Methane Cracking

CMAT Energy Solutions

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Purpose

- Producing high purity Hydrogen from Methane (Natural Gas) with low CO_2 emissions
- Current process: Steam Reforming of Methane
  - Proven Technology
  - Industry Standard
  - Relatively Inexpensive
  - Produces significant amounts of CO_2 (~ 8 ton/ton H_2)
  - Requires large quantities of water

Preferred Process

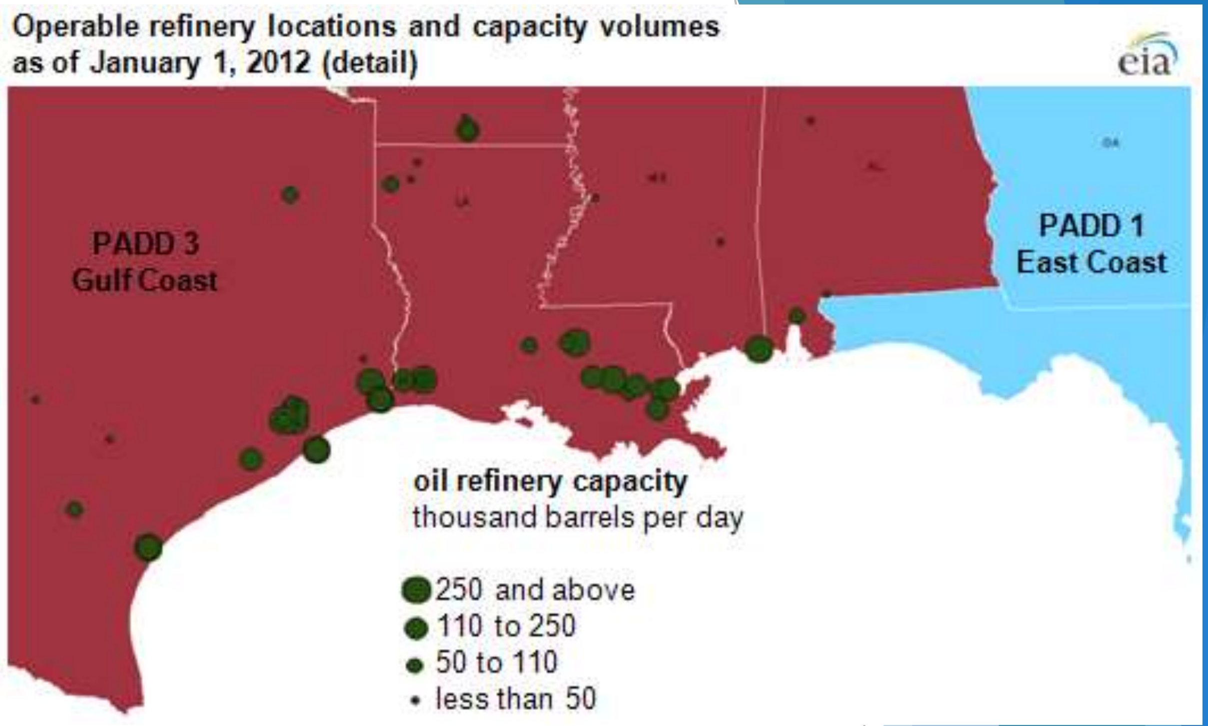
- Hydrogen Production via Direct Contact Pyrolysis of Natural Gas
  - Temperatures of 1500ºF to 1700ºF
  - Pressure ranging from 40 psia to 70 psia
- Methane conversions of 95% and higher
- $CH_{4(g)} \rightarrow C_{(s)} + 2H_{2(g)}$ $\Delta H = 75$ kJ/mol
- Requires no water for reaction to occur
- Produces CO_2 emissions from firing furnace, not from actual process
- Feedstock readily available

