POWER-GEN ASIA 2005

Technological Determinants for Asian Power Generation Fuel Scenario Outlook

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Electricity Demand

- Worldwide total demand for electricity is projected to increase on average by 2.3% per year, from 13'290 TWh[1] in 2001 to 23'072 TWh in 2025.
- According to the same forecast, the electricity consumption in developing Asia[2] is projected to increase on average by 3.7% per year, from 3'000 TWh in 2004 to 6'275 TWh in 2025.

[1] TWh=1'000GWh

[2] Without Japan & Middle East

World Electricity Consumption

Pos	Region	Actual	Projections				Annual Change
	Electricity Consumption in 1000 GWh	2004	2010	2015	2020	2025	%
1	North America [a)]	4'430	4'840	5'300	5'790	6'310	1.9
2	South & Central America	740	860	1'000	1'195	1'425	3.2
3	Europe [b)]	4'250	4'670	5'100	5'545	5'970	1.7
4	Africa	420	500	600	715	810	3.1
5	Middle East	550	635	725	820	925	2.8
6	Asia [c)]	3'000	3'725	4'510	5'340	6'275	3.7
7	Japan	820	870	920	965	1'010	1.0
8	Australia & Pacific [d)]	230	260	290	315	340	1.8
9	World	15'140	16'360	18'445	20'685	23'065	2.45

[a)] Including USA (with Hawaii), Canada & Mexico
[b)] Including Eastern Europe & former Soviet Union Countries
[c)] Excluding Japan & Middle East
[d)] Including New Zealand & Pacific Islands

Fuel Scenario Outlook

- The mix of primary fuels used for electric power generation has changed a great deal over the past three decades on a worldwide basis.
- While the coal has remained the dominant fuel, NG-fired power generation has grown steadily and very rapidly in the 1970s, 1980s and 1990s.
- NG has proven to be a very popular and clean choice for power generation worldwide.
- From 1975 to 1995, worldwide consumption of NG for power generation increased by an average of 6% per year.

Fuel Scenario Outlook

- In conjunction with:-
  - The post-world war II high oil prices caused by OPEC oil embargo in 1973-1974;
  - The Iranian Revolution in 1979; and
  - The recent crude oil price escalation;

  the use of Fuel Oil for power generation has been slowing since the mid-1970s.

Fuel Scenario Outlook

- Due to hardly acceptable price and other technical and technological reasons, the role of Fuel Oil in Asian's, power generation market is expected to diminish over the next two decades.
- The Fuel Oil will be used only as an emergency back-up fuel or for smaller power generation units in remote areas where Natural Gas is not available and coal supply is not feasible or over-expensive.

Fuel Scenario Outlook

- NG, the most noble fuel whose proven reserves are estimated for no more but half century is underestimated by the world-average price swinging between the values of 3.0 to 6.0USD/GJ, depending on region and mode of transportation.
- The crude oil has reached 70 USD/barrel price level in this year (2005). This is around 75% higher than 12 months ago.

Fuel Scenario Outlook

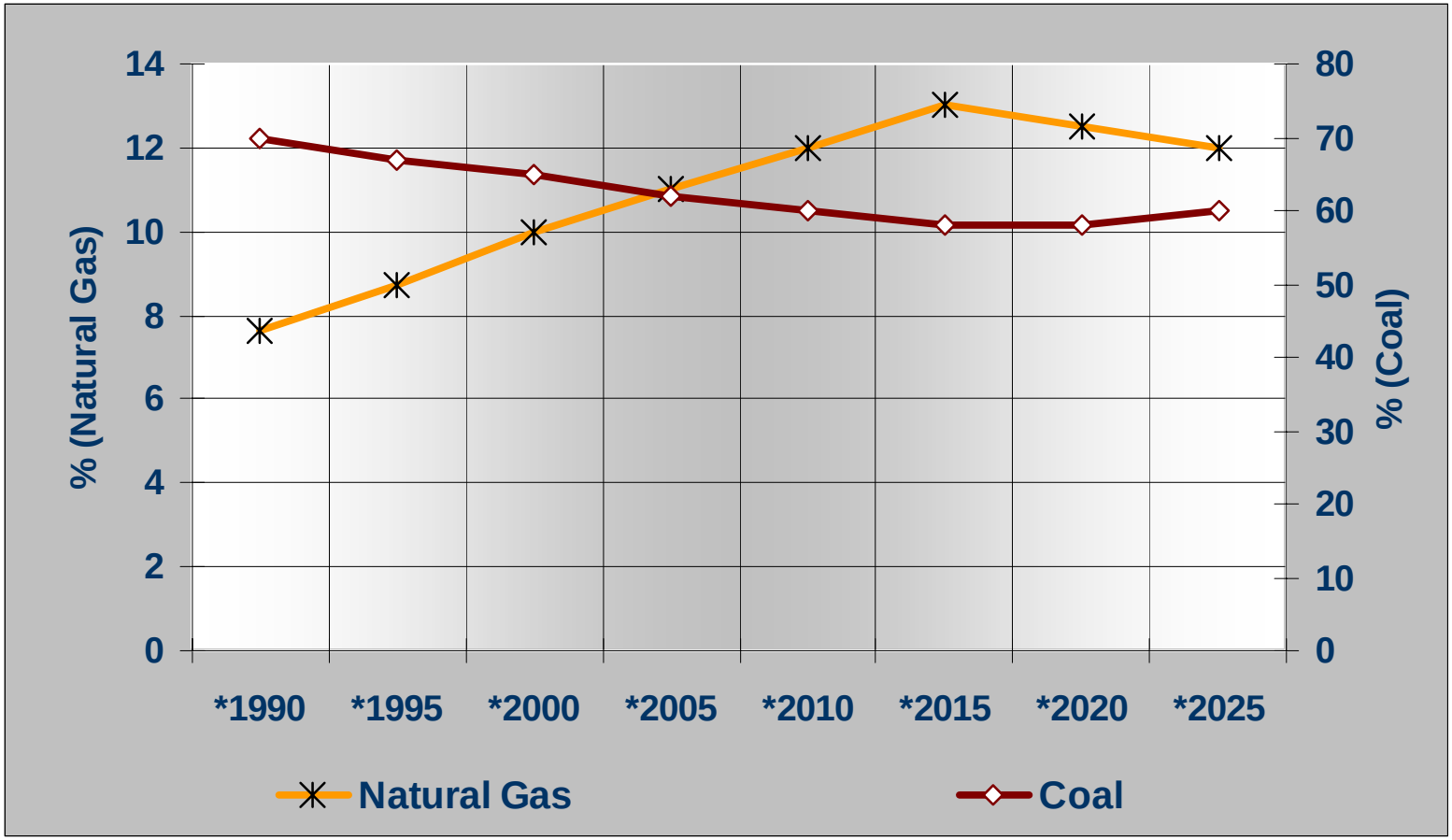
Two following important questions have to be answered:

- How far away is the horizon of Natural Gas price dominance?
- What has to be undertaken before Natural Gas supply reaches its crisis level?

Fuel Scenario Outlook

According forecasts made by miscellaneous reputable international organizations the Natural Gas dominance in power generation market shall steadily increase until year 2020 - 2025, when a break-point shall be reached.

Natural Gas vs. Coal for Power Generation in Asia



Future Fuel Market Price Trend

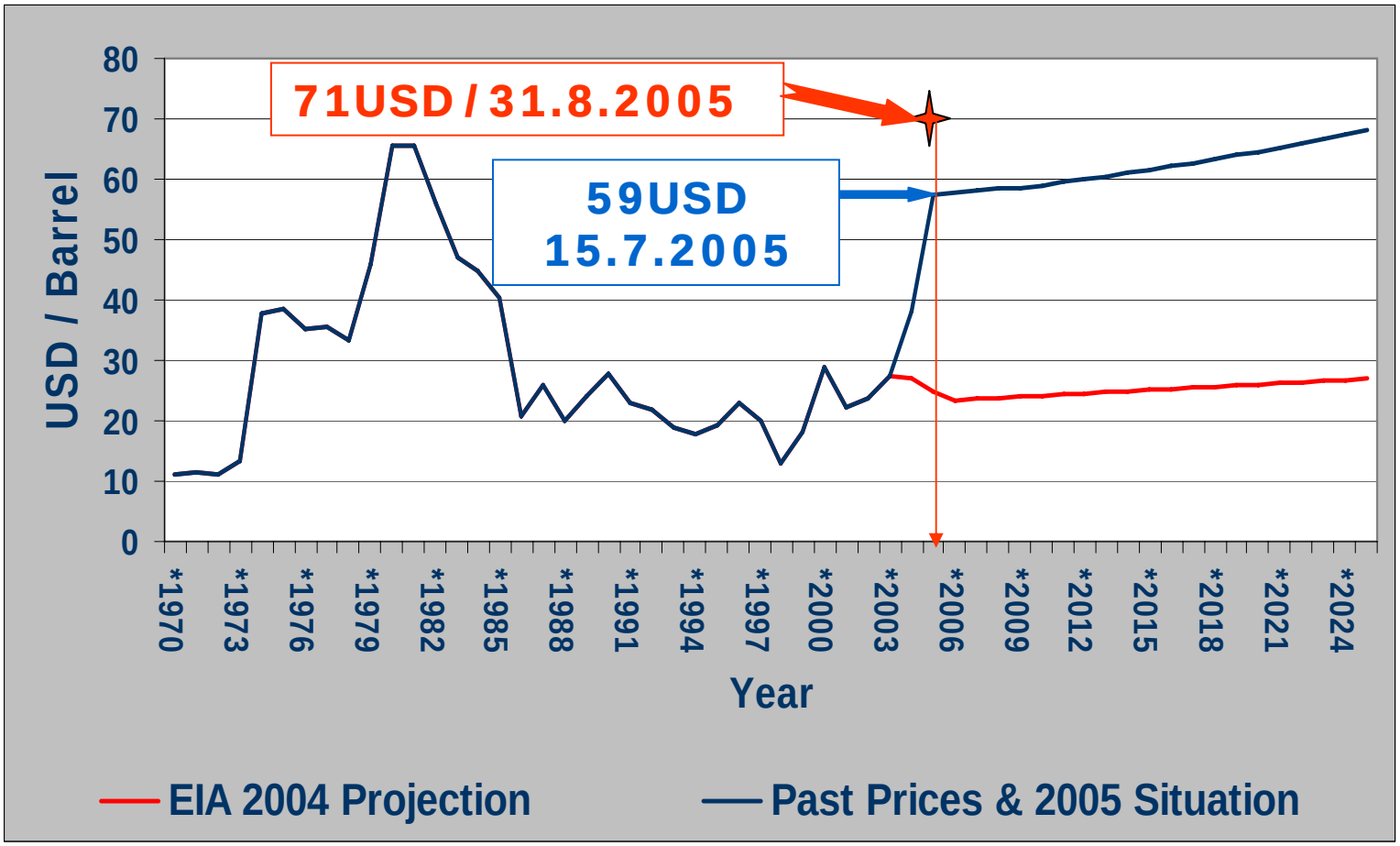
- Fuel Oil prices will, at least, remain at present high level;
- Dry Natural Gas (and also LNG) will follow, most probably not so steep and unexpected, the Fuel Oil price trend.
- Coal will also follow-up, but moderate.

