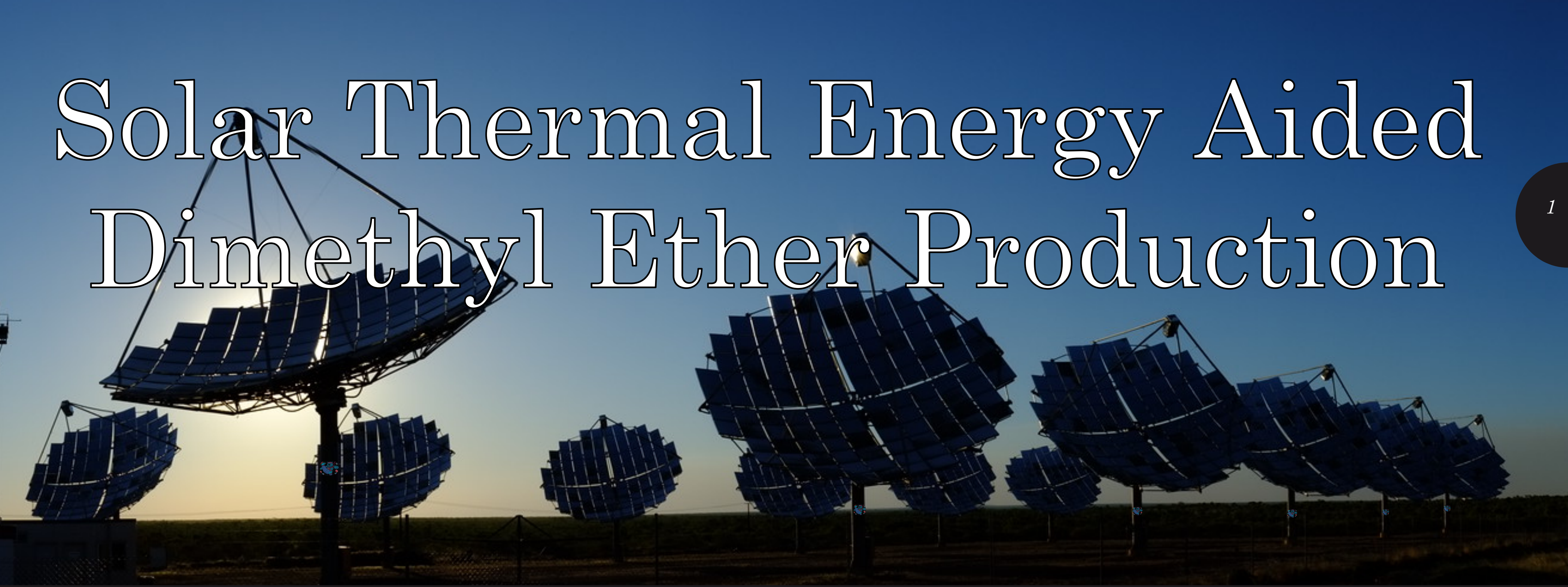
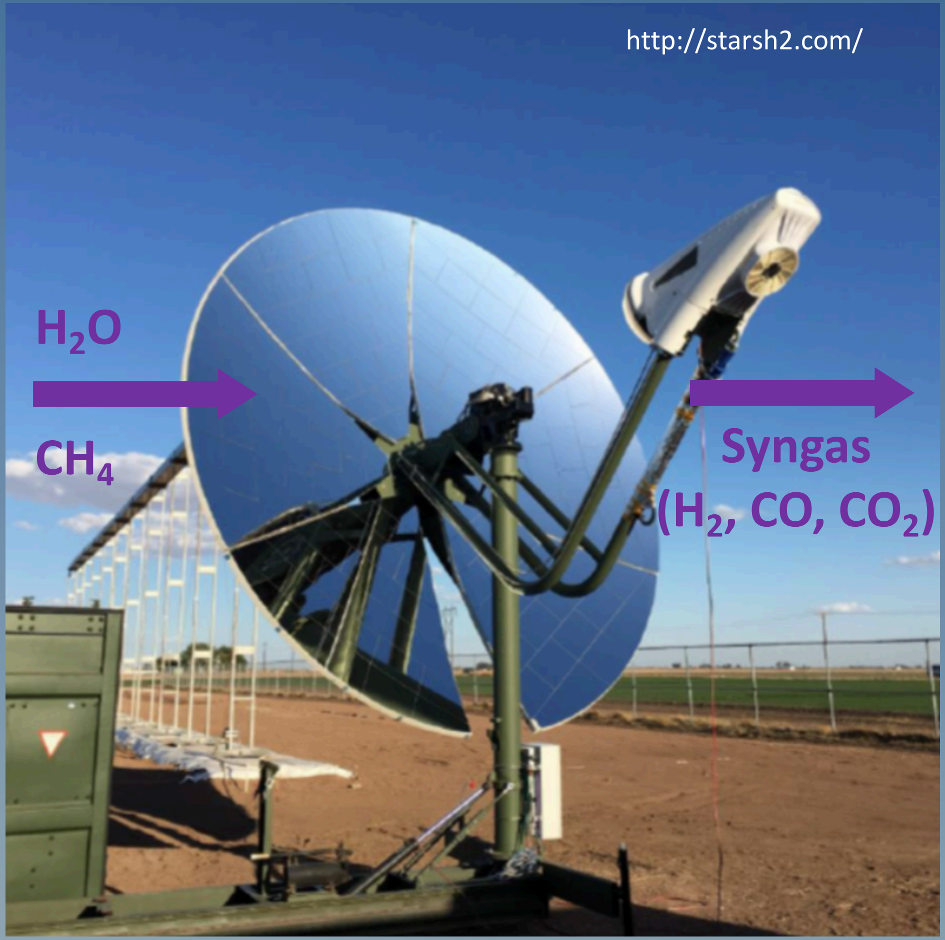


