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Can Australia run on renewable energy? The negative case

Ted Trainer*

Faculty of Arts, University of New South Wales, Australia

HIGHLIGHTS

- ▸ The capacity of renewable energy to meet Australia's probable 2050 demand is assessed.
- ▸ Assumptions re output and capital cost for wind, PV, biomass and solar thermal are established.
- ▸ Capacity to cope with energy storage, intermittency, storage and redundancy is estimated.
- ▸ A total 2050 capital cost is derived.
- ▸ It is concluded that the capital cost would be unaffordable.

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ABSTRACT

The current discussion of climate change and energy problems is generally based on the assumption that technical solutions are possible and that the task is essentially to determine the most effective ways. This view relies heavily on the expectation that renewable energy sources can be substituted for fossil fuels. Australia is more favourably situated regarding renewable sources than almost any other country. This discussion attempts to estimate the investment cost that would be involved in deriving Australia's total energy supply from renewable sources. When provision is made for intermittency and plant redundancy it is concluded that the total investment cost is likely to be unaffordable.

0. Introduction

It is often assumed that greenhouse and energy problems can be solved by intensified conservation and efficiency effort along with a transition from fossil fuels to renewable energy sources. In addition Stern (2006) and others (e.g., Jacobson and Dellucci, 2011) assert that the cost will be easily afforded.

Trainer (2010a) explores the possibility of meeting a probable global 2050 primary "business as usual" energy demand of 1000 EJ/y within "safe" greenhouse gas emission limits. The approach is to estimate the amount of renewable capacity that would be required to meet demand in winter. The conclusion is that the average winter monthly quantity could not be provided at an affordable investment cost. The present study applies this approach to the Australian situation, using more confident data on possible systems and costs.

Australia probably has the most favourable global physical conditions for maximising reliance on renewable energy sources and there are strong claims that Australia could run on renewables (E.g., Diesendorf, 2007; Eliston, 2012; Wright and Hearps, 2010).

Little attention has been given to the critical assessment of the potential and the limits of renewable energy. (Trainer, 2007 attempted a critical overview, and an updated summary is given in Trainer 2011a). The approach taken in this discussion follows that in Trainer (2010a), by exploring a probable 2050 Australian energy supply target that might be met by a combination of energy conservation and renewable energy. After establishing working assumptions, two critical issues are discussed, firstly to do with whether the quantities of alternative energy producing plant required to meet average demand can be afforded and secondly to do with the implications of solar and wind variability for plant quantities and total system capital costs.

1. Assumptions

The main purpose of this analysis is to indicate the value of the approach taken to the derivation of an energy budget, so that future studies can refine this when better data becomes available. The assumptions and derivations are transparent enabling the exercise to be reworked using other assumptions.

1.1. The probable 2050 energy target

Australian Bureau of Agricultural Economics (ABARE, 2009) estimates that Australian primary energy demand in 2008 was 5.9 EJ/y, increasing at about 2.5% p.a. ABARE expects the rate of

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* Tel.: +61 2 93851871; fax: +61 2 96628991.
E-mail address: F.Trainer@unsw.edu.au

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increase to fall to 1.9% p.a. by 2030. A rate of 2.1% p.a. will be assumed here for the 2009–2050 period, i.e., a 33 year doubling period. Thus an Australian 2050 "business-as-usual" primary demand of 13 EJ/y will be tentatively assumed for working purposes.

Moriarty and Honery (2009) report that the ratio of final to primary energy is .69. The 2050 target will therefore be taken as delivering 8.97 EJ/y of final energy. It will be assumed that 2050 "business as usual" energy consumption in the electricity and transport sectors will be the same proportions of projected final energy as they are now in Australia, i.e., 21% (i.e., 1.884 EJ/y) and 33% (i.e., 2.96 EJ/y) respectively (ABARE, 2007).

Of course given the uncertain period we seem to be entering regarding climatic conditions, economic stability, and resource availability and especially regarding the acceptability of fossil fuel use, it is quite conceivable that by 2050 demand will be far below the assumed figure. However it is suggested that the figure taken represents a useful benchmark enabling exploration of the implications of other assumptions and scenarios.

1.2. Transmission losses

Very large scale production of renewable energy, especially via solar thermal and PV farms located at the most favourable regions, will involve long distance transmission. European supply from solar thermal fields will probably have to come via several thousand kilometre long HVDC lines from North Africa and the Middle East. Losses in the vicinity of 15% are likely, along with another c. 7% for local distribution. (Mackay, 2008; Czisch, 2004; Breyer and Knies, 2009; NEEDS, 2008; Ummel and Wheeler, 2008; Jacobson and Dellucci, 2011, pp. 1183–4).

The best Australian supply regions for solar thermal electricity are in Central Australia and these will be crucial for winter supply. It will be assumed that average losses from long distance plus local distribution will be 15%.

