

Process Systems Optimization for Synthetic Fuel Production from Solar Derived Syngas

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“Sunshine to Petrol Grand Challenge”

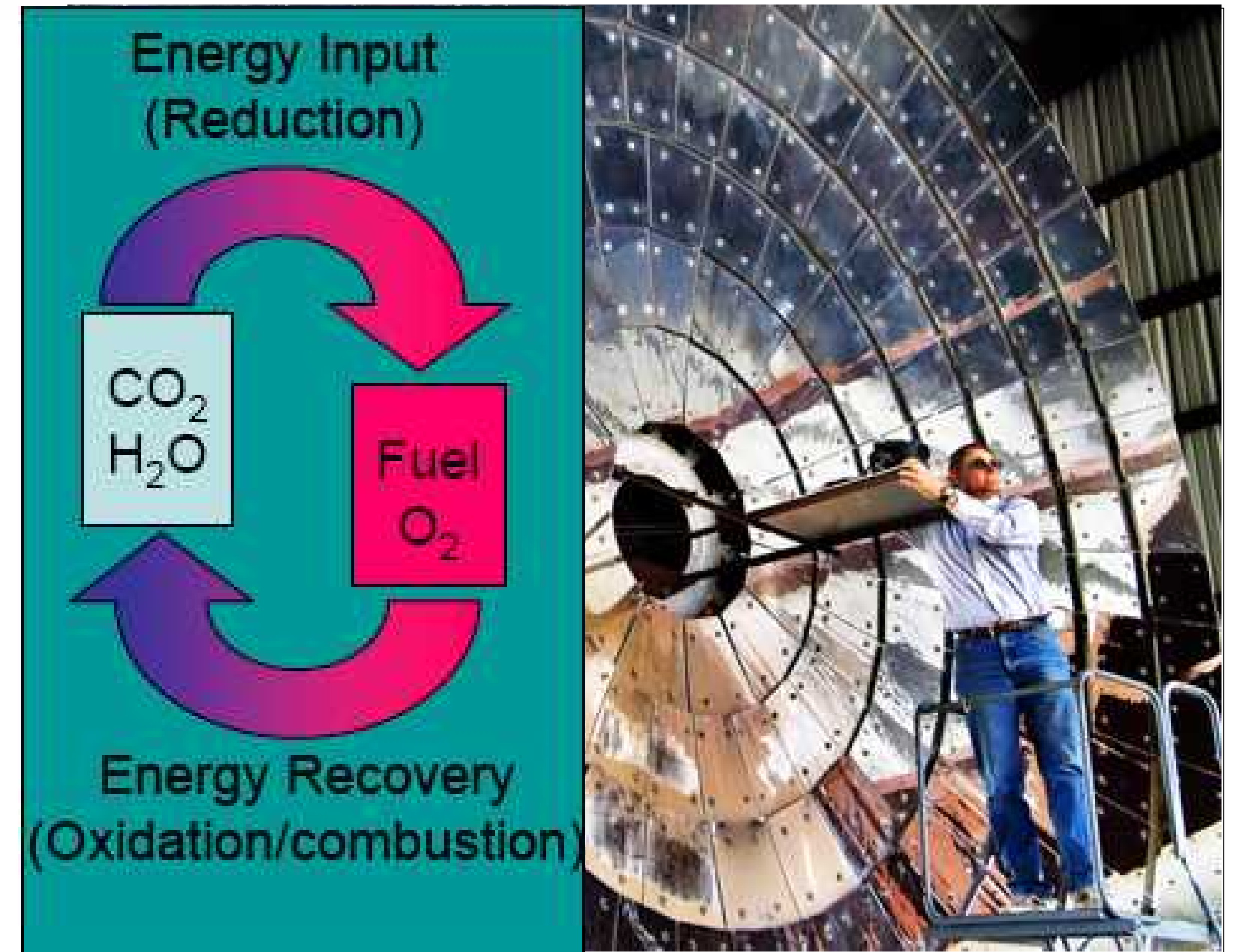
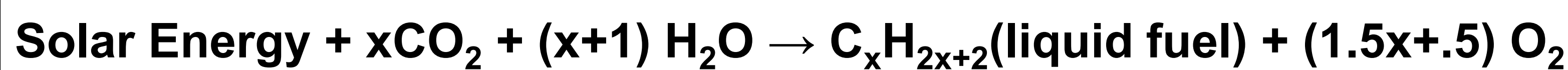
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Introduction

