Alternative Ways to Process and Utilize High CO_2 Content Shale Gas

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Presentation Outline

- Introduction
- Typical Shale Gas Processing in Horn River Basin
- Membrane Option to Reduce CAPEX
- Australian Example – Tassie Shoal Methanol Project
- CO_2 Utilization Alternatives
  - DME and MTG
  - Fischer-Tropsch Liquids
- Final Observations

Typical Shale Gas and Pipeline Gas

- Typical shale has the following composition:
  - CO_2 12.0%
  - H_2S 0.05%
  - C1 86.4%
  - C2 0.67%
  - C3 0.01%
  - C4+ nil
- Sales gas specification (TCPL)
  - CO_2 2.0% max.
  - H_2S 16 ppm max.
- As result for a 400 mmscfd plant 40 mmscfd (2,100 tpd) of CO_2 have to be removed and are typically vented

Gas Plant Configuration

- Shale gas plant typically consists of the following principal processing steps:
  - Inlet separation and filtration
  - Amine sweetening
  - TEG Dehydration
  - Residue gas compression
- For given CO_2 removal and 400 mmscfd gas plant capacity about 4,600 gpm of "MDEA" has to be circulated
- TIC for a 400 mmscfd gas plant is around $500 million
- Amine system represents 30% to 40% of TIC

Shale Gas Plant Challenges

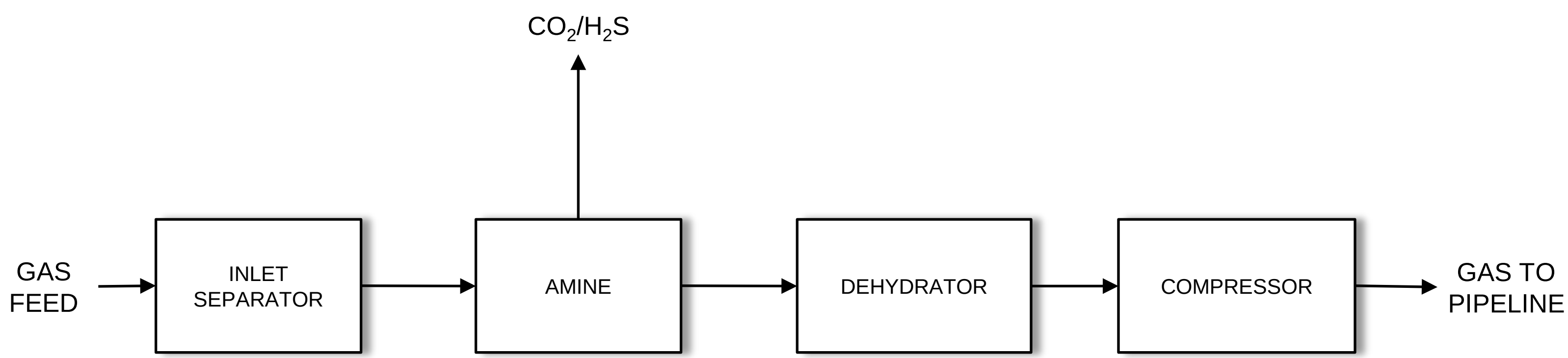
- **Capital Costs associated with amine acid gas removal systems**
  - Potential option is to use membrane/amine hybrid system
  - Based on recent WorleyParsons study 20-30% capital can be saved compared to amine based plant
- **Carbon Dioxide emissions**
  - CO_2 can be utilized to produce synthetic products such as methanol, DME, gasoline or Fischer-Tropsch liquids (naphtha and diesel)
  - CO_2 offgas will be mixed with additional shale gas, steam and oxygen for reforming into syngas