Business Opportunity

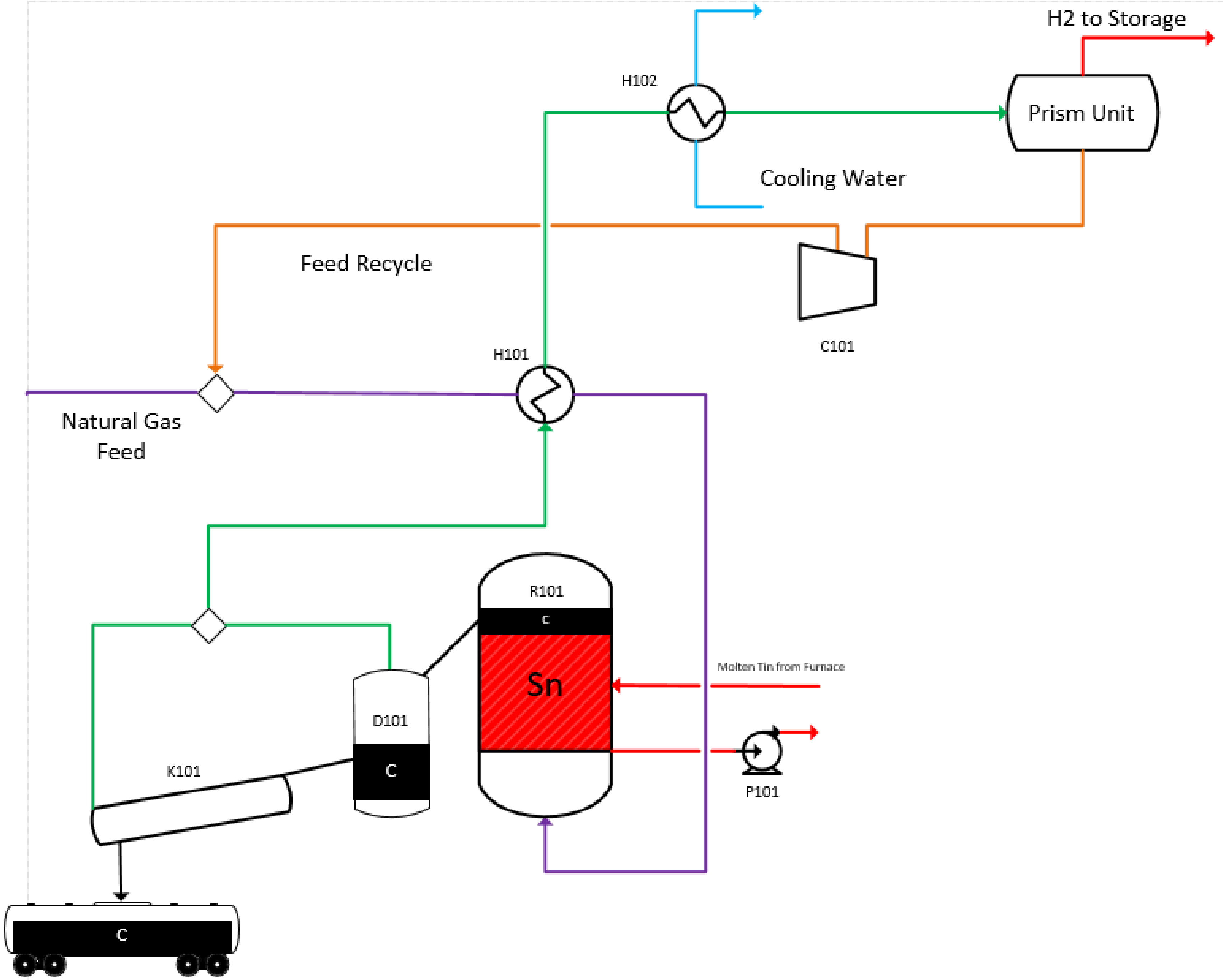
- Uses for Hydrogen
  - Ammonia Synthesis
  - Synthesis of Methanol and Cyclohexane
  - Removal of Sulfur from fuels during oil-refining
- Uses for Graphite
  - Used in steel manufacturing to coat foundry molds
  - Manufacturing of brakes, brake linings, clutch facings, friction components and mechanical seals
  - Industrial lubricants and metal powders

