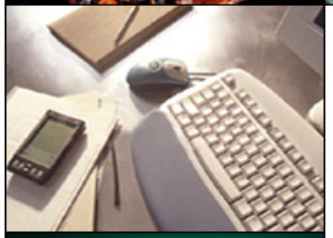

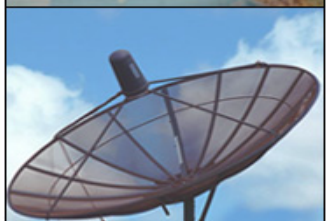

Underground Coal Gasification Workshop, Kolkata

Asian–Pacific Partnership on Clean Development and Climate

Presentation by

Mr. V.E. Chandrashekar, General Manager

Larsen & Toubro Limited

Heavy Engineering Division

13 Nov, 2006

Larsen & Toubro Limited

- *L&T builds Gasification equipment to the engineering requirements based on Process Licensor's Technology offered to the Buyers/ End Users.*
- *The contents of the presentation are based on various state-of-art informations from world renowned Technological Institutes, Process Licensors and Utility Providers.*

Topics Covered

- Coal, Its New Look and Potential
- L&T, Experience with SCGP
- Fossil Fuels, Industrial and Commercial Utility
- Gasification Challenges in Indian Scenario
- Coal for IGCC & CTL

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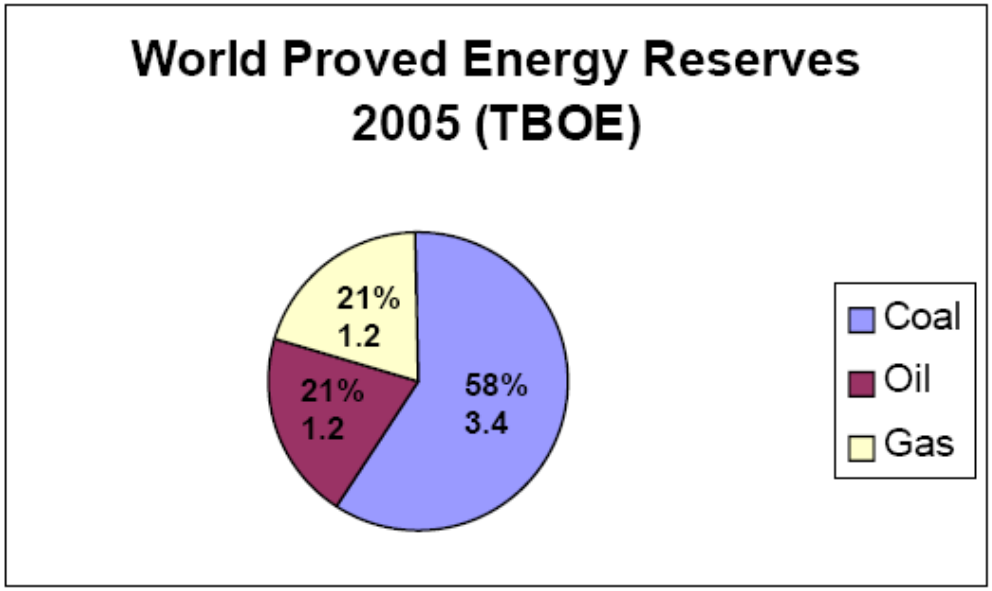
Coal, Its New Look and Potential

Energy Security: Coal Reserves Are Huge



World Proved Fossil Fuel Reserves Total 5.4 Trillion Barrels of Oil Equivalent (TBOE)-Coal is 58% of this Total

Source: BP Statistical Review of World Energy 2006

Coal, Its New Look and Potential

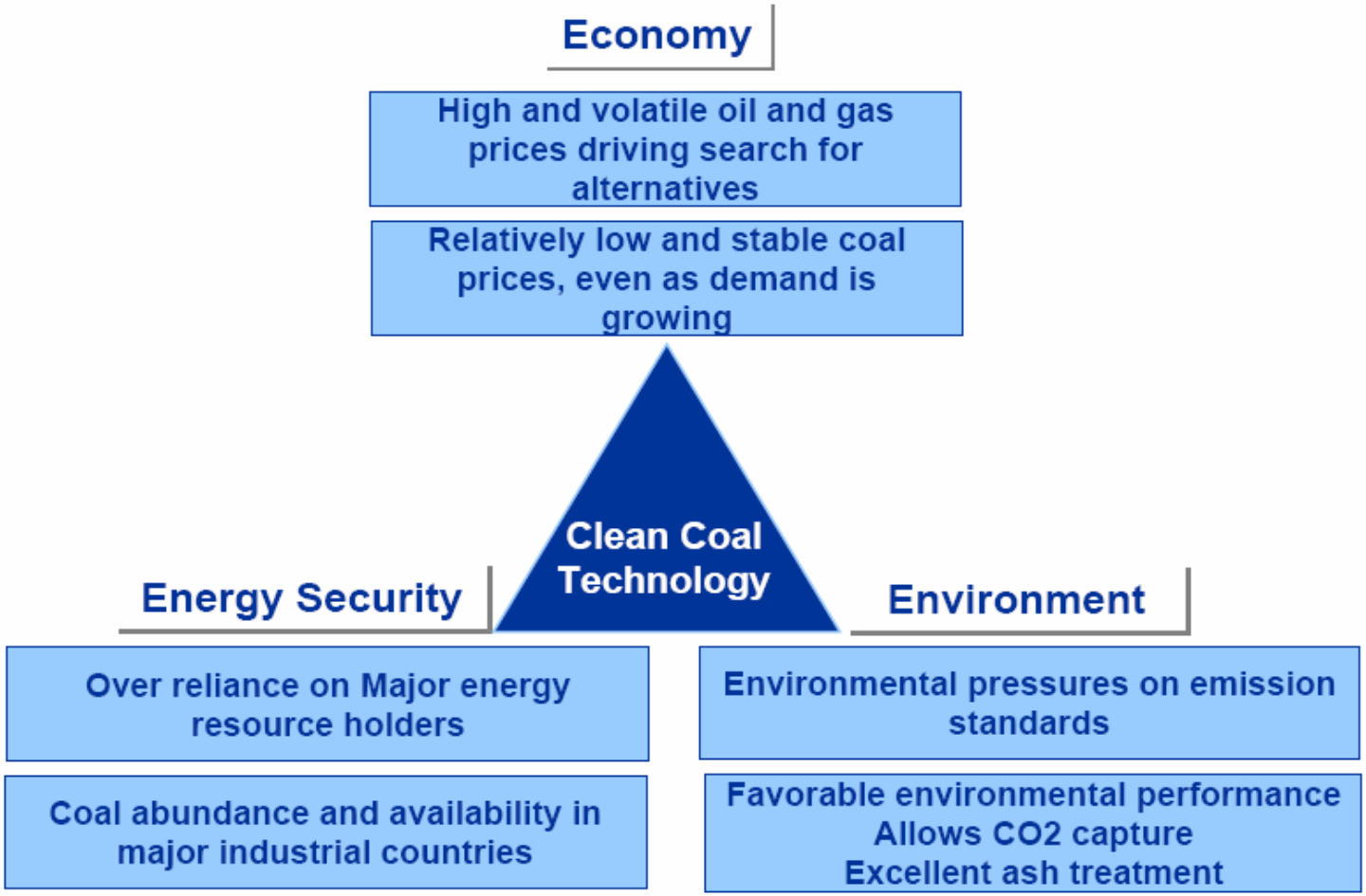
Energy Security: Oil Importers Have A Large Amount of Coal Reserves

	US	China	India
Coal Reserves (Billion Tons)	247	115	92
Net Oil Imports (MM BPD)	13.8	3.4	1.7

