Feasibility Studies for Integrated Process for Generation of Electricity, Alcohol & other products from Sugarcane (Bagasse) and Agricultural Residues

(A brief presentation on an Environmentally Friendly Program for Sustainable Energy and Increased Profitability to Sugarcane Factories)

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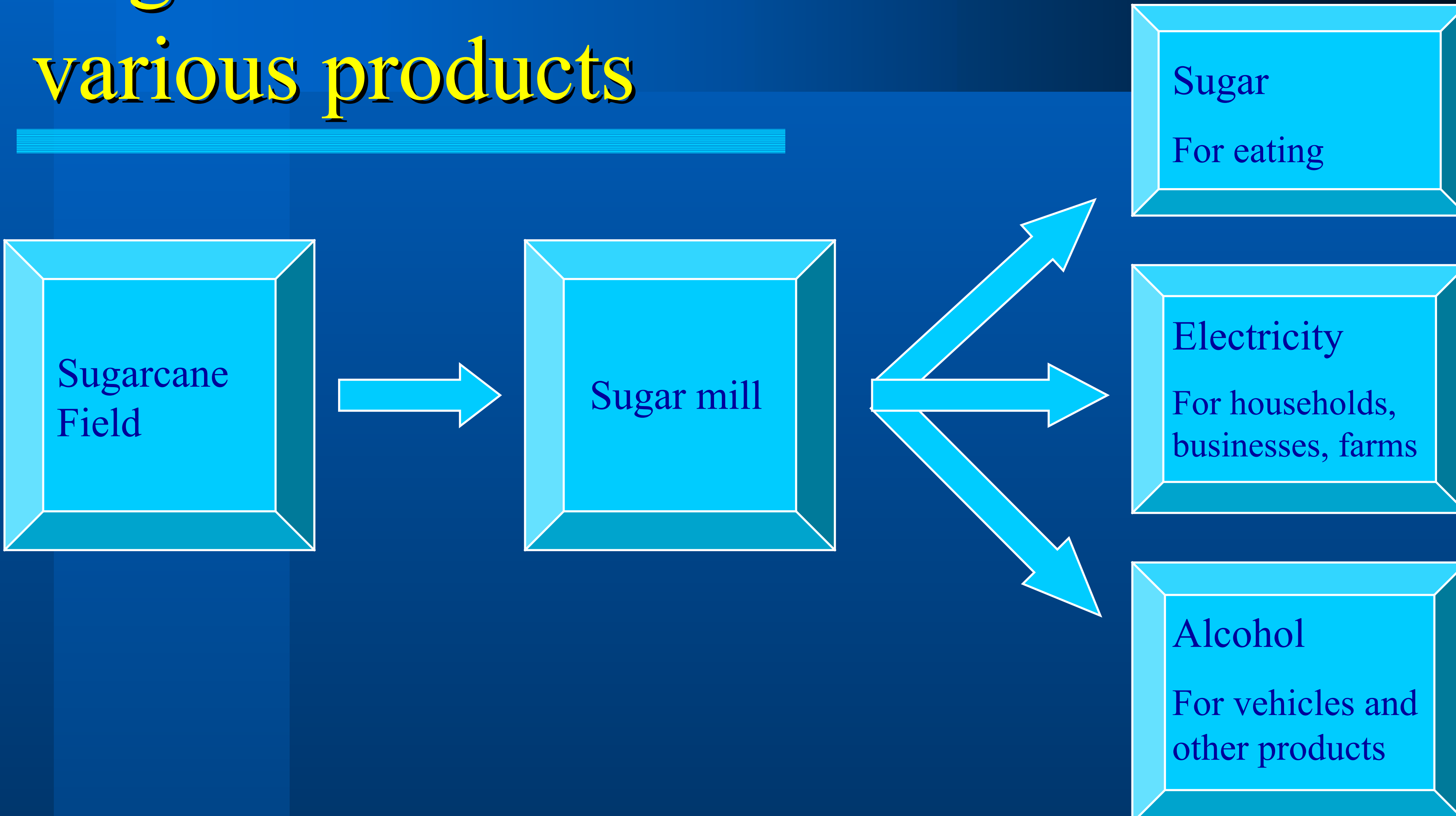
Presentation Outline (in Brief)

- **Evaluation of an economically attractive, fully diversified and environmentally sound integrated process for sugar cane utilization**
- **Maximize sugar mills revenues, profits and their long term financial performance via diversification**
- **Help sugar mills gain additional income**

Sugarcane biomass to various products



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Mission

- Evaluation of an economically attractive, fully diversified and environmentally sound integrated process for sugar cane utilization
- Maximize sugar mills revenues, profits and their long term financial performance via diversification
- Help sugar mills gain additional income

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Mission

cont.

- HELP to mitigate GLOBAL WARMING by providing renewable energy source with no net emission of carbon dioxide

Objectives of the Feasibility Study

- Prepare a plan for the integrated facility based on a comprehensive feasibility study
- Economic Evaluation of a complete utilization of sugarcane and agriculture residues in the region
- In order to meet the above objectives, the following tasks are performed as shown in the next page under "How will it be done"

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How will it be done?

Comprehensive Work Program (Feasibility Study)

- **Task 1: Meeting with the sugarmill Management & walk-through survey of the facilities to observe the current process.**
- **Task 2 : Collect Data on Process, Water & Waste Water Management, facilities review, production level, mass & energy balance, local, state & federal environmental laws**

How will it be done? cont.

- Task 3 : Assessment of quality & quantity of the other biomass materials available & their transport costs to the mill, such as cane trash & tops, wheat straws, rice husks, mango waste, potato residue and other biomass in the region for continued operation of the mill throughout the year

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How will it be done? cont.

- Task 4 : Testing & characterization of biomass samples
- Task 5 : Economic Analysis of the Proposed Integrated Process of Sugarcane Factory and Bioenergy centre
- Task 6 : Project specific Greenhouse gas emission baseline studies shall be conducted
- Task 7: Project Design Document

