



# Syngas Chemistry: Key Technology for the 21<sup>st</sup> Century

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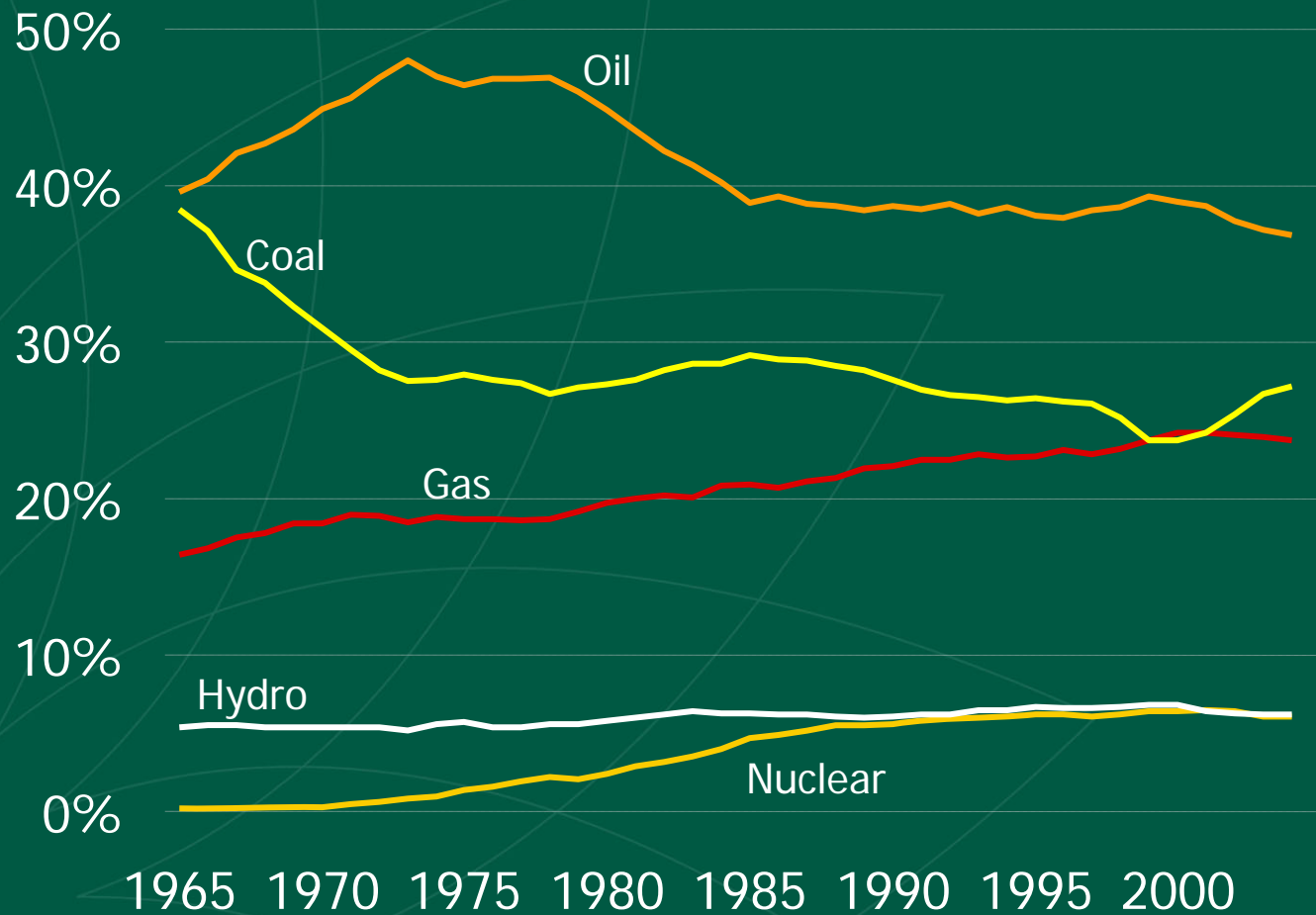
Syngas Chemistry Symposium  
Dresden, Germany  
October 4 – 6, 2006

# Outline

- Syngas: Business case
- Gas To Products (GTP) and XTP
  - Products and markets
  - Pro's and con's
  - Technologies
  - Global projects
  - Economic viability
- The future of XTP

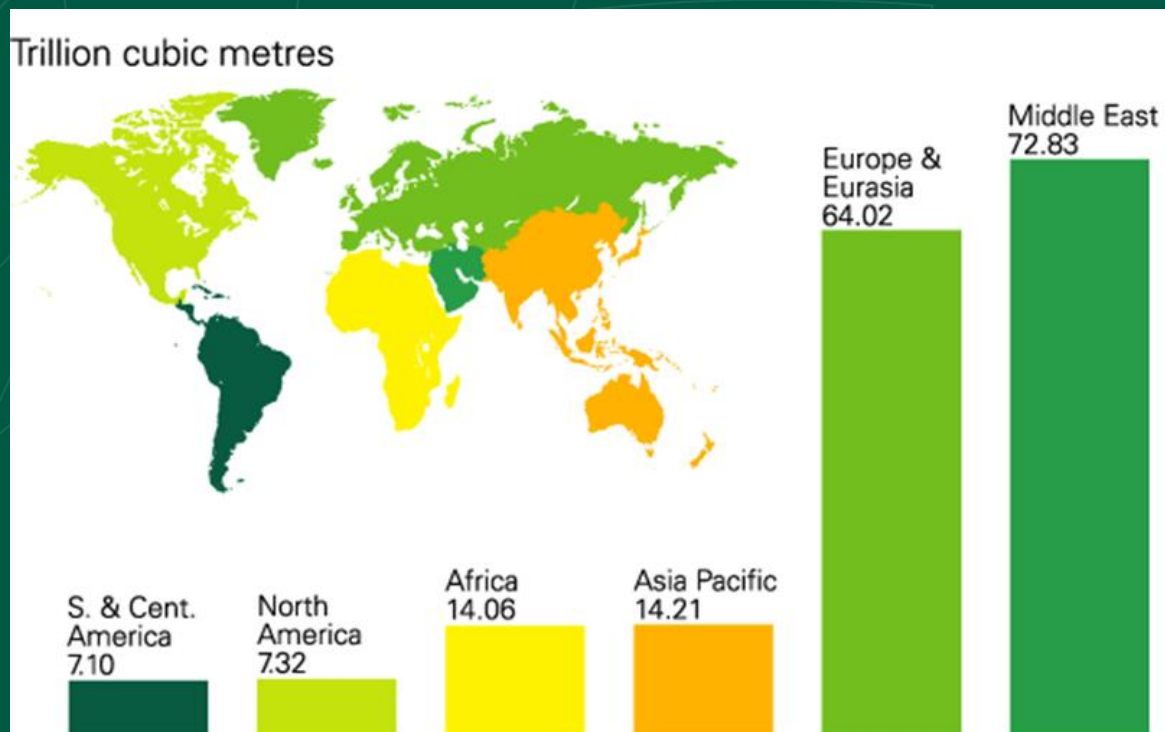
# World energy sources

Share of world primary energy consumption by fuel (1965 – 2004)



## Gas resources: plentiful but...

- Gas Reserves (2004) = 6300TCF (180TCM)
- About 40% of gas (2500TCF) is stranded (Russia—Iran—Qatar)
- R/P ratio: ~70 (versus oil at ~35)
- Transportability and market issues



## Distribution of energy consumption and flaring (15 bcfd?)



## Remote and flared gas: an inexpensive feedstock

### **GTP Value creation:**

*Feedstock:* \$0 to 1.50/MMBTU (USA: ~\$6/MMBTU)

*Products:* \$10/MMBTU

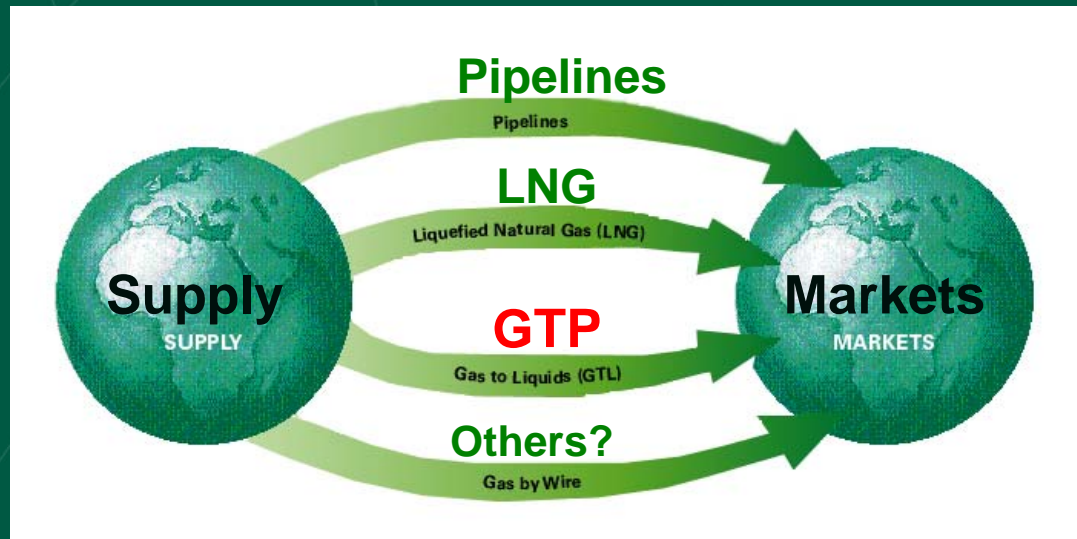
(diesel at \$50 oil or methanol at \$200/t)

