A FT-GTL technology for small-scale applications

Mark Peters, Diane Hildebrandt,
David Glasser and Xinying Liu

Material and Process
Synthesis (MaPS)
A Research Unit
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MaPS Engineering: a Research Unit @ UNISA

MaPS Engineering is a newly formed research unit based at the Science campus in Florida, with the vision of utilizing the resources in universities to serve industry, especially in the field of alternative energy.

MaPS has 20 permanent staff, among them over 10 holding a PhD's in Engineering or Science, and has over 20 postgraduate students.

Team members were all from the group winning the NST-BHP Billiton award for research for innovations through an NGO, NP, or CBO 2009-2010

XTL services provided

- XTL process design and optimization
  - Biomass-to-Liquids (BTL)
  - Coal-to-Liquids (CTL)
  - Gas-to-Liquids (GTL)
  - Waste-to-Liquids (WTL)

- Evaluation of the available XTL technologies

- XTL projects engineering
  - Opportunity Analysis and Business Proposals
  - Feasibility Study
  - Front End Engineering Design
  - Commissioning of the Fischer-Tropsch section

Conventional Fischer Tropsch Process

- Modern Fischer Tropsch process has been used only in MEGA plants
  - Secunda CTL: 160,000 bpd
  - PetroSA GTL: 36,000 bpd
  - Oryx GTL: 34,000 bpd
  - Pearl GTL: 140,000 bpd
  - Ningdong CTL: 90,000 bpd (under construction)

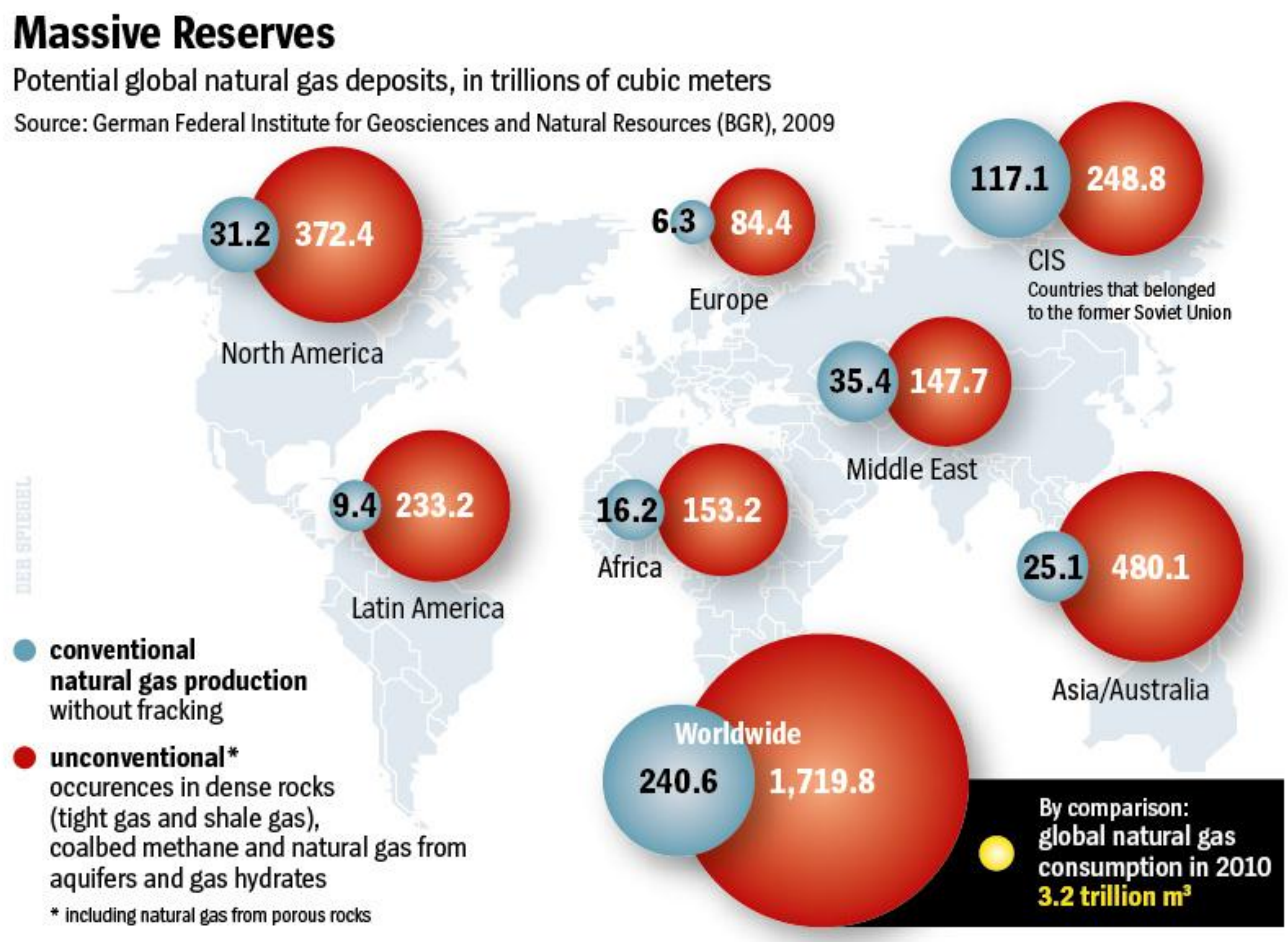
Mega Plants

- Mega plants perform at high efficiency within the
  - Flow sheet
  - Equipment used
  - Product they are designed to produce
- Rely on economy of scale to improve profitability

