A BRIEF INTRODUCTION TO ENERGY

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– SOLAR ENERGY SUPPLYING THE TOTAL ENERGY NEED

Energy is the key for a clean environment and sustainable societies. Generating our energy from stable, renewable sources will also help reduce regional and global conflicts.

A watt (W) is one Joule (J) per second. 1J is the energy required to lift a small apple (102 g) one metre above the Earth's surface.
A watt-hour is one watt of power used for one hour, which is 60 sec x 60 min = 3.600 Joules. A kilowatt-hour (KWh) is thus 3.600.000 J (3,6 megaJoules – 3,6 x 10^6 J).
Two 50 watt light bulbs (0,1 kW) left on for ten hours will use 1 kWh).
1 KW = 10^3 W
1 MW = 10^6 W
1 GW = 10^9 W
1 TW = 10^{12} W

Some examples of power consumption (effect):

100 W	approximate average power used by the human body
120 W	peak power output of 1 m^2 solar panel in full sunlight
40-200 KW	approximate range of power output of typical cars
3 GW	approximate peak power generation of the world's largest Nuclear reactor (http://en.wikipedia.org/wiki/Nuclear_reactor)
12,7 GW	average electrical power consumption of Norway in 1998
18,2 GW	electrical power generation of the Three Gorges Dam (http://en.wikipedia.org/wiki/Three_Gorges_Dam) in China when complete

We normally measure amounts of energy in watt-hours:

1 KWh	1.000 W / 0,001 MWh	(3,6 x 10^6 J)
1 MWh	1.000 KWh / 0,001 GWh	(3,6 x 10^9 J)
1 GWh	1.000 MWh / 0,001 TWh	(3,6 x 10^{12} J)
1 TWh	1.000 GWh	(3,6 x 10^{15} J)

4.186 J	is 1 kcal or food calorie (energy to heat a kilogram of water by 1 degree Celsius	
0,745 KWh	a power of one horsepower applied for one hour	
444 KWh	energy in an average car tankful (45 litres) of gasoline	(1,6 x 10^9 J)
20.000 KWh (20 MWh)	energy consumed by the average car in the USA in 2000	(7,2 x 10^{10} J)
8,4 TWh	electricity consumption in Zimbabwe in 1998	
111 TWh	electricity consumption of Norway in 1998	
29.167 TWh	energy (total) consumed by the USA in one year (2001)	(1,05 x 10^{20} J)
118.000 TWh	**energy consumed by the world in one year (2001)**	**(4,26 x 10^{20} J)**
4,2 million TWh	total energy from the Sun that hits the Earth in 24 hours	(1,5 x 10^{22}J)
11 million TWh	energy in world's estimated total fossil fuel reserves (2003) (http://en.wikipedia.org/wiki/Fossil_fuel) This equals 93 years of the world's annual energy consumption as of 2001	(3,9 x 10^{22} J)
8,3 million billion TWh	energy in world's estimated recoverable U-238 reserves (2003) (http://en.wikipedia.org/wiki/Uranium) Or, more conceiveable, 70 billion years of the world's annual energy consumption as of 2001.	(3,0 x 10^{31} J)

SOLAR PANEL EFFICIENCY AND LAND COVER

The USA counts for 1/4 of the world's energy consumption, which is about 120.000 TWh (2001).
In 2006, the world's population is about 6.7 billion (July 2006, est.). This is projected to 9.2 billion people in 2050, according to the UN (www.un.org/News/Press/docs//2007/pop952.doc.htm).

We assume rationalized energy consumption, but with population growth and increased wealth and energy consumption in developing countries, we guess an overall doubled energy consumption in 2050, up to 250.000 TWh/yr.

With the same solar-to-electricity and energy-storage efficiensy as accounted for above, this would require a collecting area of 250.000 TWh / 158 KWh = 1.580.000 km^2 (see below). Since already today, panels with twice this efficiency has been made, it is not unlikely that these may be commercially produced.

Therefore, we assume a doubled solar-to-electricity efficiency. This reduces the collecting area to 790.000 km^2, which is about the size of Turkey (or the U.S. states of Texas and Lousiana together). This is 0,5 % of the earth's total land area (149 million km^2).
Put another way, 790.000 km^2 divided by 10 billion people = 79 m^2 collecting area per human being.

Of course, we will continue to produce energy from hydroelectrical plants, from wind power plants, perhaps from wave power plants as well as solar heaters (without converting to electricity) and other renewable or clean sources.

What this shows, is that the world's future energy consumption can be 100 % renewable and with no emission.

<u>– But at which costs?</u>

According to NABCEP (North American Board of Certified Energy Practitioners – www.nabcep.org/news.cfm?pr=9) if USA since 1973 had invested the amount it spend every year on fossil fuel subsidies, PV would have provided 100 % of the US energy consumption in 2044.

No doubt costly, but certainly affordable.

SOURCES ON PV
Solar electric panels are commonly referred to as photovoltaics – PV.
According to NABCEP (North American Board of Certified Energy Practitioners):

– A conservative estimate of the solar energy reaching the ground in the United States is 1500 KWh per square meter per year (actually ranging from 1200 to over 2000) [when accounted for light and weather conditions].
– With 15% solar-to-electricity conversion via PV, usable energy is 1500x0,15 = 225 KWh/sq.m/yr.
– Assuming that hydrogen would be used as the primary energy storage medium, and using 70% for energy-storage-energy round trip efficiency via, e.g., fuel cells, the useable energy collectable by unit of ground surface is 225x0,7 = 158 KWh/sq.m/yr.

Providing the entire US energy requirements of 28,000 billion KWh per year would thus require a total collecting area of 17.5 million ha [17500 km^2]. That is less than the area presently occupied by hydroelectric power plants [dams]. Because solar technologies such as PV are highly modular and can be incorporated in common building materials such as glass and roofing products, much of this resource could be deployed on already urbanized landscapes, near points of the greatest electricity use. It would only take a small percentage – 15% of urbanized land – consisting of buildings, highways, parking lots, exclusion zones, to build the PV power structures.

NABCEP investment cost estimation:
What if, starting in 1973 (the oil embargo year), we had invested the amount we spend yearly on fossil fuel subsidies -- $40 billion - in deploying PV power plants at market price?
Noting that back in 1973, $40 billion in current dollars was worth ~ $10 billion and PV installations cost was $35/Watt; assuming that massive and consistent purchases would have induced yearly cost reductions of 5% per year, down to a minimum achievable cost of $ 1.50/Watt; further assuming a 10% overhead on initial investments, reinvestment of 70% of systems' revenues in new PV systems (breeder effect), systems' output degradation of 1% a year, and systems' maximum life span of 30 years, the total installed PV capacity in the US today (2003) would be equal to 64 GW and growing at an exponentially accelerating rate of 8 GW per year.

Continuing under these assumptions, PV would be in a position to provide 100% of the US energy consumption by 2044....

LINKS

NABCEP	www.nabcep.org/news.cfm?pr=9
Olvier Max – on solar energy	www.stanford.edu/group/solarcar/solarenergy.htm
Wikipedia on renewable energy	http://en.wikipedia.org/wiki/Renewable_energy
Sequoia Automation	www.kitewindgenerator.com
Tesla motors	www.teslamotors.com

”Historically, it seemed to us that electric cars had been designed by people who thought we really shouldn‘t be driving at all - but if we must, we should suffer every minute of it. Electric cars have had terrible range and embarrassing styling” (Tesla motors)

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