Feasibility of CLC of Industrial Tail Gases for CO Production

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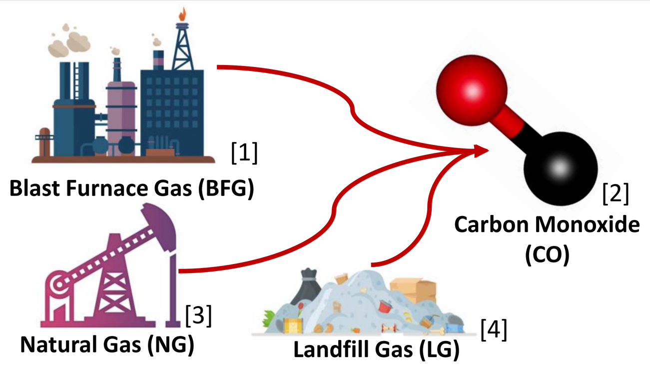
Motivations

Investigate novel pathways to carbon monoxide (CO) generation, which transform low-value industrial tail gases containing GHGs into higher value intermediate products.



Goals

1. Design a CLC process to transform industrial tail gases, Natural Gas and Landfill Gas, into the high value intermediate product CO.
2. Evaluate the throughput, sustainability, and profitability of the two feed gases.

Methods

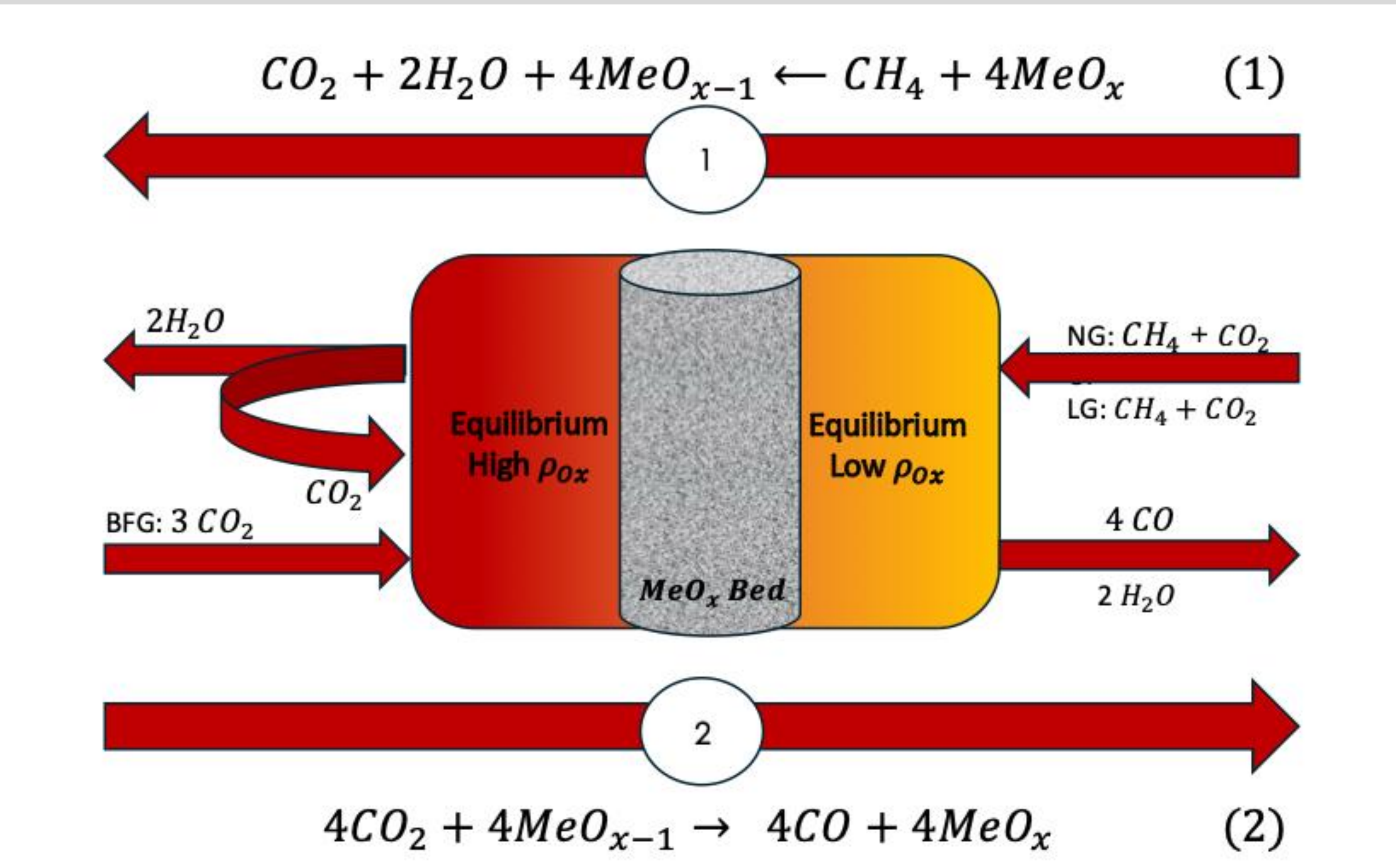


Figure 2. Schematic for Hybrid Redox Process (HRP).

Feed gas inlet compositions were established for Natural Gas (NG) and Landfill Gas (LG) scenario, whereas BFG was approximated as pure CO_2.

Table 1. Proposed Methane Feed Gas Compositions (mol %) for HSC Chemistry Simulations.[5,6]

Feed gas	CH_4	CO_2	O_2	N_2	H_2
LG	50	45	2	3	-
NG	80	15	3	-	2

HSC Chemistry simulations were completed to determine to the optimal operating temperature for each feed gas:

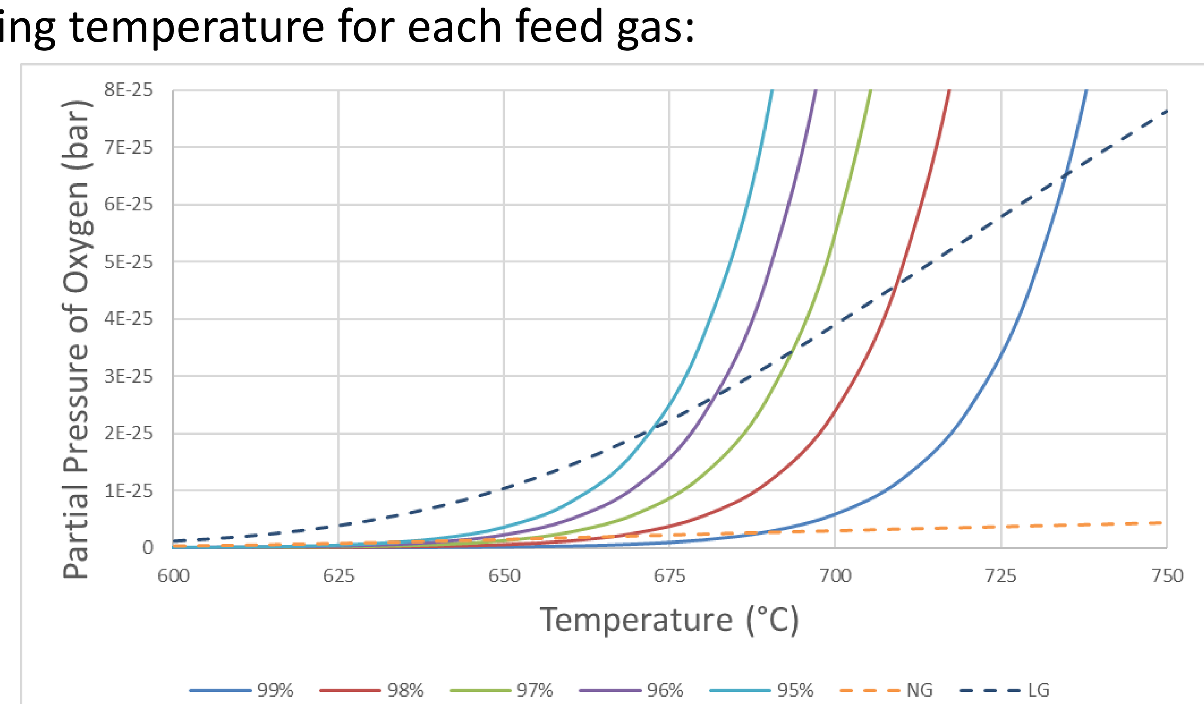


Figure 3. HSC Chemistry Simulations of Feed Gas Scenarios.