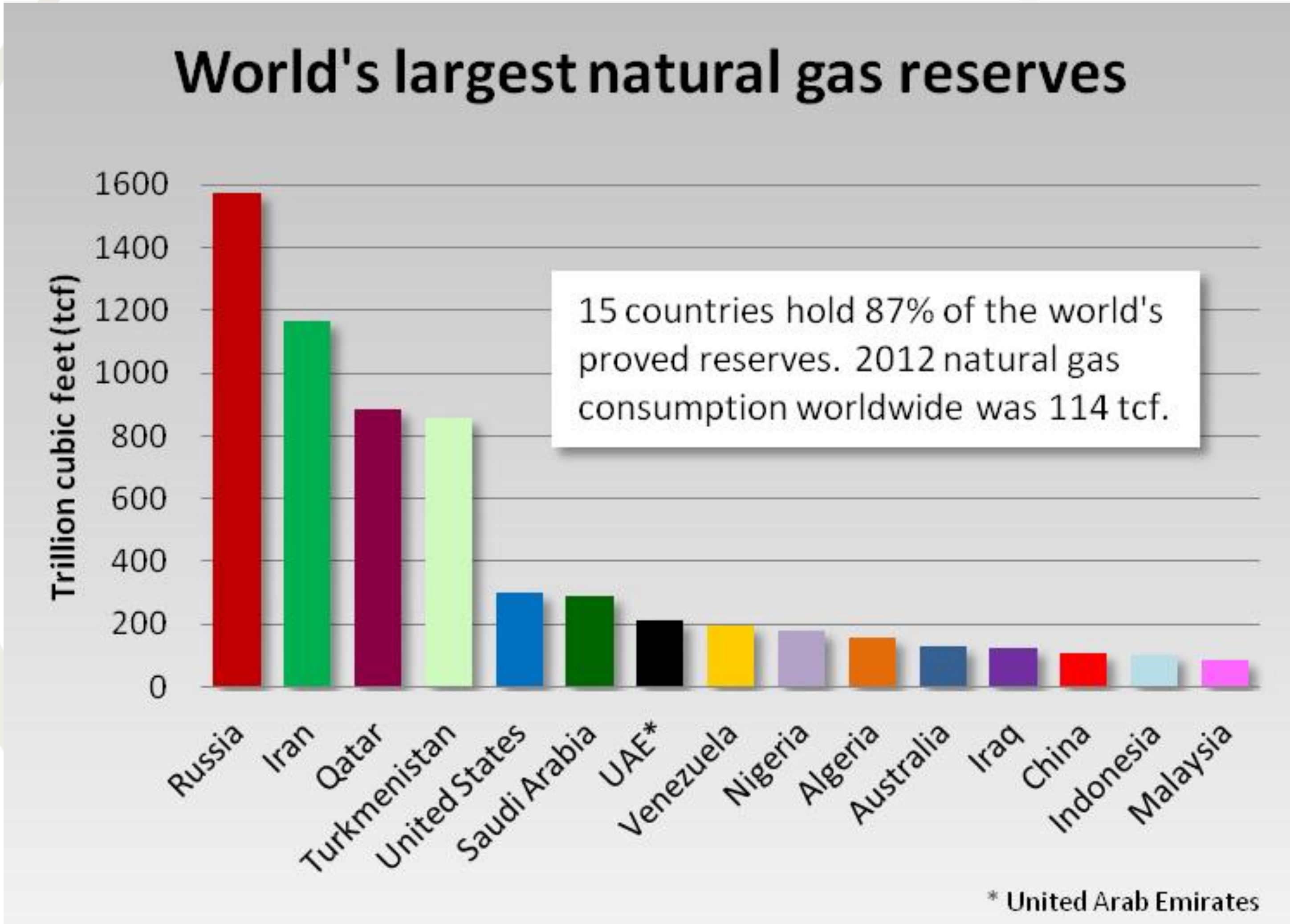
Is it too big?

- Huge investment involved
  - Sasol Two: R 2.5 B (8% of GDP of SA in 1976)
  - Sasol Three: R 3.3 B (7% of GDP of SA in 1979)
  - Pearl GTL: USD 18–19 B (11% of GDP of Qatar in 2010)
  - Long time for financing
  - Lots of politics involved
  - Long time to bring into market
- Flow sheet chosen normally conservative
  - To minimize the risk
  - Difficult to implement the latest research development
- Large amount of carbon resources needed
  - Billion tons of reserves needed to secure a long time life time
  - Large amount of CO_2 emitted from a single plant in the case of CTL

Is there a reason to think small-scale?



Why think small-scale?



There are some reasons to think small

- There are many carbon resources that are not as big
  - Small carbon reserves
  - Coal bed methane
  - Coke oven gas
  - Underground coal gasification
  - Landfill gas
  - Flare gas
  - Soluble methane
  - Biomass
  - Municipal solid waste
  - etc.
- Smaller investors want to be involved
- Shortage of engineers and skilled-labor, especially in many developing countries
- Short project startup time gives a faster response to market
- Lower financial risk as investment is smaller
- To implement latest development from research

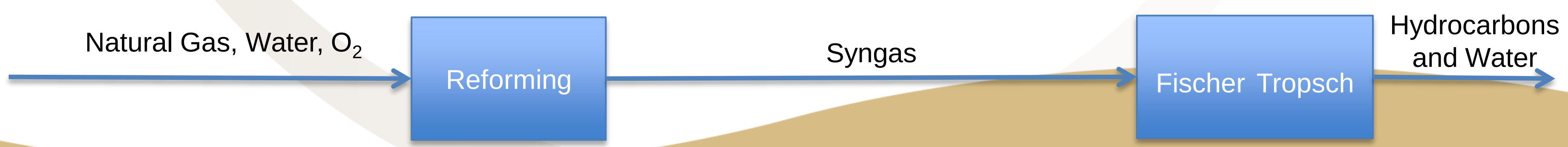
Modular Approach?

- A new approach is to build smaller modular plants.
- These have the advantages of being
  - less capital intensive
  - more flexible and
  - having a faster time-to-market
- Start giving returns on expenditure much sooner
- Later modules can incorporate newer ideas
- Good for managing risk
- Get higher efficiency by being able to incorporate new ideas
- Need a new flow sheet to make it work

Development of Conventional GTL Process: Reactions

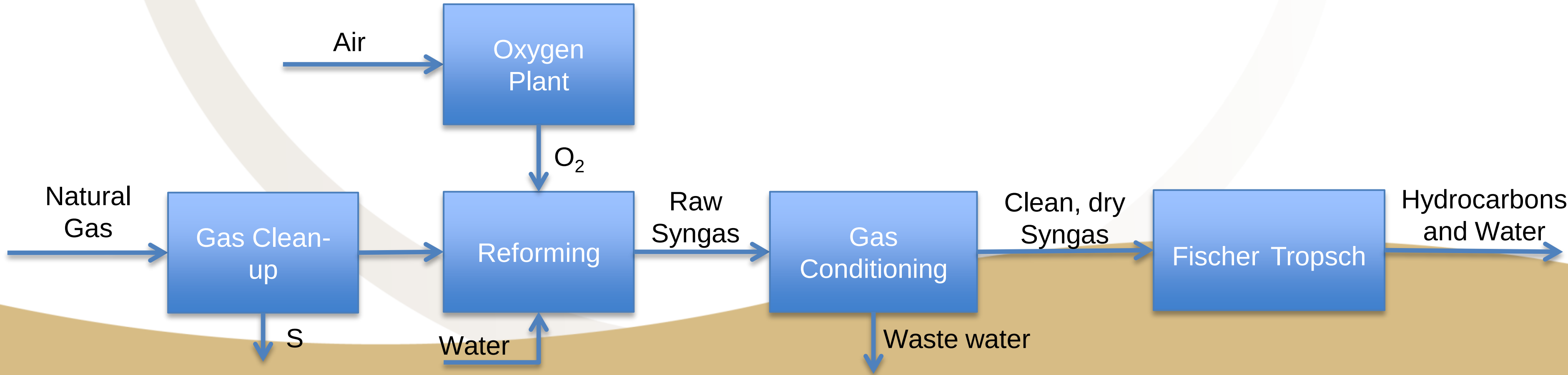
- **Reforming**:
  - Methane / Natural Gas feed to produce Synthesis Gas ("Syngas"):
    - $CH_4 + H_2O \rightarrow CO + 3\ H_2$
    - $CH_4 + \frac{1}{2}\ O_2 \rightarrow CO + 2\ H_2$
    - $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

- **Fischer Tropsch**:
  - Syngas converted to hydrocarbons and water:
    - $CO + 2\ H_2 \rightarrow\ –CH_2– + H_2O$



