Energy - The Big Picture

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OVERVIEW

The following is an attempt to put into perspective the problem of obtaining the world's energy needs by carbon free renewable means.

Table 1 - Current energy plant capital cost in $/W

Gas turbine	0.5
Wind	2.0
Solar tower	2.5
Nuclear	6.0

One MBtu is equivalent to 33.43 watts expended for a year. Multiplying the above values by 33.43 we can thus obtain energy plant cost in $ per MBtu/yr assuming a plant life of one year.

Table 2 - Current energy plant capital cost (in $ per MBtu/yr, or $B per quad/yr)

Gas turbine	17
Wind	67
Solar tower	83
Nuclear	200

The above values have to be multiplied by 10^9 to obtain cost in $ per quad/yr. So, the above numbers represent the current cost in billions of dollars per quad/yr energy creation capacity. Thus multiplying the values of Table 2 by 400 we have the cost of plant capacity to provide current world energy needs of 400 quads:

Table 3 - Current energy plant capital cost in $T to supply world needs

Wind	26.8
Solar tower	33.2
Nuclear	80.0

If we discard nuclear energy as not cost effective, and assume half solar and half wind energy production, we have 30 $T capital cost to provide all the worlds energy needs by renewable means. Assuming a 3 percent cost of capital (reasonable assuming value of energy inflates too) we have an annual cost of 1.5 trillion dollars to produce the 400 quads. That is $(10^6)(1.500 \times 10^{12})/(400 \times 10^{15})$ $/MBtu = $3.75 per MBtu.

If we triple the cost to include cost for novel energy transportation and storage methods, we have a cost of $11.25 per MBtu. This is very competitive with the DOE 2003 costs of energy, as shown in Table 4.

Table 4 - Current costs of energy in $/MBtu

Electric	25.20
Methane	9.10
Heat. Oil	9.25
Propane	13.46
Kerosene	11.41

It appears the job of converting to renewable energy can be accomplished starting now, especially where long trades are not required. The capital cost will ultimately be on the order of 90 trillion dollars, but invested over the, say, 20 years required to accomplish the plant development it will be about 4.5 trillion per year.

At $12/MBtu, the world energy requirement costs about 4.8 trillion dollars per year. The capital to achieve the conversion can be obtained by doubling the cost of energy for about 20 years. Considering most of the energy is consumed on the continents in which it is produced, the cost could be substantially less than that estimated, possibly by as much as 60 percent less. The powerful effect of economy of scale has not been applied either.

Unfortunately, as with a national renewable energy policy, all that is missing is the political will to make it happen. It is even less likely to happen on a global basis than a national basis. However, emerging capitalists should have their noises in the air. The smell of money is there. They may well wipe out those unable to think in any terms other than big oil. The future is likely another example of survival of the fittest and the adaptable.

THE ENERGY TRANSPORTATION PROBLEM

Much has been made of the as yet unsolved hydrogen storage problem. However, there are alternatives available now. See

http://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000079095.pdf for a method using silicon. This is a very well developed concept with many robust positive ramifications. It clearly shows a means of transporting energy long range and storing energy that is highly compatible with an otherwise principally hydrogen economy and which is also achievable by engineering using existing principles and processes. This closes the gap on the critical missing functions for a global renewable energy economy - long range transportation and storage. It also utilizes solar energy and equatorial regions, which is a good compliment to the extensive energy available from wind and the good thermodynamic conditions in polar regions. This seems to absolutely nail down the fact that a global carbon free renewable energy economy is feasible now if the political will exists to make it so.

There are clearly risks associated with transporting silicon by ship. As the author points out, silicon combusts spontaneously in air and produces ammonia in the presence of water. The author points out that this risk can be minimized for handling purposes by crystallization and occupation of the surface sites. Still, a ship grounding accident could be very hazardous, but nothing like the Exxon Valdez in the way of a long term environmental hazard, so that is a huge improvement. Unloading or handling solid silicon (in an inert environment?) might be a significant engineering and safety challenge, though maybe those problems would be minimal if the silicon is hermetically containerized or encapsulated. Loading and unloading would be greatly facilitated by using a liquid technology.

There is still missing a good technology for vehicle fueling, which might be handled by LN_2, etc., but which might also be handled by a silicon compound. Given that silicon is so similar to carbon energetically, one has to speculate it is economically possible to hydrogenate it to make a liquid which is biodegradable or at least which decomposes to SiO_2 and water fairly quickly, i.e. in a matter of months. Silane (SiH_4) can clearly be produced, and is environmentally friendly, but it has all the shipping and storage problems associated with natural gas. Tetrasilane (Si_4H_{10}) boils at 84.3 deg. C. so can be shipped and stored as a liquid.

It appears the principle idea proposed for obtaining the energy of Si was the production of ammonia. The information in Table 5 was given.

Table 5 - Energy to produce 1 g hydrogen

Compound	Energy to produce 1 g hydrogen
Water	143 kJ
Methane	18.75 kJ
Ammonia	15.4 kJ

The ability to produce ammonia is significant in that serves as a feed stock for fertilizer production and many other things. Since ammonia is valuable in its own right as a feed stock, and energetically valuable as well, the idea of directly producing ammonia in wind farms and shipping and storing as a liquid may be practical (without the use of silicon).

There have been attempts at producing ammonia powered fuel cells, but this has not worked out as far as I know. Hydrazine (N2H4), which can be produced from ammonia does work in fuel cells by:

$$N_2H_4 + O_2 \longrightarrow N_2 + 2\ H_2O$$

but is not a good approach for civilian vehicles due to the toxicity and other problems with N2H4.

It is reasonable that Si and/or NH3 can be used for long range trades, and bulk electrical energy production. It may be reasonable that LN2 or liquified air be produced in a local fashion for vehicle propulsion. Direct electricity generation by wind or solar could be backed by energy storage involving Si or NH3 related storage and generation facilities. Nuclear can continue to be used for electrical generation and possibly for hydrogen or NH3 production for energy storage or transportation, and fertilizer production. For intermediate energy transportation by ground, hydrogen can be piped. A carbon free global energy supply is a very real possibility through only the application of existing technology, i.e. existing engineering principles. This is an incredibly wonderful possibility. The development of new technologies, like an effective hydrogen storage medium, room temperature superconductors, or cold fusion, only enhances these possibilities.

UPDATE

Efficient and safe means of ammonia trasport may have dramatic effects on the feasibility of a global conversion renewable energy. See “Danish Researchers Reveal New Hydrogen Storage Technology”, Science Daily, Sept. 8, 2005:

http://www.sciencedaily.com/releases/2005/09/050907102549.htm

“Scientists at the Technical University of Denmark have invented a technology which may be an important step towards the hydrogen economy: a hydrogen tablet that effectively stores hydrogen in an inexpensive and safe material. ... The hydrogen tablet is safe and inexpensive. In this respect it is different from most other hydrogen storage technologies. You can literally carry the material in your pocket without any kind of safety precaution. The reason is that the tablet consists solely of ammonia absorbed efficiently in sea-salt.”

Continued reductions in energy production and storage costs in various sectors continue to increase the feasibility of the dream of a world fully powered by renewable energy. See:

http://www.mtaonline.net/~hheffner/EnergyCosts.pdf

http://www.mtaonline.net/~hheffner/HotCold.pdf