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Carbon Capture Facility for Coal Fired Power Plant

Introduction

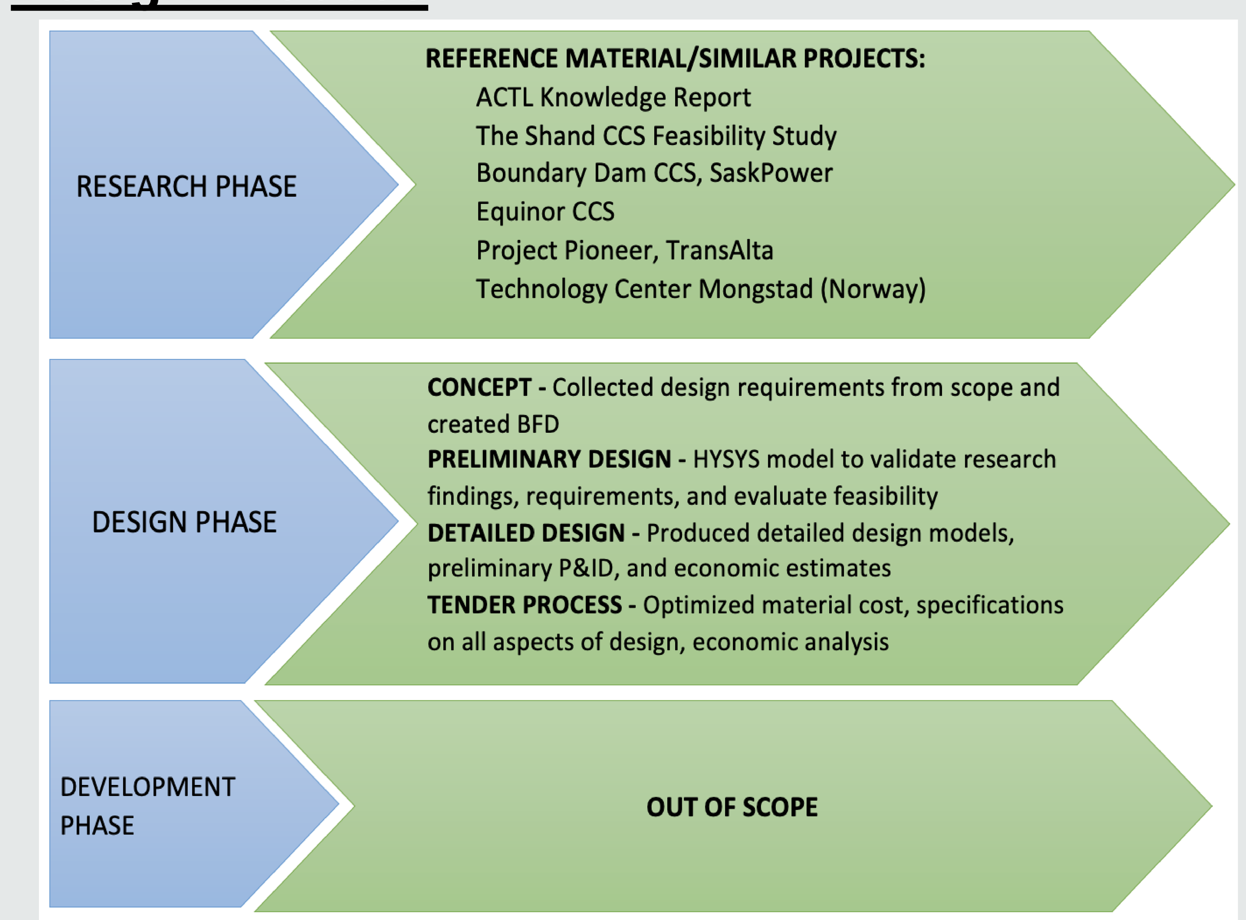
The purpose of this project is to develop a process design, equipment sizing, and estimate the capital cost and economic feasibility for a one million tonne per year carbon capture facility (CCF) with the purpose of meeting the federal "Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations" (SOR/2012-167)."