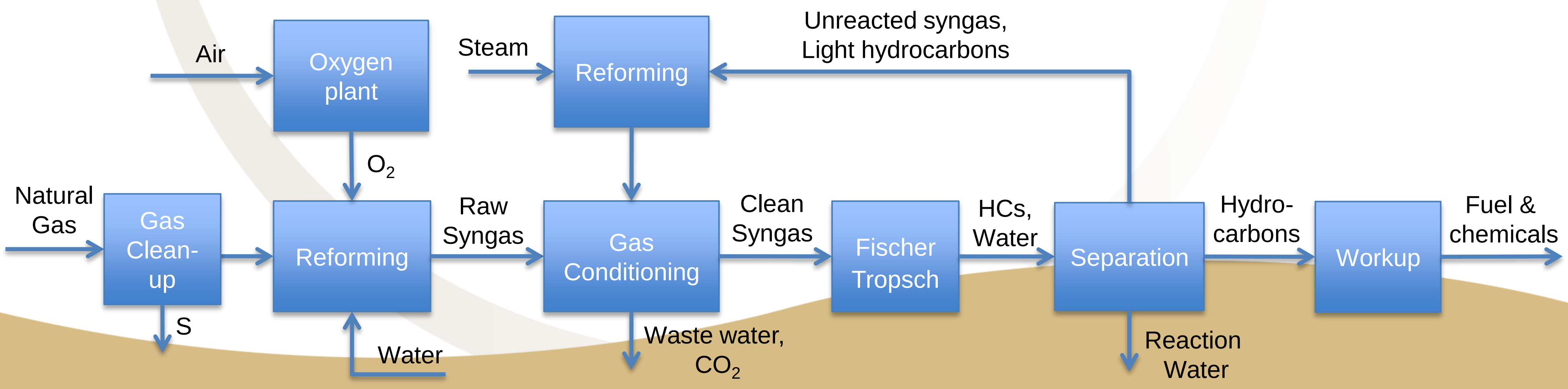
Development of Conventional GTL Process: Produce the Right Syngas

- **Pure O_2 is required**
  - Need an Oxygen Plant
- **H_2/CO is wrong**
  - Corrected by water gas shift reaction
  - $CO + H_2O \rightarrow CO_2 + H_2$
- **High moisture content in syngas**
  - Water is to be knocked out
- **Feed stock is always dirty**
  - Syngas is also dirty, clean up is needed to protect downstream catalyst and for easy operation



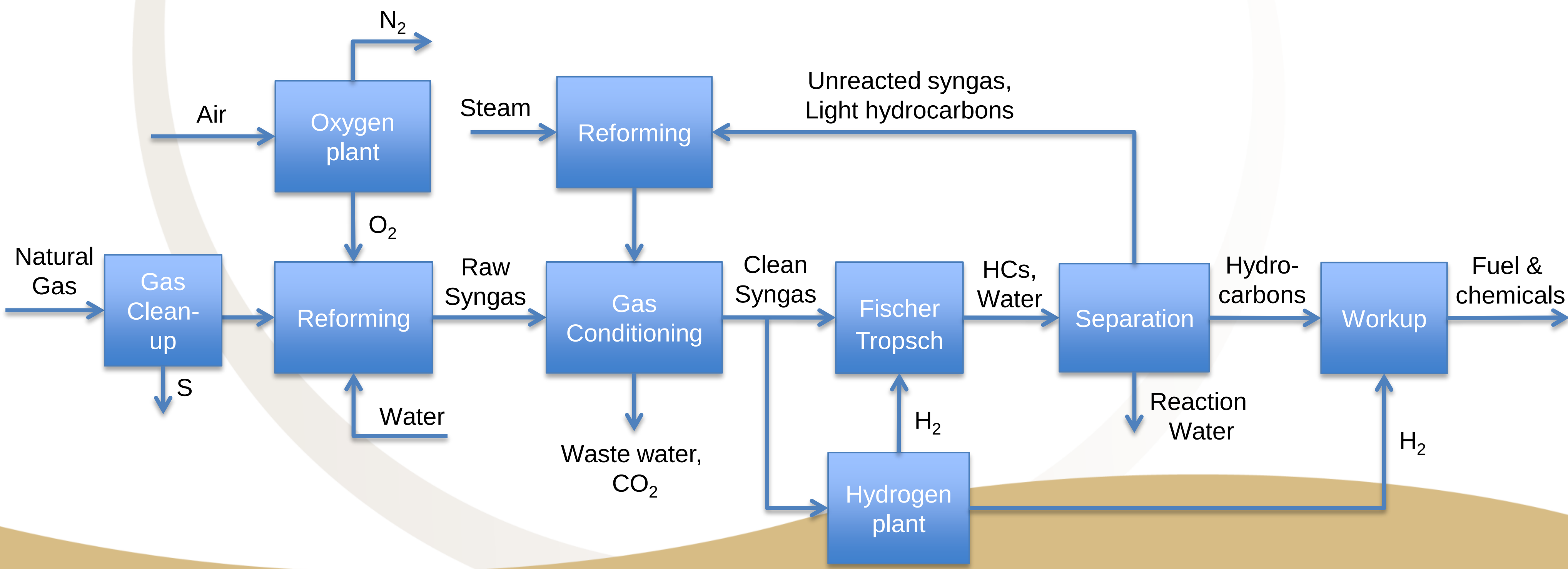
Development of Conventional GTL Process: Produce the Right Products

- **The Fischer Tropsch reaction unable achieve 100% conversion and produces a wide range of hydrocarbons from C_1 to C_{many}**
  - Normally Only C_{5+} are needed for fuel
    - Naphtha, Kerosene, Diesel, Fuel oil, Wax
  - Light hydrocarbons are useful chemicals
    - Ethylene, Propene, Butene, etc.
  - Unreacted syngas and light hydrocarbons can be recycled through reforming process
    - CO_2 need to be knocked out during gas conditioning
- **Need for Separation and Product Workup**

