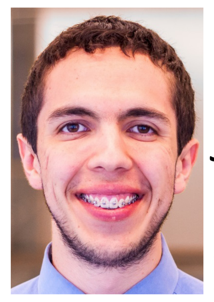
Oxy-Fuel Combustion: A ‘Made in Alberta’ Solution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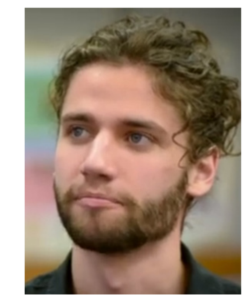
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INTRODUCTION

As coal-fired power plants are phased out in Alberta by 2030, conventional natural gas combined cycle (NGCC) power plants will become a significant source of electricity and greenhouse gas (GHG) emissions[1]. An alternative to NGCC is the semi-closed oxy-combustion combined cycle (SCOC-CC), which replaces air with O_2 and CO_2 in the combustion chamber in order to produce pure CO_2 for carbon capture and storage (CCS), thereby reducing the GHG intensity of the Alberta grid. The cost of producing O_2 from air is prohibitive, but interest in hydrogen fuel cell vehicles could allow for a low cost supply of oxygen via electrolysis. Alberta has large storage potential in its deep saline aquifers, making it ideal for CCS.

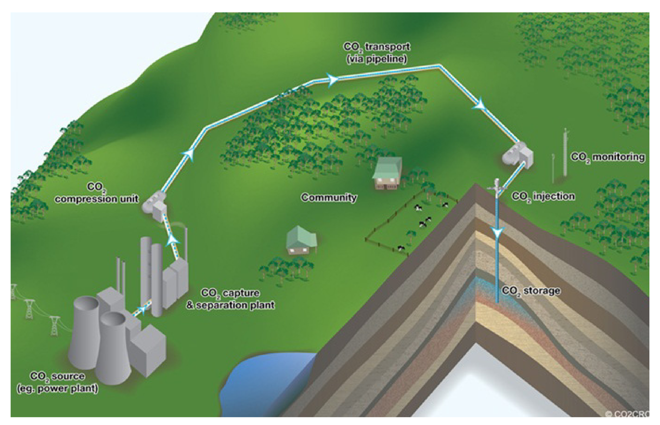


Fig. 1. Diagram of CCS operations [2]

METHODS

Dr. Straatman’s projection data [3] was the basis for the business-as-usual analyses. Also, literature and Team 3’s fuel cell adoption rates laid the foundation for the alternative scenario. The choice of the SCOC-CC as the oxy-combustion plant, the removal of its air separation unit (ASU), the addition of CCS, and an operation time of 330 days per year were the model's chosen parameters. From studies made by IEAGHG [4], the SCOC-CC was shown to have economic and environmental advantages over NGCC.

For CCS, 10 horizontal injection wells would be put in place over 16 years to store CO_2 within the subsurface at Wabamun Lake, AB. By 2060 we aim to sequester upwards of 207 Mt of CO_2 [5].