This project will resemble a typical Nova Scotia coal fired plant located in the Lingan area of Cape Breton, where Nova Scotia Power operates the Lingan Generating Station (We use a substitute 500 MW coal fired power facility).

The scope of this project does not include the trim SO_2 removal unit, quench tower leading to the absorber column, transport and underground storage of supercritical CO_2.

(this project is not affiliated with Nova Scotia Power).

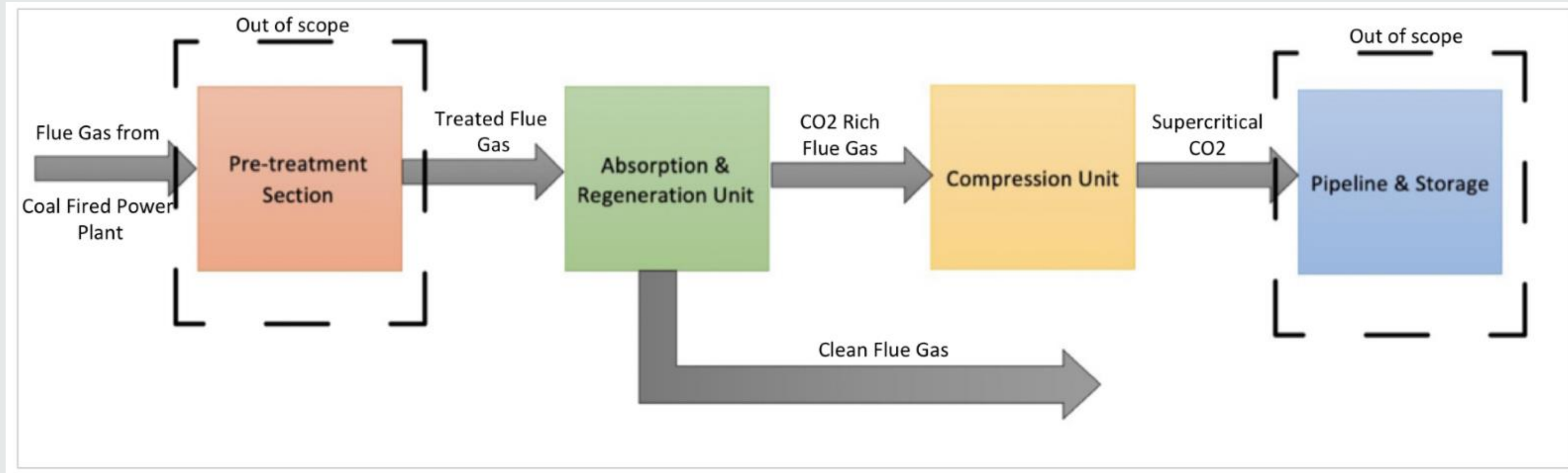
Design Process



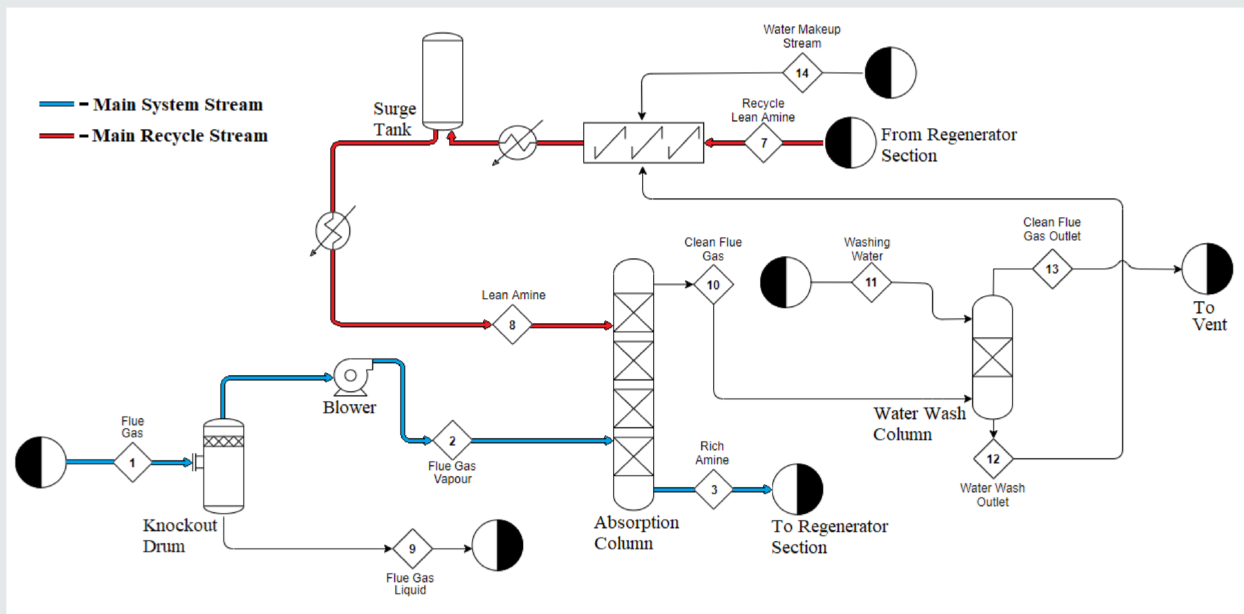
Design Requirements

- Capture and supercritical compression of 1 million tonne CO_2/year