- Feedstock Cost
  - Industrial Natural Gas: $3.28/Mcuft
- Product Price
  - Hydrogen: $0.31/lb
- Byproduct Price
  - Graphite: $0.45/lb

Sizing and Location



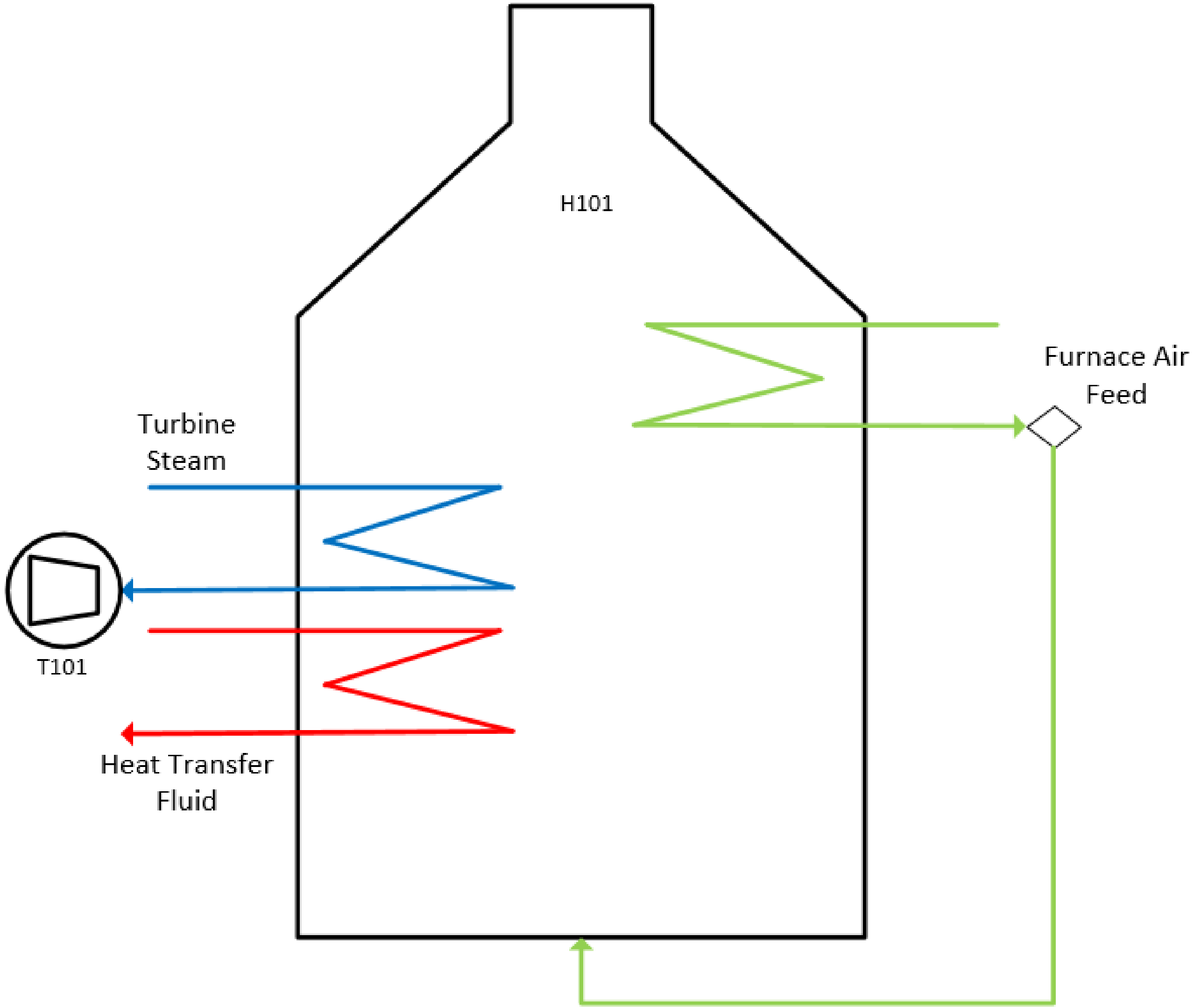
- Plant Size
  - 100 million lb/yr H_2 produced
- Location
  - Gulf Coast
  - Many refineries in a central location
  - Port Arthur, Texas offers a central location near a major refinery and is located close to the coast