Coal Fuel for Future Clean Power Generation?

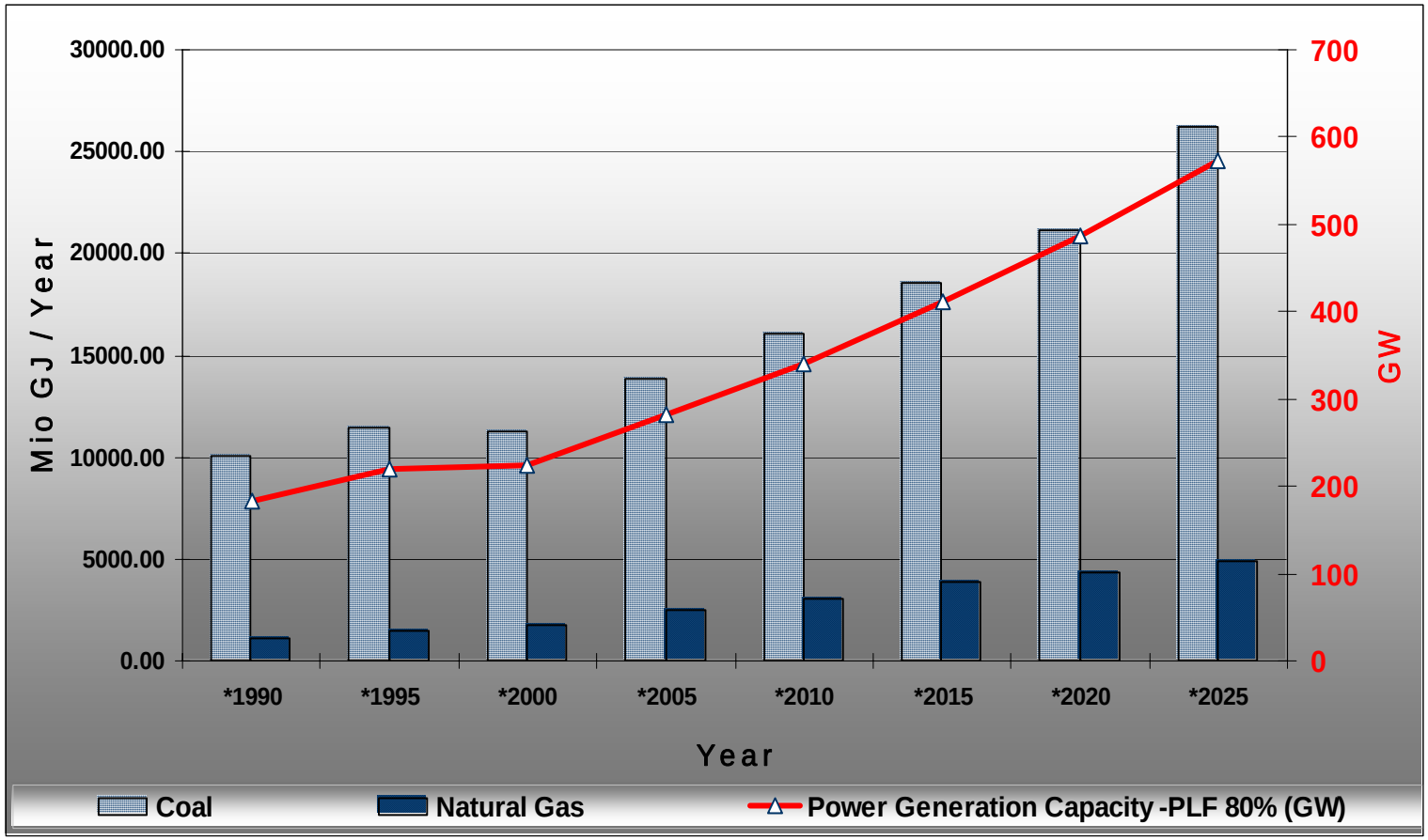
- Coal has the best prerequisite to become No. 1 Fuel for thermal power generation technology;
- Huge reserves of coal together with appropriate coal-based technologies like
  - Ultra-Supercritical Steam Cycles (USSC);
  - Integrated Gasification Combined Cycle (IGCC); or
  - Pressurized Fluidized Bed Combustion (PFBC)

will cause subsequent decline from Natural Gas towards coal based fossil fuel commodities.