- Capture 90% of CO_2 into the system

Details of Design (Capture 1,000,000 tonnes of CO_2 per annum)



Absorber Section (Captures CO2 using MEA Solution)



Absorber Column
- Carbon steel
- 31mm thick walls
- 10.34m diameter
- 12.2m tall
- Packed with MellaPak 250Y

Water Wash Column
- Carbon steel
- 21.5mm thick walls
- 6.7m diameter
- 6.1m tall
- Packed with MellaPak 250Y

Flue Gas Blower
- Carbon steel
- 603,292.46 m3/h
- 7.9 kPa pressure Increase
- 1,779.1 kW

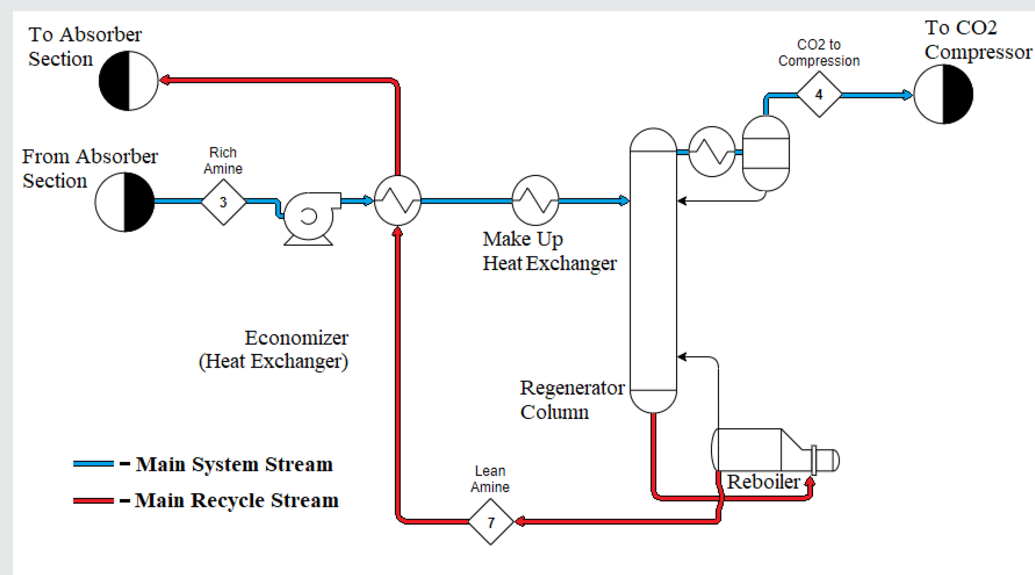
Rich MEA Solution
- 29.67 wt% MEA (11.06 mol%)
- 0.4956 mol CO_2/mol MEA rich loading
- 2,048 tonne/hr solution flowrate (85,767 kmol/hr)