Source: BP Statistical Review of World Energy 2006

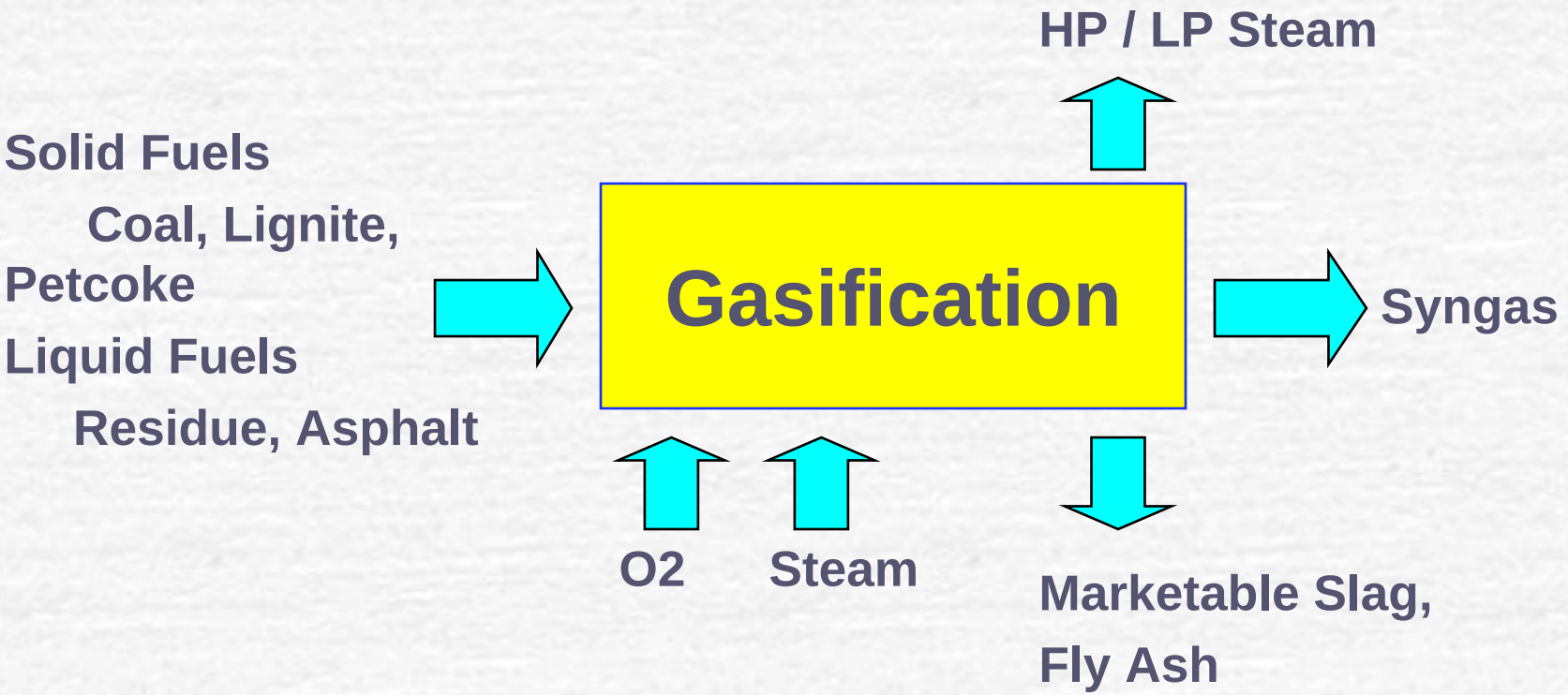
Coal, Its New Look and Potential

Conditions are right for Syngas to become a viable energy alternative



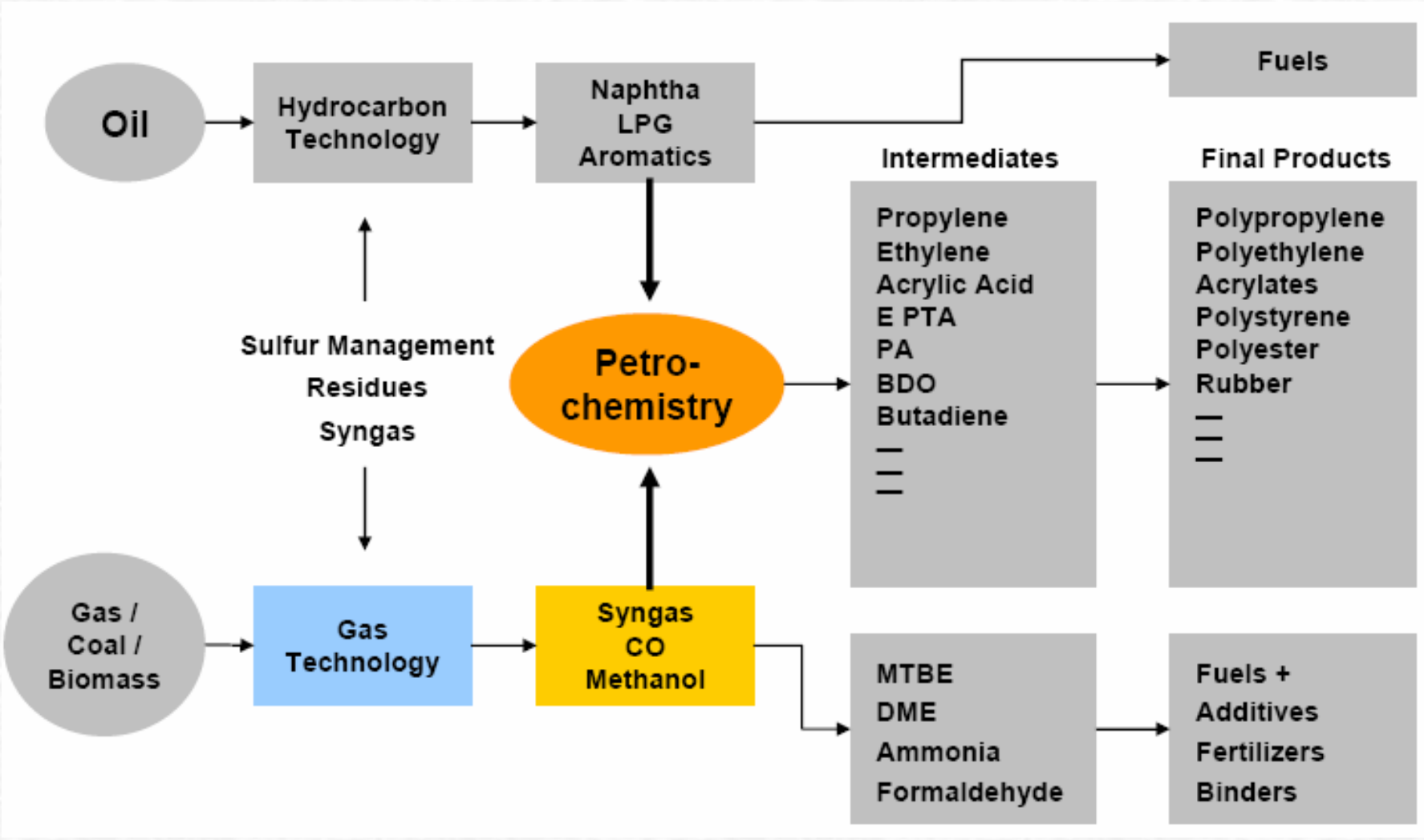
Coal, Its New Look and Potential

Gasification - Process



Gasification involves partial oxidation of carbonaceous fuels, maximizing CO + H_2

Coal, Its New Look and Potential



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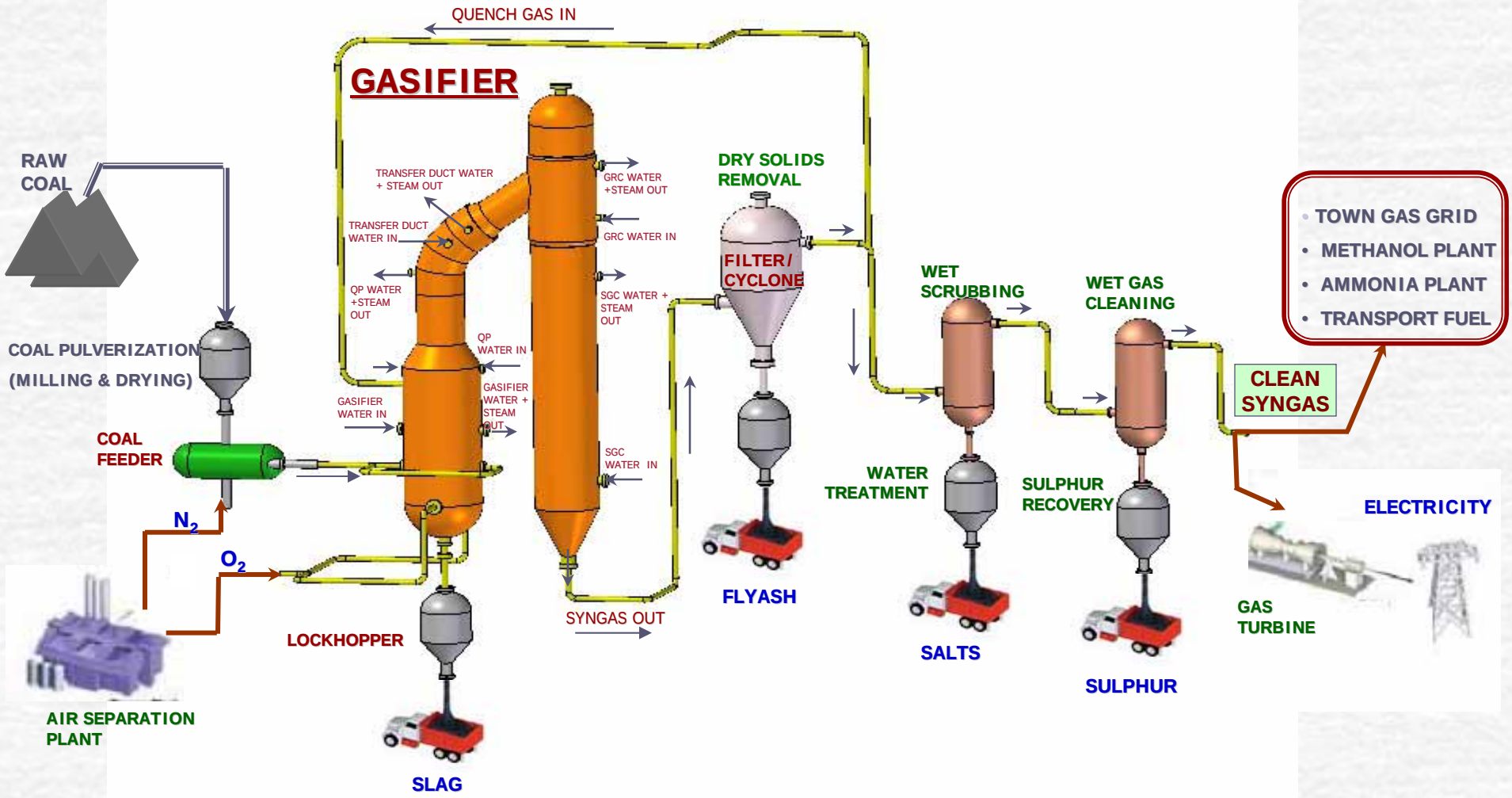
L&T, Experience with SCGP

