NC STATE UNIVERSITY

Production of CO from Waste Gases via Chemical Looping

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CHEMICAL & BIOMOLECULAR ENGINEERING
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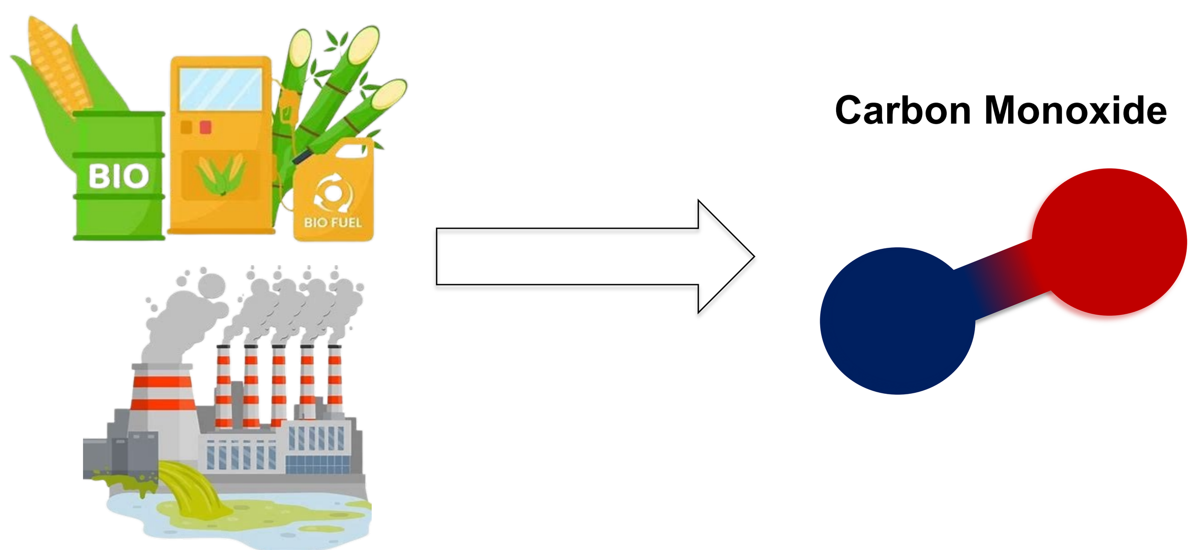
Goals

- Research and Analyze current carbon monoxide production methods
- Determine and design the best process for producing CO from industry/biogas waste streams using chemical looping
- Evaluate the cost and environmental benefits of the process



Methods

HSC Chemistry

- Used to calculate fuel/mixture thermodynamics to determine feasibility
- Used to calculate maximum possible conversion of streams.
- Equations used are shown below:

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O \quad (1)$$
$$2\,CO_2 \rightarrow 2\,CO + 2\,O_2 \quad (2)$$

Aspen

- Used for modeling process for each stream
- Used to find heating values, stream flowrates, and equipment sizes
- Results used in costing and environmental analyses

Feed Streams

Landfill Gas (LFG)

- Contaminants of landfill off-gas are removed to produce the medium BTU gas with compositions shown on the right

Coke Oven Gas (COG)

- Waste stream produced in coke ovens during steel production

Natural Gas

- Pure methane is used as the base case to compare to LFG and COG

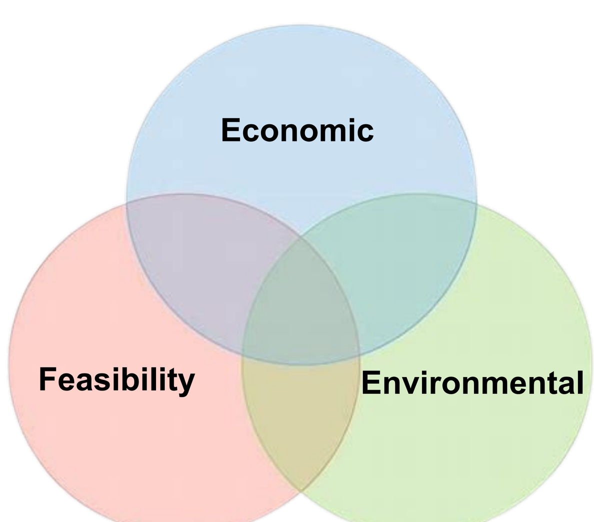
Landfill Gas

Component	Mole percent
Methane	55.63
Carbon Dioxide	37.14
Hydrogen	0
Carbon Monoxide	0
Other gases (N_2, O_2, etc.)	5.99