*Results:* Greater netback to the feedstock

AND: New markets for gas

# Role of GTP in E&P

## 1. Moving Gas to Markets



## 3. Gas Access

New gas markets can give access to stranded gas resources

New exploration opportunities for “remote” gas

## 2. Creation of New Gas Markets



Diesel, gasoline

Chemicals, plastics

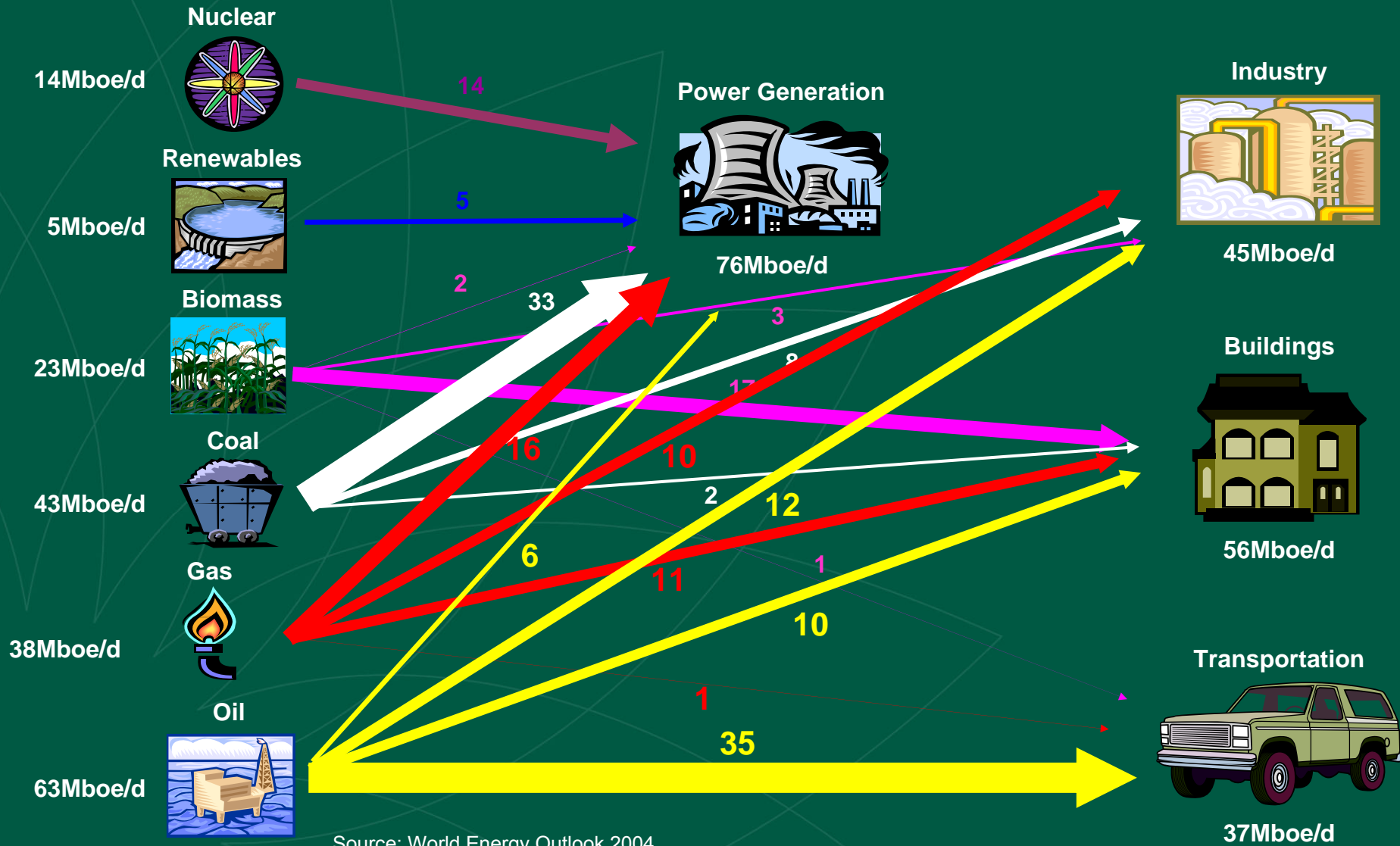
Cooking, power



## New drivers: coal and biomass

- Abundance (R/P ratio for coal is >200 years)
- Renewable fuel
- Energy security!!
- Concerns:
  - Cost (much higher than for gas)
  - CO<sub>2</sub> make with coal

# Global energy supply & demand

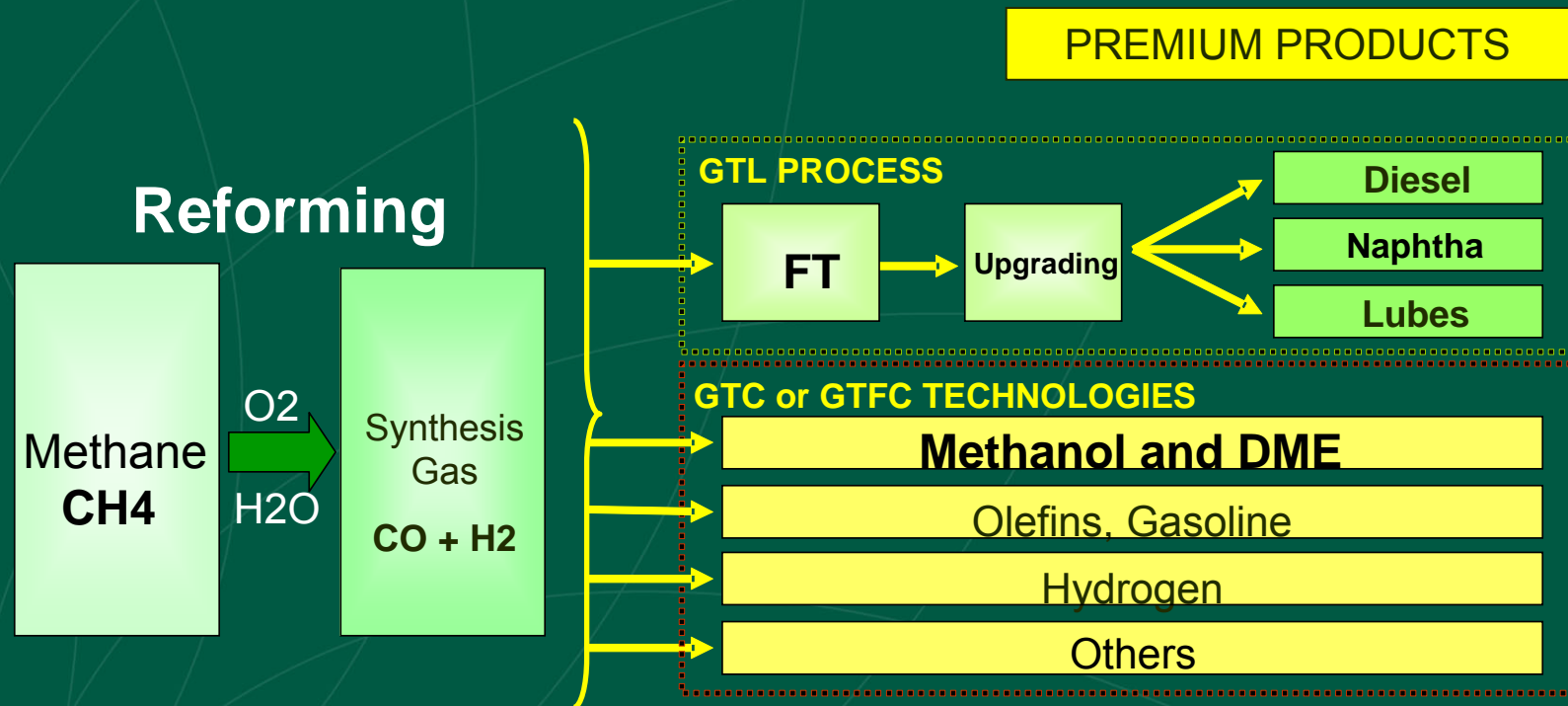


Source: World Energy Outlook 2004

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GTP: Inclusive term for all chemical gas conversion options

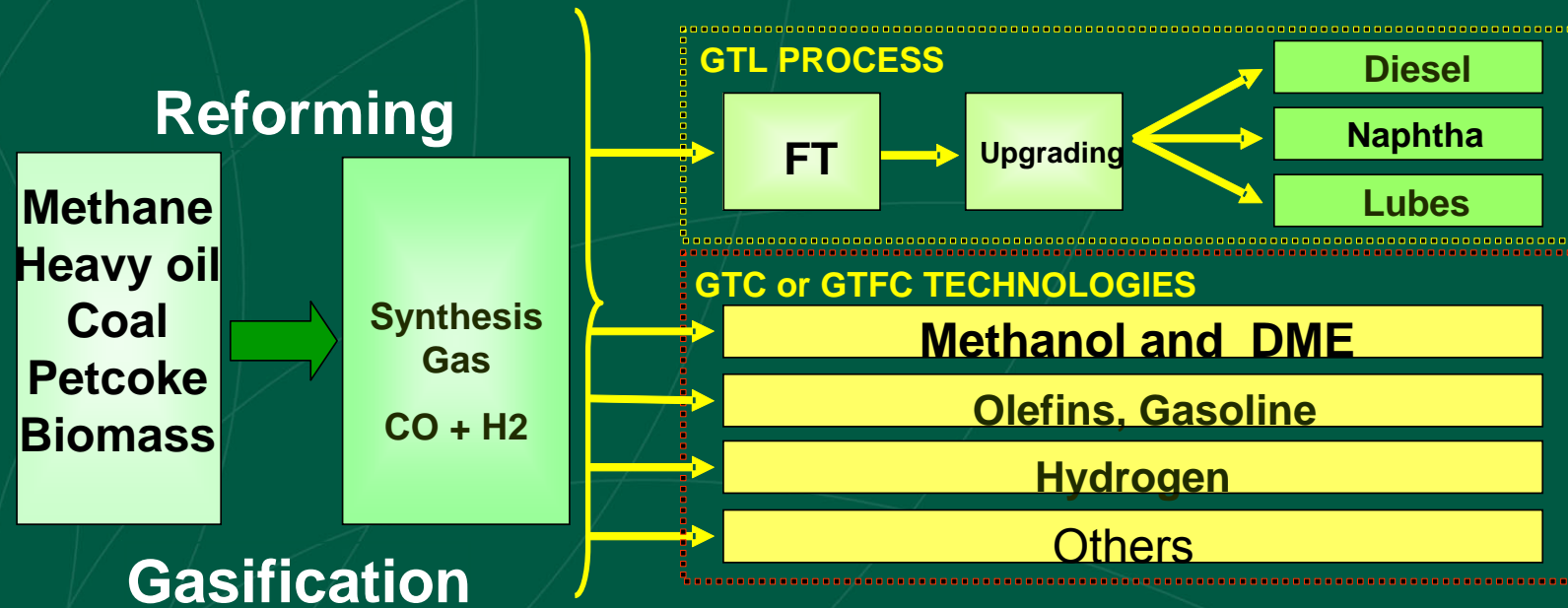


**GTL: Gas to Liquids (FT- Fischer Tropsch)**

**GTC: Gas to Chemicals**

**GTFC: Gas to Fuels and Chemicals**

# Industry moves from GTP to "XTP"



BP: XTP focus

Today's GTP business: ~20 bcf/d (7%) of world gas

Natural Gas



CO and H<sub>2</sub>  
"Syngas"