SHELL COAL GASIFICATION PROCESS



L&T, Experience with SCGP

THE SHELL COAL GASIFICATION PROCESS

Advantages of SCGP Technology

- **Entrained flow, Dry coal feed, Compact equipment, Scale-up possibility**
- **Membrane-wall gasifier**
  - **Long life time of membrane wall and coal burners**
  - **High carbon conversion (>99%);**
  - **Applicable to all coals;**
  - **Low coal consumption, and low oxygen consumption**
- **High cold gas efficiency (> 80 % LHV);**

L&T, Experience with SCGP

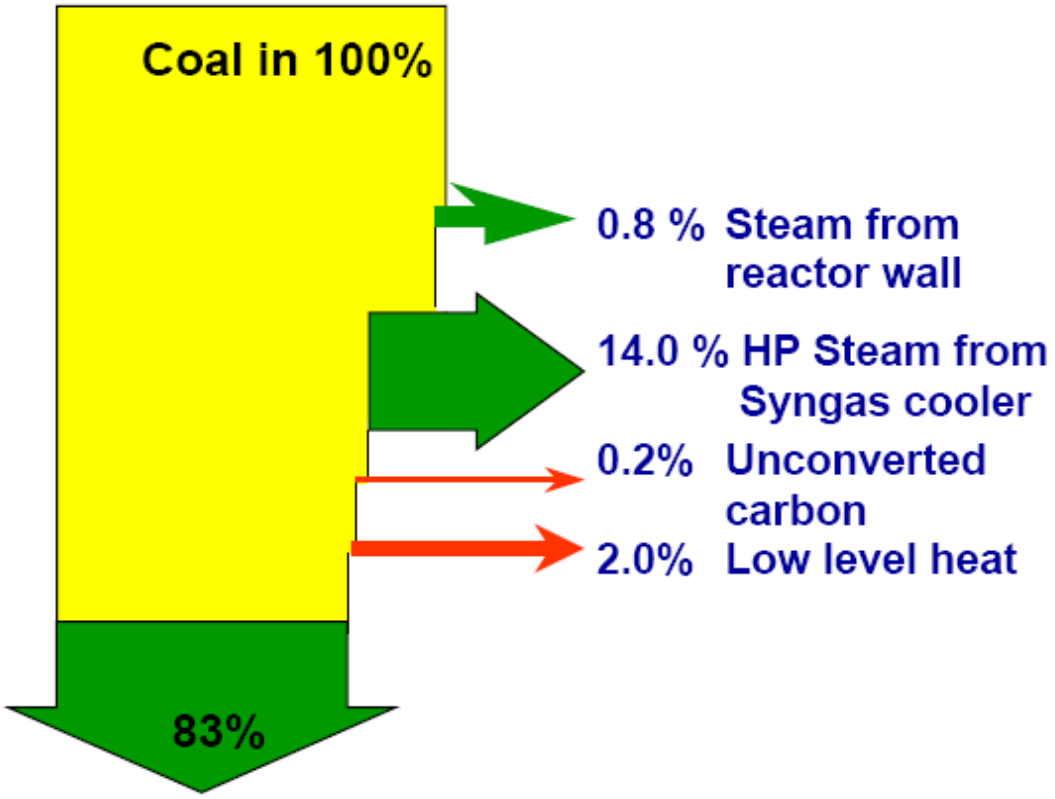
Advantages of IGCC with the Shell technology

- High net efficiency, lower fuel cost and less CO2 emissions
- Excellent environmental performance:
  - solid by-products marketable
  - extremely low NOx, SOx emission
  - virtually zero dust and volatile heavy metal emission
- Flexible to all coals and low cost fuels
- Capability in load following

L&T, Experience with SCGP

The Shell Coal Gasification Process

- Energy Balance



L&T, Experience with SCGP

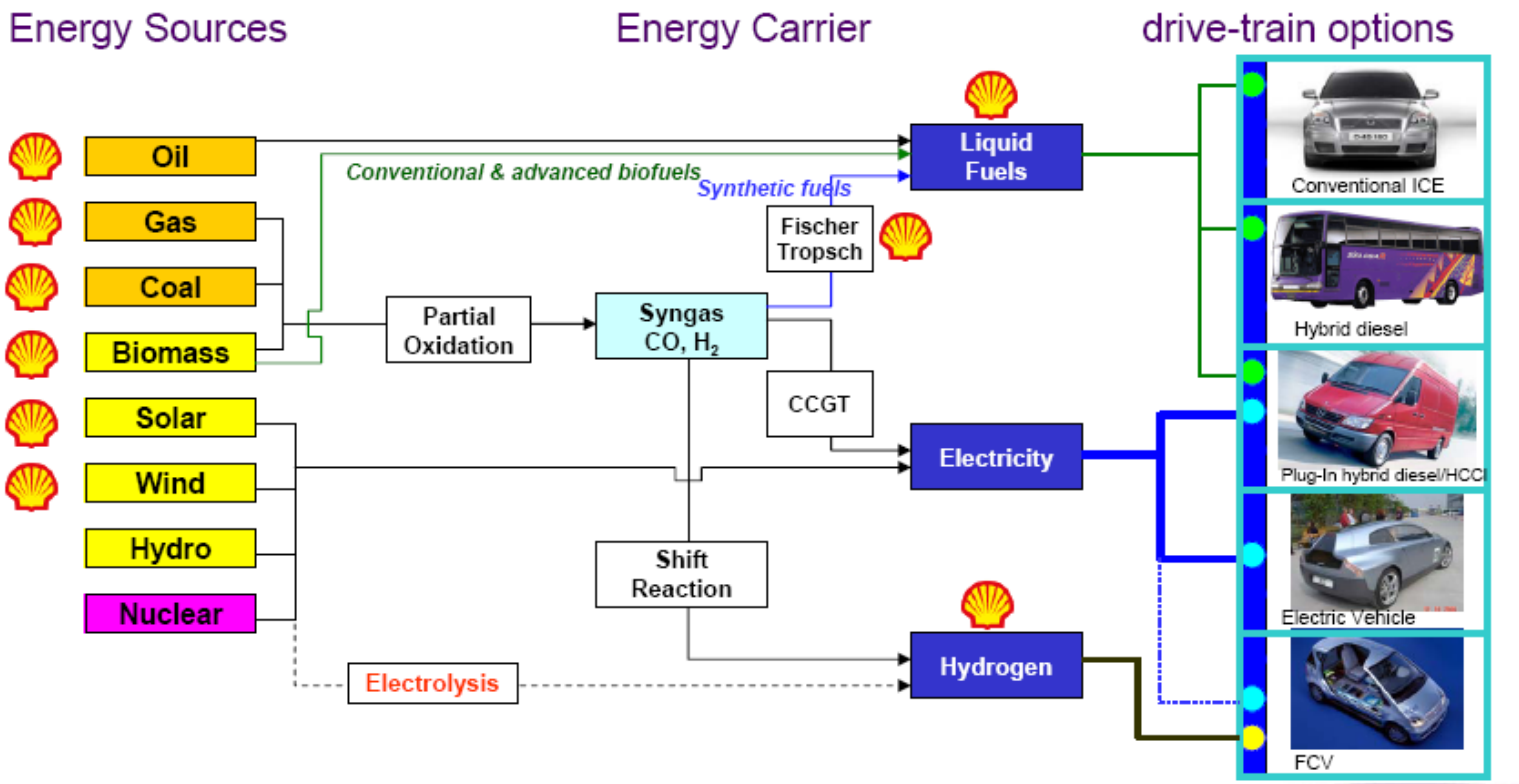
Demkolec IGCC Plant
Clean coal technology aspects

- **Extremely low NOx, typically below 10 ppm**
- **Sulphur removal efficiency over 99%**
- **Total asidification components NOx + SO2:**

  coal gas operation better than natural gas
- **Virtually zero emission of fly ash, chlorides and volatile heavy metals**
- **Zero discharge: waste water reused in plant**