H2 to Storage
H102
Prism Unit
Cooling Water
Feed Recycle
C101
H101
Natural Gas Feed
R101
C
Sn
Molten Tin from Furnace
D101
C
K101
P101
C

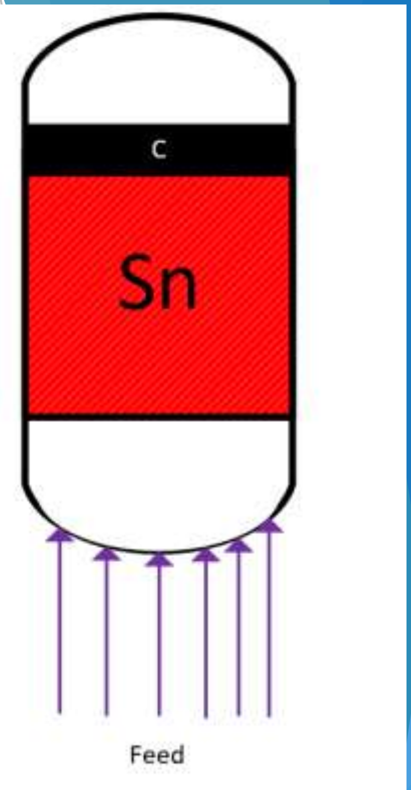
Furnace

- Utilize Heat from furnace as much as possible
  - Heat molten tin to be used as heat transfer fluid in closed loop system
  - Create steam to supply electricity to necessary components of the process
  - Generate steam to trace the lines that transfer the tin heat transfer fluid to prevent build up
  - Preheat air being fed to the furnace burners