**HYDROGEN**



Ammonia/Fertilizer  
Refineries

Ammonia: 12 bcf/d  
Refineries: 6 bcf/d



**METHANOL**

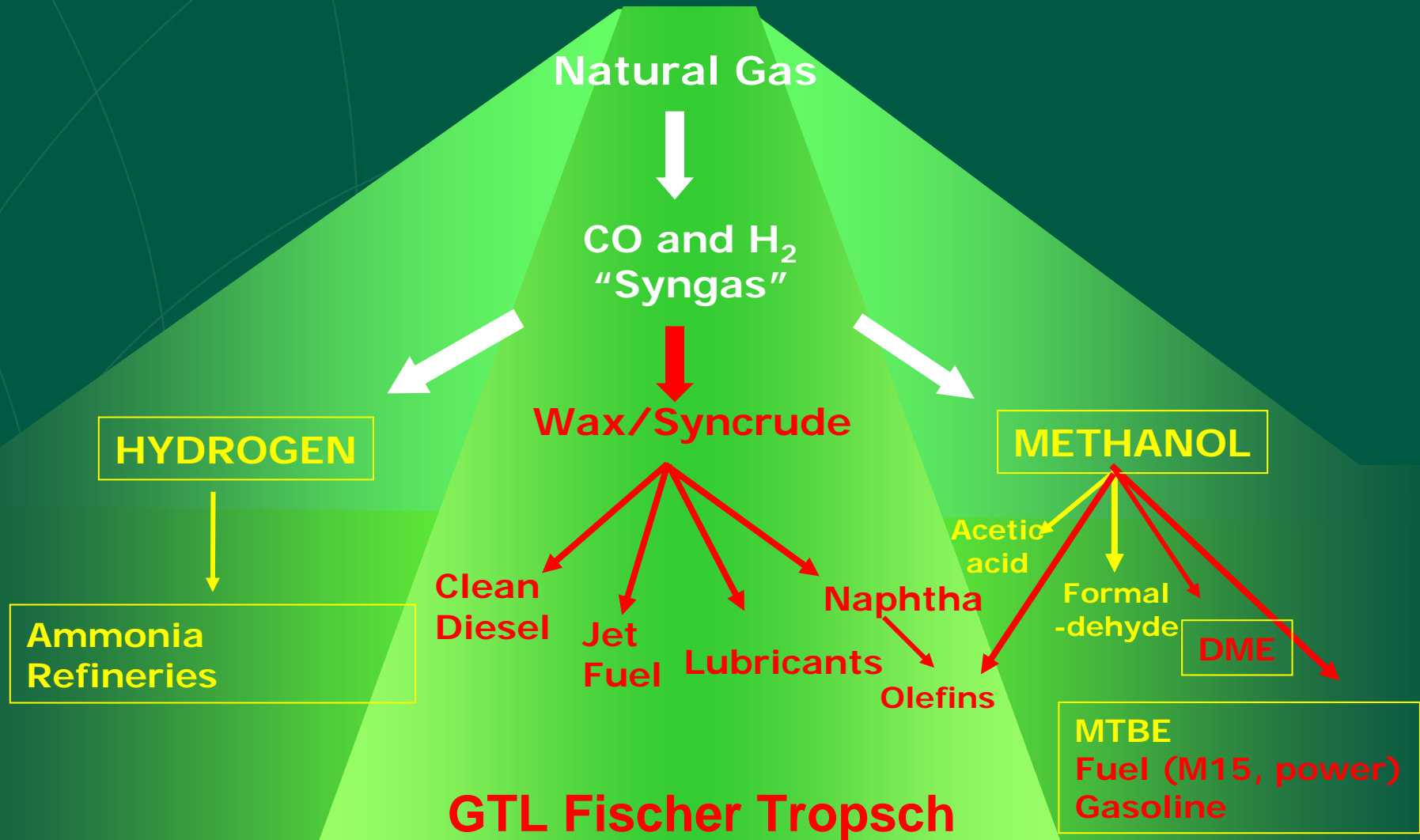
Acetic  
acid

Formaldehyde

MTBE

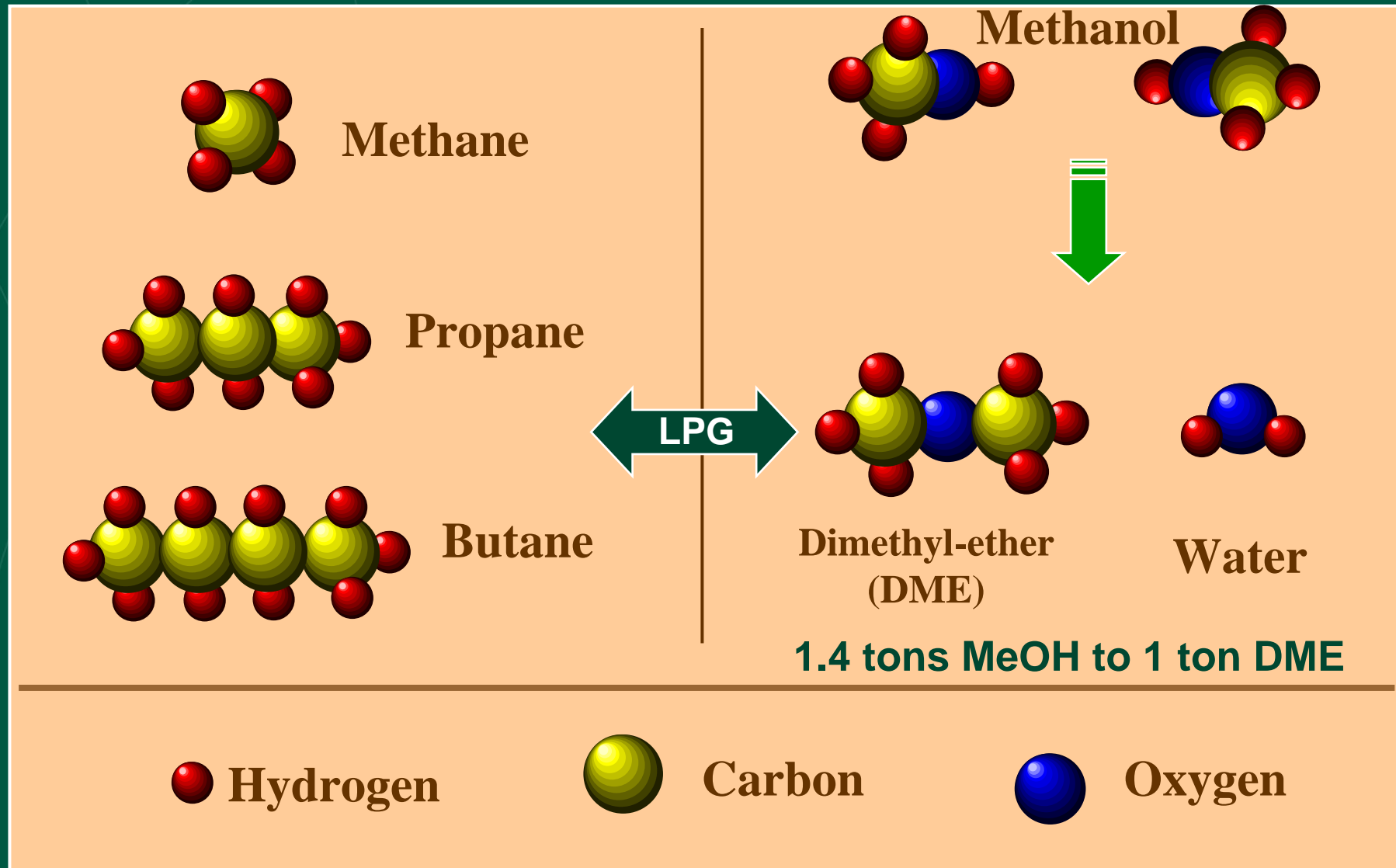
Methanol: 3 bcf/d

Tomorrow's GTP business: >40bcfd (2020 estimate)



Shift from chemicals to designer fuels

# What is DME? “Synthetic LPG”



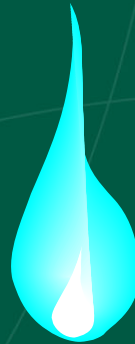
# Major DME Markets

CFC Replacement



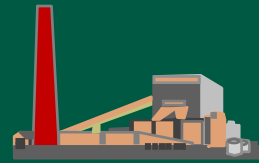
INTENTIONAL MISUSE BY DELIBERATELY  
AEROSOL PRODUCTS CAN BE HARMFUL OR  
SPARK OR WHILE SMOKING.  
INGREDIENT: Miconazole nitrate (to d  
E INGREDIENTS: Dimethyl Ether,  
od, Menthol, Polysorbate 60,  
ate 65, SD Alcohol 40-B, Sodium  
e Sorbitan Stearate, Water.  
room temperature. See container  
for lot number and expiration date.

Today



2

Ready



Power Generation

1

Commercial



LPG Alternative

3

Demonstration  
Ready 2010



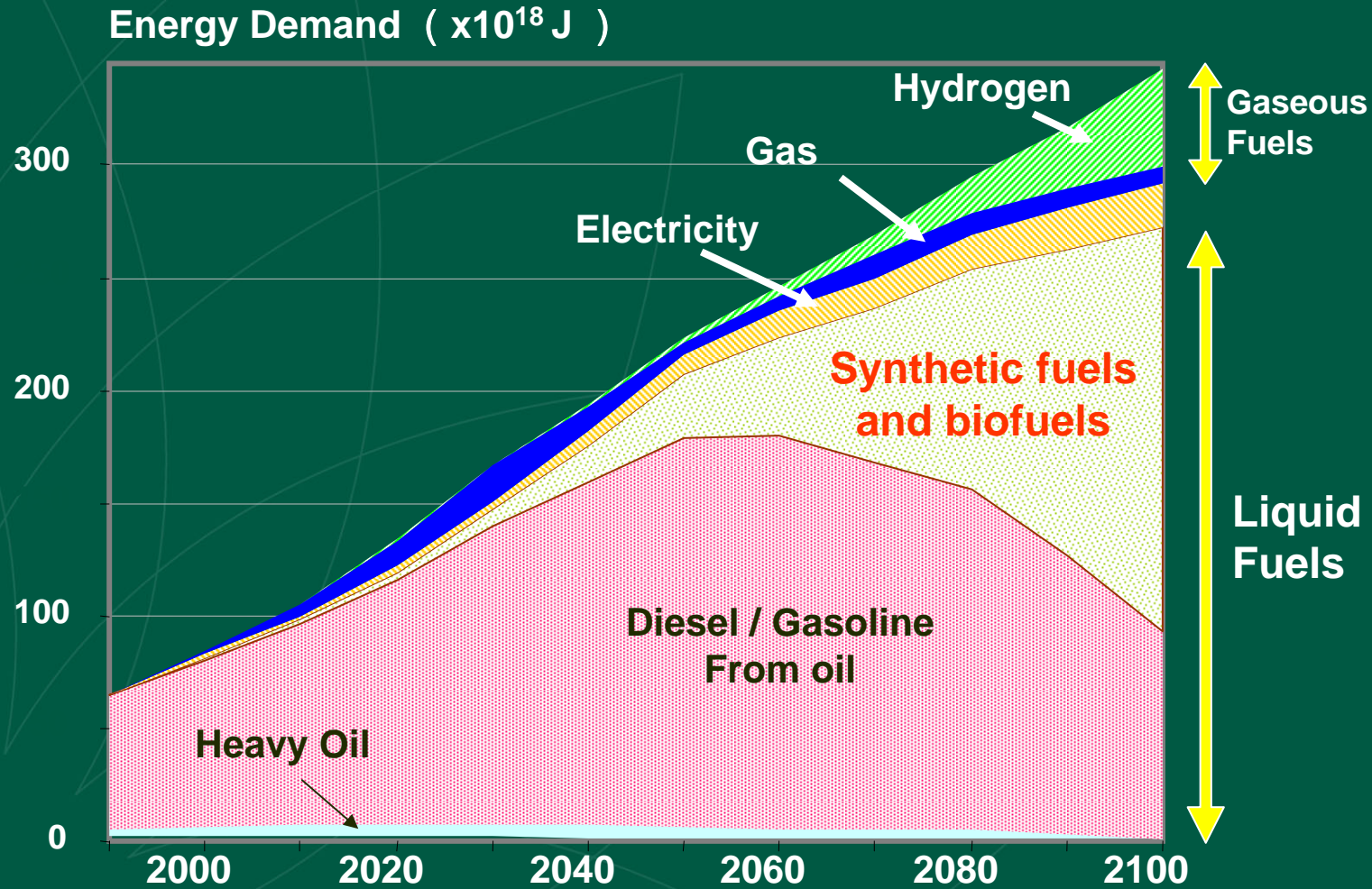
Clean Diesel Fuel

Future is  
now

## XTP offers large markets

Target Products	Product market size MMTPA
<b><i>Benchmark: LNG</i></b>	<b>140 (actual)</b>
<b>Crude Oil</b>	<b>3800</b>
<b>GTL-FT Diesel</b>	<b>1100</b>
<b>Methanol, chemical</b>	<b>34</b>
<b>Methanol as/to gasoline</b>	<b>900</b>
<b>Methanol to LPG (DME)</b>	<b>215</b>
<b>Methanol to Olefins</b>	<b>140</b>
<b>DME (power, diesel)</b>	<b>200</b>
<b>Ammonia</b>	<b>130</b>