NG: 685°C LG: 708°C

ASPEN Reactor Model

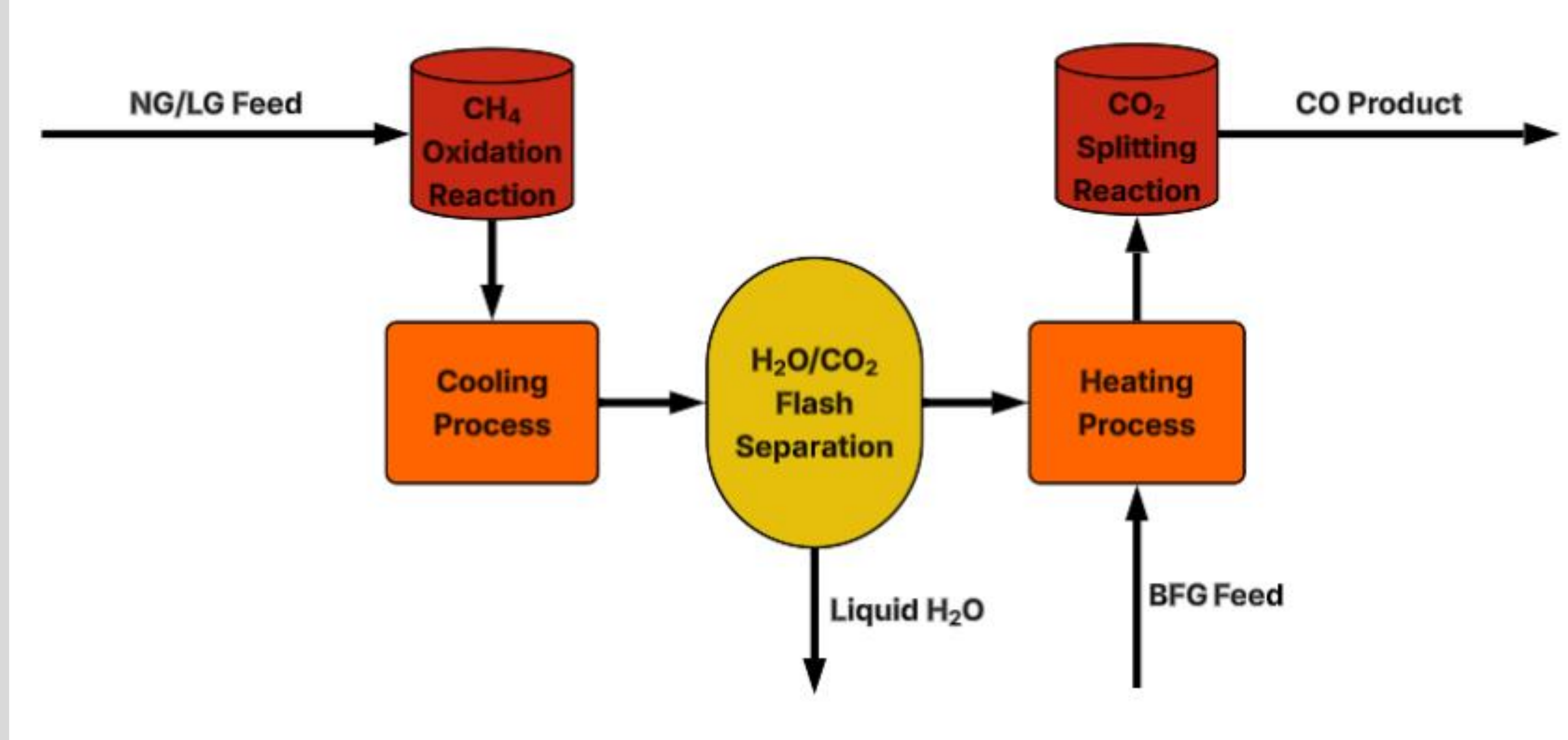


Figure 4. Overview of reactor model created in ASPEN.

- CH_4 oxidation reaction produces stream mostly consisting of CO_2 and H_2O.
- CO_2/H_2O stream cooled from ~700°C to 40°C for flash separation.
- H_2O removed and CO_2 combined with an additional CO_2 feed, BFG.
- CO_2 stream heated back to ~700°C preparing for the CO_2 splitting reaction.
- CO_2 reacts and produces ~94% purity CO product stream.