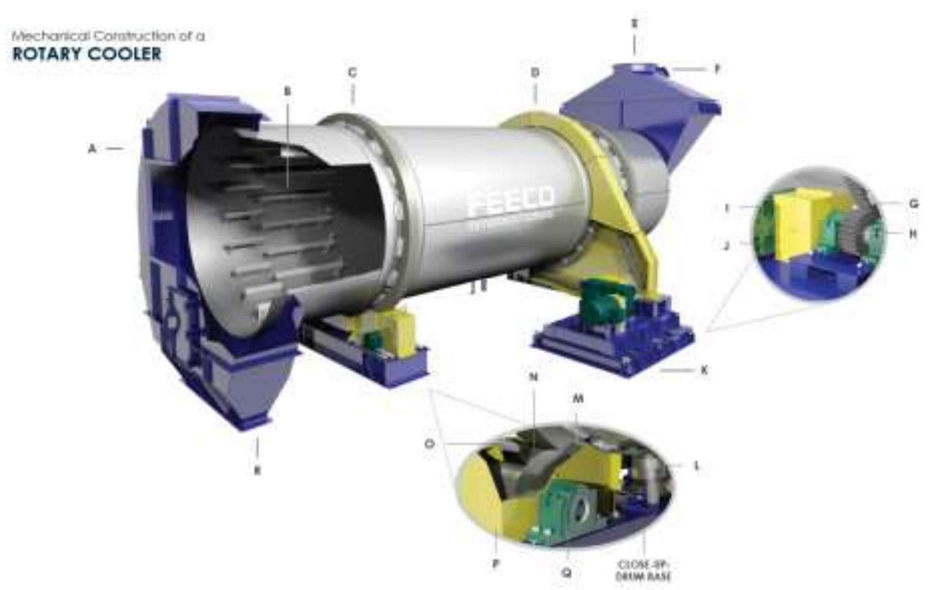
Reactors

- 1 reactor necessary for continuous process
  - Overflow system used
  - Carbon will continuously overflow and be taken out of the reactor
- Reactor Size
  - Diameter: 12 ft
  - Height: 52 ft
- Reactor building material
  - 316 Stainless Steel
  - Silica firebrick to help withstand extreme conditions
- Mott Corporation porous metal filters to increase heat transfer area
- Insulation
  - Reactors will be insulated to prevent as much heat loss as possible

