Dr. Eric Miller
Department of Chemistry
San Juan College, New Mexico

How Much Solar Collector Area would be needed To Run the United States?

In 1998 the United States used approximately 100 Quad BTU of total energy consumption. Of that, approximately 1/3 was from oil[1]. So, using 100 quad BTU as a target, the following calculation shows how much area will be needed to collect this amount of energy.

1 Quad BTU = 10^{15} BTU = 2.931×10^{11} kWhr

(100 Quad BTU/yr) x (2.931×10^{11} kWhr/ Quad BTU) = 29.31×10^{12} kWhr/yr

So approximately 30×10^{12} kWhr of energy is used by the US each year. Breaking up the units

(30×10^{12} k J hr / s yr) x (60 min/hr) x (60 s/min) x (1000 J / k J) = 108×10^{18} J/yr

is the total energy used per year. For about 6 hrs per day (a solar day), we have about 1kW/m^2 of solar power hitting the earth. At 10% conversion efficiency (this is conservative, most solar panels operate at 12% to 15%), we would have about 100W/m^2 of energy collected.

(100 J / s m^2) x (60 s / min) x (60 min/hr) x (6 hr/dy) x (365 dy/yr) = 788×10^6 J / yr m^2

This would be the energy collected per square meter per year. Now we can find the area we need to supply the US energy demand.

(108×10^{18} J / yr) / (788×10^6 J / yr m^2) = 137×10^9 m^2

(137×10^9 m^2) x $(.00062137 \text{ mi / m})^2$ = 52.9×10^3 mi^2

So taking the square root of this, we would need approximately a 230 mi by 230 mi solar farm network array to supply the US. Therefore, in order to build such an array mainly in the desert southwest areas, the panels need to be built as inexpensively as possible, thus the motivation behind Eric Miller's Research at San Juan College.

How much would 100 Quad BTU Cost?

To find out how much such a large solar electric farm network would cost, we first must find the average wattage that will need to be installed, since photovoltaics are typically sold and rated by wattage. Using the results from above

(108×10^{18} J/yr) x (yr / 365 dy) x (dy / 6 hr) x (hr / 60 min) x (min / 60 s) = 13.7×10^{12} W would be the total average watts needed to be installed. This does assume that there will be an average of 100 W per square meter of energy collected for 6 hours every day. As of 2005 we could expect that the raw solar panels could be purchased for $2.5 per watt. Therefore,

$$(\$2.5 / W) \times (13.7 \times 10^{12} W) = \$ 34.2 \times 10^{12}$$

That's approximately 34.2 trillion dollars. In comparison, the entire 2003 federal budget was 2 trillion dollars.

What Kind of Income Could This Large Solar Array Generate?

The news is not all bad however. The solar farms have a tremendous potential to generate income. If the electricity is sold at 16 cents per kWhr (the top end of current electricity prices), the price per Joule of energy is

$$(.16 \$/kWhr) \times (k / 1000) \times (hr / 60 min) \times (min / 60 s) \times (W s / J) = 44.4 \times 10^{-9} \$/J$$

Using these results and those above we have

$$(44.4 \times 10^{-9} \$ / J) \times (108 \times 10^{18} J / yr) = 4.8 \times 10^{12} \$/yr$$

This would be double the approximate current federal budget. The break even on the investment would take approximately

$$\$ 34.2 \times 10^{12} / 4.8 \times 10^{12} \$/yr = 7.1 \text{ years}$$

This would be true no matter how many Watts are installed. Each watt pays for itself in 7 years. This is pessimistic in that some estimate the payback to be 2 to 4 years[2]. The lifetime of photovoltaic panels is anywhere from 20 to 40 years depending on the type of panels. After 7 years, if the farms were built and run as a public enterprise, the entire federal and state governments could possibly be run without any further taxation of the public for some 15 to 35 years. This also does not include any additional income that could be made from selling solar hydrogen.

After the profitability period, the panels will require replacement. Much of the material should be recyclable, particularly the metals, so the material costs of replacement could be less than the original cost of installation.

References

1. "United States Energy and World Energy Production and Consumption Statistics", USGS, Central Region Energy Resources Team, 1998.
http://energy.cr.usgs.gov/energy/stats_ctry/Stat1.html

2. Knapp, K., E., Jester, T., L., "PV Payback", Home Power, 80, December, 2000