Solar Thermal Energy Aided Dimethyl Ether Production

Daniel Goddard, Joe Johnson, and James Merlo

June 5, 2020

Background



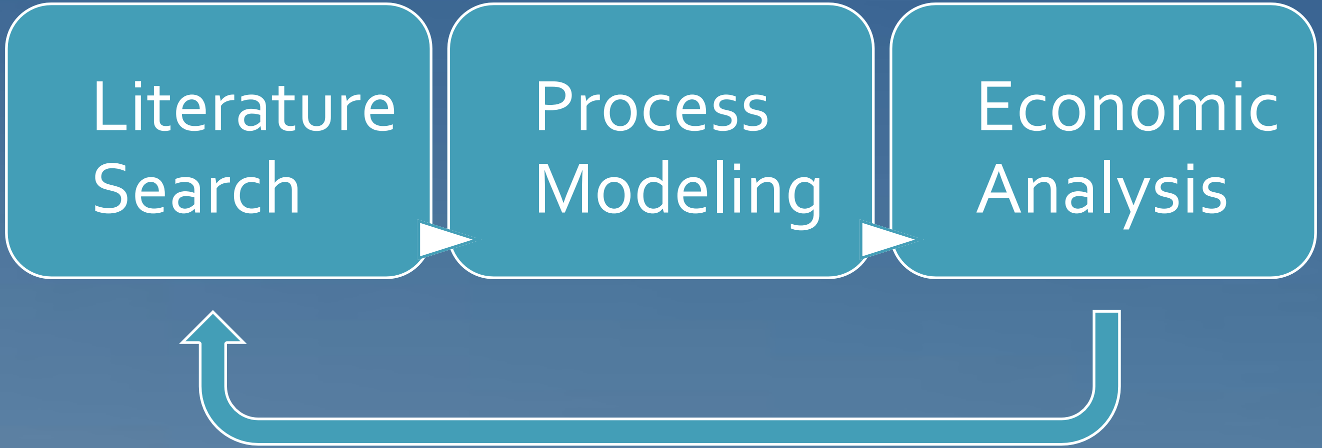
What Is the Dimethyl Ether (DME)?