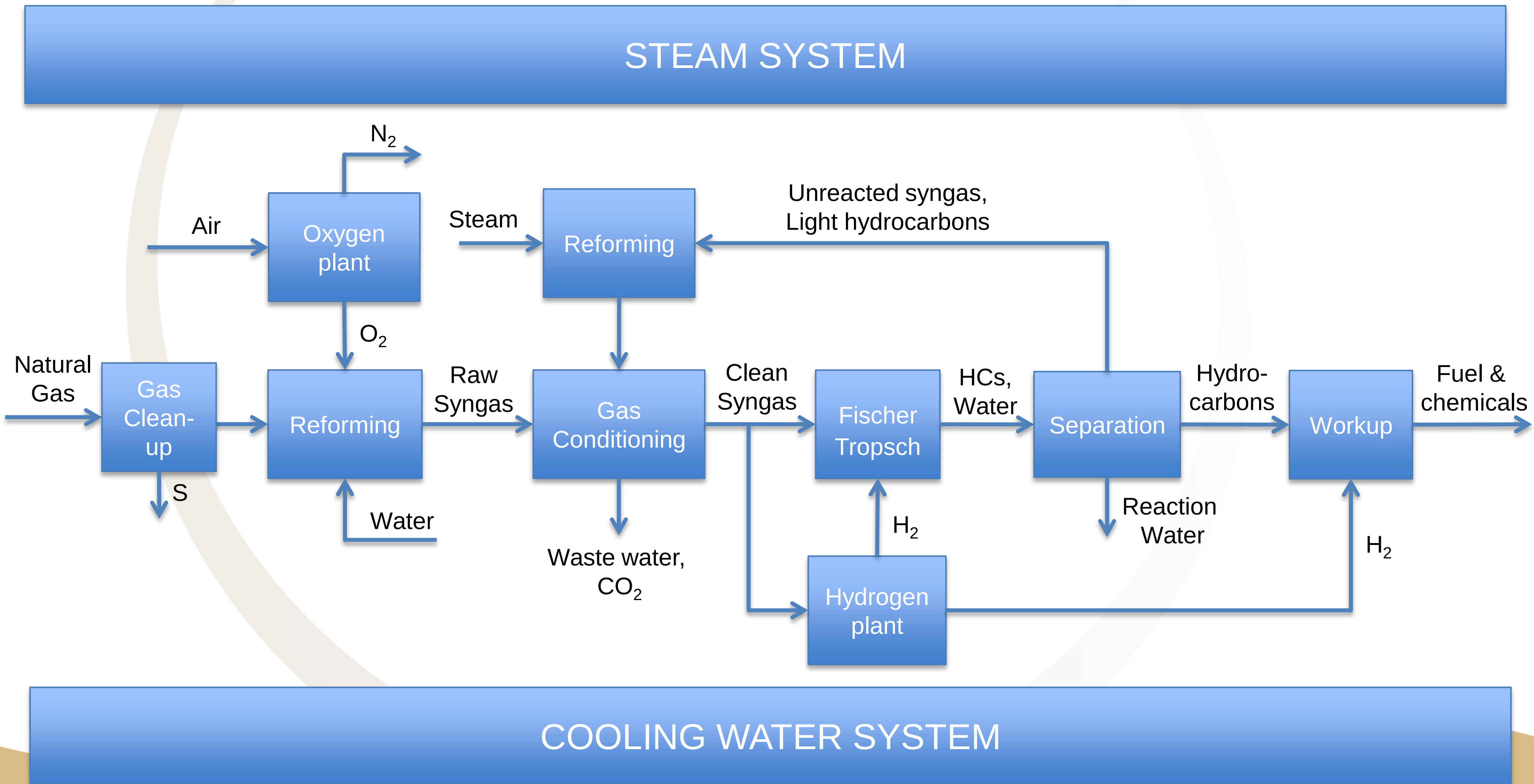


Development of Conventional GTL Process: Consider the Start-up and Activation

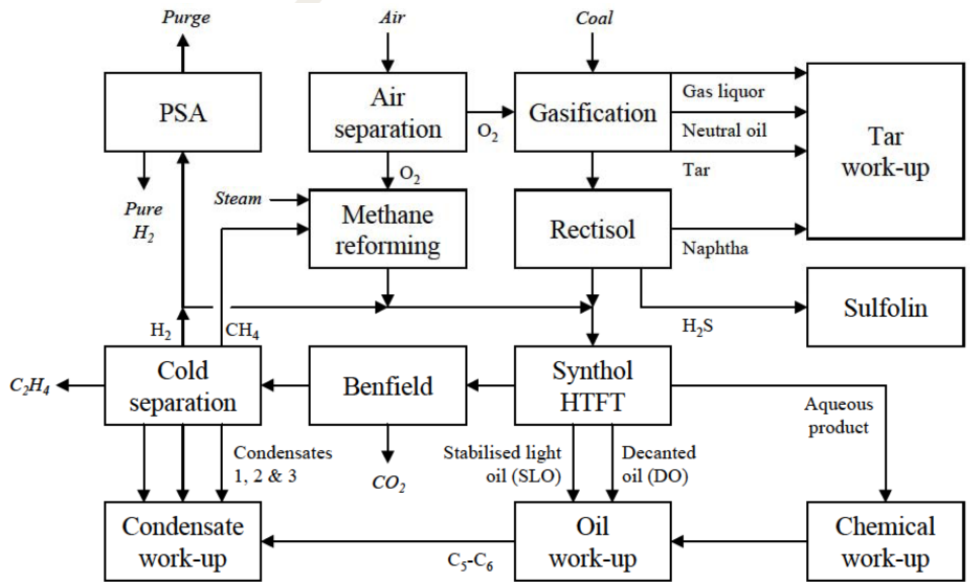
- **Inert gas needed for start-up**
  - Normally N_2 is used, which is also produced from the oxygen plant
- **Hydrogen needed for catalyst reduction/activation, and product workup**
  - H_2 can be produced from syngas via water gas shift reaction

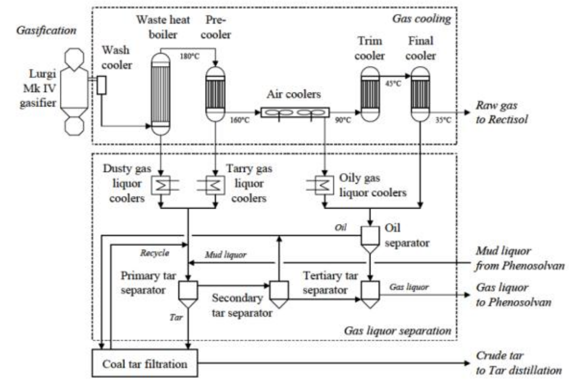


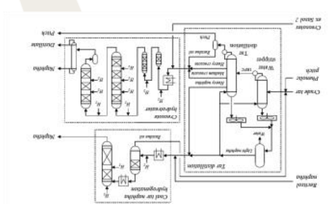
Development of Conventional GTL Process: And Utilities

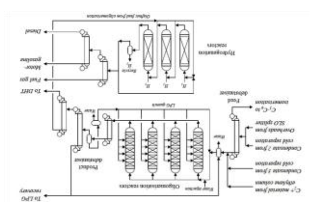


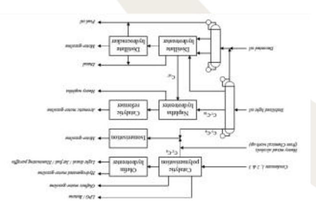
Development of Conventional GTL Process: A Real Case