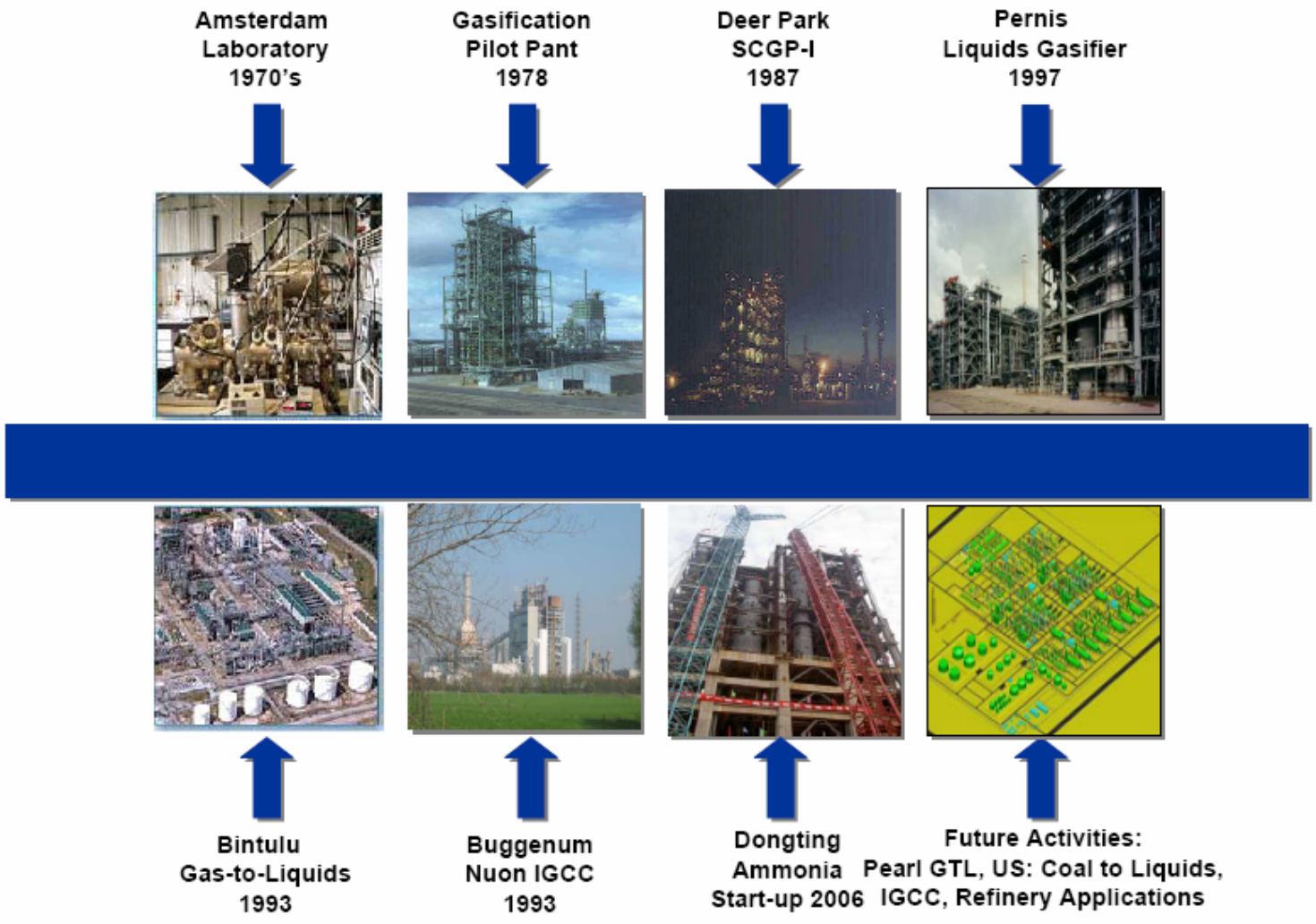
L&T, Experience with SCGP

Focus on fuels

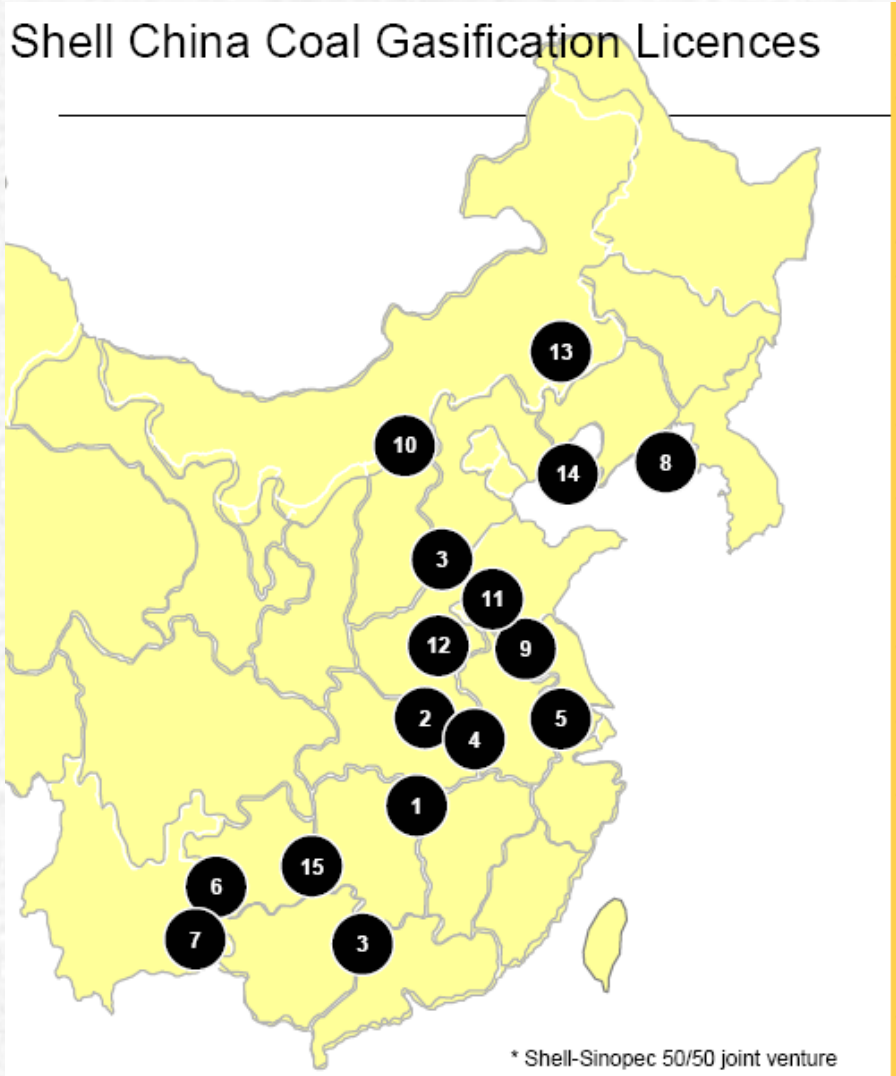


L&T, Experience with SCGP

…and is committed to continued improvement



L&T, Experience with SCGP



1. Yueyang Sinopec & Shell Coal Gasification Co Ltd
2,000 t/d plant to supply a fertiliser plant.

2. Hubei Shuanghuan Chemical Group Co Ltd
900 t/d plant to supply a fertiliser plant.

3. Liuzhou Chemical Industry Co ltd
1100 t/d plant to supply fertiliser plant.

4. Sinopec Hubei Chemical Fertiliser Co
2000 t/d plant to supply a fertiliser plant.

5. Sinopec Anqing Company
2000 t/d plant to supply a fertiliser plant.

6. Yunnan Tianan Chemical Co Ltd
2700 t/d plant to supply a fertiliser plant.

7. Yunnan Zhanhua Co Ltd
2700 t/d plant to supply a fertiliser plant.

8. Dahua Group Ltd
1100 t/d plant to supply methanol plant.

9. Yongcheng Coal and Power Group
2100 t/d plant to supply a methanol plant.

10. China Shenhua Coal Liquefaction Corporation
2x2200 t/d plant to supply hydrogen for DCL..

11. Henan Zhongyuan Dahua Group
2100 t/d plant to supply a methanol plant.

12. Henan Yima Kaixiang Group
1100 t/d plant to supply a methanol plant.

13. A Power Company in Inner Mongolia
3x 4000 t/d plant to supply a methanol plant.

14. Tianjin Soda Plant of Tianjin Bohai Chemical Group
2x2000 t/d plant to supply ammonia and methanol plants.

15. A Chemical Company in Guizhou
2000 t/d plant to supply ammonia and methanol plants.

L&T, Experience with SCGP

- Manufactured and delivered 4 sets of Key Coal Gasification Equipment (SCGP) to 3 sites in P R China.
- 175 L&T crew working at 3 sites to assemble and erect Gasifiers along with Buyers. The toughest site : minus 25 Deg. C.

Sr. No.	Year	Project	Fuel	End Product	Startup
I	Mar-04	Yunnan	1 X 2700 TPD Coal	500,000 MTPA Ammonia	2007
II	Aug-04	ZhongYuan	1 X 2000 TPD Coal	500,000 MTPA Methanol	2007
III	Sep-04	Shenhua	2 X 2000 TPD Coal	1 MMTPA CTL	2007
IV	Mar-06	Datang	3 X 3500 TPD Coal	3x 500,000 MTPA Methanol to PP	2009

- L&T completed fabrication of 4 Gasifiers, all working in parallel. L&T has built up capacity to handle 8 Gasifiers concurrently.