Coke Oven Gas

Component	Mole percent
Methane	22.7
Carbon Dioxide	1.8
Hydrogen	60.7
Carbon Monoxide	6.4
Other gases (N_2, O_2, etc.)	8.4

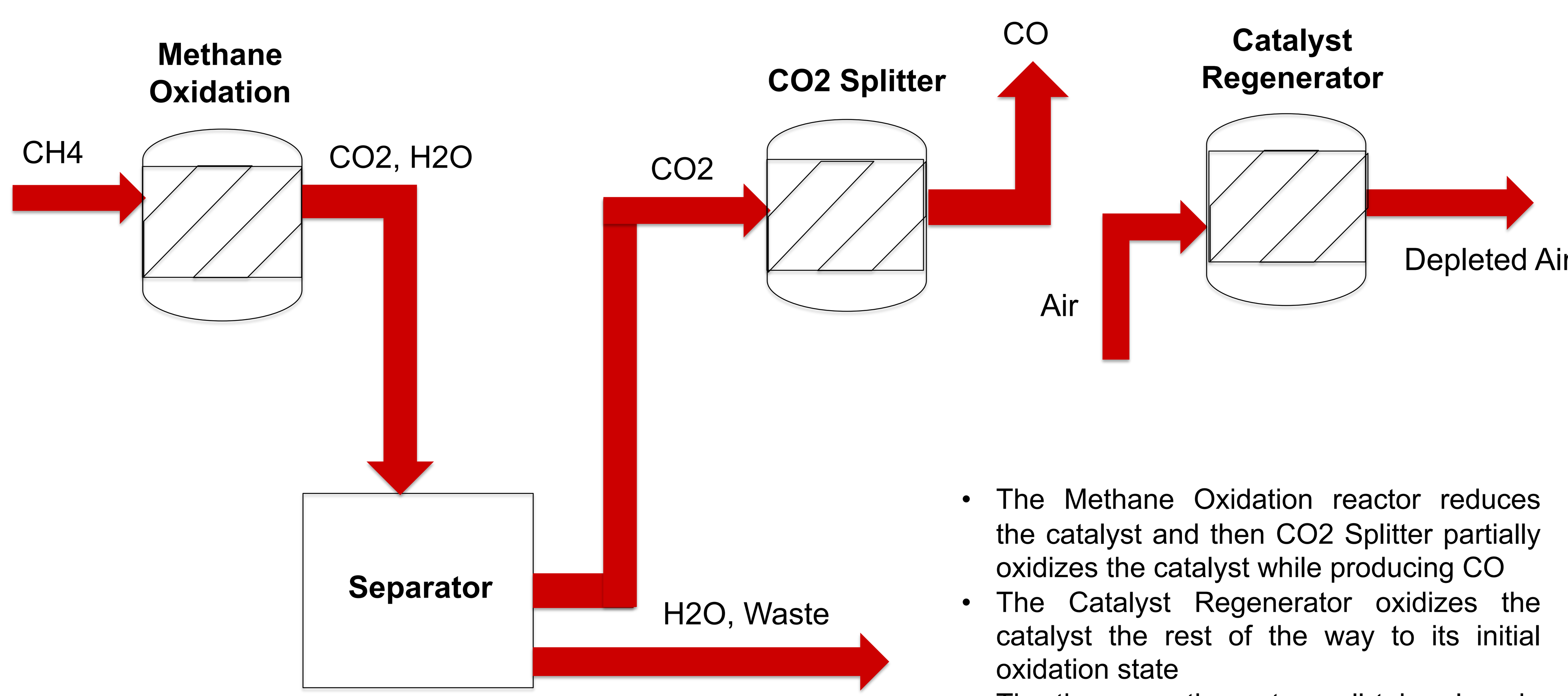
Motivation



Environmentally and Economically Sustainable

- Creating a high-quality carbon monoxide product from waste streams
- Eliminate greenhouse gas emissions from the waste streams, while operating a process with net-zero carbon emissions

