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CCS Research Development and Deployment in a Clean Energy Future: Lessons from Australia over the Past Two Decades

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ABSTRACT

There is widespread, though by no means universal, recognition of the importance of carbon capture and storage (CCS) as a carbon mitigation technology. However, the rate of deployment does not match what is required for global temperatures to stay well below 2 °C. Although some consider the hurdles to achieving the widespread application of CCS to be almost insurmountable, a more optimistic view is that a great deal is now known about CCS through research, demonstration, and deployment. We know how to do it; we are confident it can be done safely and effectively; we know what it costs; and we know that costs are decreasing and will continue to do so. We also know that the world will need CCS as long as countries, companies, and communities continue to use fossil fuels for energy and industrial processes. What is lacking are the necessary policy drivers, along with a technology-neutral approach to decrease carbon emissions in a cost-effective and timely manner while retaining the undoubted benefits of ready access to reliable and secure electricity and energy-intensive industrial products. In this paper, Australia is used as an example of what has been undertaken in CCS over the past 20 years, particularly in research and demonstration, but also in international collaboration. Progress in the large-scale deployment of CCS in Australia has been too slow. However, the world's largest storage project will soon be operational in Australia as part of the Gorgon liquefied natural gas (LNG) project, and investigations are underway into several large-scale CCS Flagship program opportunities. The organization and progress of the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) Otway Project, which is currently Australia's only operational storage project, is discussed in some detail because of its relevance to the commercial deployment of CCS. The point is made that there is scope for building on this Otway activity to investigate more broadly (through the proposed Otway Stage 3 and Deep Earth Energy and Environment Programme (AusDEEP)) the role of the subsurface in carbon reduction. There are challenges ahead if CCS is to be deployed as widely as bodies such as the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) consider to be necessary. Closer international collaboration in CCS will be essential to meeting that challenge.

1. Introduction

Overwhelming evidence indicates that the increase of anthropogenic greenhouse gases, and particularly carbon dioxide (CO_2), in the atmosphere is resulting in climate change and global warming. There is also a compelling case for saying that in order to keep the rise in global temperatures to well below 2 °C, there must be deep cuts in emissions, especially those resulting from the use of fossil fuels. Greater energy efficiency, greatly improved energy storage, large-scale deployment of renewable energy, more nuclear power, and more carbon capture and storage (CCS) or carbon capture, utilization, and storage (CCUS) will all be globally needed. At the same time, it is necessary to take a more holistic approach to the trilemma of having access to affordable, secure, and low-emission energy.

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Many countries and regions are reviewing how best to achieve these three objectives, and each country and region will obviously choose the technology mix that suits its particular circumstances.

Why, then, does this paper focus on CCS alone? A major reason is because, as the Intergovernmental Panel on Climate Change (IPCC), the International Energy Agency (IEA), and other bodies have shown, the cost of staying well below a 2 °C temperature rise will more than double if CCS is not deployed [1]. Indeed, it is unlikely that the global rise in temperature can be kept below 2 °C in the absence of CCS. Despite this, the speed of deployment of CCS technology is far below what is required. The Global Carbon Capture and Storage Institute (GCCSI) documents 16 commercial CCS facilities operating today and storing approximately 30 million tonnes of CO_2 per annum, with another six under construction. Together, these 22 facilities will store a total of 40 million tonnes of CO_2 per annum by about 2020. This amount is not insignificant. Nevertheless, it is far below what will be required if CCS is to play its necessary role in mitigating global emissions and meeting agreed-upon emission targets.

In the IEA's 2 °C Scenario (2DS), CCS delivers 12% of the necessary cumulative emission reductions up to 2050, meaning that approximately 94 Gt of CO_2 will need to be captured and stored. Of this, almost 14 Gt is in the form of negative emissions through bioenergy with CCS (BECCS), leaving 80 Gt to be applied to large-scale emission sources in the power and industrial sectors. At the current rate of CCS mitigation, we will store little more than 1 Gt of CO_2 by 2050. In other words, an increase of two orders of magnitude in the deployment of CCS will be required over today's figures, in order to keep the rise in temperature to well below 2 °C. This is a massive task.