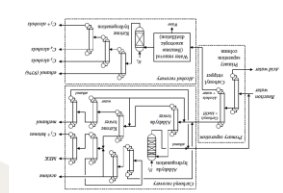


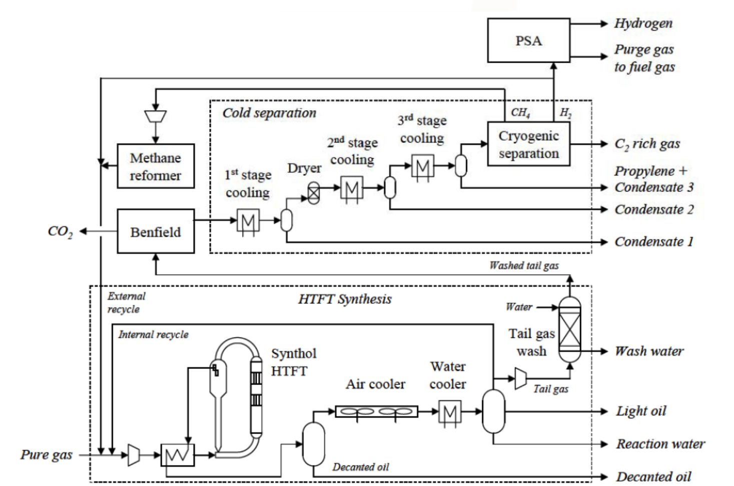






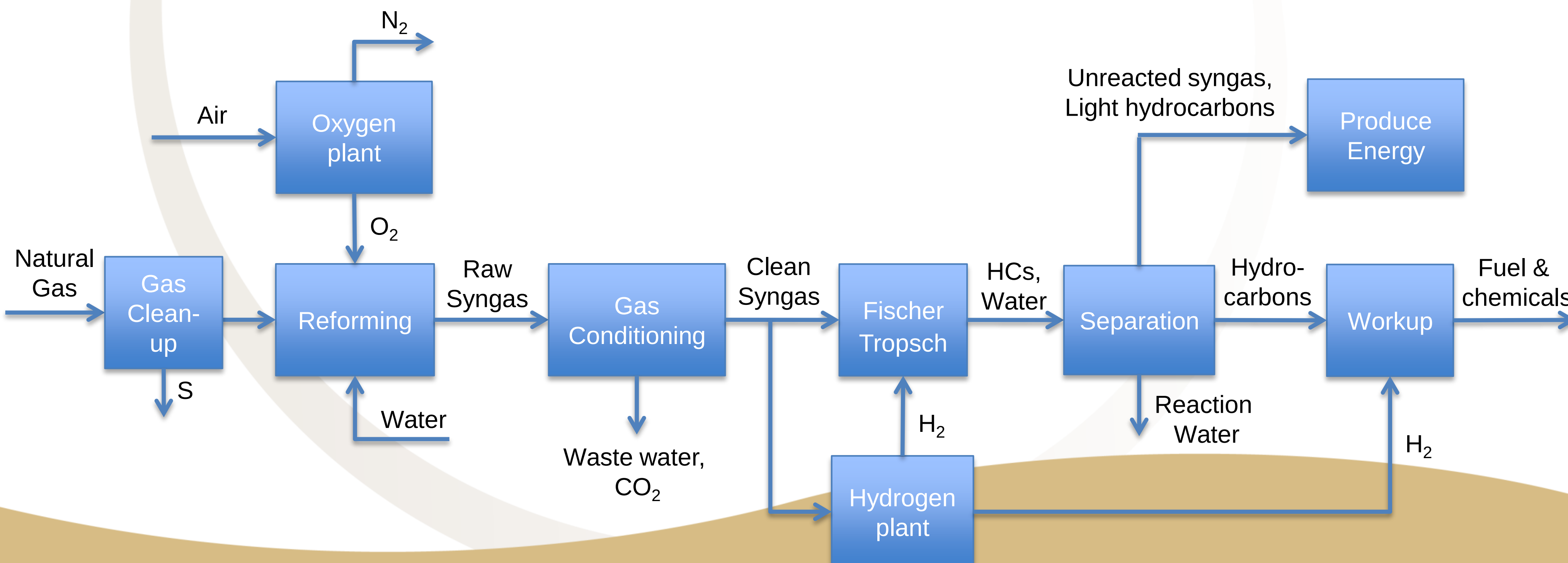






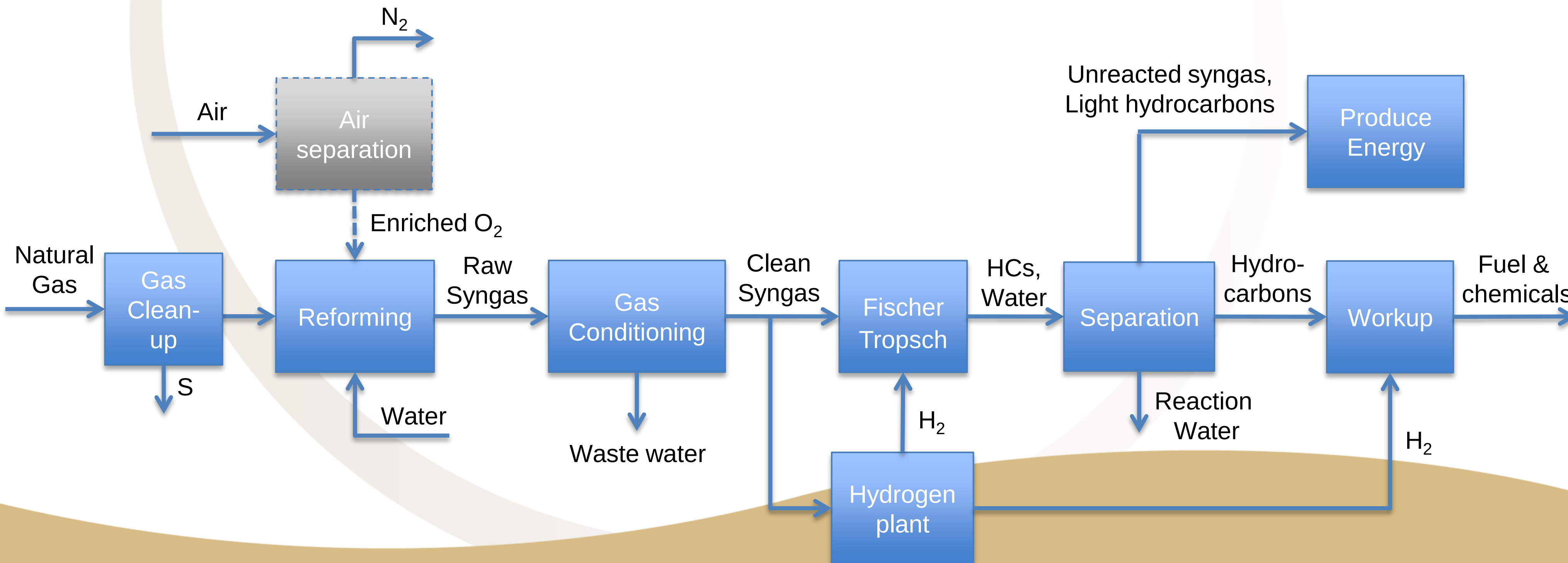
Small-scale approach: Can we simplify it?

- **Do we need a recycle?**
  - By pushing conversion & heavy hydrocarbon selectivity higher, recycle can be removed
  - Unconverted syngas and light hydrocarbons can be used to provide energy (heat or electricity)



