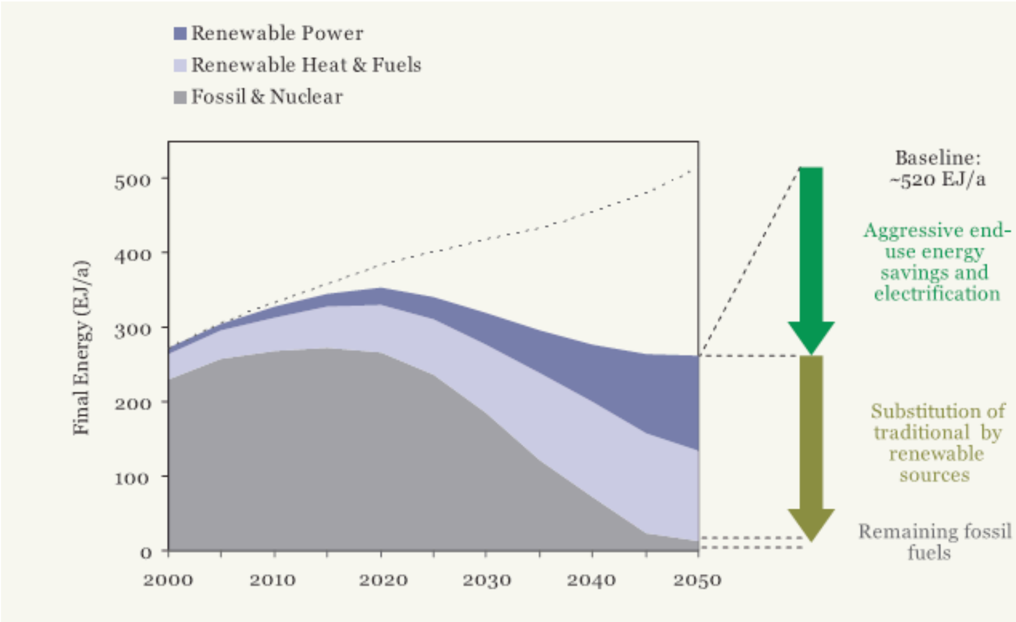

Figure 1
Evolution of energy supply in the Energy Scenario, showing the key developments.
Source: The Ecofys Energy Scenario, December 2010.

The key graph from the WWF report. It projects that the benefits of energy use can be increased by 60% above present levels, thus allowing economic growth to continue, largely as a result of using power more efficiently, while at the same time, a rapid expansion of renewable energy availability will enable fossil fuel use to be almost completely phased out.

A glossy report but of no significant value

Ted Trainer

The WWF's recent publication *The Energy Report* aligns itself with several others that have appeared in recent years (e.g., Zero Carbon Australia, 2010) in confidently claiming that we could transition to full reliance on renewable energy# without any disruption of high material living standards or the pursuit of economic growth. These reports are typically quite impressive involving glossy formats with lots of coloured graphs and pictures, a large cast of heavy-weight authors, and a long list of high-powered endorsements. It is not surprising that the dominant view among officials, people in general, and especially the green movement is that we could run everything on renewable energy sources...while we all go on getting richer and pursuing economic growth.

I have challenged this common belief in various publications over several years, groping towards better ways of assessing it. It is not difficult to put forward a convincing-looking case for the abundant potential of renewables but those I have examined rest on shaky or invalid assumptions and reasoning, and fail to deal with crucial considerations.

Following is a brief indication of the problems evident in *The Energy Report*. In my view the Report is of no significant positive value because in general derivations for its conclusions are not given, making it impossible to check their plausibility, and some crucial counter considerations are not dealt with. Its conclusions are mostly unsupported statements. One cannot see that conclusions follow from assumptions and reasoning that are sound, and some major difficulties and limits are not discussed.

The main problem of this kind is the assumed 2050 global supply target of 250 EJ of final energy. There is considerable agreement that we are heading towards a primary consumption rate of 1000-1100 EJ, and a final amount around 700 -770 EJ/y. If we assume conservation and saving effort plus better technology will cut this by one-third the figure becomes 520 EJ/y, twice the *Energy Report* target. The difference seems to be due mainly to the *Energy Report's* much greater assumed savings achievable by conservation effort and technical advance. It is important therefore to consider in some detail this general issue of how large the reductions are likely to be.

