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Production of Ethylene from Shale Gas via Oxidative Coupling of Methane

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ABSTRACT

The objective of this project is to design a chemical facility which will produce ethylene. The proposed plant will be located in New Albany, Ohio because of its promising shale deposits. This plant will operate at a rate of 350,000 kg/hr of shale gas input to produce 1.87 million tons of ethylene, 220,000 tons of ethane and 93,000 tons of propane on an annual basis using the Aspen Plus simulation software. Certain units were out of the scope of this project such as the Air Separation Unit (ASU), Power Generation Unit and Compression Unit. The cost of installed equipment (capital cost) was estimated to be around $87.2 million.

CHEMICAL REACTION (OCM REACTOR)

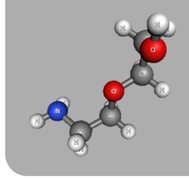
$$2CH_4 + 0.5O_2 \rightarrow C_2H_6 + H_2O$$
$$C_2H_6 + 0.5O_2 \rightarrow C_2H_4 + H_2O$$
$$C_2H_6 \rightarrow C_2H_4 + H_2$$
$$CH_4 + 1.5O_2 \rightarrow CO + 2H_2O$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$
$$CO + H_2O \rightarrow CO_2 + H_2$$

These six major reactions occur in the OCM reactor. The selectivity and conversion in the reactor is effected directly by the ratio inlet of methane to oxygen. As the ratio increases the ethylene production is more favored.

COMMERICAL USES

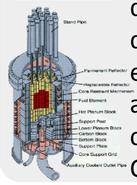
NOVELTY

Diglycolamine (30 wt.% water)



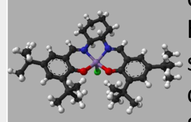
Diglycolamine (DGA) captures 99.9% of CO_2 as opposed to the commonly used Methyl-diethanol amine (MDEA) which captures 93.8% of CO_2.

OCM Reactor



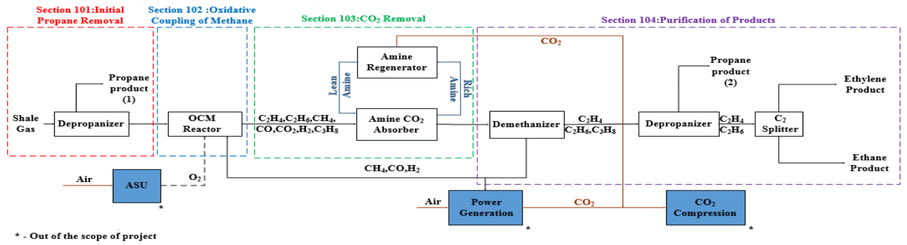
A catalytic reactor based on catalytic oxidative dimerization of methane directly to ethylene and ethane (by-product). This is an advanced method compared to Methanol-to-Olefin (MTO) process.

$(La_2O_{3(27\ wt.\%)}/CaO_{(73\ wt.\%)})$ catalyst



This catalyst at about 800 ^{O}C is better at converting shale gas to olefins with relatively high activity & selectivity compared to common catalyst like SAPO-34 and ZSM-5.

