Energy Policy 109 (2017) 539–544

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

'Can renewables meet total Australian energy demand: A "disaggregated" approach

Ted Trainer[1]

ARTICLE INFO

Keywords:
Renewable energy limits

ABSTRACT

Attempts to assess the possibility of deriving all energy from renewable sources typically deal only with the aggregate amount of energy required, and do not consider the implications and difficulties arising from the need for differing forms of energy. In a 100% renewable system some of these forms will have to be provided by conversion from others, mostly from electricity. Conversion involves inefficiencies, losses, and embedded energy costs of infrastructures, and thus energy and dollar costs. In this study an attempt has been made to determine the magnitude and effect of this general problem, by beginning with estimates of the quantities required by different sectors and of the different forms they use. How these needs might best be met in a renewable system is then considered. Although there is insufficient data to enable confident conclusions, this "disaggregated" approach indicates that a 100% renewable system to meet Australian energy demand would involve costs that would probably constitute an unacceptably large fraction of GDP.

1. Introduction

The recent simulations of a 100% renewable power supply system for Australia by Elliston et al. (2012, 2013) and by Lenzen et al. (2016) have significantly advanced understanding of the feasibility and cost of such a scenario. However at present electricity makes up less than 20% of total Australian energy demand in a rich country, and it is the form most easily provided by renewables. Biomass is the only renewable form that does not directly produce electricity. To provide all forms of energy needed (e.g., liquid fuel) from renewables would be a much more difficult task than simply scaling up the power supply system by a factor of five. This is mainly because most of the remaining 80% of energy needed sets problems to do with a) the nature and number of these other uses and forms, and b) costs and losses in switching uses to electricity c) the amount that cannot conveniently be switched, and d) the energy and dollar costs of converting electricity or biomass into these more difficult forms (e.g., hydrogen).

2. Method

To analyse the situation satisfactorily we would need to have confident answers to several unsettled questions, such as, what quantities of what kinds of energy are currently needed in the total energy budget, how much liquid fuel is needed for what purposes, and to what extent can electricity replace each of these. How might trucks, ships, aircraft, remote mines etc. be run? How much demand could be met by available biomass in an ecologically sustainable way? How much demand could not be shifted to electricity or available biomass and what transformations of electricity (e.g., to hydrogen) might be feasible, in what quantities and at what efficiencies and costs.

Unfortunately there is little information on several of these issues, especially the quantities of demand in the sectors other than power and transport. Therefore the following exploration is offered as uncertain and indicative only, but it does provide strong reasons for thinking that achieving a 100% renewable system will at best be very difficult and costly, and possibly unaffordable.

It is hoped that the approach being taken here will be followed by more thorough future studies. It might be regarded as a"disaggregated" approach as it does not work with a simple total energy figure but attempts to estimate what quantities of energy in what forms might be needed in Australia by 2050. A number of previous approaches to the issue of 100% renewable supply have given little or no attention to the significance of the differing forms needed. (For instance, Greenpeace, 2015, The Greens, 2016, Teske et al., 2016.) It will be seen below that significant difficulties and costs emerge when it is recognized that there is a need for much energy in forms that are not easily provided by renewable energy sources.

3. Data

Following is a summary of the data used and assumptions made regarding forms and quantities needed in the Australian economy by 2050, followed by derivations based on these. Almost all arithmetic is set out, possibly complicating the text but enabling all assumptions and

[1] No institution; retired lecturer at University of NSW.

http://dx.doi.org/10.1016/j.enpol.2017.07.040
Received 18 April 2017; Received in revised form 14 July 2017; Accepted 17 July 2017

Table 1
Quantities assumed.

Final Australian energy consumption, 2015,	4130 PJ.
Electricity, 20% of final,	810 PJ
Transport, 39% of final,	1603 PJ
Population in 2050, c. 42 million, 1.82 times present. (ABS, 2012.)	

derivations to be transparent and capable of independent critical reassessment.

3.1. Estimating a 2050 Australian total energy budget

The 2050 "business as usual" (BAU) demand cannot be estimated with confidence. Australian power demanded from the grid declined in the 2010–2014 period, but this has been partly due to the lingering post GFC recession, the closure of some larger scale industrial power users, steeply rising electricity prices, and to the rapid uptake of rooftop PV. More recently demand has begun to increase again. The approach here is to consider what 2050 demand would be given continuation of the longer term BAU trend, then add the effect of various factors such as a shift to electric vehicles. It will be assumed that BAU demand will increase in proportional to population, and thus be 7520 PJ. There is reason to think this could be an underestimate because since 1974 energy consumption has shown a smooth increase that has been faster than population growth. Again this assumption is quite uncertain and the implications of taking a much lower 2050 BAU target will be discussed later (Table 1).