<u>Reductions due to conservation effort and technical advance.</u>

It does not seem to be possible to be at all confident regarding the amount we can cut off energy demand through greater conservation, saving and technical improvement effort. My search for evidence and estimates indicates little certainty and widely varying estimates and guesses. In addition the field is fraught with traps for the unwary.

The *Report's* values are summarised in Fig. 3 – 4, p. 135, where 50 – 75% reductions are listed, including 75% reductions for passenger vehicles and for buildings. Little or no evidence is given for these values, although several are common in the literature. The main case seems to be the stated assumption that required energy will decline by 2% p.a. This is not an acceptable way to proceed; there is no good reason to assume that even if this rate characterises the recent past it will continue, for 40 years, and there are reasons for thinking it will not. (I am expecting to hold the world high jump record soon. All I have to do is go on improving my present 1.2 m performance by 2% per week.)

The Report says that by 2050 world transport will treble but energy use will go from the present 80 EJ/y to 65 EJ/y(3 – 17.). This is to claim that for all travel, not just passenger cars, the reduction can be to about 25% of present amount of energy per unit of travel. (Changes in "mode", e.g., from car to bike, are also assumed.)

Following are factors which must be taken into account when making claims about the reductions conservation effort and technical advance might make. Engineers and economists make the following distinctions.

1. "<u>Technical potential</u>." This is what a technology could achieve if fully applied with no regard to cost or other problems.

2. "<u>Economic (or ecological) potential</u>". This is usually much less than the technical potential because to achieve all the gains that are technically

possible would cost too much. For instance it is technically possible for passenger flights to be faster than sound, but it is far too costly to become common. It would be technically possible to recycle almost all lead used, but it would be much too costly in dollars and inconvenience to do so. Some estimate that it would be technically possible to harvest 1,400 million ha for biomass energy per year, but the *Energy Report* itself concludes that when ecologically sensitive regions are taken out the yield might only be 250 million ha. (p. 181.) The Report refers to the Smeets (2008) finding that it would be technically possible for the world's forests to produce another 64 EJ/y of biomass energy p.a., but that the ecologically tolerable potential is only 8 EJ/y. (p. 181.)

3. Net effects must be derived. It can cost resources and energy to achieve a technically possible gain or saving. Following is an indication of the difference a thorough accounting might make in the case of car. The *Report* makes the common claim that electric cars are four times as efficient as petrol driven cars. This seems to be misleading because it doesn't take into account several relevant factors. It seems to be a valid statement re the amount of energy in a petrol tank or battery needed to put a unit of energy through wheels, but a full accounting would include:

- The weight and size differences. The average petrol driven car might get 9 km per litre, but it will be 3-4 times the weight and internal space of a typical electric car. Size and weight cab be important for security in crashes.

- The loss of energy getting energy to the vehicle. The energy-return for petrol is quite high; only a small amount of energy is needed to produce it and to get the petrol to the service station and the petrol tank. For electric cars the amount is much higher. Large scale renewable systems will probably have to depend heavily on solar thermal farms thousands of km from users, meaning considerable embodied energy costs in building the plant (maybe 10% of energy produced in its lifetime), and maybe 15% energy lost in the long distance transmission and city reticulation.

- Losses at the tank or battery. For petrol cars there is no loss in filling the tank, leaving petrol in the tank, or drawing petrol out. However to charge a battery and get energy out again will involve a 30-40% loss of energy, and there will be a further slight loss as the battery stands idle.

- Replacement of the tank or battery. Petrol tanks do not deteriorate significantly and do not have to be replaced during the life of the car. Smil (2010) says Lithium-ion batteries last only 3 years, less in hot conditions, and a new set will cost $35,000. If this is so then in effect you will have to pay as much as would buy you two new small cars every three years. More important here is the embodied energy cost of a battery, containing fairly scarce Lithium. A minor consideration would be deterioration in battery performance as it approaches the end of its life, meaning less efficiency and more energy needed to charge it.

- What will be the energy cost of producing and recycling the special plastics from which the new light bodies of electric vehicles are made, compared with the costs for metals etc? Mateja (2000) claims these costs are high. Plastics in general take maybe 4+ times as much energy to make than steel, tend to be difficult to recycle, and to be made from petroleum.

If all these factors could be quantified and taken into account, especially those to do with the batteries, the net lifetime energy efficiency of an electric car might be no better than that of a modern diesel.

