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Pathways for deploying low-emission technologies in an integrated electricity market: an Australian case study

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Abstract

In this paper, Australia is used as a case study to evaluate potential pathways for staged deployment of low-emission technologies in an integrated, emission intensive electricity market. We assume that carbon capture and storage is implemented at existing and new power plants. To meet projected demand increase by 2050, the total generation capacity increases by 35 %. The cost of electricity in 2050 is more than double the current value, with a moderate annual increase between now and then. An 80 % emission reduction target can be achieved by 2050. The results are compared with the future generation scenarios previously analysed by CSIRO and AEMO.

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1. Introduction

The global electricity sector is a large CO_2 emitter that accounts for more than 40 % of global CO_2 emissions [1]. In response to climate change challenges, options need to be explored for the electricity sector to transition towards a low-carbon future whilst ensuring the security of energy supply. In this paper, Australia is used as a case study to evaluate the potential for reducing CO_2 emissions by deploying low-emission technologies while meeting projected electricity demand in an integrated electricity market.

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The Australian National Electricity Market (NEM) is a wholesale market that supplies electricity to retailers and end-users in the eastern and southern states of Australia. It represents around 90 % of the total Australian electricity demand. Electricity is predominantly produced by fossil-fuel power plants – approximately 80 % from black and brown coal and 10 % from natural gas [2]. Australia has committed to reduce its CO_2 emissions by between 5 % and 25 % below 2000 levels by 2020, and by 80 % below 2000 levels by 2050 [3].

One option for decarbonising the NEM would involve the widespread deployment of carbon capture and storage (CCS). The recently published paper by Elliston et al. [4] conducted a comparison of the least cost scenario of 100 % renewable energy with a number of CCS scenarios. The study concluded that CCS scenarios can only compete with the renewable scenario under a few combinations of future carbon prices, gas prices and CO_2 storage costs. However, the study assumed that all power plants are new-build. It did not consider retrofitting CCS at existing power plants, for which costs would be much lower. By 2030, a large number of existing fossil-fuelled plants will still be operating. In addition, only one type of plant was considered in each CCS scenario. In practice, a combination of technologies is more likely in the NEM and might achieve a lower system cost.

In this paper, we examine a scenario that implements CCS at existing and new power plants. We analyse the potential impact on the cost of electricity and the emissions trajectory for the entire system. The results are then compared with the future generation scenarios previously published by CSIRO [5], Elliston et al. [4] and the Australian Energy Market Operator (AEMO) [6].

While the scenarios analysed and discussed in this paper might not represent the actual future generation mix in the NEM, they are snapshots of possibilities that provide a simple basis for comparing different options for decarbonising the NEM.

2. Setting up scenario

The total electricity generation in the NEM was around 200 TWh during 2010–2012 [7-9]. We use the actual demand data from AEMO from 2010 to 2012 and assume a growth rate of 1.15 % from 2013 to 2030 and 0.98 % from 2030 to 2050 based on projections by AEMO [10]. This results in a total estimated demand of 289 TWh in 2050.

The NEM has a total existing generation capacity of 50,300 MW [11]. This is comprised of around 28,100 MW from coal-fired plants, 10,100 MW from gas-fired plants, 7,800 MW from hydro plants and 4,300 MW from other renewable plants. We assume that all existing plants will operate until the end of their expected technical life based on the data provided by the AEMO for each individual plant [2].

We assume that CCS is retrofitted at existing black coal, brown coal and CCGT plants. To meet future growth in electricity demand new fossil-fuel plants with CCS are installed. Existing peaking plants, smaller plants and renewable based plants are assumed to operate at business-as-usual. Those new renewable plants (mainly wind) that are already committed or recently completed and expected to start operating in 2–3 years are also included in the generation mix [12].

Implementation of CCS in Australia is not yet a commercial reality although options are under consideration. Current reports suggest that around 10 years of exploration and appraisal are required for potential storage sites to be ready for large scale CO_2 injection [13]. For simplicity, we assume that CCS is implemented at successive 20 % increments on the existing fleet from 2025 at 5-year intervals, until 2045 when the entire fleet is assumed to be operating with CCS [14]. For this paper, 5 year time intervals are used but other time intervals could be used if desired.

Given the age of existing coal and CCGT plants, the remaining life for some plants is shorter than the operating life of CCS facilities. There are also some plants that are expected to retire before CCS is ready. While the current coal prices are still low in Australia, there are a couple of coal plants being upgraded to extend life and improve efficiency [12]. Therefore, as an extreme case, we assume that all coal and CCGT plants will be refurbished, with the coal plants being upgraded to ultra-supercritical at the time of their original expected retirement. After upgrading, the thermal efficiency (higher heating value) of coal and CCGT plants are increased to 45 % and 46.1 % respectively [15]. Plant life is assumed to be extended for 30 years after upgrading. We assume that these plants are able to vary their annual capacity factors up to 85 % to meet electricity demand while still allowing for scheduled maintenance and forced outages.