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Comparing least cost scenarios for 100% renewable electricity with low emission fossil fuel scenarios in the Australian National Electricity Market

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ABSTRACT

Policy makers face difficult choices in planning to decarbonise their electricity industries in the face of significant technology and economic uncertainties. To this end we compare the projected costs in 2030 of one medium-carbon and two low-carbon fossil fuel scenarios for the Australian National Electricity Market (NEM) against the costs of a previously published scenario for 100% renewable electricity in 2030. The three new fossil fuel scenarios, based on the least cost mix of baseload and peak load power stations in 2010, are: (i) a medium-carbon scenario utilising only gas-fired combined cycle gas turbines (CCGTs) and open cycle gas turbines (OCGTs); (ii) coal with carbon capture and storage (CCS) plus peak load OCGT; and (iii) gas-fired CCGT with CCS plus peak load OCGT. We perform sensitivity analyses of the results to future carbon prices, gas prices, and CO_2 transportation and storage costs which appear likely to be high in most of Australia. We find that only under a few, and seemingly unlikely, combinations of costs can any of the fossil fuel scenarios compete economically with 100% renewable electricity in a carbon constrained world. Our findings suggest that policies pursuing very high penetrations of renewable electricity based on commercially available technology offer a cost effective and low risk way to dramatically cut emissions in the electricity sector.

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1. Introduction

There is a growing recognition of the urgency for large, rapid and sustained emissions reductions to avoid dangerous global warming. Achieving deep cuts to greenhouse gas emissions in some sectors (e.g., transportation, agriculture) is likely to be more difficult than the electricity sector. The Australian Government has a policy to reduce greenhouse gas emissions to 80% below year 2000 levels by 2050. Electricity generation in the Australian National Electricity Market (NEM) is responsible for around one third of national emissions [1] and is therefore an obvious candidate for early efforts to reduce emissions. Given the availability of low carbon options for electricity generation, it could be argued that the electricity sector should be almost completely decarbonised to contribute towards the 2050 target. One approach to decarbonising the electricity sector being considered world-wide is a transition to 100% renewable energy sources.

In this paper, we compare the cost estimates of previously published scenarios for 100% renewable electricity ("RE100") hour-by-hour in the NEM against a number of alternative options available to policy makers: greater use of efficient gas-fired generation, and the use of carbon capture and storage (CCS). Nuclear power is not examined as it is prohibited in Australia under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. The key question being addressed is how these alternative scenarios compare with the RE100 scenario and whether they are likely to be significantly lower cost. Indeed, is it worth either deploying gas-fired generation with lower, but still substantial emissions, or waiting for immature CCS technologies to emerge at sufficient scale? The intent of this paper is to help inform policy as governments develop strategies in the face of significant uncertainty about technology development and costs.

The national circumstances of Australia are somewhat unique for a developed country. Australia is a wealthy nation with a well educated workforce and a technological services sector, but with a large share of commodity exports from primary industries. The electricity sector has an ageing fleet of fossil-fuelled thermal generators and is highly emissions intensive by world standards due to

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its dependence on domestic supplies of lignite and black coal [2,1]. Yet, Australia has manifold low carbon electricity options including wind, solar, biomass, marine and geothermal energy [3], and considerable aquifer storage for 70–450 years of emissions at an injection rate exceeding current NEM annual emissions [4]. If CCS cannot be developed rapidly to commercial scale, there will be no future for coal-fired electricity in a carbon constrained world. While some mature renewable energy technologies, namely wind power and photovoltaics (PV), have experienced rapid cost reductions in recent years, progress on scaling up and commercialising CCS has been poor [5].

The Australian Government presently has one main policy to promote utility-scale renewable electricity: a tradeable certificate scheme to reach 41 TWh per year of renewable generation by 2020, or 20% of generation forecast at the outset.[1] There is now an active discussion in Australia about long-term future energy scenarios and appropriate policies to enable the necessary electricity industry transition. The Australian Bureau of Resources and Energy Economics (BREE) published the Australian Energy Technology Assessment (AETA) in July 2012 [6]. The report extensively examines the current and projected costs of 40 electricity generation options in Australian conditions including renewable, fossil and nuclear technologies; not all are commercially available today. Where technologies are not yet commercially available, the report estimates when they will become so. Although some cost figures in the report are disputed, the AETA has found wide use as a consistent basis for modelling by universities, government and industry researchers.