Process Design



- The Separator removes water and any other impurities to flow pure CO2 into the CO2 Splitter.
- The Methane Oxidation reactor reduces the catalyst and then CO2 Splitter partially oxidizes the catalyst while producing CO
- The Catalyst Regenerator oxidizes the catalyst the rest of the way to its initial oxidation state
- The three reactions steps all take place in a single reactor
- Three reactors will be running in parallel, so that each reaction is continuous

Environmental Impact

Carbon Dioxide Release vs. Carbon Sequestration

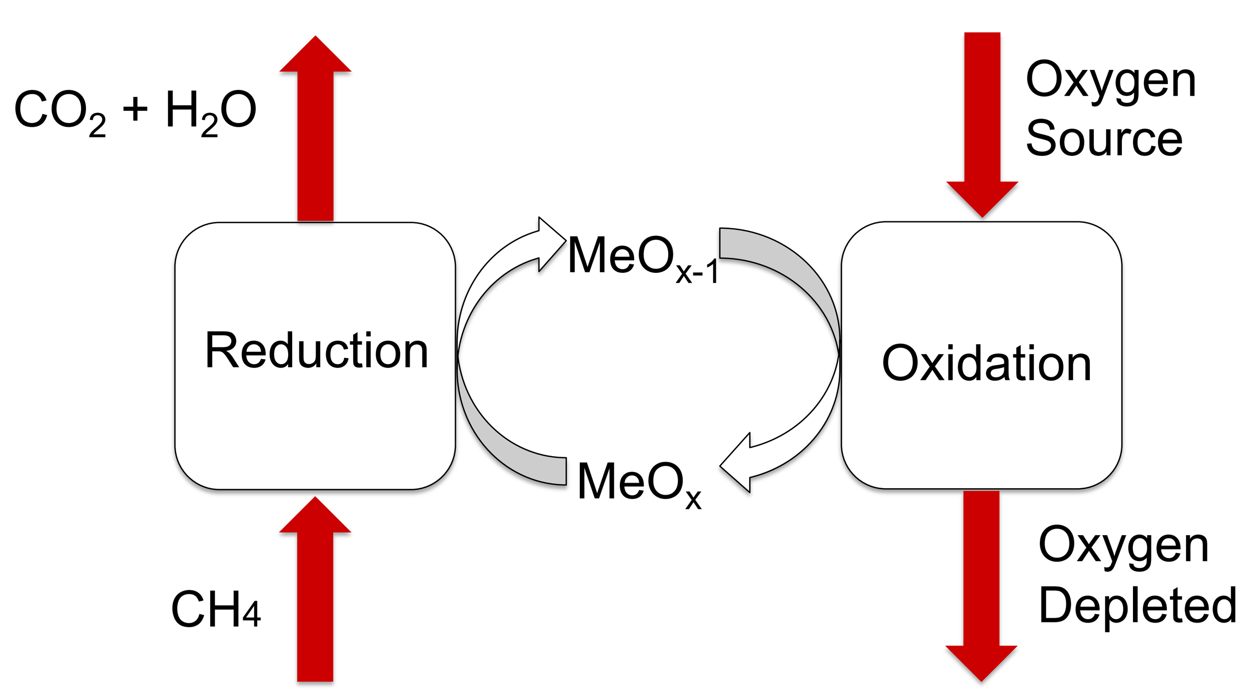
- Landfill gas, COG and pure methane for this process release 0.6%, 0.9%, and 1% respectively of the carbon dioxide emissions as compared to current practices.
- On top of this, in each three cases, the process consumed carbon dioxide in approximately the same quantities as the amount that would be released under current practices.

Conclusions & Recommendations

- Landfill gas is the optimal feed source for the chemical looping process based on the costing and environmental benefits
- COG has better ROR than LFG, but the quantity of COG is limited, making scale up challenging
- Further work needs to be done to optimize the LFG process
  - Using higher pressures or separating CO_2 from the feed before the methane oxidation reaction
- The process may be more economical in the future if a carbon capture tax is considered