Regenerator Section (Regenerate Captured CO_2)

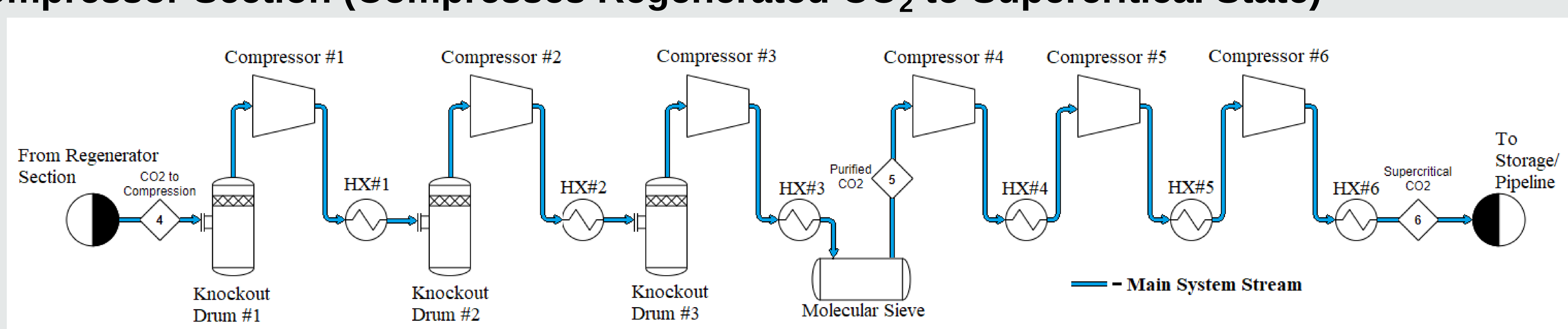
Regenerator Column
- Carbon steel
- 29.0mm thick walls
- 8.0m diameter
- 18.9m tall
- Packed with MellaPak 250Y
- Percent powerplant power output reduction of 13.34%

Heat Economizer
- Reduce direct heating demand of the make-up heat exchanger.
- Shell and tube heat exchanger.
- Heating Area 60.3 m^2
- Duty 45,848 kW

CO2 Recovery
- 140,000 kg/h CO_2 (1,048,572 tonnes/yr)



Compressor Section (Compresses Regenerated CO_2 to Supercritical State)



Knockout Drums
- Carbon steel
- 1m diameter & height

Compressors
- Carbon steel
- Centrifugal compressors
- LP ratio: 2.466 & HP ratio: 1.850

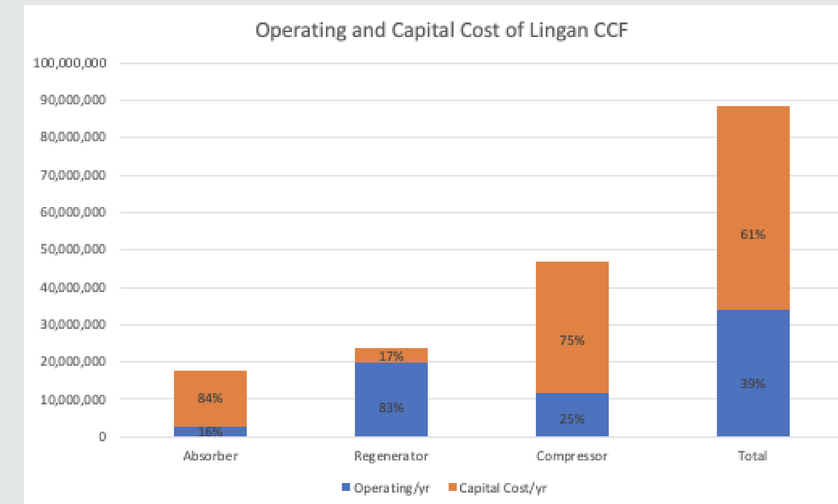
Heat Exchangers
- Shell & tube heat
- Outlet temperature of 60°C after each stage

