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Advanced Clean Coal Technology for Power Generation- An Opportunity for Southeast Asia

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- Advanced Clean Coal Technology is defined as technology designed to enhance both the efficiency and the environmental acceptability of coal extraction, preparation and use.
- It reduces emissions & waste, and increases the amount of energy gained from each tonne of coal.

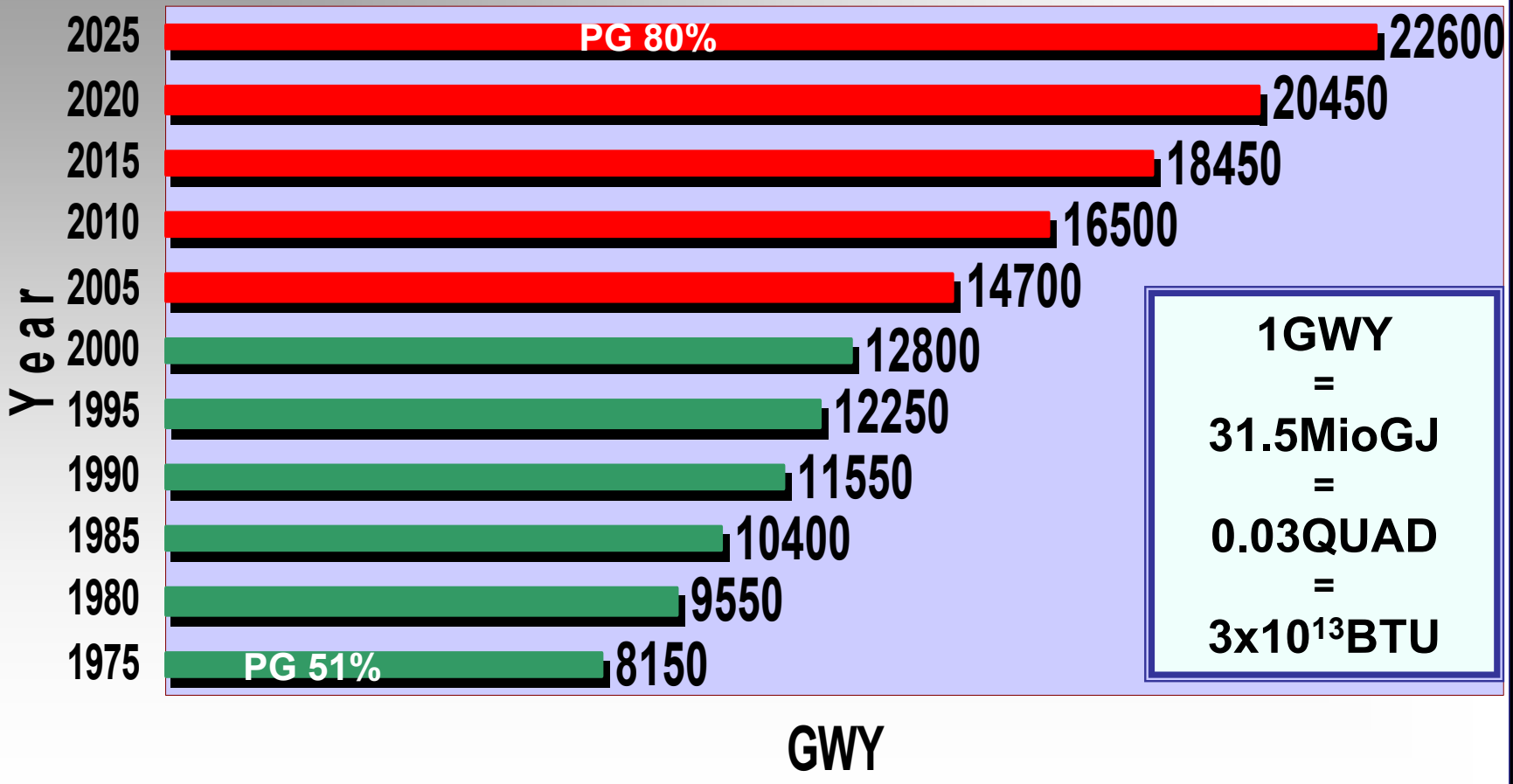
For example, a coal fired power plant without any environmental controls generates between 1000 and 1500 ppm of NOx.