# Automotive Fuel Demand Scenario



Source: IEA

## The dangers of technical prediction

- **Radio has no future. Heavier-than-air flying machines are impossible. X-rays will prove to be a hoax** - William Thomson, Lord Kelvin, 1899
- **There is not the slightest indication that nuclear energy will ever be obtainable. It would mean that the atom would have to be shattered at will** -- *Albert Einstein, 1932*
- **There is no reason anyone would want a computer in their home** - Ken Olson, president of Digital Equipment Corp. 1977
- **Drill for oil? You mean drill into the ground to try and find oil? You're crazy.** - Drillers who Edwin L. Drake tried to enlist in 1859
- **Nuclear-powered vacuum cleaners will probably be a reality in 10 years** - Alex Lewyt, president of vacuum cleaner company Lewyt Corp., 1955

## Role of GTP in host countries

- Gas resource holder increasingly value GTP
  - Qatar: “GTL Capital of the World”
  - Trinidad: “GTP Capital of the World”
  - Algeria: Tinrhert GTL bid
- Key advantages
  - Diversity of products and markets
  - Acceleration of gas monetization
  - Higher in country investments
  - Industrialization of country

# Pros and cons of GTP

## PROS

- Deep liquid markets
- Host country appeal
- Premium “designer” products
- Robust economics
- Proven technologies
- Scaleability

## CONS

- Capital intensive
- Scale-up risks
- Poor efficiencies
- Aversion to new products

## Comparison GTL and Methanol/DME

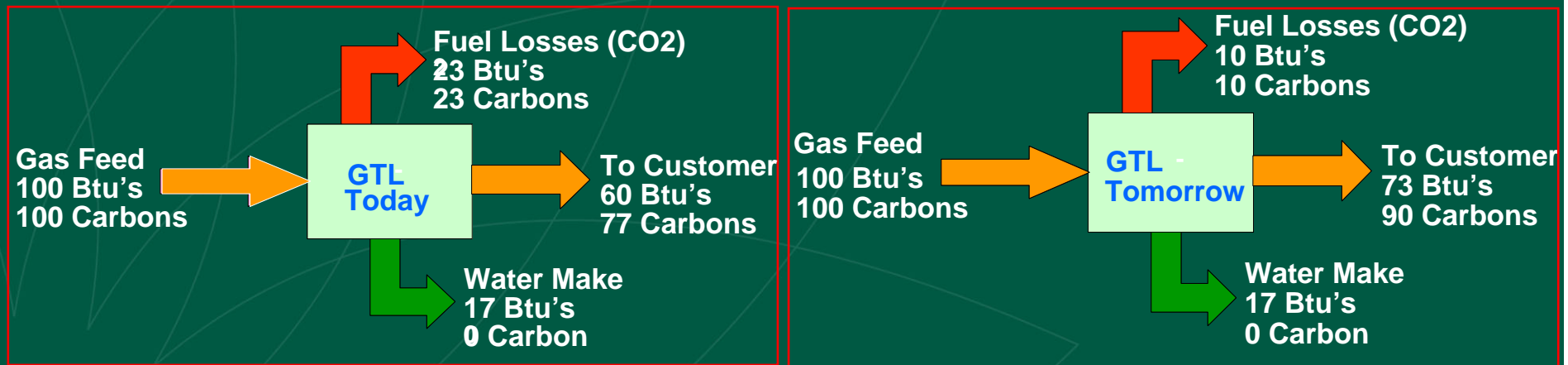
	<b>GTL-FT</b>	<b>Methanol/DME</b>
<b>Technology</b>	To be proven	<b>Global Choice</b>
<b>Process steps</b>	3	2
<b>Thermal/carbon efficiency</b>	60/77	70/82
<b>Fuel markets</b>	Traditional	New

# GTL Emissions and Efficiencies

GTL PROCESS: 1. Inherent energy loss through water make



2. Process fuel energy losses (CO<sub>2</sub> make)



Energy Efficiency: 60%

Carbon Efficiency: 77%

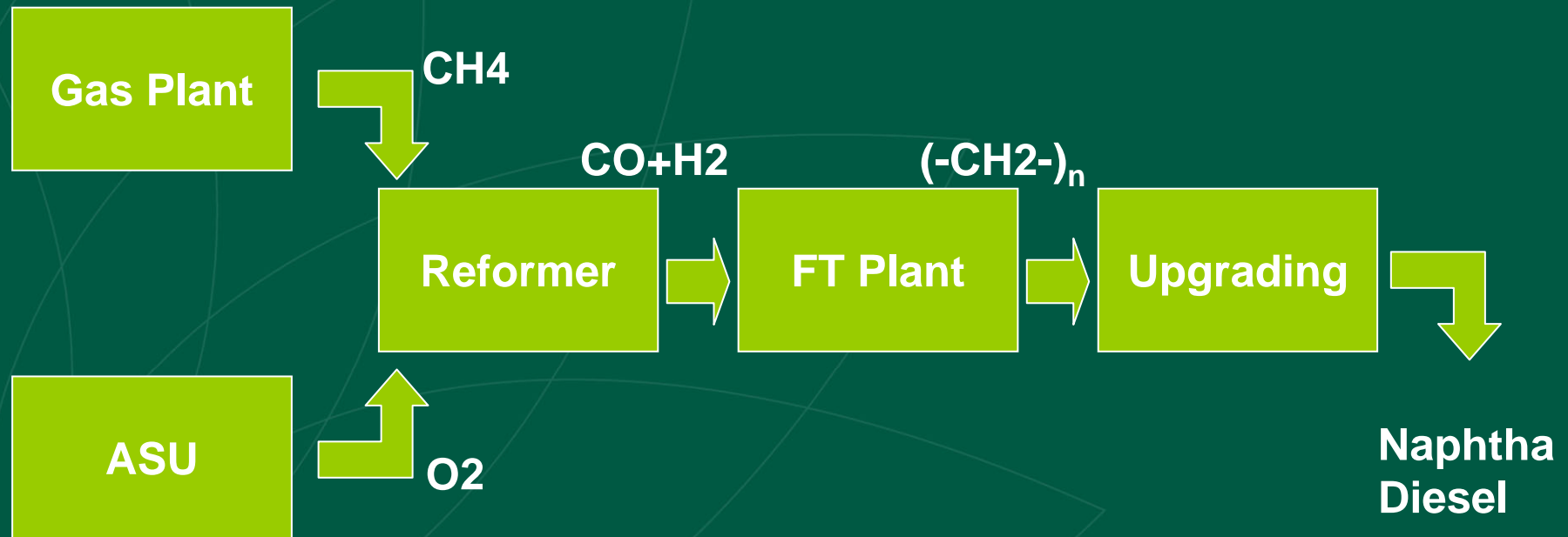
73%

90%

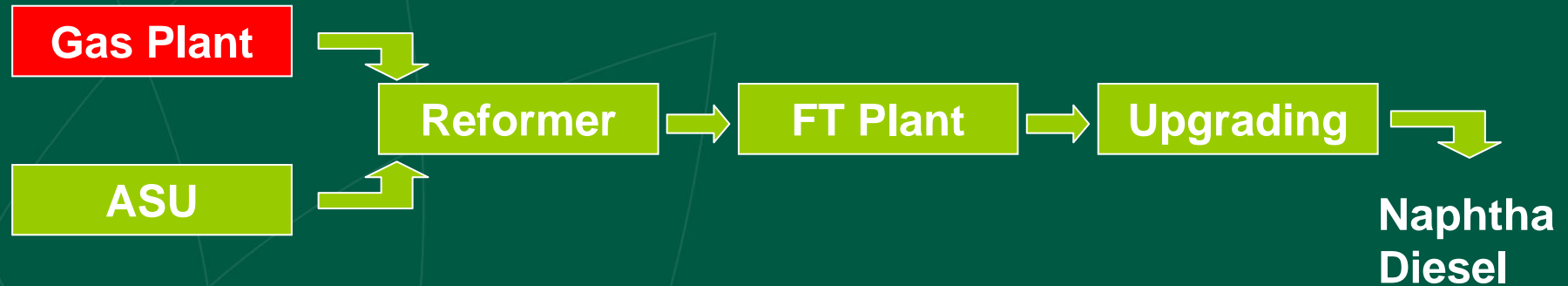
# Outline

- Syngas: Business case
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  - Products and markets
  - Pro's and con's
  - **Technologies**
  - Global projects
  - Economic viability
- The future of XTP

# GTL technology challenges

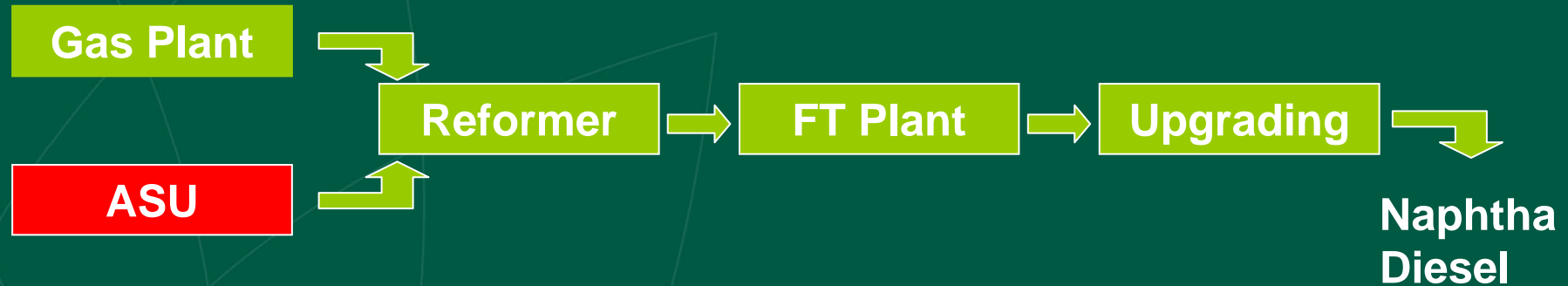


## Gas Plant challenges



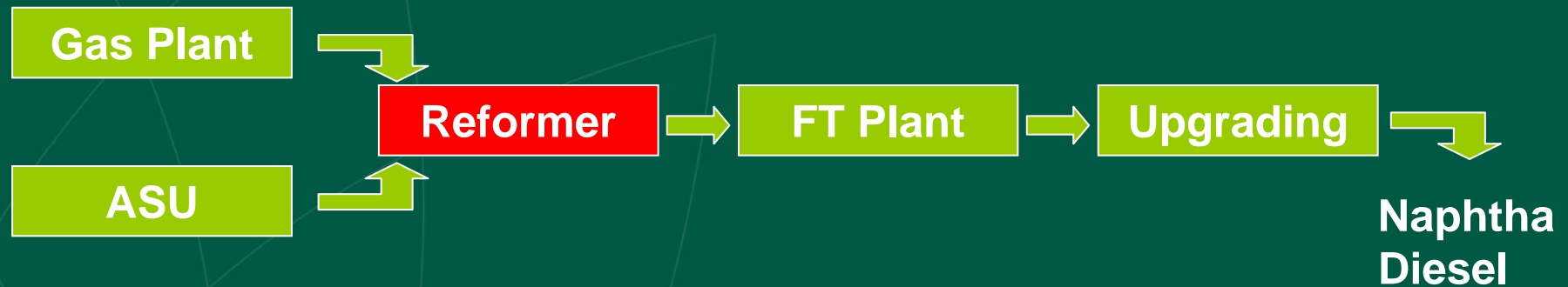
- Conventional, proven technologies
- Multiple vendors
- Technologies:
  - Separation (liquids, LPG, C2);
    - C2+ in feed: pre-reformer required
  - Dehydration
  - H<sub>2</sub>S: must be removed
  - CO<sub>2</sub>: inert in FT, a reactant in methanol synthesis