World Oil Prices 1970 - 2025



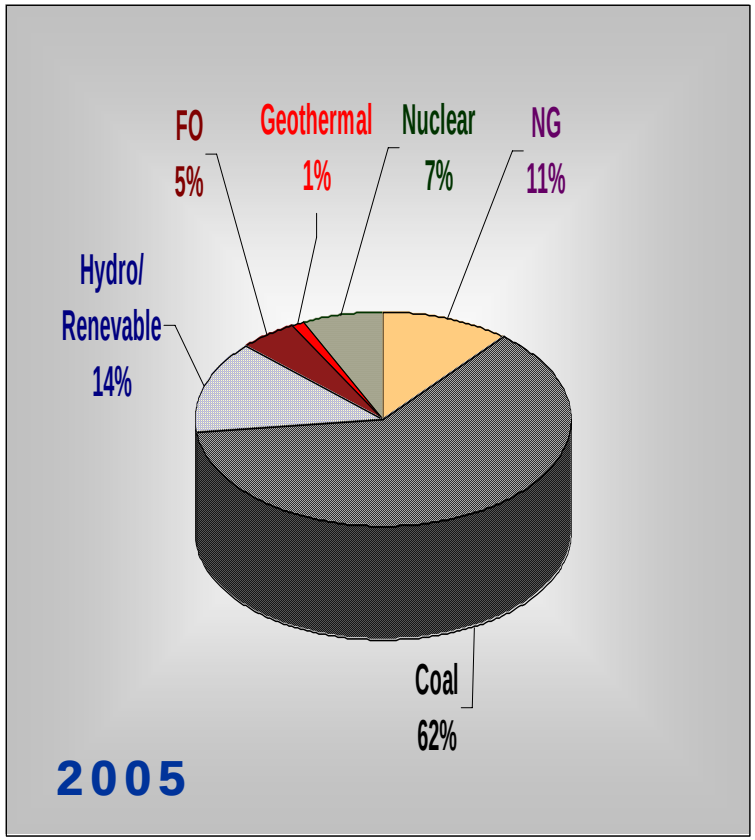
Natural Gas & Coal Utilization for Power Generation in Asia

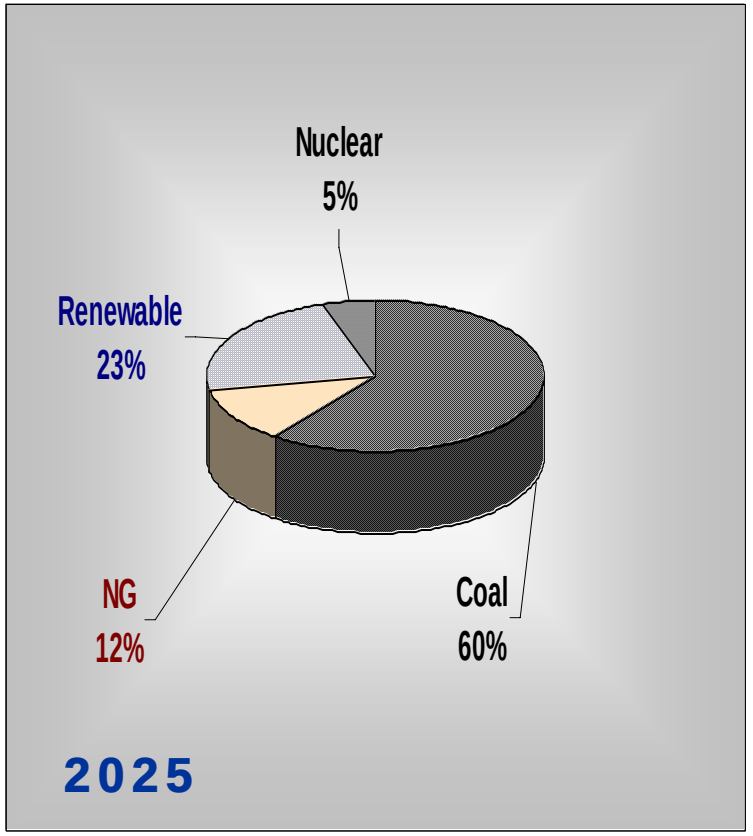


Coal Consumption in China

- 21st Century Business Herald reported that China's annual coal demand is expected to reach 2.5 billions metric tons by 2010 and 2.9 billions metric tons by 2020.
- China Coal Industry Development Research Center (CCIDRC) predicted that coal consumption by power producers in China will reach 1.1 billions Metric tons in 2005, 1.5 billions metric tons by 2010 and 1.9 billions metric tons by 2020.

Fuel Mix Scenario in Asian Power Market (2005 – 2025)





