Energy, power and the solar constant

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You are used to using the expression energy however in physics, we have a very precise understanding of what energy is. In our scientific system of units, energy comes in units of Joules. There are two type of energy that we can consider, namely kinetic potential energy (U) and kinetic energy (K). We will do a simple calculation with both to understand them. In the examples below, Δ means "the change of " and is calculated by subtracting the initial value of something from the final value.

U: Potential Energy: Raise a book with a mass of m=1 kg through a distance of h=2 m. What is the change in potential energy ?

$$\Delta U = mgh = 1\,kg\,x\,10\,m/s^2\,x\,2\,m = 20\,kg\,m^2/s^2 = 20\,Joules$$

Here g is the acceleration due to gravity near the earth's surface (9.8 m/s^2) which I am approximating to 10. In the scientific system of units force is measured in N (Newtons) and is give the weight as F=mg. When this force is exerted through a distance (h), we have an increase in potential energy or kinetic energy or both, and this is called work and in this case is against gravity.

K: Kinetic Energy: A book with a mass of 1 kg is moving with a speed of 2 m/s. It is then stopped. What is the change in kinetic energy of the book?

$$\Delta U = -1/2\,mv^2 = -1/2\,x\,1\,kg\,x\,[2\,m/s]^2 = -(4/2)\,kg\,m^2/s^2 = -2\,Joules$$

Energy conservation: The total energy of a closed system is conserved. This means that $\Delta U + \Delta K = 0$.

Power: The rate of doing work (or energy converted) is called power. In the scientific system, the units of power are Watts . This is the same thing exactly that you would see light bulbs rated in (120 W, 60 W, etc). We can calculate energy if we know how much power is collected per unit time.

Solar Panel collection example: a 1 m^2 solar panel collects power at the rate of 100W for 60 s. How much energy does the solar panel collect in this time?

$$Power = \frac{Energy}{time} \Rightarrow Energy = Power\,x\,time = 100W\,x\,60s = 6000\,Joules$$

This is enough energy to raise a 1Kg mass through about 600 meters. Suppose the same panel under the same conditions had an area of 2 m^2. Then it would collect 1200 J of energy in 60 s.

G_{sc} :The Solar Constant: The solar constant tells us how much power per unit area the Earth receives from the sun. In the upper atmosphere, the value is about 1400 W/m^2 and by the time it reaches the earth, we have about 500 W/m^2 available as a conservative estimate. An example: suppose a solar panel which is 1 m^2 collected 1/4 G_{sc} for 60 seconds. How much energy is collected?

$$Power = 1\,m^2\,x\,G_{sc}/4 = 350\,Watts : Energy = 350\,W\,x\,60\,s = 21000\,Joules \approx 20\ \ BTU$$

This is enough energy to raise a 1 kg mass through a distance of about 2000 m.

Now you may wonder how do these things convert to English units? A 150 lb person has a mass of about 70 kg. In 3600 s (1 hour), our solar panel above would provide enough energy to raise this person through 1800 m or slightly over 1 mile. You will often see the unit of energy BTU. For the solar panel example above, since 1 BTU = 1055 J, we would have collected about 20 BTU. In a 6 hour day of collection with this panel, we would collect 7200 BTU (about the cooling power of a medium window air conditioner). With an array of 8 panels we would collect 57300 BTU of energy:

$$(350 Watts)\,x\,(6\,hours)\,x\,(3600\,s/1hour)\,x\,(8\,panels)\,x\,(1\,BTU/1055 Joules) = 57327\,BTU$$

Your assignment: write a short paragraph about energy collection from G_{sc}.