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My SPE Distinguished Lecture tour

SPE DISTINGUISHED LECTURE

The End of Stranded Gas: The Emergence of the Gas to Products Option

Dr. Theo H Fleisch
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Houston, TX 77079

Outline

- Problem with gas: stranded or associated
- Gas monetization options
- The case for Gas To Products (GTP)
  - What is GTP and GTL?
  - Products and markets
  - Technologies
  - Global projects
  - Economic viability
  - BP's role in GTP
- The future of GTP

Gas resources: plentiful but…

- Gas Reserves (2005) = 6500TCF (185TCM); "under-explored"
- R/P ratio: ~70 years (versus oil at ~35)
- About 40% of gas (2500TCF) is stranded
  - (Russia, Qatar, Australia, Alaska, …)
  - Solution: conversion of gas into transportable liquid
- Associated gas: re-injected or flared

Flaring of associated gas (in red; 15 bcfd?)

Remote and flared gas: an inexpensive feedstock

GTP Value creation:

Feedstock: $0 to 1.50/MMBTU

Products: $10/MMBTU

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

GTP: Transportable, high value products

Greater netback to the feedstock

New markets for gas

Remote Gas Monetization Options

PIPELINE	PUSHING THE LIMITS ($25B)
LNG	TECHNOLOGY OF CHOICE TODAY
GTL (FT, Fischer-Tropsch)	BIRTH OF A NEW INDUSTRY
METHANOL	TRANSITION FROM CHEMICAL TO FUEL
DME	"SYN-LPG", ASIAN TIGER AWAKENS
CNG	A NICHE FOR SMALL & SHORT (EnerSea)
GAS BY WIRE	DC TRANSMISSION COST DECREASING
HYDRATES	MOVING A LOT OF WATER
GAS BY BAG	A VERY SMALL NICHE

Gas by Bag

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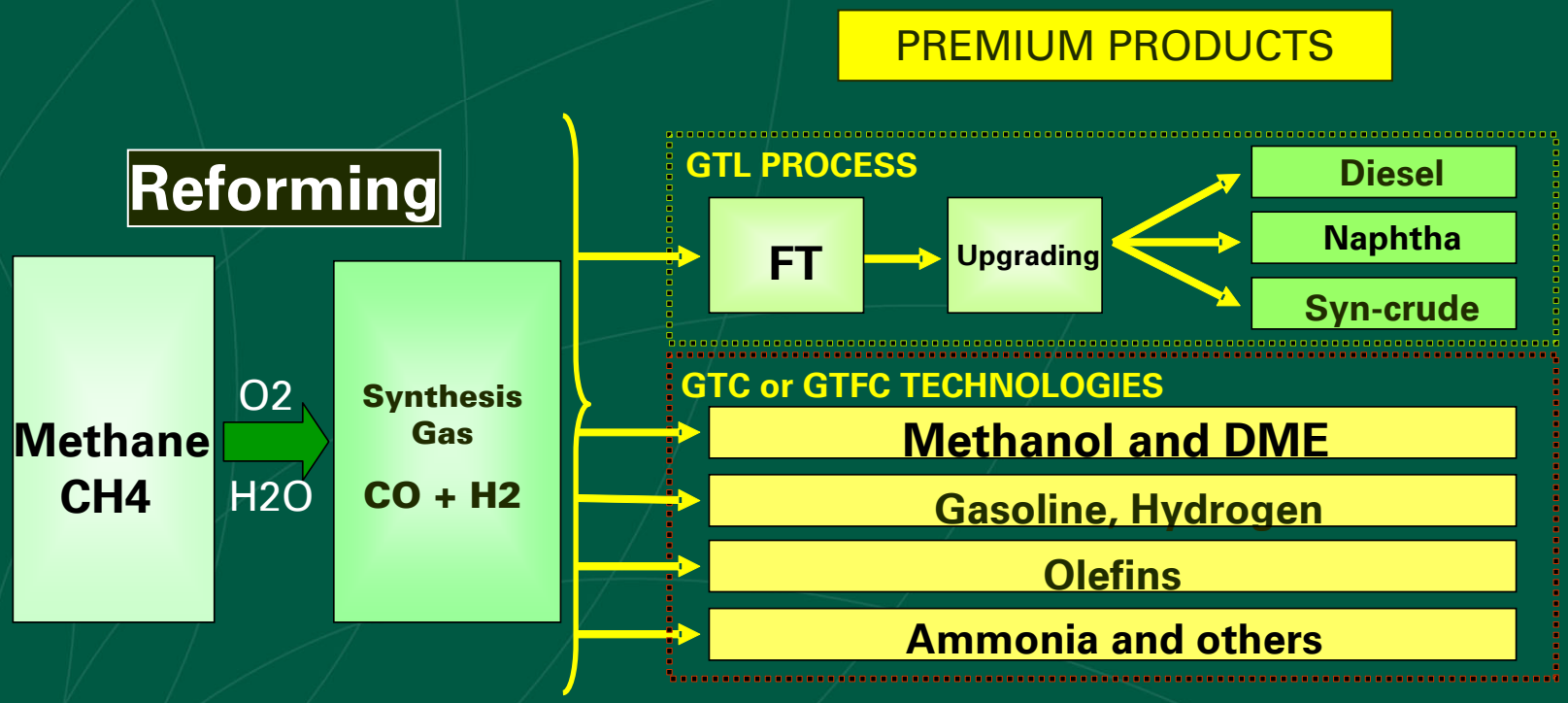
GTP: Inclusive term for all chemical gas conversion options (today: 20 bcf/d)

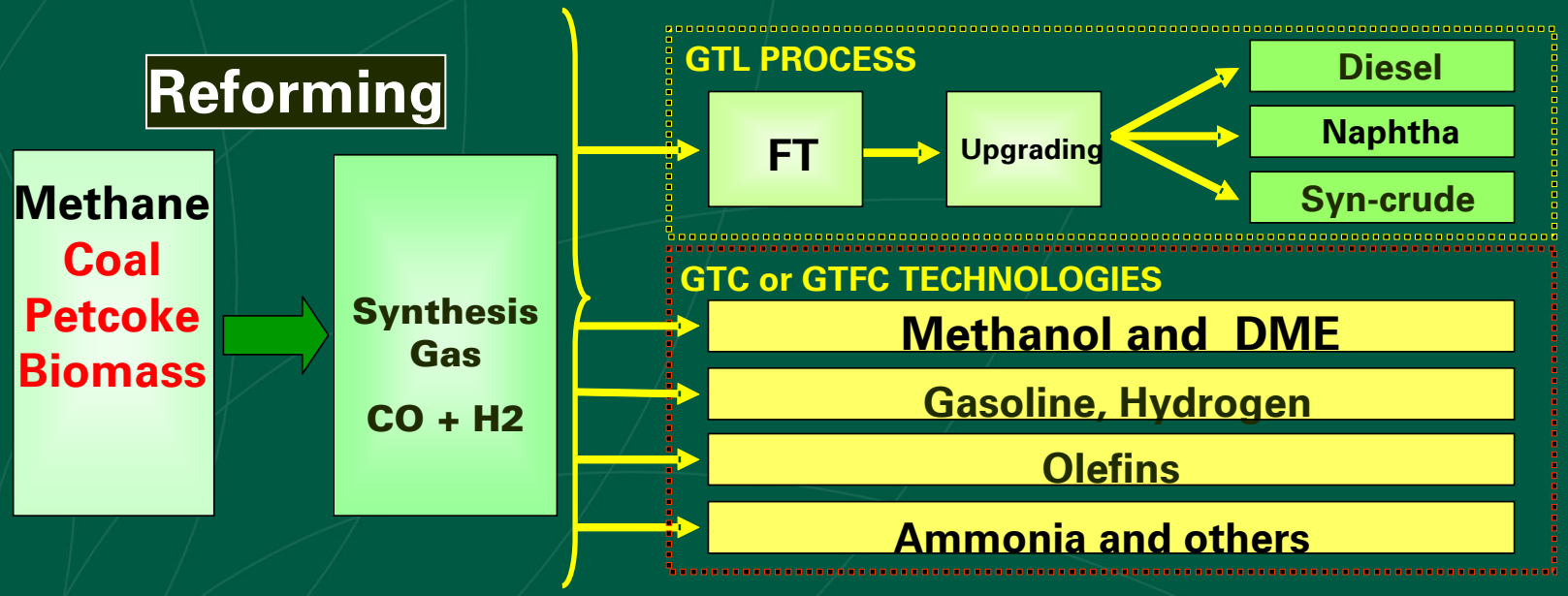


GTL: Gas to Liquids (FT- Fischer Tropsch)

GTC: Gas to Chemicals

GTFC: Gas to Fuels and Chemicals

Industry moves from GTP to "XTP"