A body of previous research has examined the technical and economic feasibility of operating the NEM completely from renewable energy sources, leading to zero operational emissions. Scenarios have been developed by the Australian Energy Market Operator (AEMO) [7], by the authors [8,9], and by environmental research organisation Beyond Zero Emissions [10]. In evaluating the cost of a 100% renewable electricity scenario, it is necessary to compare with other future scenarios produced by a consistent method. A criticism of the AEMO study [7] has been that no reference scenario is provided to put the costs into context with alternative scenarios that can equally fulfil climate protection objectives [11]. The authors have also previously compared the cost of a 100% renewables scenario against a replacement of the current fossil-fuelled NEM generation fleet with modern, thermally efficient plant [8]. This "efficient fossil" scenario cannot meet the 2050 target but provides a basis against which to compare the evaluation of the cost of 100% renewable electricity. Further research into long-term scenarios for the NEM requires considering other possibilities including gas-fired plant and CCS.

In this paper, we consider three lower carbon scenarios for the NEM based on the estimated least cost mix to meet actual demand in 2010 of:

(i) conventional combined cycle gas turbines (CCGTs) and open cycle gas turbines (OCGTs);
(ii) CCS-equipped coal plant and non-CCS OCGTs; and
(iii) CCS-equipped CCGTs and non-CCS OCGTs.

For these scenarios, a criterion used to select technologies for our previous RE100 scenarios is relaxed: that the technologies be currently commercially available, although we use 2030 cost estimates for them. Scenario (i) above employs commercially available technology, but scenarios (ii) and (iii) do not.

The paper is organised as follows. In Section 2, we briefly review recent developments in 100% renewable electricity scenarios. The current status of CCS, particularly in Australia, is given in Section 3. Section 4 describes each of the scenarios. Section 5 provides an overview of the simulation tool developed to model 100% renewable electricity scenarios and describes how this tool is used to simulate the least cost mixes in the three fossil fuel scenarios. Section 6 outlines sources of data used in the simulations. Section 7 documents the results for each of the scenarios. Section 8 discusses the implications of our findings and concludes the paper.

2. Status of 100% renewable electricity scenarios

Numerous scenario studies have been published that model the potential for countries, regions, and the entire world, to meet 80–100% of end-use energy demand from renewable energy by some future date, typically mid-century. National scenarios now exist for Australia [7–10], Ireland [12], New Zealand [13,14], Portugal [15], the Republic of Macedonia [16], Japan [17], the United Kingdom [18], the United States [19], Germany [20] and Denmark [21]. More broadly, regional studies have been produced for Europe [22,23], northern Europe [24], and several studies of the global situation have been produced [25–29].

Over time these scenarios are becoming more sophisticated in scope and detail, chiefly due to greater available computing power and, to a lesser extent, improved data. For example [13], have revised their scenario for New Zealand extending the analysis period from three to six years. Recent studies by AEMO and the U.S. National Renewable Energy Laboratory have been completed to a high level of detail and with participation from industry [7,19].

In July 2011, the Australian Government commissioned AEMO to undertake a detailed techno-economic feasibility study of 100% renewable electricity in the NEM. Acknowledging the many differences in assumptions such as what technologies are considered available (e.g., the inclusion of geothermal power), AEMO produced findings broadly consistent with our own previously reported findings. AEMO noted, "the operational issues appear manageable", and that the costs of such a system might increase current retail electricity tariffs by less than nine cents per kilowatt hour or around 30% of current residential rates [7].

3. Status of carbon capture and storage

Like other emerging energy technologies, CCS faces challenges due to competition from other lower carbon sources (e.g., unconventional gas and wind power), a lack of ambition in climate policies, and a difficult policy environment. The International Energy Agency (IEA) reports that there are 13 large-scale CCS demonstration projects operating or under construction world-wide [5]. The majority of these projects are capturing, or will capture, emissions from gas processing facilities, not power stations. Several integrated CCS power generation projects are operational or under construction, capturing a small fraction of total plant emissions.

In its two degree scenario (2DS), the IEA projected that around 65% of all coal-fired generation world-wide in 2050 would be equipped with CCS. Some pilot projects have been cancelled in recent years, causing a large shortfall in the annual rate of CO_2 expected to be sequestered by 2012: 65 Mt CO_2 per year as against 260 Mt CO_2 per year in the 2DS. The IEA has expressed concern that, "To deploy CCS on the scale and timeline outlined in the 2DS, policy makers will need to take immediate actions to enable and, further, to actively encourage private investment in CCS" and that, "CCS must be developed and demonstrated rapidly if it is to be deployed after 2020 at a scale sufficient to achieve the 2DS". Currently, there are no coal-fired power stations demonstrating CCS at commercial

[1] The 41 TWh target now equates to approximately 25% of forecast generation in 2020.

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