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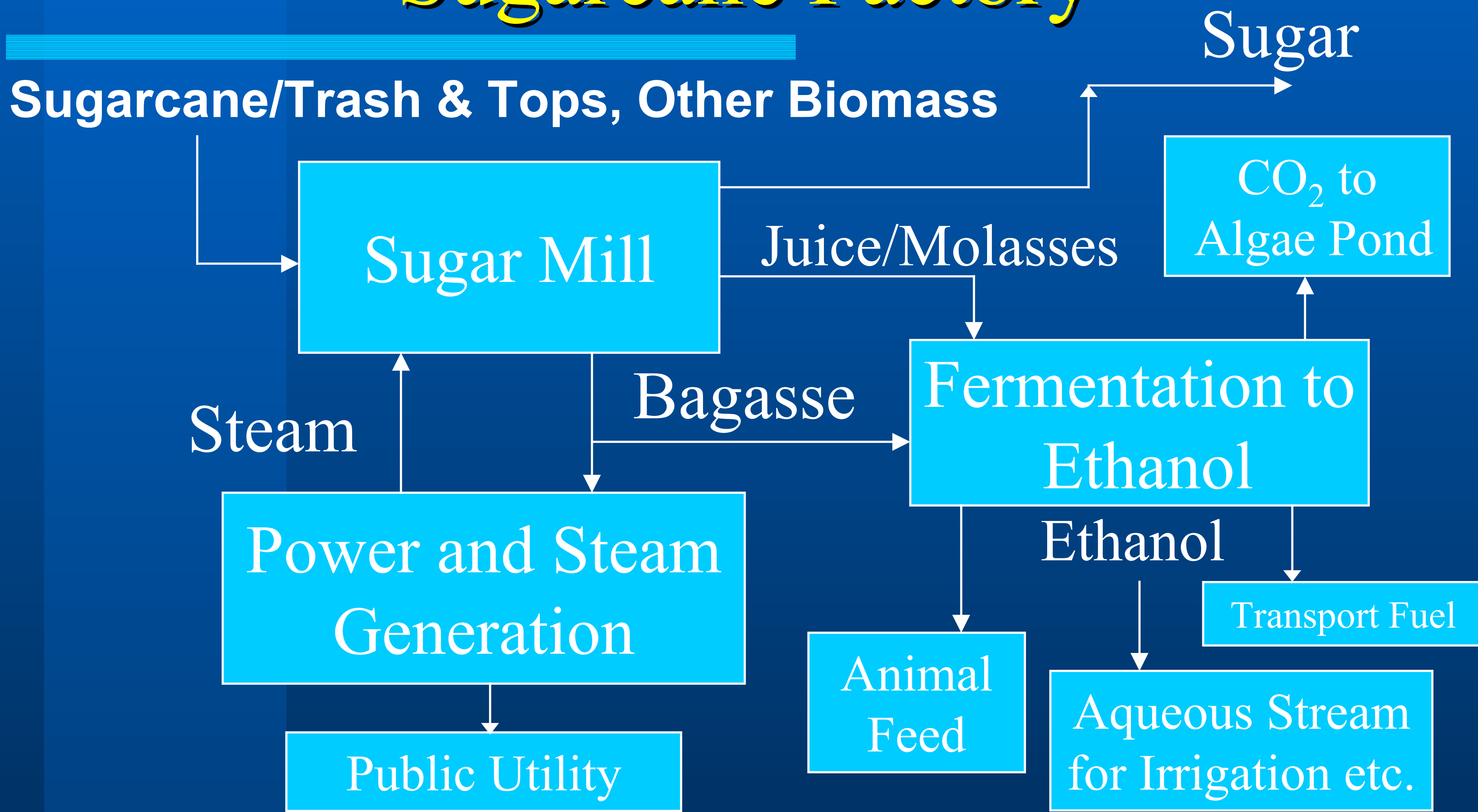
Proposed Integrated and Diversified Sugarcane Factory



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Proposed Sugar mill facility to include:

- Power and steam generation from cane residue
- Ethanol for transportation fuel by fermentation.
- Production of chemicals and fertilizers.
- Animal feed production.
- Carbon dioxide utilization by algae growth.
- Utilization of aqueous stream generated.

List of Commercial Products of Proposed facility

- **Sugar, Molasses, Rum**
- **Power & Steam**
- **Lignin**
- **Gypsum**
- **Carbon dioxide**
  - Carbonated drinks
  - Fire extinguisher
  - Dry Ice
- **Dehydrated Ethanol***
- **Protein for Animal Feed**
- **Water for Crop Irrigation**

Note: These products are further high-lighted on the next page with their estimated quantities.

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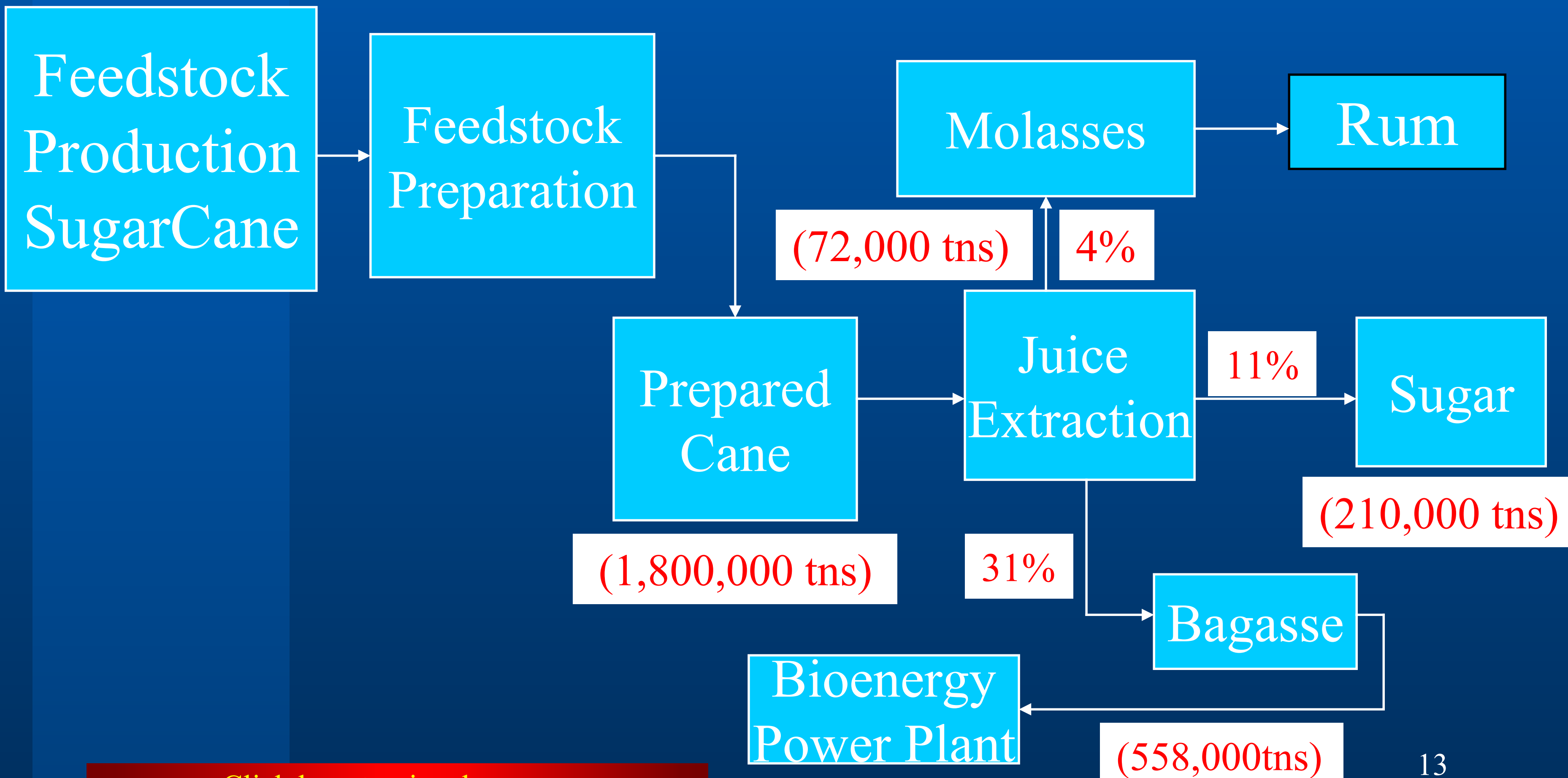
Some Quantitative Estimates of Products of Proposed Integrated Process