Also highly uncertain is the likely effect of energy conservation effort. There is considerable scope for this and quite optimistic possible reductions are often claimed. However there seem to be few if any numerically based technical estimates of whole system savings (as distinct from discussions of specific areas in which spectacular achievements are likely to be made; Amory Lovins' works provide many of these, e.g. Lovins and Von Weisacher, 1997, Lovins, 2011.) The possible effect of this conservation factor will be considered later, and brief reference will be made to the many factors likely to increase energy demand and to overwhelm reduction achievements.

Thus 2050 final BAU energy demand will be taken as,

Electricity,	1472 PJ
Transport,	2917 PJ
Remainder	3131 PJ
Total	7520 PJ

3.1.1. Electricity provision

It will be assumed that 94% of electricity can be provided by wind, solar and hydro, plus 6% from biomass used for back up purposes. These figures are drawn from the simulations by Elliston et al. (2012, 2013) which assume up to 58% of electricity can come from wind. They are quite optimistic assumptions for wind and solar; others point to evidence of increasing difficulties and costs where wind contributes more than 30% of supply (Lenzen et al., 2016, refer to several studies making this point.) The biomass quantity is less challengeable, but is in the region of one-third of the amount found to be needed in the "real-world probable" scenario discussed by Lenzen et al. This means that the assumption made in this analysis leaves much more biomass available for use in meeting liquid fuel demand than might be realistic.

The Australian Energy Market Operator (Crawford et al., 2013) estimates that Australia could harvest c. 96 million tonnes p.a. for biomass energy, i.e., 1728 PJ/y, including municipal wastes. These figures are likely to be considerably too high as AEMO notes that they do not include energy costs for biomass production and transport, nor any embodied energy costs in plant, trucks etc. Farine et al. (2012) arrived at a figure around half as large. However Foran (2008) assumes much greater amounts could be provided (…considered again below.) It will be assumed here that a net amount of about 1600 PJ can be provided. Thus after backing up power (at c. 26% conversion efficiency; Crawford et al., 2013), about 1260 PJ of biomass would be left. (A larger assumption will be considered below.)

The amount of electricity to be generated from non-biomass sources is therefore 94% of 1472 PJ = 1384 PJ.

3.1.2. Transport energy provision

It will be assumed that a) all passenger vehicles can be electric, doubling energy efficiency (not trebling, in view of the high embodied energy cost of EVs (Sharma et al., 2013; Mateja, 2000), b) that electricity, ethanol and hydrogen can each power one third of light trucks, and c) half of heavy trucks run on ethanol and half on hydrogen. (Friedmann, 2016; and Bossel, 2004, below, explain the reasons for not assuming heavy truck transport based on electricity or hydrogen.) Transfer of much freight to rail is not accounted here; it would reduce heavy truck use but would greatly increase light truck use for distribution from rail heads. Air transport will be assumed to be fuelled by ethanol. No figures for shipping are included although the amount involved in the Australian economy would be significant. Almost all vessels carrying imports and exports to Australia are foreign owned so fuel quantities are not recorded in Australian accounts. In a 100% renewable world shipping fuel would have to be liquid or hydrogen etc., not electrical, so production from renewable sources would be problematic, given the scarcity of biomass.

From above the amount of transport energy required in 2050 would be 2917 PJ.

The breakdown of present amounts and proportions, (from Australian Bureau of Statistics, 2014), would be:

Road. 73% of transport energy, i.e.,				2129 PJ
Passenger,		58%	of transport energy	1235 PJ
Light trucks	17%		" " "	362 PJ
Heavy trucks	22%		" " "	468 PJ
Other	3%		" " "	64 PJ
Rail. 3% of transport energy, i.e.,				87 PJ
Air. 19+% of transport energy, i.e.,				**554** PJ
N.e.i. 4% of transport energy.				120 PJ

Amounts and forms of transport energy required in 2050:

Passenger vehicles: 1235 PJ needed if BAU. It will be assumed all are electric vehicles, but at only double present energy efficiency, not treble (see above), therefore 617 PJ of electricity would be needed.

Light trucks: 362 PJ needed if BAU. Some trucks for light deliveries can be electric vehicles, but some for heavy distribution would have to be hydrogen or biomass-ethanol. It will be assumed one third each will be fuelled by electricity, hydrogen and biomass ethanol, therefore the need will be for 120 PJ of hydrogen and of biomass ethanol and 60 PJ electricity for EV light trucks. (This unrealistically assumes light trucks would use no more energy than passenger vehicles. It is assumed that short distances would enable frequent refueling by hydrogen, and thus avoidance of heavy tanks.)

Heavy trucks: Under the BAU assumption 468 PJ would be needed. Friedmann (2016) and Bossel (2004) detail the reasons why they are not likely to be ERVs or fuelled by hydrogen. Very large and heavy tanks would be necessary to store sufficient compressed hydrogen for long distance transport meaning that the net freight weight that could be moved long distances would be quite low. In addition the equipment needed to produce, compress, store and distribute hydrogen would significantly reduce net energy delivered. Finally the efficiency of the electricity-hydrogen-fuel cell path would be in the region of 30%. Therefore it will be assumed that the 468 PJ needed would have to be biomass ethanol.