Can the world run on renewables, nuclear energy and geo-sequestration? The negative case

Contributed by Ted Trainer
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Editor's note: This article is a summary of a new paper published in Energy Policy, available at sciencedirect.com. For a detailed discussion of renewable energy's limits see Renewable energy – Cannot sustain an energy-intensive society. The author told Culture Change, "Central in the delusion system moving us
to the brink is the unquestioned faith that renewables can preserve affluence and the
growth society; it is extremely difficult to get anyone to think about this."

For many years I have been arguing that consumer-capitalist society is so grossly unsustainable that technical advance cannot solve the problems it is generating. I have especially developed the case against the dominant belief that alternative energy sources can substitute for fossil fuels. This is not an argument against transition to renewables. We must do that, and we could live well on them, but not at anything like the levels of consumption we have today.

Very little attention has been given to the possible limits of renewable energy sources. Everyone has wanted to believe that they can save us. This paper offers an analysis of quantities that would be required to meet average demand through winter months, and it concludes that these would be far too costly in terms of investment. Even if we could afford these quantities there would still be the problem of gaps in supply due to the intermittency of renewables (including solar thermal; below).

The first part of the paper establishes assumptions, including,

• A 2050 global energy supply target of 1000 EJ/y of primary energy, about twice the present amount, meaning a final energy supply task of about 700 EJ/y.

• A saving of one third of demand by energy conservation, improved efficiency and general technical advance.

• A "safe" greenhouse gas emission rate of 3 GT/y, corresponding to 51 EJ/y of electricity on the assumption that c. 80% of emissions can be captured and geo-sequestered. (However it is likely that it will soon be agreed that by 2050 no emissions at all will be acceptable; See Meinschausen, et al., 2009.)

• Nuclear energy will continue to contribute only 8 EJ/y, for about 80 years, due to scarcity of Uranium.

• Biomass ethanol can be produced on1 billion ha at a rate of 7 tonnes per ha and 7 GJ/t net, meaning a total of 50 EJ/y.

• Hydroelectricity will increase to providing 19 EJ/y.

• Wind can contribute no more than 25% of electricity demand, due to problems of integrating highly intermittent sources into existing grids. (Lenzen, 2009.)

• Solar thermal 'Big Dishes" operating in Central Australian winter DNI of 5.7 kWh/m2/day, (ASRDHB, 2006) at .19 solar to electricity efficiency (Lovegrove, Zawadsky and Coventry, 2004), and storing energy via ammonia dissociation with an efficiency of .7, and losing 15% of electricity in very long distance transition (e,.g., North Africa to the UK) would deliver an average of only 20 W/m2 continuous flow in winter.

• About 60% of transport could be run on electricity, i.e., not trucks, ships and aircraft.

• As only 25% of energy needed is in the form of electricity, and almost all renewable sources, plus nuclear and geo-sequestration provide only electricity, and biomass cannot make up the shortfall, a great deal of energy in non-liquid form would have to be produced by converting electricity to hydrogen, at a quite low energy efficiency. In this discussion .5 efficiency is assumed, although .33 is more plausible, and for some purposes .25 (e.g., wind to wheels, Bossel, 2004)

• The cost of a 1.5 MW wind turbine is $2.25 million, the fully installed cost of 1 square metre of PV panels is $1000 (approx $7/W which Lenzen reports as current average), and the cost of a 400 square metre Big Dish will be $163,000. The cost of the ammonia dissociation plant and storage pipe, and the long distance transmission lines have not been included.

The winter supply task

The focal question in the discussion of a 2050 budget is what amount of alternative generating capacity would be required to meet the 445 EJ/y total final demand (after subtracting 33% for assumed energy conservation/efficiency gains, and 10% of final energy for low temperature heat) for in the period of the year when total renewable supply is most constrained, i.e., for providing 37 EJ/month in winter.

Let us assume a system in which wind and PV sources each contributes 25%, i.e., 9.25 EJ/month, and solar thermal contributes 50%, i.e., 18.5 EJ/month. (Different assumptions are also explored.)

Wind: Although the present world average wind capacity factor is .23 (IPCC, 2007, Section 4.3.3.2), in winter in several European countries it rises to around .38. (Wind Stats, undated.) At this rate a 1.5 MW turbine would generate 1.5 TJ/month (less when down time for repairs is taken into account). Therefore to generate the required 9.25 EJ per winter month 6.17 million turbines would be needed, and the total cost might be in the region of $13.8 trillion.

PV: Even in the most favourable US regions in winter solar radiation on a square metre tilted at latitude is only around 2.8 kWh/m2/day. However in mid European countries it is around .7 kWh/m2/d. (Morrison and Litvak, 1998.) The higher figure will be used here although this invalidates the application of the conclusions arrived at to the European situation.