L&T, Experience with SCGP

L&T, Experience with SCGP

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L&T, Experience with SCGP

Shenhua d-CTL Gasifier hoisting – August 2006

Shell Coal Gasification Process (2x2000 t/d) used to produce Hydrogen

Hoisting of gasifiers
August 2006

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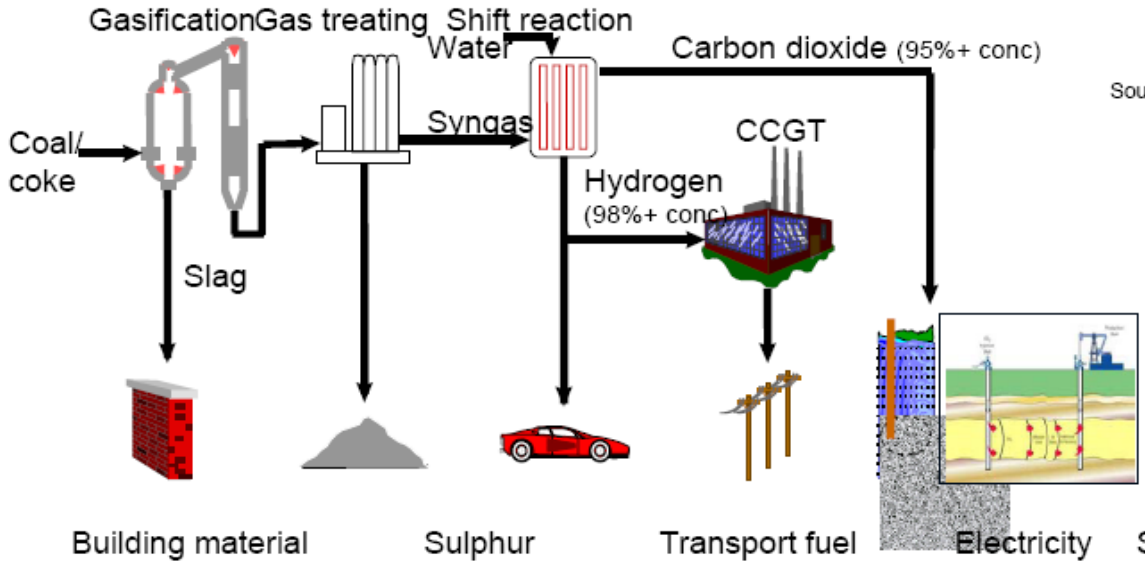
Fossil Fuels, Industrial and Commercial Utility

Coal Gasification (CG) and sustainable development



Advantages of Coal Gasification

- significant CO_2 reduction in coal-based economies
- CO_2 containment allows its subsequent storage ("near zero emissions")
- near complete mercury removal (v.s.around 60% with advanced boiler technology)
- a production option for hydrogen

Renewables & Hydrogen

Fossil Fuels, Industrial and Commercial Utility

Shuanghuan Yincheng Coal Gasification Project

Shell Coal Gasification replacing oil gasification to produce syngas for fertilizer manufacturing