A similar analysis could be given for the common claim, which the *Energy Report* makes, that energy used in buildings could be cut by 75%. The *Report's* Figs. 3 – 11 and 3 – 12 show that although their measures would reduce heat used in buildings by 90%, electricity used would increase c. 50%. In addition there is no reference to what the embodied energy cost of manufacturing the equipment, triple glazing, heat pumps and insulation might be. It is not clear that the graphs show any net reduction in building energy use.

4. What is socially/politically possible? Then there are limits on what can be achieved that are set by what people will accept. It would be technically possible for many people in Sydney to get to work by public transport, but large numbers would not give up the convenience of their cars even if they saved money doing so. The energy efficiency of American cars is much lower than what is technically possible, and in fact lower than it was decades ago ... because many people want big energy-intensive vehicles. Australians are now building the biggest and most energy-wasteful houses in the world. A beautiful, tiny, sufficient mud brick house could be built for less than $10,000 (Trainer, 2010)...but most people would not want one. These examples make it clear that the problems of over-consumption in many realms are mainly social rather than technical problems, and that they can't be solved by technical advance.

5. The Jeavons or "rebound" effect. Finally there is the strong tendency for savings made possible by a technical advance to be spent on consuming more of the thing saved or something else. For instance if we found how to get

twice the mileage per litre of petrol many would just drive a lot more, or spend the money saved on buying more of something else.

It should be clear therefore that it is not satisfactory for the Report to proceed on largely unsupported and unexamined gross claims of the kind set out in Table 3 - 11. These values can commonly be found in the literature, but their significance always needs to be carefully assessed. In my view the above considerations mean that the actual net reductions likely to be achieved will be far less than those commonly stated and assumed, and that in the coming era when the energy and dollar costs of doing everything are likely to rise significantly, the 33% general reduction I assume could turn out to be much too optimistic.

The integration problem.

Without a satisfactory way of storing electricity in very large quantities the intermittency of solar and wind energy sets severe limits on the proportion of total demand they can contribute. What are we to do when winter calms set in across the whole of Europe for a week? If the answer is draw on solar thermal farms in North Africa then to start with this sets a huge redundancy problem. It means having to build enough solar thermal plant to substitute for all the wind and PV plant, only to have much of it sit idle most of the time. The Report does not recognise this redundancy problem, apart from suggesting that biomass would plug the gaps. If it is assumed that biomass will come to the rescue when wind and sun are down, is it realised that this might mean building enough biomass generating plant to meet total demand at some times?

Generation of electricity from biomass is likely to have a significantly lower overall efficiency than generation from coal, due to the need to locate plant relatively close to forests because transporting the bulky low-density biomass is costly, and the need to dry it. These factors impose dollar and energy costs. (El Bassam , 1998, states efficiencies under 30% and down to 5% for small plant, and says US average plant efficiency is only 18%.)

The Report assumes that wind can come to supply 60% of electricity demand, again with little or no discussion or support. (Three references are given.) Lenzen's recent review of renewable states that the limit is 25%. (2009.) The limit for PV is likely to be less than for wind (for the reasoning see Trainer, 2009.) The report briefly refers to grid improvements and pumped and hydrogen storage. The development of "smart grids" can't make much difference; the only thing that could would be the advent of very large scale storage but at present there are not good reasons for thinking it will become available. The best way to store is via pumped hydro, but the potential capacity for this is far below what would be needed. Hydro provides only about 7% of Australian electricity, and few of the dams could be fitted for pumped storage. Mackay (2008) gives a convincing numerical demonstration that it can't solve the UK wind gap problem, despite much higher rainfall than Australia has. (On the reasons why the problem is not likely to be solved by use of electric vehicle batteries see Trainer, 2009.)

Biomass.

The *Report's* discussion of biomass energy is much more satisfactory, being based on a considerable amount of evidence and references, and for the most part it seem to me its conclusions could be sound. It concludes that an additional 250 million ha can be put into biomass energy production. Estimates of the area that could be used vary greatly, from c 1.4 billion ha (Hoogwijck, et al., 2009, Smeets and Faaij, 2007) down to a small fraction of the Energy Report's figure, so it is not unusually high. However it can be argued that no land should be used for biomass energy production. Patzak argues that any such use will deplete soils over time. There is also a significant problem of water demand. More worrying I think is the impact on biodiversity. The holocaust of extinction we are causing is due primarily to the taking of so much habitat by humans. We should be returning very large areas to natural forest etc., not contemplating the taking of more.