## ASU challenges



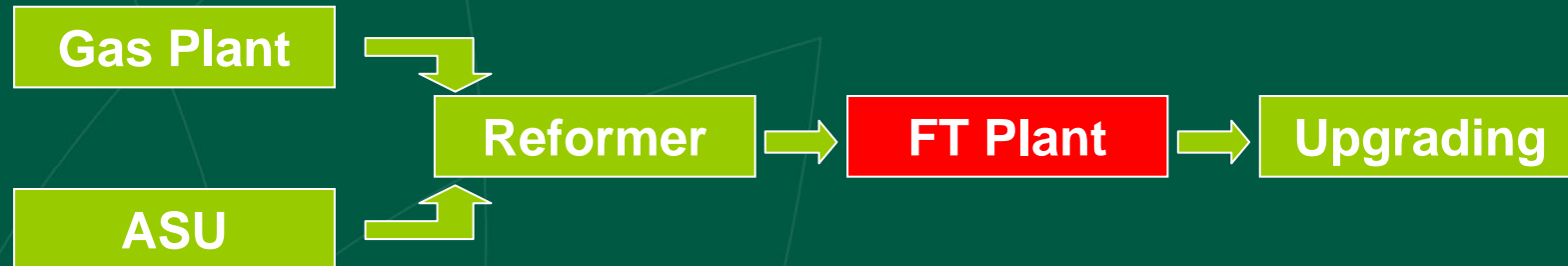
- Multiple vendors (APCI, Air Liquide, Linde)
- Rapid increase in size: 5000 tpd offered
- Oryx: 2 x 3500 tpd corresponding to 2 x 17,500 bpd GTL-FT
- Preferred business model: vendor owned/operated – O2 sales
- Synergies: N2 for EOR, noble gases
- High reliability, low technical risk
- Offshore application: safety concern; steam reforming preferred (CR?)

## Reformer challenges



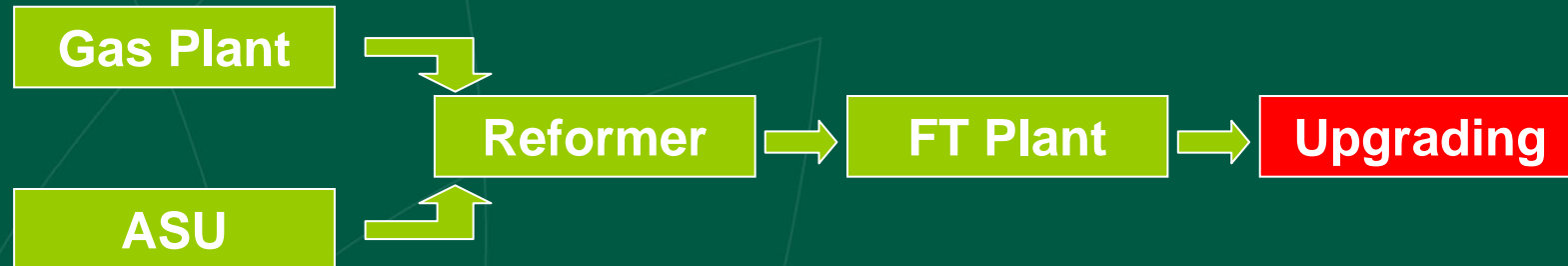
- Multiple technologies available (SMR, ATR, Comb. Ref, POX)
- Expensive, inefficient process: ~1000C, 40bar;
- H<sub>2</sub>/CO (CO<sub>2</sub>) ratio management: syngas processing
- Leading vendors: HTAS, Lurgi, DPT
- Atlas Methanol: largest reformer in the world (Comb. Ref);

## FT plant challenges



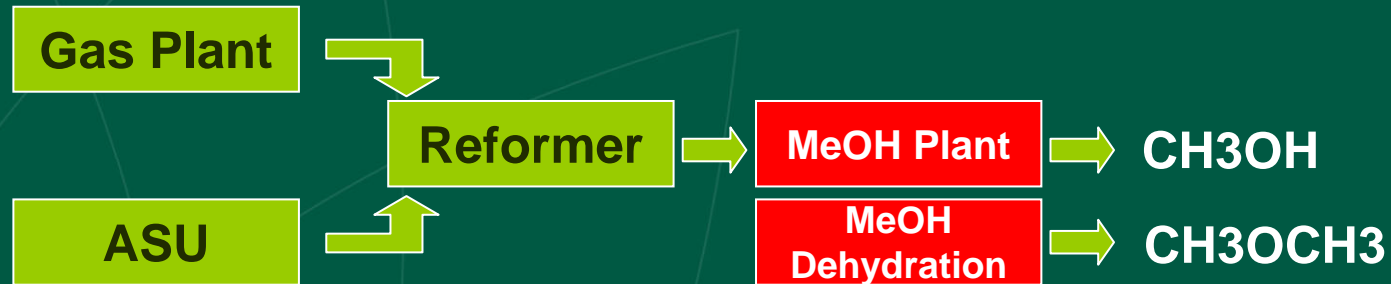
- 11 technologies under development: lots of patents!! Mostly Co catalysis.
- Available through licensing: BP, Syntroleum, Axens/IFP/ENI
- Large reactors: >10m diameter; slurry technology: ~20,000bpd capacity
- Mild conditions: ~250C, ~20bar
- Challenge: heat management!
- Wax/catalyst separation
- Challenge for high “alpha” (minimize C1 make)
- Catalyst life, regeneration, cost

## Upgrading challenges



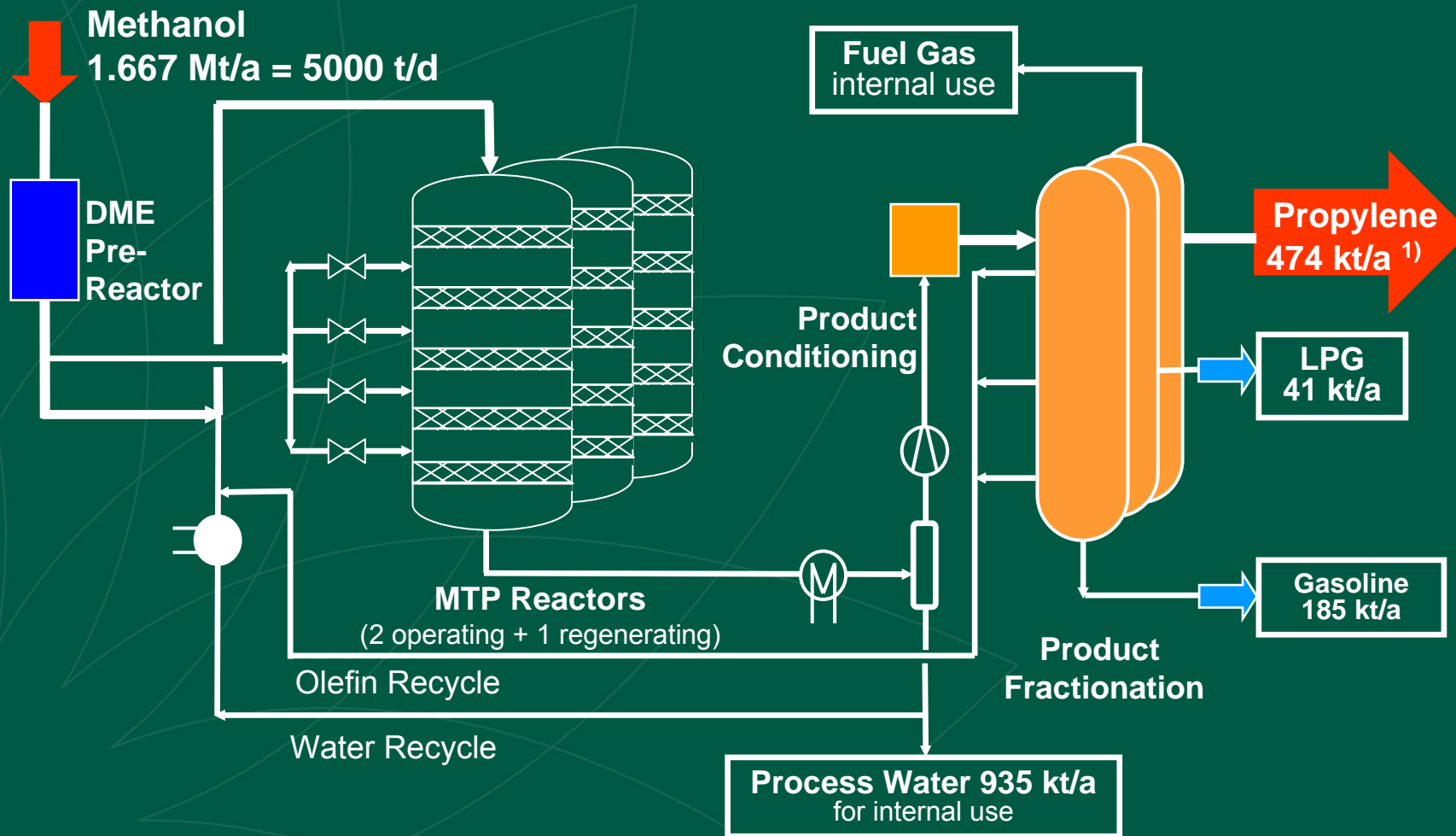
- Conventional refinery technologies: hydrocracking (H<sub>2</sub> required)
- Vendors: UOP, Syntroleum, Chevron,...
- Product mix: naphtha, diesel (jet, kerosene options)
- Option: high quality lubestocks (Shell, ExxonMobil)
- Proven, very low risk technologies