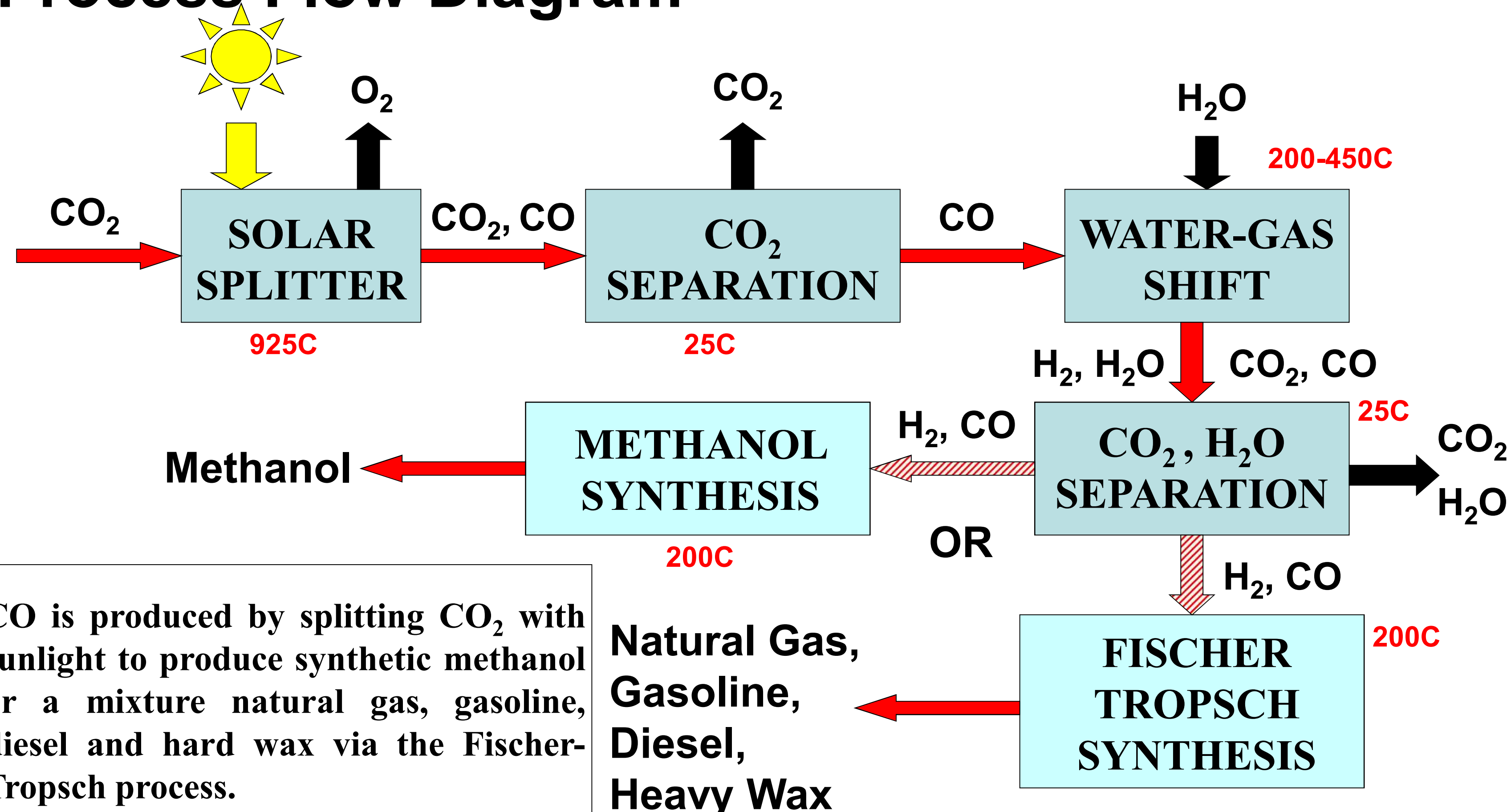
Petroleum fuels are the foundation of industry in the United States. The U.S. presently consumes almost a quarter of the world's oil production. Securing a stable, renewable source of fuel for transportation may be one of the most important challenges for the future. A liquid hydrocarbon fuel has the added advantage of utilizing existing infrastructure for processing and distribution.

Sunlight is a readily available source of energy that is capable of heating gases up to very high temperatures. Utilizing solar energy, we can “reverse” the process of combustion to split CO_2 into its components CO and O_2 . It is possible to synthetically produce many fuels from a mixture of CO and H_2 .