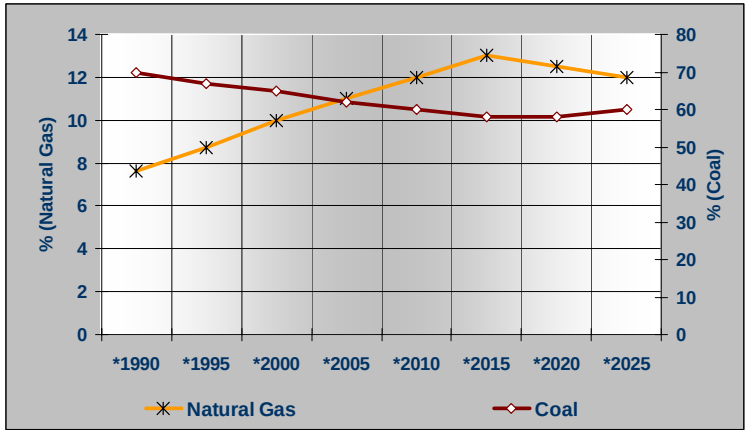
Equilibrium btw. Natural Gas & Coal

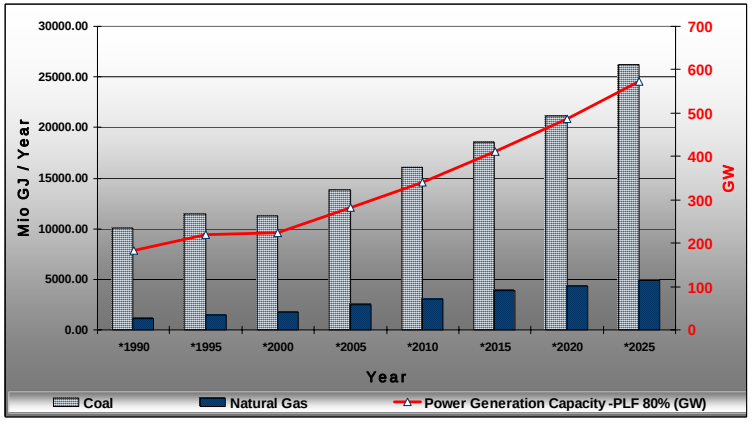
- During mid of 70's many of the world's well recognized projections have given NG no more than 30-35 years life time span.
- Present situation? All proven NG reserves worldwide are not lower than 30 years ago.

Equilibrium btw. Natural Gas & Coal

The starting point at which the inversion between the two main fuel commodities, Natural Gas and coal, might to be expected in 2025, when Natural Gas may start to decline accompanied with ever increasing share of coal in fossil-fuelled generation.

Equilibrium btw. Natural Gas & Coal





Equilibrium btw. Natural Gas & Coal

NG, with all of it excellent attributes in CCGT construction- and ecology preferences, would have to cost at least 3.0 USD/GJ more than the coal, to be replaced by this fossil fuel commodity.

Equilibrium btw. Natural Gas & Coal

Even though that the current Natural Gas fired CCGT power plants market share is still rising, the larger coal reserves and wider availability, the coal based power generation technologies will dominate in future's the long term.

Clean Coal Technology – the Solution for the Future?

- Three major coal utilization technologies for cleaner power generation are available for commercial use and partly implemented in various Asian countries:
  - Supercritical- & Ultra-supercritical Steam Technology;
  - PFBC Technology; and
  - IGCC Technology.

IGCC Technology

- IGCC technology has remarkable implications for energy conservation and environmental protection resulting in indirect economic and social benefits;
- If the predicted growth in coal-fuelled power generation continues without widely applied pollution-suppressing technologies, emissions levels would increase by 350% within the next double-decade, and by 1000% by the year 2035. Such estimates have been issued by the World Bank.
- As worldwide air emissions standards become stricter, the superior environmental performance of IGCC will take on added economic benefits because the technology can achieve greater emissions reductions at lower cost than less advanced technologies.

Clean Power

- For example, a coal plant without environmental controls generates 1000 to 1500 ppm of NOx, compared to about 20 ppm for NG fired CCGT power plant.
- State-of-the-art, IGCC power plants generate as little as 20 ppm of NOx, or about the same as NG fired power plants.
- Similarly, an uncontrolled coal power plant generates 2500 ppm of SO2, while a state-of-the-art IGCC power plant generates as little as 10 ppm SO2.