- Solar thermal energy used to generate syngas
- Syngas is converted to Dimethyl Ether (DME)

Why DME?

- More easily stored and transported than hydrogen
- 4x energy density per volume than hydrogen fuel
- Burns cleaner than fossil fuels – can be used as diesel additive

Design Approach



Literature Search

Process Modeling

Economic Analysis

aspentech HYSYS

5/29/20

Project Goals

- Design a process that co-produces fuel-grade hydrogen and DME.
- Design energy efficient product purification process
- Maximize usable thermal energy to reduce operating cost and environmental footprint
- Sell hydrogen and DME at competitive market price

Process Overview

Generate Syngas from Methane

- Solar Thermal Advanced Reactor System (STARS)

Optimize H2:CO Ratio

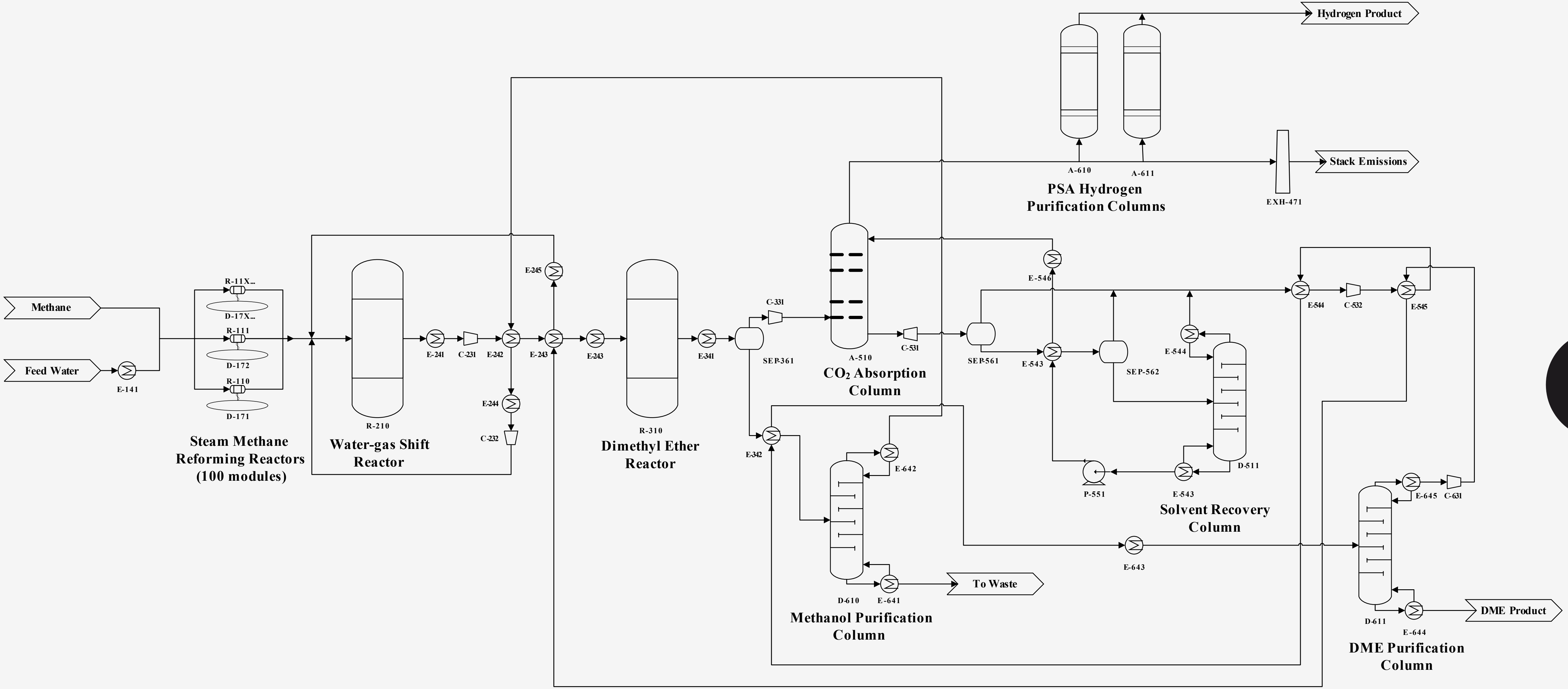
- CO_2 Recycle
- Water-gas shift reactor (WGSR)