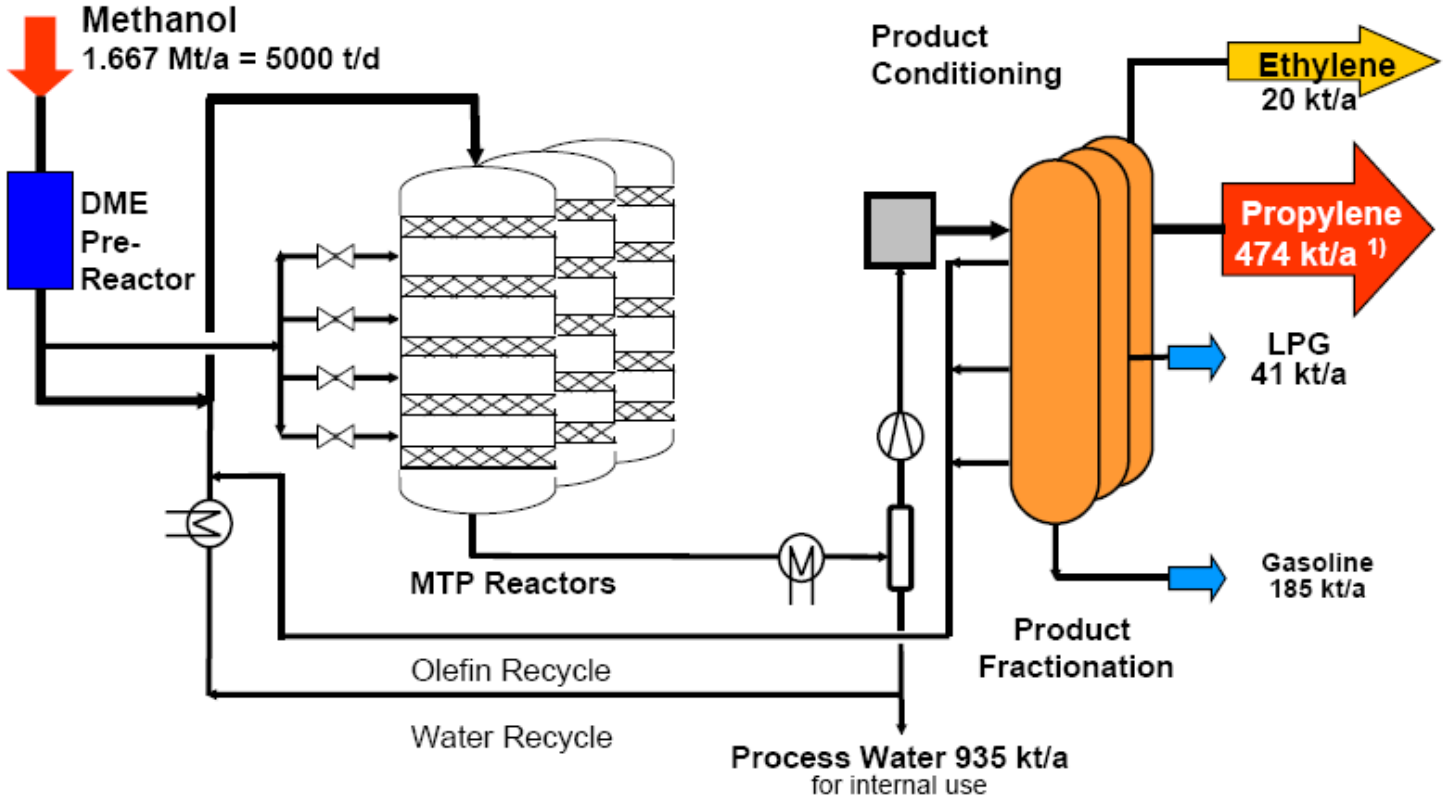
Start –up successful on 17th May 2006

13 Nov 2006

Fossil Fuels, Industrial and Commercial Utility

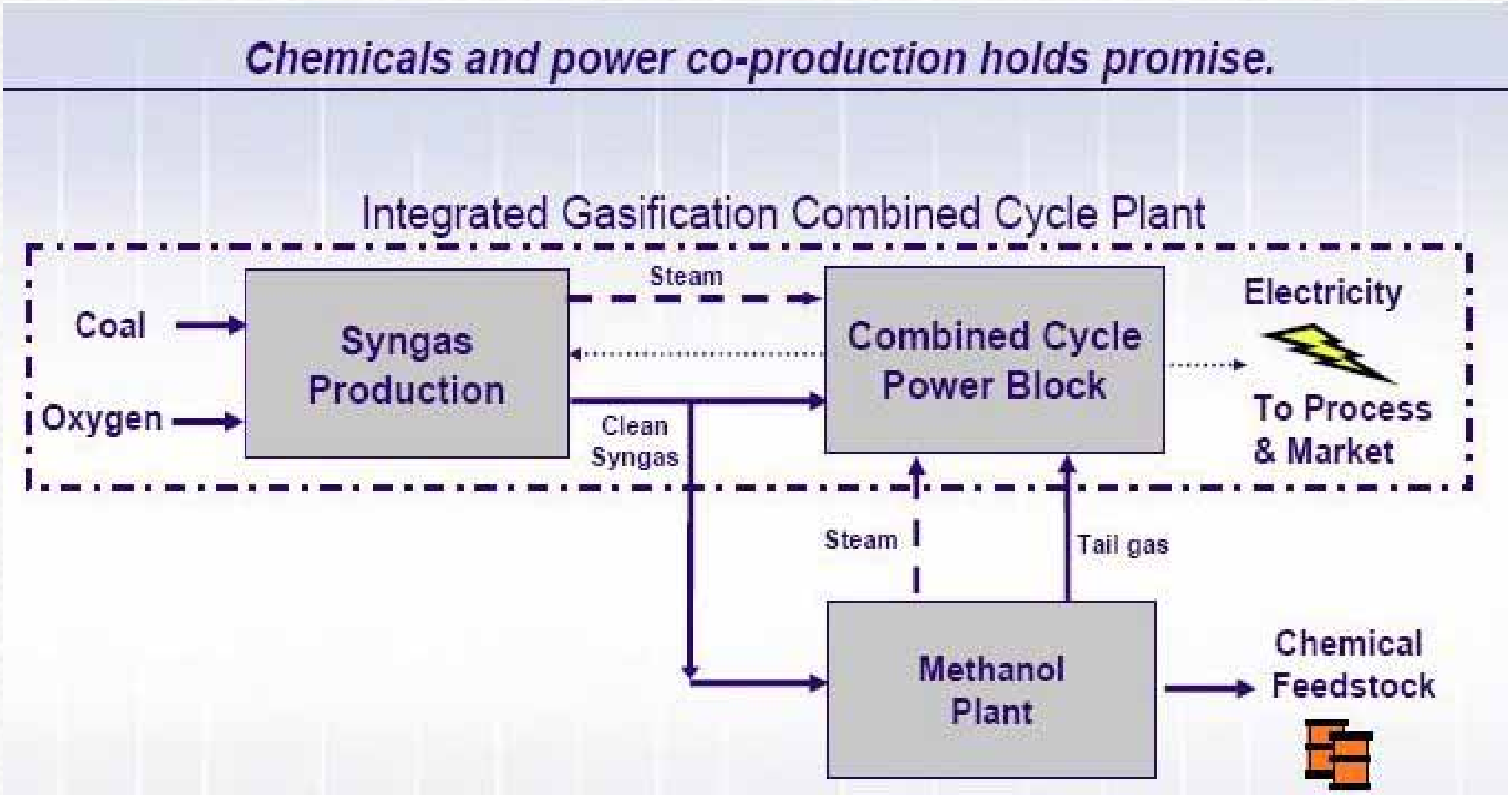
MTP®: Simplified Process Flow Diagram

Lurgi



1) Propylene Purity 99.6 wt. %

Fossil Fuels, Industrial and Commercial Utility



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Gasification Challenges in Indian Scenario

- Indian coal contains high ash content and other minerals. Wastage disposal poses environmental pollution.

- The Entrained flow type Gasifiers facilitate burning of pulverised coal at higher temperatures (1200-1600 ºC) and complete gasification.

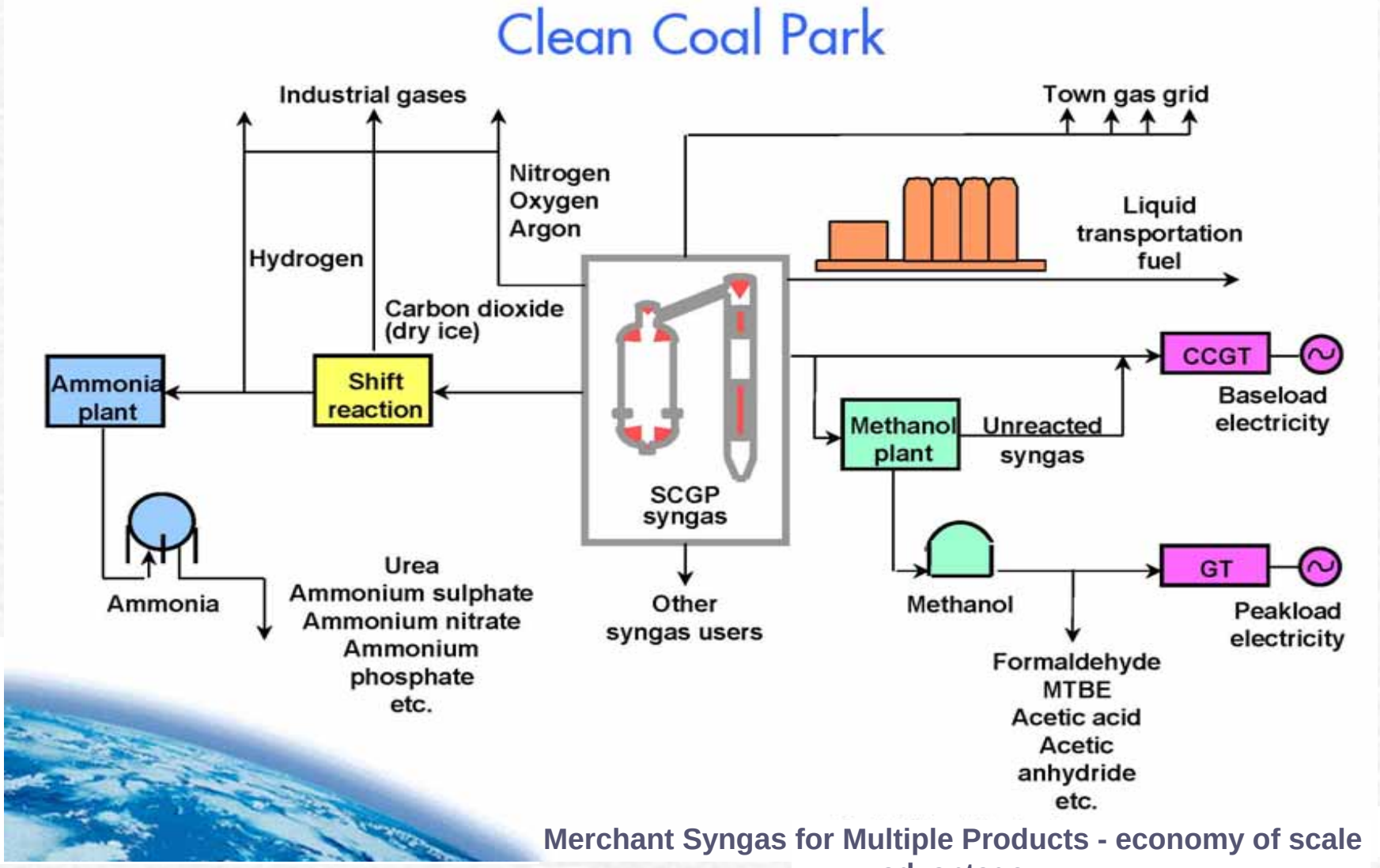
  The constituents of ash, phenolics, COS and the minerals in the coal get melted and flushed out as slag.

- The selected technology must facilitate controls for disposing all waste materials without polluting the environment.

Gasification Challenges in Indian Scenario

- Blend Indian Coal with high grade coal / Pet coke to counter the effects of high ash content. Coal washeries too can be engaged to clean up the coal.
- Put up large sized Gasifiers in a cluster near Coal resources. This would make Syngas available to multiple industries from the single point.
- The Gasification Sites also need to be adequately equipped with water resources.

Gasification Challenges in Indian Scenario



Merchant Syngas for Multiple Products - economy of scale advantage

Topics Covered

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Coal for IGCC & CTL

- Bright future awaits for coal users as proven technologies to produce High quality transportation fuels from Syngas are becoming available.

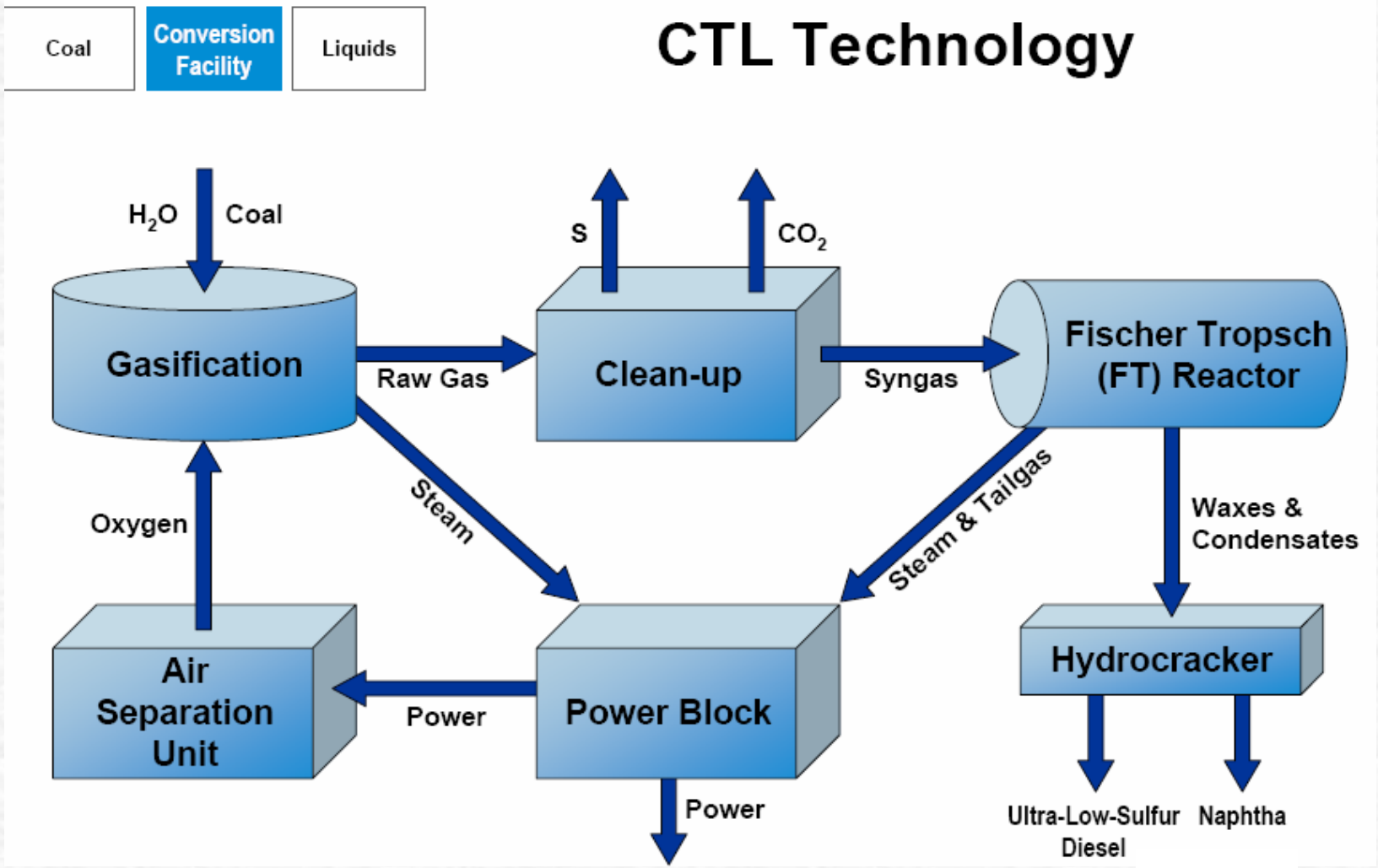
  Fischer-Tropsch reactions, middle distillate synthesis process, hydrocracking…, will enable obtaining ultra clean fuels from coal.