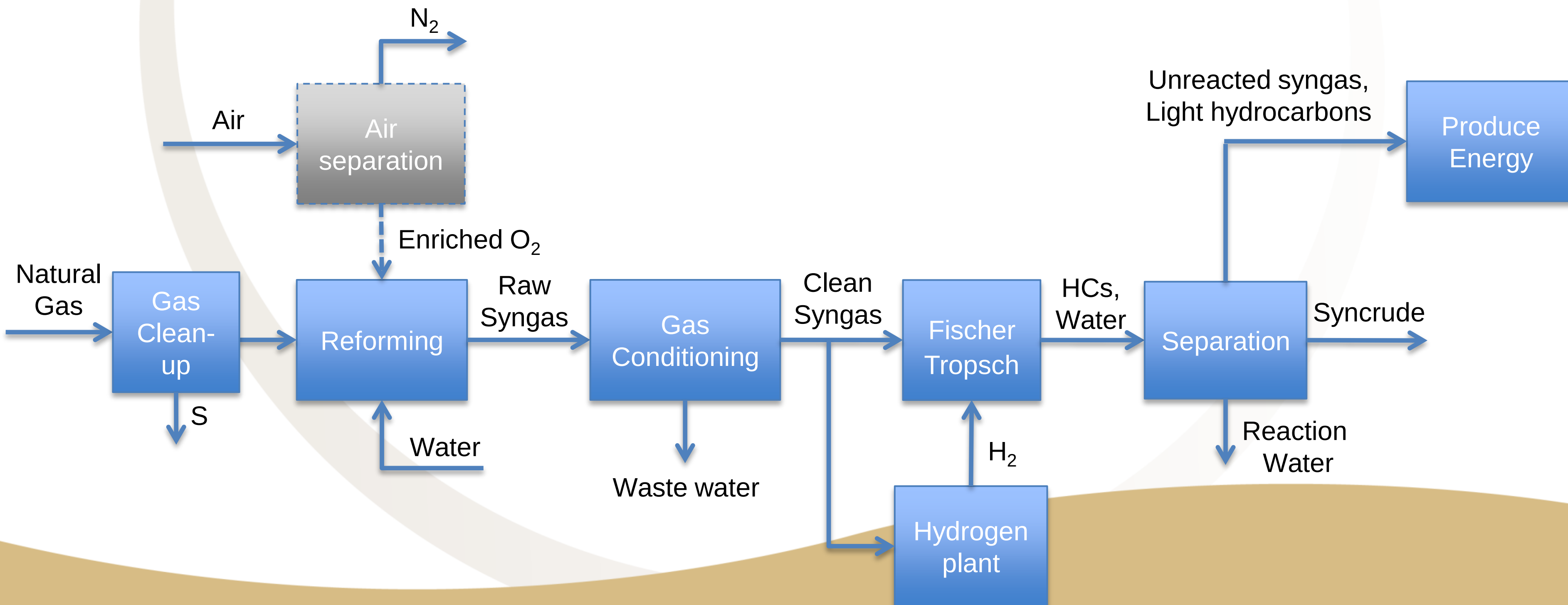
Small-scale approach: Can we simplify it?

- **As there is no recycle, we don't have to use pure oxygen for reforming**
  - Air plant can be smaller or be removed
- **We can tolerate more CO_2 in the FT section**
  - Removing CO_2 in gas conditioning is not a must



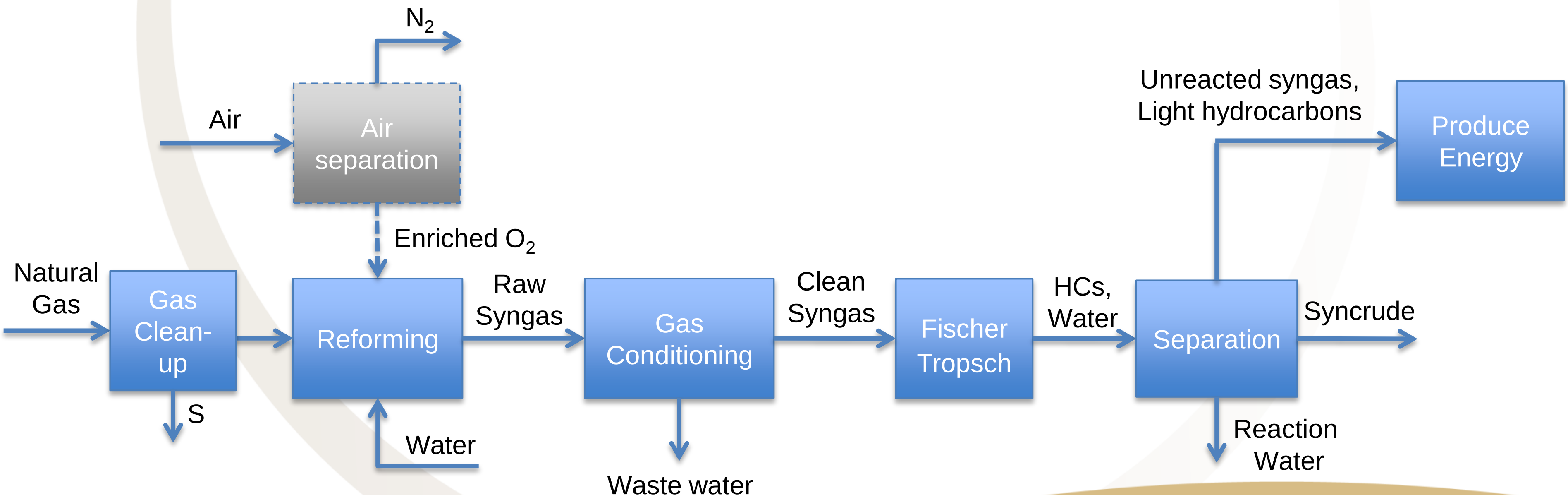
Small-scale approach: Can we simplify it?

- **Is producing syncrude sufficient?**
  - Produce syncrude and sell to refineries



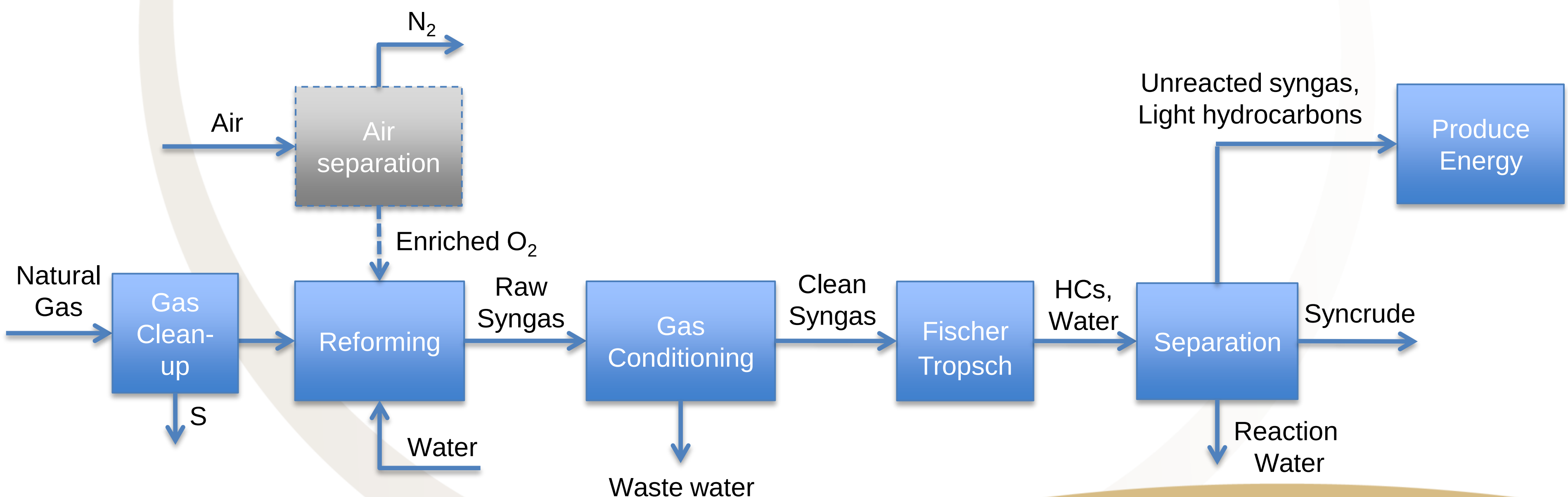
Small-scale approach: Can we simplify it?

