A POLICY AND ECONOMIC COMPARATIVE ANALYSIS OF CARBON CAPTURE AND STORAGE (CCS) WITH RENEWABLE ENERGY TECHNOLOGIES (RETs) IN AUSTRALIA WITH CARBON CONSTRAINS

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Overview

As the world's fifth largest coal producer(IEA 2013), the share of coal production accounted for about 75% of Australia's energy production in 2012, while oil production was about 7.8%, and natural gas production was at 15.1% (IEA 2013). Australia energy consumption is also heavily reliant on fossil fuel. In the year 2011-12, coal, oil and gas accounted for 34.2%, 38.9%, and 22.6% of Australian energy consumption, while renewable only accounted for 4.3% (BREE 2013). In particular, Australian electricity generation is largely dependent on fossil fuel. In 2011-12, about 69.1% of electricity was generated by coal, 19.3% was by natural gas, and only about 9.4% of electricity was produced by renewable energy, 5.5% of which was by hydropower (BREE 2013).

In accordance to Australian energy production and consumption fuel sources, while Australia total carbon emissions ranked 18th in the world in 2010, its CO_2 emissions per capita was the world's twelfth largest with 16.9 metric tons CO2 emitted per capita (World Bank n.d.). This figure increased by 3.1% and reached 17.43 metric tons in 2011 (IEA 2013). In 2011, the CO_2 emissions from electricity and heat production for Australia was 207.8 million tonnes, accounting for 52.4% of total CO_2 emissions of Australia (IEA 2013).

The IPCC Fifth Assessment Report released on March 31st, 2014 concluded with high confidence that increasing greenhouse gas concentrations have contributed to rising average temperature in Australia. Australia climate is changing with demonstrated long term trends toward higher surface air and sea-surface temperatures, more hot and fewer cold weather extremes, and changed rainfall patterns (IPCC 2014).

This research is driven by exploring future promising portfolios of energy technologies for electricity generation in Australia to meet the growth of energy demands and tackle climate change mitigation at the same time. Considering constraints of resources endowment and requirements of economic development and climate change mitigation, this research believes that carbon capture and storage (CCS) technologies and the renewable energy technologies (RETs) are the most promising options for Australia to equip its electricity generation sector in short- and long-term future.

CCS technologies are expected to play the key and important role in mitigating climate change given almost inevitable continued use of fossil fuels (European Commission 2008; Global CCS Institute 2011). The renewable sources such as solar and wind (Joselin Herbert, Iniyan et al. 2007; Parida, Iniyan et al. 2011; Kaldellis 2012) are projected by IPCC that they could supply up to 80% of the world's energy needs by 2050 and play significant roles in fighting global warming (IPCC 2011). This research focuses on investigating and comparing potential roles of CCS and the RETs in Australia's future energy system within the timeframe of 2010 to 2050.

Methods

This research applies Long-range Energy Alternatives Planning (LEAP) model as the simulation tool to investigate future roles of CCS and the RETs in the portfolio of energy technologies of Australia to meet its growth of energy demands and carbon emission reduction requirements.

The LEAP model is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute (SEI). It has been adopted by hundreds of governmental, academic, and non-governmental organizations and companies in more than 150 countries worldwide (SEI 2011). It is an integrated modelling tool that can be used to track energy consumption, production, and resource extraction in all sectors of an economy (SEI 2011). LEAP contains a full energy system accounting framework, which enables consideration of both demand- and supply-side energy technologies and accounts for total system impacts (Song, Lee et al. 2007). It can simulate all costs within an energy-system, as well as externalities for any pollutants, decommissioning costs, and unmet demand costs.

This research uses LEAP to create models of Australia energy system and establish the long-range scenarios with focus of projecting Australia's future energy technology mix for electricity generation in a long-term timeframe. LEAP modelling process in this study consists of four major steps: energy demand analysis and projection, energy transformation analysis, long-range scenario analysis, and CO2 emissions mitigation and social costs analysis.

Results

The timeframe for the energy system modelling is from 2012 to 2050. The key assumptions for predicting plausible future include GDP growth, population growth, and sector value added. For compling the storyline for Australia's future, the GDP growth is projected with average growth rate to 2050 at 2.5%, the population projection is at 23.35million in 2013, 31.19million in 2035, and 36.26million in 2050. The average growth rate for economic sectors' value added is at 2.5% to 2050.

This study designs three major scenarios and eight sub-scenarios. The Baseline Scenario is the reference scenario with no carbon price and Renewable Energy Target imposed. The Current Policy Scenario is featured with current carbon price scheme and renewable energy targets. The Mitigation Scenario is deviced with more progressive carbon price scheme and renewable energy target as shown in Table 1 below. The modelling results show the energy demand, electricity supply requirements, capacity expansion, the environmental effects, and costs of all scenarios.