Membranes in Acid Gas Removal Application

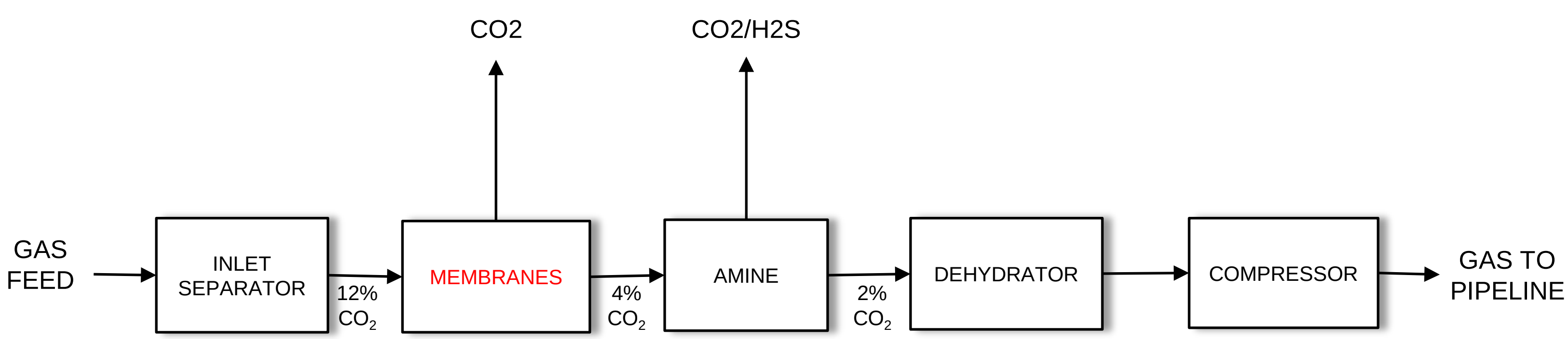
- Using membranes for CO_2 removal is state of the art technology (polymer based, flat sheet or hollow fibre)
- Membrane process is environmentally attractive and offers cost and operational advantages
- Membranes remove CO_2 and water, however, do not meet H_2S pipeline specifications
- Additional drawback is the methane loss to permeate, this can be mitigated by installing a multi-stage system (typically 2-stage)
- These membranes shortcomings can be overcome through combining with other acid gas removal technologies (e.g. amine) – “hybrid systems”

Shale Gas Processing

Amine Sweetening Option



Hybrid Sweetening Option



400 mmscfd Shale Gas Plant Example

- Amine Based System
  - Amine circulation rate 4,600 usgpm
  - Capital Costs $510 million
- Hybrid System
  - Amine circulation 1,180 usgpm
  - Capital Costs $360 million
- Hybrid System Design Parameters
  - Membrane CO_2 removal 12 to 4%
  - Two-stage system, methane loss less than 3%
  - Permeate is absorbed in fuel system
  - Amine CO_2 removal 4 to 2% and H_2S removal pipeline specification (4 ppm)

Natural Gas Feedstock and Value Added Utilization of CO_2 in the Production of Petrochemicals

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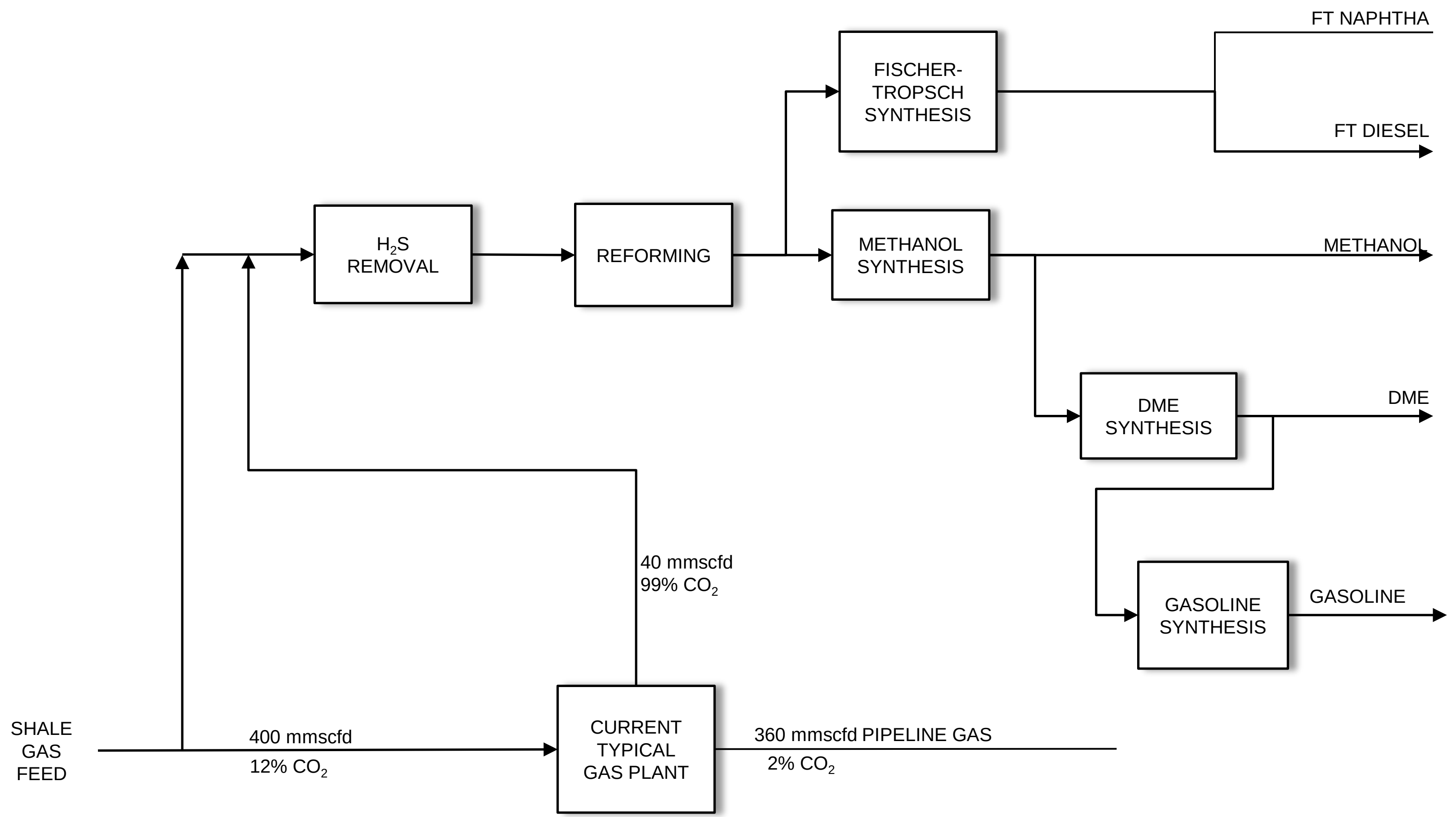
High CO_2 Content Gas Utilization Examples