The winter problem.

The report does not discuss the problem of meeting demand in winter, the time of the year when demand is often significantly higher than average and when solar resources are significantly lower than average.

The Report does not recognise that it is a mistake to focus on average demand, output and renewable resources when discussing renewables. What matters are the peak demands and the minima in source availability. Coal-fired systems include 30-50% more generating capacity than is needed to meet average demand, in order to meet peak demand. NASA climate data shows that even at good solar thermal sites Direct Normal Irradiation can be 40% below the mid winter monthly average. If you want enough plant to meet a peak demand when DNI is that low then you will probably have to build twice as much plant as a consideration of average demand and resources would indicate. (In addition average winter demand is usually higher than average annual demand.)

The "fractions of annual demand" trap.

A common mistake, which Stern made, is to assume that because wind for instance is to provide 8% of total annual energy supply (62 EJ/y by 2030), then we will need only enough wind plant to generate 62 EJ in a year. At 1.5 MW turbine operating at .33 average efficiency will generate 15.8 TJ/y, so it might seem that we'd need 4 million of them. But this fails to recognise that there will be times when there is little or no sun shining on your continent and then you will then need sufficient wind (and/or solar thermal) plant to meet far more than 8% of demand.

ZCA (2010) makes the same mistake re biomass, assuming that it will only need to supply a small proportion of total annual demand and drawing the conclusion that therefore only a small number of biomass generating plants will be needed, when in fact there will be times when almost all electricity demand would have to come from biomass. Thus capital costs in a system requiring such large amounts of redundancy would be far greater than is indicated by attending to fractions of total annual demand to be met by the various sources.

A quite different analysis.

Trainer (2010a) offers an approach to the estimation of plant quantities and costs that would be required to enable 2050 world energy demand to be met by renewable sources (plus 8 EJ/y nuclear, 50 EJ/y biomass and 96 EJ/y from Coal with CCS.) The plant costs used for solar thermal were those the (unsatisfactory) literature estimates for future systems. (The assumptions and the arithmetic is set out in the paper enabling the derivation of its conclusions to be evaluated.) The conclusion arrived at is that the amount of solar thermal, wind and PV plant needed would cost about 10% of 2050 world GDP assuming 3% p.a. growth until then. This would be 14 times the present fraction of world GDP that is invested in energy supply (i.e. plant building, as distinct from purchasing energy.) The Energy Report's conclusion is that the average investment sum to 2050 would be only 1.17% of world GDP. (Fig. 6 – 5.)

Note that this amount of generating capacity would provide a world of 9 billion with an average of 77 GJ per person, probably around one-fifth of the amount Australians are heading for by 2050. In other words if the target had been to provide all people with the energy consumption the rich countries are heading for in 2050 the supply target, and the capital cost, would have been five times as great.

The exercise did not take into account several large factors that would add greatly to the investment cost, including the cost of the hydro, nuclear, biomass and coal-fired power generators, the CCS system, the long distance transmission lines from huge desert solar thermal farms, the biomass production and supply system, and the cost of providing 100 EJ/y of low temperature space and water heat. Including these would probably more than double the cost conclusion stated above.

The coal plus CCS component assumed would be generating 1.5 times present world electricity output, and consuming 12 billion tonnes of coal p.a., meaning probable exhaustion of world coal resources in two decades. However when the IPCC takes feedback loops into account, e.g., warming of tundra releasing methane, the consensus is likely to be that no emissions will be tolerable, meaning that the 96 EJ/y attributed to this component in the exercise would have to be added to the tasks for the sun and the wind, increasing their capital costs accordingly.

Also note that the exercise estimated quantities required to meet average winter monthly demand and as has been explained far more capacity would be needed to cope with the coincidence of above average demand and below average wind or solar conditions.

Had all these additional factors been taken into account the resulting investment figure arrived at would probably have been three times that arrived at.

The *Report* concludes that under its provisions 2050 global average per capita energy use will be a mere 28 GJ/person. It is difficult to understand this given that the Australian average now is c. 290 GJ/y, and we are heading towards 400-500 GJ/y. That means the *Report* is claiming that affluent "living standards" can be provided to all, in a world with 3.4 times the present global GDP (ER, p. 121), on a per capita energy budget that is one-tenth of the present Australian amount...and that there will be no need to question continued growth of economic output and consumption. (ER, p.116.)

