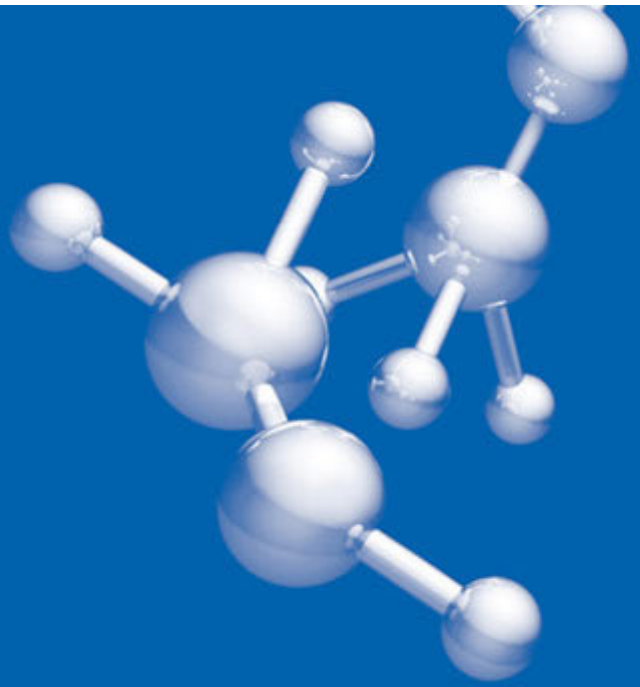


Lurgi's Technology for GtL / CtL Project.

Mr. Amitava Banerjee ,Mr.Pietro DeZanno & Dr.Horst Kalfa

Asia Gas Partnership Summit

22-23 March 2010,New Delhi

2008-05-13

Presentation Overview

AIR LIQUIDE Lurgi

- Air Liquide & Lurgi
- Technology Portfolio : Change in Focus
- Global & Indian Energy Scenario
- Syngas : The Driver for Alternate / Liquid Fuel
- GtL /CtL Technology & Lurgi's Involvement
- Present Initiatives in India
- Typical Economics
- Project Conceptualisation and Approach

Air Liquide in brief

AIR LIQUIDE
Lurgi

- Air Liquide is a **world leading international Group** specializing in industrial and medical gases and related services. Today they are present in **75 countries**

- Founded in **1902**, Air Liquide currently combines the resources and expertise of a global Group with a powerful local presence, based on independent **customer-focused teams**

- From the start, Air Liquide has based its **development on innovation, geographic expansion, creativity and initiative**

- Air Liquide supply **oxygen, nitrogen, hydrogen** and many other gases and services to many customers (steel and oil refining, chemistry and glass, electronics and paper, metallurgy and food-processing, aerospace and healthcare). Their **innovative solutions** improve customers' industrial performance while helping to **protect the environment**

Air LIQUIDE Performance 2009

AIR LIQUIDE
Lurgi

- **€12 bn** total sales
- Over **8,800 patents** and nearly 2,700 protected inventions
- **43,000 employees**
- **365,000 individual shareholders**
- Net profit exceeds **€1.2 bn** (highest in history)

Lurgi Portrait

Lurgi was purchased by Air Liquide in summer 2007.

Lurgi is a leading technology company operating worldwide in the fields of process engineering and plant contracting.

The strength of Lurgi lies in innovative technologies of the future focussing on customized solutions for growth markets.

The technological leadership is based on proprietary technologies and exclusively licensed technologies in the areas

- NG / Coal to-petrochemical products and synthetic fuels,
- Syngas generation and treatment,
- refining,
- petrochemical intermediate and end products,
- polymers,
- biofuels,
- Veg. Oil, Starch and Oleochemicals.

From project development to the turn-key construction of plants through to full plant operation Lurgi globally engineers, builds and commissions plant complexes from a single source and under its overall responsibility.

Scope of Services

- Lurgi provides total technology solutions
- Full-service operating centers worldwide
- All aspects of project development from financing through start-up and operation

We offer the following comprehensive services:

- Consulting
- Market Studies
- Pre-feasibility and Feasibility Studies
- Product Marketing
- Contracting
- Global Sourcing

- Basic and Detail Engineering
- Value Engineering
- Authority Engineering
- Project Management
- Construction
- Operation and Maintenance
- Revamping/Retrofitting
- Technical Service

Aromatics Complex, Shanghai

Lurgi Product Portfolio

Traditional
(from crude oil)

Alternative
(from gas & coal)

Renewable
(from biomass)

Chemicals, Fuels & Energy

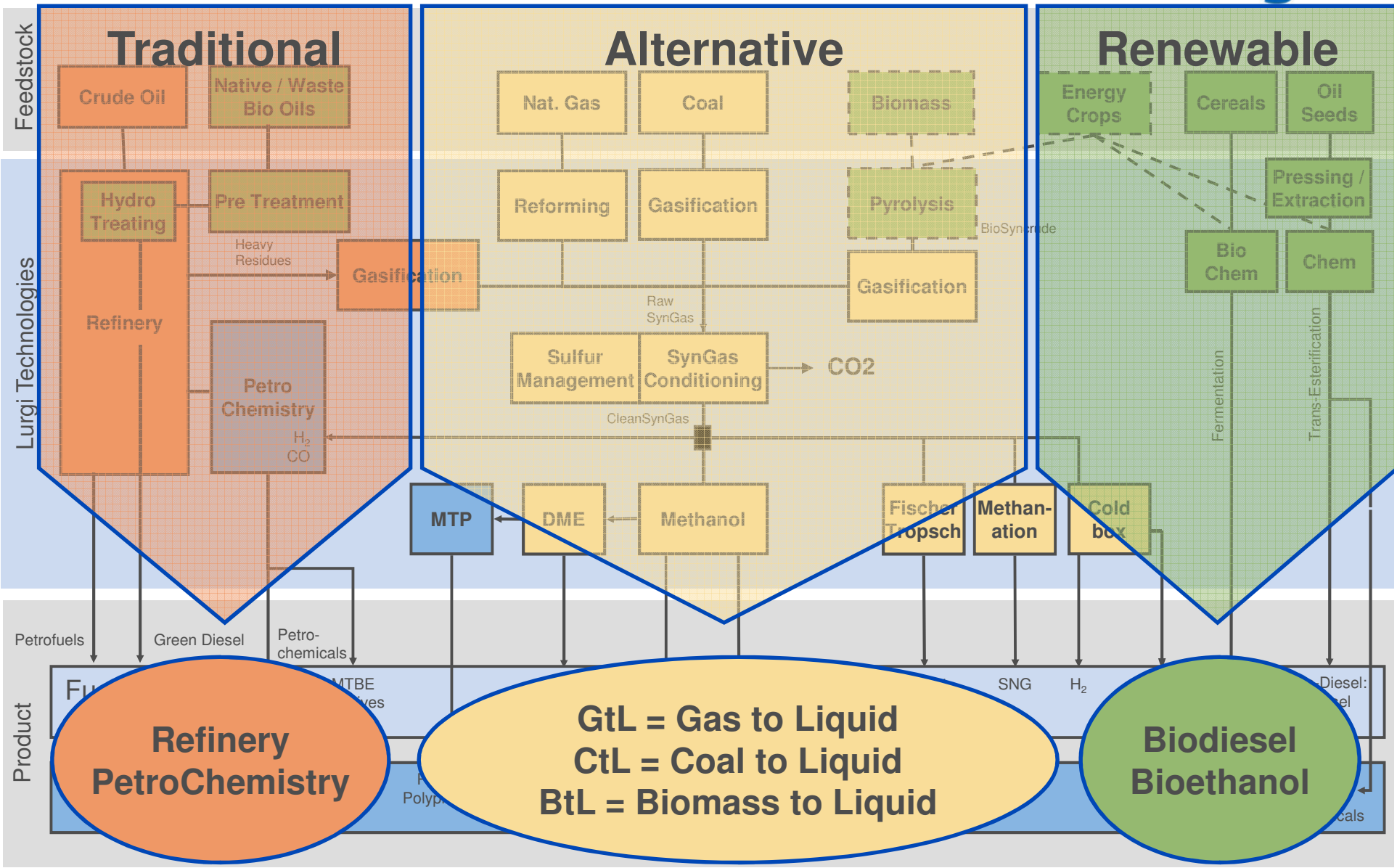
- Sel. Refinery Technologies
- Hydrocracker
- FCC
- HDS
- Petchems
- Aromatics
- Polymers

- Syngas
- Hydrogen
- Methanol
- MTP
- DME
- FT
- MPG
- Coal Gasification

- Biodiesel
- Ethylester
- Fatty Acid
- Fatty Alcohol
- Bioethanol

Advanced Fuels and Chemicals Technologies by AL & Lurgi
Main Process Streams for Fuels and Chemicals

AIR LIQUIDE
Lurgi



Fossil / Renewables and Downstream

AIR LIQUIDE Lurgi

Biomass - Coal
Crude Oil - Natural Gas

Wood - Starch
- Seeds -

SynGas and Hydrocarbon Upgrading Processes

Raffination,Fermentation, Splitting, Hydrogenation

FT, Synfuel Hydrocarbons

Methanol

Alcohols

Ester

Ammonia, Urea/Melamin

MTP, DME, MtSynfuel

FattyAcids

Fats, Oils

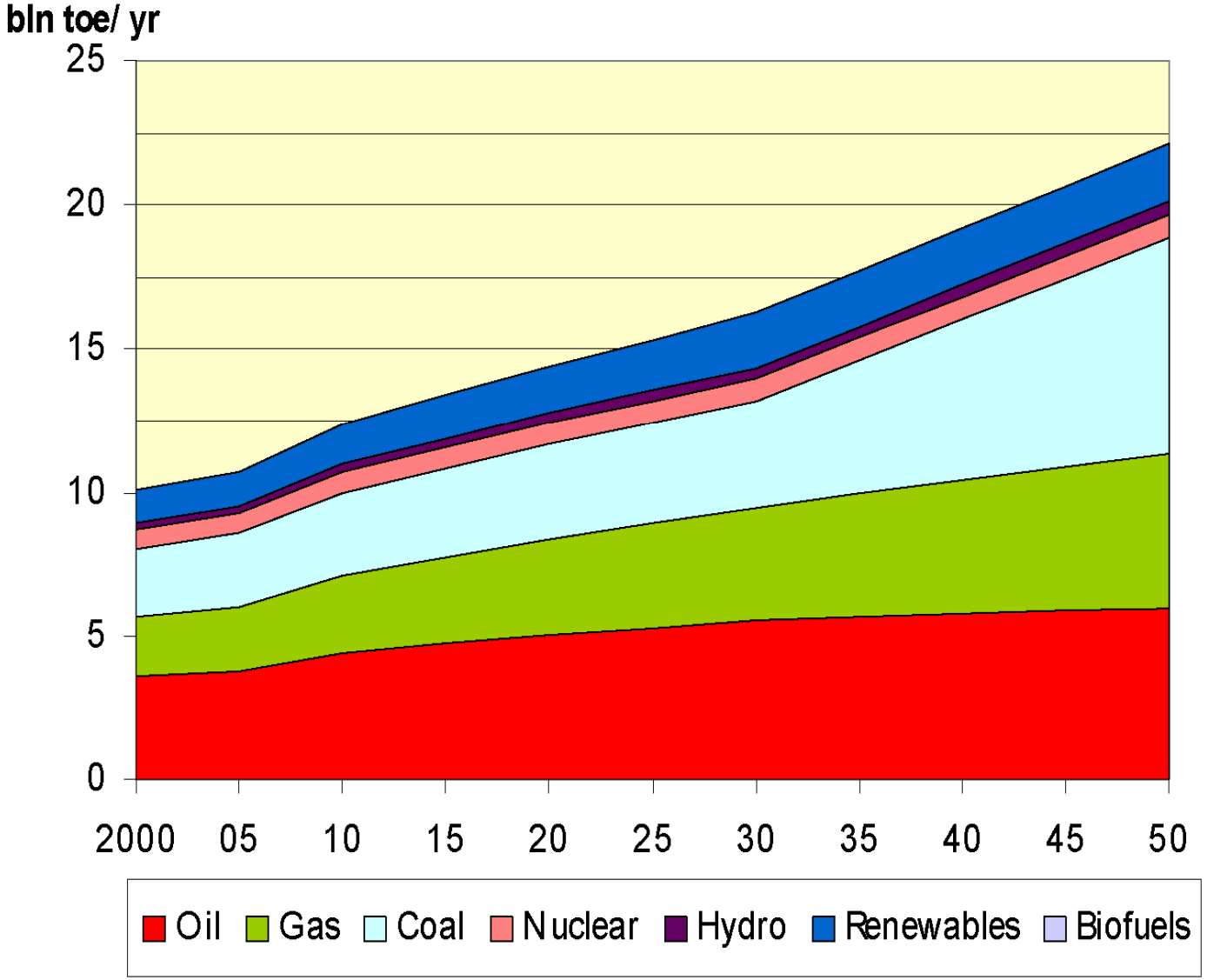
Energy, N-Derivatives GTL , CTL , BTL

Fuels Chemicals

Food, Health Care, Cosmetics

Global Energy Demand / Resource Use

AIR LIQUIDE Lurgi

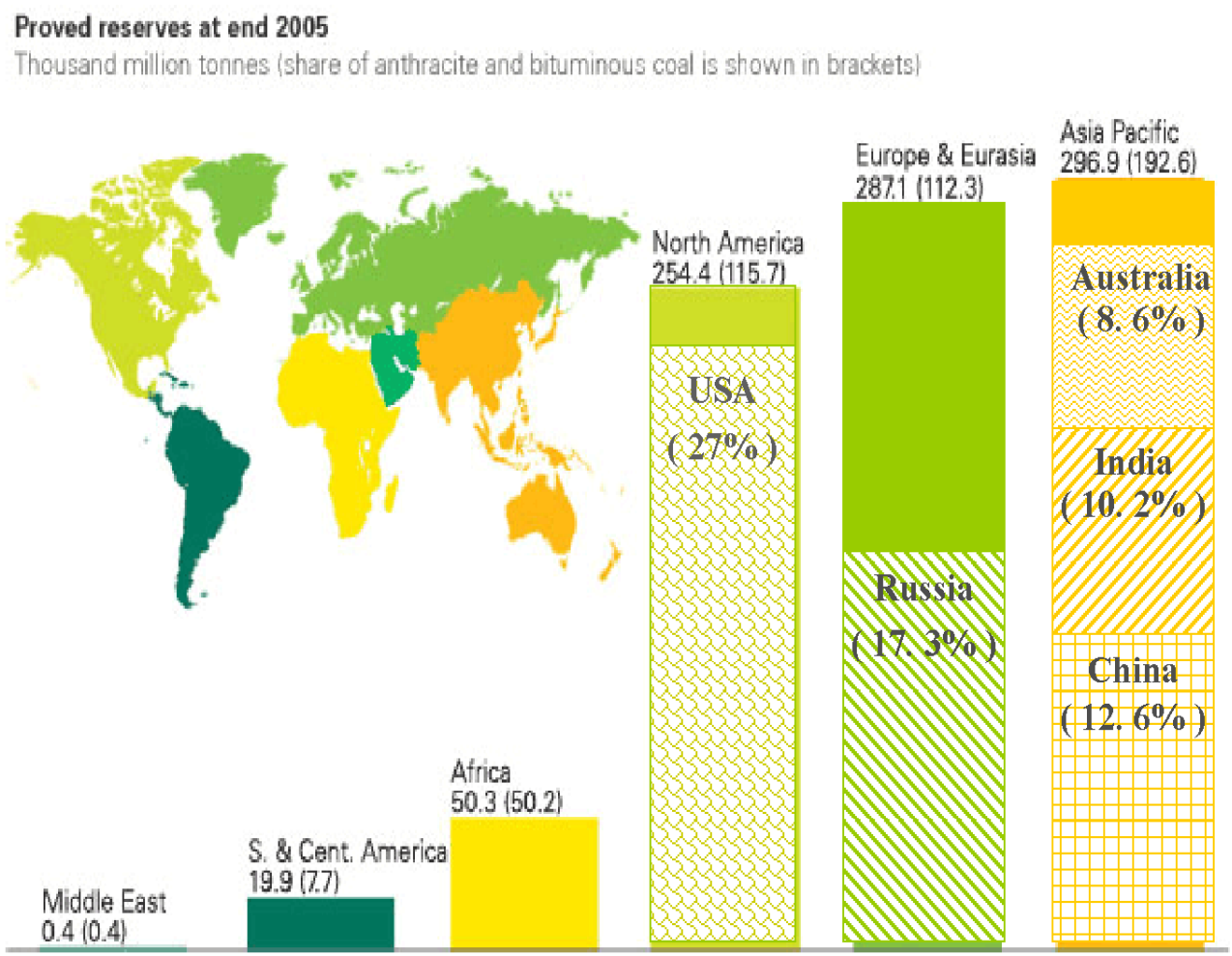


Source: IEA: Energy Technology Perspectives 2006 – Scenarios & Strategies to 2050