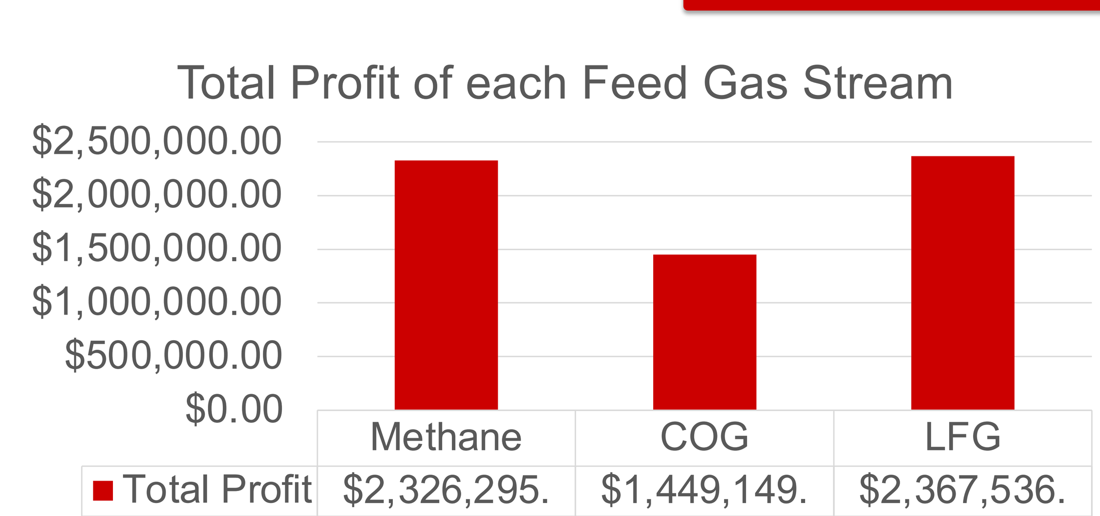
Chemical Looping

Chemical Looping is the process in which a metal oxide catalyst is depleted of its oxygen for one set of desired reactions and is then regenerated with oxygen with another set of desired reactions. With this, two sets of reactions can be achieved with the same catalyst. For our process, it is used to partially oxidate methane in a fuel gas into carbon dioxide and then reduce that carbon dioxide into carbon monoxide.

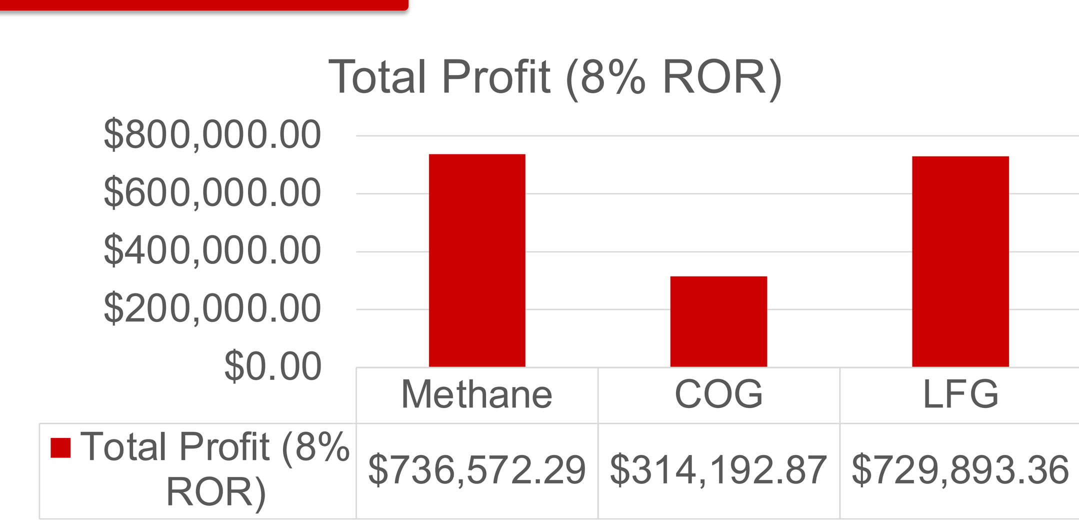


$$MeO_x + CH_4 \rightarrow MeO_{x-1} + CO_2 + 2\,H_2O \quad (1)$$
$$MeO_{x-1} + 2\,CO_2 \rightarrow MeO_x + 2\,CO + 2\,O_2 \quad (2)$$

Costing



Assuming 15-year plant life and $0.32/kg CO, the ROR of each stream is:
• Methane: 25.3% • COG: 36.9% • LFG: 25.9%



For 8% ROR, CO price per kg must be:
• Methane: $0.28/kg • COG: $0.25/kg • LFG: $0.27/kg

Acknowledgments

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References

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