The present work aims to determine the most efficient system architecture that minimizes capital and operating cost. Prior to fuel synthesis, the Water-Gas Shift reaction is used to obtain a 2:1 H_2 : CO ratio. The optimal arrangement and operating parameters of a reactor and two CO_2 separations steps needs to be determined.



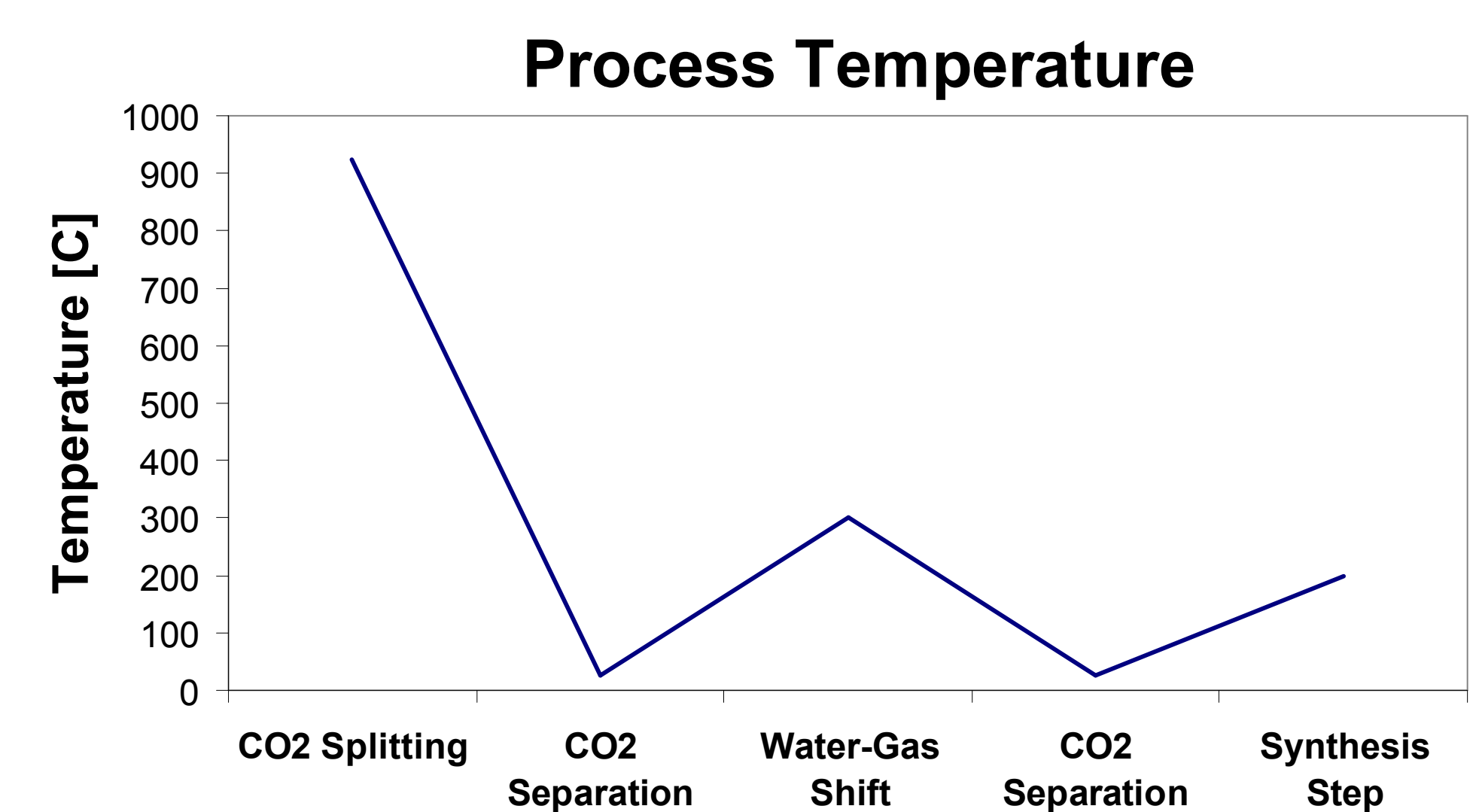
Process Flow Diagram



Process Temperature Effects

-Process temperature “dips” in CO_2 separations make it the largest source of energy consumption. If one or both of the CO_2 separation stages could be eliminated, the total savings would be significant.