Coal Dominates Global Energy Resource

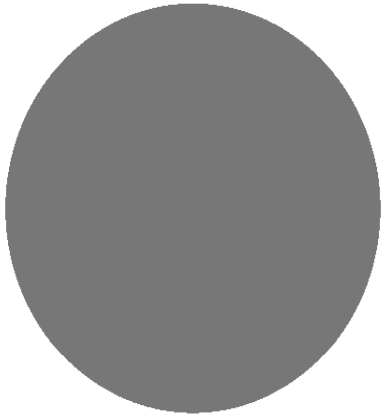
AIR LIQUIDE Lurgi

World Coal Reserves



Source: BP Statistical Review of World Energy 2006

Fossil Fuel Reserves



Coal - 44 x 10^{12} boe

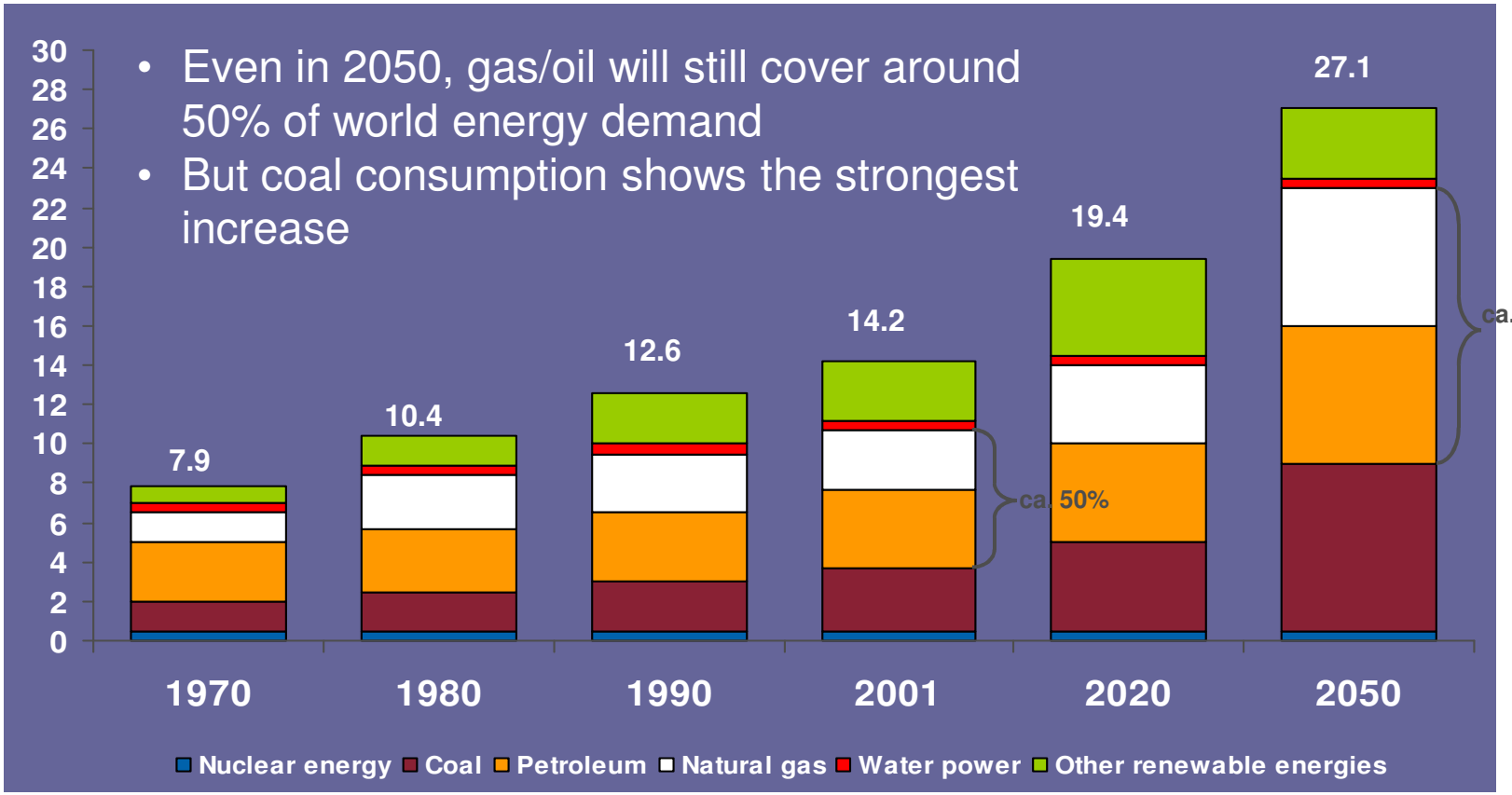
Natural Gas -1.2 x 10^{12} boe

Non-conventional Oil - 4.4 x 10^{12} boe

Conventional Oil - 1.2 x 10^{12} boe

World Energy Consumption by Energy Source

Billion tons of coal equivalent



Source: BP (until 2001), World Energy Council

Future Growth : The Driving Factors

AIR LIQUIDE Lurgi

- Oil & Gas Price
- Coal / Biomass Price
- Technology Performance
- Environmental Expectations / Stipulation

Energy Reserves : India

AIR LIQUIDE Lurgi

Coal (in Million Tonnes - MT)	Natural Ga(in Billion Cubic Meters) : BCM	Crude Oil (in Million Tonnes - MT)
253,000	1076	800
106,000 (MMtOE)	930 (MMtOE)	800 (MMtOE)

Source :

Coal – Ministry of Coal .

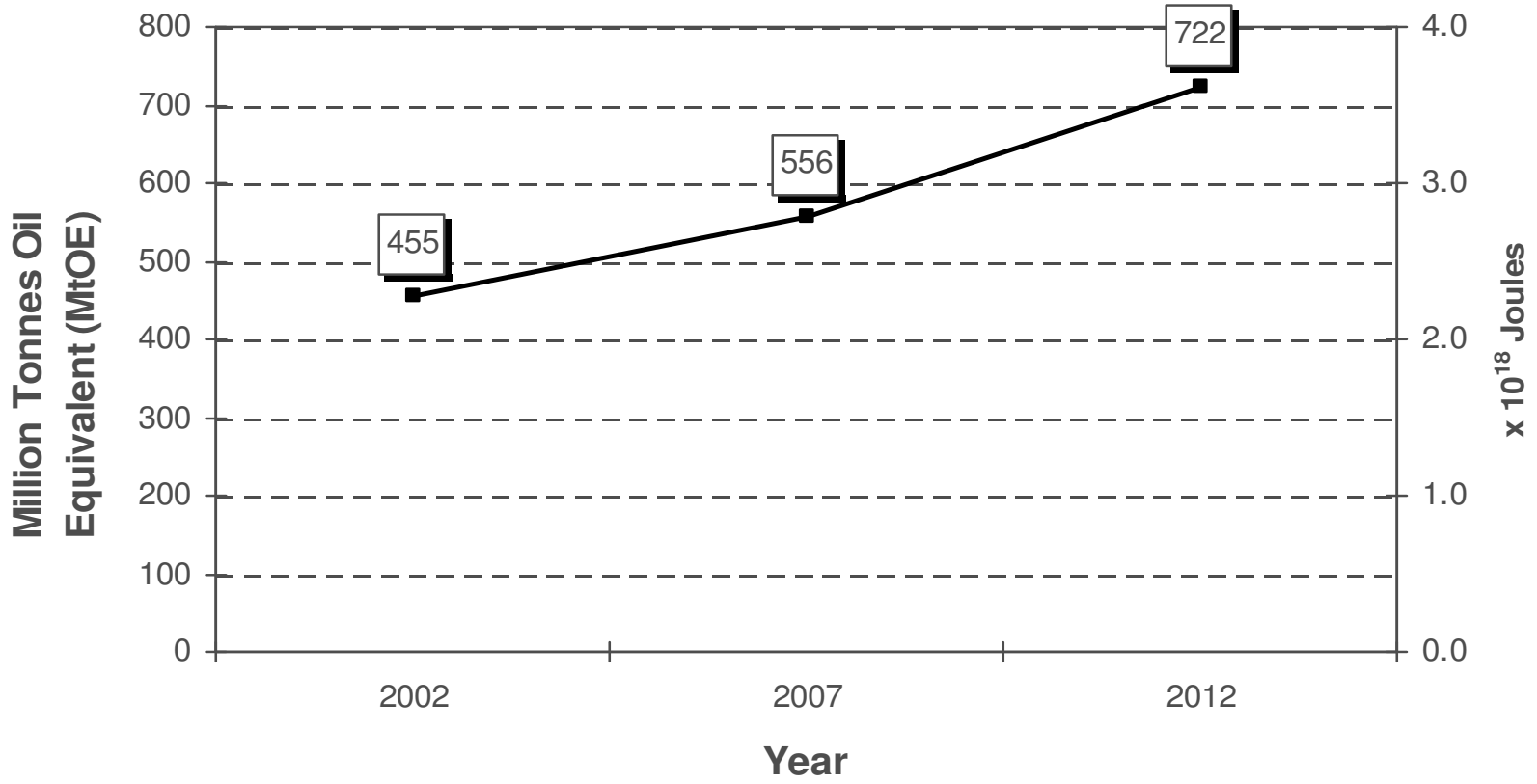
Natural Gas : India in Business ,GOI

Crude Oil – India in Business ,GOI

The Primary Energy Demand in India

AIR LIQUIDE Lurgi

Primary Energy Demand: India



- ✓ Energy Demand rise at 6.5% (2007-2012)

  Ref: Planning Commission, Govt. of India (report on IXth, Xth Plan)

The Future Energy Mix in India

AIR LIQUIDE Lurgi

The Energy Mix: India

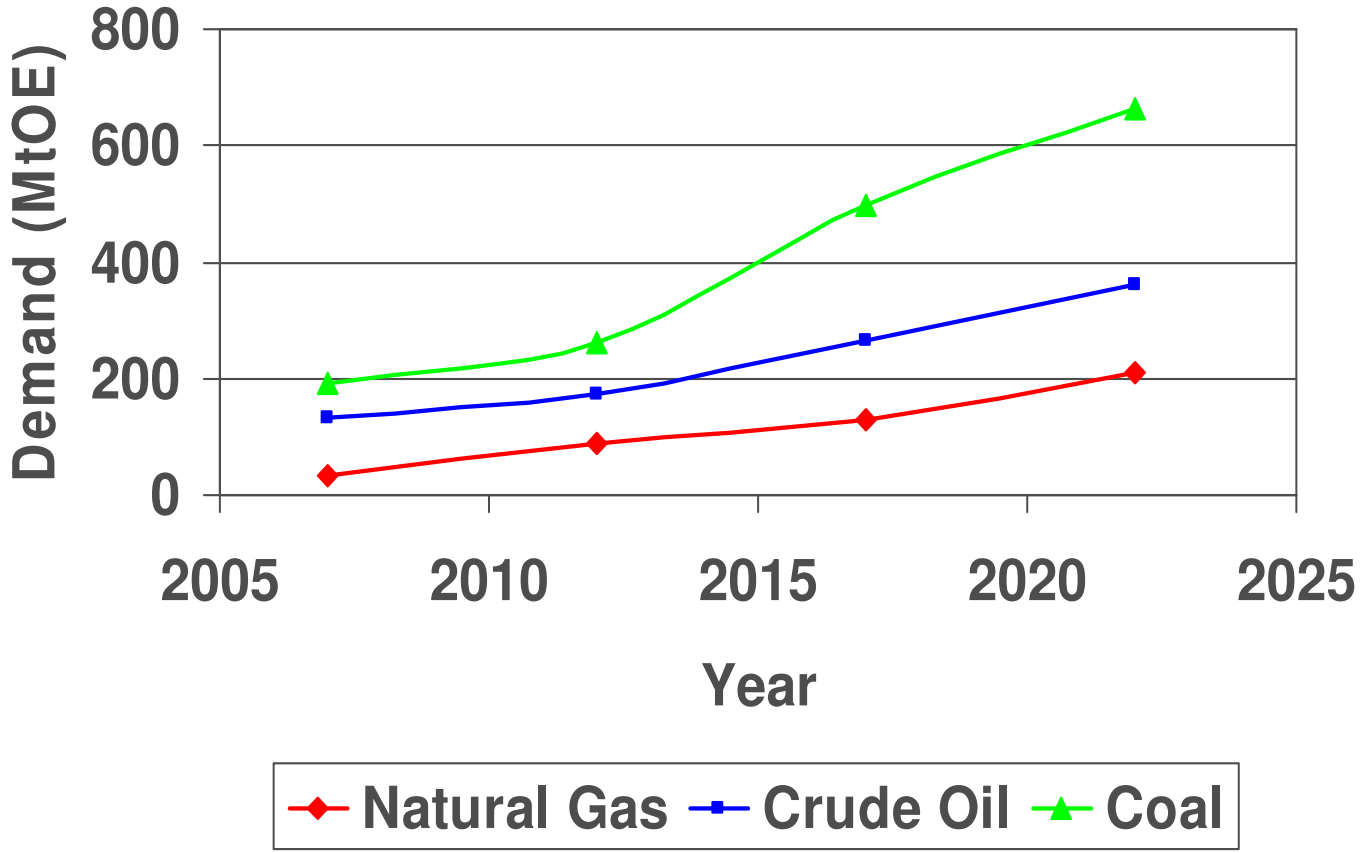
Primary Fuel	Unit	Av. Yearly Demand Xth Plan (2002-2007)	Equivalent MtOE (2002-2007)	Av. Yearly Demand XIth Plan (2007-2012)	Equivalent MtOE (2002-2007)	Energy Mix (%) (2012)	Energy Security Drive Energy Mix (%) (2030)
Low Rank Coal	MT	460	190	620	255	46	54.0
Lignite	MT	58	155	81.5	22.0	4	
Crude Oil	MT	134	135	172	173	34	25.7
Natural Gas (NG)	BCM	47.5	43	64	58	10.5	5.5
Hydroelectric	gKWH	148	12.7	216	18.5	3.3	0.7
Nuclear	gKWH	23	6.0	58	1.4	2.6	4.0

- ✓ Source: Integrated Energy Policy Report, Planning Commission, Govt. of India.
- ✓ The above is based on Commercial Energy Consumption data. The non- conventional energy consumption is at 151 MtOE and 170 MtOE respectively in 2006-2007 and 2011-2012.