Sugar Factory Products



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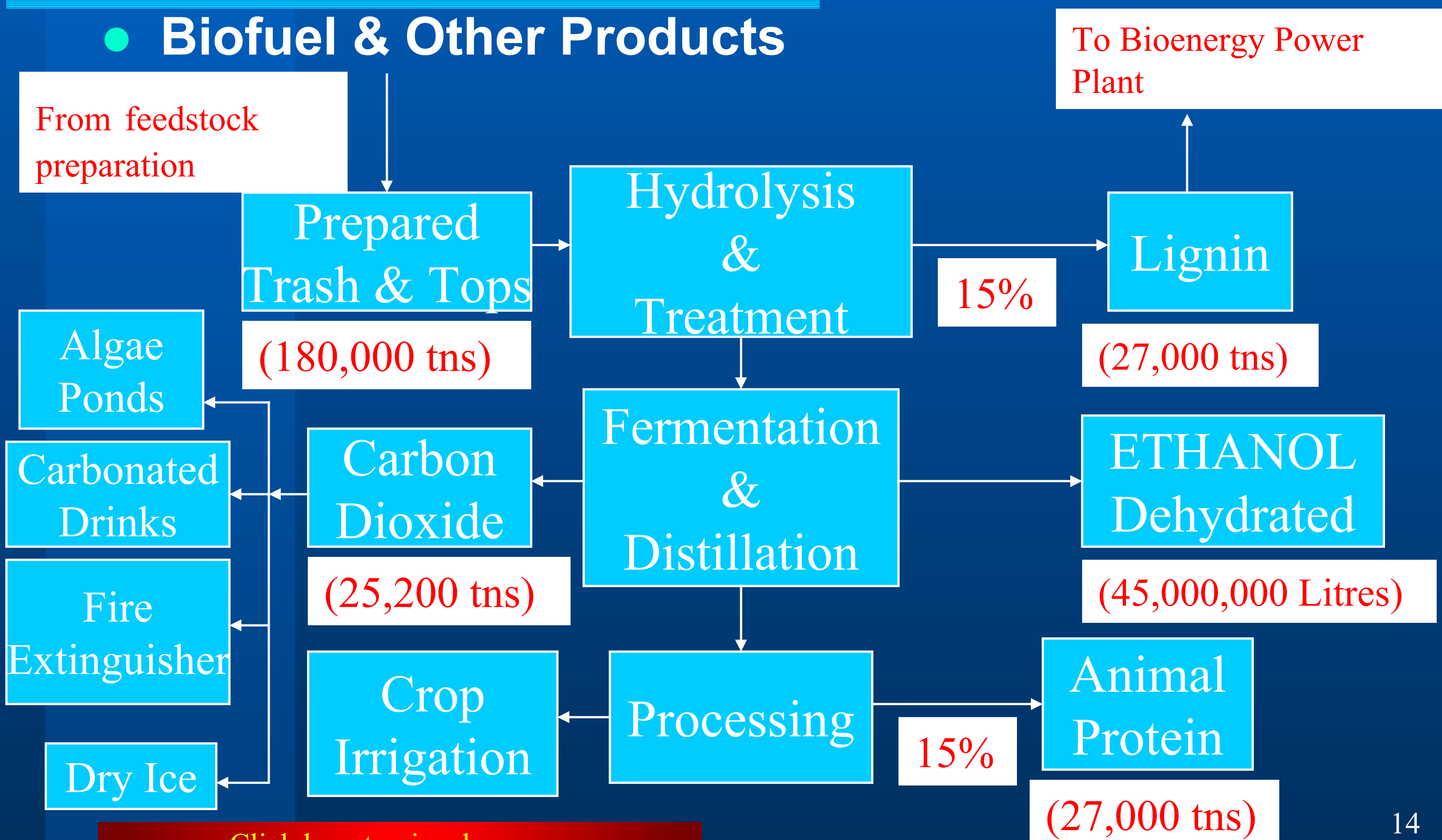
Some Quantitative Estimates of Products of Proposed Integrated Process

cont.

- **Biofuel & Other Products**



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Reflection on the Major Economic Advantages

- Sugar mill revenues multiply by a factor of about 2
- Ethanol can be easily blended with gasoline thereby reducing dependence on petroleum driven fuels
- Maximize energy efficiency and profitability of Sugar mills

Environmental Advantages

- A Sustainable renewable fuel for the 21st century
- Bagasse is a biomass material and thus there is no net emission of Carbon Dioxide
- When Coal or other fossil fuels are displaced by bagasse or other biomass material there are enormous savings of Greenhouse gas (GHG) emissions to prevent climate change

Environmental Advantages cont.

- CO_2 causes Global Climate change. Increase: 0.5% per year. Since 1960 atmospheric CO_2 is up more than 10%.
- The longer the period we use oil and coal to produce CO_2, the tougher will be the crisis which will follow.
- It is therefore imperative to increase the use of our sustainable energy alternative.

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Environmental Advantages cont.

- <u>IMMEDIATE OBJECTIVE</u> : Slow down the Greenhouse Effect, Stabilize the CO_2 concentration
- The combined capability of the sugar mills, for example, the 450 in India, & many more in each of the other 80 Countries of the world, by using the proposed Integrated Process, have the potential to meet the Global GHG reduction objective

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Typical Example of Per-Capita Carbon Dioxide Emissions (tonnes) per year by various countries

Country	Per Capita CO_2 (metric tonnes)
Brazil	1.39
China	2.27
Czech Republic	13.04
Japan	8.79
Russia	14.11
Swaziland	0.33
India	0.88
Malaysia	3.74
UK	9.78
US	19.13
Canada	18.19 (assuming 564 megatonnes emission per year)

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Current Focus:

Fulfilling the upcoming Energy demand from non-polluting sources

- **As seen CO_2 emissions of developing countries are lower than developed countries**
- **Growth for necessity of developing countries would require Energy consumption to approach developed country as a model**
- **Proposed Integrated Process directs away from polluting sources to non-polluting sustainable energy**
- **The favorable impact on Air Quality and Global Climate change shall be phenomenal in the long term and has the potential to meet the Kyoto Protocol**

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HIGHLIGHTS OF SOME OF THE RECENT AND CURRENT RESEARCH PROJECTS AT THE TECHNOLOGY CENTRE