-Composition of gas exiting solar splitter is 3:1 CO_2 : CO . An optional separation step strips out CO_2 prior to the Water-Gas-Shift reaction. The removal of this initial separation stage has the potential to save operating cost by ameliorating or eliminating the temperature dip exhibited above.



The Water-Gas Shift Reaction

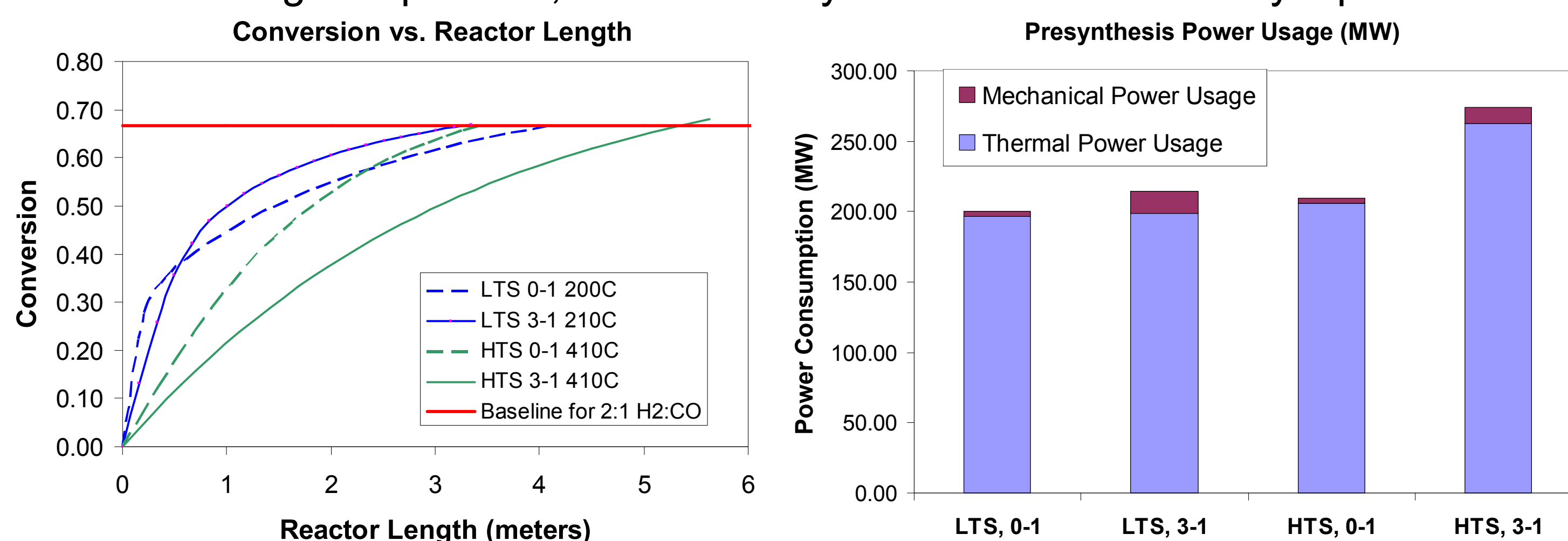


•Was modeled using Aspen Plus Process Simulator

•Two modes of operation to choose from:

-Low Temperature (200-220°C): higher Activity, expensive, $\text{CuO}/\text{ZnO}/\text{Al}_2\text{O}_3$ based, sensitive to poisoning and sintering, rate limited by adsorption to activation sites.

-High Temperature (350-400°C): lower Activity, inexpensive, $\text{Fe}_2\text{O}_3/\text{Cr}_2\text{O}_3$ based, strong, resistant to sintering and poisons, rate limited by diffusion into the catalyst pellets.

