Energy

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1 Saving Energy in California, Mike Emery

Mike lives in San Anselmo California, near San Raphael. The solar energy panels and the inverter cost 11,000 dollars, with a 5000 dollars rebate from the state of California. His panels are on his garage roof: 9 at 200 watts per panels, for a total of 1800 watts. They average 5.5 hours of sunlight. He is billed once a year by the power company. Last year he paid 220 dollars. Before the solar panels were installed, the electric bill had been about 100 dollars a month, or about 1200 a year. They are saving about 1000 a year. In California electric rates are usually about 8 cents per kilowatt hour, except in the summer, when the noon to 6 rate is 25 cents per kilowatt hour. In the summer when there is much sunlight during the daytime, Mike is putting power back into the electric grid, and so being paid 25 cents per kilowatt hour.

He is building a new house on the side of a mountain in Fairfax CA. There is a creek coming down from the mountain, and he is thinking of putting in a Micro-Hydro system that uses a tall pipe, to get a large head that drives a Pelton wheel, with adjustable nozzles. Pelton wheels are among the most efficient types of water turbines. It was invented by Lester Allan Pelton (1829-1908). Mike measured the flow of the creek at about 300 gallons per minute. Schwarzenegger has cut off the solar panel rebate now. Mike also has a small wind turbine that he is thinking of installing in the dead of the night to avoid restrictions on such turbines. It generates at 24 volts DC.

2 Some Properties of the Earth

The average radius of the earth is 6378.1 kilometers.

$$r = 6.3781 \times 10^6 (M).$$

Assuming that it is a sphere, its surface area is

$$A_s = 4\pi r^2 = 5.112 \times 10^6 (M^2).$$

Its cross sectional area through the center is 1/4 this

$$A_c = \pi r^2 = 1.278 \times 10^6 (M^2).$$

The solar constant is the power received from the sun just outside the earth's atmosphere. The value varies from

$$C_s = 1412 (W/M^2)$$

in early January to

$$C_s = 1321(W/M^2)$$

in early July. Multiplying by the cross sectional area of the Earth this gives an average power of about

$$P_s = 1.740 \times 10^{17}(W).$$

This is 174,000 terawatts. The solid angle of the Earth as seen from the sun is approximately 1/140,000,000 steradians. Thus the Sun emits about 3.86×10^{26} watts. The solar irradiance is the received solar power divided by the surface area of the earth

$$I_s = 340(W/M^2).$$

The Earth cools at a rate of about 44 terawatts. Human consumption of energy is about 15 terawatts. The North American proportion of this is about 22 per cent or, about 3.3 terawatts There are about

$$24(365) = 8760$$

hours in a year. So about 131400 terawatthours, are used by humans in a year. The U.S. uses about 29000 terrawatthours per year. This is about 22 percent of the total. The world population is about 5978 Million people. The population of North America is about 307 Million people, or about 5 percent of the population of the earth. The average power used per person on the earth is

$$15 \times 10^{12}/(5978 \times 10^6) = 2509.2W,$$

or 2.5 Kilowatts. The average power used by North Americans is

$$(.22)15 \times 10^{12}/(307 \times 10^6) = 10749W,$$

or 10.749 Kilowatts.

3 A Guess at the US Energy Consumption

Lets say that the average family spends 200 dollars a month on utilities. And say 40 dollars a week on gasoline. That is 4480 dollars per year. Guessing that there are about 200 million households in the US, that comes to about 8.96 times 10^{11} dollars. Assuming that the cost of energy is about 10 cents per kilowatt hour, that gives about 9×10^{12} kilowatt hours. Assuming that the energy use outside of the home is a bit more than that, we might estimate the US energy use at 20×10^{12} kilowatt hours, which is 20×10^{15} wh, or 20000 Terrawatthours. Wikipedia says the consumption was estimated at 29000 TWh in 2005.

4 Wind Power

The power P in the wind is given by:

$$P = \frac{1}{2}\alpha\rho\pi r^2 v^3,$$

where the maximum efficiency of a wind turbines is about $\alpha = .59$ (Betz' law). For an 18 mi per hour wind and a wind turbine of 100 meters diameter the turbine could generate a maximum of 1.5 megawatts. Estimating the width of the state of Kansas at about 200 miles, or $1.61 * 200 = 322$ km, and spacing a wind turbine every 200 meters, we could position 1620 wind turbines generating 2.4×10^9 watts, which is about 2000 megawatts. There are about $24 * 365 = 8760$ hours in a year, so this is about 2.1×10^{13} watt hours. This is a very small percentage of the needed US energy, about .001 of that required (about .1 percent).