1.3. Embodied energy costs

From the gross output figures for a renewable energy device the amount of energy needed to produce the device should be deducted. Clear and confident figures are elusive, partly due to the difficulty of setting "boundaries" regarding which costs are to be included. More importantly, few estimates take into account all "upstream" costs, e.g., the energy needed to produce the steel works that produced the steel used in solar thermal plant construction. These factors can greatly increase cost conclusions. (Lenzen, 2009,1999, p. 359; Dey and Lenzen, 1999; Lenzen and Treloar, 2003; Lenzen and Munksgaard, 2001). Lenzen (2008) derives an all-inclusive embodied cost of 6.6% for wind, and 33% for PV (See also Lenzen et al., 2006). Hall and Pietro (2011), state an even higher figure for PV located in Spain, and Crawford (2011,2012) finds that the all-inclusive PV figure can reach 50%. However the wind assumption made here is 4% and the PV assumption is only 15%.

The situation regarding solar thermal plant is more uncertain. The relatively few studies have indicated a 1–11% cost but assumptions have varied considerably. (Dey and Lenzen, 1999, p. 359; Weinrebe et al., 2008; Norton, 1999; Vant-Hull, 2006; Kaneff, 1991; Lechon et al., 2006; Lenzen, 2009, p. 117). No study taking into account all upstream factors seems to have been carried out (Lenzen, 2012; Crawford, 2012). The unsettled state of this field prohibits the confident assumption of a value for this discussion. A 10% cost will be assumed.

These three assumed values are regarded as probably being too low. However in view of the magnitude of the capital cost conclusion arrived at below it will be seen that even much lower figures would not invalidate that conclusion.

1.4. PV

If 15% efficient PV panels in large power stations are assumed to be located in Central Australia where total global solar radiation in winter is 7 kWh/m^2/day on average (ASRDHB, 2006), then the electricity produced would be 1.05 kWh/m^2/day, corresponding to a continual 24 h flow of 44 W/m^2. After deducting transmission losses and the above embodied energy costs a net 32 W/m^2 would be delivered at distance.

Tracking systems and concentrating PV systems would achieve higher efficiencies, but at higher capital costs. The accounting methodology followed below enables other analyses to estimate the effect of such assumptions.

1.5. Biomass

Large scale supply of liquid fuel from biomass will have to come mostly from celulosic inputs produced by forest plantations. Probable crop and municipal waste inputs in Australia are only a small fraction of potential plantation quantities (Wood et al., 2012, Ch. 8, p. 4). Diesendorf (2007, p. 43) reports an estimate of potential Australian crop waste bio-energy inputs at 8% of total biomass energy potential, on the assumption that it is acceptable to leave 1 t/ha in the fields.

The extent to which biomass could and should be used for energy production is controversial. The main cause of the serious biodiversity crisis occurring is the amount of natural habitat that humans have taken, indicating that large areas should be returned to nature rather than put into biomass-energy production.

When the harvested crop mass is added to the above rate of "waste" at least 80% of biomass growth would not be being returned to the soil. Pimentel and Pimentel (1997, p. 241) argue that no material should be removed for long term sustainability of soil carbon levels. This is also the reason why Patzek (2007, p. 21) challenges the viability of biomass energy production. He reports on marked long term carbon loss in rich world soils and argues that in the long term no net loss of biomass is possible without decline in NPP.

In the coming era of probably severely limited availability of petroleum and fertilizers it is likely that agriculture will have to focus more intensively on the organic factors contributing to yields, as distinct from external and artificial inputs, meaning that maximum retention of soil carbon and therefore maximum recycling of crop "wastes" is likely to become crucial.

Haberl et al. (2012) point out that over the long term using biomass for energy production means that half its carbon content is in the atmosphere, whereas all of it could have been left locked up in the unharvested biomass. Crutzen et al. (2008) find that nitrogen release from biomass-energy production could actually outweight the gain re greenhouse gas effects achieved by replacing fossil fuel use.

Unfortunately estimates of land areas that could be devoted to biomass energy production vary greatly, are often questionable and do not enable confident conclusions. The highly unsettled state of the field is often noted (Farine et al., 2011; IPCC, 2011; Harvey, 2010; World Wildlife, 2010) and is evident in the range of estimates given. For example, Smeets and Faaij (2007), arrive at 1500 EJ/y whereas at the other extreme Field et al. (2007) conclude that when social, economic, moral/justice and ecological considerations are taken into account the figure is only 27 EJ/y. An examination of such analyses reveals the large difference there can be between "theoretical potential" and plausible harvest in view of all combined limiting factors.

Although Australia is much more favourably situated regarding potential biomass energy resources than most countries, having around five times the world average amount of productive