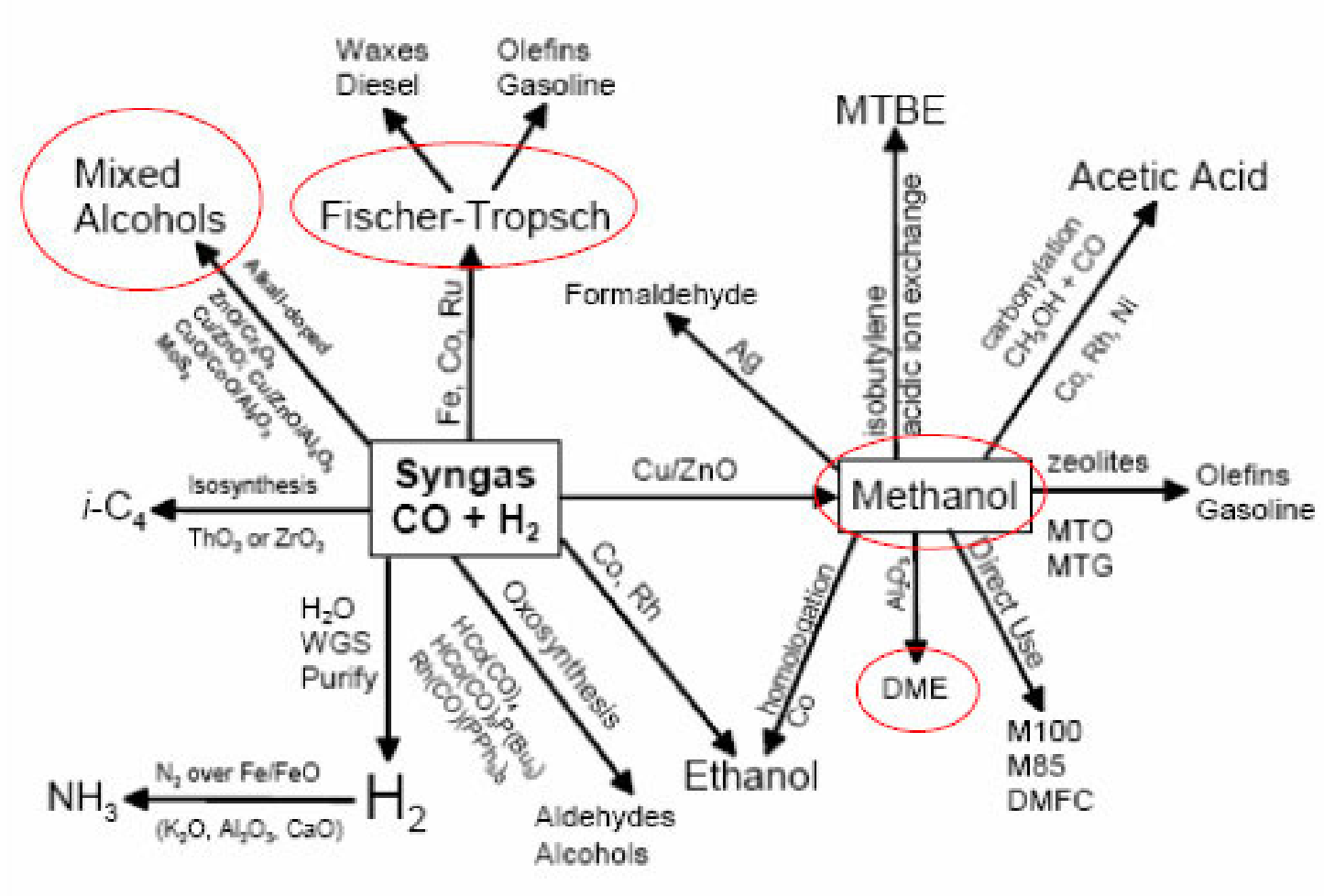
Fossil Energy Use Forecast in India

AIR LIQUIDE Lurgi

Energy Use Forecast - India

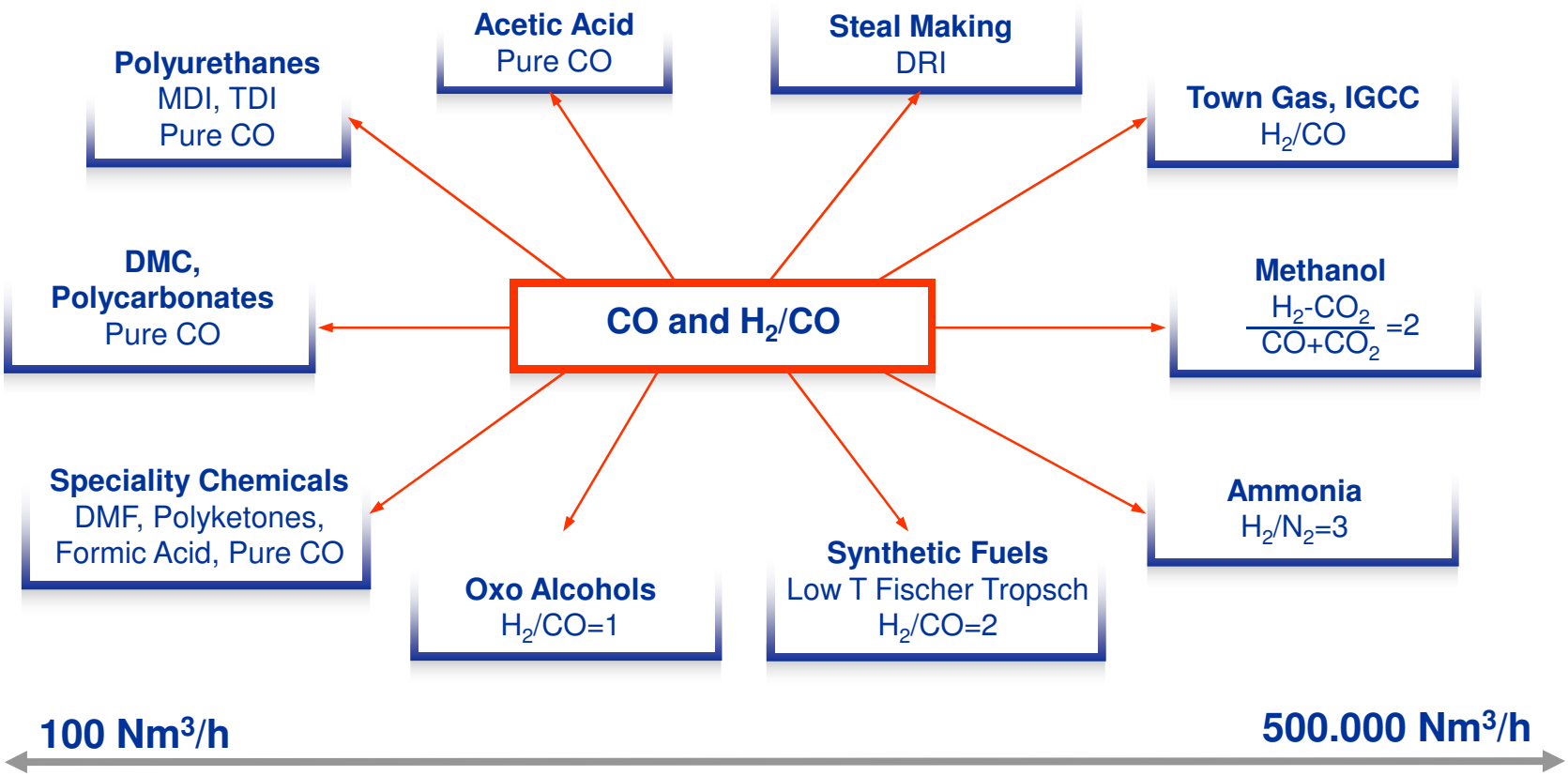


Syngas Conversion to Products



Chemicals and Products from Syngas

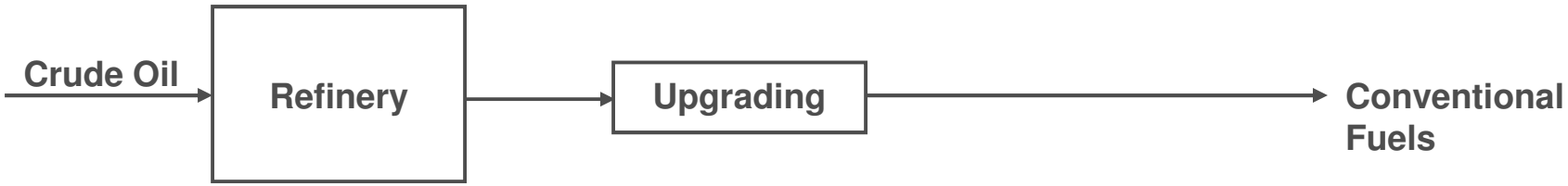
AIR LIQUIDE Lurgi



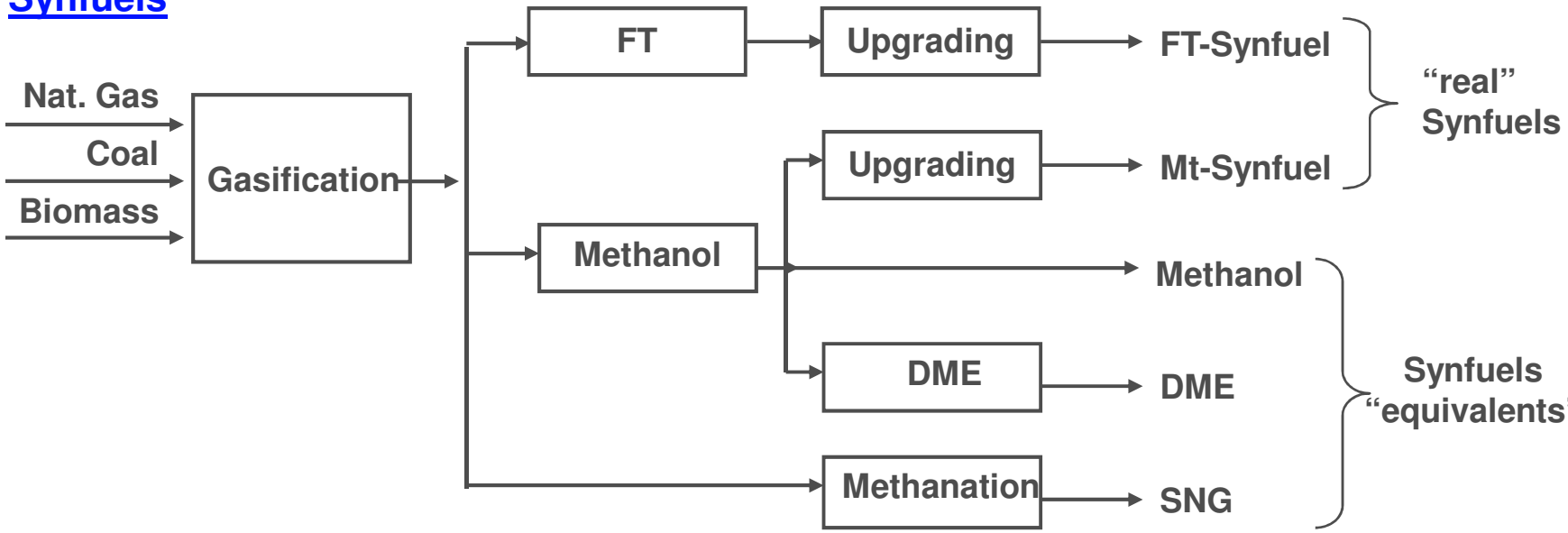
Fuel Production Technology Portfolio / Expertise from Lurgi

AIR LIQUIDE Lurgi

Conventional fuels



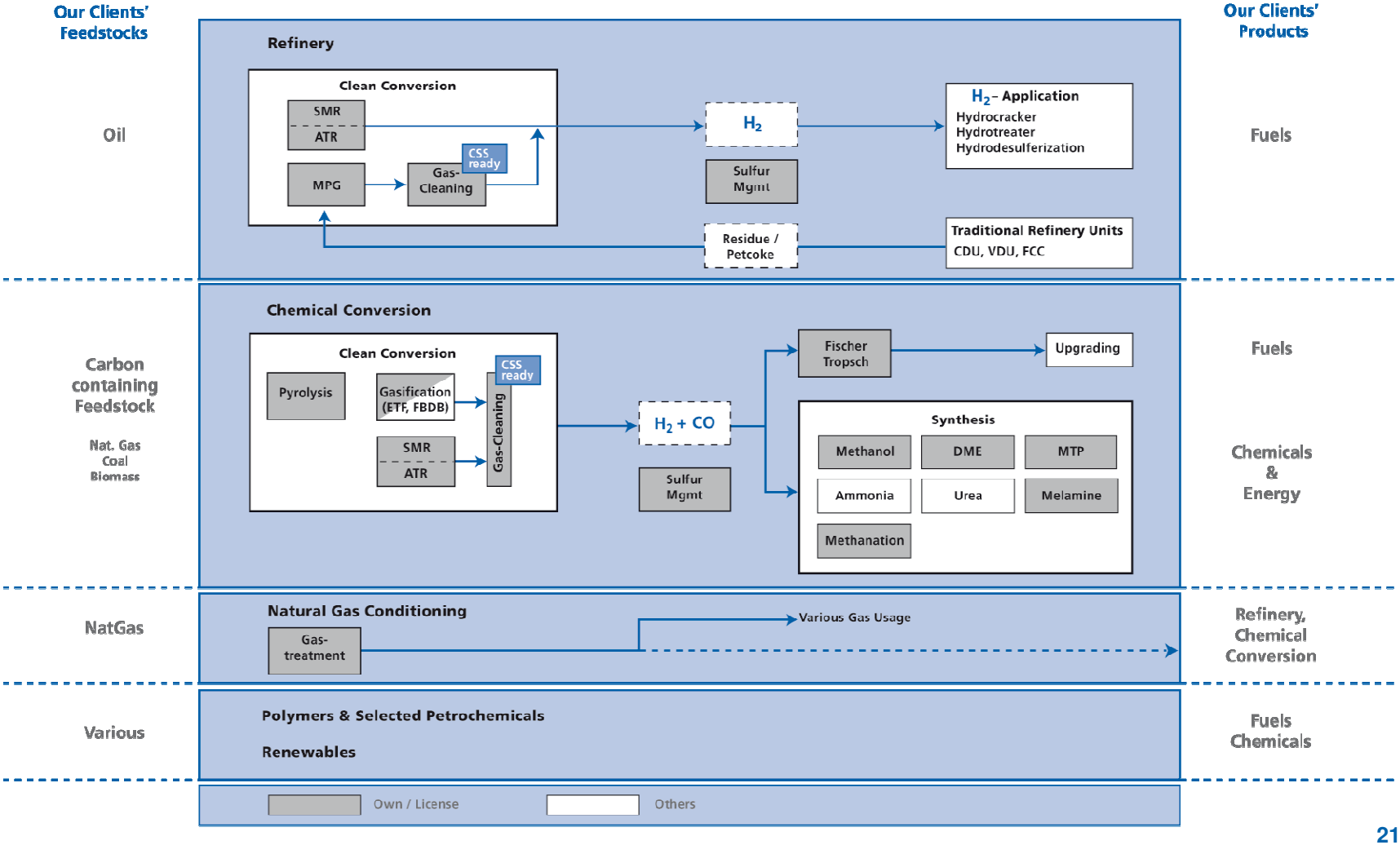
Synfuels



Technology Expertise

Lurgi`s Markets and Technologies

AIR LIQUIDE Lurgi



FT comeback after Historical discontinuity ??

AIR LIQUIDE Lurgi

- FT is making a “comeback” in a big way
- High cetane zero sulfur diesel
- Attractive economics
- Difficult for new “players” to enter competition

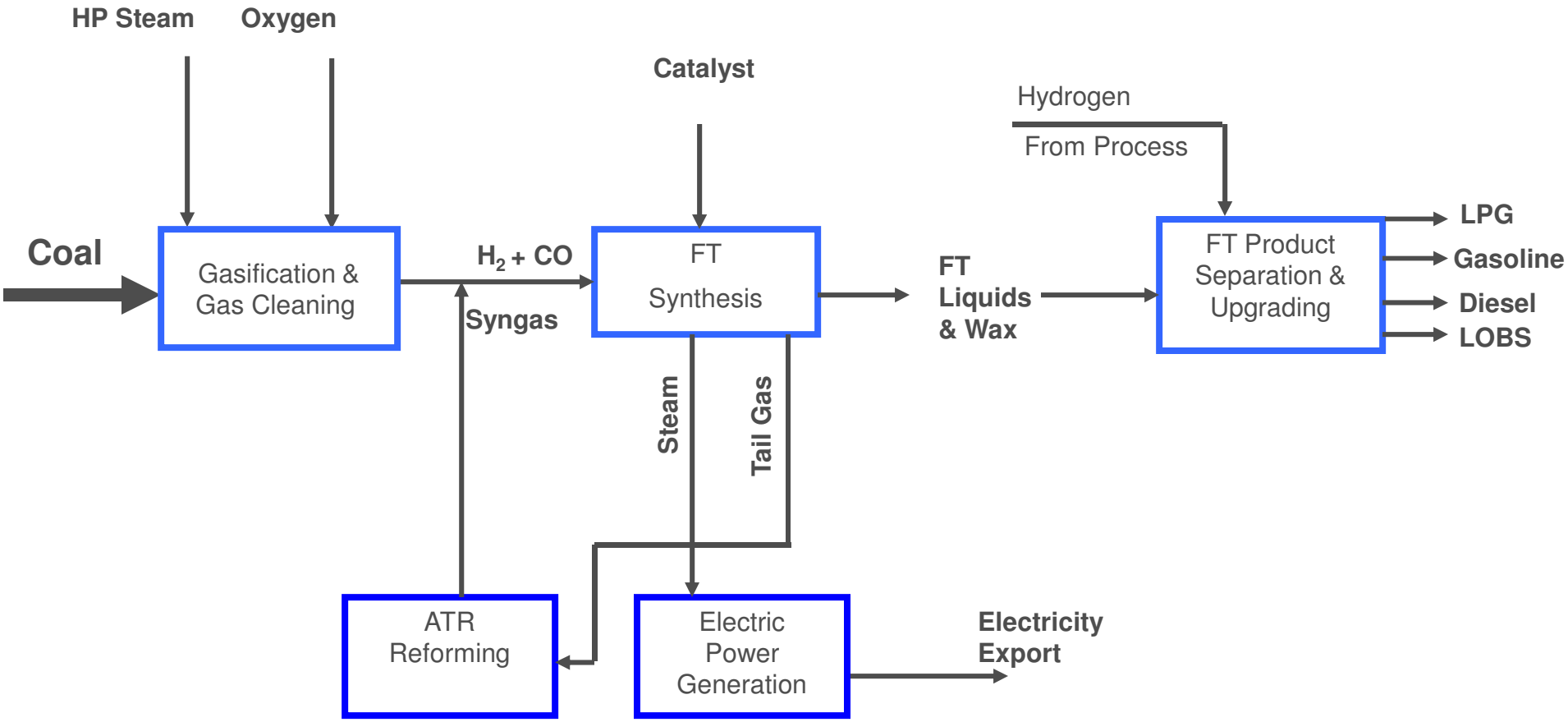
What is Fischer - Tropsch ???

AIR LIQUIDE Lurgi

FT refers to a chemical process whereby various carbon-containing fuels or materials like coal, refinery bottoms, biomass, and natural gas are converted to diesel fuel, naphtha, and other hydrocarbon products.

CtL : Overall Process Block Diagram

AIR LIQUIDE Lurgi



Major Process Steps

1. Syngas Production: gasification (partial combustion) or reforming of the carbon-containing material to a mixture of hydrogen (H_2) and carbon monoxide (CO) called syngas
2. FT Synthesis: converting the syngas in a FT catalytic reactor to naphtha, diesel and wax
3. Upgrading: converting the wax to diesel and other products

Possible Feed for FT Synfuel

AIR LIQUIDE Lurgi

- Solid Feedstocks
  - Coal
  - Bitumen
  - Biomass
- Liquid Feedstocks
  - Refinery residue
  - Orimulsion™
- Gaseous Feedstocks
  - Natural gas
    - Associated gas
    - Remote gas
    - Sub-pipeline quality gas/ CBM

The FT Chemistry

AIR LIQUIDE Lurgi

German Chemists, Franz Fischer and Hans Tropsch:- 1923

$$CO + 2H_2 \xrightarrow{\text{Catalyst}} -CH_2- + H_2O$$

Main Reactions

Parafins

$$nCO + (2n+1)H_2 \longrightarrow C_nH_{2n+2} + nH_2O$$

Olefins

$$nCO + 2nH_2 \longrightarrow C_nH_{2n} + nH_2O$$

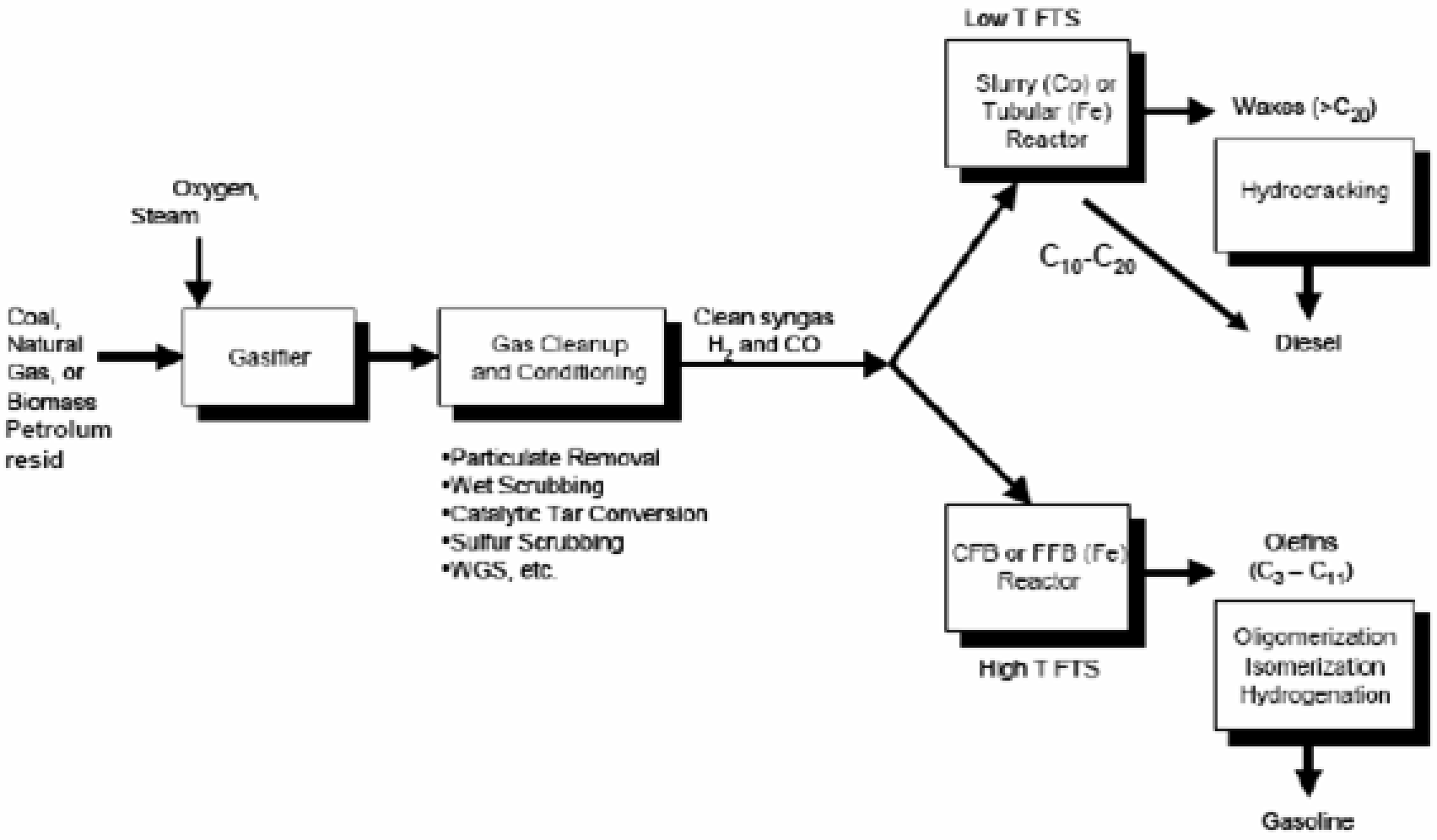
Water-Gas Shift

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

- Multi-phase reaction
- Strongly exothermic ($\Delta H = -180$ kJ/mol)