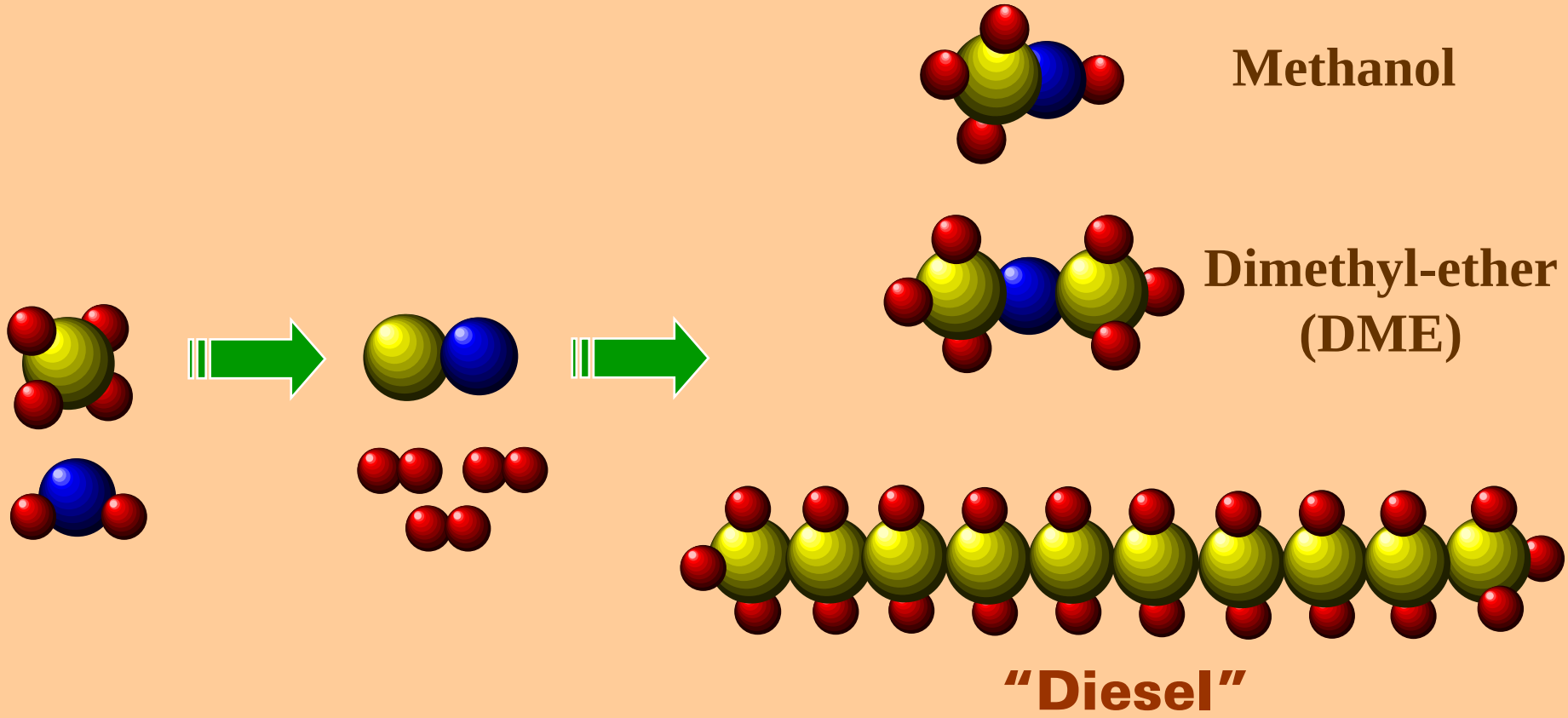


Gasification/UCG
"Clean Coal Technologies"

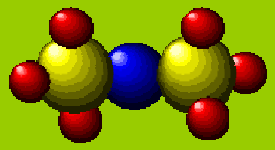
GTP offers large markets for gas

Target Products	Product market size **MMTPA**
Comparison: LNG	***150 (actual size)***
Synthetic "crude"	**3800**
GTL-FT Diesel	**1100**
Methanol, chemical	**34**
Methanol as/to gasoline	**900**
Methanol to DME (LPG)	**215**
Methanol to Olefins	**140**
Power (methanol, hydrogen)	**Very large**
Ammonia	**130**

Some simple conversion chemistry



About DME



- Easily made from methanol
- Physical properties: like LPG
- Clean bill of health
- Multi-purpose fuel
  - LPG extender (commercial)
  - Ultimate Diesel fuel (fleet demos)
  - Power production (CCGT)
  - Other: olefins, hydrogen, gasoline

- International DME Association (IDA)
- www.aboutdme.org

Methanol/DME in China

2020: 60/30

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

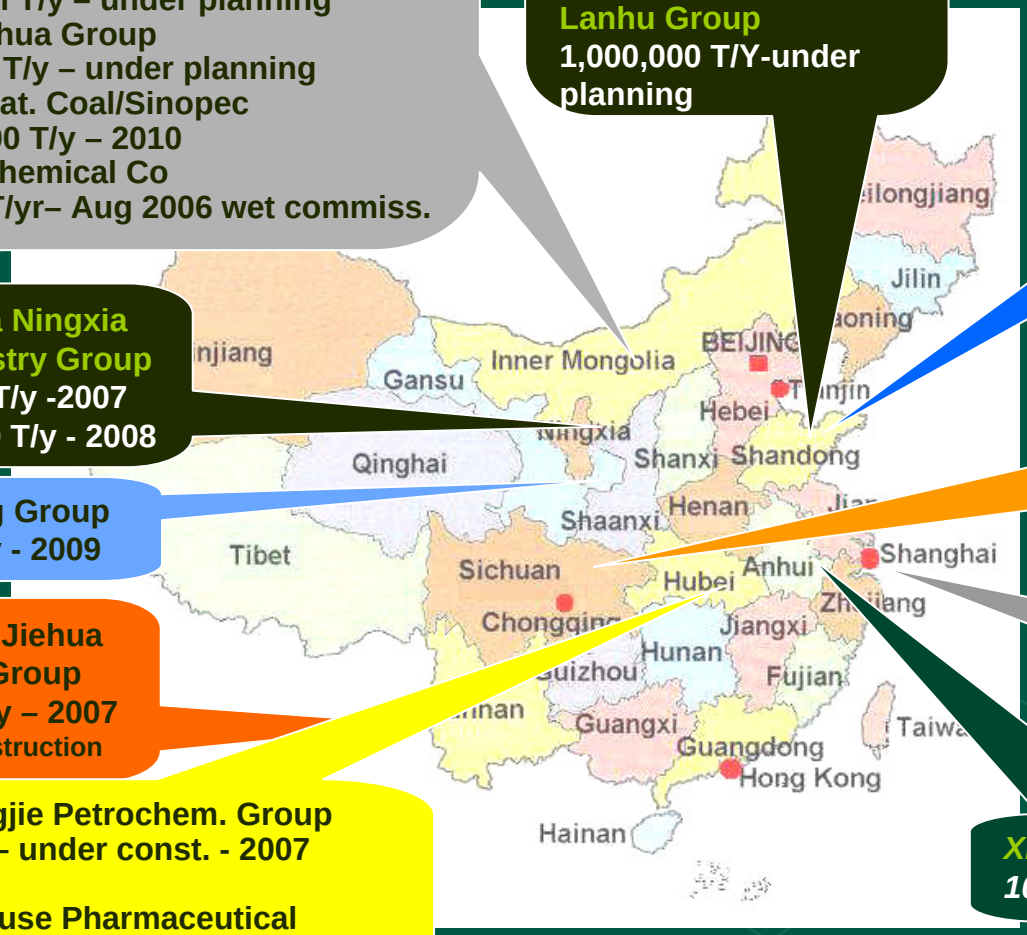
Yuannan Jiehua Chem. Group
150,000 T/y – 2007
Under construction