Table 2. ASPEN Simulation Throughput and Heat Results.

Flow Type	NG	LG
Feed throughput (kmol/yr)	54,800	87,600
Amount of CO_2 fed (BFG) (kmol/yr)	111,000	82,800
Annual Production of CO (kmol/yr)	154,000	
Annual Heat Duty (GJ/tonne CO)	9.15	11.1

Sustainability

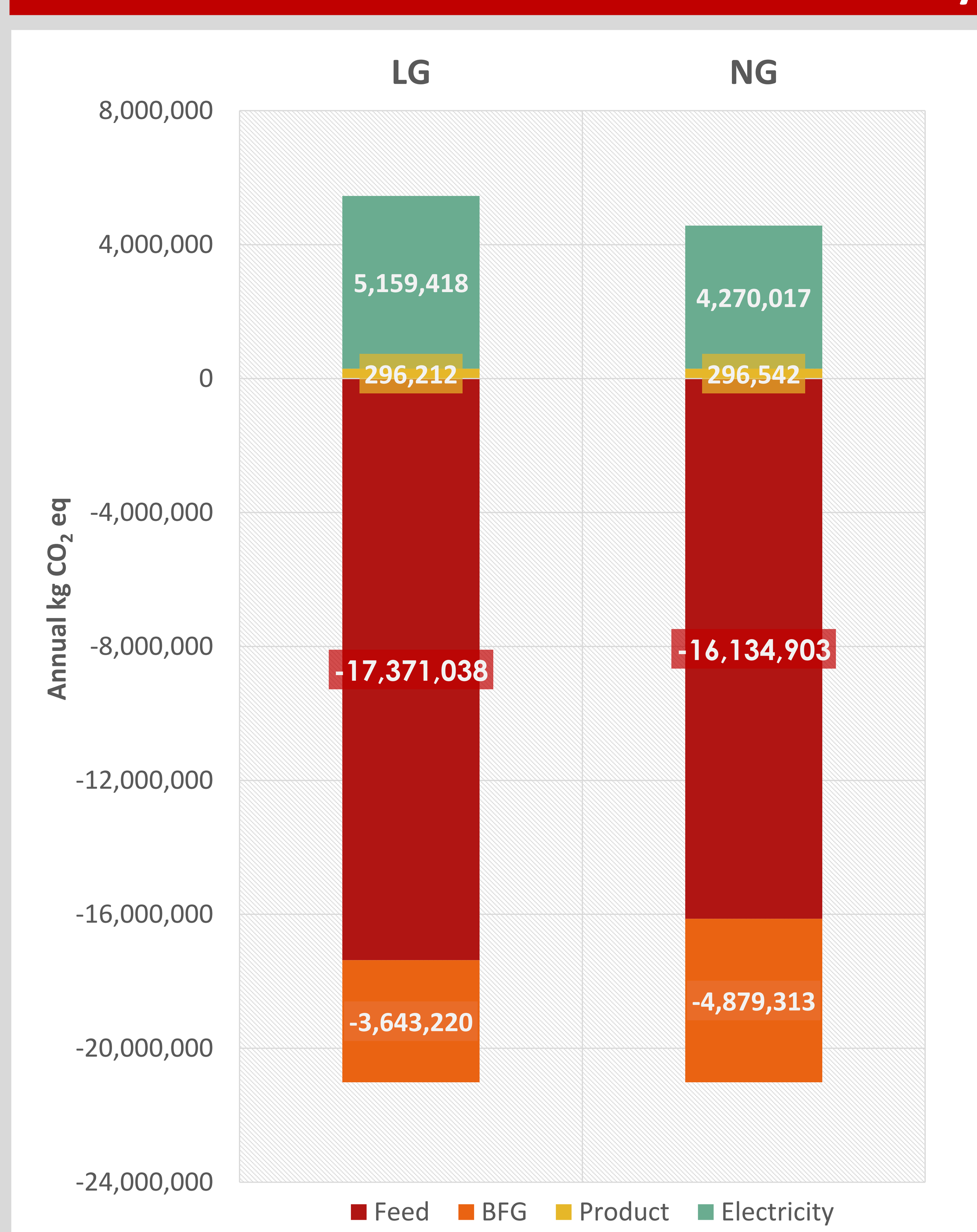


Figure 5. Annual Net GWP of NG and LG Feed Scenarios.