- Coal gasification utilises coal to the extent that only fraction of carbon gets converted to CO_2.
- Shift Syngas (with steam) and separate H_2 and CO_2 (cost effectiveness). Sequester CO_2.. and use H_2 for clean burning.
- Separated CO_2 can be stored in depleted oil & gas fields, saline aquifers or deep oceans.

Coal for IGCC & CTL

- H_2 can fuel CCGT power plants. Cost of electricity will be around 30 to 40 % more expensive than conventional plants.
- P.R.China has implemented using syngas from coal as feed for Ammonia (fertilizer plants), Methanol plants and for producing H_2 for direct coal liquefaction plants.
- Shell coal gasification process enables controlling / almost eliminating the environmental pollutants –
  low NOx – below 10 ppm, sulphur removal efficiency over 90% and virtually zero emission of fly ash.

Coal for IGCC & CTL



Source: DKRW Energy LLC.

Coal for IGCC & CTL

Key CTL Elements

Coal	Conversion Facility	Liquids
Secure Coal Resources	Package Technology & EPC	Sell Products
❖ Acquisition of reserves ❖ Operating contract ❖ Mine-mouth production	❖ Gasification ❖ Fischer Tropsch ❖ Hydrocracking ❖ EPC ❖ Modular Design ❖ Scale	❖ Diesel (low sulfur) ❖ Naphtha ❖ CO2

Source: DKRW Energy LLC.

Coal for IGCC & CTL

Coal

International CTL Opportunities

Country	World Rank by Reserves	Coal Reserves BT	Share of World Reserves	Petroleum Demand MM BPD	Petroleum Supply MM BPD	Petroleum Imports MM BPD
USA	1	247	27.1%	20.7	6.8	13.8
Russia	2	157	17.3%	2.8	9.6	-6.8
China	3	115	12.6%	7.0	3.6	3.4
India	4	92	10.2%	2.5	0.8	1.7
Australia	5	79	8.6%	0.9	0.6	0.3
South Africa	6	49	5.4%	0.5	0.3	0.3
Ukraine	7	34	3.8%	0.3	0.1	0.2
Kazakhstan	8	31	3.4%	0.2	1.4	-1.2
Poland	9	14	1.5%	0.5	0.1	0.4
Brazil	10	10	1.1%	1.8	1.7	0.1
Total World		827	91.0%			

Top 10 Countries in Coal Reserves – 91% of Reserves

Source: DKRW Energy LLC.

Coal for IGCC & CTL

Australia Monash CTL Project

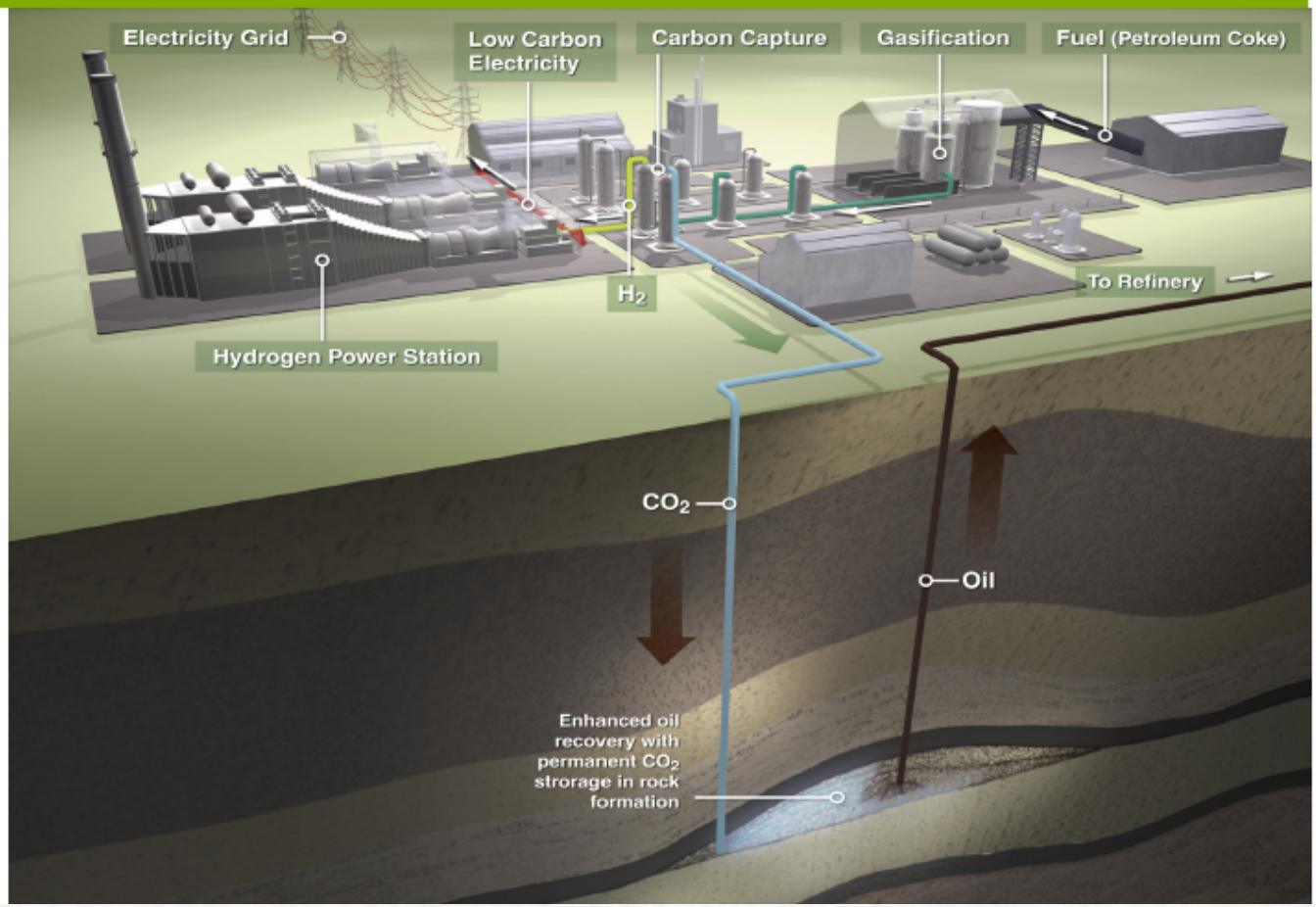
Shell and Anglo American join forces to progress an Australian Clean Coal to Liquids project

21st September 2006,

JDA signed to advance the Monash Energy clean coal-to-liquids project in the state of Victoria, Australia