However, is it possible that the picture is not as bleak as it appears, given some of the developments in CCS or CCUS that are happening in various parts of the world? In the past 20 years, a great deal has been achieved in our understanding of CCS through commercial projects such as the Statoil's Sleipner (Norway) project, which commenced the injection of CO_2 in 1996, and which has now successfully injected and stored 20 million tonnes of CO_2 over the subsequent 20 years. The Boundary Dam (Canada) and Petra Nova (the United States) projects have successfully integrated CCS with power generation. In addition, many pilot and demonstration projects that have been undertaken in recent years around the world, such as those in Australia (Otway), China (Yanchang), Japan (Tomakomai), Germany (Ketzin), and the Regional Carbon Sequestration Partnerships in the United States and Canada, have contributed to a firm base of knowledge for the acceleration of CCS. These projects, along with laboratory-based studies, provide confidence that there are no insurmountable technical barriers to CCS deployment. Nonetheless, hurdles exist, such as bringing down costs and increasing confidence in the technology. Underlying all this is the need to address the concerns of politicians, industry leaders, bureaucrats, non-governmental organizations, and the public at large, who have yet to be persuaded that CCS is safe, practical, and necessary [2]. Given this background, this paper briefly outlines the Australian energy context, within which CCS and related issues are being considered; it also reviews some of Australia's activities in CCS over the past 20 years, and looks at future options for research and clean energy opportunities, such as the conjunctive use of the subsurface for clean energy.

2. Australia's energy portfolio and mitigation options

Australia contributes less than 2% of global greenhouse gas emissions, yet has one of the world's highest per capita emission rates. It has signed the Conference of the Parties (COP) 21 Paris Agreement and will significantly decrease its absolute and per capita emissions over the next few years to meet its international greenhouse gas obligations. Australia will do this through a number of measures including an increase in the percentage of renewable energy, a decrease in its energy-intensive industrial base, and the closure of coal-fired power stations. Legislation and regulations have been major drivers for change, including a mandatory Renewable Energy Target (RET) that has resulted in the accelerated uptake of wind and rooftop solar energy systems. Because of Australia's federal system, the proportion of renewables varies greatly from state to state; for example, South Australia relies on wind and solar energy for 40% of its power. However, a major flaw in Australia's climate policy is the priority that is accorded to introducing more renewables, over a policy that focuses on decreasing emissions.

Australia is richly endowed with energy resources including coal, gas, and uranium (it has no nuclear power). It is the world's largest exporter of coal and will be the world's largest exporter of liquefied natural gas (LNG) by 2020. At the same time, it is facing the increasingly contentious issue of how to ensure that electricity in Australia is affordable, reliable, and has low emissions. This issue has been brought into focus in the past year or so by soaring electricity and gas prices, increased uncertainty in the supply of natural gas to the domestic market, and major power outages. This and related issues are comprehensively canvassed in the recently concluded review of the National Electricity Market (NEM) [3]. Among other conclusions, the review states that a more technology-neutral approach should be taken toward reducing emissions.

Australia's NEM was established in the 1990s to deliver cheap and reliable electricity, not emission reductions. However, over the past decade, energy and climate strategy in Australia has been dominated less by a policy of decreasing emissions and more by a policy of introducing increasing amounts of renewable energy into the energy mix without full regard for the consequences. Renewable energy backed up by battery storage will contribute to energy security at the household and district level, but is unlikely to do so to any great extent at the grid level for some time to come. Hydro power, including pumped hydro, will contribute to greater energy security, although opportunities in Australia are limited. Therefore, other modes of dependable, cost-effective, low-emission electricity that can work alongside renewables and can address energy security concerns must be considered in a technology-neutral manner. Coal-fired power generation currently provides much of Australia's grid stability, but it also results in Australia's relatively high rate of CO_2 emissions. In response to the need to decrease emissions, the proportion of Australia's coal-based power generation has decreased in recent years, while the proportion of intermittent wind and solar power has increased, resulting in the unintended but inevitable consequence of a less secure grid.

High-efficiency low-emission (HELE) coal-fired generation would be preferable to current largely critical or sub-critical coal-fired generation for providing lower emission grid stability. However, if used alone, HELE coal-fired generation would still produce per-megawatt hour emissions in excess of emission standards for power stations, such as those recently suggested by Victoria, and in excess of emissions from gas-fired power generation. Furthermore, although gas is cleaner than coal, it still produces significant greenhouse gas emissions. Biomass can be used to provide base-load power and can potentially be carbon neutral or even carbon negative. However, if coal, gas, or biomass continue to be used to provide cost-effective and secure power, only CCS can produce the required deep cuts in emissions for a future low-emission and secure energy mix.

As outlined by Finkel's report [3], Australia's energy security is provided by a range of measures, with varying degrees of success. Unabated coal- or gas-fired power generation still dominates electricity production and provides necessary inertia to the grid; however, it does so with a high carbon intensity that is inconsistent with the government's greenhouse policy and with community ex-