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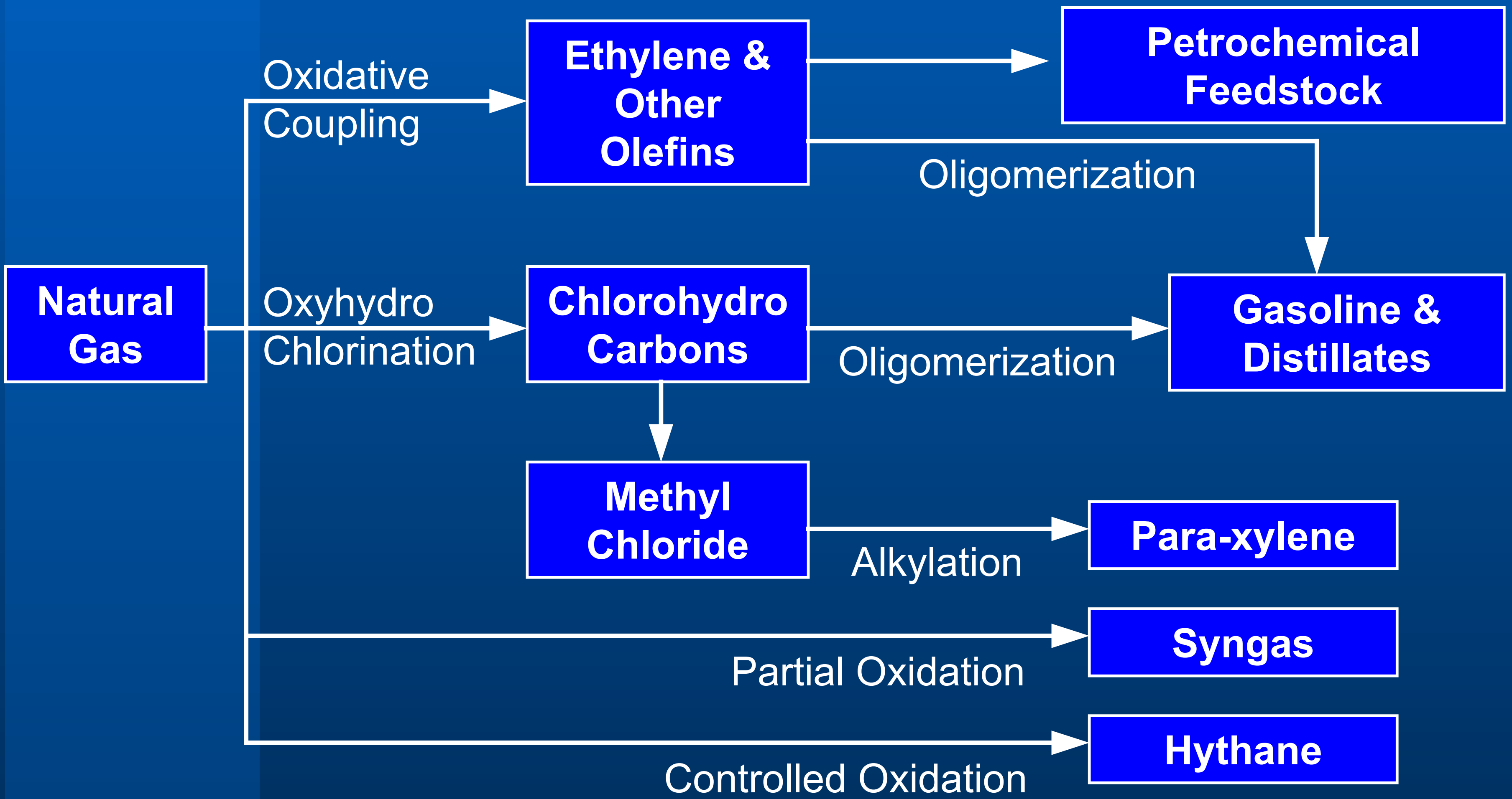
Direct Conversion of Natural Gas to Value-added Products



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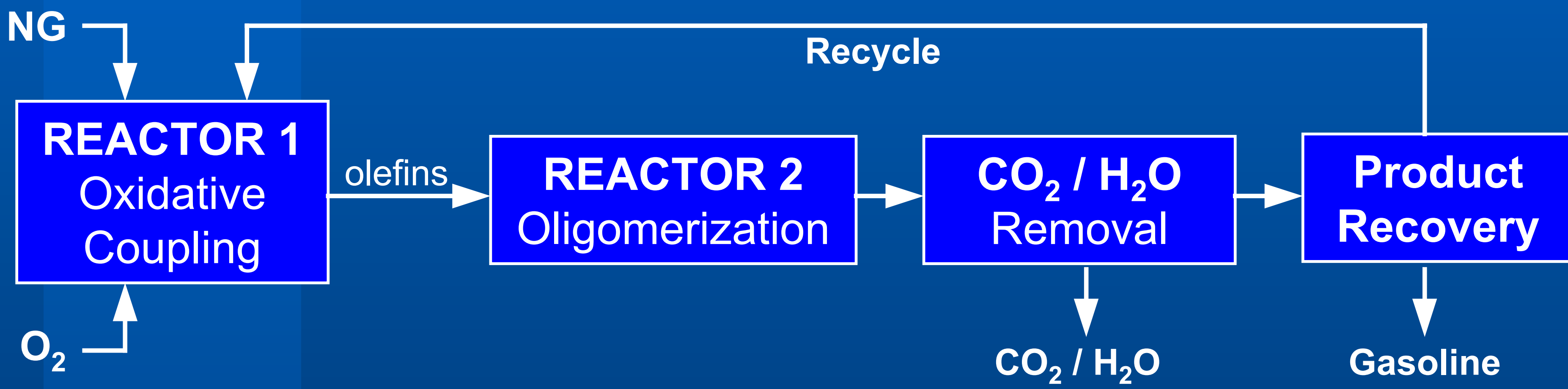
Conversion of Natural Gas to Gasoline via Oxidative coupling and Oligomerization



Reactor 1: Oxidative Coupling

Methane + Oxygen $\xrightarrow[\text{Catalyst}]{600\text{-}800^{o}\,C}$ Olefins (Ethylene, propylene)

Reactor 2: Oligomerization

Olefins $\xrightarrow[\text{Catalyst}]{600\text{-}800^{o}\,C}$ Gasoline

The project focuses on conversion of natural gas to gasoline-boiling range hydrocarbons via an integrated approach of oxidative coupling and oligomerization. Natural gas reacts with oxygen in the Reactor 1 over a metal oxide based catalyst to produce olefins, predominantly ethylene and propylene. The reactor effluent is then fed to Reactor 2 where olefins undergo oligomerization over a zeolite based catalyst to produce gasoline range hydrocarbons.