Diverse FT Routes and the Products

AIR LIQUIDE Lurgi



Critical Process Design Issues

AIR LIQUIDE Lurgi

- Catalyst
- FT Reactor
- Patents

Catalyst , Products & New Projects

AIR LIQUIDE Lurgi

- Iron or cobalt based
- Iron is fuel flexible; cobalt limited is specific (diesel)
- All of the proposed gas to liquids (GTL) plants will use cobalt because it is better suited for high H_2/CO ratio syngas
- Huge GTL plants have been announced in Qatar by
  - -Shell
  - -Sasol/Chevron
  - -Exxon

Typical Comparison in FT Technologies

AIR LIQUIDE Lurgi

Parameter	LTFT	HTFT
Temperature, °C	232	330
Pressure Bar (g)	25.5	22.0
Conversion of fresh feed ($CO+H_2$)	65	85
entering, %	1.9	2.10
H_2 / CO ratio in Feed Gas		
Product Selectivities, %		
CH_4		
C_2H_4	5.0	10.0
C_3H_6	0.2	4.0
C_3H_6	2.4	6.0
C_3H_8	2.0	12.0
C_4H_8	2.8	2.0
C_4H_{10}	3.0	8.0
Gasoline Fraction	2.2	1.0
C_5 to C_{12}	22.5	39.0

Typical Comparison in FT Technologies

AIR LIQUIDE Lurgi

Parameter	LTFT	HTFT
Temperature, °C	232	330
Pressure Bar (g)	25.5	22.0
Conversion of fresh feed ($CO+H_2$) entering, %	65	85
H_2 / CO ratio in Feed Gas	1.9	2.10
Product Selectivities, %		
Diesel Fraction		
C_{13} to C_{18}		
Heavy Oil and Wax	15.0	5.0
C_{19} to C_{21}		
C_{22} to C_{30}	6.0	1.0
C_{31}	17.0	3.0
NAC	18.0	2.0
Acids	3.5	6.0
	0.4	1.0
Total:	100.0	100.0
Ratio of tail gas to fresh fed	0.53	0.33

Fischer-Tropsch Synthesis (Low Temperature)

AIR LIQUIDE Lurgi

Typical Reactor Product Selectivity

Product	Carbon Atom %
Methane	4
C2 - C4 Olefin	4
C2 - C4 Paraffin	4
Light Naphtha	18
Middle Distillate	19
Heavy Oil and Waxes	48
Water Soluble Oxygenate	3

Advantages of FT Synthesis

AIR LIQUIDE Lurgi

- Commercially proven technology
- FT hydrocarbons ideal for diesel due to paraffinic nature
- FT Diesel
  - Cetane Number > 70
  - Zero sulfur
- Gasification/FTS can be an economic as well as attractive alternative to replace additional world oil demand:
  - Long-term energy security
  - Co-production of electricity and other products
  - Ultra-clean energy process
  - Indigenous investment and jobs

FT Diesel Spec. : Environmental Compliance

	Commercial	California	2006 EPA	FT
Cetane Index	>32	>48	>46	>70
Aromatics (Volume%)	< 35	< 10	< 35	0
Sulfur (wt%)	< 0.3	< 0.05	< .0015	0

Modern FT Reactor Technology

AIR LIQUIDE Lurgi

Slurry Phase Reactor (by far preferred)

Tubular Reactor

Fluidised Bed Reactor

Lurgi has commercial experience in all these reactor technologies

Lurgi has historic experience in commercialization technologies around the World

History of Lurgi's FT Process Development

- Approach to FT-technology (early 1930s)
  - Development of catalyst
  - Development of reactor system
- Cooperation of Lurgi with Ruhrchemie (ARbeitsGEmeinschaft, 1947 - 1950) resulted in:

ARGE-Synthesis (multi tubular fixed bed FT reactor)

History of Commercialisation of Lurgi's FT Synthesis (ARGE)

- Commercialisation of ARGE-synthesis in 1952
  - Location: Sasolburg / South Africa
  - Start up: 1955
  - Number of reactors: 5
- All original Lurgi reactors operated till 1990 and extension of capacity in 1987 (+1 reactor)

FT Syngas Production :
Lurgi‘s Unique Experience

AIR LIQUIDE Lurgi

Lurgi‘s Technology & Design for Syngas production units for the Operating FT- Plants :

Sasol/Secunda , RSA	(Coal Gasification)
Mossgas, RSA	(Combined Reforming of NG)
Shell /Bintulu , Malayasia	(Partial Oxidation of N G)

F-T Commercial Plants

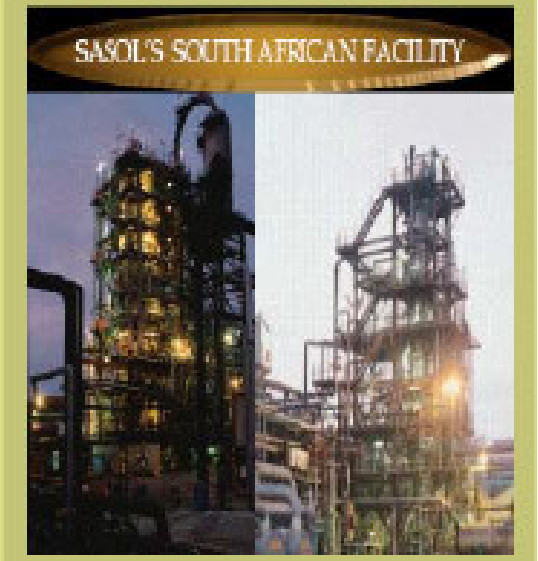
AIR LIQUIDE Lurgi

- SASOL – South Africa
  - 45 Years Commercial Experience
  - 160,000 B/D
  - Coal Feedstock
- Mossgas – South Africa
  - >15 Years Commercial Experience
  - 22,500 B/D
  - NG Feedstock
- Shell – Bintulu, Malaysia
  - > 13 Years Commercial Experience
  - 15,000 B/D
  - NG Feedstock
- QP/SASOL – Ras Laffan, Qatar
  - > 3 Years Commercial Operation
  - 34,000 B/D
  - NG Feedstock

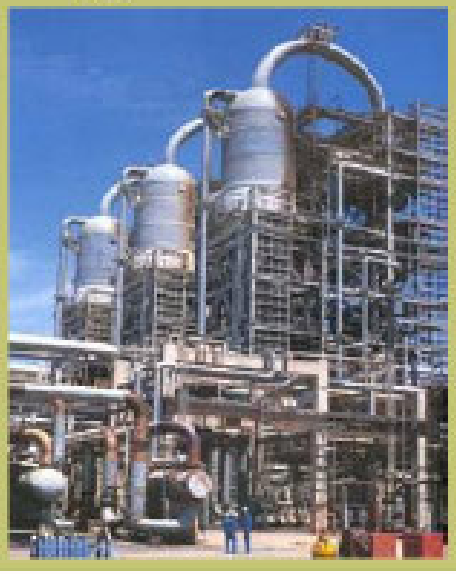
Worldwide FT Commercial Plants

AIR LIQUIDE Lurgi

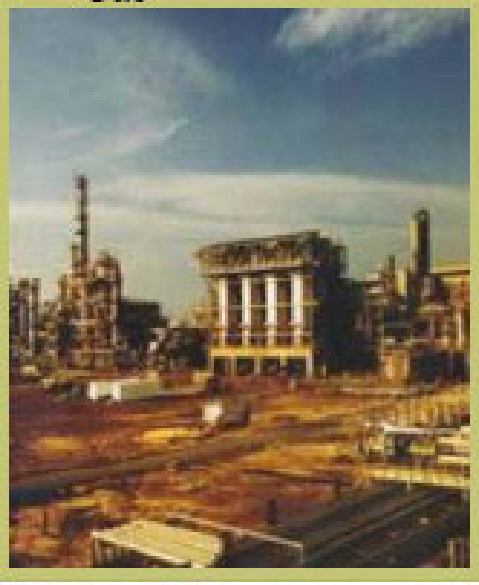
SASOL (S. Africa)
- 45 years commercial
  - 160,000 b/d+
  - Feedstock Coal



MossGas (S. Africa)
- 11 years commercial
  - 22,500 b/d+
  - Feedstock Natural Gas



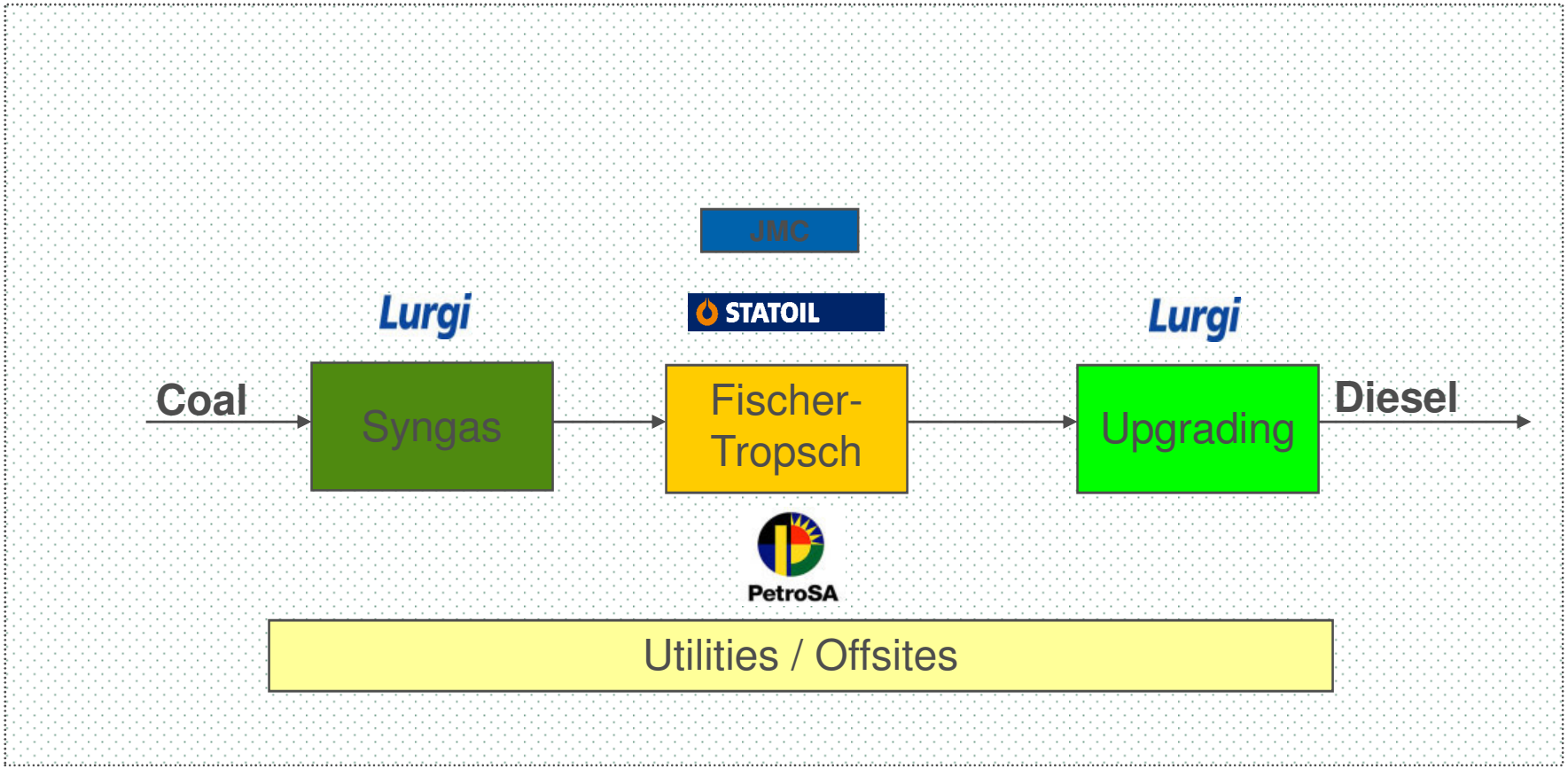
Shell (Malaysia)
- 9 years commercial
  - 15,000 b/d+
  - Feedstock Natural Gas



Licensing of CTL /GTL Technologies

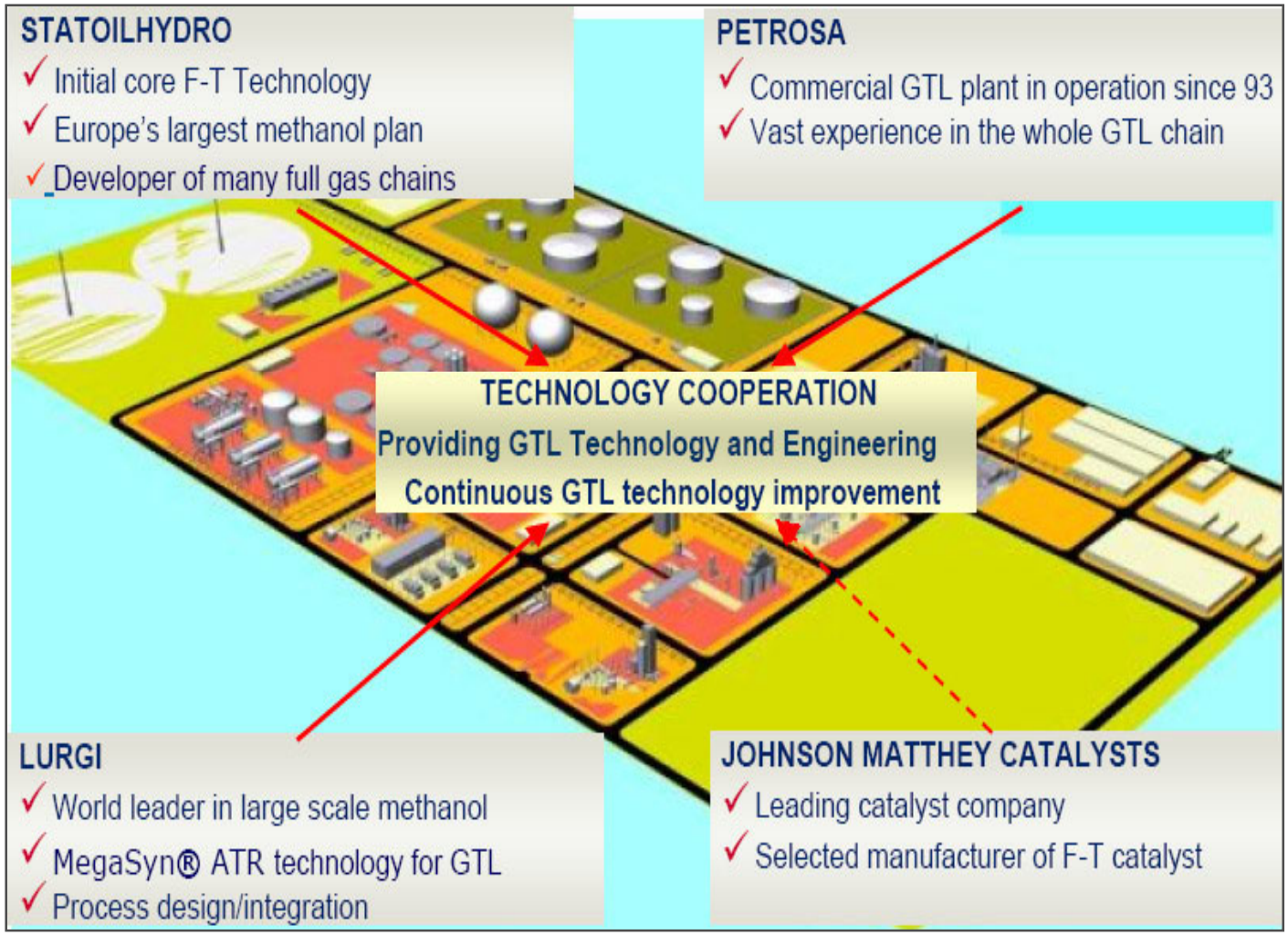
AIR LIQUIDE Lurgi

Bringing together first tier technologies and know-how



Demonstration of LT- FT Synthesis
GTL / FT Synthesis, Mossel Bay, RSA

GTL.F1 brings together the synergy of complimentary skills of three companies who are leaders in their respective fields…



LTFT Semi-Commercial Unit in Mossel Bay, South Africa

AIR LIQUIDE Lurgi

Key Figures:

- Capacity : Up to 1000 bpd
  45 000 Nm3/h
  Syngas
- Diameter : 2,7 m
- Height : 40 m
- Footprint : 25 m X 40 m

The world's largest demonstration plant for cobalt slurry bubble column reactor operation.