- Tassie Shoal Methanol Development
  - Tassie Shoal is surrounded by gas fields with high levels of CO_2 (>10%)
  - 1.75 MTPA Methanol Plant is proposed in parallel to commercialize high CO_2 regional resources and CO_2 vented from LNG plant feed
  - The MeOH plant is based on proven technology (Davy Process Technology SMR) and utilizes to maximum practical extent CO_2 which otherwise would have to be vented
  - Gas feed to the MeOH plant contains 10-28% CO_2
  - This situation is very similar to the Horn River shale gas cases
- Maui Gas Fields with CO_2 content in New Zeeland for Methanex's Waitara Valley Methanol since 1980s
- Kapuni Gas Fields for Motuni Gasoline Plants

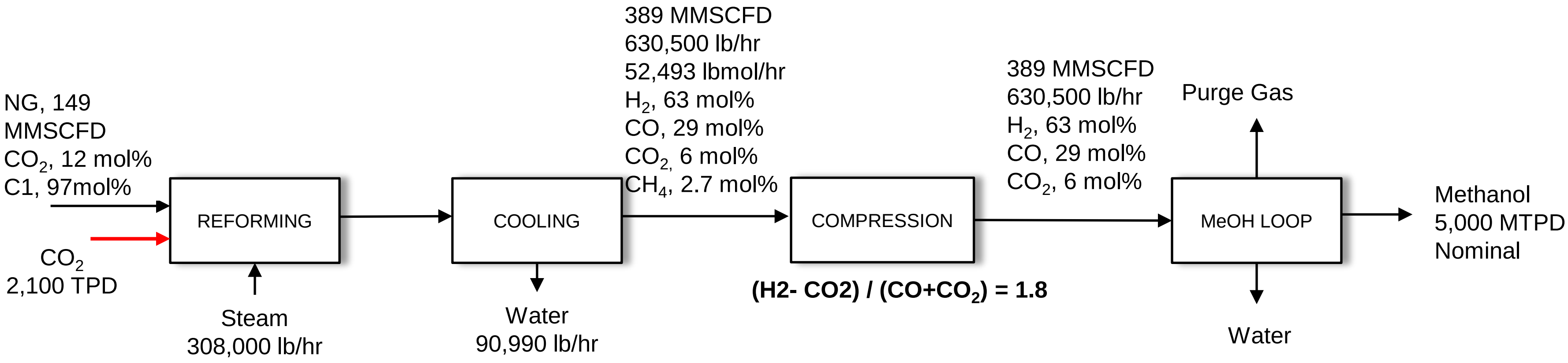
Methanol Derivatives and Fischer-Tropsch Products