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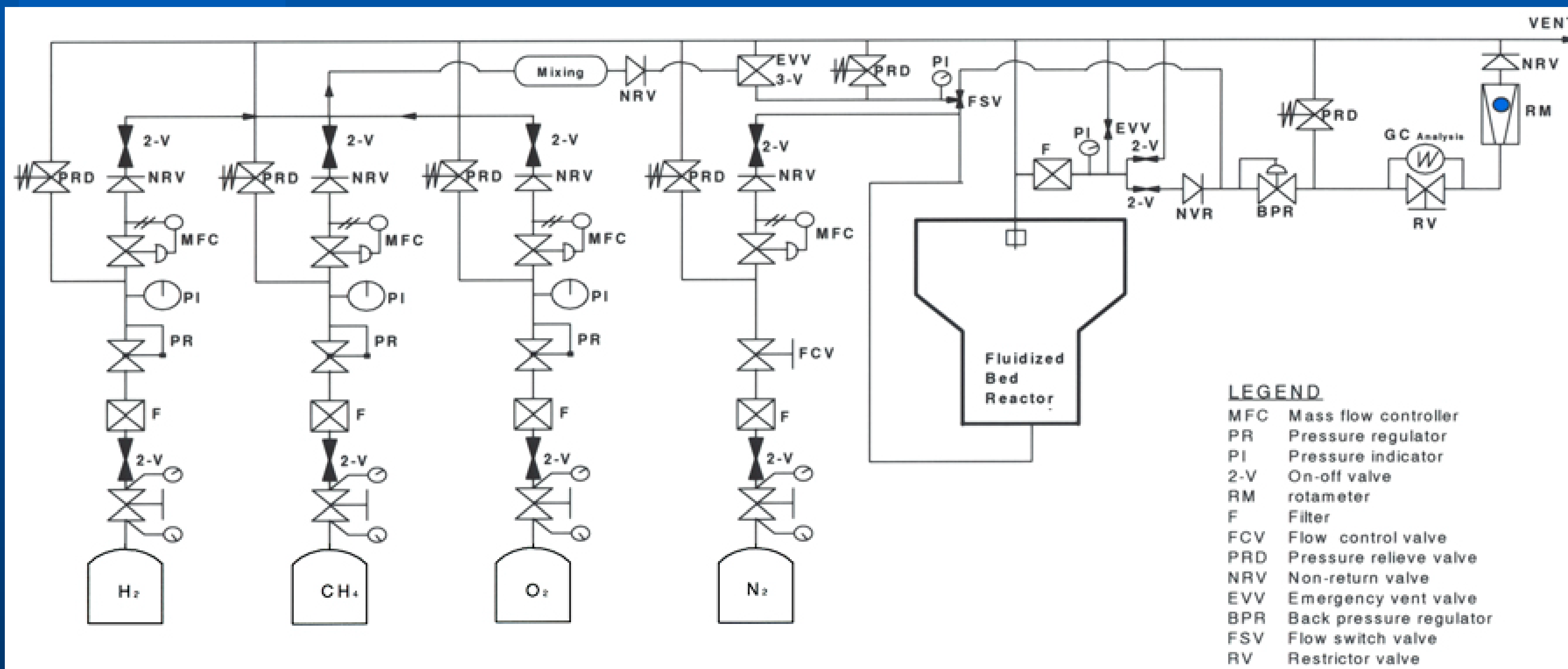
Chemisar Fluidized Bed Reactor System For Studying Methane Oxidative Coupling Process



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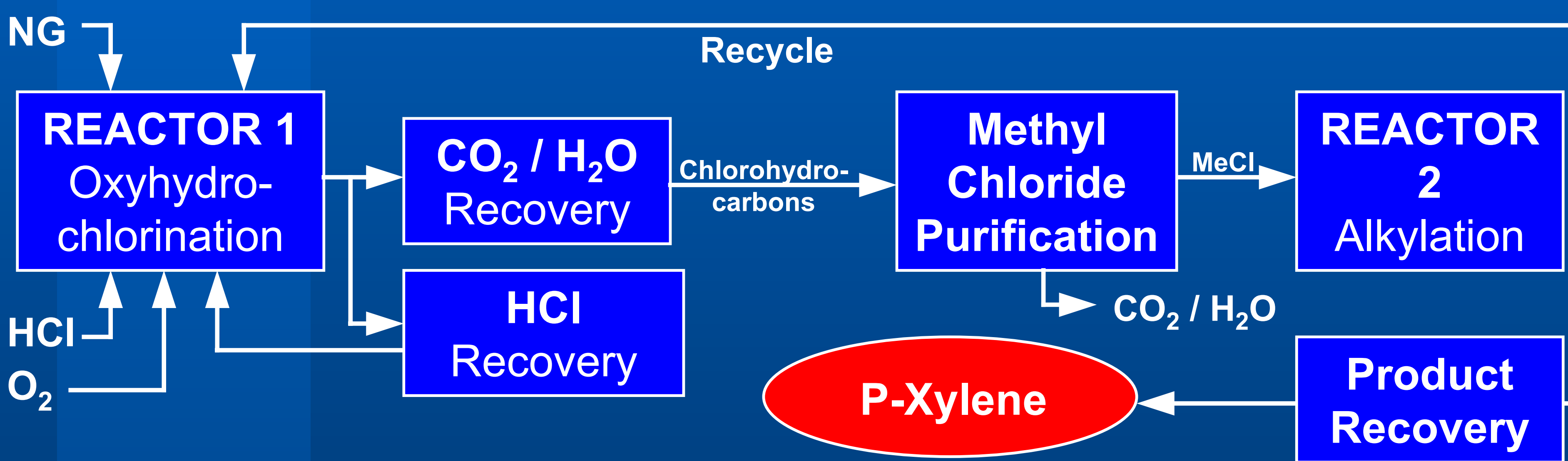
Conversion of Natural Gas to Para-xylene via Oxyhydrochlorination and Alkylation



Reactor 1: Oxyhydrochlorination

$$\text{Methane} + \text{Oxygen} \xrightarrow[\text{Catalyst}]{300\text{-}400^{o}\ C} \text{Methyl Chloride}$$

Reactor 2: Toluene Methylation

$$\text{Methyl chloride} + \text{Toluene} \xrightarrow[\text{Catalyst}]{325\text{-}400^{o}\ C} \text{p-Xylene}$$

This project focuses on the conversion of natural gas to p-xylene via the integrated approach of oxyhydrochlorination and alkylation. Para-xylene is an important industrial feedstock used in the manufacture of polyester fibres and film, Polyethylene Terephthalate (PET) and Polybutylene Terephthalate.

Natural gas reacts with oxygen and hydrogen chloride over a mixed chloride catalyst in the oxyhydrochlorination reactor, producing chlorohydrocarbons. MeCl is separated from the chlorohydrocarbon mixture and fed to a second reactor to which toluene is introduced. MeCl reacts with toluene over a shape selective catalyst producing x-xylene.