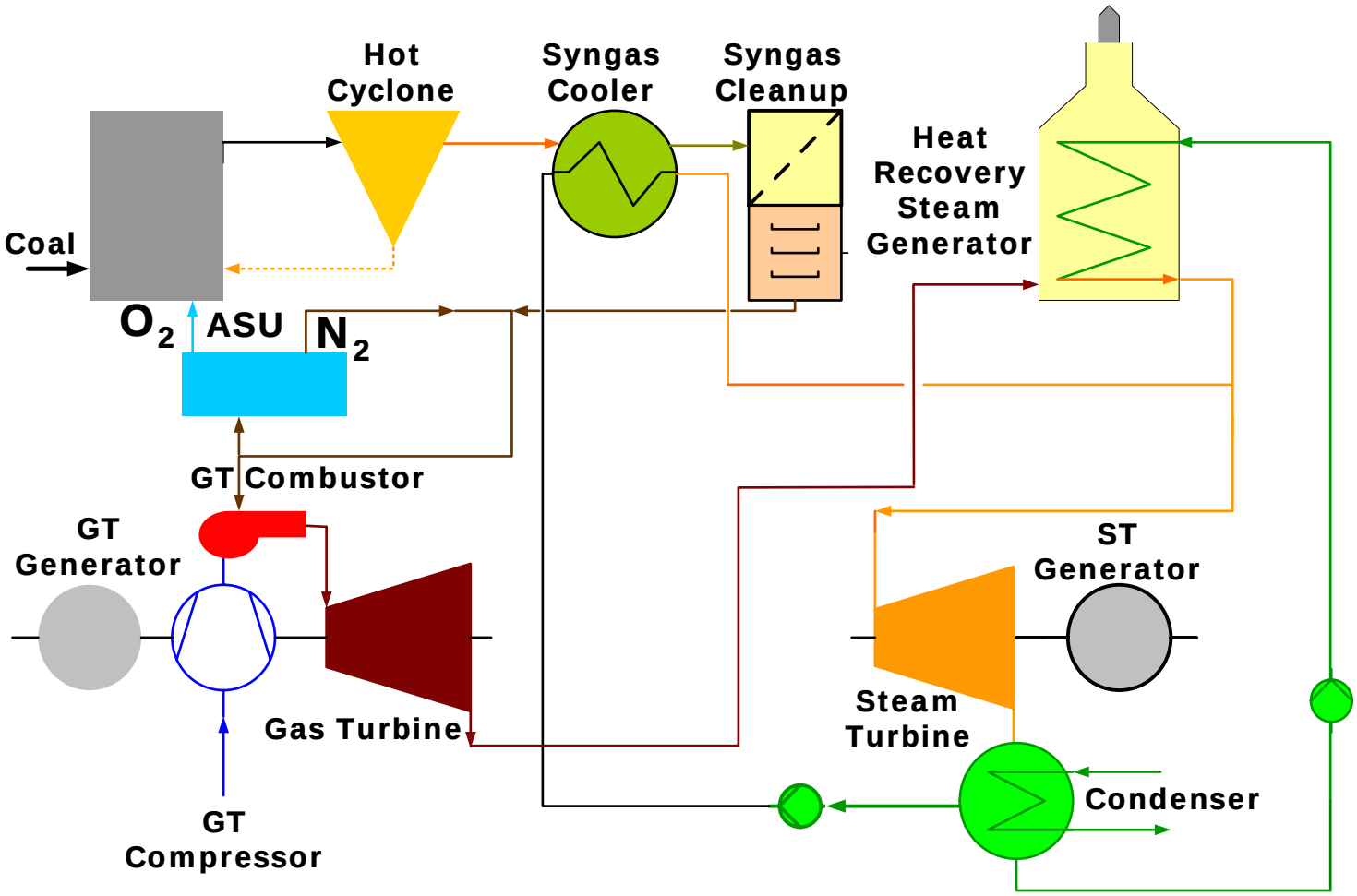
IGCC Technology

- IGCC technology combines both GT and ST in combined cycle operation;
- Depending on the level of integration of the various processes, IGCC may in short term achieve 40 to 42% and in long term upto 50% efficiency;
- Approximately 60-70% of the power comes from the GT (GT contribution in PFBC plant is only 20%).

Selected IGCC Power Plants

Project Location	Gasification Technology	Fuel	Efficiency (%)	Total Power Output (MW)	Start of Commercial Operation	Capital Costs (USD/kW)
SUV / EGT-CR	Lurgi	Lignite	40	350	1997	
Elcogas SA-E	Prenflo-O_2	Coal/Pet	45.0	335	1997	2'660
Tampa Electric US	Texaco	Coal	40	313	1996	2'000
PSI / Destec US	E-GAS	Coal/Pet	39.7	260	1995	1'600
W. Alexander-NL	Shell	Coal	41.3	253	1994	2'110
Lakeland/ DOE US	ACFBCC	Coal	40.6	250	2005	
Steag Kellerman D	BGL	Coal	31.7	170	1969	
LGTI US	E-GAS	W-Coal	36	160	1987	2'140
SCE US	Texaco- O_2	Coal	31.2	100	1984	2'000
Sierra Pacific US	KRW-air	Lignite	38	99	1996	2'300
SchwarzePumpe D	Lurgi-O_2/BGL	Coa/Wst		75	1996	
Vresova CR	HTW	Lignite		2x200	1996	