5 Peak Oil

The Hubbert peak theory posits that for any given geographical area, from an individual oil-producing region to the planet as a whole, the rate of petroleum production tends to follow a bell-shaped curve. It is one of the primary theories on peak oil.

Choosing a particular curve determines a point of maximum production based on discovery rates, production rates and cumulative production. Early in the curve (pre-peak), the production rate increases due to the discovery rate and the addition of infrastructure. Late in the curve (post-peak), production declines due to resource depletion.

The Hubbert peak theory is based on the observation that the amount of oil under the ground in any region is finite, therefore the rate of discovery which initially increases quickly must reach a maximum and decline. Extraction roughly follows the discovery curve after a time lag (typically about 35 years[1][2]) for development. The theory is named after American geophysicist M. King Hubbert, who created a method of modeling the production curve given an assumed ultimate recovery volume.

In 1956, Hubbert proposed that fossil fuel production in a given region over time would follow a roughly bell-shaped curve without giving a precise formula; he later used the Hubbert curve, the derivative of the logistic curve, for estimating future production using past observed discoveries.
Beyond Oil: The View from Hubbert's Peak by Kenneth S. Deffeyes

6 The Energy Received From The Sun

The solar constant is about 2 calories per square cm per minute. This is the solar energy received from the sun on a plane perpendicular to the sun direction. A calorie is about 4.19 jouls. So the solar constant is about 1397 watts per square meter. The radius of the earth is about 6451 km, or $r = 6.451 \times 10^6$ meters. The cross sectional area of the earth is about $A = \pi r^2 = 1.3 \times 10^{14}$ square meters. So the earth receives about 1.83×10^{17} Watts from the sun (183000 terawatts). Note that in the section on Earth properties, we used a value of 174000 terawatts for the sun's received energy. Let us continue to use that value, namely 174000 terawatts. This is

$$174000/15 = 11600$$

times the human energy consumption.

So we would have to intercept only .009 percent of solar energy to furnish our human consumption.

7 The Energy Received From the Earth's Interior

The energy received on the earths surface from the interior of the earth consists of the heat coming from the molten core and the heat produced by internal radiation processes.

About 44.2 terawatts flows to the surface of the earth from the interior (Michael Wysession, "How the Earth Works"). So in a year this amounts to 3.87×10^5 TWh per year.

8 Energy Radiated From the Earth's Surface

The Earth radiates as a Black Body at a mean temperature of about 15C or 59F degrees. 85 percent is reflected back from the atmosphere, if this were not so, the average earth temperature would be about -40 degrees.

9 Sun Dimming Question from John Biggerstaff

I wish I could get to these meetings. I do have a question to pose to this very intelligent and diverse group of people. I watched a segment of Nova that talked about the sunlight dimming effect of pollution and its cooling of the earth. It also talked about the balancing act of this dimming vs the greenhouse gas and warming of the earth. A short piece of the dimming discussion had to do with a scientist who measured the temperature effect of the shutdown of air traffic for 3 days at 9/11/2001. The loss of the "clouds" from the airplanes had increased the range of temperatures by a significant amount over the 3 days, something that couldn't be shown in any other data. My question to this group is could we utilize the domestic airline industry and all of the daily flights they make to put into the atmosphere additional clouding that would help cool the earth further. We would want to put particulates in the atmosphere that were not harmful pollutants. At the same time, could any of that be used to leech out any of the greenhouse gasses chemically? I'm not a chemist so these may be nonsense type questions but I was intrigued by the idea that we might be able to utilize the airplanes that are already going to be in the air daily to help combat a very serious problem of global warming. John

10 Bibliography

[1]Wikipedia, **Solar Radiation**,
[2]Wikipedia, **Wind Turbine**,
[3]Wysession Michael, **How the Earth Works**, The Teaching Company.
[4] Deffeyes Kenneth S. **Beyond Oil: The View from Hubbert's Peak**