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

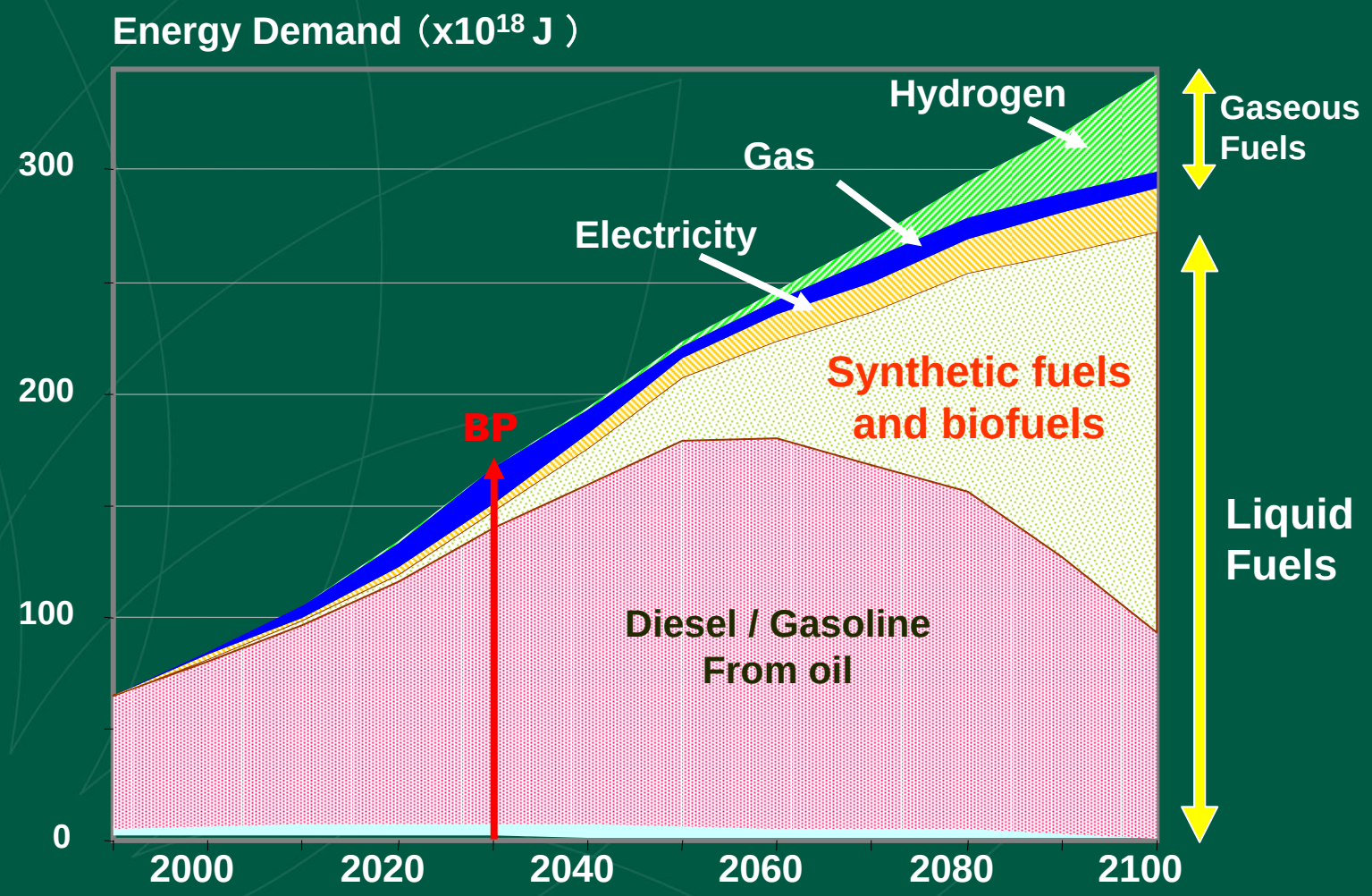
Xinao Group
10,000 T/y – Jan. 2006



Memo: This is a work in progress, Ron Sills, Sept. 19, 2006

1 MT DME requires 1.4 MT methanol

Automotive fuel demand scenario to 2100



Source: IEA

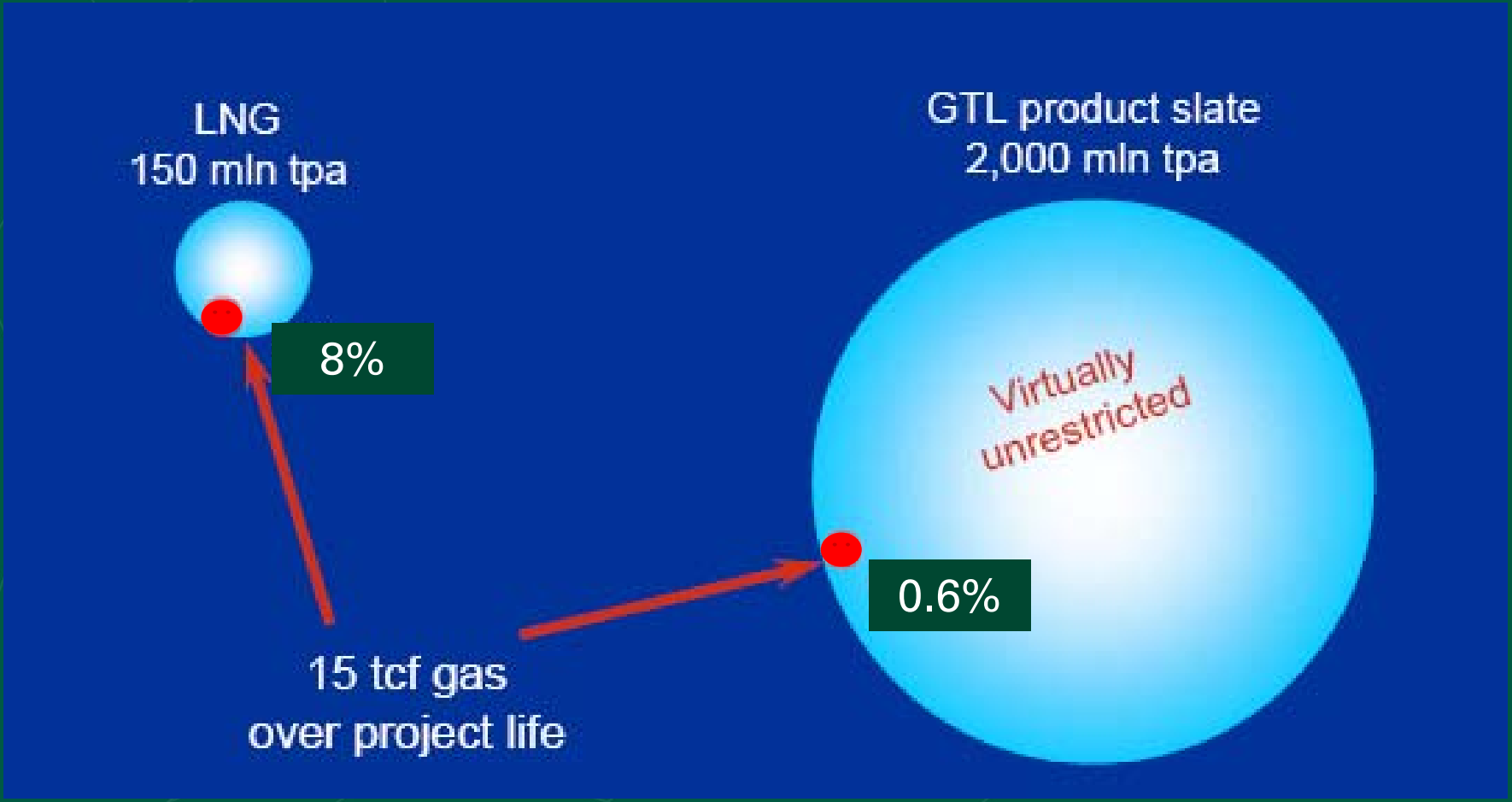
The dangers of technical prediction

- **Nuclear-powered vacuum cleaners will probably be a reality in 10 years -** Alex Lewyt, president of vacuum cleaner company Lewyt Corp., 1955
- **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
- **Radio has no future. Heavier-than-air flying machines are impossible. X-rays will prove to be a hoax** - William Thomson, Lord Kelvin, 1899

Role of GTP in host countries

- Gas resource holder increasingly value GTP
  - GTP: Requirement for gas access and country entry
  - Algeria: Tinrhert GTL bid
  - Qatar: “GTL Capital of the World”
  - Trinidad: “GTP Capital of the World”
  - No more flaring policies
- Key advantages
  - Diversity of products and markets
  - Country industrialization (investments, jobs)
  - Acceleration of gas monetization
  - New “unconstrained” markets for gas

GTL: large unconstrained markets



GTL (and some other GTP) markets are virtually unconstrained

GTP is an excellent complement to LNG

Gas resource consideration

- LNG: massive scale; multiple trains
  - >10 tcf resource requirement
- GTP: massive scale AND smaller scale
  - World scale methanol/DME plant: 150mmscfd, <2 tcf
  - World scale GTL plant: 300mmscfd, ~3tcf

Summary: Products and markets

- XTP offers a broad product portfolio
  - Improved conventional fuels (diesel, gasoline, jet fuel, etc)
  - New “designer” fuels and fuel additives (methanol, DME, hydrogen, ethanol, etc)
  - New large volume chemicals (olefins)
- Fuel properties
  - Greatly improved performance and emissions
  - Preferred (early) applications: blends
- XTP is a must have tool in the tool box