BLOCK FLOW DIAGRAM

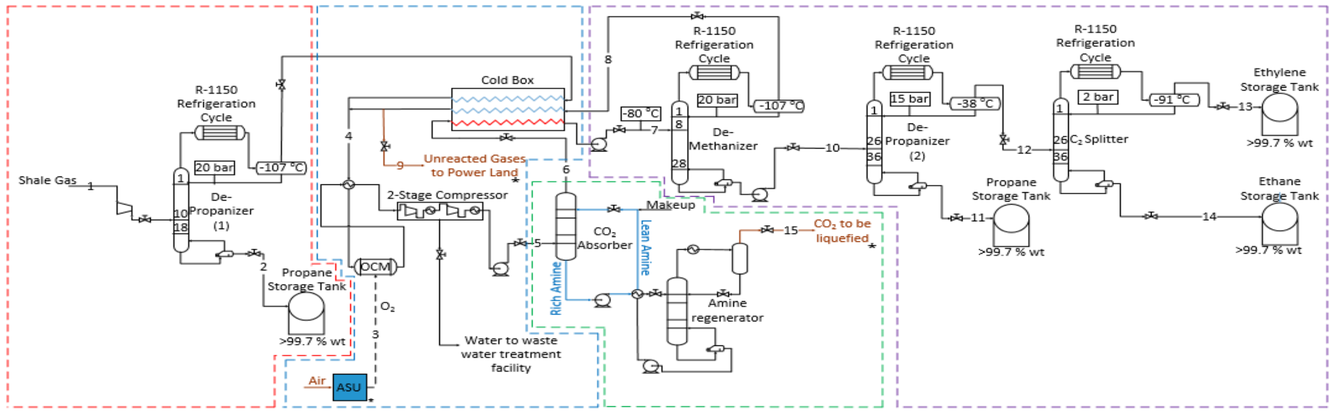


* - Out of the scope of project

What is Shale Gas?

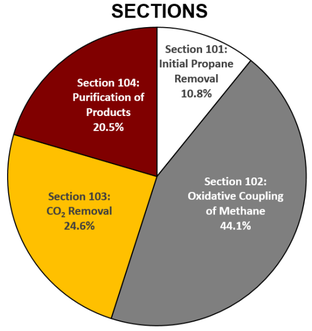
Shale gas is natural gas that is trapped within shale formation which is a rich source of petroleum. It was successfully extracted after the discovery of hydraulic fracturing in the late 1990's and boomed in 2008.

PROCESS FLOW DIAGRAM



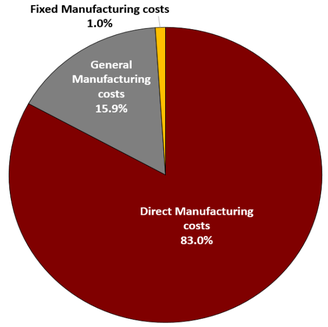
PRELIMINARY ECONOMIC ANALYSIS

CAPTIAL COST FOR THE DIFFERENT SECTIONS



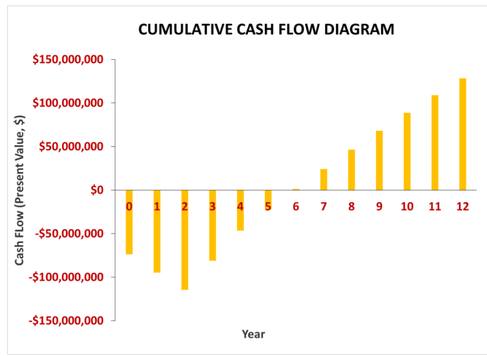
The OCM section is highest mostly due to the pressure & temperature drops in the compression stages.

MANUFACTURING COSTS FOR THE PLANT



The raw materials are the most expensive of the direct manufacturing costs, mostly due to shale gas costs.

CUMULATIVE CASH FLOW DIAGRAM



A breakeven point occurs between year 5 & 6. For a plant life of 12 years, the interest per year was 19.4%.

MOTIVATION

Since Niger is an economically unstable country with a potential shale gas basin.

This New Albany, Ohio based project is to be the first of many plants to fully test the plant feasibility.

A similar plant is to be placed in countries such as Niger; to stabilize the economy.

Since ethylene is a great source of plastic, many useful products could be produced to help third world countries like Niger.

PROCESS SPECIFICATIONS

- Most equipment are made from carbon-steel (Cost effective and durable).
- All separation columns were optimized for best possible output.
- CO_2 to be liquefied and sent to pipeline.
- Waste water to be sent to treatment facility.
- All unreacted gases are sent to power facility.
- Cold box decreases the refrigeration load of the de-methanizer's condenser.
- Ethylene refrigeration cycles are above all separation columns.

DISCUSSION & CONCLUSION

Upon sensitivity analysis to inspect the profitability of the plant, changing the feed to Fayetteville shale gas (negligible propane present) didn't have an effect on the breakeven point. Rather, this lead to a 17% interest per year on a plant life of 12 years. Thus, this preliminary sensitivity analysis has shown that this chemical plant is profitable on high methane shale gas feed, either with or without propane content.

Future work: To examine the effects of more shale gas feeds on the profitability of the plant.

NORTHROP GRUMMAN

Engineering & Science Student Design Showcase at Florida Institute of Technology