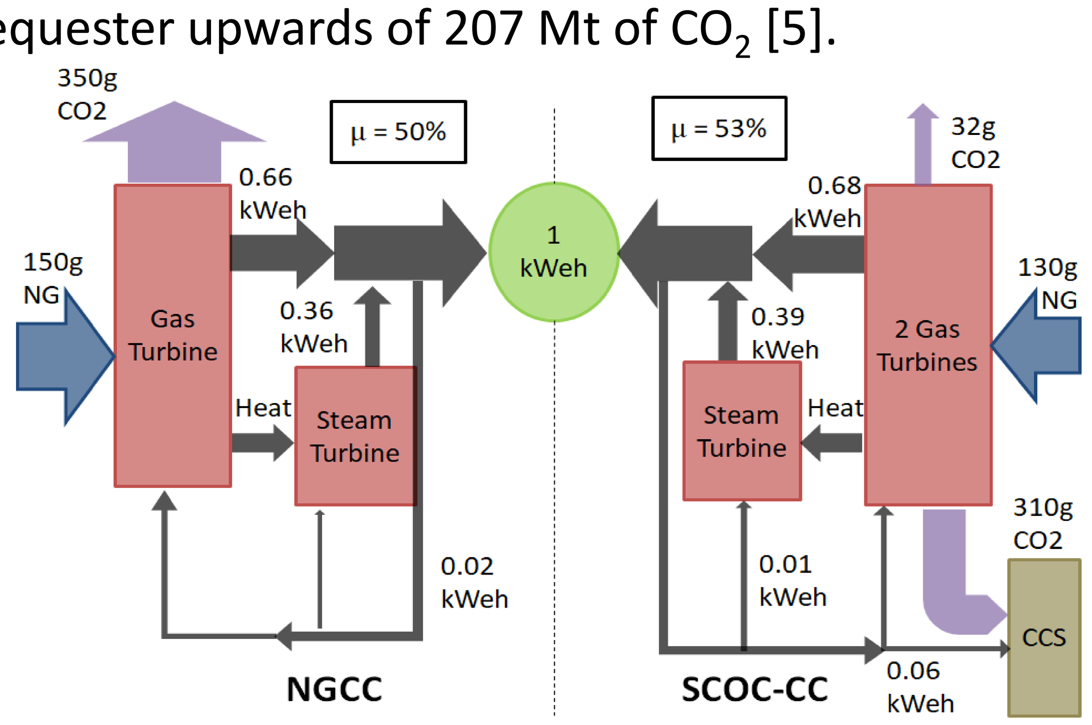


Fig. 2. Comparison of Energy Flows in SCOC-CC and NGCC Generation Plants [6]

RESULTS

REFERENCE | **OXYFUEL COMBUSTION**

Fig. 3. Alberta Power Generation (TWh/yr)
38.5 TWh/yr in oxy-fuel combustion generation by 2060

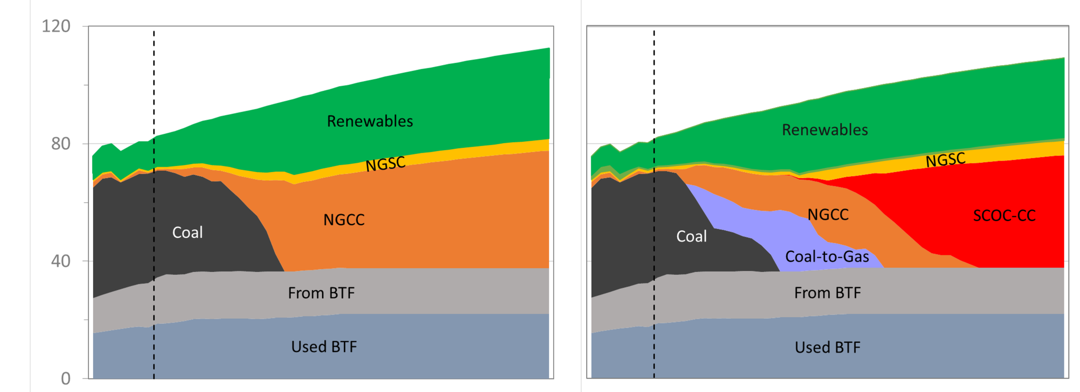


Fig. 4. Alberta Power Capacity (MW)
5300 MW in oxy-fuel combustion capacity by 2060

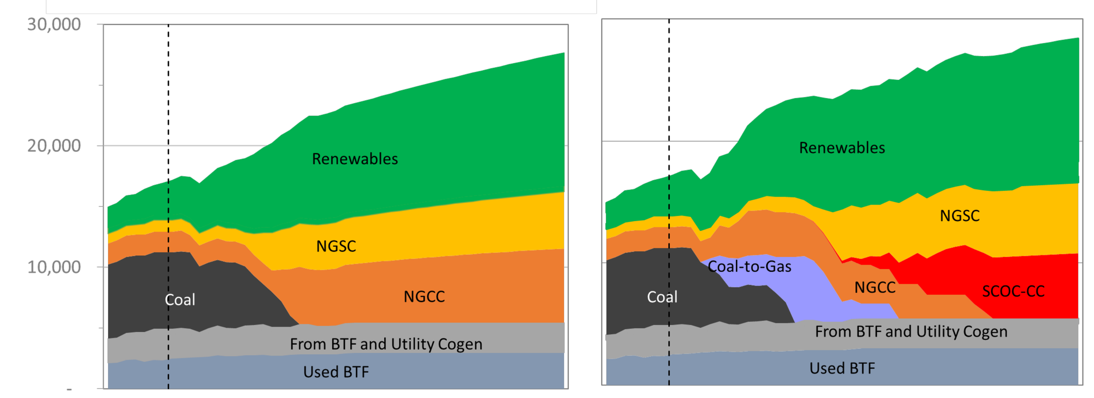


Fig. 5. Emissions from Power Generation (Mt CO_2/yr)
2060 emissions will be reduced by 14 Mt CO_2/yr