GTL.F1 LTFT Demonstration Plant Experience

- More than 14 000 hours on-stream.
- Catalyst and reactor performance exceed targets.
- Initial filtration challenges have been overcome by increased catalyst strength and optimized reactor internals.
- The chosen large scale of the semi-commercial demonstration plant largely reduces surprises in first commercial project, as compared to qualification by using pilot and / or smaller demo plants.
- Continuous performance evaluation and optimization of proprietary technology components.
- Operation of LTFT technology at semi-commercial size confirms design basis for commercial plants.

Recognition of GTL.F1 technology

CWC WORLD GTL AWARD 2008
LONDON UK 12 - 14 May 2008

Innovation in the Development of the GTL Industry

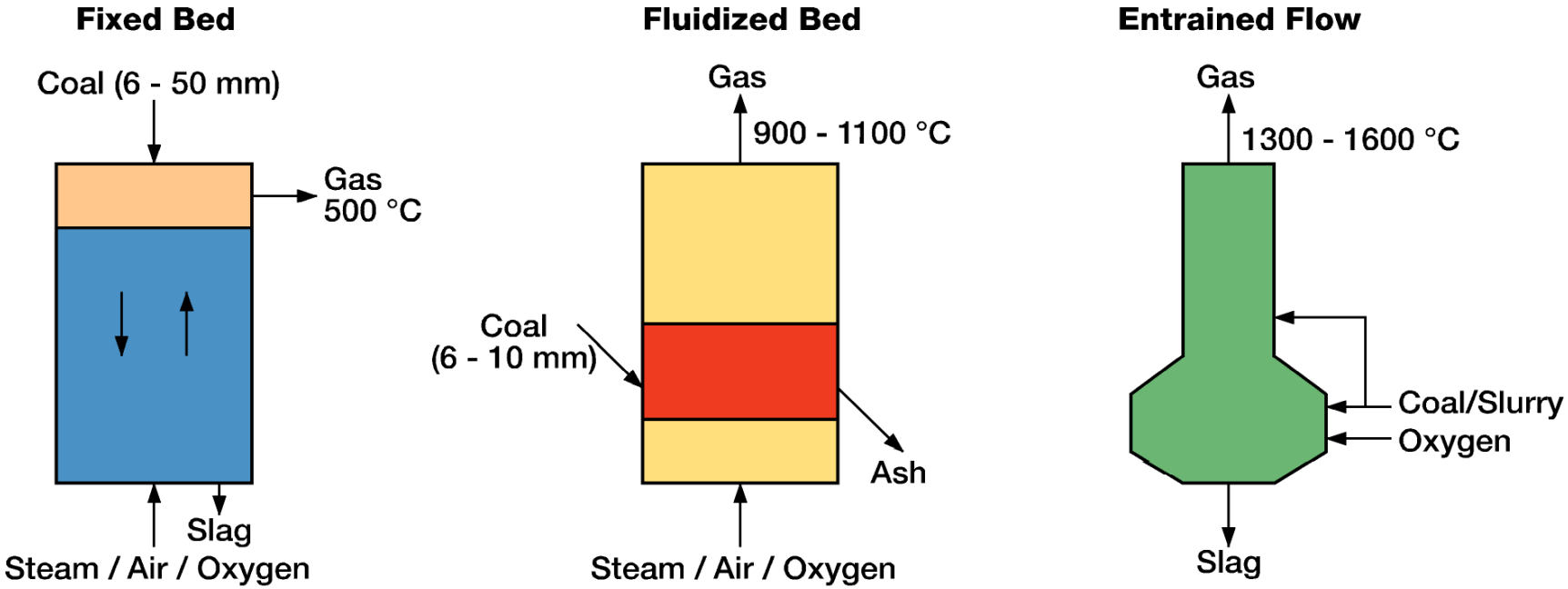
- " The Innovative solutions developed by GTL.F1 over the past 12 months concluded in the successful demonstration of a scale-up strategy adopted to mitigate the risks of licensing a full scale commercial plant. GTL.F1 reported successes in finding innovative solutions for slurry bubble column reactor design, wax-catalyst separation and to FT catalyst attrition."

Project Innovator of the year 2008

- " For the technology project which demonstrates the use of a progressive and innovative approach – an example of cutting edge thinking put into practice. This award recognizes projects in all areas of energy industry that push the boundaries of standard practice, and in so doing, promote new ways of thinking and understanding."

Overview on Gasification Technologies

AIR LIQUIDE Lurgi



Commercial and Demonstrated Processes

Lurgi dry bottom BGL	HTW Lurgi CFB	↑ *) PRENFLO) dry feeding ↑ SHELL) ↑ DESTEC) slurry feeding ↓ TEXACO)

*) gas flow

Coal Gasification Selection Basis : Feed Coal Characteristics

AIR LIQUIDE Lurgi

Gasifier Reactor	Fixed Bed		Fluidized Bed		Entrained Flow
Commercial Gasifier System	FBDB	BGL	Lurgi - CFB	HTW	Shell, GE, Conaco
Preferred feedstocks	Lignite, reactive bituminous coals, wastes	Bituminous coals, petcoke, wastes	Lignite, bituminous coals, cokes, biomass, wastes	Lignite, reactive bituminous coals, wastes	Lignite, bituminous coal, petcoke
Ash content	No limitation	< 25%	No limitation		25% (Maximum)
Preferred ash melting temperature	>1200° C	<1300°C	>1000°C	>1100° C	<1300° C
Caking / swilling	Non-caking to highly caking acceptable			Non-caking	Non-caking to highly caking
Ash removed as	Ash	Slag	Ash	Ash	slag

AIR LIQUIDE Lurgi

	Lurgi FBDB Gasifer *(Fixed Bed Dry Bottom)*	**BGL Gasifier** *(British Gas Lurgi)*	**Lurgi CFB Gasifier** *(Circulating Fluidized Bed)*	**HTW gasifier** *(High Temperatur Winkler Process -Fluidized Bed)*	**Shell / GSP Gasifier** *(Entrained Flow Process)*	**E-Gas Gasifier** *(2 Stage Entrained Flow Process)*	**Texaco Gasifier** *(Entrained Flow Process)*
feed	screened	screened	screened & crushed	screened & crushed	ground & dry (dense flow)	ground & wet (slurry)	ground & wet (slurry)
fuel size requirements	size 6 - 50 mm (max 80 mm)	size 6 - 50 mm (max 80 mm)	2 - 6 mm (max 10 mm)	2 - 6 mm (max 10 mm)	< 0.5 to 0.1 mm	< 0.5 to 0.1 mm	< 0.5 to 0.1 mm
gasification agent(s)	air + steam, oxygen + steam	oxygen + steam	air + steam, oxygen + steam, CO_2 + oxygen		oxygen + steam	oxygen + (steam)	oxygen + (steam)
products	town- gas, syn-gas, fuel-gas						
Gasification pressure (MPa)	3 to 10	3 to 7	atm → 0.15	1 – 3	2.5 to 4	2.8	2.5 to 40
Unit capacities MWth (max.)	350	350	150	700	700	520	500
Typical gas composition (oxygen blown, main components Vol-%)							
Feedstock	Lignite	Bituminous	High ash Bit.	Lignite	Bituminous	Petcoke	Bituminous
CO_2	33.0	3.2	16.9	20.0	0.8	17.1	0.8
CO	14.6	53.5	41.6	36.3	62.1	47.2	62.1
H_2	40.0	27.4	37.9	33.3	31.2	28.1	31.2
C_{2+}	11.7	7.6	2.9	6.5	Traces	4.0	Traces
H_2S/COS	0.4	1.0	0.2	0.2	0.3	1.6	0.3
N_2	0.3	7.3	0.5	3.7	5.6	2.0	5.6

Typical Low Rank Sub-Bituminous Indian Coal Analysis

AIR LIQUIDE Lurgi

➢ Proximate Analysis of Coal (Typical Air Dried Coal) (in % Wt)

- Moisture : 6.4 – 7.5
- Ash : 34 – 37
- Volatiles 26.2 – 26.5
- Fixed Carbon : 31.6 – 31.9

➢ Ultimate Analysis of Coal (Typical DAF Basis) (Figures in % Wt)

- Carbon : 76.1 – 76.4
- Hydrogen : 5.3 – 5.4
- Nitrogen : 1.8 – 1.9
- Sulphur : 0.6 – 0.7
- Oxygen : 15.5 – 16.1 (By Diff)

➢ Ash Characteristics (AFT)

- Initial Deformation/Softening Temp : 1500 – 1550°C
- Hemispherical Temp : 1550 – 1590°C
- Flowing : (+) 1600°C

Ash Composition (% Wt)

- Silica : 60 – 67%
- Alumina : 25 – 25%
- Alkali Metal ($CaO+MgO+K_2O+Na2O$) : 1.8 – 2%
- Fe_2O3 : 2.0 – 4.5%

FBDB Gasifier and Coal Acceptibility

AIR LIQUIDE Lurgi

- Gasifier are in operation for 320 days continuously, 24 hours per day without any standby & spare units
- Reliability: annual gasifier availability in excess of 92% for total train (average)
- Longest down time period of 30 days for major overhaul
- Inherent fail-safe process design
- Cold start up to design load within 10 hours
- Turn down ratio (design to minimum): 2.7 (Av 35%)
- Can accept a wide range of coal characteristics:
  - Particle Size: 5-50 mm
  - Ash Content: 6-40 %
  - (Ash + Moisture) Content: 50 %
  - Coal Rank: Bituminous; sub-bituminous; lignite and anthracite

Coal Characteristics for FBDB Gasification

AIR LIQUIDE Lurgi

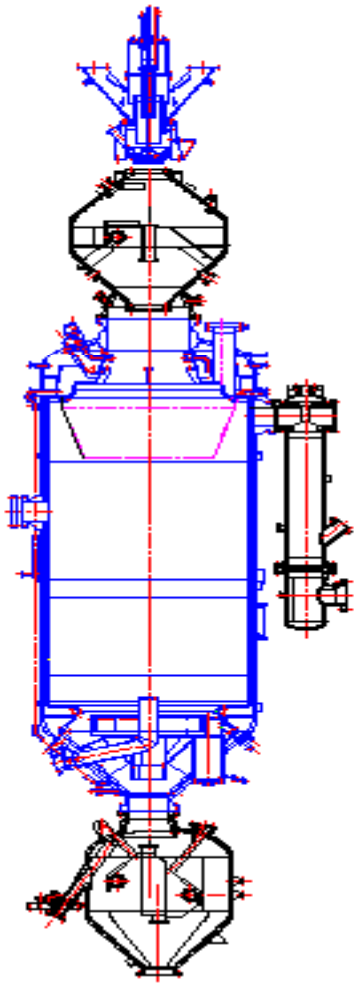
• Total moisture (wt%)	2 – 36
• Proximate analysis (air dry basis wt%)	
- Inherent moisture	4 - 34
- Ash content	6- 35
- Volatiles	12 -38
- Fixed carbon	30 - 54
- Total sulphur	0.3 – 1.5
• Calorific value (MJ/kg- air dry basis)	12 – 27
• Free swelling index	0 – 1.5

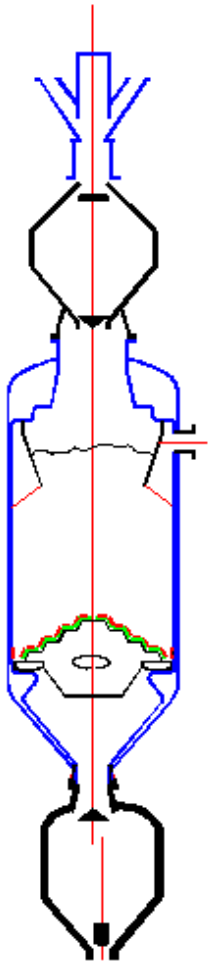
Critical Ash Characteristics in Coal for FBDB Gasification

AIR LIQUIDE Lurgi

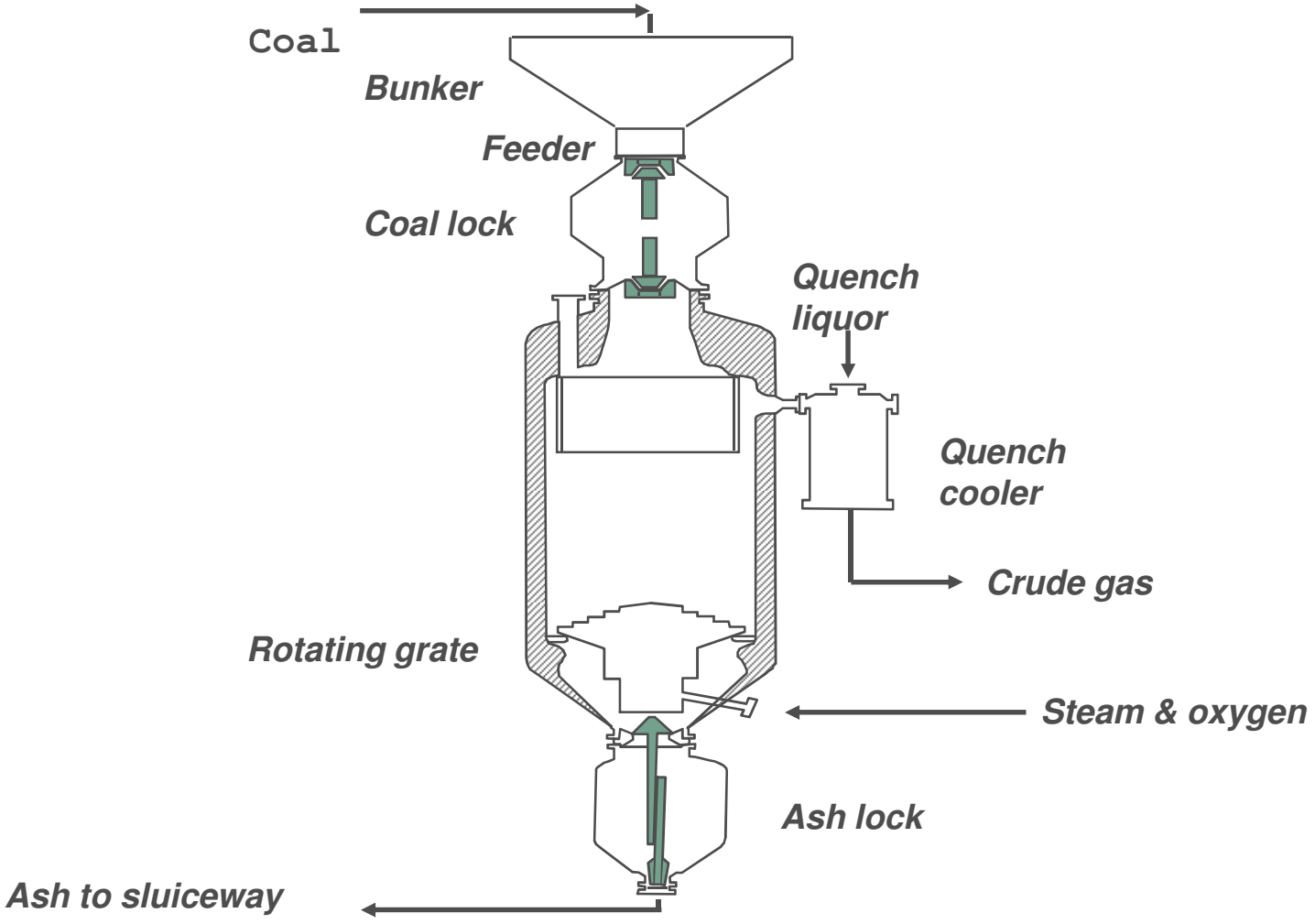
• Ash fusion temperature (°C) - Oxidizing conditions	
• *Initial deformation point*	1190 - > 1500
• *Hemispherical point*	1220 - > 1500
• *Fluid point*	1338 - > 1500
• Types of coal	Bituminous; Sub-bituminous Anthracite; Lignite