Molecular Sieve
- Carbon steel
- 0.9m in diameter & 1.8m in height
- Optimal stream pressure is 30 bar

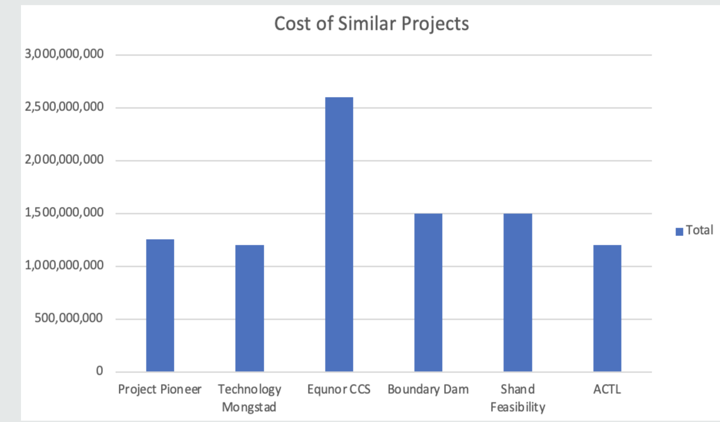
Enhanced Oil Recovery Final Product
- Outlet Pressure = 179 bar
- Temperature = 60°C
- Final H2O content level = below the 84ppmw limit as specified from ACTL pipeline specifications.

Economics

Displayed here is the estimate of the annual payback costs using current estimation methods.



This chart does not include cooling towers, buildings, storage facilities, etc. Capital costs for this project are expected to be 10-20x higher once a full scale design is completed.



Project Pioneer is a CCF that targets a similar capture rate to this project and had a capital cost of C$669M and an operating cost of C$586.6M over 10 years to give a realistic reference.

The approved alternative to this, the Muskrat Falls project combined with the Maritime Link Transmission Line will provide 500MW of renewable power at the current cost of C$12.7B (not including operation) for a minimum of 50 years. Supplying a CCF to a 500MW plant using the Project Pioneer values would cost approximately C$3.6B assuming no additional major costs are incurred.

The CCF creates a cheaper alternative that allows the continued and environmentally safe use of coal power for older power plants, though there is still CO_2 output. Though the CCF would not be viewed equally due to the use of coal and mining operations. Both would provide maintenance jobs, but the CCF would provide more mining and transportation jobs.

Conclusion

The design of this carbon capture facility is sufficient in satisfying the requirement of capturing 1 million tonne of CO_2 per year. The power output reduction associated with the operation of the CCF is significant at 20.51% meaning a lower efficiency of the plant and would require additional coal and generation systems to offset the power loss. This would have a significant economic impact on the coal fired power plant's operating costs and is not sustainable solution as coal supplies can be depleted over time. This technology is useful in cases where non-renewable sources are required and can help mitigate the negative emissions associated with combustion.

Recommendations

- Design for the pre-treatment section (flue gas desulphurization & quench tower)
- Design plant layout and pipe connections to improve economic estimates further
- Addition of interstage cooling on the absorption column to improve capture efficiency
- Design of the CO_2 pipeline and ultimate disposition of the CO_2 product

References

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