Assuming a solar to electricity efficiency of 13% and radiation of 2.8 kWh/m2/d, PV systems would generate 41 MJ/m2/month. To provide 9.5 EJ/month 232 billion square metres of PV panels would be needed. At an all-inclusive cost of c. $1000/m2 (approximately the same as Lenzen’s stated $7/W, 2009, p. 111), the cost would be $232 trillion.

Solar thermal: If beam radiation in winter of 5.5 kWh/m2/d is assumed, then given the assumptions made above (i.e., including only the losses quantifiable here), indicating a 21 GJ/month winter output per dish, 896 million dishes comparable to the ANU Big Dish would be required to contribute 18.5 EJ/month. At the estimated present commercial cost of $440,000 per dish (Luzzi, 2000) the total cost would be $394 trillion. On the estimate that future costs will be one-third present costs (Lenzen, 2009) the sum would be in the region of $131 trillion.

The total would be $377 trillion. When averaged over an assumed 25 year plant lifetime this would be 33 times the present amount of world annual energy investment, $450 billion. (Birol, 2003.)   Some analysts asssume 20 year lifetimes for wind and solar thermal systems. (Lenzen, 2009.)

There are several major components of the total energy supply system assumed here whose costs have not been taken into account, in addition to the omitted costs for solar thermal systems mentioned above. These include the embodied energy and dollar costs of the systems for biomass energy production on 1 billion ha, geo-sequestration, nuclear power (equivalent to present capacity), hydroelectricity, long distance transmission lines, low temperature heat collection panels and tanks, the ammonia dissociation plant and storage pipe, and the components of the hydrogen processing equipment, such as electrolysers, compressors and pumps, storage facilities, nation-wide pipeline systems, and equipment for converting stored hydrogen back into useful energy, such as fuel cells. Losses in transmission from distant wind farms or PV power stations have not been taken into account. Nor have operations and management energy costs for the lifetimes of any plant or components within the total energy system been accounted, except for solar thermal. Down time for repairs has not been taken into account for any but solar thermal components. Finally the cost of the coal-fired power stations plus coal capable of providing 51 EJ/y which is 82% of present world electricity generation have not been included. Thus the all-inclusive investment cost would be far higher than the sum arrived at here which deals only with collection costs for wind, PV and solar thermal.

When 8 of these assumptions are set at much more optimistic values the investment multiple is reduced to 5 times current global energy investment. Whether or not a different combination of renewable contributions would significantly alter the general conclusion is explored. The patterns examined include a) wind, the cheapest of the three options, taking 60% of the load, b) wind taking 100% of the the load and converting much output to hydrogen, and c) solar thermal providing 100% of demand. These options do not indicate that the general problem can be eliminated by adjusting assumed contribution proportions.

Most uncertainty in the derivation is to do with the probable solar thermal winter output. If the assumed 20 W/m2 net delivered-at-distance figure is doubled the investment multiple is 12.

The energy target assumed, 1000 EJ/y of primary (700 EJ/y final) would only provide 9 billion people with less than one-third of the energy Australians consume today. In other words if the goal was to provide all people with the consumption levels we are heading for the task for renewables would be about 3.6 times as great as has been taken in this exercise.

This exercise is concerned only with providing the average quantity of energy required through a winter month, and there is in addition the even more difficult problem of constantly maintaining a sufficient supply. From time to time there will be periods of several consecutive days of negligible wind and sun. It is shown that it would be impossibly costly to solve this problem through heat storage capacity.

The numbers assumed and the conclusions arrived at cannot be regarded as at all precise but the magnitude of the investment cost conclusions is very big, especially as many significant cost factors have not been included. The importance of the paper lies mostly in demonstrating an approach to the issue of the potential and limits of renewables and it is hoped that others will apply it. I am working on a similar approach to the Australian situation. Australia probably has greater renewable potential than any other country but preliminary results indicate an investment multiple of around 10 times the present proportion of GDP.

If this argument is valid it reinforces the case that major global problems such as the greenhouse effect, peak oil, energy supply, resource scarcity, Third World “development” and environmental destruction cannot be solved on the supply side, i.e., by finding more resources or moving to alternative technologies. These rapidly worsening problems can only be solved by dramatically reducing consumption. This means consumer-capitalist society cannot be fixed; it must be replaced by what I refer to as The Simpler way. This must involve very low levels of material consumption, mostly small

and highly self-sufficient local economies, designed to meet need and not driven by profit motivation, and with no growth at all. (For the detail see The Simpler Way website, Trainer, 2006, and especially ssis.arts.unsw.edu.au
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