Synthesis Gas Production Technologies

- Synthesis Gas (H_2 + CO) which could include CO_2
- Current Synthesis Gas production Technologies include:
  - Steam Methane Reforming – w/ or w/o CO_2
  - Partial Oxidation
  - AutoThermal Reforming w/ O_2
  - Combined Reforming
- Reforming technologies under development:
  - Ceramic Membranes w/ or w/o CO_2
  - Compact Reformers
- Key technology providers: Sasol, Shell, Axens, Haldor Topsoe, Davy PowerGas, Toyo, KBR, Lurgi, Linde, Mitsubishi, etc.
- EPC contractors: WorleyParsons, Uhde, Fluor, Bechtel, Jacobs, Deawoo and others will engineer and build synthesis gas, methanol, DME and gasoline plants under licenses of others.

Injecting CO_2 at SMR for Methanol Production



Overall Mass Balance

IN	lb/hr	OUT	lb/hr
NG	294,000	Syngas to MeOH	630,500
Steam	308,000	Water	154,500
CO_2	195,998	Purge	12,498
Total	797,998		797,498

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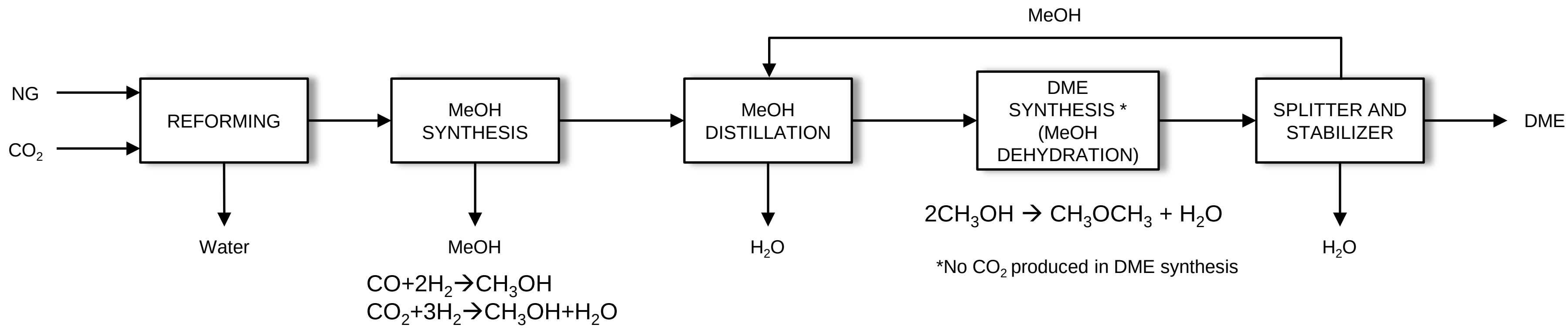
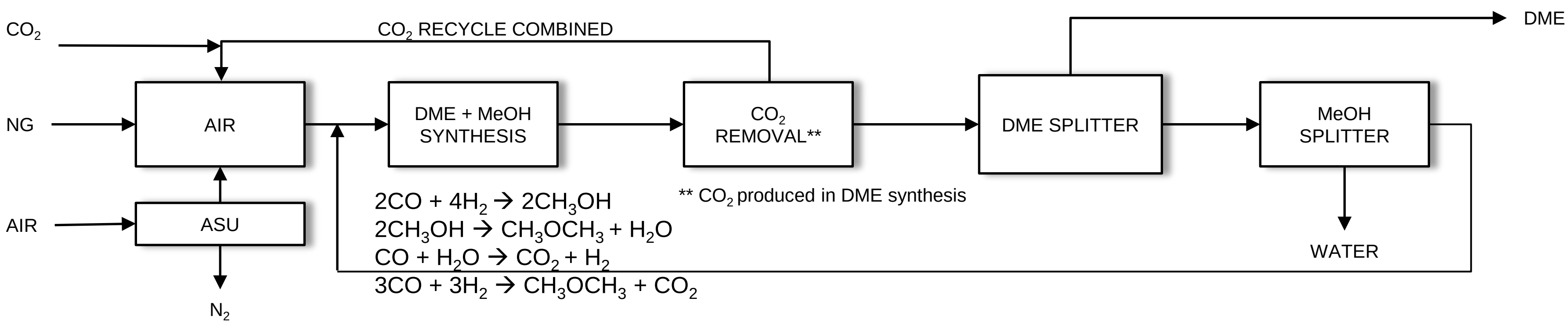
NG Feedstock to GTL - DME Processes