## MeOH/DME plant challenges



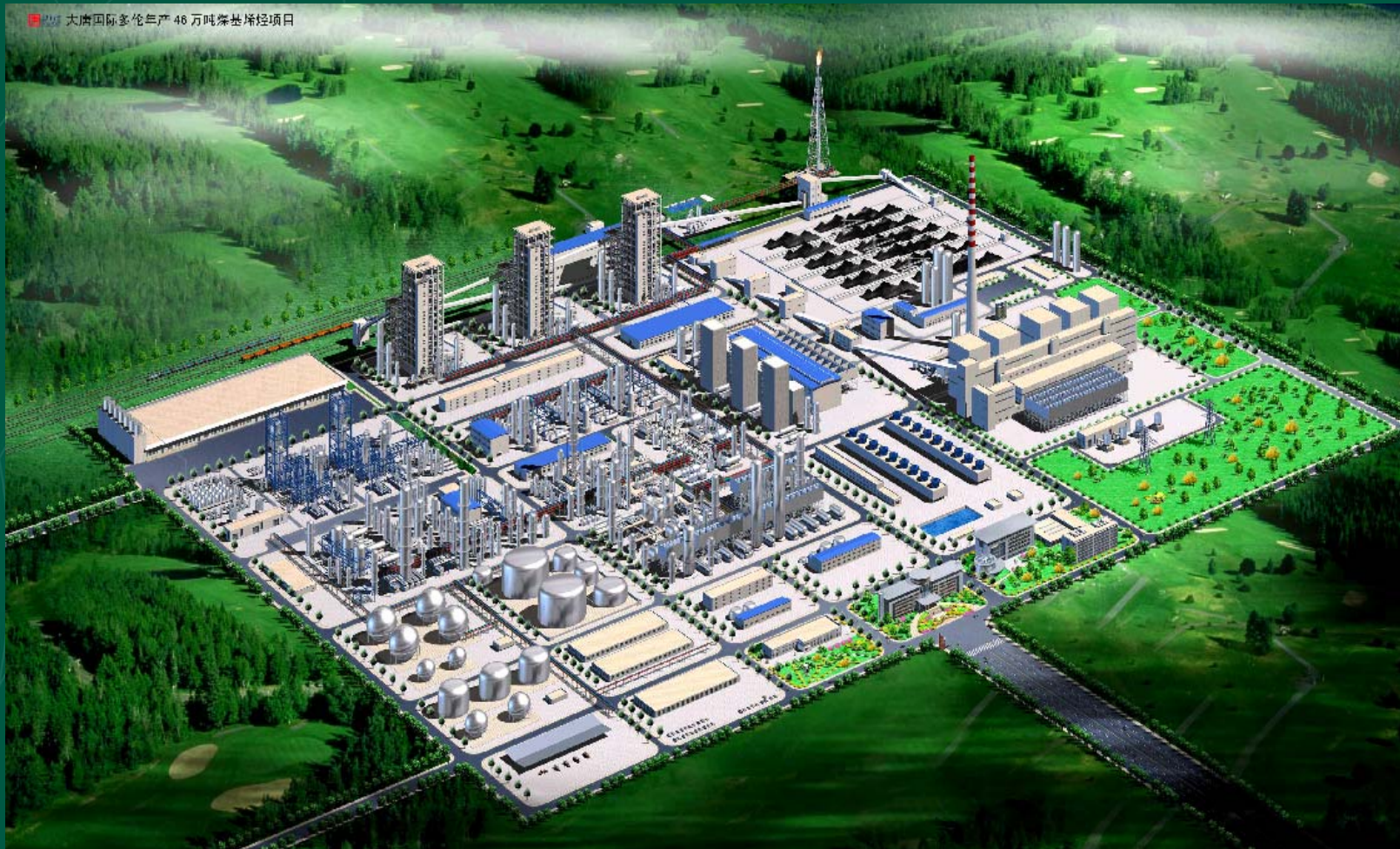
- Multiple proven technologies
- Vendors: Lurgi, DPT, HTAS, Toyo, Kvaerner, JFE, ...
- Direct versus indirect DME synthesis: different degrees of integration
- DME synthesis simple and cheap; integrated plants same costs
- Smaller plant sizes: ~5000tpd capacity corresponds to ~ 15,000bpd FT equivalent)
- However: ~>5000tpd, low cost feedstock and economic fuel
- New MeOH/DME conversion reaction: MTO (UOP, XOM), MTP (Lurgi)

# Lurgi MTP<sup>®</sup>: Simplified Process Flow Diagram



1) Propylene Purity 99.6 wt. %

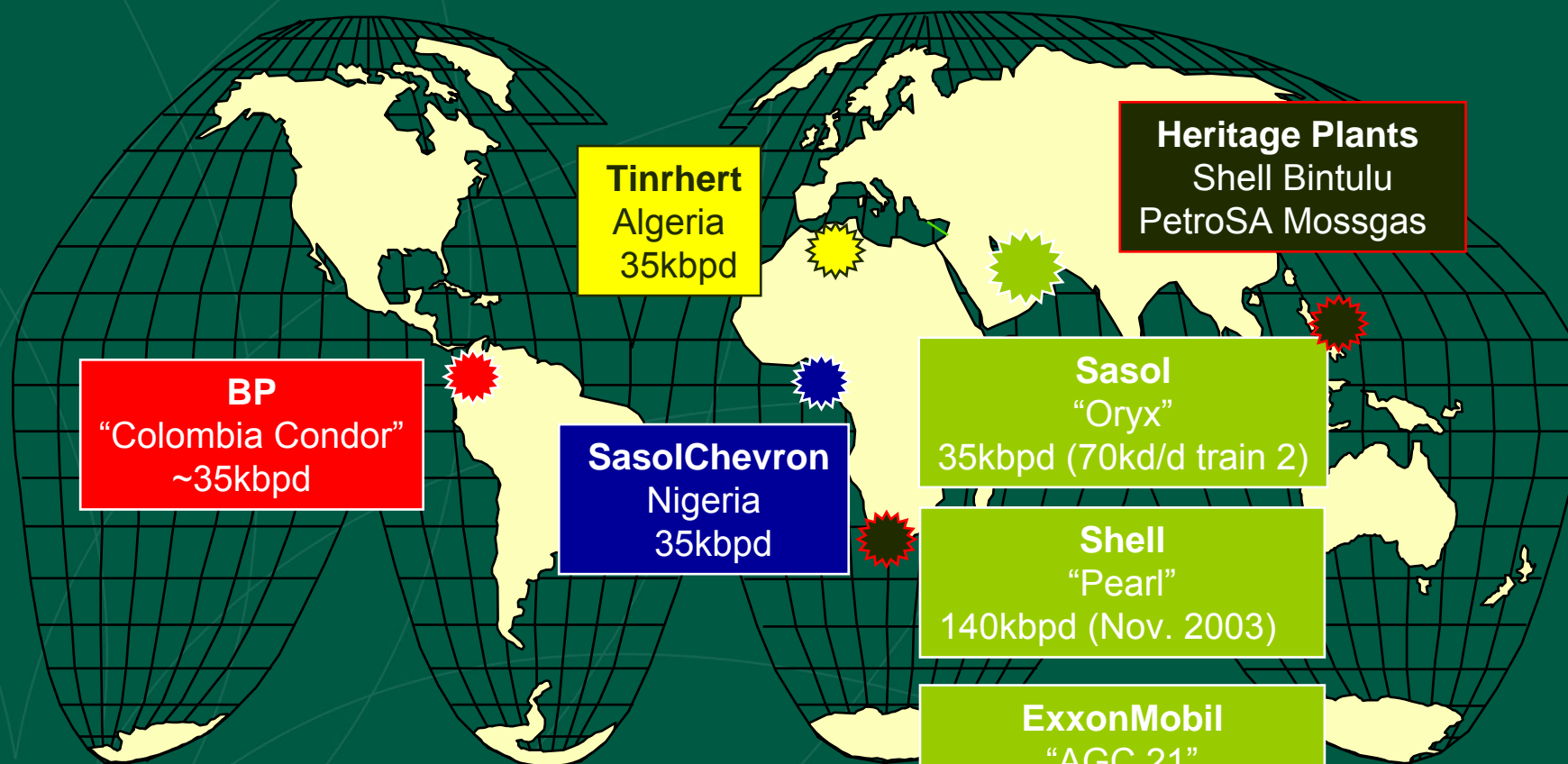
# Lurgi MTP in China



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# The birth of the GTL business: Qatar “World Capital”



**BP**  
"Colombia Condor"  
~35kbpd

**Tinrhert**  
Algeria  
35kbpd

**SasolChevron**  
Nigeria  
35kbpd

**Sasol**  
"Oryx"  
35kbpd (70kd/d train 2)

**Shell**  
"Pearl"  
140kbpd (Nov. 2003)

**ExxonMobil**  
"AGC 21"  
160kbpd (July, 2004)

**ConocoPhillips**  
**SasolChevron**  
**Marathon/Syntroleum**  
**POSTPONED**

**Heritage Plants**  
Shell Bintulu  
PetroSA Mossgas

# Oryx Plant Inaugurated June 6<sup>th</sup> 2006

“As we stand here today to celebrate the inauguration of Oryx GTL, we are changing the world’s energy paradigm with gas-to-liquids (GTL) technology.”

- His Excellency Abdullah Bin Hamad Al-Attiyah, Second Deputy Premier, Minister of Energy and Industry, Qatar, and Qatar Petroleum chairman.



## Plant Statistics

34,000 bpd capacity

- 24,000 bpd Diesel
- 9,000 bpd Naphtha
- 1,000 bpd LPG

Construction Start – Dec 2003

Project Completion – June 2006

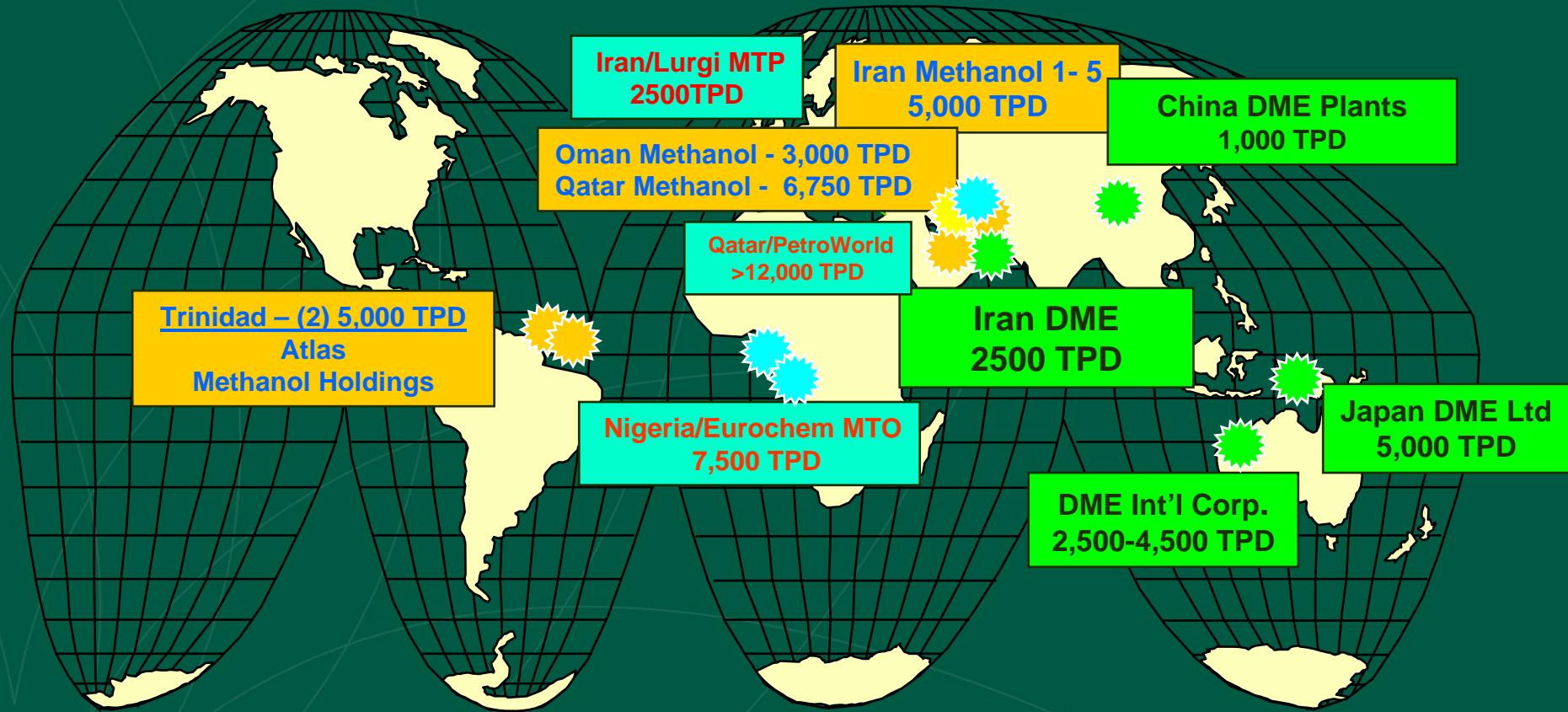
Believed to have cost \$1.5Billion

## Commissioning Progress

Syngas plant operational

Superheater problem

# Large Methanol/MTO/DME plants (built, proposed)



- Methanol
- Methanol for Power/Olefins
- DME

Memo: Not including <5,000 MTPD methanol plants

Atlas Methanol Plant (5000tpd = 15,000bpd GTL)  
Methanex, BP, Lurgi



**Atlas Methanol, Point Lisas Industrial Park, Trinidad**

# DME in China

Year	Thousands MT/yr
2004	40
2005	155
2006	275
2007	935
2008	1555
2009	4155
2010	8355

Shandong Jiutai Chemical industry  
 1 million T/y - 2009  
 Xinao Group  
 400,000 T/y - under construction  
 Mengda Group  
 1 million T/y - under planning  
 Luthianhua Group  
 200,000 T/y - under planning  
 China Nat. Coal/Sinopec  
 3,000,000 T/y - 2010  
 Yigao Chemical Co  
 20,000 T/yr - Aug 2006 wet commiss.