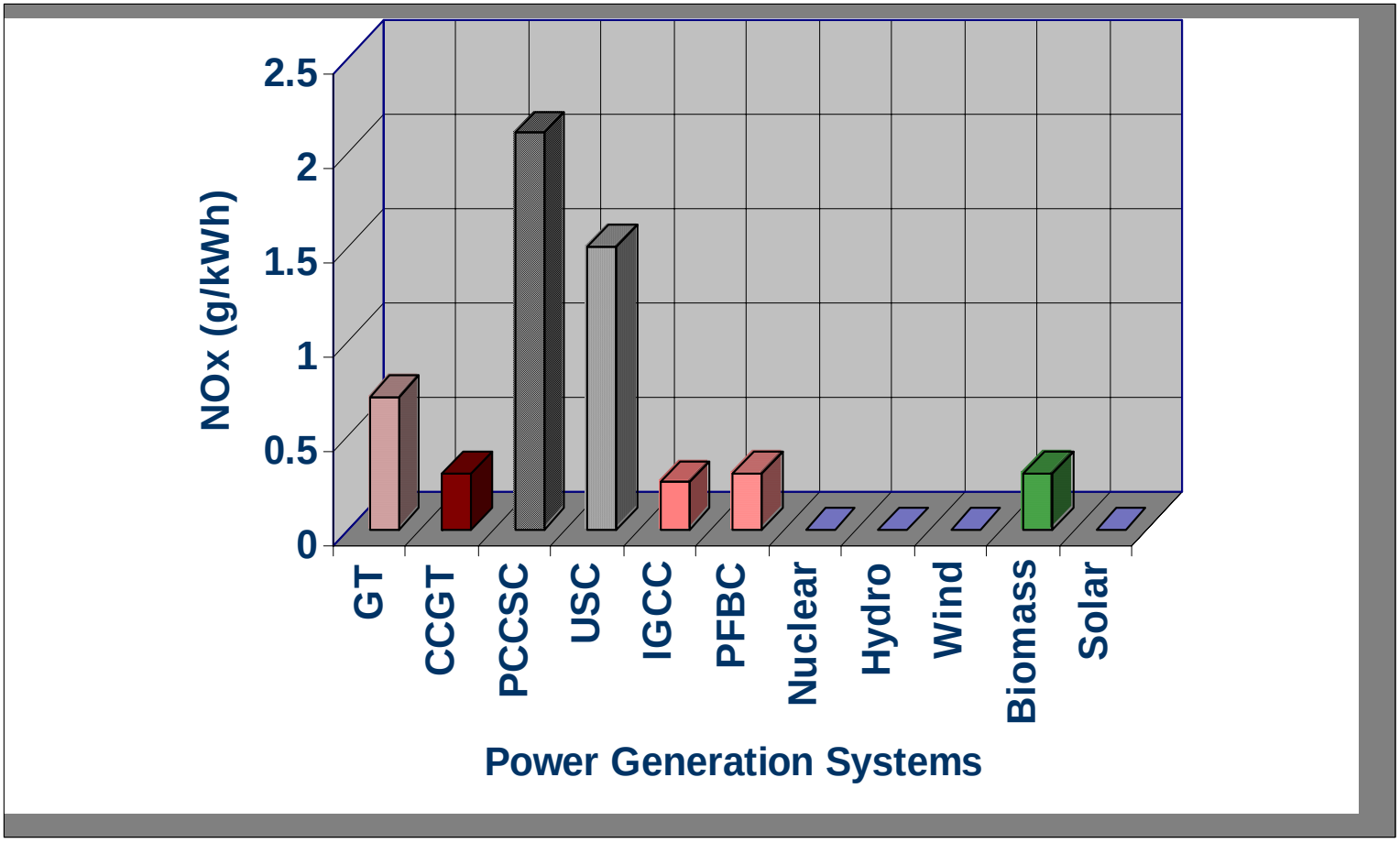
Simplified IGCC Process Diagram



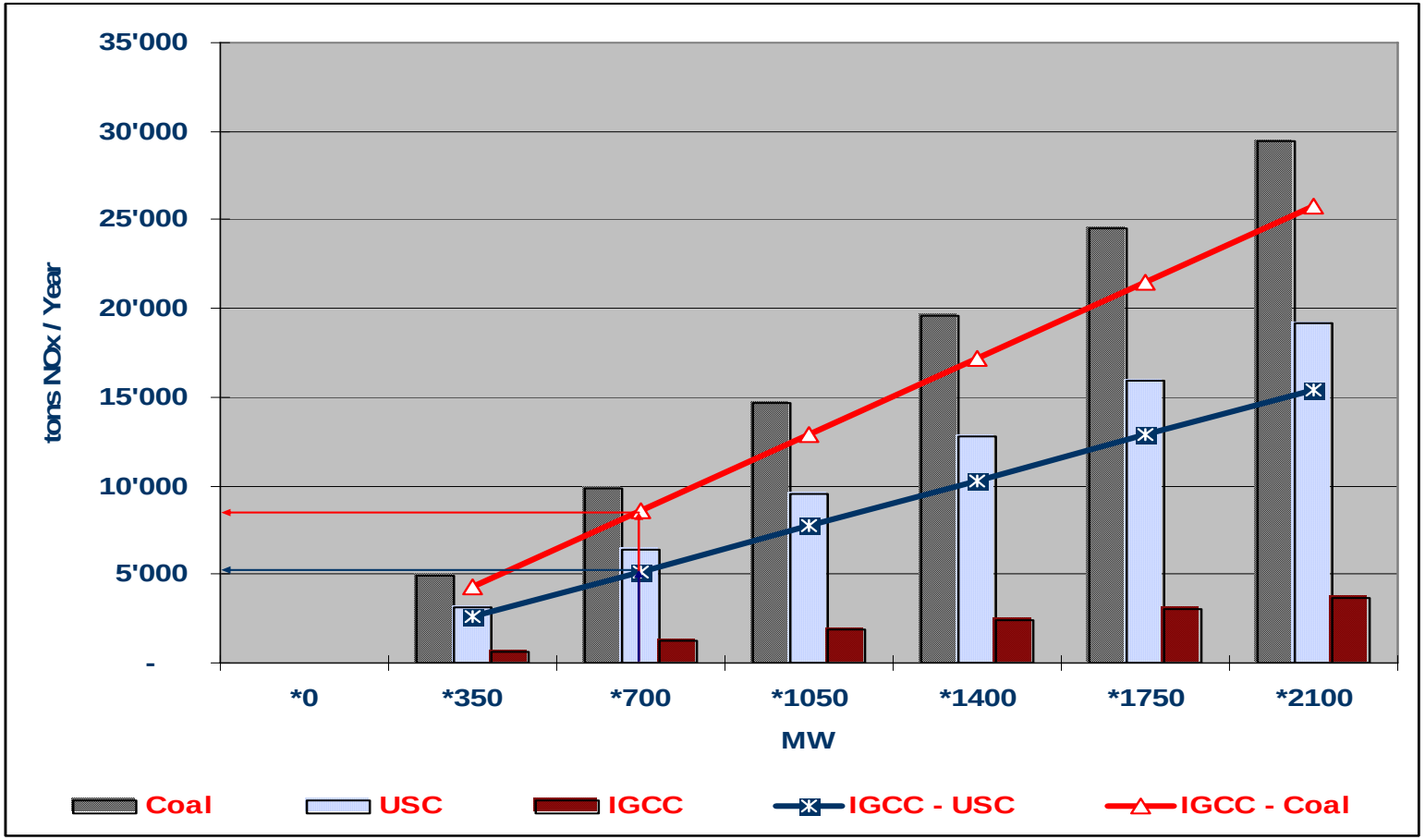
IGCC Technology

- IGCC systems can be built down to 100-150 MW modules, allowing flexibility in capacity expansion and lower unit costs.
- Efficiencies approaching 50%, >99% SO2 removal, and NOx <50ppm, normally impracticable with any other solid fuel fired technology, are potentially possible.

Specific NOx Emissions from selected Power Plants



Comparison of NOx Emissions from selected Power Generation Systems



Comparison of NOx Emissions from selected Power Generation Systems

- One 700MW sub-critical power generation block produces 9’800 tons NOx per year (with PLF=80%).
- This is around 8-times more as IGCC yearly NOx production (1’200 tons per year from 700 MW power generation block).

IGCC Economics

- Dramatic improvements have been made in IGCC technology capital costs. Coal base plants have been recently bid for less than 1'200USD/kW on a turnkey basis.
- This capital cost reduction is due to variety of factors, the most influential being:-
  - GT performance enhancement;
  - Gasification system enhancement;
  - IGCC EPC learning curve

Coal Reserves

- Coal is one of most important fuel commodities for power generation.
- Total world probable reserves of coal are around 12’000 metric Gt (12’000 Billion Tons)
- Of this, around 985 metric Gt (more than 25% is located in Asia and about 8% in Australia) are considered proven, economically recoverable coal reserves.

Coal Future

- The current worldwide coal consumption is 4.4 metric Gt per annum.
- Even if an average consumption increases 2.5% each year, the probable proven coal reserves are good for 320 years and
- The proven coal reserves are sufficient to cover coal consumption for next 215 years.

IGCC Future

- Both, PFBC and IGCC represent a unique partnership between coal gasification and Gas Turbine technology, resulting in high system efficiency at very low emissions production.
- As worldwide air emissions standards become stricter, the superior environmental performance of IGCC will take on added economic benefits because the technology can achieve greater emissions reductions at lower cost than less advanced technologies.

Significant barriers to further market penetration of IGCC technology

- Price, as the technology is around 20-30% (with cost projections 1’000 – 1’300USD/kW based on US & Europe price level) more expensive than competing alternatives;
- The next generation IGCC plants must have an investment cost of less than 1’200 USD/kW and a net efficiency of more than 48%, to be competitive with other clean coal technologies;
- IGCC is projected to be more cost-effective than NG fired CCGT plants when the cost-differential between NG and coal is at least 3.0 USD/GJ; and
