ET3034TUx - 6.2.1 - Solar thermal energy 1 - Basic principles

Solar thermal energy is a whole different field of study from photovoltaics, employing some rather complicated thermodynamics concepts.

However, in this block I will try to explain the basic functioning of these systems and the different types of possible applications.

First of all, what is heat?

Heat, also called sometimes thermal energy, is caused by the potential energy and kinetic energy of the molecules in matter, and results in the system temperature.

There are two forms of heat that can be differentiated: latent heat and sensible heat.

Sensible heat is the one that results in changes in temperature, and can be defined as the product of the specific heat capacity of the material C_p, the mass of the sample m and the temperature difference.

On the other hand, the latent heat is the one that without change in temperature is able to make the material change its phase.

In other words, it is the energy needed to go from solid to liquid or from liquid to gas.

It can be calculated simply by multiplying the mass of the substance by the latent heat lambda.

When the phase change happens, the extra heat provided will result in a further increase in the sensible heat, but notice that the specific heat capacity changes when the substance changes phase.

This is evident from the two different slopes that the substance exhibits in the temperature-heat graph in the two phases.

Now that we know what heat is, I will explain the three basic mechanisms of heat transport: conduction, convection and radiation.

Conduction is the transfer of heat in a medium due to a temperature gradient.

So let's imagine a house with a heating system during winter.

The inside of the house is warm, but the outside is cold.

Then a gradient between the inside and the outside is established and therefore there will be conduction of heat through the house walls.

Conduction is described by Fourier's law, in which q is the heat flux in watts, k is the thermal conductivity of the particular material in watts per degree Kelvin per meter, A is the contact area in square meters and dT/dx is the temperature gradient in x direction in degree Kelvin per meter.

Convection is the second possible mechanism for heat transfer.

Convection is the transfer of heat by the movement of a fluid.

When a moving fluid is hot, it will transport that heat with its mass.

Convection can be forced, when the movement of the fluid is caused by external variables, or natural, by the density difference caused in the fluid due to the temperature gradients.

In both cases, the heat transfer can be described by Newton's law, in which h is the heat transfer coefficient in watts per square meter per Kelvin.

I won't go into detail on how to calculate the heat transfer coefficient, but it is important to know that it will depend on several operational factors such as the velocity of the fluid, the shape of the surface or the kind of flow that is present.

Finally, we arrive at the radiation mechanism.

This is the most important mechanism of heat transfer for solar thermal systems.

Thermal radiation is basically electromagnetic energy propagated through space at the speed of light.

Thermal radiation is emitted by bodies depending on their temperature.

This is caused by the excitation of electrons, which when returning to lower energy states liberate energy as electromagnetic radiation.

The emitted radiation is usually distributed over a range of wavelengths, between 0.2 micrometers up to 1000 micrometers, covering most of the visible and infrared range.

It depends on the emitting body's temperature.

An important definition here is the one for black body.

As discussed in week 1, a black body is a perfect absorber of radiation, no matter what wavelengths or directions describe the radiation incident on a black body.

A black body is also a perfect emitter of thermal radiation.

In fact, if a body is a perfect emitter, it must also be a perfect absorber.

Planck's law describes the electromagnetic radiation at a certain temperature in any medium as a function of wavelength, as shown in this graph.

By integrating Planck's law over all wavelengths, it gives the total energy emitted per unit of area by the formula given here, where sigma is the Stefan-Boltzmann constant and T is the temperature of the body in Kelvin.

But most of the bodies are not perfect black bodies; they don't absorb all the radiation incident upon them.

Therefore, they are called grey bodies.

The energy emitted and absorbed can still be described by Planck's law, but introducing an emission coefficient, which represents the amount of light that is absorbed and emitted in the material.

An emission coefficient of 1 will be the one for a black body.

Now that we understand the basic principles of heat transfer, I will explain how to apply them for heating systems or power production in the next blocks.

See you in the next block!