Both NG and LG scenarios are strongly net negative, with GWPs of -16,400,000 and -15,600,000 kgCO_2-eq.

- NG is more sustainable due to its lower energy demand
- Thus, NG produces less CO_2 from fossil fuel burning.
- Both are so strongly net negative that either feed is a sustainable improvement.

The sustainable improvement upon traditional CO production is the use of BFG as an oxidizing agent.

- For NG and LG, the magnitude of GWP better than SRM can be observed as -4,880,000 and -3,640,000 kgCO_2-eq.
- NG requires more BFG due the greater CH_4 content.

Economics

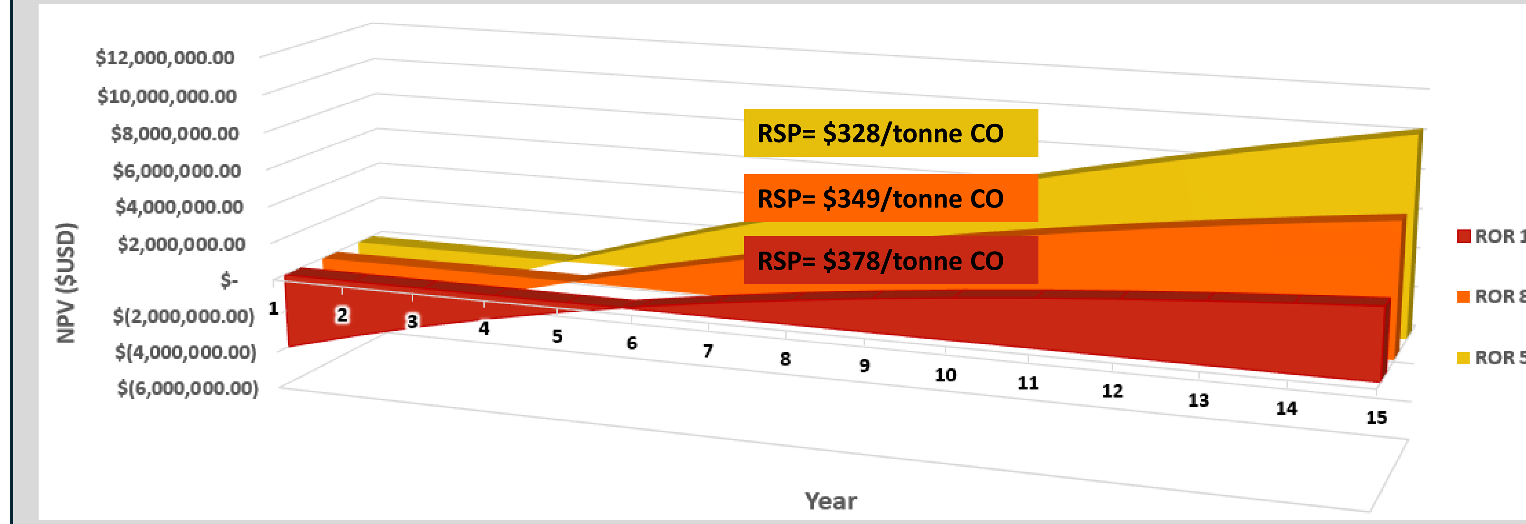


Figure 6. NG Discounted Plant Lifetime Profitability.

