens concentrates the solar energy into a target, which is an aluminium alloy plate, with high absorption and low emissivity. The concentrated heat passes through the module that converts electrical energy and is dissipated by a water pipe. The system is entirely isolated, even around the air cavity of the tube, to minimize thermal losses.

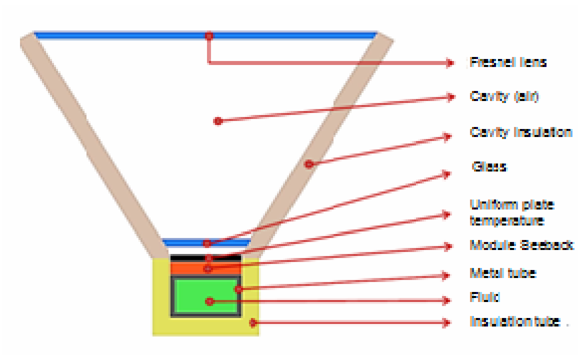


Fig. 4 - Components of the solar concentrator

This solution still requires a system with a fluid circuit and an insulated container. The heat passes from the module to the water until it reached a temperature of about 50 ° C, above which the heat would be rejected by opening a valve connected to a heat exchanger with the environment, this would happen when there is no need for hot water.

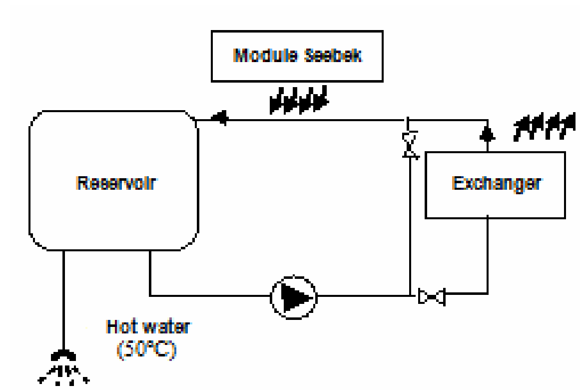


Fig. 5 - Schematic of the flow water

To calculate the various temperatures, concentrator efficiency, electricity and hot water production we used the system described in Fig. 2.

The heat dissipation module is provided through the cooling fluid (water) that has the function of maintaining a low temperature in the cold face of the module.

With the increased water flow, the efficiency of the module has a rapid growth and then tends to a constant value, as can be seen in Fig. 6. The ideal is for the establishment of a compromise between the temperature of hot water (for domestic use) and module efficiency.

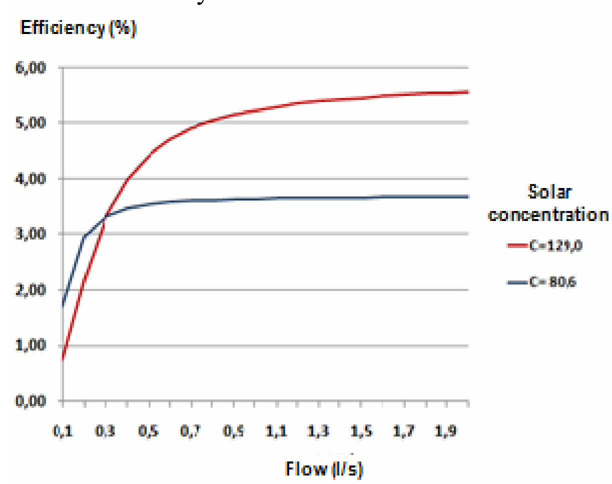


Fig. 6 - Influence of water flow variation in system efficiency

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This system can supply up to about 200 W/m² (of Fresnel lens) of electricity. The Seebek module efficiency, applied to this system fall from 5% to 4,5% when the cooling water passes from 30°C to 50°C.
A flow rate of one liter of water per second per square meter of the exposed lens to the sun is more than sufficient in terms of hot water needs for a home, which is considered as 150 $m^2$ for four persons.

### 3.2 Data on building

The building is at ground level and has three bedrooms, two bathrooms, a living room, a kitchen and one hall.

Table 2: – The home area

| Accommodations | Area A [m²] | High [m] |
|---|---|---|
| Hall | 18,41 | |
| Bathroom 1 | 7,63 | |
| Bathroom 2 | 6,27 | |
| Kitchen | 27 | 2,6 |
| Bedroom 1 | 15,05 | |
| Bedroom 2 | 15,05 | |
| Bedroom 3 | 13,11 | |
| Living room | 46,58 | |
| **Total living area** | **150 [m²]** | |

Total requirement of hot water for the peoples who live in this home, using the utilities like washing machine, washing dishes, or for bath is N= 266 l/day, and specific flow for a person in one day is:

$$q_s = 66.5\ l/person\ on\ a\ day$$

We considered that the hot water has average temperature of $45^0$C.
For energy consumption, we use a program that simulates the potential of electricity in every part of the building.
So in the table below we present the main electronics that are used for four persons with their power consumptions:

Table 3: The main electronics and appliances, along with their power

| Nr. Crt. | The name of the device | Nr. of devices | Nominal power [W] |
|---|---|---|---|
| 1. | Fluorescent lamps | 9 | 75 |
| 2. | TV | 4 | 90 |
| 3. | PC | 1 | 250 |
| 4. | Printer | 1 | 90 |
| 5. | Scanner | 1 | 70 |
| 6. | Washing machine | 1 | 1600 |
| 7. | Refrigerator | 1 | 100 |
| 8. | Electric oven | 1 | 2300 |
| 9. | Hood | 1 | 150 |
| 10. | Microwave | 1 | 1000 |
| 11. | Toaster | 1 | 750 |
| 12. | Air Conditioning | 3 | 1800 |
| 13. | Telefon | 1 | 5 |
| 14. | Iron | 1 | 800 |
| 15. | Vacuum cleaner | 1 | 1250 |
| 16. | Other home appliances (blender, juicer, hair drying, encharger...) | 1 | 1330 |

During the winter and summer seasons, we schedule the time of using the consumers for electricity in every day used in every room of the house, as can be seen in Fig. 7.
We can see that in some days the consume is higher than the others days.

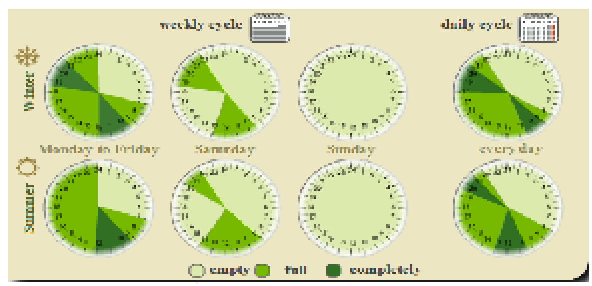


Fig. 7 - Schedule of using electricity for the consumers, in summer and winter

For the house we considered all the equipments required, as electric device like TV, PC, light, fridge, washing machine, air conditioning etc.

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Fig. 8 – Total consumption of the home per one month

We can see that the house consume is 85.74 kWh in a month by using the utilities with a power of 16330 W. The price of energy may vary depending on the way it is used. But for home we use the simple cost. The consumption of the house it is divided by each room.

### 3.3 Results

After inserting all the inherent properties of the fluids and materials of the module Seebek, presented in green sells, are introduced the following input parameters presented in the Table 3.

Table 3: Parameters of the module Seebek

| | | |
|---|---|---|
| Width mod Seebek<br>0,062 (m) | Dist. focal (f)<br>5,000 (m) | Rad. sun media<br>750 (W/m²) |
| Fresnel lens width<br>5,00 (m) | Dist. of the model (F')<br>4,938 (m) | Concentration<br>80,645 % |
| Temp. module<br>147,73 (ºC) | The module efficiency<br>3,08 % | |
| No. of modules (m linear)<br>16,129 | Flow<br>1,10 (l/s) = 0,0011 (m³/s) | |

In Fig. 9, we can see the relation between the variables: water flow, outlet temperature of the water, energy produced by the concentrator, energy used for pumping and module efficiency.

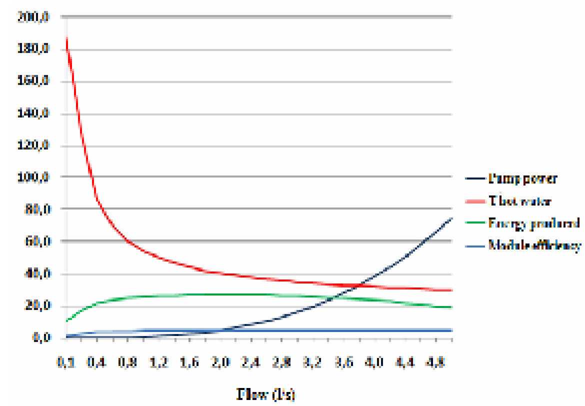


Fig. 9 - Comparison chart of harvest of electrical energy as well as thermal energy produced by the Seebek module

As the water flow increases, the outlet temperature drops and the energy extended when pump increase. The energy produced by concentrator increase rapidly to a value and this is because the flow is increased for to cool the cold face of the module (dark blue line). Once stabilized, because from a certain flow, the water comes out near the temperature at which entered and can not cool more than that (red line).

If the flow continues to grow, pumping losses increase exponentially and justify this loss of energy produced (green line).

Obviously, the module efficiency is not affected by pumping losses and its line (blue line) tends to be horizontal.

## 4 Conclusions

It was noted that a solar power station, occupies large areas of land, changing the landscape, fauna and flora. This impact can be reduced by using smaller plants, which collect the energy into small points.

Major limit of this project is mainly Seebek module efficiency (currently about 5% of potential), but this technology is developing, and the future evolution of modules will make the system more efficient.

To obtain a reasonable efficiency of the module with a solar incidence medium (750 W/m²), in intervals of high incidence, so the module does not exceed the allowable temperature, water flow would be so great as to involve a very high speed, and therefore greater pressure drops in the tube. The pressure drop increases exponentially with speed liquid, so the energy consumption for pumping

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would not justify the gain in efficiency. You will need to make a commitment.

This problem can be resolved with the approach system of the target (or fall in the set, with the fixed target), shown in Fig. 4.

This system is easy to implement, obtain two types of energies (electrical and thermal energy), being more efficient than other systems and representing a good solution for future.

## ACKNOWLEDGEMENTS

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