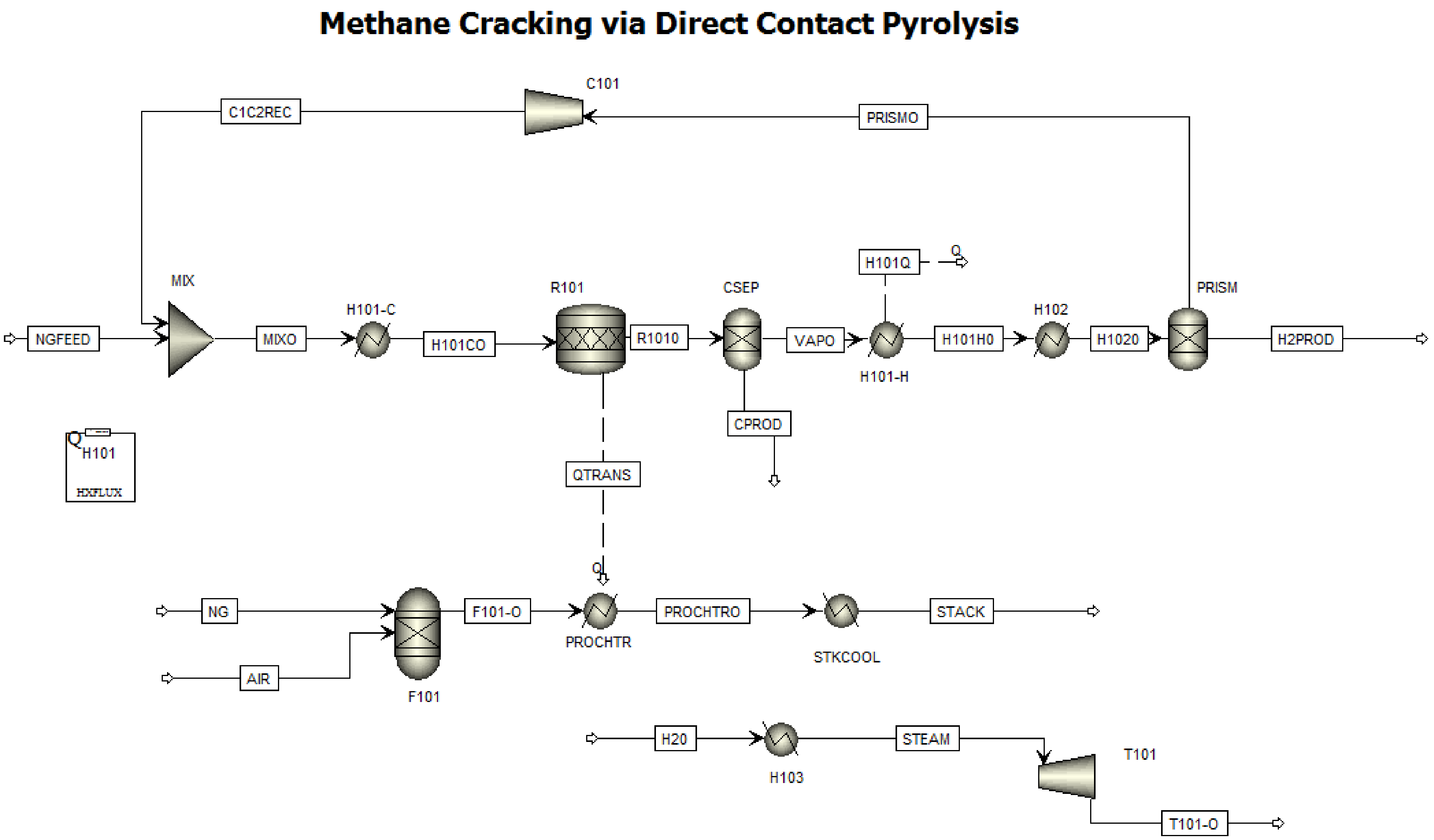


Carbon Separation

- Carbon will build up in reactor until it reaches an overflow port.
- This port will funnel the carbon to a cyclone separator.
- Vapor flow from the reactor will serve as driving force to ensure carbon reaches the cyclone.
- Once in the separator, carbon will settle and vapor will exit out of the top of the cyclone.
- The carbon will fall from the cyclone into a water deluge rotary cooler to be cooled and then transported off site or to storage.



Simulation


Methane Cracking via Direct Contact Pyrolysis
C101
C1C2REC
PRISMO
H101Q
Q
MIX
H101-C
R101
CSEP
H102
PRISM
NGFEED
MIXO
H101CO
R1010
VAPO
H101H0
H1020
H2PROD
H101-H
CPROD
Q
H101
HXFLUX
QTRANS
Q
NG
F101-O
PROCHTRO
STACK
PROCHTR
STKCOOL
AIR
F101
H20
STEAM
T101
H103
T101-O

Safety

- High explosion hazard
  - Due to temperatures being above auto ignition for carbon flakes and hydrogen
  - Must be an oxygen free environment
- High temperature of reactor
  - Personal Protective Equipment (PPE) needed for personnel
  - Proper control systems needed to maintain stability
- Corrosion and embrittlement
  - High temperatures of tin and hydrogen can cause possible risks of corrosion and embrittlement

Environmental

- Carbon Dioxide
  - 197,432.47 tons/yr --- .03% of Texas overall CO_2 production.
    - No EPA regulations exist for industries yet
    - 1.97 tons/ton Hydrogen
- Carbon Monoxide
  - 21.86 tons per year. --- 4.99 pounds per hour
    - EPA regulation 9 ppm per 8 hours
- NOx
  - 1003.22 tons per year --- 228.89 pounds per hour
    - EPA regulation .08 pounds of NOx /MMBtu (furnace)
    - Control methods- SNCR and SCR

Economic Analysis

- FCI: $111 million
- Revenue: $165 million/yr
- TCI: $130 million

- NPV0: $1.82 billion
- NPV10: $686 million
- IRR: 50%

$ (36,899,401.34)	$ (73,798,802.68)	$ (130,246,101.16)	$ (45,695,341.00)	$ 61,769,947.40
1.21	1.10	1.00	0.91	0.83
$ (44,648,275.62)	$ (40,589,341.47)	$ (56,447,298.48)	$ 76,864,327.42	$ 88,814,287.93
$ (44,648,275.62)	$ (85,237,617.10)	$ (141,684,915.57)	$ (64,820,588.15)	$ 23,993,699.78
NPV0	1,823,828,888	$	IRR	50%
NPV10	**685,823,923**	$		
NPV10	685.82	MM$		

Final Recommendations

- Perform process on lab scale followed by intermediate scale to verify conversions, design integrity, safety and overall performance.
- Further verify that overflow system and carbon removal steps will perform adequately.
- Attain specific quotes on equipment using operating conditions and dimensions.
- Further analysis on global impact of producing such a high amount of graphite.

Questions?