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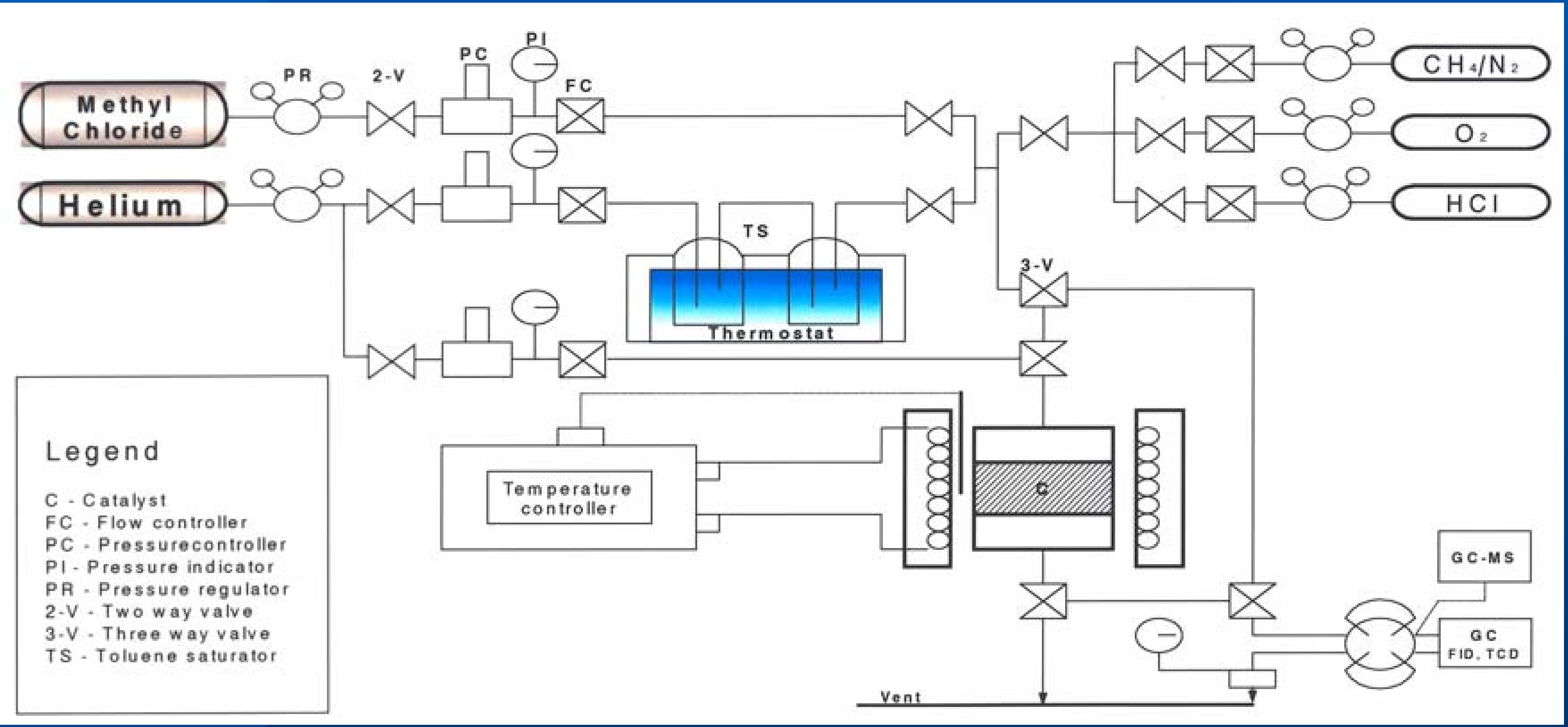
Reactor Assembly to Study Production of P-Xylene by Alkylation of Toluene with Methyl Chloride



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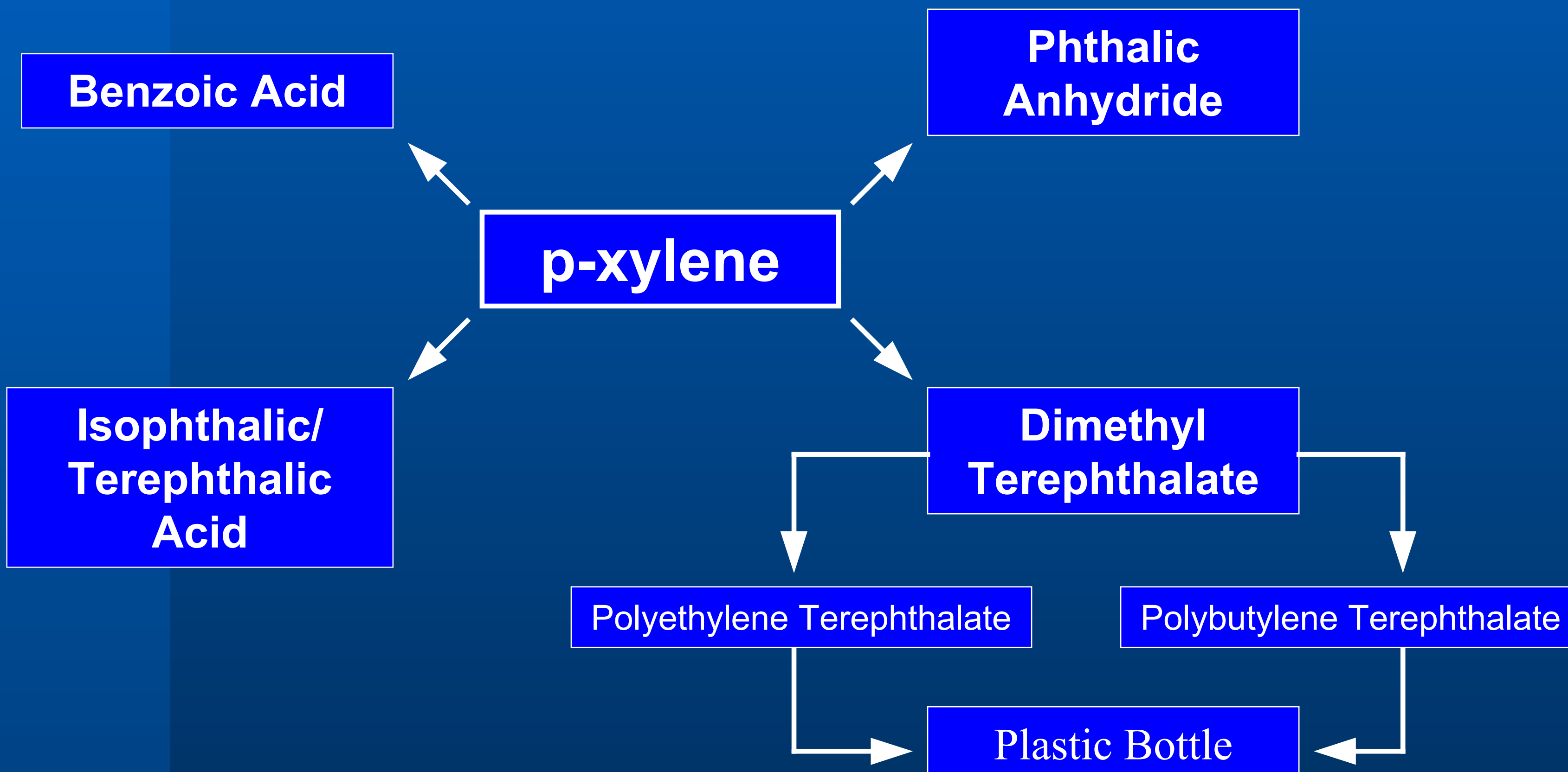
Industrial Use of p-Xylene

(p-xylene is an important feedstock)



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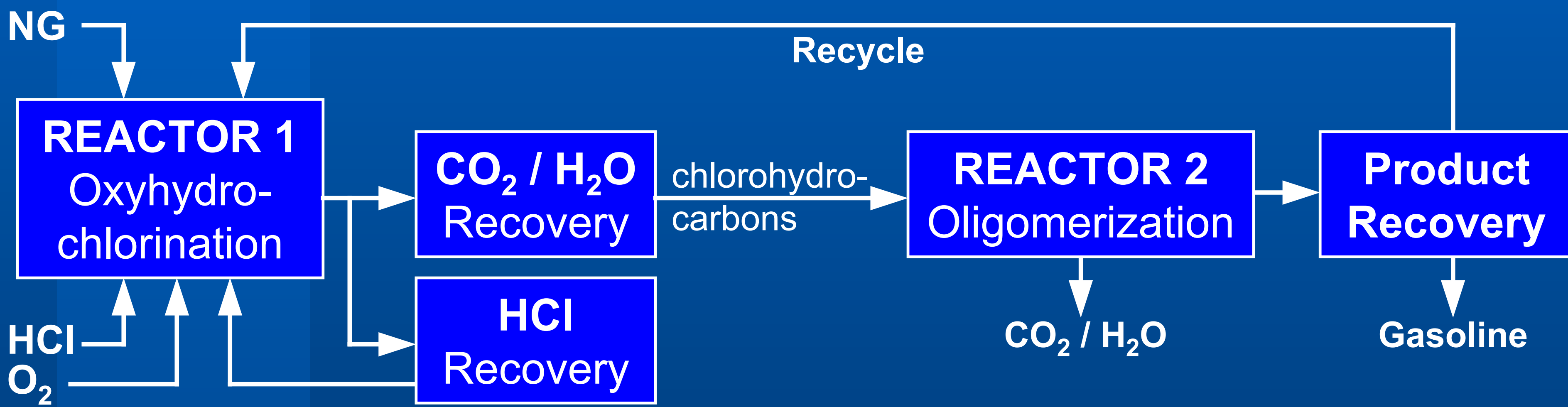
Conversion of Natural Gas to Gasoline via Oxyhydrochlorination and Oligomerization