- Technology risk, as many of the existing systems don't have long-term operating histories.

Conclusions

- It is important to evaluate the power generation technologies well in advance;
- IGCC technology it is one of the advanced coal utilization technology with high efficiency and low environmental emissions including NOx, sulphur and CO2;
- IGCC can use low quality coal or lignite which can be found in many Asian countries such as India, Indonesia and China;
- IGCC in a combination of coal gasification technology with the most advanced, large heavy duty GTs and advanced steam-bottoming cycle with once-through heat recovery steam generator operating under supercritical steam parameters will result in unbeaten coal based power generation efficiency;

Conclusions

- Reusable process media remove sulphur from syngas prior to combustion in the GT. By contrast, plants that employ flue gas desulphurization techniques use limestone, dolomite, or other sulphur sorbents. These substances require disposal;
- With the advent of IGCC systems, coal-fired plants can realistically expect to attain maximum efficiency levels above 50% as early as the year 2015;
- IGCC system removes 99% of the coal's sulphur before combustion, NOx is reduced by over 90%;
- The water required to operate an IGCC plant is less than 50% of the quantity required to run a pulverized coal plant with a flue gas desulphurization system;
- The IGCC process generates a minimum of waste. Moreover, the by-products produced by the process have marketability;

Conclusions

- In addition to electricity production, the coal gasification process is easily diverted to co-production of such products as methanol, hydrogen, gasoline, urea for fertilizer, and assorted chemicals;
- IGCC technology provides flexibility to power producers because the combined-cycle portion of the process can be fuelled by NG, FO or coal.
- A power plant can switch to coal from NG as NG becomes unavailable or unacceptably expensive. In addition, most gasifier systems are easily adapted to different coals;
- Surging crude oil and NG/LNG prices, combined with supply security and environmental concerns, are prompting power generators and industrial firms to further develop coal gasification technologies;
- Coal gasification, the process of breaking down coal into its constituent chemical components prior to combustion, will permit the Asian region to more effectively utilize its enormous, low cost coal reserves.

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It is crucial that today we optimize the development and use of modern clean power generation technologies, which we can apply tomorrow, after tomorrow and in the future, to assure sustainable progress of our planet's healthy development.

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