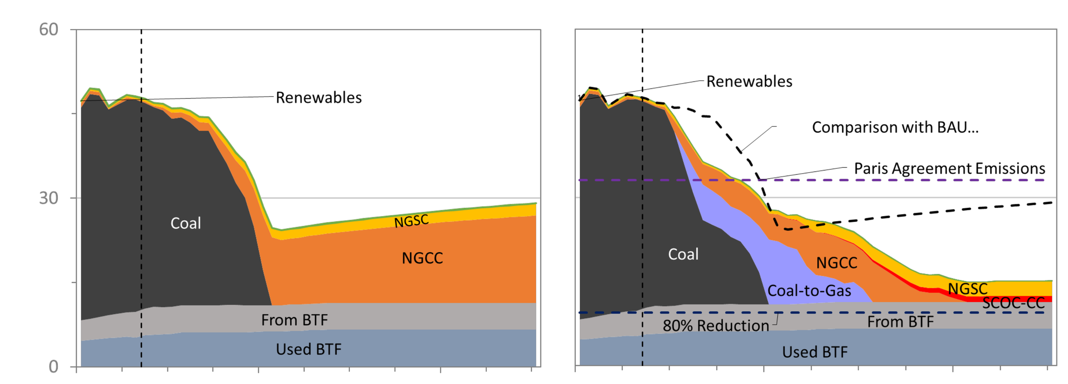


Fig. 6. Levelized Cost of Electricity (LCOE) (CAN $ 2017)
Oxy-fuel is economically competitive by 2018

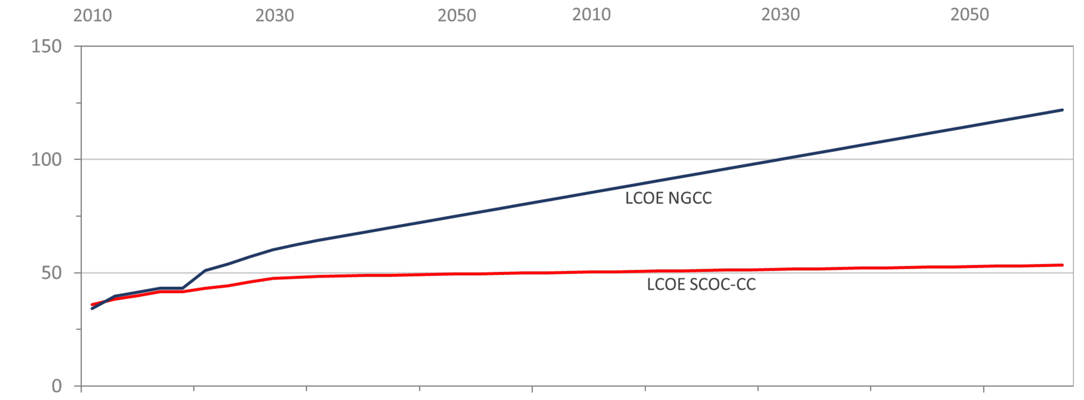


Fig. 7. Map of Proposed Location of Carbon Capture and Storage [7]
Large saline aquifer West of Edmonton

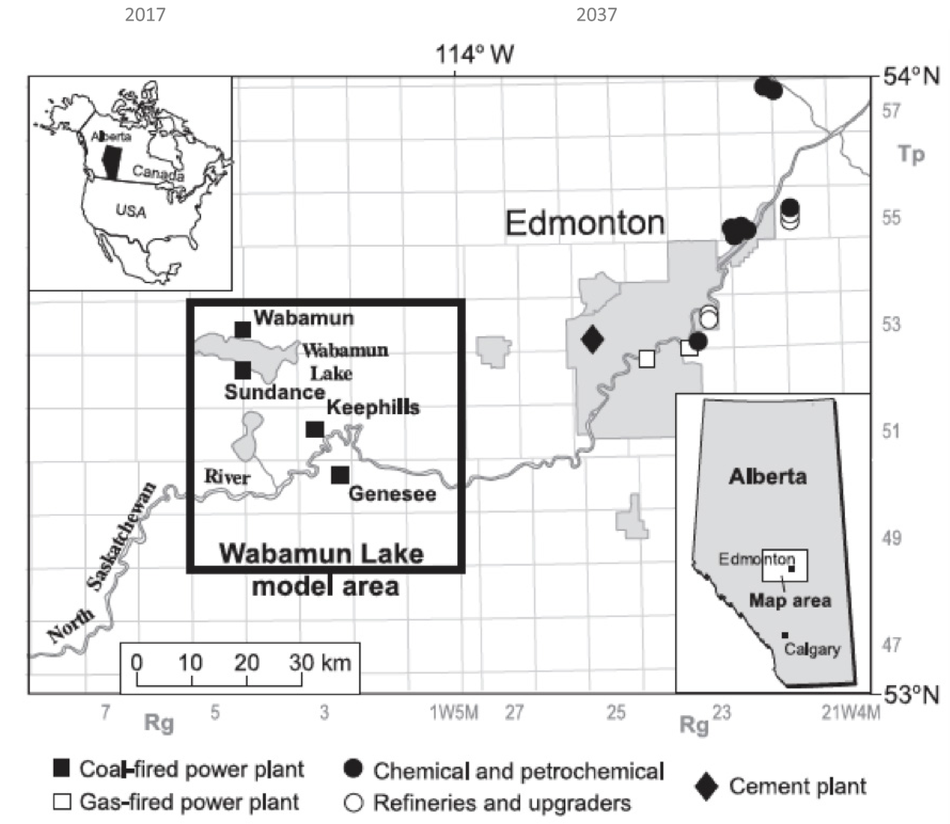
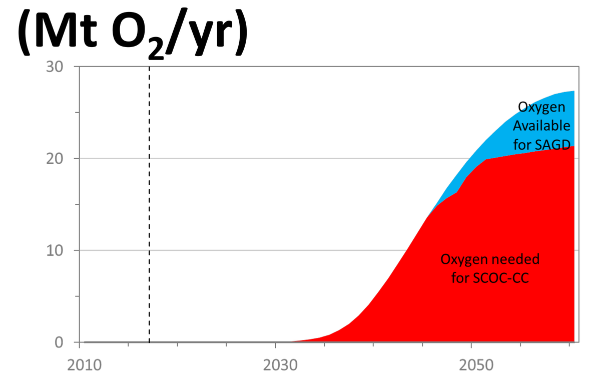