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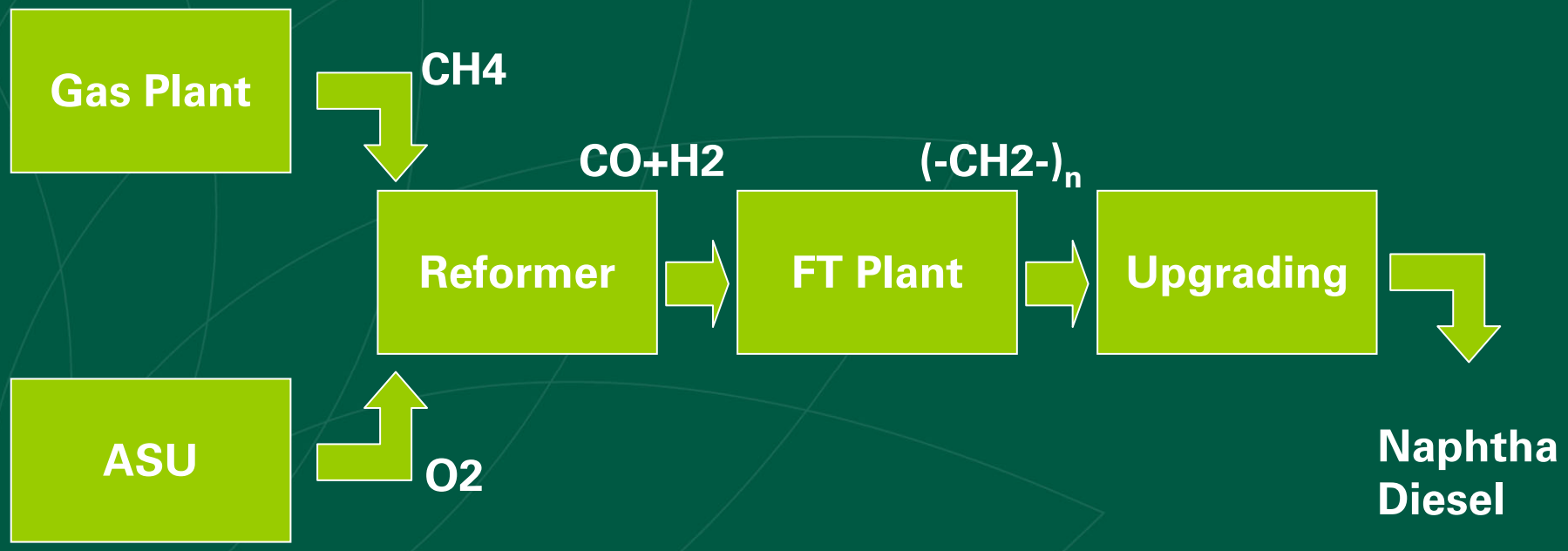
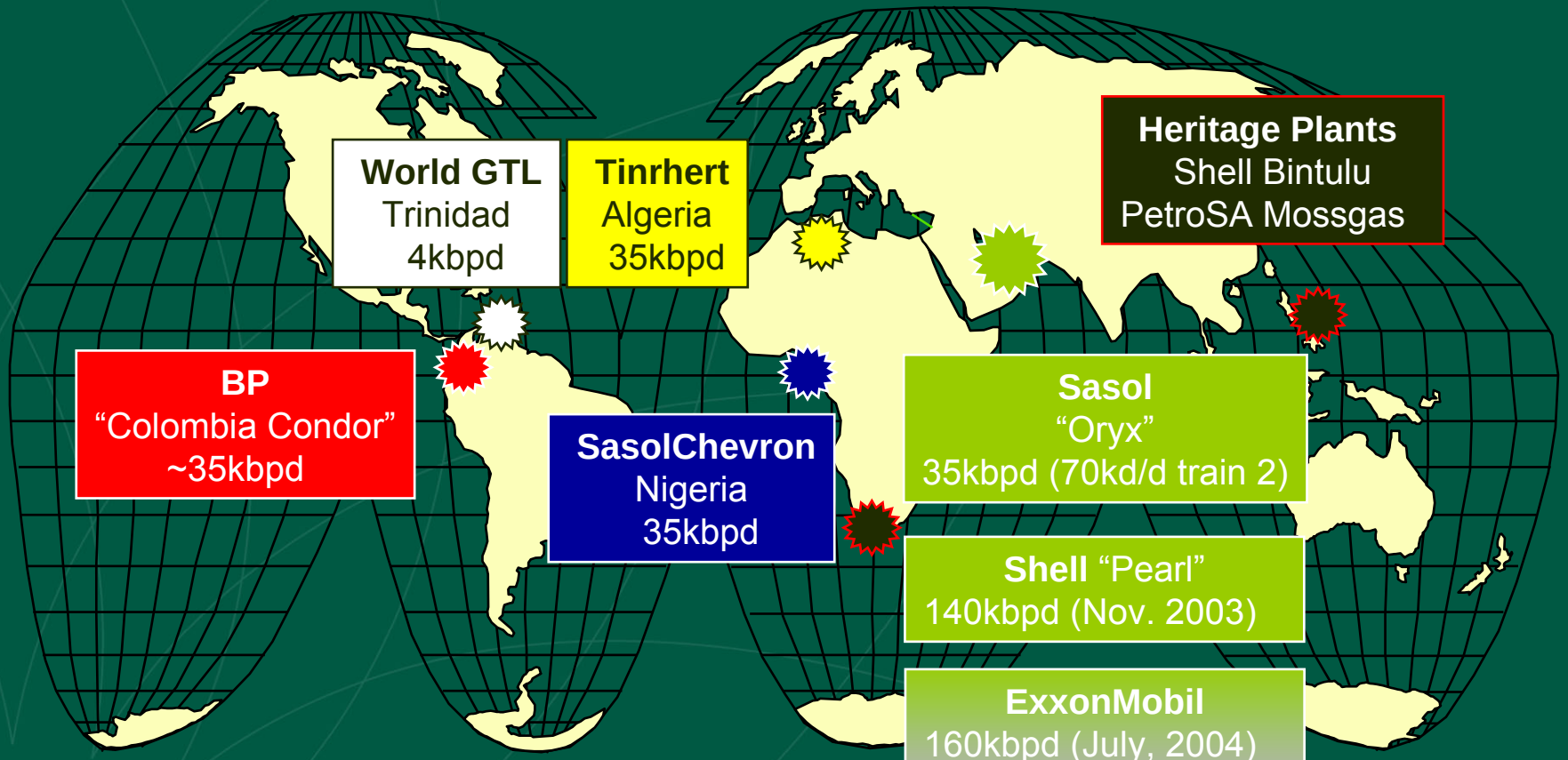
GTL technology challenges