Lurgi FBDB Coal Gasifier

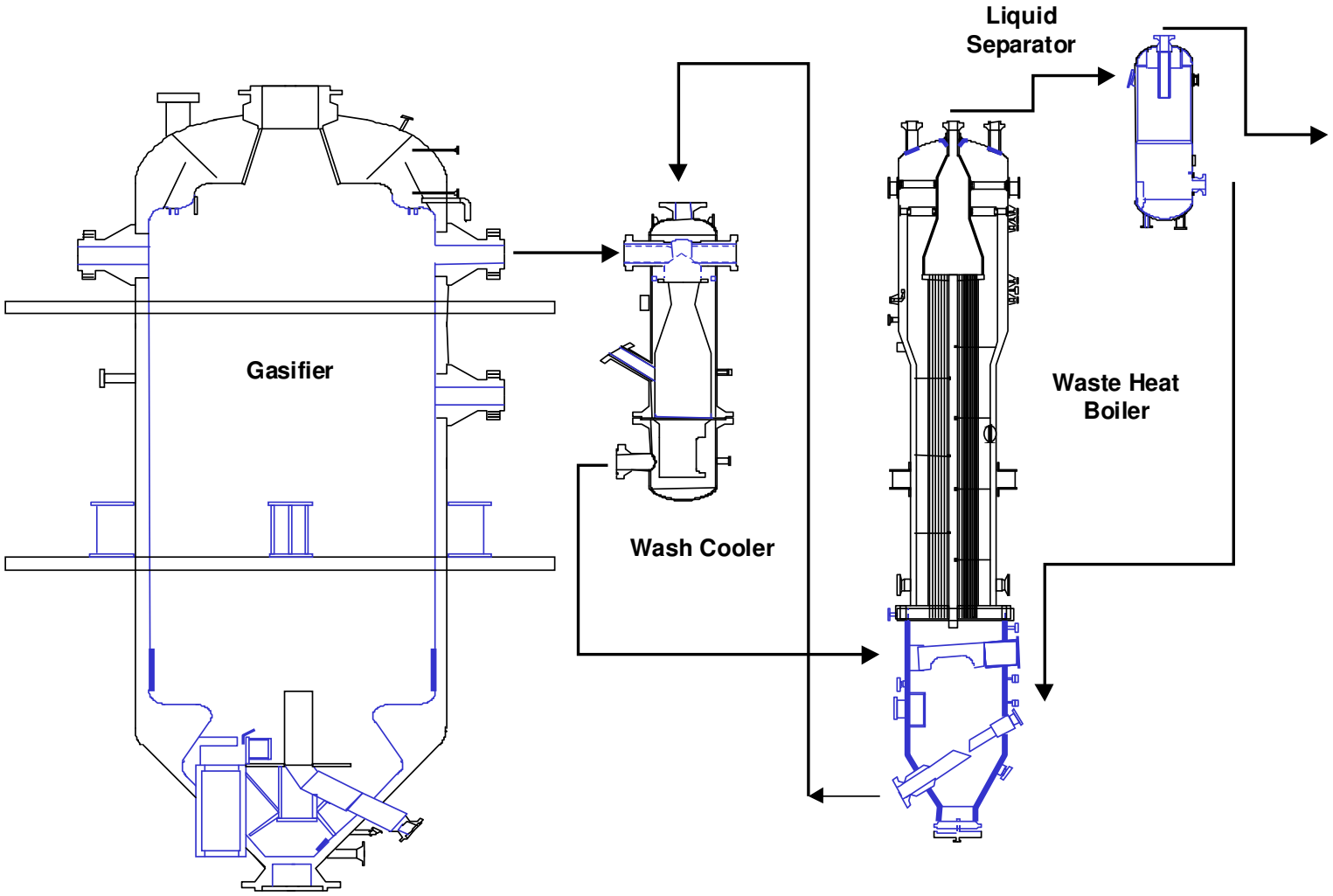




Sasol-Lurgi Fixed Bed Dry Bottom Gasifier



FBDB Gasifier Module Definition



Recommendations II

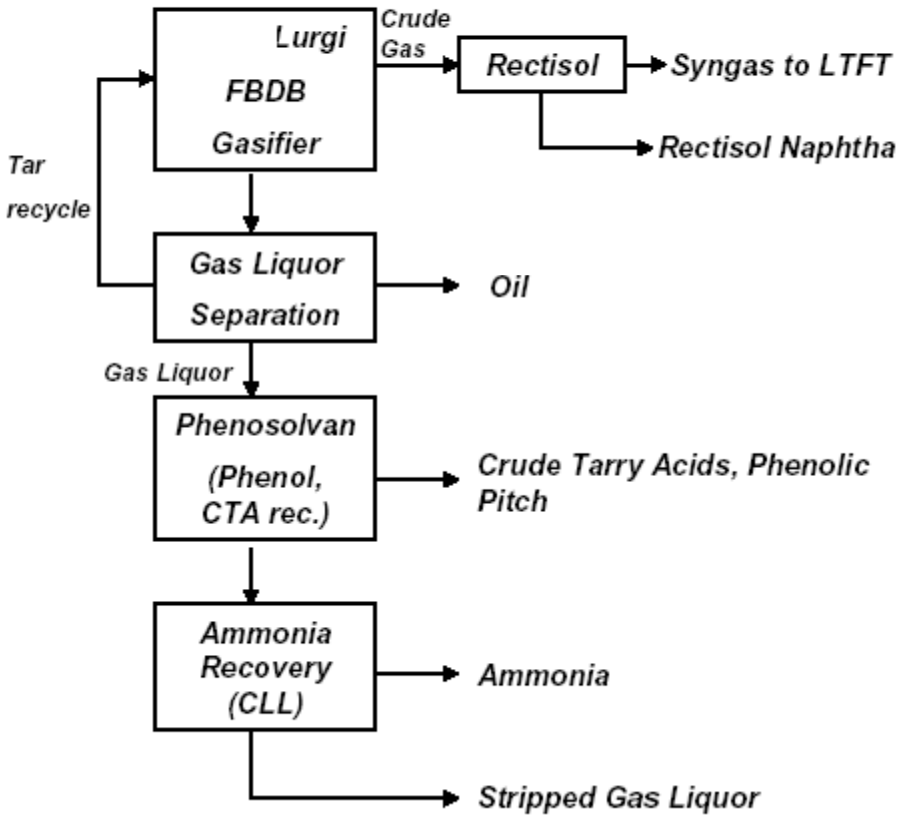
AIR LIQUIDE Lurgi

- ***The FBDB coal gasification process is:***
  - Strategic alternative to oil and gas.
  - Well demonstrated, low risk, proven technology.
  - Suited to a wide variety of low grade, high ash content coal.
  - Robust and mature technology – very high reliability and on-line availability factors.
  - Technology can be deployed for various coal based applications including the production of Town Gas; Substitute Natural Gas; Electricity or a combination to maximize coal utilization.

- ***The FBDB Coal Gasification Process offers:***
  - Unsurpassed experience and expertise in the field of coal and gasification science.
  - Expert input throughout entire project cycle related to a coal gasification venture.

Gas Island - Base Scheme

Lurgi FBDB Gasifier Island - typical Coal-to-Liquids flow scheme



Key Baseline Technology Selections

Gasification: Mark IV / V S-L FBDB Gasifiers (55 - 85 km3n/h crude gas per gasifier)

Gas Cooling: Double waste heat boiler (8bar steam, 4 Bar Steam) heat rec. configuration

GL Sep: Square modular sep. design, suff. sep capacity, sep oily / dusty GL routes, req. chemical/temp density information.

Phenosolvan: Std design, improved heat integration, less direct steam

Ammonia Recovery: CLL technology, total-stripper improved design.

Rectisol/Sulphur Recovery: Selective Rectisol / Oxy-Claus

Environment: Application of latest vent/fugitive emission control technology (e.g. vapour recovery), closed drains, tanks & pits, no tar filtration

The Suggested Approach to CtL

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- Coal characteristics will largely determine technology choice – Analyze coal for gasifiability
- Perform site specific, comparative study including all techno-economic considerations on suitable gasification technologies
- CTL Gasification study must include integration considerations with Fischer-Tropsch technology
- Consider only proven, commercial scale technology to minimize risk for multi train applications

The Proposed CTL plant concept in India will have capacity of 80,000 bbl/d

AIR LIQUIDE Lurgi

- The project will be realized in two distinct phases each having capacity of 40,000 bbl/d which shall consist of
  - Two trains of Coal Gasification,
  - Two trains of Gas Cooling & Purification,
  - Two trains of FT Synthesis and Product Separation and
  - Single train of Product upgradation & Separation
- 57800 TPD Sized Coal (19.3 MMTPA) is estimated to be required for 80,000 bbl/d CTL plant.

Future expansion of the project will be undertaken after detailed evaluation of all possible options.

Typical CtL Product Yield
Fischer Tropsch Diesel

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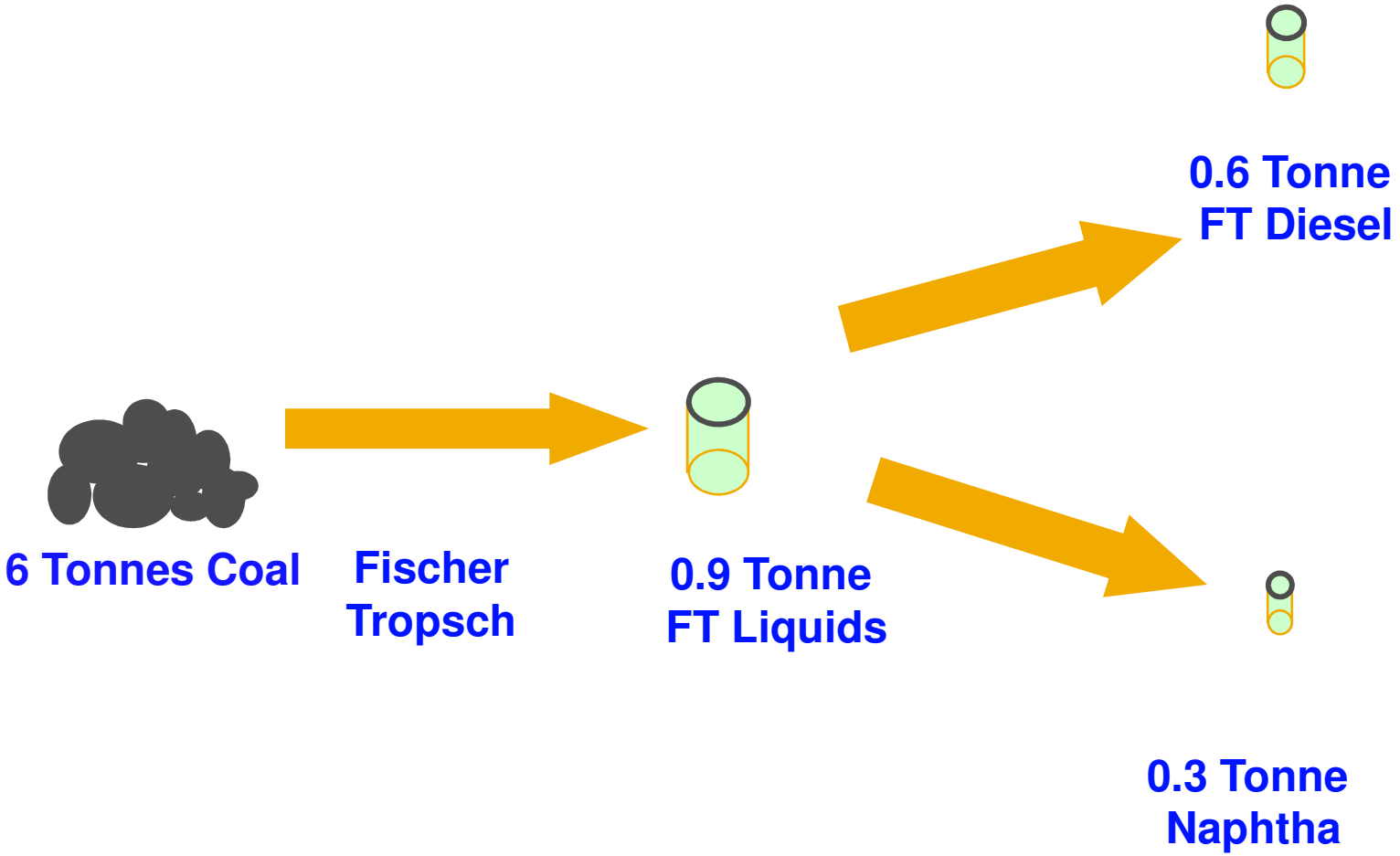

Source : BP 2006

CTL, Orissa, Global Mass and Balance and Overall Efficiency

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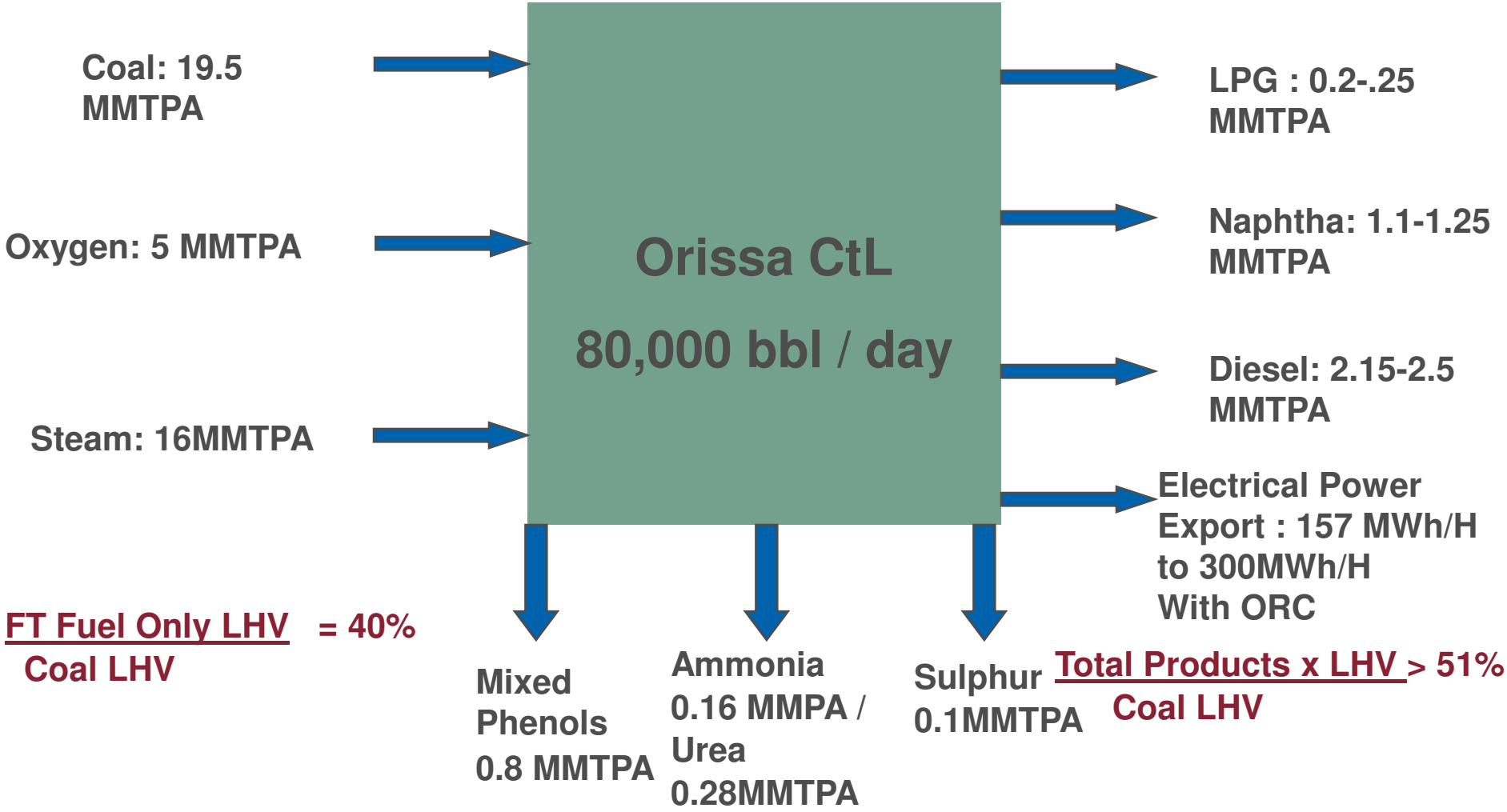

FT Fuel Only LHV / Coal LHV = 40%

Total Products x LHV / Coal LHV > 51%

Advantages of FT Synthesis

AIR LIQUIDE Lurgi

- Commercially proven technology
- FT Hydrocarbons ideal for diesel due to paraffinic nature
- FT Diesel
  - Cetane Number > 70
  - Zero Sulphur
- Gasification/ FTS can be economic as well as attractive alternative to replace additional World Oil demand:
  - Long term Energy Security
  - Co-production of electricity and other products
  - Ultra-clean energy fuels
  - Indigenous investment and employment

The CtL Concept from Lurgi :
For High Ash Low Rank Indian Coal

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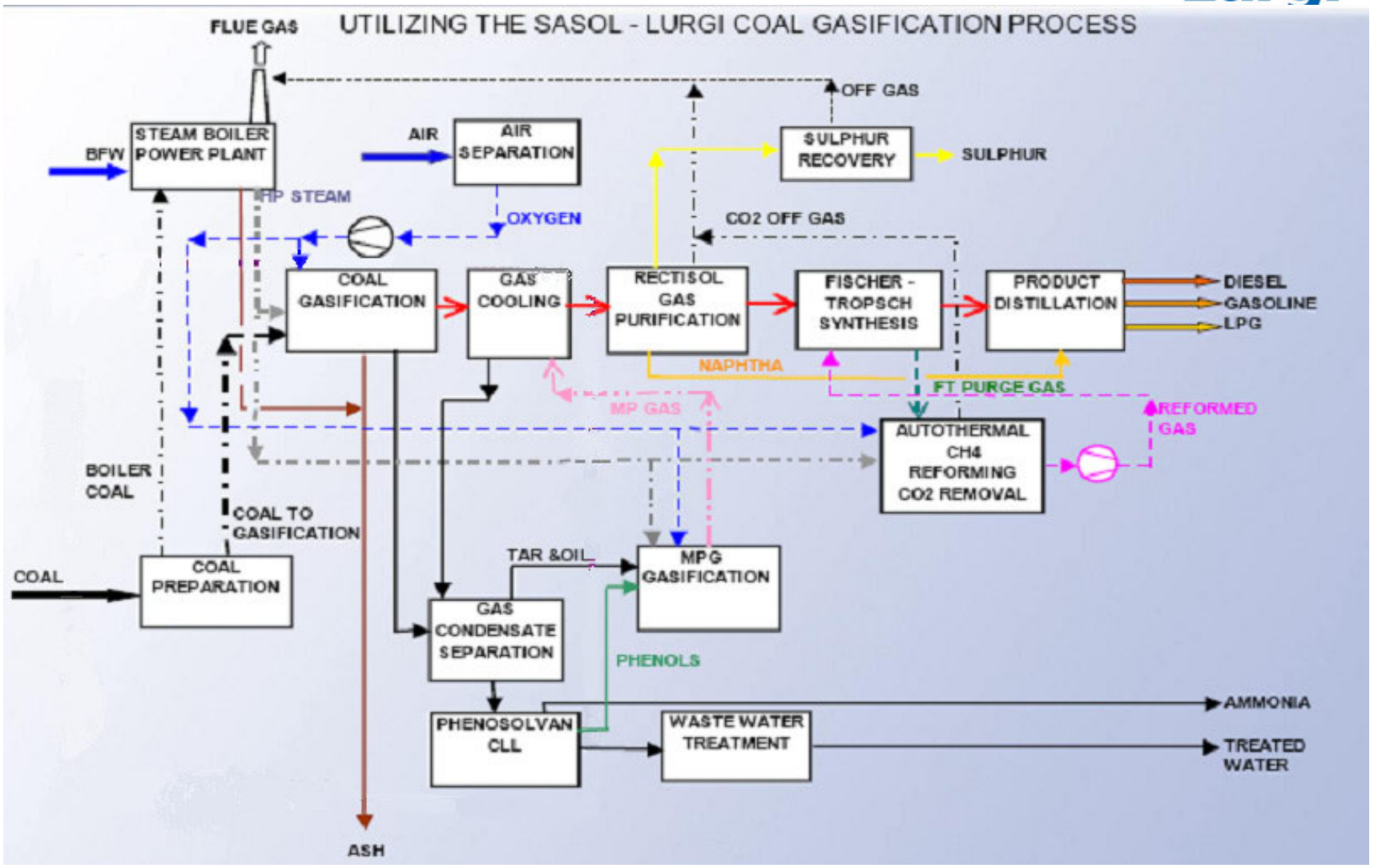