Two Step Process (Catalytic Dehydration of Methanol)



Material Balance: NG 150 MMSCFD → 5000 MTPD MeOH → 3500 MTPD DME

One Step Process – Direct Synthesis Route - Typical



Material Balance: NG 150 MMSCFD → 3400 MTPD DME

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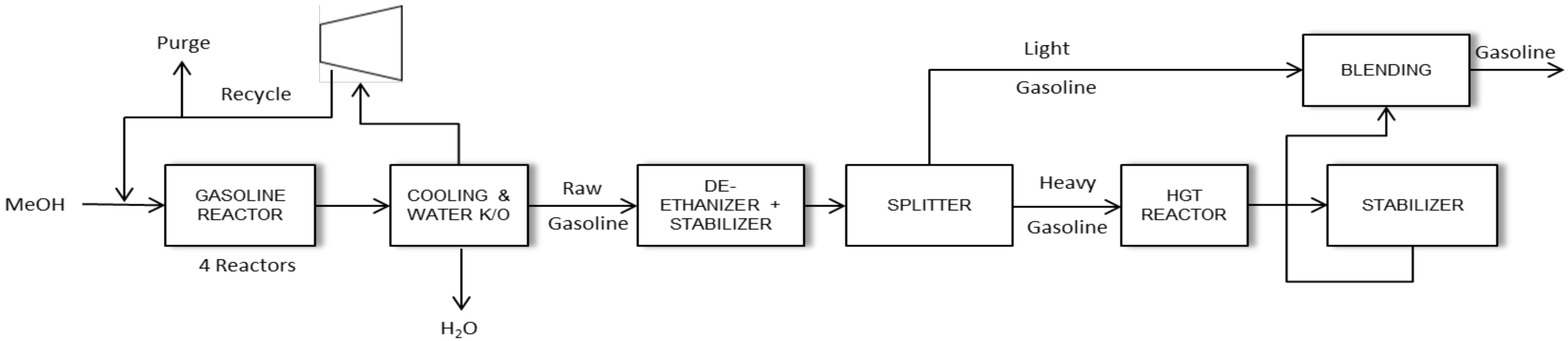
Methanol-to-Gasoline (MTG)



- In the first part, methanol is dehydrated to an equilibrium mixture of methanol, dimethylether and water. Water gets knocked out.
- In the second step, the methanol and DME equilibrium mixture is passed over ZSM-5 catalyst to produce hydrocarbons in gasoline boiling point range (C4 to C10) and consists of highly branched paraffins, olefins, napthenes and aromatics.
- The gasoline product is similar in composition and volatility and meets gasoline specifications with octane number (RON+MON/2) of 88.

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Methanol-to-Gasoline (MTG) Heat & Mass Balance

Methanol		Gasoline		Water
nCH_3OH	→	$(CH_2)_n$	+	nH_2O
100 Kg	→	44 Kg	+	56 Kg
100 GJ	→	95 GJ	+	0 GJ

*5GJ of fuel gas recycle to fuel system

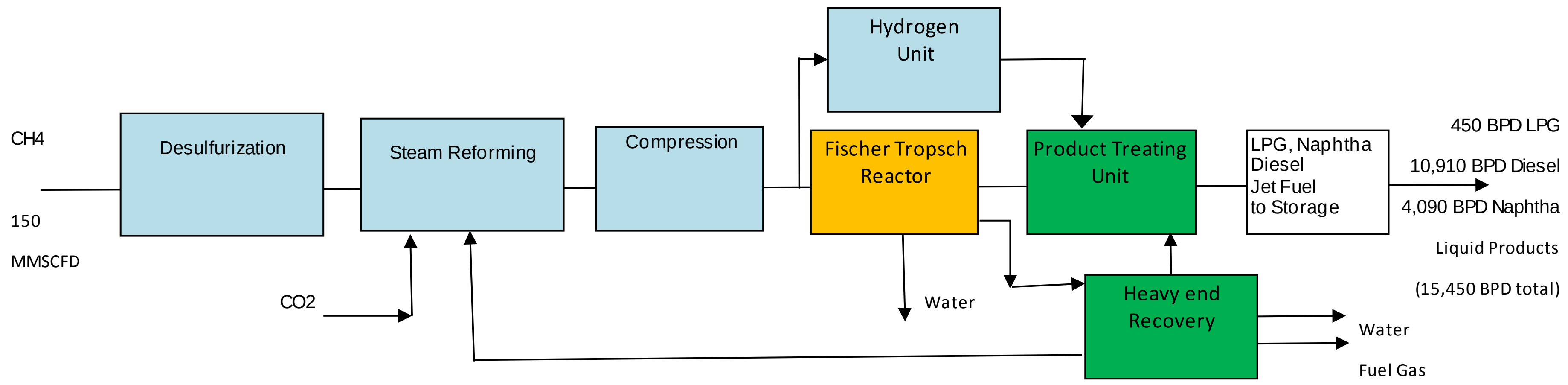
149 MMSCFD → 5,000 MT → 2200 MT (16,500 BPD) + 2800 MT

