Renewable Energy Center

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CO_2 Recycling by Reaction with Renewably-Generated Hydrogen

Goals/Objectives

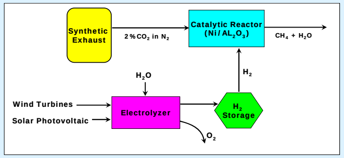
- Demonstrate the recycle of CO_2 into CH_4 by reaction with H_2
- Reduce Greenhouse Gas (GHG) emissions
- Use renewably generated Hydrogen

This project investigated a method to reduce GHG emissions from the natural gas power generation sector. CO_2 in exhaust can be reacted with renewably produced H_2 to generate CH_4 that can be recycled back into an engine or turbine, reducing greenhouse emissions and increasing the engine/turbine efficiency.

Concept

$$CO_2 + 4\,H_2 \underset{}{\overset{\Delta,\ \text{Catalyst}}{\rightleftharpoons}} CH_4 + 2\,H_2O$$

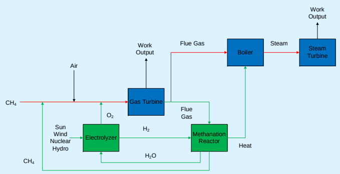
The exothermic Sabatier Reaction occurs at moderate temperatures (<400 °C) over a Ni or Ru catalyst. Haldor Topsoe PK-7R Ni based catalyst was used for this project.



A Stuart KOH 5 kW electrolyzer produced H_2 through electrical power generated from photovoltaic panels and wind turbines.

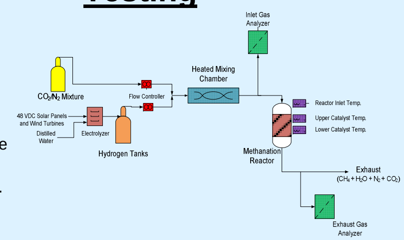
Overall Scheme for CO_2 Capture and Recycle in a Natural Gas Power Plant

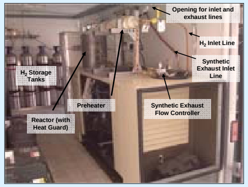
The Sabatier reaction can be implemented in a combined cycle power plant reducing emissions and increasing the efficiency of the gas turbine while supplying heat for the boiler.



Testing

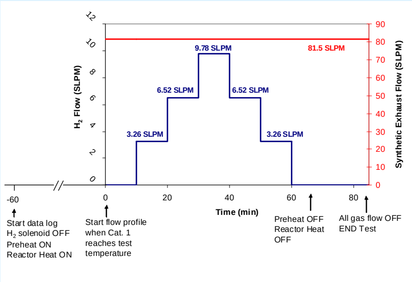
Synthetic exhaust gas (2% CO_2 in N_2) was mixed with renewably produced H_2 and heated to roughly 200°C before entering the methanation reactor.



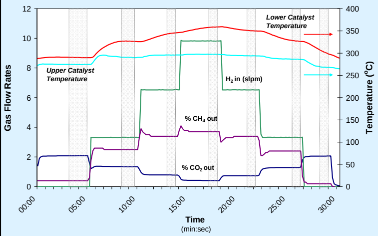


The experiment was setup in DRI's renewable energy trailer. The reactor is a 0.55 L stainless steel reactor, with top to bottom flow. A National Instruments Compact Field Point unit controlled the experiment. Exhaust gas analyzers outside the trailer tested the gas stream before and after the reactor.

Experiments were performed at various temperatures, flow rates, and gas mixing ratios. In most cases, the synthetic exhaust gas flow rate was held constant while varying the flow of H_2. (Shown below, with H_2 flow in blue, N_2/CO_2 in red).

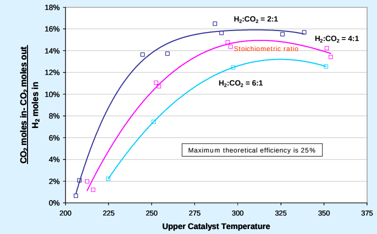


Results



With increasing H_2 flow, the % CO_2 decreased and CH_4 increased. The exothermic reaction can also be seen at the top of the graph.

H_2 utilization efficiency is shown on the right. While more CO_2 is reacted with higher H_2 flow rates, the efficiency of CO_2 conversion per mole of H_2 used decreases.



Conclusions

- A nickel-based catalyst is effective for reducing CO_2 to CH_4 using H_2 at moderate temperatures (300-350ºC)
- Approximately 60% conversion of CO_2 was demonstrated at a stoichiometric ratio of H_2/CO_2 of 4/1 and space velocity of 10,000 hr^{-1}
- With renewably-produced H_2, this CO_2 recycle approach is effective in reducing GHG emissions

Acknowledgements

Funding for this work was provided by Recycle CO_2 Inc. We also acknowledge the contributions of Alan Gertler, Rick Purcell, Larry Sheets and Roger Jacobson from DRI.