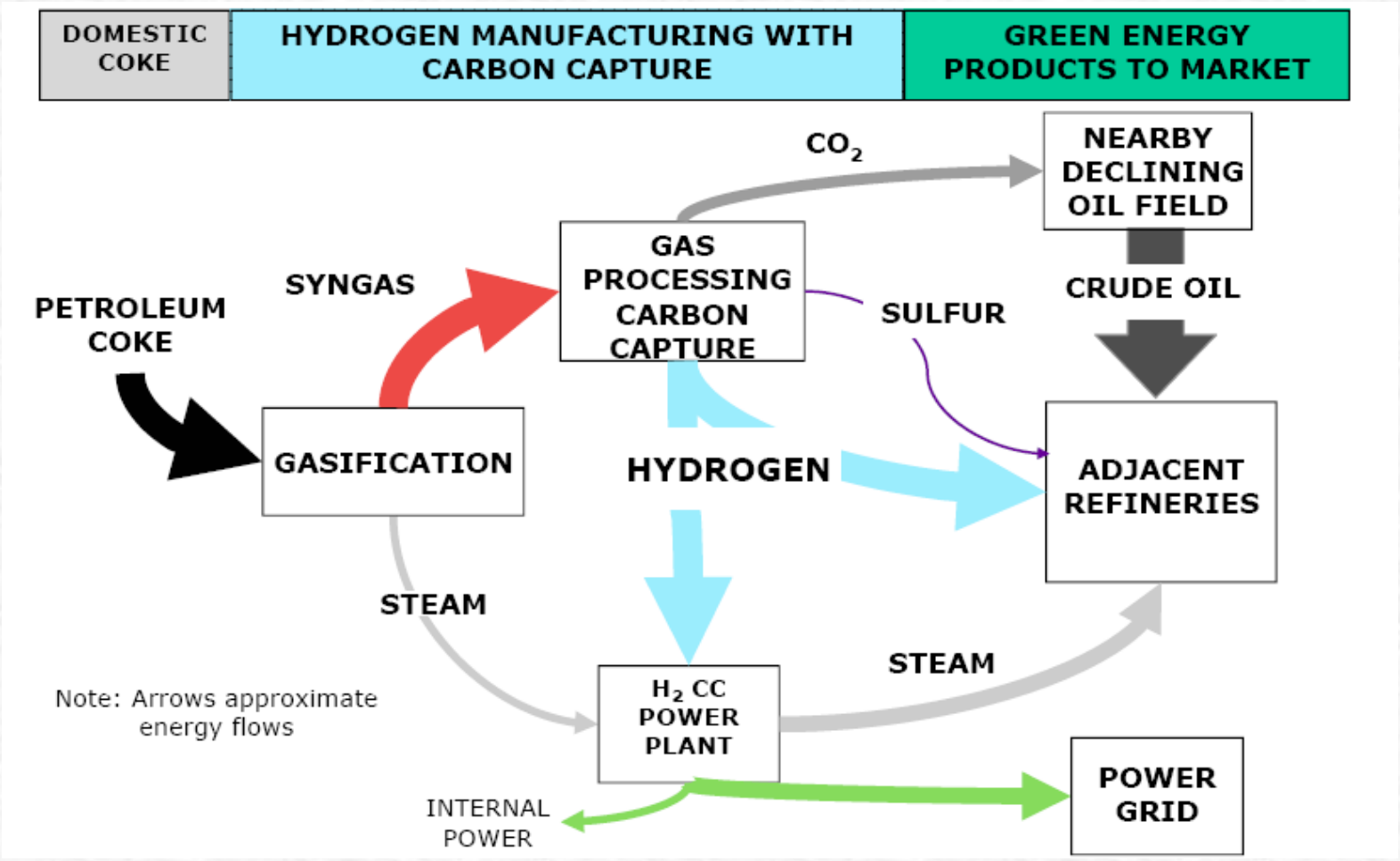
Coal for IGCC & CTL

Carson Hydrogen Power Plant



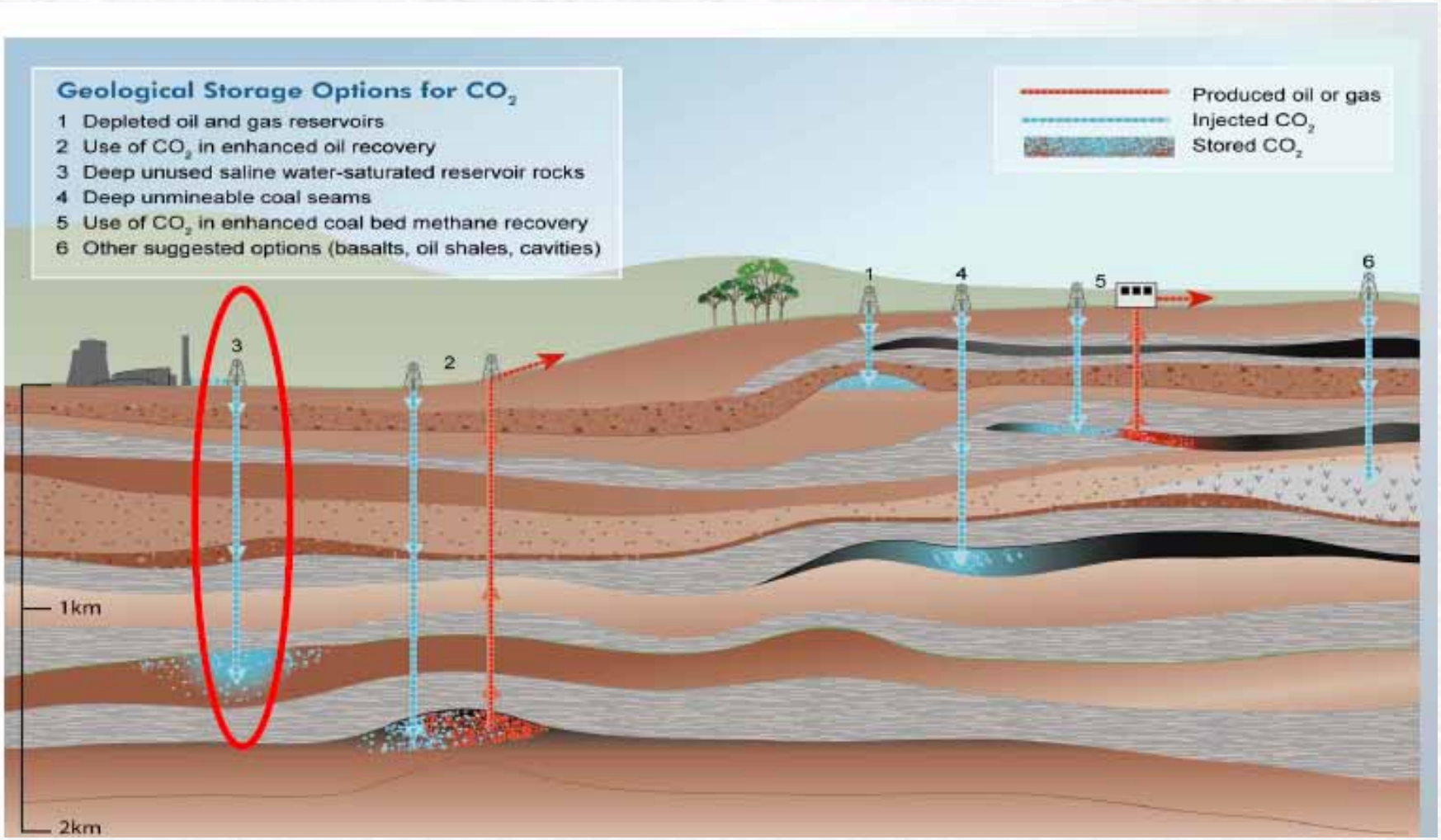
Source: BP/EDISON MISSION GROUP

Coal for IGCC & CTL



Source: BP/EDISON MISSION GROUP

Coal for IGCC & CTL



Source: FutureGen Alliance

Coal for IGCC & CTL

Shell Coal Gasification in action: NUON IGCC plant, Buggenum, NL

COAL INTAKE	2000 t/d	
NET OUTPUT	253 Mwe	
NET EFFICIENCY (LHV)		43%

- Availability > 90% (excl. planned downtime)
- Excellent environmental performance
- Extremely low NOx, typically below 10 ppm
- Sulphur removal efficiency over 99
- Total acidification components NOx + SO2:
  - coal gas operation better than natural gas
  - Virtually zero emission of fly ash, chlorides & volatile heavy metals
  - Zero discharge: waste water reused in plant

Future Biomass co-gasification

40% (wt) co-gasification tested (pure and mix) already

30% (wt) co-gasification planned; facilities in construction

Renewables & Hydrogen

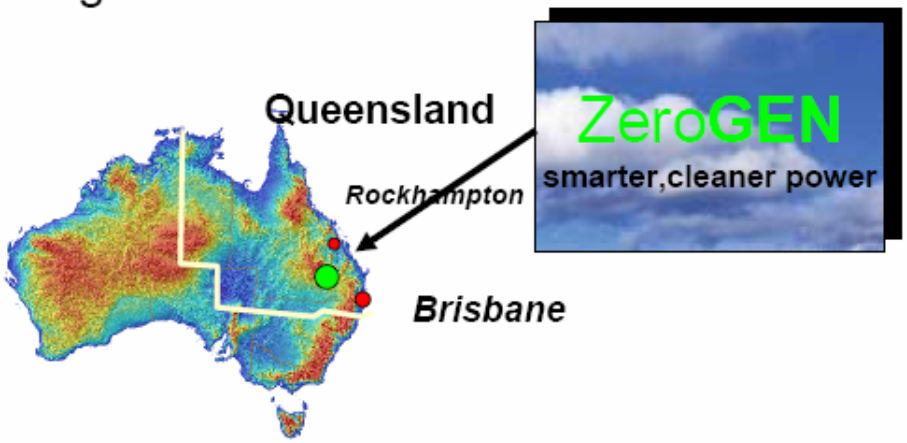
Coal for IGCC & CTL

ZeroGEN project (Australia)

World 1st Zero Emission Power Project

- Integrated coal-based gasification
- Carbon Dioxide capture & storage

To Produce:
Low carbon emission
baseload electricity



Aim:
Safe, reliable, low cost
Utilize vast coal resource

Renewables & Hydrogen

Coal for IGCC & CTL

Halten – An integrated value chain

Gas-fired power station at Tjeldbergodden	CO_2 capture and transport	CO_2 for enhanced oil recovery/storage

860 MW gas-fired power station:

Meet the electricity requirements offshore

Secure energy supplies in mid-Norway

CO_2 capture for offshore injection

Annual volumes up to 2.5 million tonnes of CO_2

Enhanced oil recovery from:

- Draugen
- Heidrun
- Possibly other fields

Thank You