GTL projects: the birth of an industry



World GTL
Trinidad
4kbpd

Tinrhert
Algeria
35kbpd

Heritage Plants
Shell Bintulu
PetroSA Mossgas

BP
"Colombia Condor"
~35kbpd

SasolChevron
Nigeria
35kbpd

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

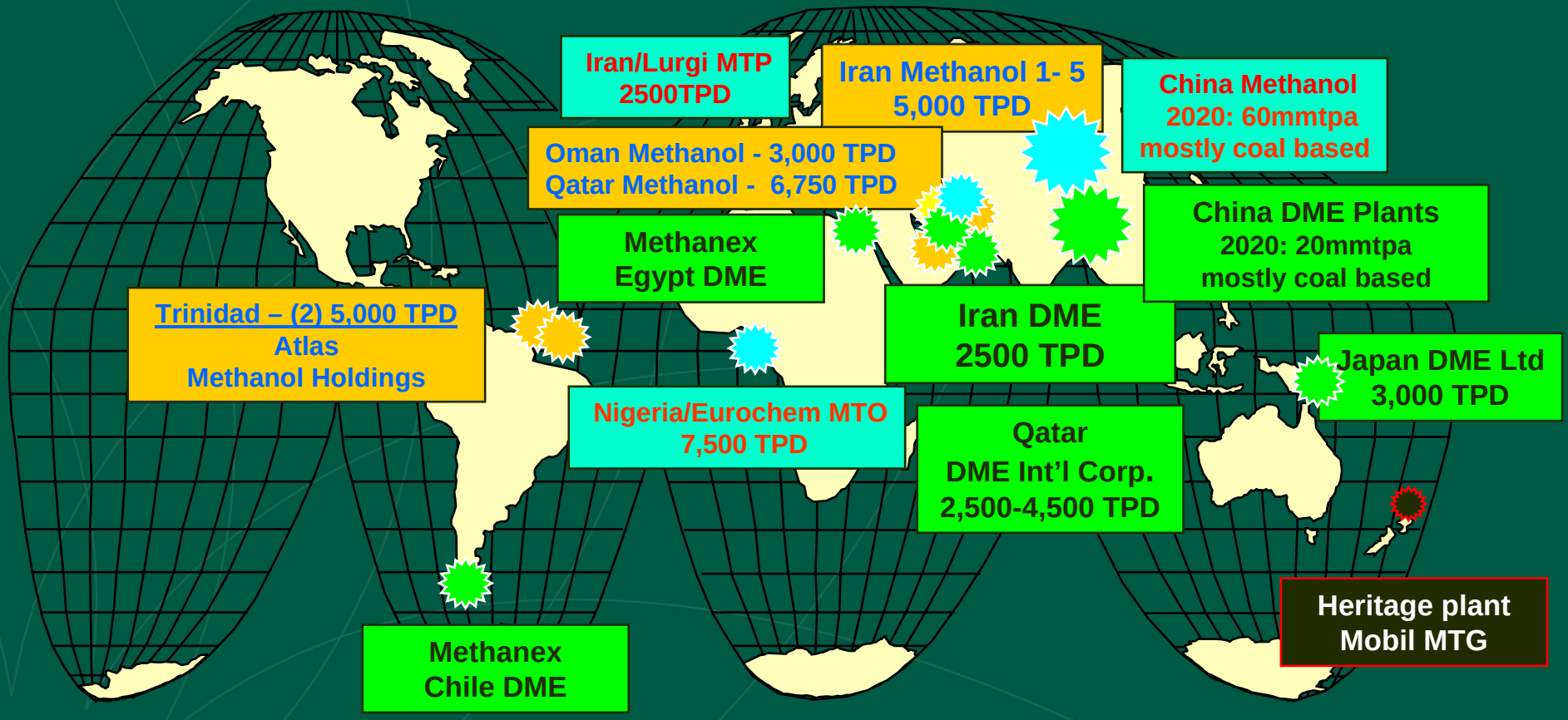
Shell "Pearl"
140kbpd (Nov. 2003)

ExxonMobil
160kbpd (July, 2004)
PP: Feb. 2007

Many other proposed projects

ConocoPhillips
SasolChevron
Marathon/Syntroleum
POSTPONED

Methanol/DME projects: transition from chemicals to fuels



- Methanol
- Methanol for Fuel, Power/Olefins
- DME

Memo: Not including <5,000 MTPD methanol plants

Oryx Plant: Pioneer GTL plant
Inaugurated June 6th 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.

<u>Plant Statistics</u>

34,000 bpd capacity

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

Construction Start – Dec 2003

Project Completion – March2007

Believed to have cost $1.2Billion

Atlas Plant (Trinidad): Pioneer methanol plant

- 5000tpd (160MMscfd); equivalent to 15,000bpd GTL
- Operated by Methanex, BP is 40% equity partner
- World's largest single train reformer

GTP Economics: summary

- 2000: GTL reached parity with LNG in economic returns
  - Robust economics at $20 crude and Capex of $25k/bbl (2000)
  - But EPC cost increases: >$50k/bbl (2006)

- 2006: Relative economic viability
  - GTL (~$35/bbl), CTL (~$50 - 60/bbl), BTL (~$85/bbl)
  - Higher crude prices favor GTP over LNG

- Methanol and DME can be delivered at $5-7/MMBTU and become viable as fuels above $30 crude
  - Fuel methanol and DME are commercial realities in China
  - Olefin projects underway (new low cost technology)