Table 1: Scenarios of Australian LEAP model.

Scenario	Carbon Price	Renewable Targets	CCS Deployment	Assumptions for Available Electricity Generation Capacity Expansion
Baseline	No	No	No	PC Super on black coal CCGT, OCGT, Wind, Solar, and Biomass
Current Policy	\$23/ton in 2012, rising by 2.5% per year until 2050	20% of production by 2020	No	PC Super on black coal CCGT, OCGT, Wind, Solar, and Biomass
Renewable - Current Policy	\$23/ton in 2012, rising by 2.5% per year until 2050	20% of production by 2020	No	Wind, Solar, Biomass, OCGT, Wave and Geothermal(available from 2030)
CCS - Current Policy	\$23/ton in 2012, rising by 2.5% per year until 2050	20% of production by 2020	From 2020	PC Super with CCS, IGCC with CCS, CCGT with CCS, OCGT
Renewable and CCS - Current Policy	\$23/ton in 2012, rising by 2.5% per year until 2050	20% of production by 2020	From 2020	PC Super with CCS, CCGT with CCS, Wind, Solar, Biomass, and OCGT
Optimization - Current Policy	\$23/ton in 2012, rising by 2.5% per year until 2050	20% of production by 2020	n/a	Capacity expansion calculated internally by LEAP
Mitigation	\$23/ton in 2012, rising by 5% per year until 2050	20% of production by 2020	No	PC Super on black coal CCGT, OCGT, Wind, Solar, and Biomass
Renewable - Mitigation	\$23/ton in 2012, rising by 5% per year until 2050	20% of production by 2020, same to 2030, 30% by 2040, 40% by 2050	No	Biomass, OCGT, Wave (available from 2025), and Geothermal (available from 2020)
CCS - Mitigation	\$23/ton in 2012, rising by 5% per year until 2050	20% of production by 2020, same to 2030, 30% by 2040, 40% by 2050	From 2020	PC Super with CCS, IGCC (available from 2020), CCGT with CCS, Biomass, OCGT, and Wave and Geothermal (available from 2030)
Renewable and CCS - Current Policy	\$23/ton in 2012, rising by 5% per year until 2050	20% of production by 2020, same to 2030, 30% by 2040, 40% by 2050	From 2020	PC Super with CCS, CCGT with CCS, OCGT, Wind, Solar, Wave and Geothermal(available from 2030)
Optimization - Mitigation	\$23/ton in 2012, rising by 5% per year until 2050	20% of production by 2020, same to 2030, 30% by 2040, 40% by 2050	n/a	Capacity expansion calculated internally by LEAP

Conclusions

This research utilizes an energy system optimization model to examize technical and economic feasibility of CCS and the RETs for meeting Australia's projected scenarios with different economic and carbon constraints. Overall, this research applies LEAP model to simulate Australian energy demand and electricity generation system. Eleven scenarios established to project different electricity capacity expansion trajectories and compare the CCS and RE technologies.

The modeling results show that any other scenarios with measures of reducing carbon emissions cost more compared to baseline scenario which is business-as-usual scenario without carbon price and RE development targets.The Optimization Mitigation and RE Mild Mitigation Scenarios require the largest amount of capacity installed, while the CCS Current Policies scenario requires the least amount of electricity generation capacity. General speaking, the scenarios contain CCS cost significantly more than the RE scenarios in terms of costs of electricity generation system capacity expansion to 2050. The Optimization Current Policies scenario has least costs of electricity generation capacity expansion way. Except Baseline scenario, the Current Policies and the Optimization Current Policies scenarios emit the largest amount of CO_2, while the RE Current Policy Scenario emits the least amount of CO_2. The RE Current Policy Scenario has the least cost of avoided CO_2 emissions. Base one the current costs assumptions of electricity generation technologies, the CCS would not be as competitive as conventional and RE technologies. The further research could be done to investigate the feasible financial mechanisms for promote CCS.

The results provides useful information and references for Australian Government to make long-term decisions on supporting research and development of advanced electricity generation technologies, especially CCS and the RETs to achieve targets of sustainable economic growth and climate change mitigation feasibly and effectively. At the same time, the scenario analysis of this research would be also beneficial for policy-makers to design and alter countries national climate change mitigation targets and energy policies.Currently, Australia has been undergoing a heated debate about scrapping its present Renewable Energy Target due to high electricity costs. The results of this research would contribute to making more rational choices on developing and deploying different categroies of electricity generation techonoliges for Australia Goverment.

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