Objectives
- Understand temperatures and pressures throughout the whole process.
- Design a process flow for methanation process.
- Research suitable carbon feedstock.
- Research water electrolysis technologies.
- Model methanation in Aspen Plus software.

Carbon Feedstock
The carbon feedstock for methanation will be Landfill Renewable Natural Gas (RNG). Benefits of Landfill RNG:
- Low sulfur content.
- A landfill site can produce anywhere from 1 to 15 million ft³ of RNG a day.
- Several landfill RNG locations in Michigan.

Methanation
- Four main reactions:
  - CO₂ + H₂ ⇌ CO + H₂O (2)
  - CO + 3H₂ ⇌ CH₄ + H₂O (3)
  - 2CO + 2H₂ ⇌ CH₄ + CO₂ (4)
  - CO₂ + 4H₂ ⇌ CH₄ + 2H₂O (5)
- Reactions 2, 3, and 4 occur in a stepwise fashion while reaction 5 occurs parallel to the other reactions.

Design
- Recommended Reactor Type: Adiabatic Fixed Bed Reactor.
- Recommended Catalyst Type: 50% Ni/Al
- Catalyst (Zhang et al., 2013).
- The implementation of a CO₂ methanation process based on the selected final process components identified via the design alternatives uses an empirical approach.
- A simplified process model was used to calculate stream mass flow rates and process energy balances (Fig. 3).

Water Electrolysis
- Water Electrolysis is the process of splitting water into hydrogen.

Power to Gas (PtG)
- Methanation should be used as an energy storage technology. Since natural gas can store large amounts of energy and has already existing infrastructure, methanation is a good candidate for producing synthetic natural gas.
- PtG is the use of excess energy generated by renewable resources to produce synthetic natural gas.
- In the methanation process, water electrolysis requires electricity to produce hydrogen gas.
- The use of renewable energy can create a natural gas that is carbon neutral.

Implementation
- Based on scaling calculations, a reactor required to produce 17 bcf annually would have an effective volume of 28.05 cubic meters.
- Operating temperature of this reactor would be 673.15K and an operating pressure of 20 bar.
- The corresponding catalyst load of this reactor would be 3741 kg/m³ of 50% Ni/Al₂O₃.

Economic Analysis
- The synthetic natural gas produced from methanation is considered an Alternative Fuel candidate for producing synthetic natural gas.
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Simulation
- Aspen Plus simulations allow for sensitivity analysis across a range of varying parameters, comprehensive economic analysis of process components, and stream characteristics.
- The CO₂ methanation reactor was modeled using an R-Gibbs reactor operating under a general Ideal Gas Law rate model.
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Funding
- The Department of Energy offers loans to projects that reduce air pollution and greenhouse gases. The loan is intended to support early use of advanced technologies.
- The synthetic natural gas produced from methanation is considered an Alternative Fuel and qualifies for this loan.

References

Constraints
- Produce an output of 17 billion Cubic Feet (bcf).
- Design must assist with Net Zero methane emission target.
- Contain less:
  - 5 ppm of Oxygen
  - 97.5% or greater methane.

Justification
- Carbon dioxide being a greenhouse gas contributes to climate change due to its ability to store heat.
- Due to both State of Michigan’s and Consumers Energy promise to lower carbon emissions, developing ways to turn carbon into a methane is important for carbon reduction.
- The process of methanation would decrease carbon emissions due to taking the carbon emissive molecules such as carbon dioxide, injecting hydrogen into the process and turning it into methane, which can be used for energy such as heating buildings and houses.

Problem Statement
Design a net zero methanation process coupled with water electrolysis.

Background
Introduction
- Methanation is the process of converting carbon monoxide (CO) and carbon dioxide (CO₂) into methane (CH₄) through hydrogenation.
- CO₂ + 4H₂ ⇌ CH₄ + 2H₂O (1)

Justification
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