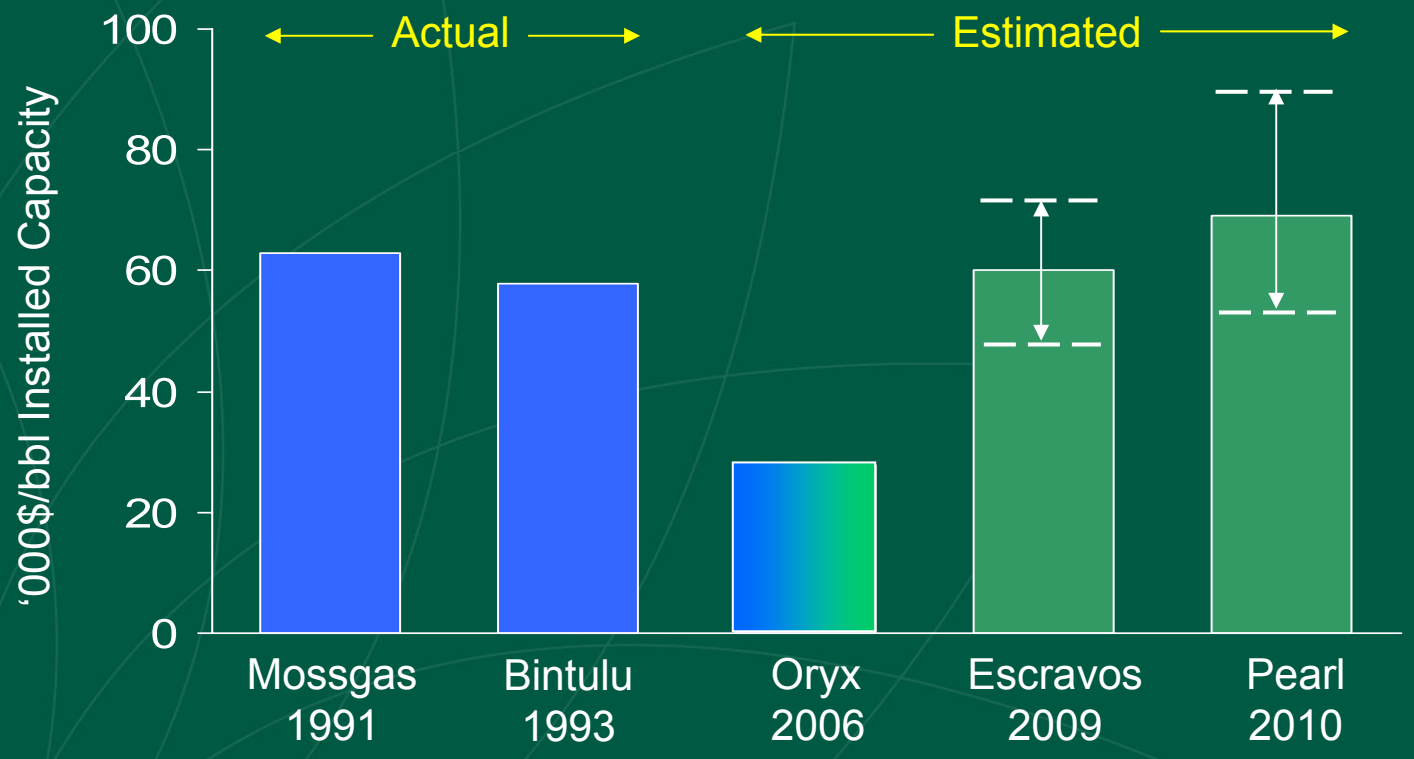
Important factors for economics

1. Feedstock cost

2. Capital cost
   - Location factor
   - Boundary conditions
   - Inflation

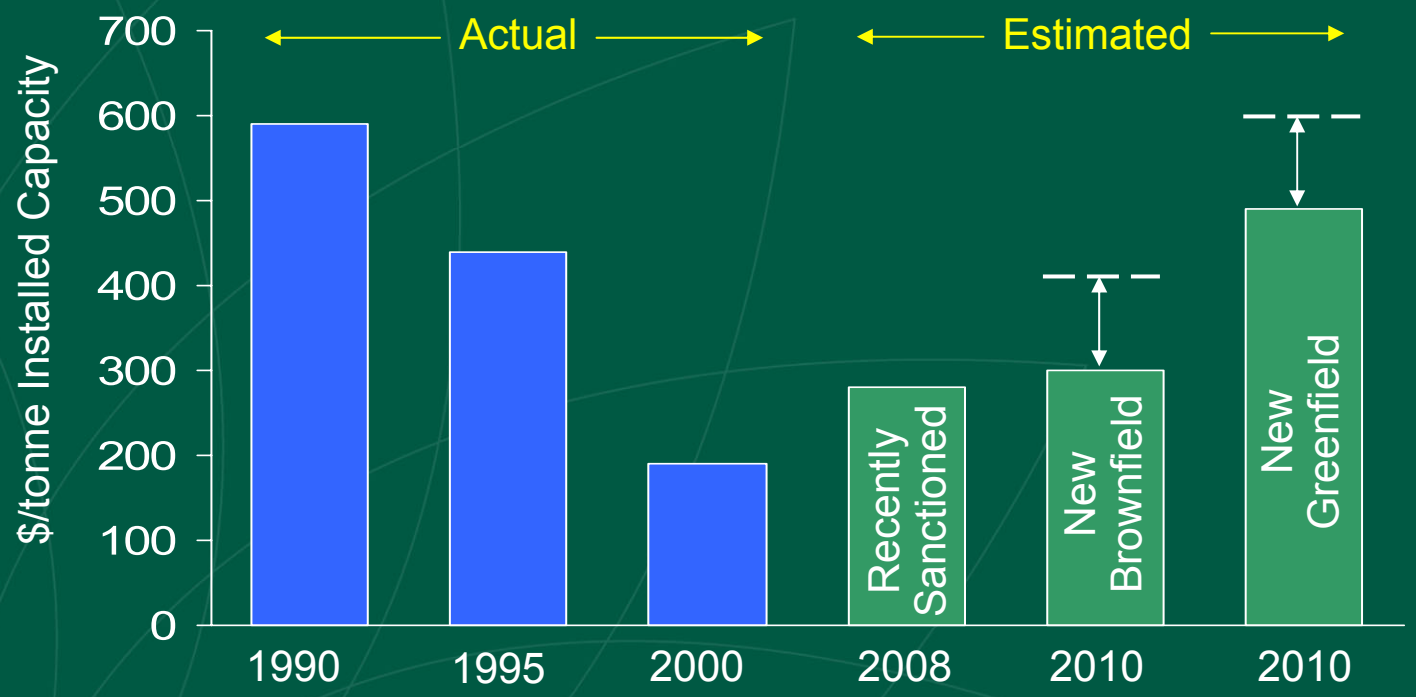
3. Product prices

GTL Cost Trends



- Relatively few commercial-scale projects to date
- Significant scope, scale and location-specific differences
- Estimates based on published data

LNG Liquefaction Cost Trends



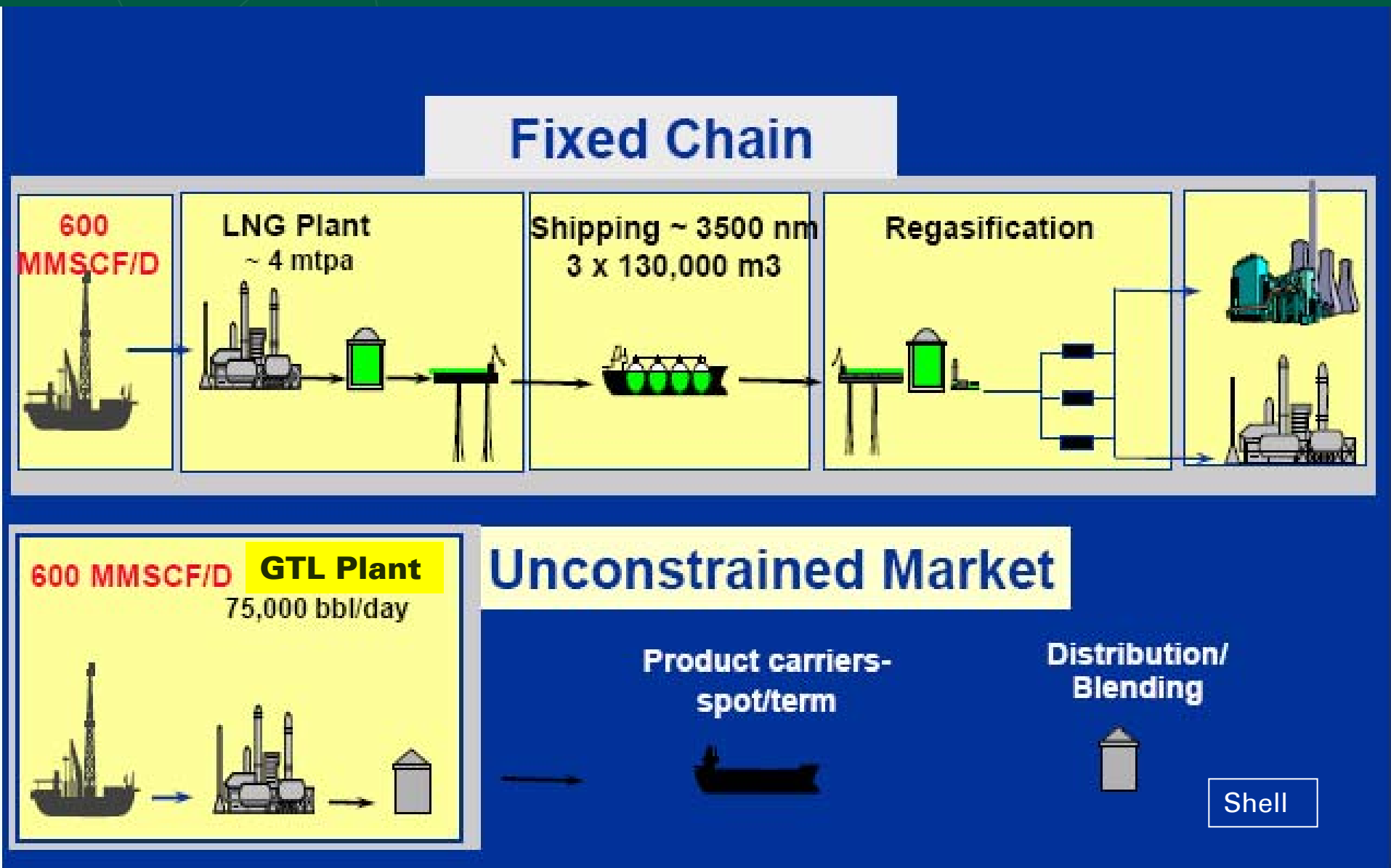
Drivers :

- Economies of scale (e.g. liquefaction, storage & shipping)
- Increased competition (e.g. licensors, contractors, suppliers)
- New technology (e.g. cryogenic pipelines; flexible hoses)

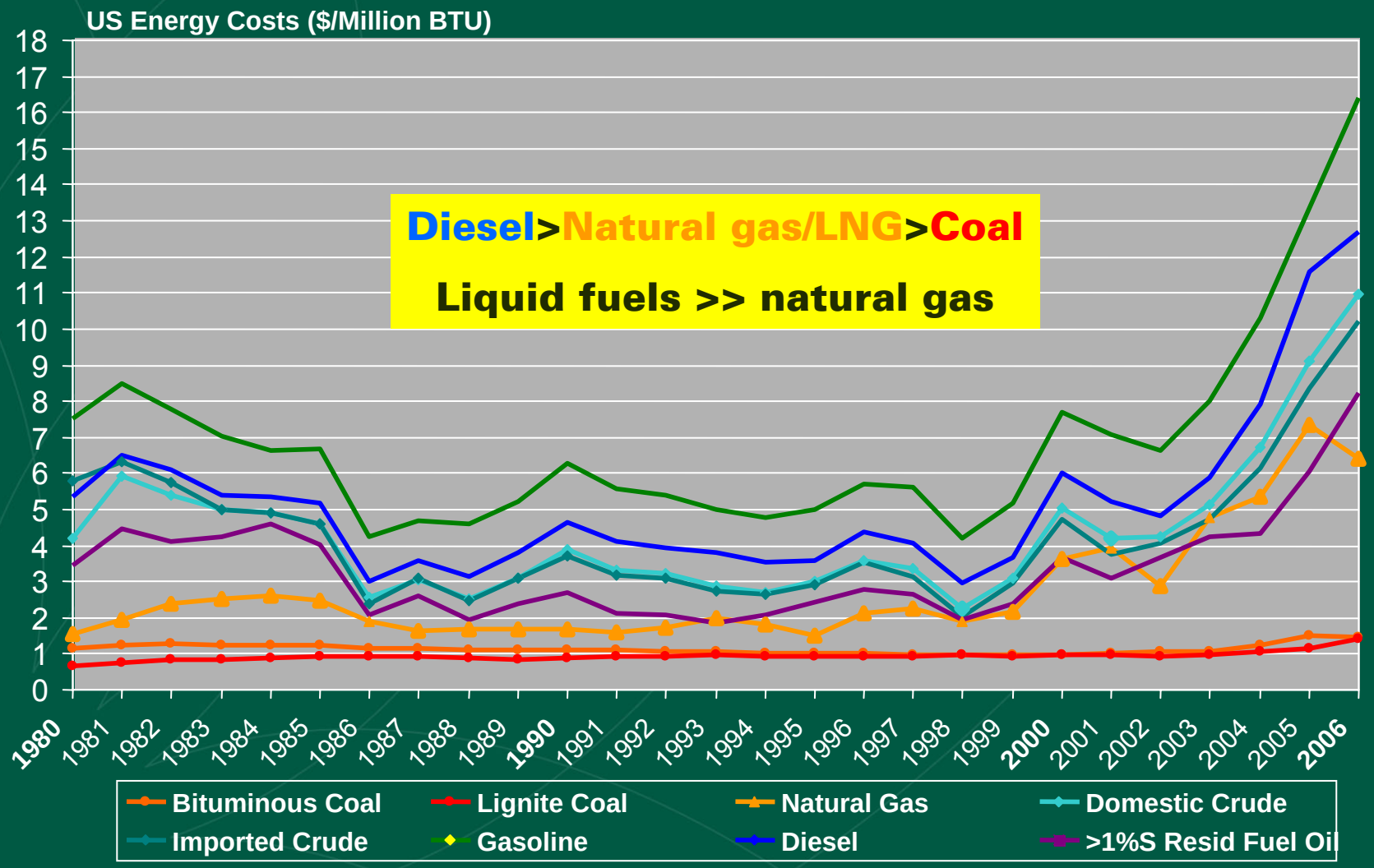
Drivers :