Process Block Diagram :FT SynGas from Coal

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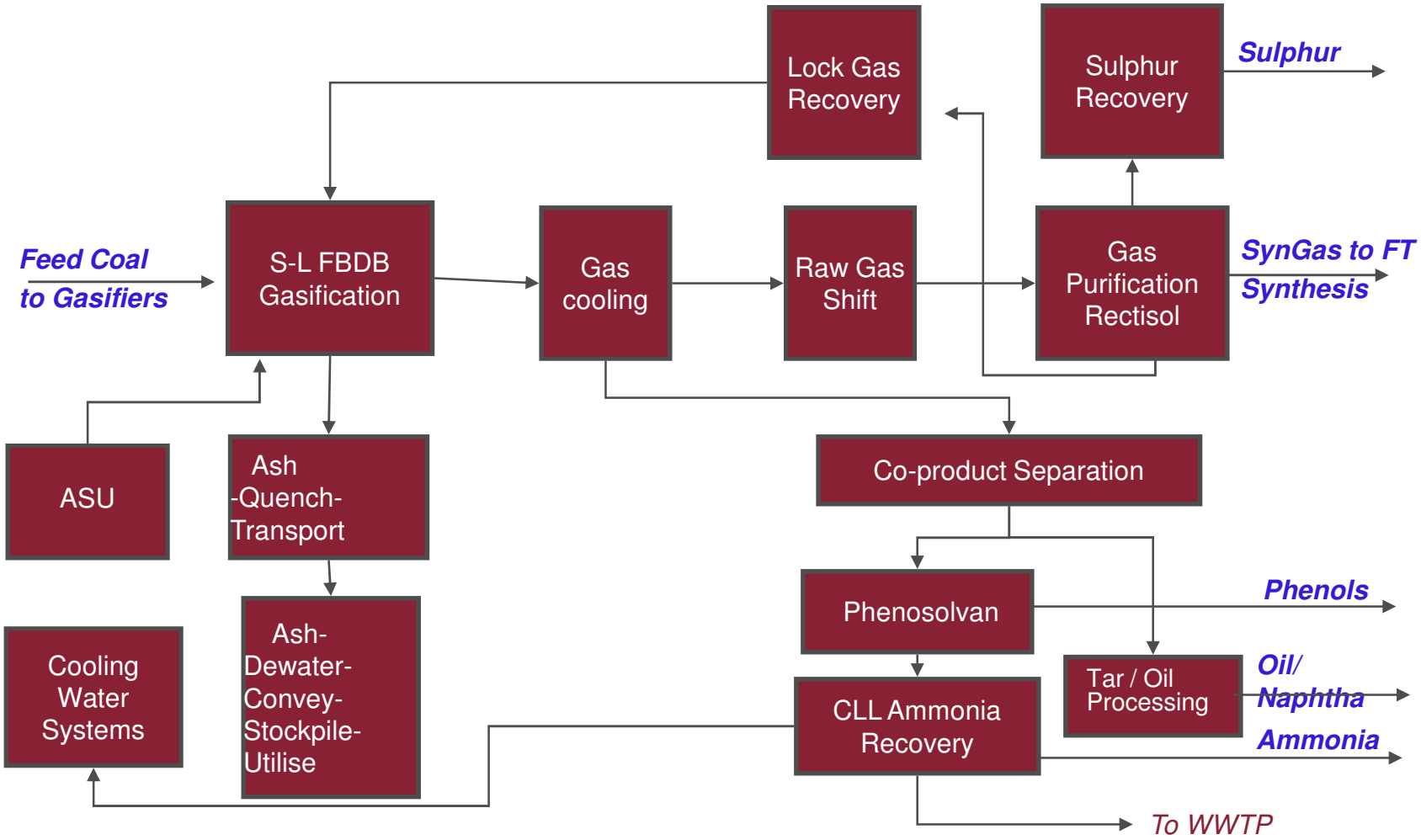

Reference Plant for Lurgi's FBDB Gasification & ARGE FT Synthesis

Comparison: Crude Oil Refinery versus Coal to Synfuels (CTL)

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Daily cost comparison Refinery against CTL with capacity 35.000 bpd

	Unit of measure	Refinery	CTL
Investment (Specific)	US$/bl	25.000	70.000
Opex	US$/bl	4	10
Capex	US$/bl	13	36
Depreciation	years	5	5
Crude Oil Coal 10 US$/st	US$/bl	35 -	- 6
Production cost	US$/bl	52	52

CtL Economic Competitiveness

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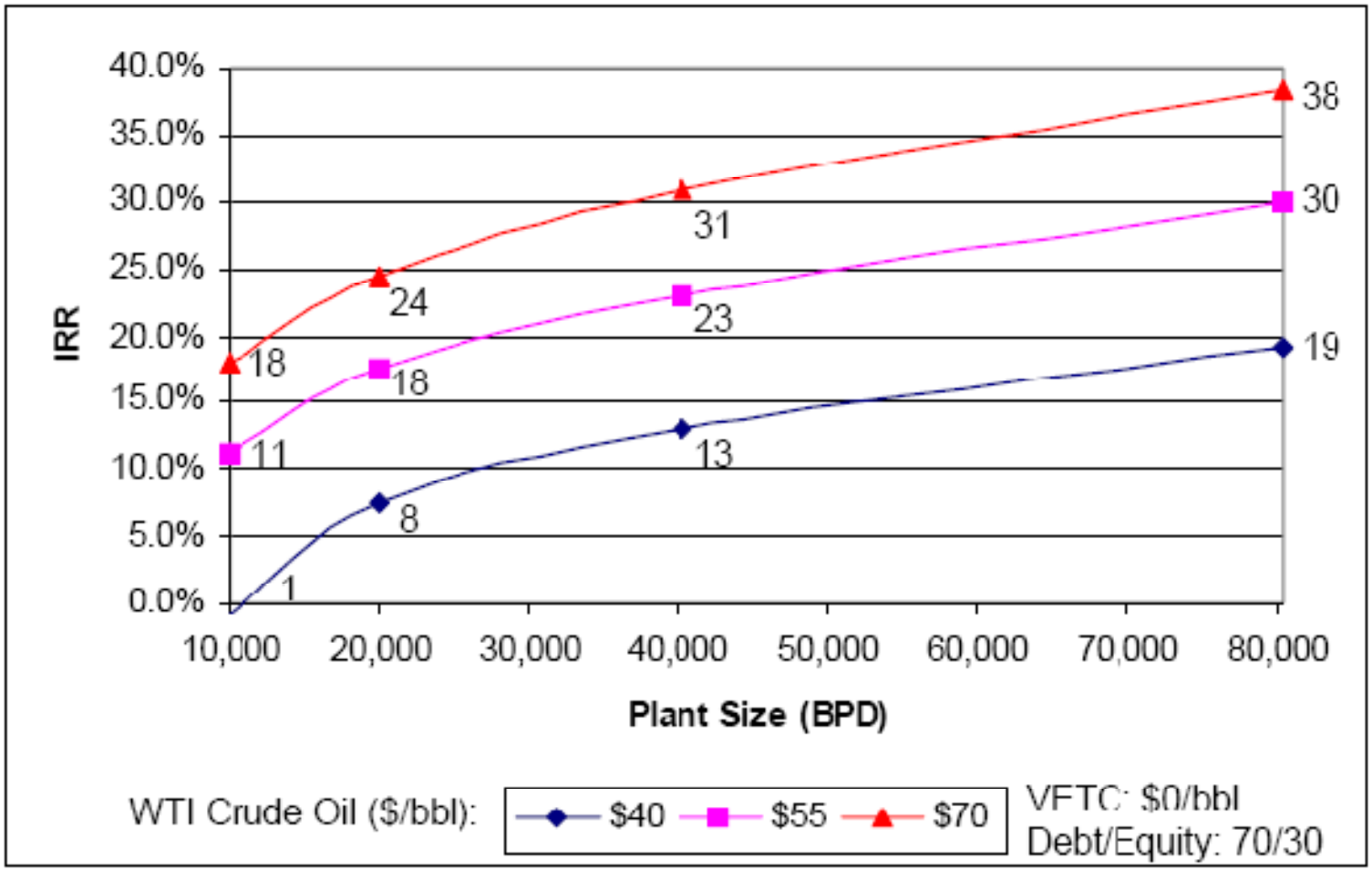

Project Execution Model for Integrated Gasification Facility

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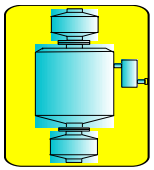
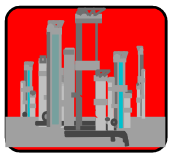
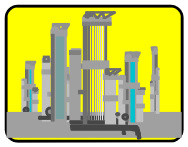


Gasification



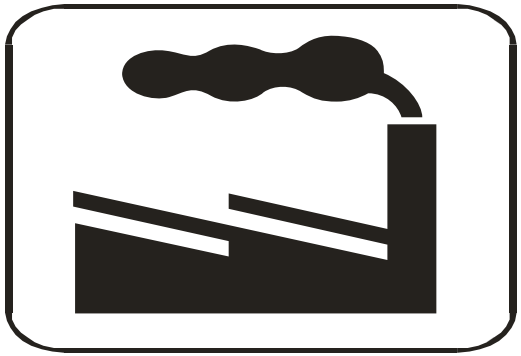
Steam Generation



Oxygen Supply

Coal Mining

Coordinating Engineering Contractor



TECHNOLOGY / PLANT SUPPLIERS

Typical Project Stages for Integrated Project Execution

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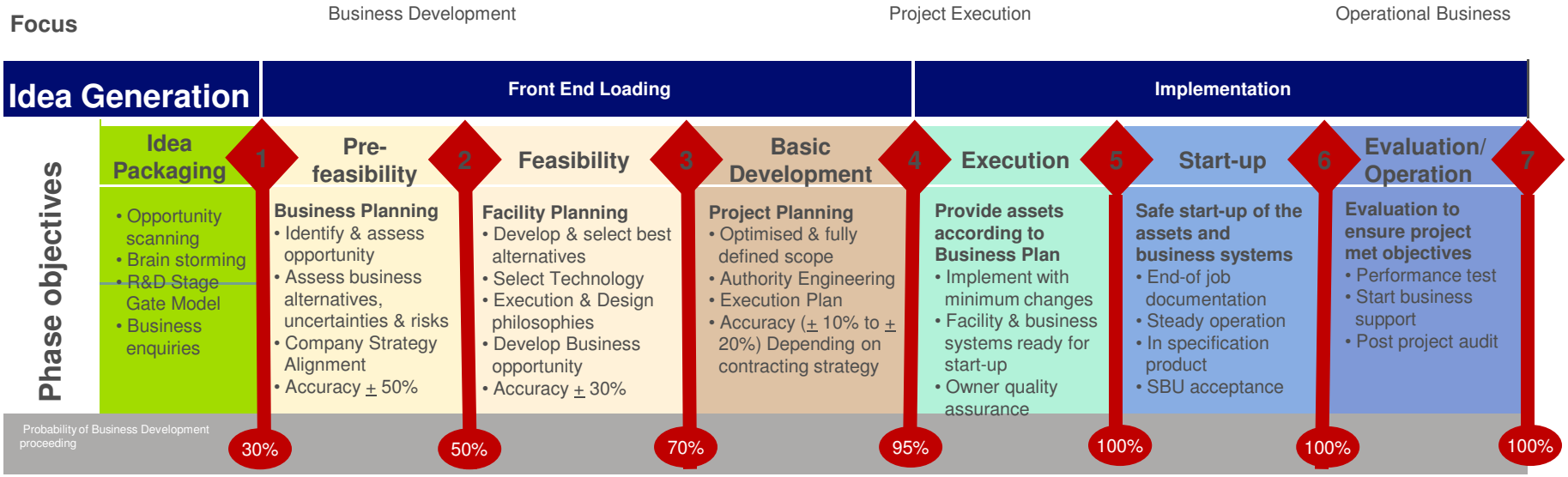

Coal to SNG & CO2 Sequestration

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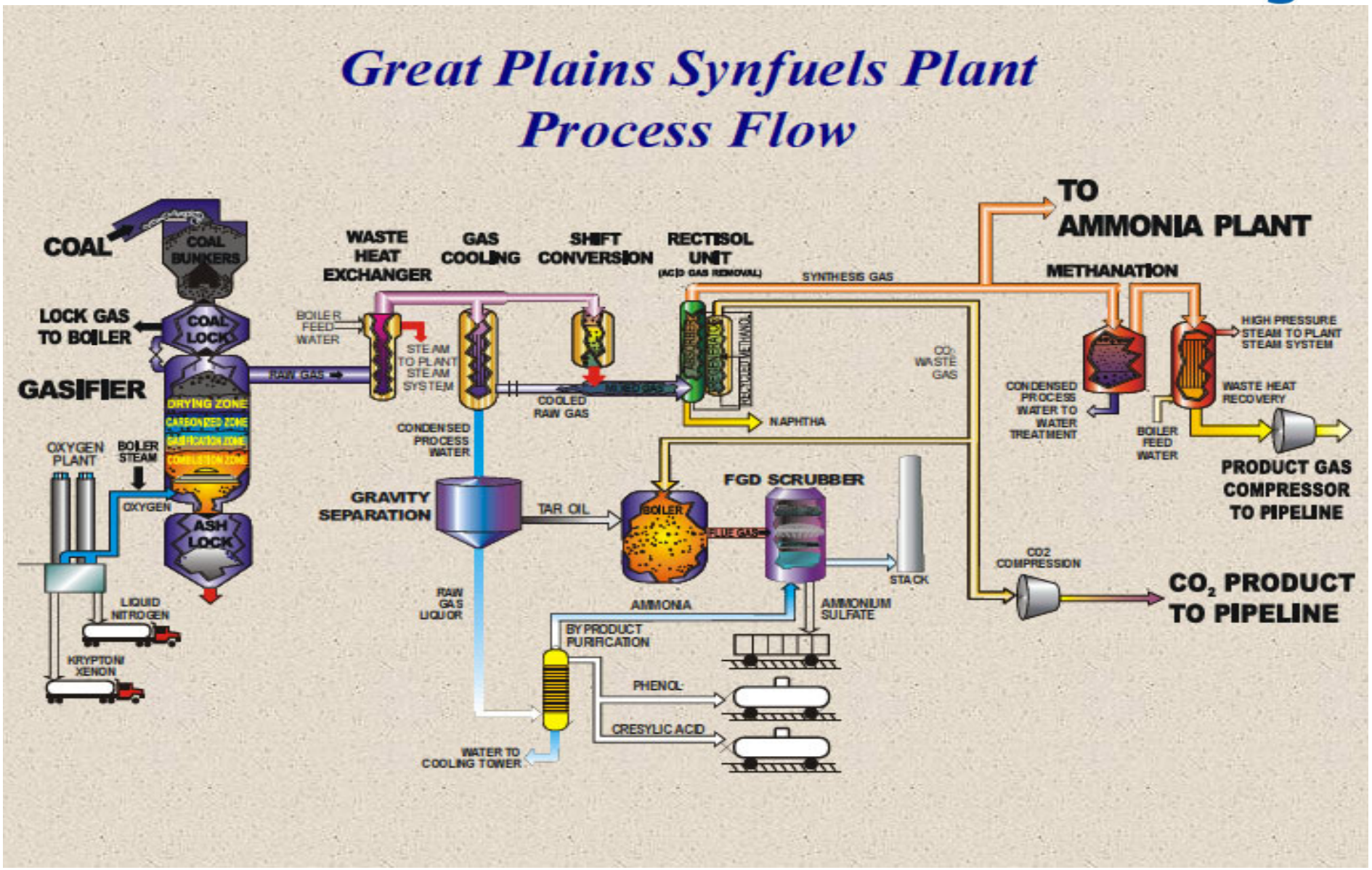