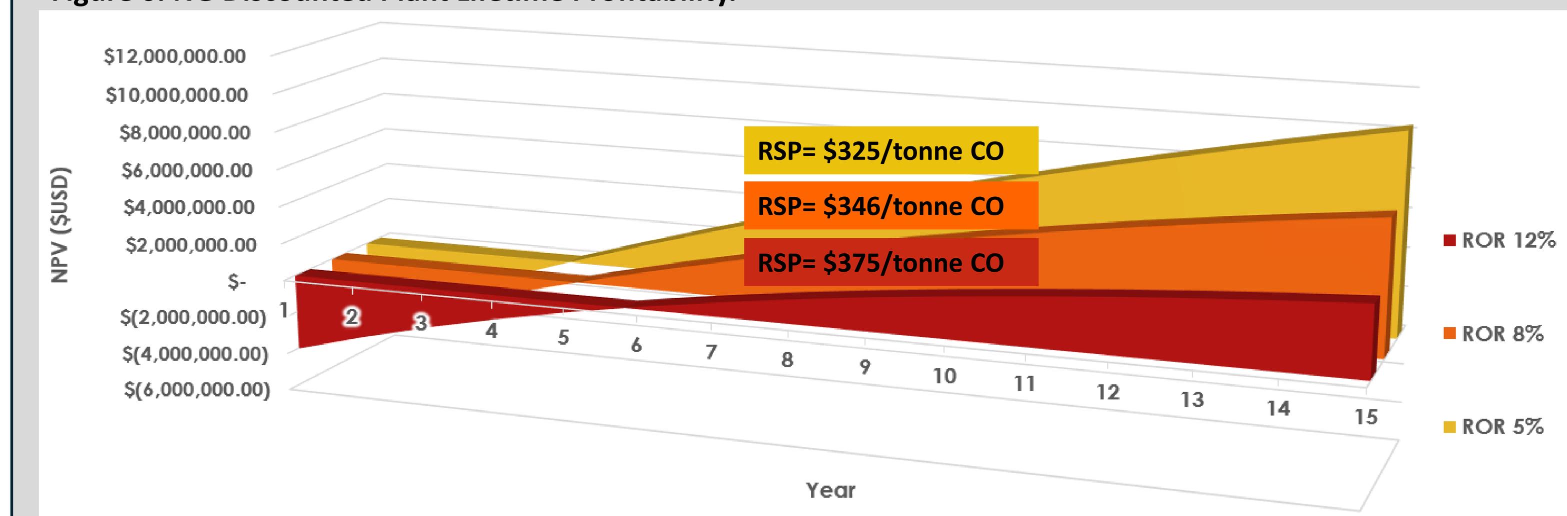


Figure 7. LG Discounted Plant Lifetime Profitability.

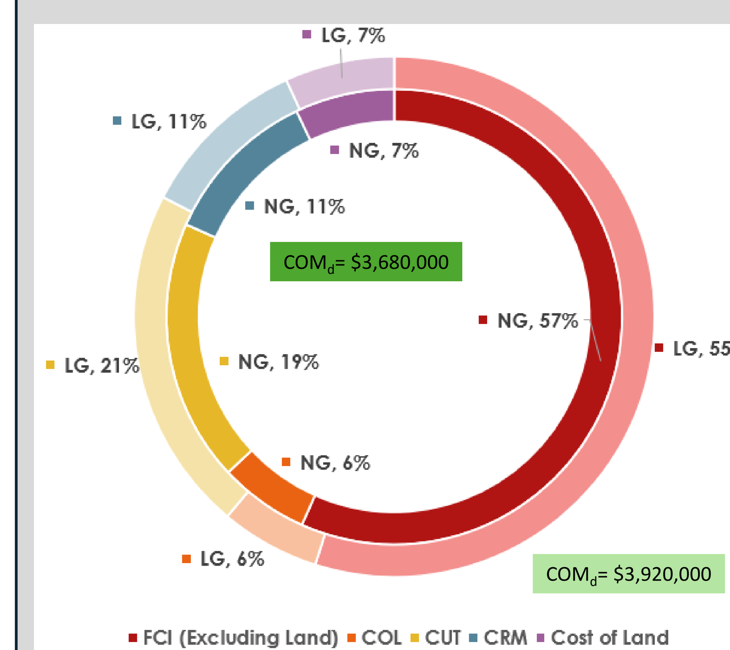


Figure 8. Non-Discounted COM$_d$ of NG and LG.

- The discounted ROR of 5% in both scenarios produces a higher profit by the end of plant lifetime.
- The discounted ROR of 8% reveals an RSP at the top of the market ($345/tonne CO)[7] making the process vulnerable to market fluctuations.
- NG COM$_d$ < LG COM$_d$ due to lesser utility costs from having better heat integration.
- Non-Discounted Net Profitability:

NG: -$747,000, LG: -$515,000 as LG generates more CO_2 credits

Conclusions

1. An ASPEN simulation of the process was completed, proving it is possible at 97% yield for 94% purity CO product.
   - The NG scenario had a lower energy demand, which improved its profitability and sustainability.
2. The sustainability metrics of this process show that it consumes a significant amount of CO_2, making this process much more desirable than traditional CO production pathways.
3. The process is profitable under an 8% ROR, though a 5% ROR is more realistically feasible, as it keeps economic efficiency through market fluctuations under both NG and LG scenarios.

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References