- EPC demand and supply imbalance
- Materials and labour costs
- Vendors and manufacturing (e.g. exchangers, turbines, compressors)
- LNG shipping and yard availabilities
- Increase in schedules

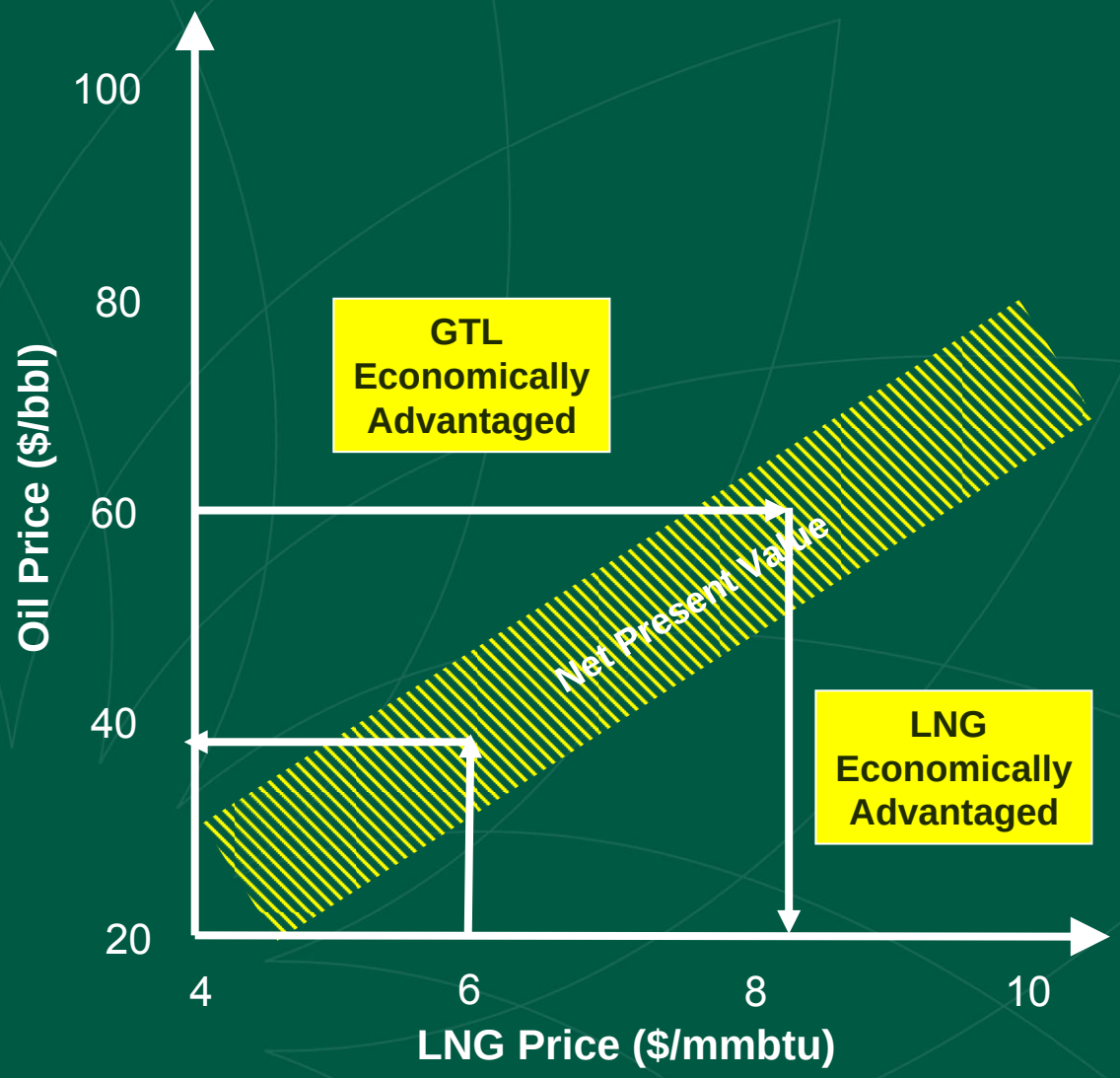
LNG and GTL comparison: boundary conditions



Impact of product prices (USA)



Economics of GTL vs. LNG



Key Issues :

- Oil:gas price relationship; gas capped by coal
- LNG capex: plant only or value chain capex?
- Strategic value :
  - Revenue diversification
  - Value added in-country
  - LNG and GTP

Summary: Pros and cons of GTP

PROS	CONS
• Large new markets • Host country appeal • Premium "designer" products • Robust economics • Proven technologies • Scaleability	• Capital intensive • Scale-up risks • Aversion to new products • Poor efficiencies

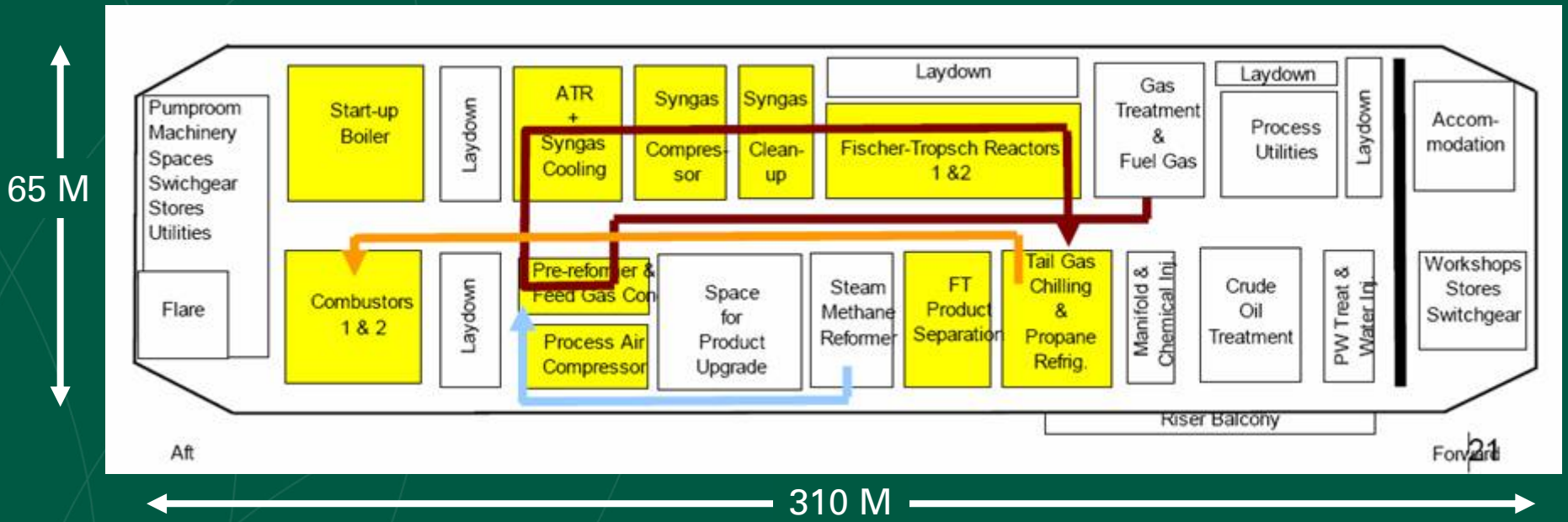
Process carbon efficiencies

	Carbon efficiency (%)
Benchmark: LNG and refineries	85 - 90
GTL today Goal	75 – 80 ~/>85
Methanol/DME today Goal	80 – 83 85 - 90