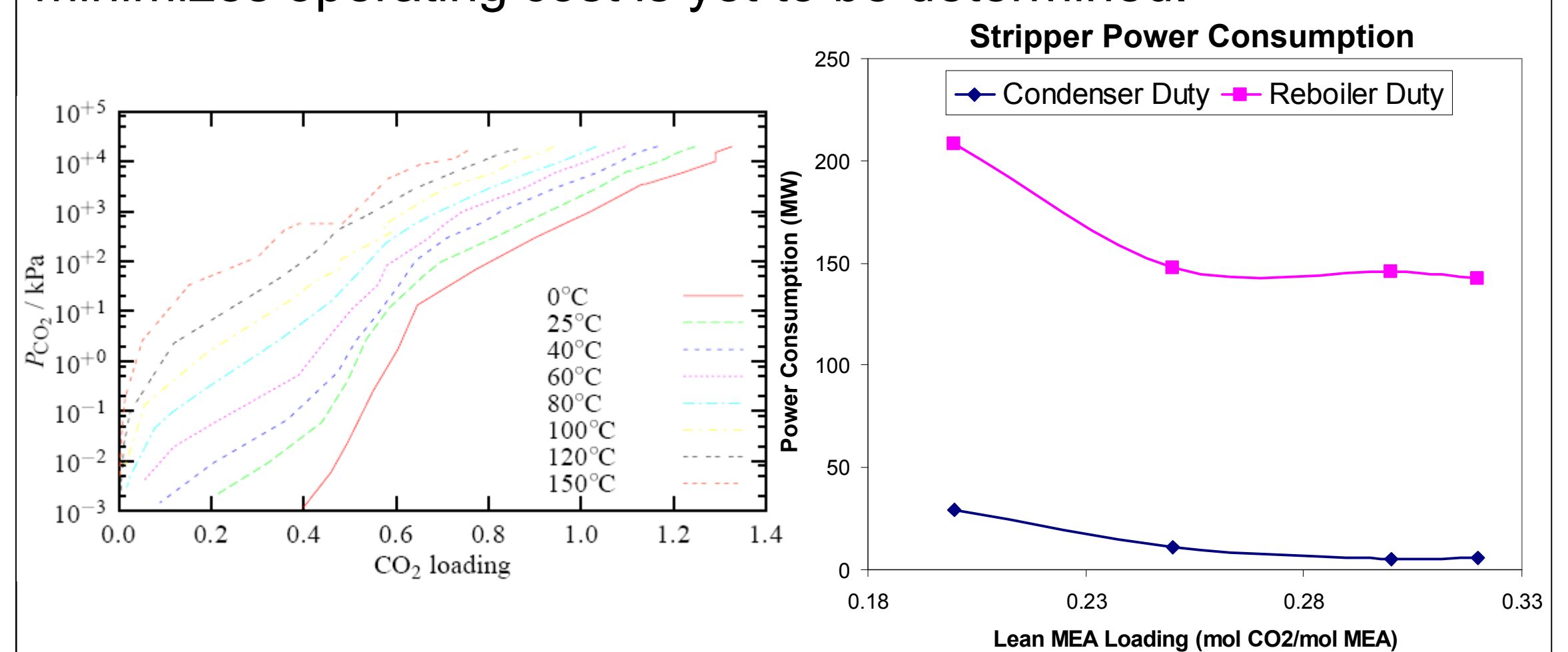


•The LTS 0-1 reactor exhibits a higher initial activity than HTS 0-1, but HTS kinetics speed up as temperature increases along reactor length. Equilibrium limits the kinetics of LTS.

•HTS at 3:1 CO_2 : CO exhibits greater heating/cooling costs due to equilibrium shift at high temperatures and CO_2 concentrations. More steam must be added to the reactor inlet in order to push the reaction forward. Because more steam is used, more steam must be heated.

CO_2 Separations

-Currently the most well understood technology for carbon dioxide separation uses an absorbent with a strong affinity for CO_2 , methyl ethanol amine (MEA). After scrubbing CO_2 out of the process gas, the MEA mixture is then recovered and recycled using a stripper column by boiling off CO_2 . The optimal level of CO_2 to be separated from the charged MEA which minimizes operating cost is yet to be determined.



-Condenser/Reboiler Duty is higher for lower lean MEA loadings. In order to obtain a more pure lean MEA solution, a greater portion of the fluid must be boiled/condensed over a higher number of stages. Using a “dirty” lean MEA solution has the potential to save in thermal energy requirement.



References

- [1] Singh, C.P.P., Saraf, D.N., “Simulation of High-Temperature Water-Gas Shift Reactors,” Ind. Eng. Chem., Process Des. Dev., 1977, Vol. 16, No. 3
- [2] Bussche, K.M., Froment, G.F., “A Steady-State Kinetic Model for Methanol Synthesis and Water-Gas Shift Reaction on a Commercial $\text{Cu}/\text{ZnO}/\text{Al}_2\text{O}_3$ Catalyst,” Journal of Catalysis., 1996, Vol. 161, No. 156
- [3] Newsome, D.S., “The Water-Gas Shift Reaction,” Catal. Rev. Sci. Eng., 1980, Vol. 21, pg. 276-314.