By-product Recovery at Coal based SNG Complex, Dakota, USA

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Ammonia
1150 tpd

Ammonium Sulfate
350 tpd

Phenol
33 million lb/yr

Cresylic Acid
33 million lb/yr

CO_2 from Rectisol for EOR at SNG Complex at Dakota USA

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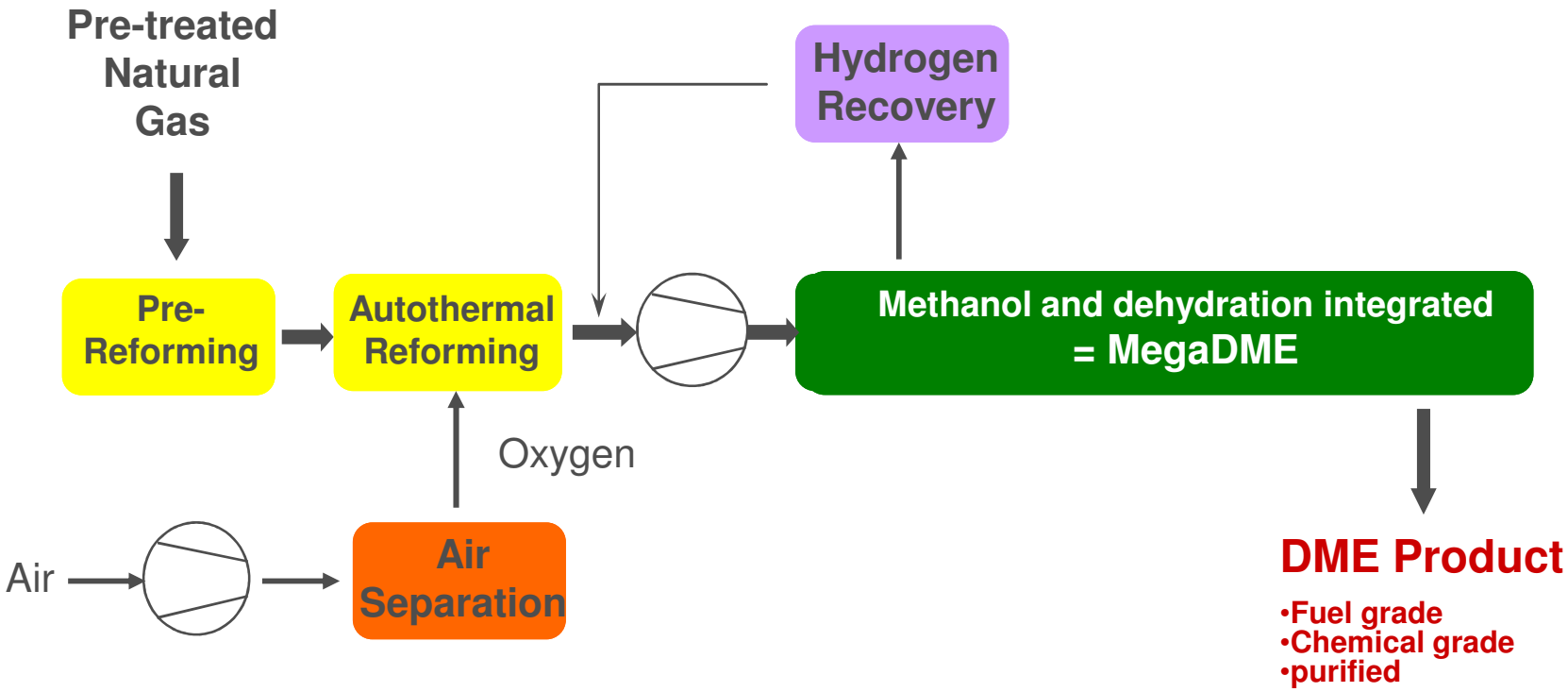
Natural Gas Based Mega DME

Lurgi MegaDME® Process – natural gas based



From MegaMethanol® to MegaDME®: "just" add the dehydration, meaning, to integrate it with methanol loop and distillation!

Coal Based Methanol and Propylene
Lurgi MTP Technology

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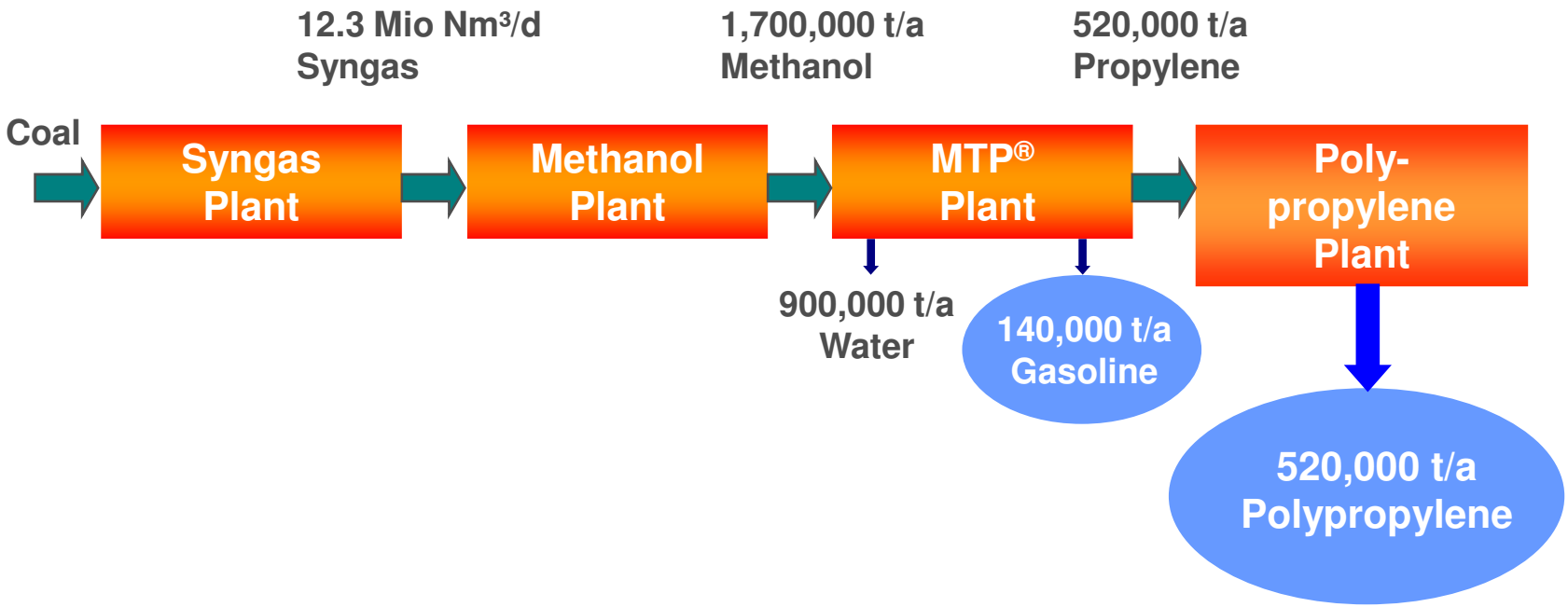
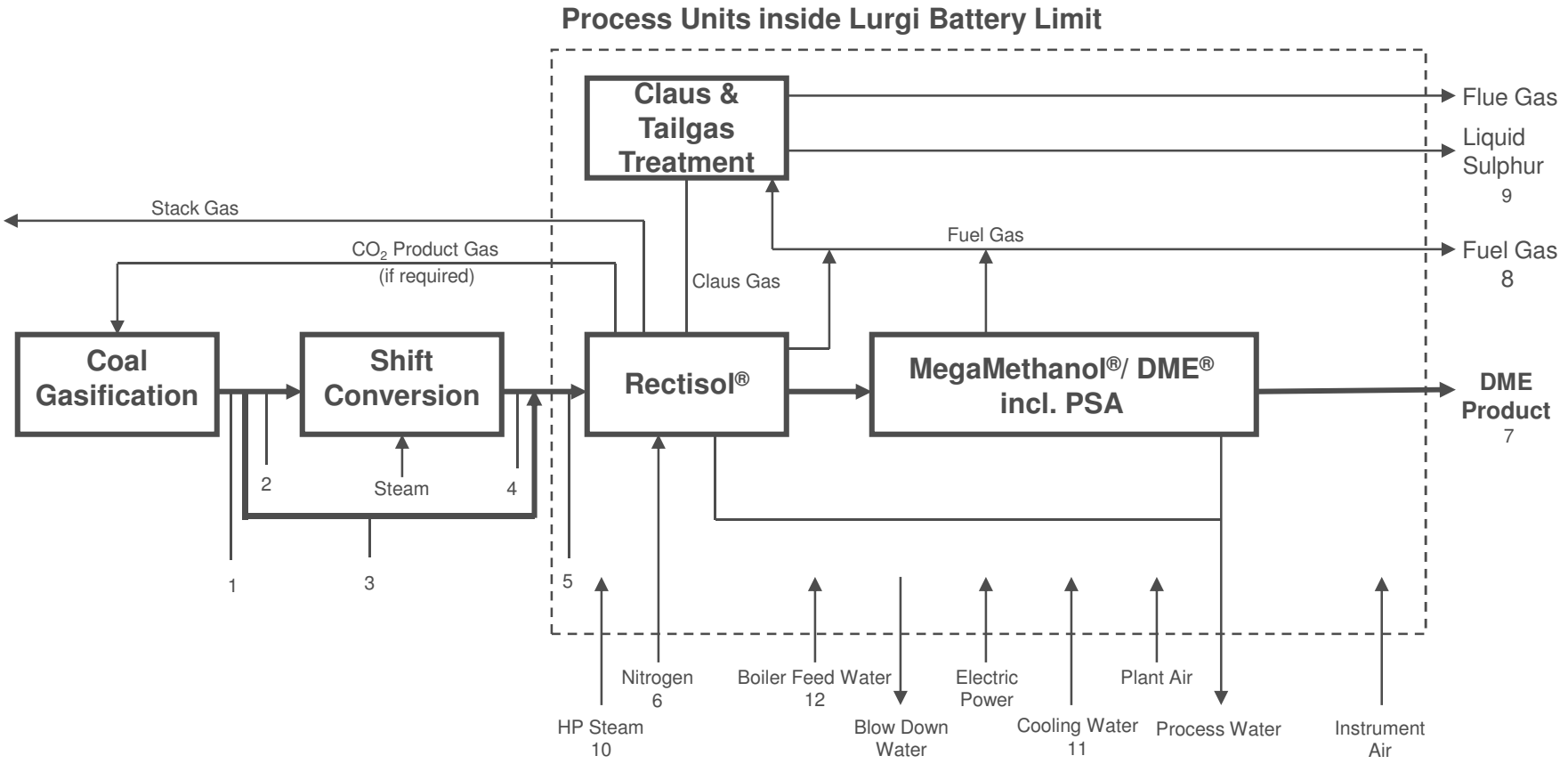


Lurgi MegaDME® Process – coal based

Process Block Flow Diagram – 3 in 1 "MegaDME"



From MegaMethanol® to MegaDME®

MegaMethanol plant
Capacity 5.000 t/d Methanol (gas-based)

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Methanol Economy : George Olah

AIR LIQUIDE Lurgi

“ Storing Energy in the form of Methanol, not Hydrogen, could end our dependence on Fossil Fuels and transform Carbon Dioxide (CO2) from a Global Warming Liability into an essential Raw Material for a Methanol based Economy “

George Olah
Beyond Oil & Gas : The Methanol Economy

Commercial Applications

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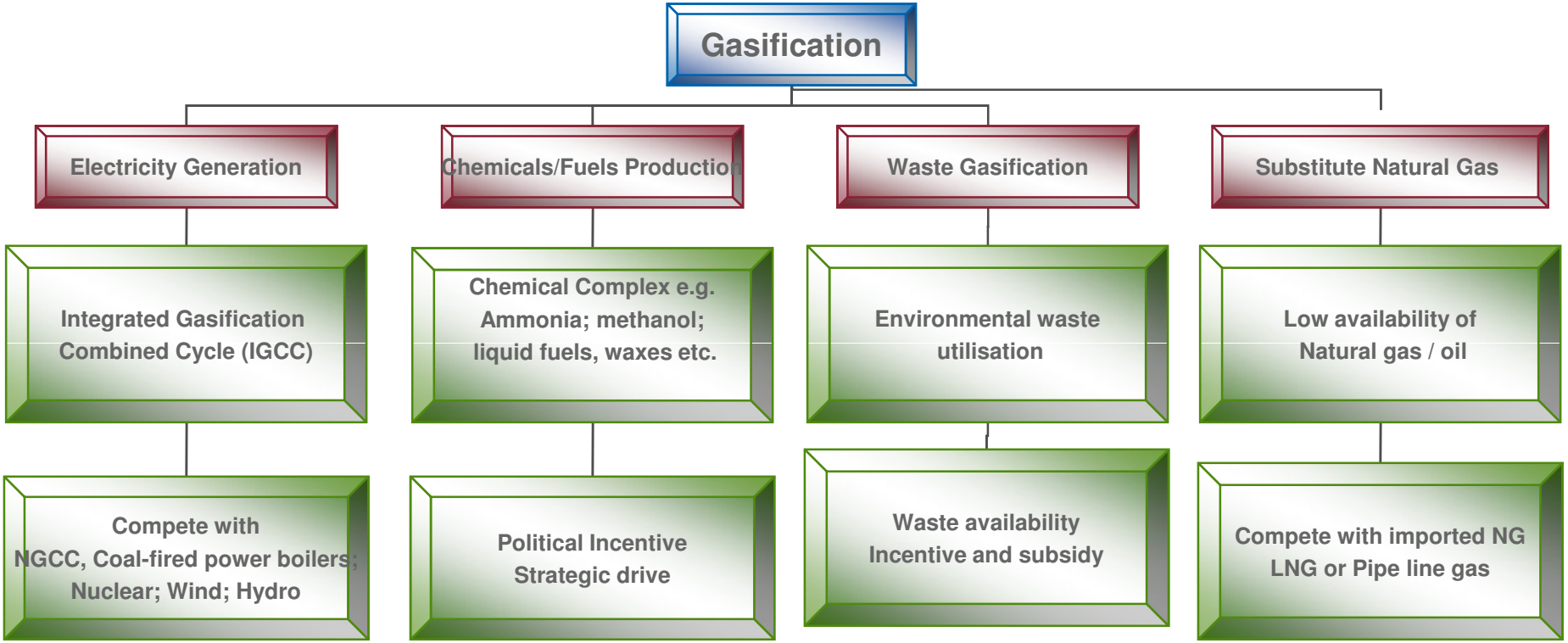
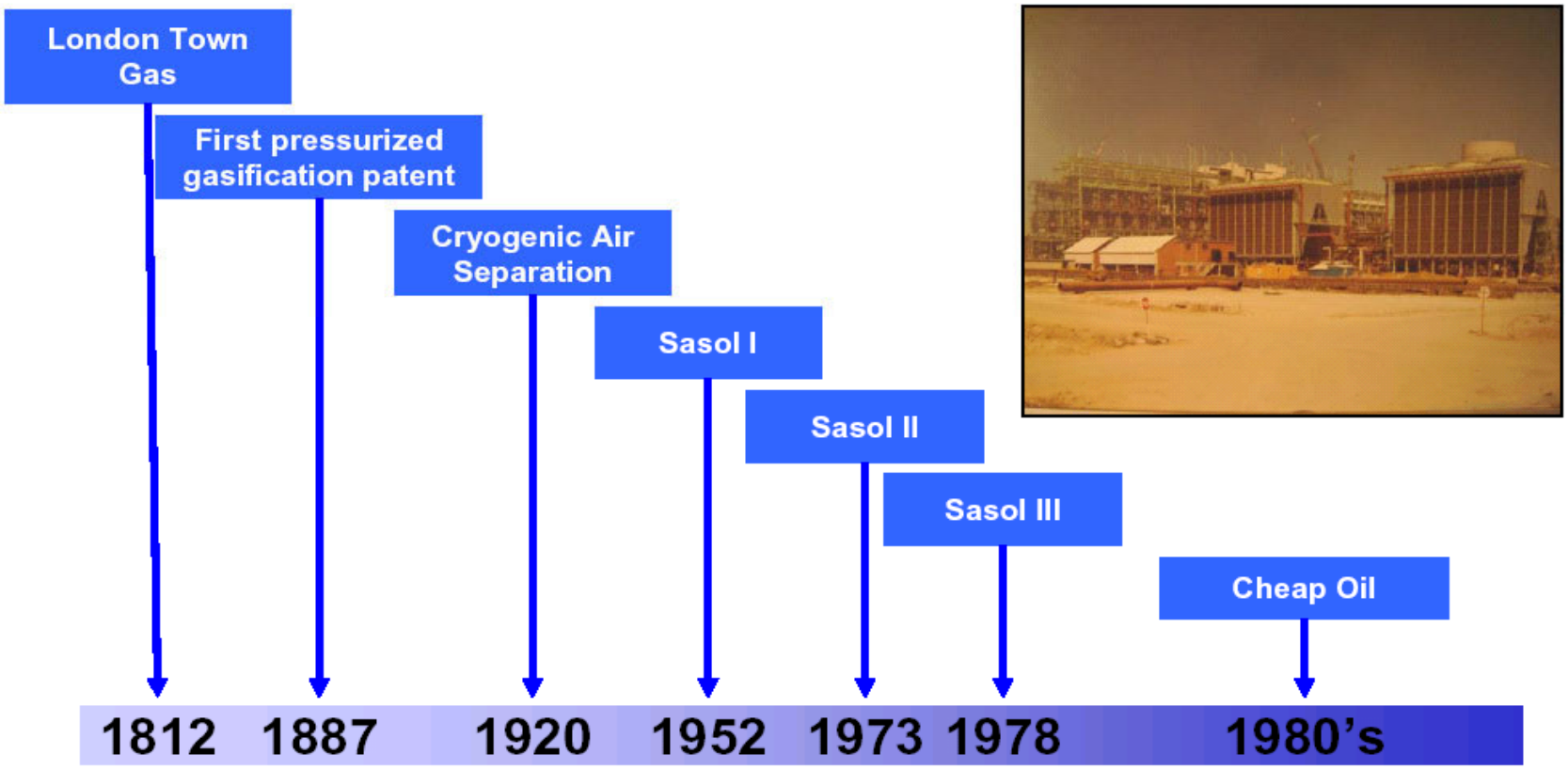


Gasification is unique – "…creates a primary energy carrier…"

Gasification Development

History of Gasification…



Higman, C. & Van der Burgt, M. 2003 Gasification. United States of America: Elsevier.