- **Is Hydrogen a must?**
  - By developing new catalyst, catalyst can be reduced by syngas, thus no need for Hydrogen



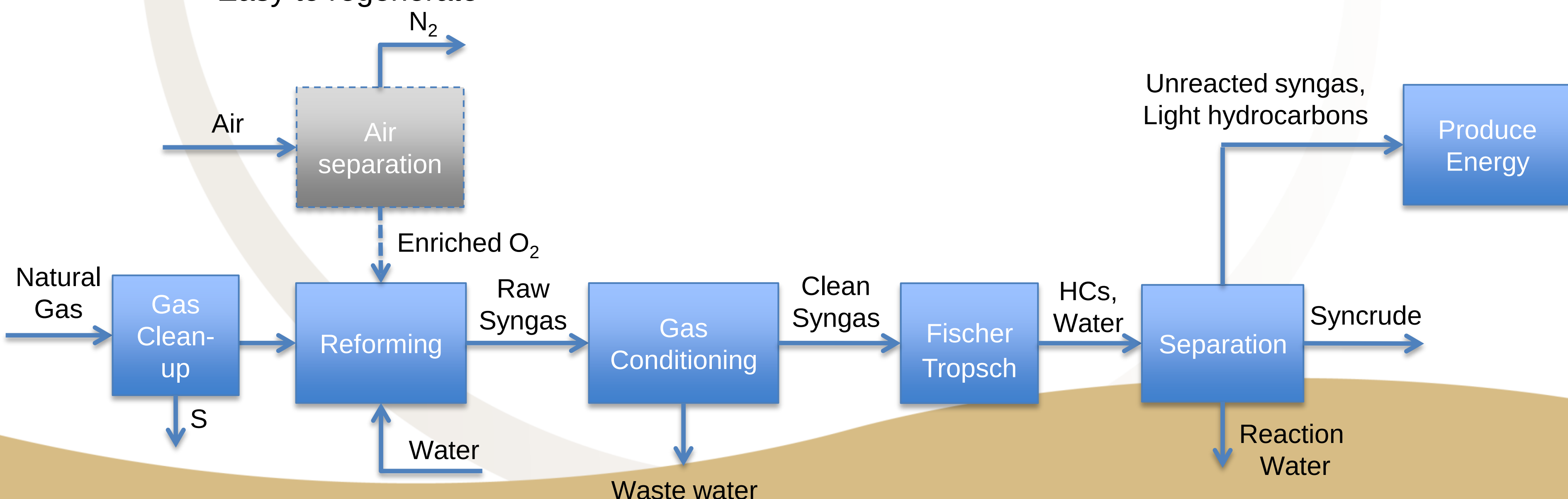
Small-scale approach: Can we simplify it?

- **Is Air Separation necessary?**
  - By developing new catalyst, it can be dried by syngas
  - Reactor can be flushed with clean natural gas in shutdowns



Now we have a simplified process

- **More Robust, modular, once-through**
- **Less Capital intensive**
- **Request for catalyst:**
  - Active at low syngas partial pressure
  - High heavy hydrocarbon selectivity
  - Tolerant to CO_2
  - Reduction using syngas
  - Easy to regenerate



500bpd GTL: Feasibility Study

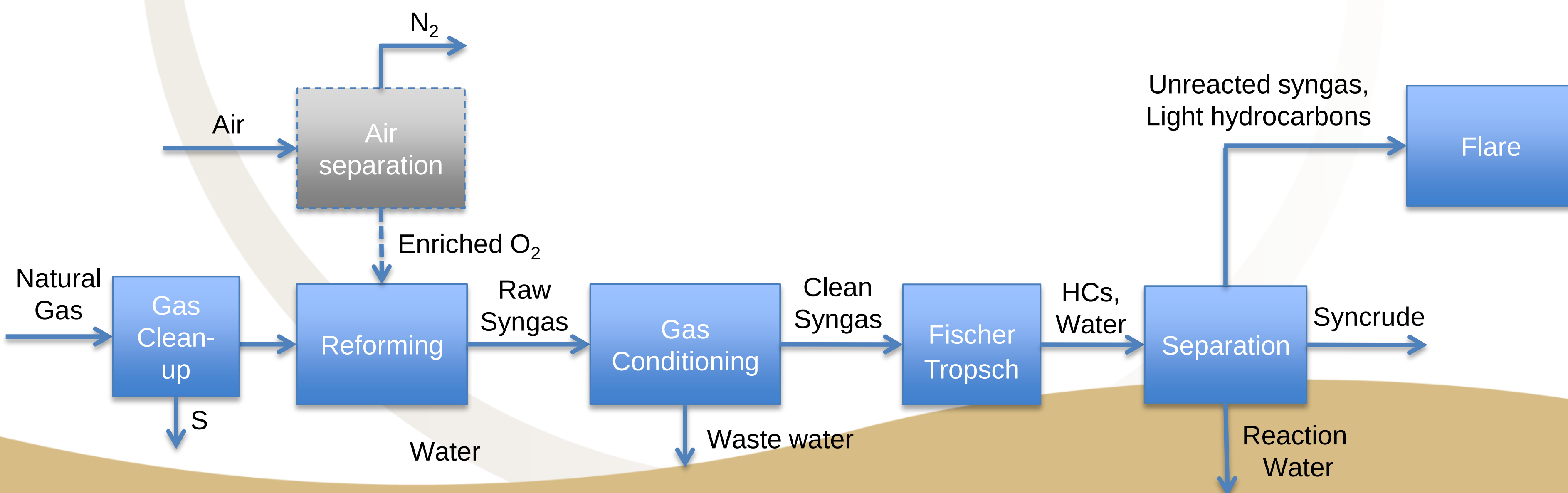
- Request from client:
  - Conduct a Feasibility Study of a 500bpd GTL demo unit
  - Location: USA
  - Feed: pipeline gas
  - Required products: Syncrude & Wax
  - MaPS responsibility: FT Section (using modular approach)
  - Rest of plant to be done by client-chosen vendors

500bpd GTL: Feasibility Study

- Feasibility Study included:
  - Concept design
    - Operating conditions (T, P, syngas ratio, etc.)
    - Catalyst selection (Fe vs Co)
    - Environmental considerations
  - Equipment listing and sizing
  - Cost estimates and quotes
  - Syncrude and Wax Product offtake