**Shanxi Lanhua Sci-Tech**  
 100,000 T/y - under construction, 2007 (Jincheng)  
**Lanhu Group**  
 1,000,000 T/Y - under planning

**Shandong Jiutai Chemical Industry**  
 30,000 T/yr - 2003  
 100,000 T/yr - 2005

**Shenhua Ningxia Coal Industry Group**  
 210,000 T/y - 2007  
 To 830,000 T/y - 2008

**Luthianhua Group Inc, Sichuan**  
 10,000 T/y - 2003  
 110,000 T/y - 2006

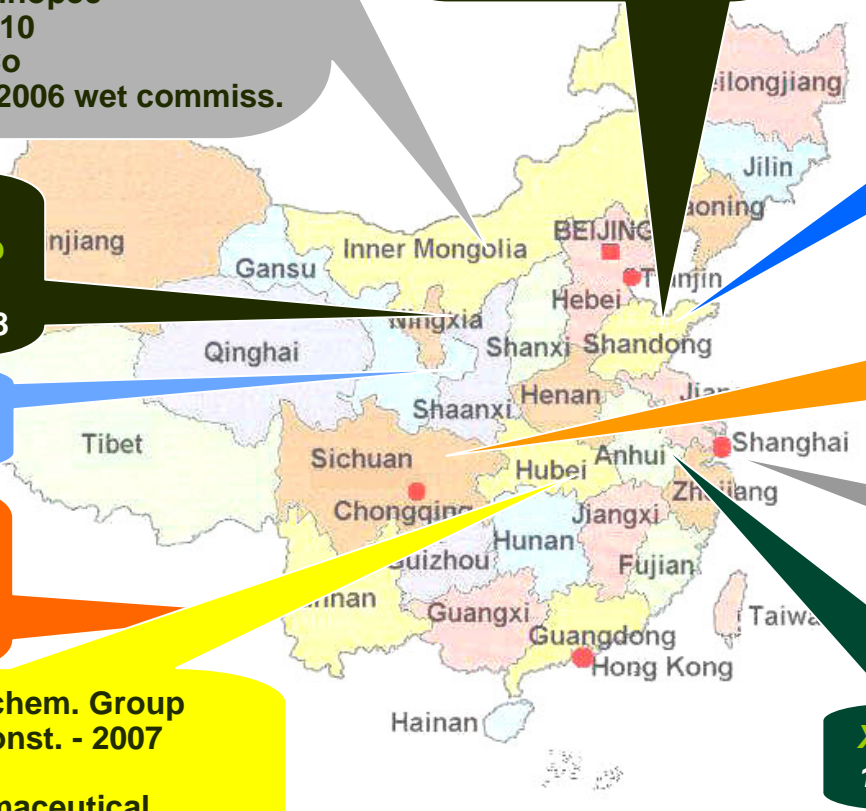
**Yankuang Group**  
 200,000 T/y - 2009

**Yuannan Jiehua Chem. Group**  
 150,000 T/y - 2007  
 Under construction

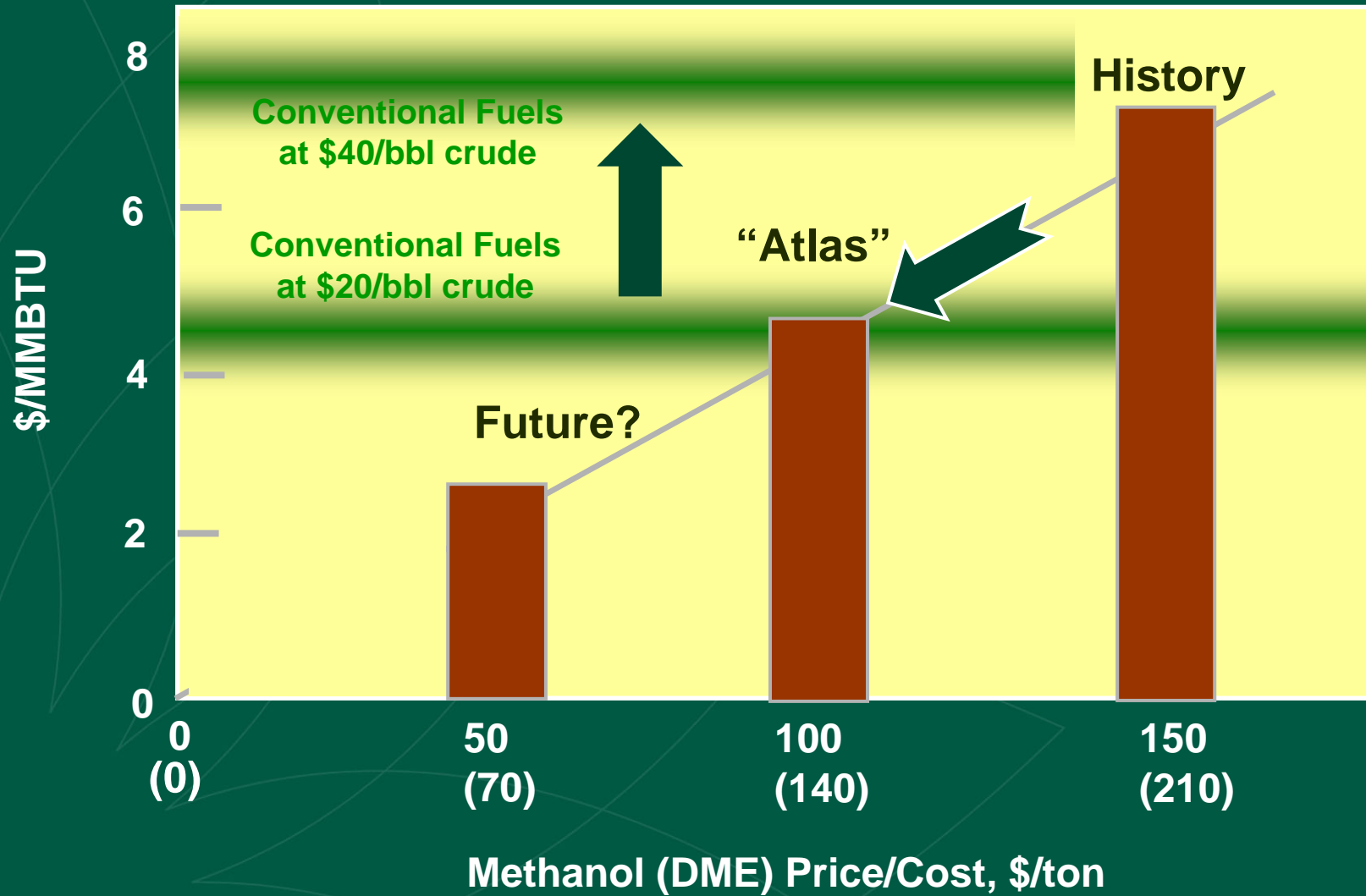
**Shanghai Coking/Huayi Company**  
 5000 T/y - Apr. 2006

**Hubei Zhongjie Petrochem. Group**  
 100,000 T/y - under const. - 2007  
  
**Hubei Biocause Pharmaceutical**  
 100,000 T/y - under planning - 2007

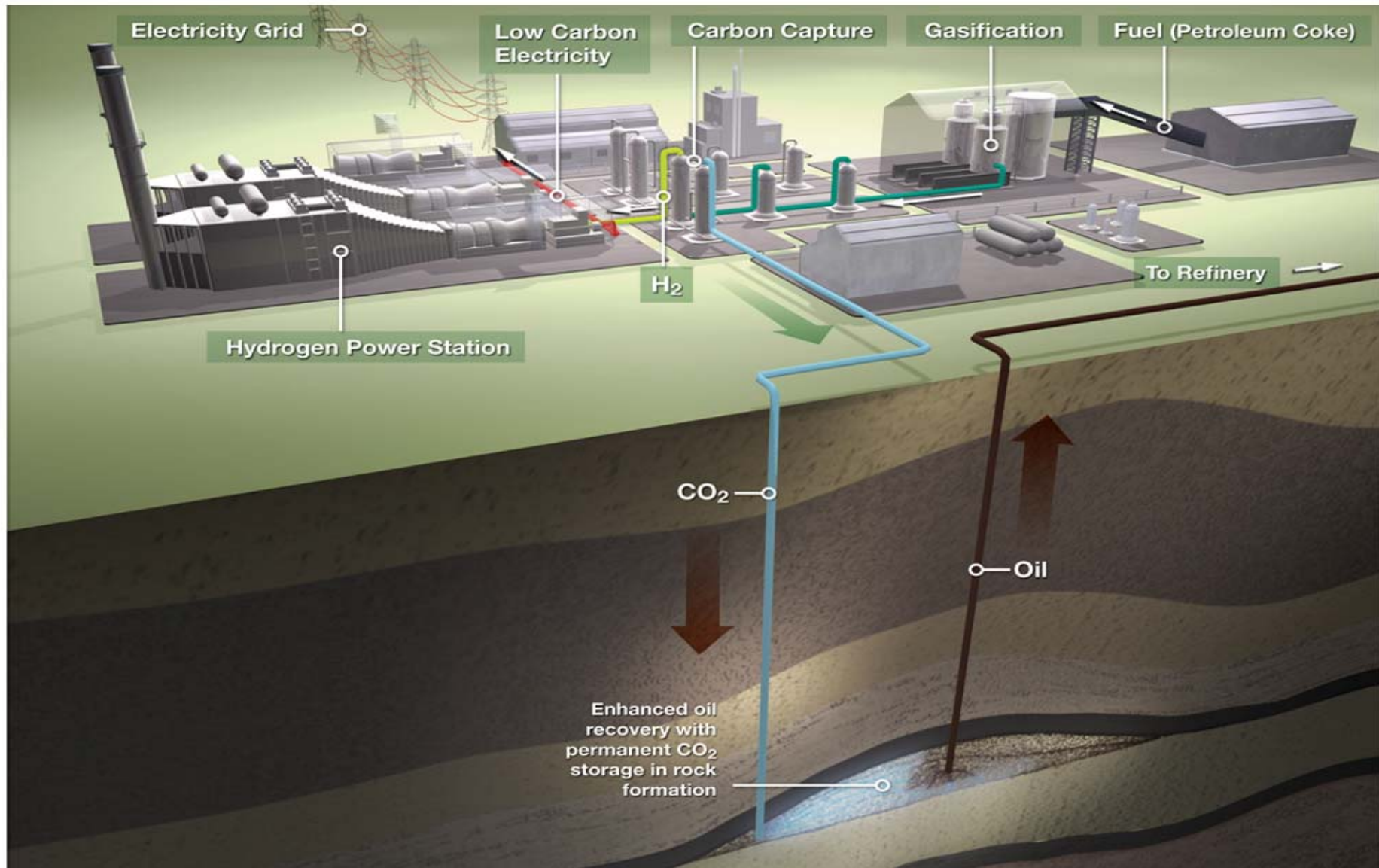
**Xinao Group**  
 10,000 T/y - Jan. 2006