Methanol		DME		Olefins		
$2\ CH_3OH$	- H2O ⟷ + H2O	CH_3OCH_3	- H2O ⟶	= = C2 - C5	⟶	Paraffins Aromatics Cycloparaffins

NG Feed + CO2 + Steam → SMR or ATR or POX → Syngas → Methanol Synthesis → DME Reactor → Gasoline Reactor → Splitter → **Gasoline Product**

Gas-to-Liquids (GTL) – Fischer Tropsch

- Simplified Typical Fischer Tropsch Configuration



- The cooled synthesis gas feeds the LTFT reactor, entering at the bottom of the slurry bed of liquid hydrocarbons and F-T catalyst. It is converted into paraffinic hydrocarbon chains via the exothermic F-T synthesis reaction: $CO + 2H_2 \rightarrow -CH_2^- + H_2O$
- The exothermic reaction inside the LTFT reactor is cooled by steam and the MP steam generated.

Gas-to-Liquids (GTL) – Fischer Tropsch

- The heavier fractions are removed from the slurry and fed into the product work-up unit, licensed by Chevron.
- Proprietary hydrocracking and fractionation techniques, known and proven in the refining industry, are used to break down these long-chain hydrocarbons into the required product slate of GTL diesel (70–80%) and naphtha (20–30%).

Gas-to-Liquids (GTL) Proven Technologies

- These are all commercially proven technology steps.
- XOM MTG plant (2 trains) in NZ has been in operation since 1980s.
- Two GTL plants using the Fischer Tropsch (F-T) process are located in South Africa operated by Sasol and PetroSA (under Sasol licence) and one in Malaysia, operated by Shell.
- ORYX GTL 34,000 bpd, a joint venture between Qatar Petroleum and Sasol with approximate TIC of $950MM which employs Cobalt-based catalyst in the new generation Slurry Phase Distillate process.
- Shell Pearl Project in Qatar (120,000 bpd) GTL Plant
- Sasol plans 96,000 bpd GTL plant in Alberta

Overview Comparison

	Capacity MTPD	TIC, $MM	Typical Cost of Production at 2.25 $/MMBTU	Current Market Price	Energy Efficiency
		(based on 150 MMSCFD gas feedstock)			
Methanol Plant	5,000	$250	120 $/MT	420 $/MT 1.27 $/Gal	26.5 - 27.5 MMBTU/MT
DME Plant	3,500	$500	140 $/MT	600+ $/MT	40.5 MMBTU/MT
Gasoline Plant	2,200 16,500 BPD	900+	~220 $/MT	750 $/MT 100 $/Bbl	60 MMBTU/MT
Fischer Tropsch to Liquids	1,850 (15,450 BPD)	$600	~225 $/MT	750 $/MT 100 $/Bbl	70 MMBTU/MT 8.5 MMBTU/Bbl of total liquid product

Final Observations

- Using membranes for gas separation, especially for CO_2 removal, is state of the art technology
- For every project a sweet spot for a hybrid membrane/amine system can probably be found
- All value added technologies are commercially proven and can be effectively used to combat GHG emissions (CO_2)
- Type of value added option will be project specific depending on economics and political acceptance

Final Observations (Cont'd)

- At current North American depressed gas prices almost any of the value added option can be economically attractive
- Present low cost feedstock and healthy margins is an invitation for the comeback of petrochemicals sector
- High CO_2 content shale gas is ideally suited for the production of value added petrochemicals

Thank You!

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