The future in GTP

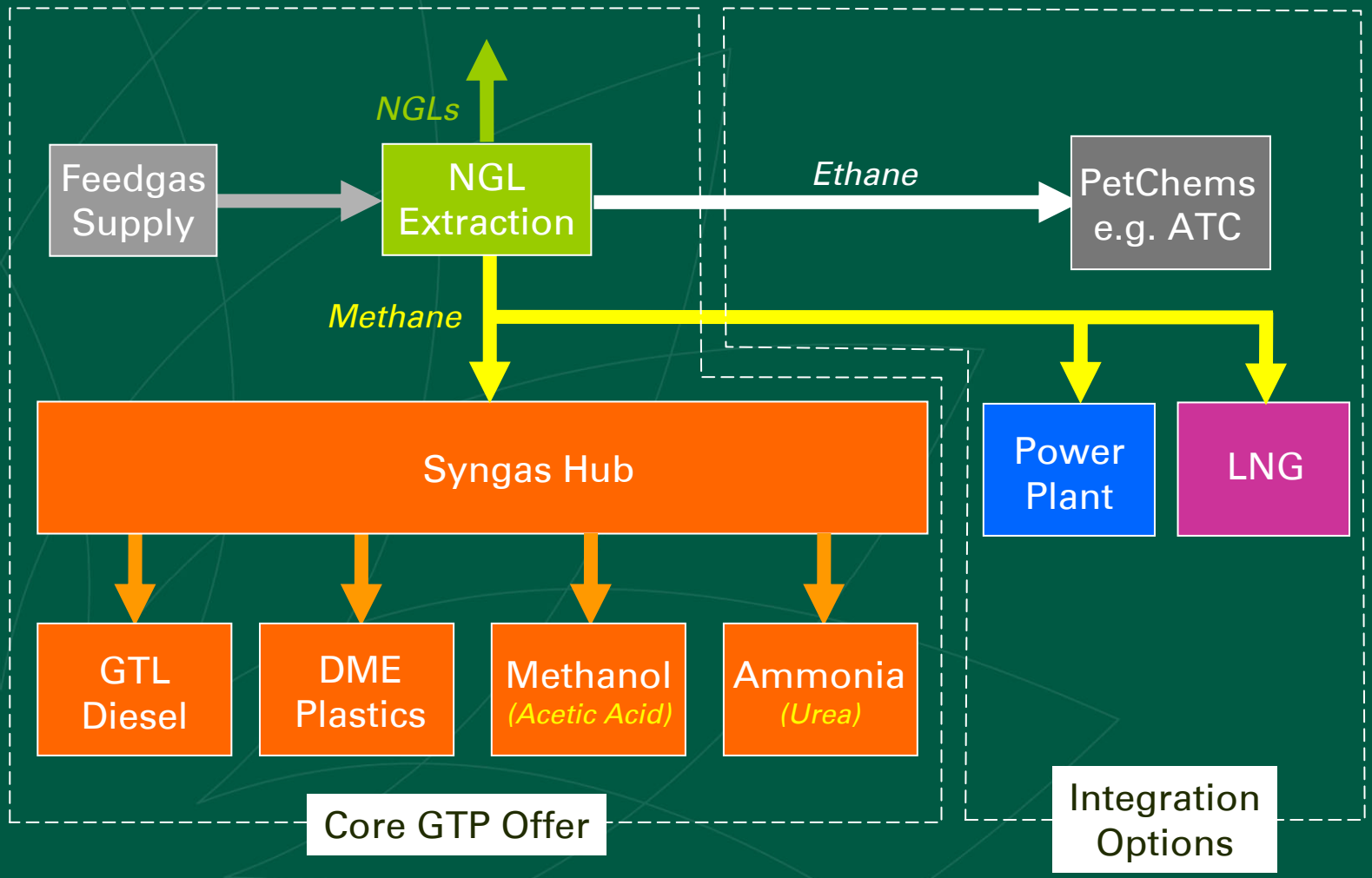
- On-going R&D and value engineering
  - lower cost plants
  - Higher efficiencies
- Floating applications
  - Marinization of GTL FT
  - Micro-channel technologies (Velocys, CompactGTL)
- New products from syngas
- Gas refinery
  - Integration of different plants
  - Further conversion of primary products into consumer products (plastics)

Technology Benchmark: Syntroleum FPSO



16,300 bpd GTL
150 mm-scfd Gas
$1.2b EPC
20,150 M^2

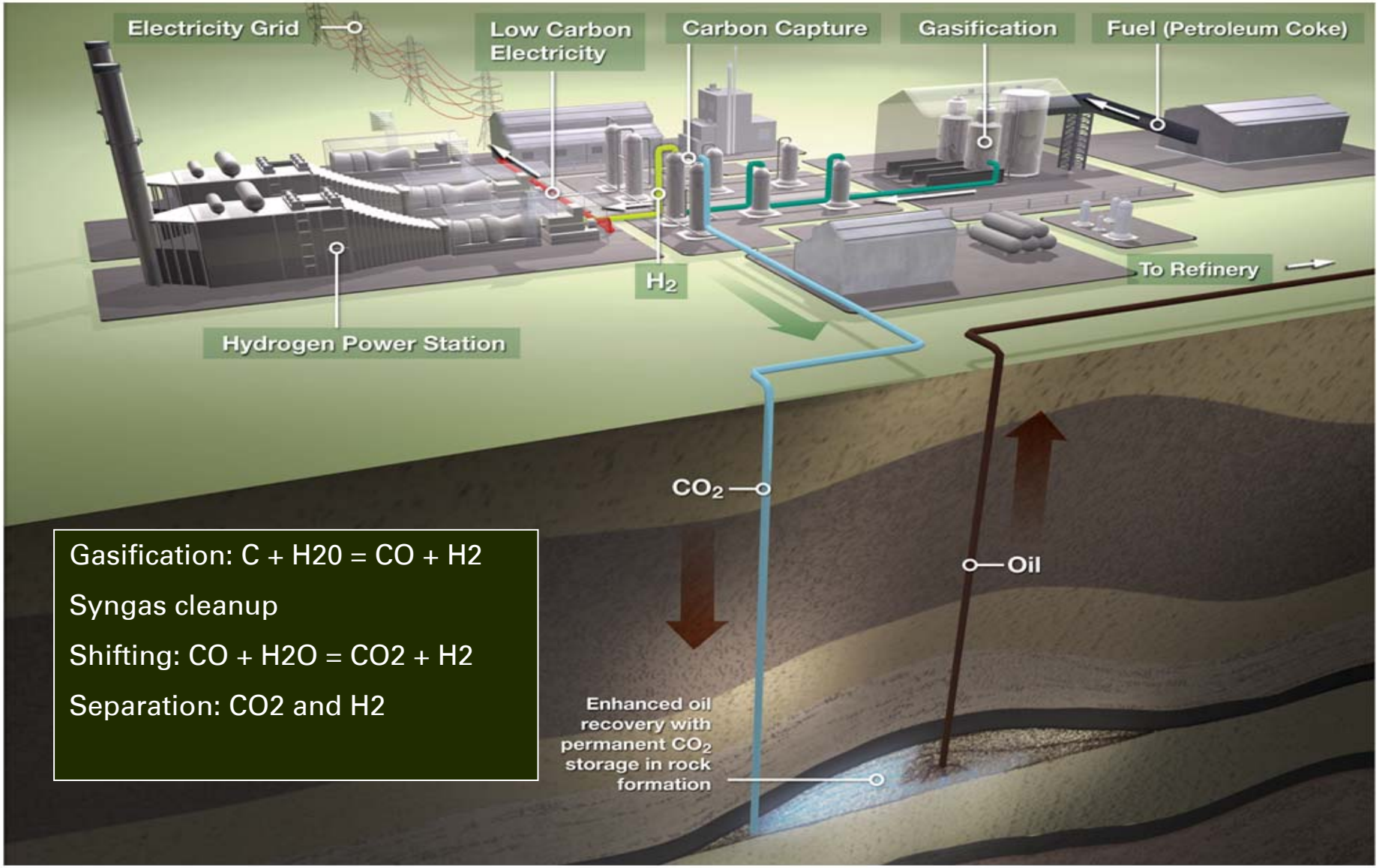
Integrated Gas Refinery Concept



BP GTP Profile

- World class R&D group (~60 people)
- Relationship with Berkeley, Caltech, DICP (~60)
- Broad GTP product portfolio (CR, FT, alcohols,…)
- Atlas methanol plant (with Methanex)
- Portfolio of project options
- Decarbonized fuel projects
- Jan 2007: Transition to XTP

Hydrogen power projects: “DF2” – Carson Refinery



Gasification: C + H20 = CO + H2

Syngas cleanup

Shifting: CO + H2O = CO2 + H2

Separation: CO2 and H2

Summary

- GTP and XTP are here to stay: new options for resource holders
- Oryx and Atlas: pioneer plants for new GTL and methanol/DME business
- Target feedstocks: stranded gas, flares, domestic coal
- Products: high performing, low emitting fuels
- No more stranded gas