# Methanol and DME Competitiveness in fuel markets



# Hydrogen power projects



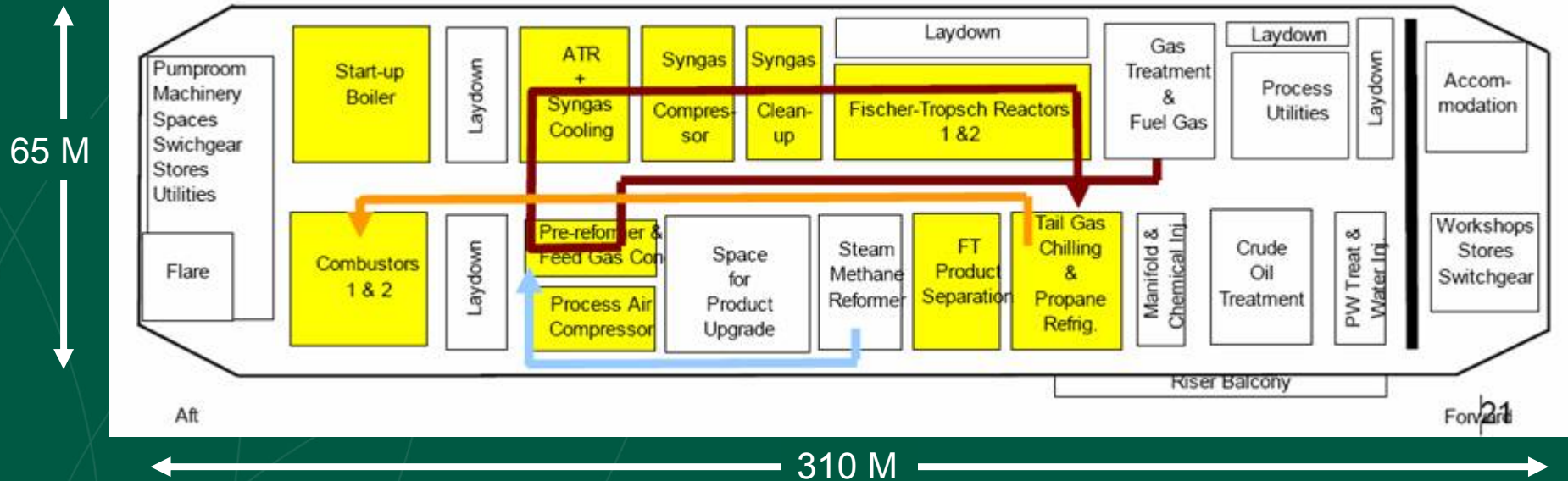
## GTP Economics

- Benchmark LNG: GTL reached parity with LNG in ~ 2000
  - Robust economics at \$20 crude (2000)
  - Fantastic economics at higher crude prices!? (yes, since GTL product prices are directly linked to it)
  - However, EPC cost increases: \$70k/bbl (1980) to \$25k/bbl (2000) to \$50k/bbl and beyond (2006)
- Methanol and DME can be delivered at \$4-6/MMBTU and become viable as fuel above \$25 crude oil
  - DME is commercial reality in China
  - MTP, MTO projects underway (new low cost technology)

## Developments in GTP

- Scalability: from big (Qatar) to small (Trinidad)
- Floating applications
- Flare busters (microchannel technologies)
- Reduced Capex through R&D and value engineering
- Gas refinery
  - Integration of different plants
  - Further conversion of primary products into consumer products
  - Integration of LNG and power

# Technology Benchmark: Syntroleum FPSO



16,300 bpd GTL  
 150 mm-scf/d Gas  
 \$1.2b EPC  
 20,150 M<sup>2</sup>

## BP GTP Profile

- World class R&D group (~60 people)
- Relationship with Berkeley, Caltech, DICP (~60)
- Broad GTP product portfolio
- Mini-reactors, pilot plants, demonstration plant
- World scale methanol plant (with Methanex)
- World class partners
- Portfolio of project options
- Decarbonized fuel projects
- “Conversion”
  - Center of Excellence in Group Technology



## Conclusion

- **GTP and XTP technologies**
  - Available, mostly mature, economic
  - Need for better technologies
  - Must have for energy companies
- **Syngas is a key intermediate in 21<sup>st</sup> century**
  - Feedstock versatility
  - Premium liquid fuels (conventional and new)
  - Syngas refinery

Thank you! Questions?



# Back-up slides

# Gas by Bag



# Summary

- **GTP technologies offer new MULTIPLE options to monetize gas**
  - LARGE, new markets for gas
  - Mature technologies and proof of technologies
  - Product values tied to crude oil (diesel, LPG, etc)
- **GTP options are welcomed/required by gas resource holders**
  - Product diversification
  - Gas value optimization
  - Country industrialization (more in country investments, jobs)
  - NO MORE STRANDED GAS
  - NO MORE FLARING

## GTP project challenges

- **Size of projects**
  - ~\$1B: Oryx GTL in Qatar
  - ~\$0.5B Atlas methanol in Trinidad
  - ~\$5 – 10B: integrated 150,000bpd projects
- **Marketing**
  - Fuel blends: OEMs and customers
    - FT/diesel; DME/LPG
  - Novel fuel applications: OEM's, customers, HSE, demos!
    - MeOH, DME in gas turbines; DME in diesel engines
  - Distribution and marketing (premiums)
- **Value chain optimization**
  - Sub-surface to ship
  - Loading/unloading; pipeline transport
  - Shipping: larger and dedicated ships

# The Gas Economy

- Natural Gas:
  - Step-child in 20<sup>th</sup> century
  - Dominant fuel of the 21<sup>st</sup> century
- Abundant, inexpensive supplies (especially stranded gas)
- Resource Push
  - Need novel gas transportation options (beyond pipelines/LNG)
  - Need new markets for gas
- Market Pull
  - Increased costs of conventional liquid fuels
  - Need for cleaner, improved liquid fuels
  - Need for low cost chemical feedstocks and improved processes

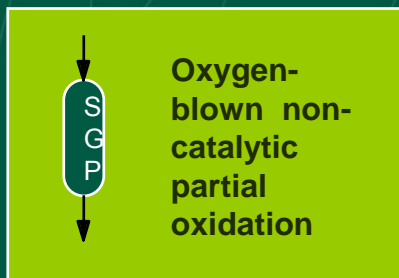


**Need and Opportunity  
for Gas To Products, GTP**

# Overview: syngas production

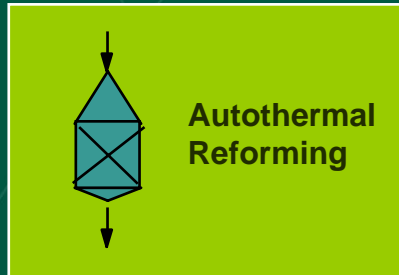


- Dominant technology
- Ni catalysis
- Heated tubes (large multi-tubular reactors)
- H<sub>2</sub>/CO: high

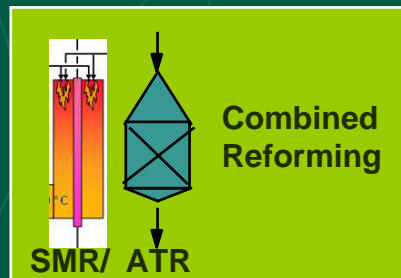


- Not widely used (Shell does)
- High temperature, no catalyst
- H<sub>2</sub>/CO: <2 !

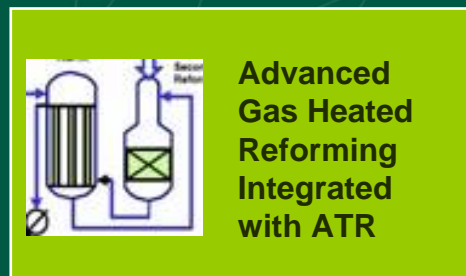
# Overview: syngas generation



- **Autothermal Reforming (ATR)** Part of the natural gas is combusted with oxygen in a sophisticated burner. The hot effluent is reformed over a conventional reforming catalyst with additional natural gas. Advantage: the heat of combustion is used for the endothermic reforming reaction. Simple, ceramic clad reactor.

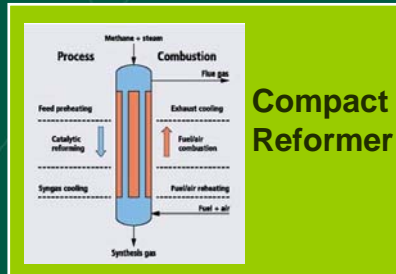


- **Combined or Two-Step Reforming: Steam Methane Reforming + Autothermal Reforming.** Natural gas feed is split into two parts. One part is added to the primary steam methane reformer, and the other part is sent directly to the secondary reformer. The effluent from the primary steam reformer is also sent to the ATR.

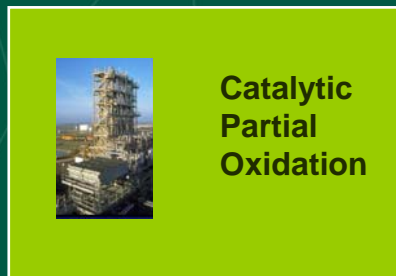


- **Advanced Gas Heated Reformer:** Uses compact heat exchange reformer, with gas and steam feed, followed by a secondary oxygen-blown ATR. The effluent gas from the ATR provides high-grade heat directly back to the heat exchange reformer. Advanced design for heat exchange reformer simplified internal design.

# Glossary – syngas generation



**Compact Reformer**



**Catalytic Partial Oxidation**

- **Compact reforming** represents a novel mechanical design approach to conventional SMR. The reformer design resembles a conventional shell and tube heat exchanger, which is much more “compact” than the conventional SMR furnace design configuration.
- **Catalytic Partial Oxidation (CPOx)**. The hydrocarbon feed stream, oxygen and steam are mixed upstream from the catalytic reactor. All the chemical conversion takes place in the reactor and no burner is used. feature a combined ignition and a reforming noble metal catalyst operating at very low residence time (very high space velocity).

## Remote Gas Monetization Options

**PIPELINE**

**LNG**

**GTL (FT)**

**METHANOL**

**DME**

**CNG**

**HYDRATES**

**GAS TO WIRE**

**GAS BY BAG**

**PUSHING THE LIMITS (\$25B)**

**TECHNOLOGY OF CHOICE TODAY**

**BIRTH OF A NEW INDUSTRY**

**TRANSITION FROM CHEMICAL TO FUEL**

**“SYN-LPG”, ASIAN TIGER AWAKENS**

**A NICHE FOR SMALL & SHORT?**

**MOVING A LOT OF WATER**

**DC TRANSMISSION COST DECREASING**

**A VERY SMALL NICHE**