Generate DME

- Dimethyl ether reactor (DMER)
- Methanol Recycle

Separate Products

- Distillation columns
- Pressure Swing Adsorption
- Phase Separators



PROCESS FLOW

Key Design Challenges

1. **Low distillation temperatures**
   - High energy costs
2. **High operating pressure**
   - Leads to thick walled (expensive) equipment
3. **Economy of scale**
   - Large scale required for reasonable product cost

Safety Consideration DME Reactor

Image from Taiyuan Heavy Industry Co http://product.tyhi.com/index/Chemical_Equipment/Coal_Chemical_Products/Dimethyl_Ether_Reactor.htm

Safety Concerns

- Pressure – 30 bar
- Temperature - 285˚C
- Flammability

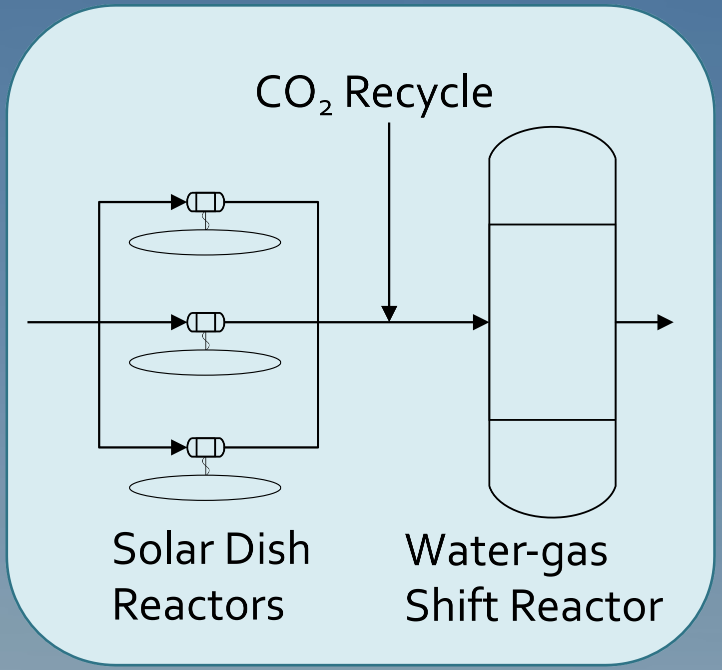
Hazard Evaluation

- HAZOP

Design Choices

- Compatible materials
- Safeguards to prevent fire/explosion

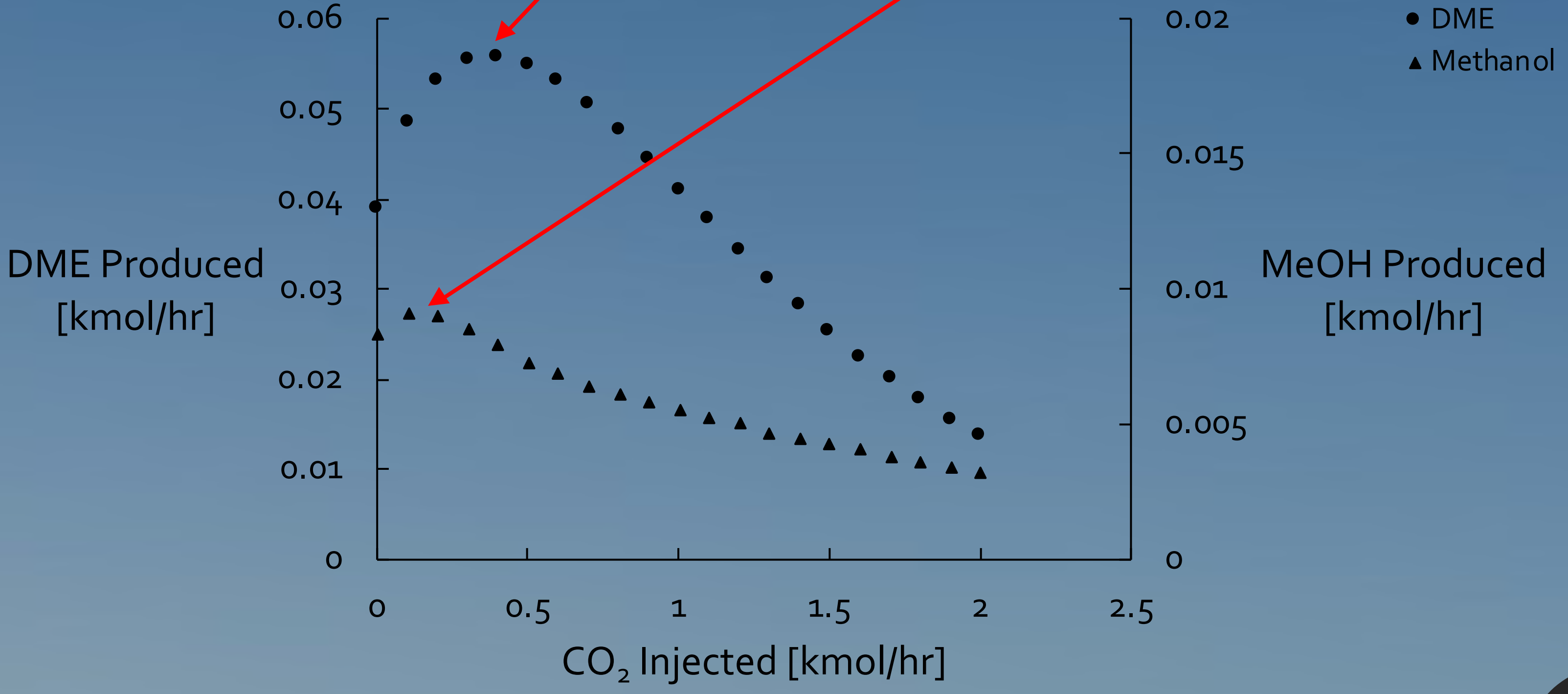
Case Study: Recycling CO_2 to Increase DME Production