Reactor 1: Oxidative Coupling

$$CH_4 + O_2 + HCl \xrightarrow[\text{Catalyst}]{300\text{-}400^{o}\,C} \text{Chloromethane}$$

Reactor 2: Oligomerization

$$\text{Chloromethane} \xrightarrow[\text{Catalyst}]{600\text{-}800^{o}\,C} \text{Gasoline}$$

This project is focused on conversion of natural gas to liquid fuels by the integrated process of oxyhydrochlorination and oligomerization.

Natural Gas reacts with oxygen and hydrogen chloride over a mixed chloride catalyst in an oxyhydrochlorination reactor to produce chlorohydrocarbons. The chlorinated hydrocarbons are fed to the second reactor where they are oligomerized to gasoline.

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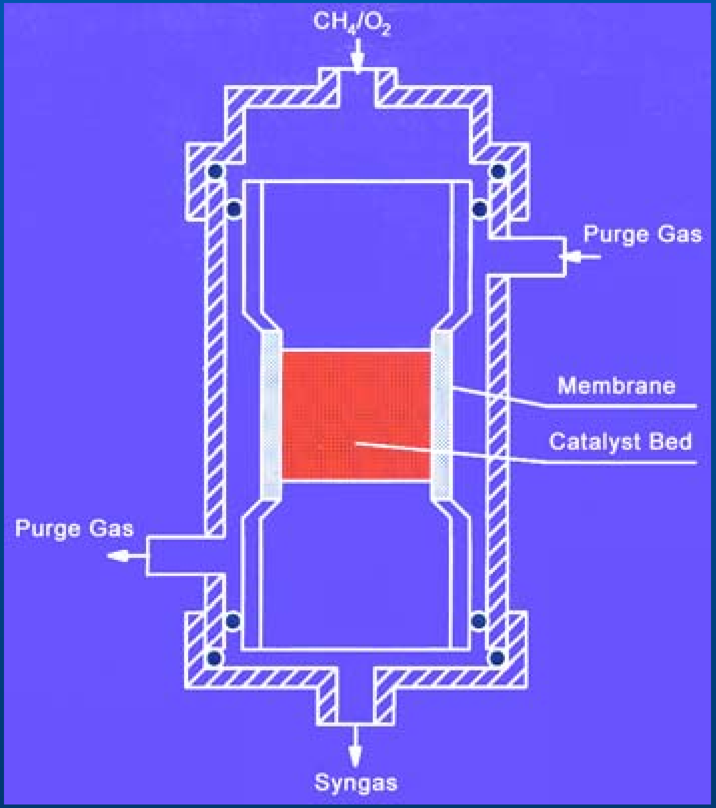
Synthesis Gas Production by Partial Oxidation of Methane Using Membrane Reactor

This project focuses on the development of membrane reactor technology for the production of synthesis gas by partial oxidation of methane. Methane reacts with oxygen over a catalyst in an H_2-permeable membrane reactor, producing synthesis gas (a mixture of CO and H_2). Membrane reactor permits continuous and selective withdrawal of H_2 from the reaction zone, so that conversion yield surpassing thermodynamic equilibrium values can be achieved.



<u>Membrane Reactor: Partial Oxidation</u>

Methane + Oxygen $\xrightarrow[\text{Catalyst}]{600\text{-}750^{o}\,C}$ Syngas **(mixture of CO and H_2)**

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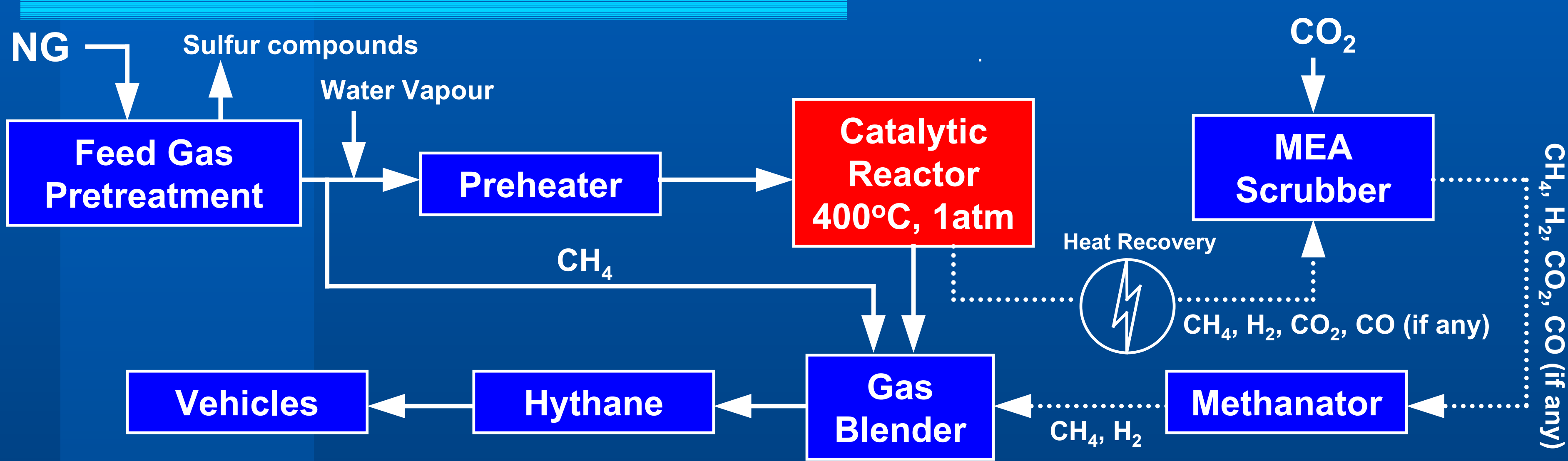
Conversion of Natural Gas to Hythane (a Fuel of the Future)



$$\text{Methane} + \text{Water} \xrightarrow[\text{Catalyst}]{600\text{-}750^{o}\,C} \text{Hythane}$$

Advantages of Hythane Fuel

- Very low emissions of CO, NO_x and THC
- Smaller volume of CO_2 emissions as combustion products, compared with other fuels including natural gas
- Increase of lean operating limits

This project deals with the conversion of Natural Gas to Hythane fuel. Hythane, a mixture of Hydrogen and Natural Gas (10% - 20% hydrogen, 80 - 90% natural gas) is receiving considerable attention as a promising alternative fuel.