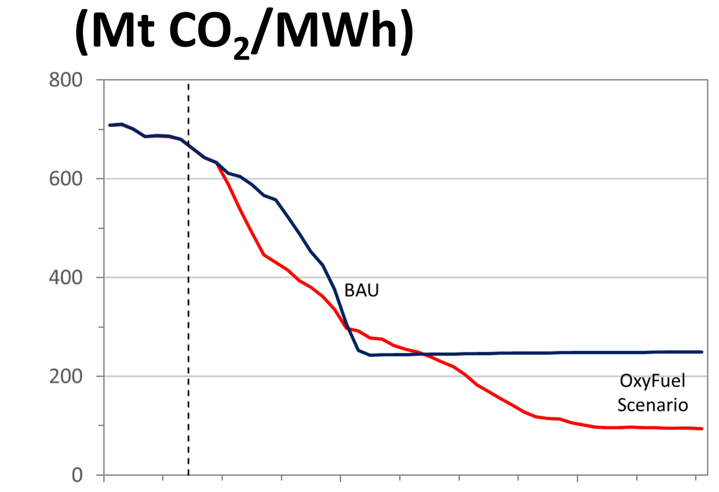
Fig. 8. Oxygen Production (Mt O_2/yr)



NOTE:

- Oxy-fuel pilot plants will be brought online in 2020, with full scale generation growing from 2031 onwards based on O_2 supply.
- As the oxygen needed for oxy-fuel begins to plateau, there will be enough oxygen to supply 4 SAGD operations by 2060.
- Single cycle (NGSC) capacity will have to increase substantially to maintain grid stability since renewables have a low capacity factor and oxyfuel plants will run at a high capacity factor.

Fig. 9. Carbon Intensity (Mt CO_2/MWh)



- Alberta's electricity grid carbon intensity decreases by 155 Mt CO_2/yr in 2060.
- This proposed model will allow Alberta to meet its 2030 climate goals, and changes to behind the fence (BTF) (private) generation could allow for further greening of Alberta's grid.
- The economic feasibility of SCOC-CC generation is driven by the quickly rising price of carbon.
- The plant location was chosen near Wabamun Lake due to existing infrastructure, prior knowledge of the subsurface and the existence of large saline aquifers.

DISCUSSION

Since oxygen is supplied from electrolysis, an ASU is not required. This provides a major reduction in cost (29%) and energy (15%) for the proposed system over standard SCOC-CC. The oxygen supply is the limiting factor for the implementation of SCOC-CC.

The proposed plant does not need an additional CO_2 compressor station for CO_2 injection, since the CO_2 from the plant is compressed to 110 bar. This is sufficient for transportation through pipelines in its supercritical phase for short distances (about 5 km).

Alberta has the opportunity to invest in cleaning up its public grid emissions by almost two thirds, by replacing NGCC with SCOC-CC. The LCOE's of SCOC-CC and NGCC are very comparable by 2018, but SCOC-CC remains nearly constant whereas the LCOE of NGCC increases with time, mainly due to the carbon price.

CONCLUSIONS

SCOC-CC power generation will reach peak values in 2060 with 100% of NGCC power generation being replaced. The carbon capture system associated with the oxy-fuel plant will be able to store over 207 Mt CO_2 over 29 years. Overall, there will be a reduction of 14 Mt CO_2/year when compared with the business-as-usual scenario.

The SCOC-CC is very similar to NGCC generation, allowing the technology to be ready for pilot testing in the next five years, based on its Technology Readiness Level. Both cycles utilize similar sized turbines and thermodynamic cycles, which operate at similar temperatures. Oxy-fuel power generation using the SCOC-CC design, but removing the air separation unit, will operate at 53% efficiency, and can generate approximately 5400 TWh/year for the Alberta grid in 2060.

REFERENCES

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