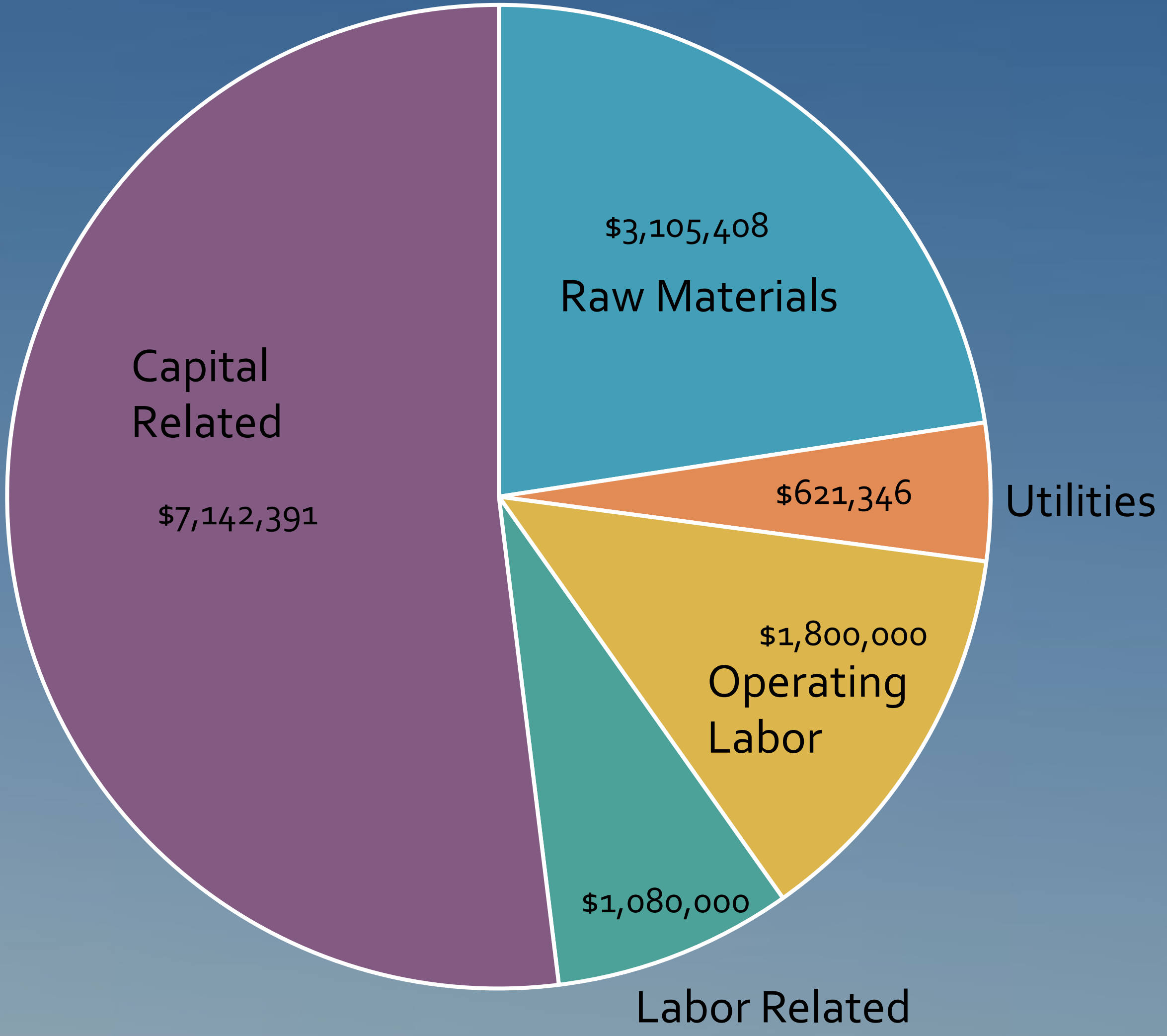


$CO + H_2O \rightleftharpoons CO_2 + H_2$

Max DME production at 0.4 [kmol hr^{-1}] CO_2

Max MeOH production at 0.1 [kmol hr^{-1}] CO_2



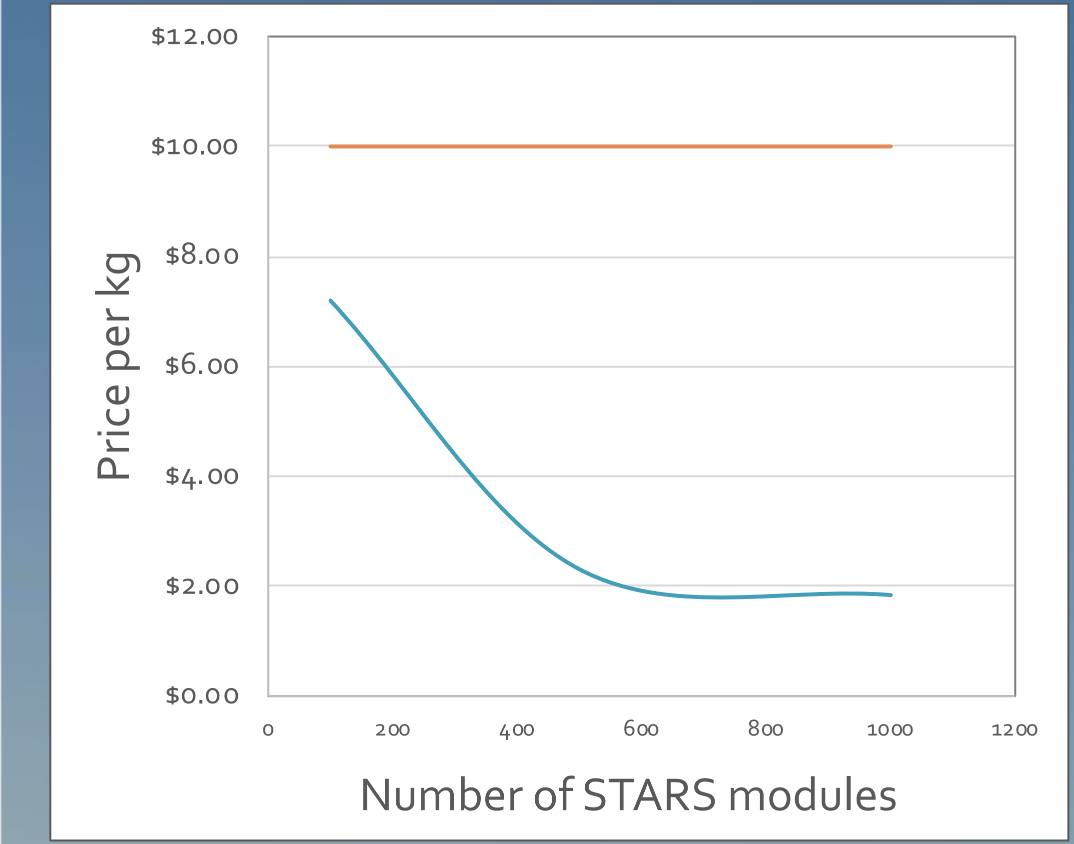


Final Costs

100 STARS Module System

- Capital Investment: $27.5 Million
  - Final Product Cost: $1.1 Million/year
  - Capital Related: $7.1 Million/year
- 95.3% Carbon Conversion from feed to final product.
- Comparable Market Cost: $3 per kg DME
- **Final Product Cost:**
  - **$7.20 per kg DME**
  - **$10.00 per kg H_2**

Conclusions & Recommendations



Limitations

- In order to have a competitive price per kg of DME, need to have ~ 300-500 STARS modules

Future Work Consideration

- Investigate using less expensive materials or lower pressures to produce DME with fewer modules

Positive Aspects

- Current Method has been the most feasible in terms of avoiding cryogenic temperatures
- Successfully converted syngas into DME and H_2 with 95.3% carbon conversion

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Questions?

HAZOP Study For DMER

Guide Word	Deviation	Cause	Consequences	Action
No	No inlet Flow	Line Blockage	Stopped production	Clean lines
		Valve closed	Potential safety issues down the line	Level Control
		Pump Closed		Backup pump
More of	higher inlet flow	valve stuck open	Low temperature	Control and Monitoring of vessel T & P
		lower conversion	explosion	Proper PRV
			out of control reaction	
As well as	impurities	recycle stream control problems	low conversion	pipe maintenance
		corrosion in pipes	poor product quality	proper control and bypass of recycling streams if necessary
		poor raw materials	Additional corrosion	
Reverse	Flow	Leaks/Pressure deviations	decrease in production rate	Proper Pressure Control/PRV
		Blockages up the line	high pressure buildup/explosion	Interlock in feed stream