Our laboratories have developed a process for on-site production of Hythane at gas filling stations. It involves controlled oxidation of methane with water vapour over a metal based catalyst at temperature between 300 and 400°C

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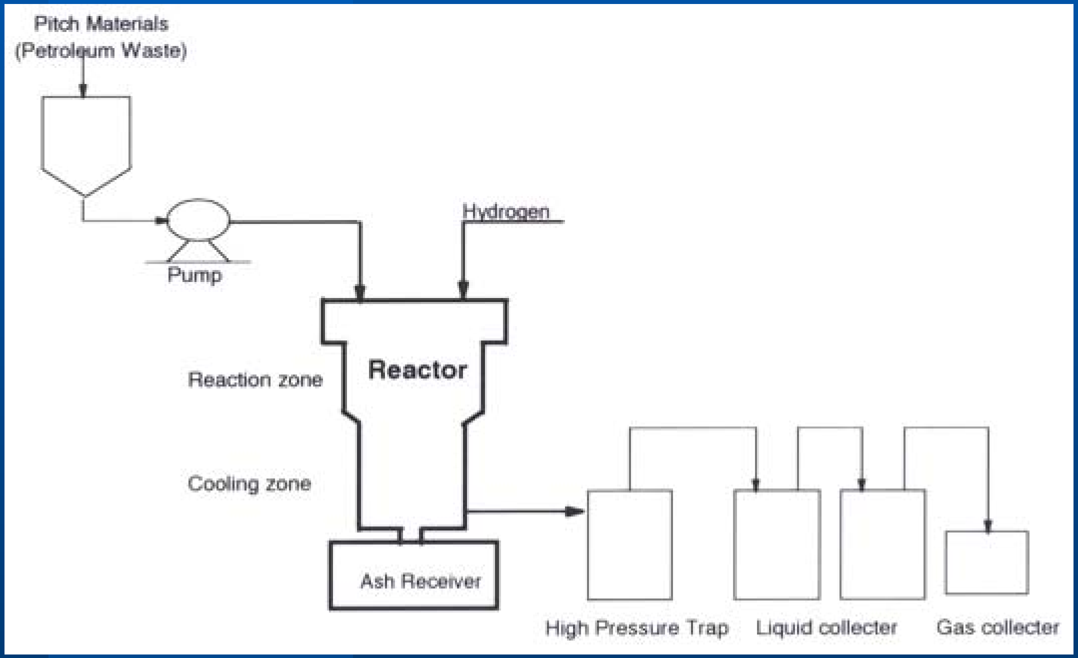
Production of Gaseous and Liquid Fuels from Pitch Materials by Flash Hydropyrolysis



This project deals with production of transportation of fuels from low-value carbonaceous materials such as pitch and tar.

- **The pitch feedstock is pumped along with hydrogen at high pressure to flash hydropyrolysis reactor, maintained at high temperature.**
- **The pitch is rapidly heated to high temperature under flowing hydrogen.**
- **The high molecular weight material is converted to fragments of lower molecular weight, which react with hydrogen to form valuable gaseous and liquid fuels.**

$$\textbf{Pitch+ Hydrogen} \xrightarrow[\text{400-800° C, with or without Catalysts}]{\text{Flash Hydropyrolysis}} \textbf{Gaseous Fuels} + \text{Liquid Fuels}$$

(Methane, Ethane) (Gasoline, Diesel)

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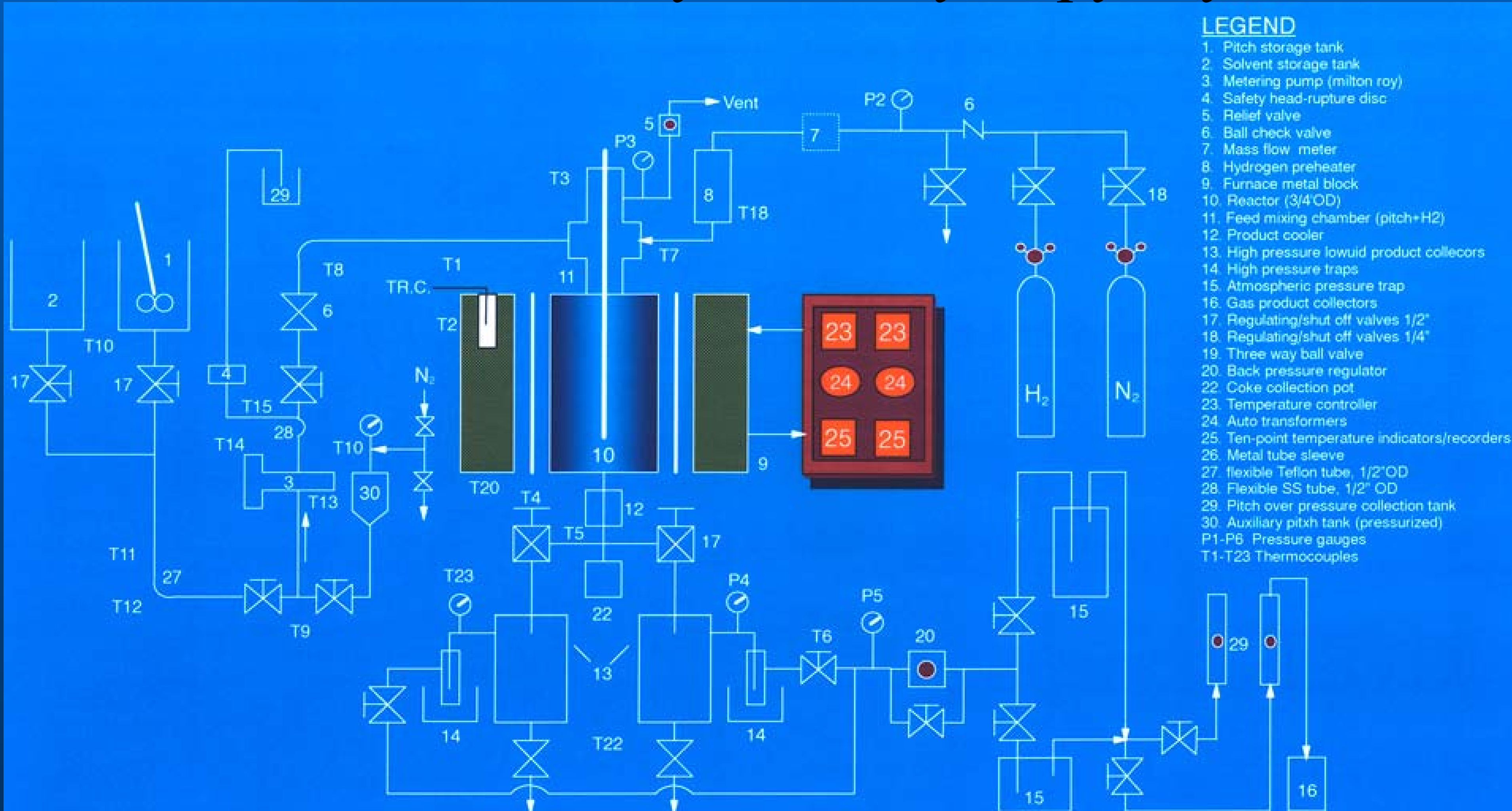
Production of Gaseous and Liquid Fuels from Pitch Materials by Flash Hydropyrolysis cont.



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