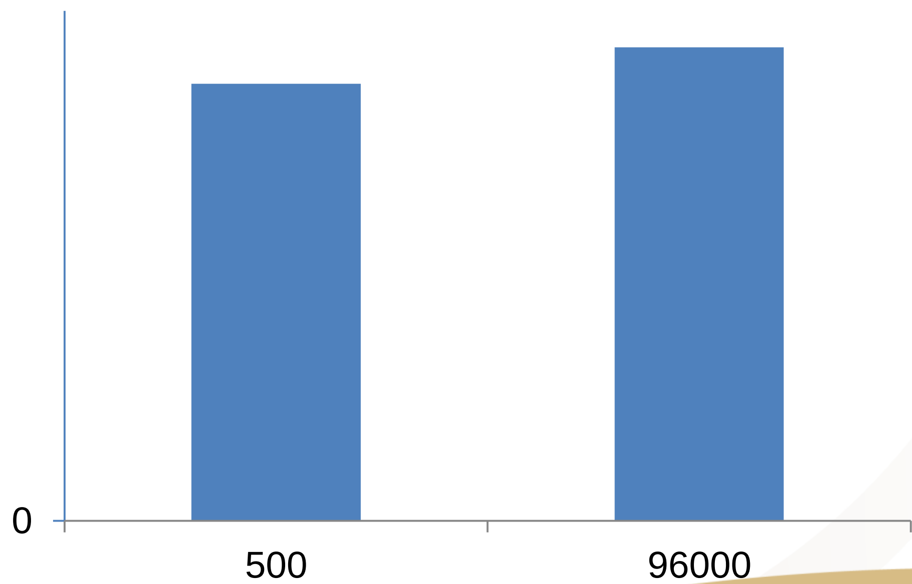
Flow Sheet

- **Flow sheet of entire plant:**
  - Choose ATR conditions
  - Enriched O_2 VS Air
  - Minimize utilities required
  - No heat/electricity needed (by client): thus flare tail-gas



Economics

- CAPEX comparison with a recent large-scale (96,000bpd) GTL case for USA (feasibility study, 2012)



Problems encountered

- Products – what to do with them?
  - Refineries?
  - Other end users?
- Process Engineering aspect has progressed for small-scale modular plants. Other engineering disciplines need to also. This is vital to the economics
- The large-scale design and manufacturing approach can not be applied

Biomass to Liquid Pilot Plant

- Funded by SA NRF and China MoST
  - Capacity: up to 1 L syncrude production a day
  - Collaboration with Hebei Academy of Agricultural and Forestry Sciences
    - In Shijiazhuang, Hebei, China
- Full demonstration of biomass to syncrude process
  - Air blow biomass gasification
  - Syngas conditioning
  - Fischer Tropsch Synthesis
- Successful commissioned in 2012

Gasification

Down draft air blow ambient pressure biomass gasification unit
Load: 50 kg of compressed wood
Capacity: 10 Nm^3/hr

Gasification → Water scrubber → Corn cob drier → Buffer tank → Raw gas clean up → Compressor

Typical gasification results (v%)

	N_2	CH_4	CO	H_2	O_2	H_2/CO
1	62.3	6.0	13.2	20.0	1.7	1.5
2	59.9	2.3	21.0	13.6	0.9	0.65
3	41.5	5.7	11.0	18.7	1.2	1.7
4	46.6	4.8	13.3	16.0	0.7	1.2
5	46.9	4.8	13.5	15.6	0.6	1.2

Guard Bed

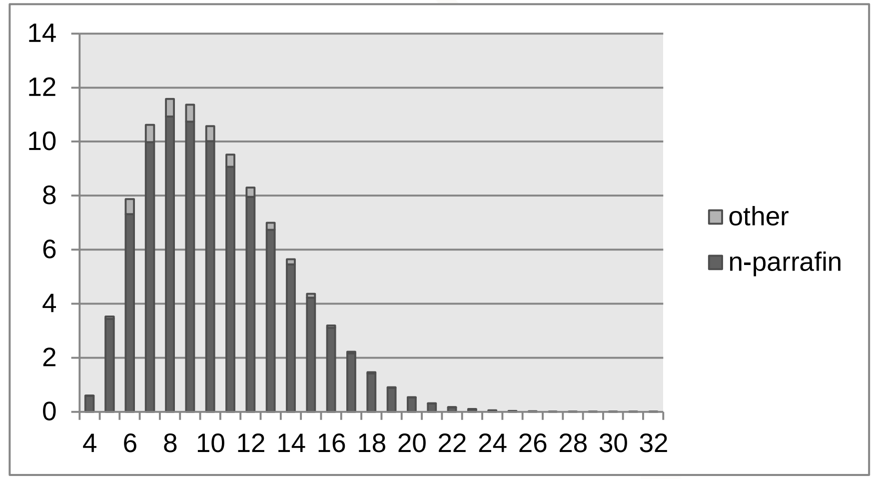
Remove H_2S → Hydrolysis → Remove H_2S → Remove O_2 → Drier

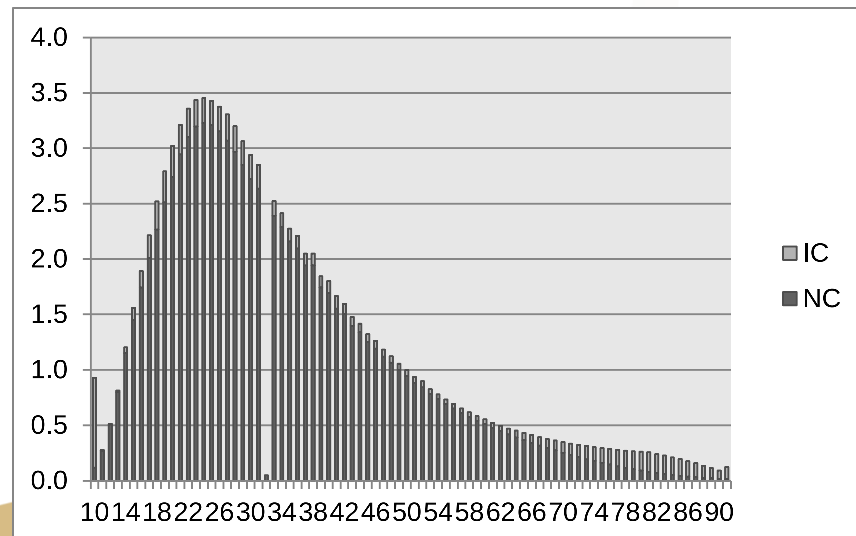
- Total S level is lowered
  - From ~ 10 ppmv to < 10 ppbv
- O_2 < 0.1 v%
- Over 2000+ hrs operation experience achieved
  - No deactivation observed

Fischer Tropsch Synthesis

- Single tube fixed bed reactor
  - i.d. 50 mm
  - Length 900 mm
  - Max catalyst bed 600 mm
    - 1.2 L
- Heated by
  - heating oil (< 260 C)
  - Nitrogen (250 – 400 C)
- Reaction pressure up to 4 MPa
- Two steps products separation
  - Step one: 150-190 C
  - Step two: 4 C

Liquid products





Simulation results based on pilot data

- At the right operation condition, 1 barrel of syncrude (including wax) can be produced using 1 ton of biomass (LHV ~ 20 MJ/kg), without energy input from outside.
- More fuel can be produced if electricity is provided from grid

Current and future work

- Container scale waste to liquid demonstration plant in design phase
  - 1 barrel syncrude production a day from municipal solid waste
  - Collaboration with Nuclear Energy Cooperation South Africa (NECSA)
  - To be constructed later 2014
  - Targeting
    - Fully independent plant, or
    - Maximum fuel production
- Further simplify the process by looking at the utility requirement

Thank you