The energy budgeting exercise summarised above is crude and its numerical conclusions are not offered with confidence. However it is the kind of visible, numerical analysis that is needed to clarify the potential and the limits to renewables. It was not possible to ground the exercise confidently on reliable data (renewable generators usually do not make their performance data publicly available) but the assumptions made in the study would have to be grossly mistaken before the general significance of its conclusion was invalidated.

Conclusions

In my view the *Energy Report* does not provide a satisfactory analysis of the issue. It fails to defend assumptions adequately and it omits discussion of crucial issues. To put it mildly, its general conclusion is not established at all persuasively. More importantly, the *Report* appears to provide yet more proof that renewable can save energy-intensive and growth obsessed societies. It therefore helps to ensure that thought will not be given to the possibility that sustainability cannot be achieved unless there is dramatic reduction in levels of production, consumption, affluence and GDP, and therefore unless there is extremely radical social change, including the abandonment of growth economies.

The Simpler Way perspective on the global situation argues that the many alarming problems confronting us are primarily due to over-production and over-consumption. Energy shortage is only one of these problems so even if renewables could solve it we would still have huge environmental, resource, Third World, conflict, justice, social cohesion and quality of life problems, all being exacerbated by the impossible quest for limitless increase in affluence and GDP, when we are already far past sustainable limits. *The Simpler Way* project seeks to show that all these problems can only be defused by action on the demand side, that is by shifting to values, ways, institutions and systems which allow us to live well in zero-growth economies not driven by market forces and profit and the quest for limitlessly increasing material "living standards". The vision is detailed in Trainer (2010b), and The Simpler Way website, http://ssis.arts.unsw.edu.au/tsw .

Coelingh, J. P., (1999), Geographical dispersion of wind power output in Ireland, Ecofys, P.O. Box 8408, NL – 3503 RK Utrecht, The Netherlands. www.ecofys.com.

El Bassam, N, (1998), Energy Plant Species; their Use and Impact on Environment and Development, James and James, London.

E.On Netz, (2004), Wind Report 2004, http://www.eon-netz.com

http://www.nowhinashwindfarm.co.uk/EON_Netz_Windreport_e_eng.pdf

Hoogwijk, M., A.Faaij, B. Eikhaut, B. de Vries, and W. Tuckenberg, (2009), "Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios", Biomass and Bioenergy, 29, 4, Oct., 225 – 257.

Lenzen, M., (2009), Current State of Electricity Generating Technologies, Integrated Sustainability Analysis, The University of Sydney.

Mackay, D., 2008, Energy – without the Hot Air. http://www.withouthotair.com/download.html

Mateja, D., (2000), "Hybrids aren't so green after all', www.usnews.com/usnews/biztech/articles/060331/31hybrids.htm

Sharman, H., 2005b, 'Why UK power should not exceed 10 GW' ,Civil Engineering, 158, Nov., pp. 161 - 169.

Smeets, E., and A. Faaij, (2007), "Bioenergy potentials from forestry in 2050 -- An assessment of the drivers that determine the potentials", Climatic Change, 8, 353 – 390.

Smil, V, (2010), Energy Myths and Realities, The AEI Press, Washington, D.C.

Stern, N., (2006), Review on the Economics of Climate Change, H.M.Treasury, UK, Oct. http://www.sternreview.org.uk

Trainer, T., (2008), "Renewable energy – cannot sustain an energy-intensive society", http://ssis.arts.unsw.edu.au/tsw/RE.html

Trainer, T., (2010a), "Can renewables etc. solve the greenhouse problem? The negative case", Energy Policy, 38, 8, August, 4107 - 4114. http://dx.doi.org/10.1016/j.enpol.2010.03.037

Trainer, T., (2010b), Transition: Getting To A Sustainable and Just World. Sydney, Envirobook.

Trainer, T., (2010a), "Can renewables etc. solve the greenhouse problem? The negative case", Energy Policy, 38, 8, August, 4107 - 4114. http://dx.doi.org/10.1016/j.enpol.2010.03.037

Trainer, T., (2010b), The Transition To A Sustainable and Just World. Sydney, Envirobook.

Zero Carbon Australia, (2010), A Sustainable Energy Zero Caron Australia, Energy Research institute, Melbourne University.