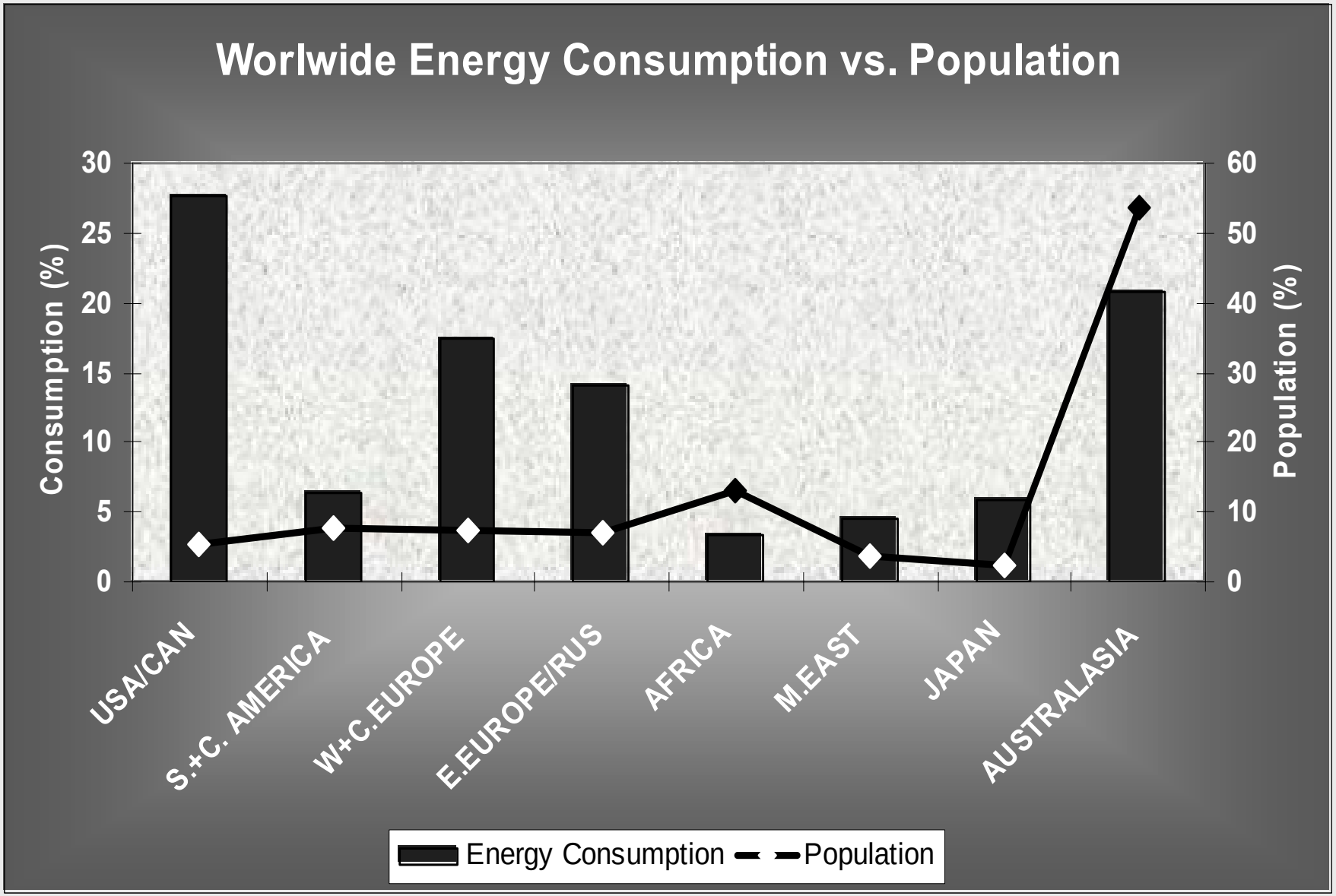
State-of-the-art, IGCC power plant generates as little as 20 ppm of NOx, or about the same as NG fired power plant.

Advanced Clean Coal Technologies

- Integrated Gasification Combined Cycle (IGCC)
- Pressurized Fluidized Bed Combustion (PFBC)
- Hybrid Combined Cycle (HCC)
- Direct Coal fired Combined Cycle (DCCC)
- Molten Carbonate Fuel Cell (MCFC)
- Magneto Hydrodynamics (MHD) Power Generation
- Supercritical Steam (SC)
- Ultra-SC (USC)

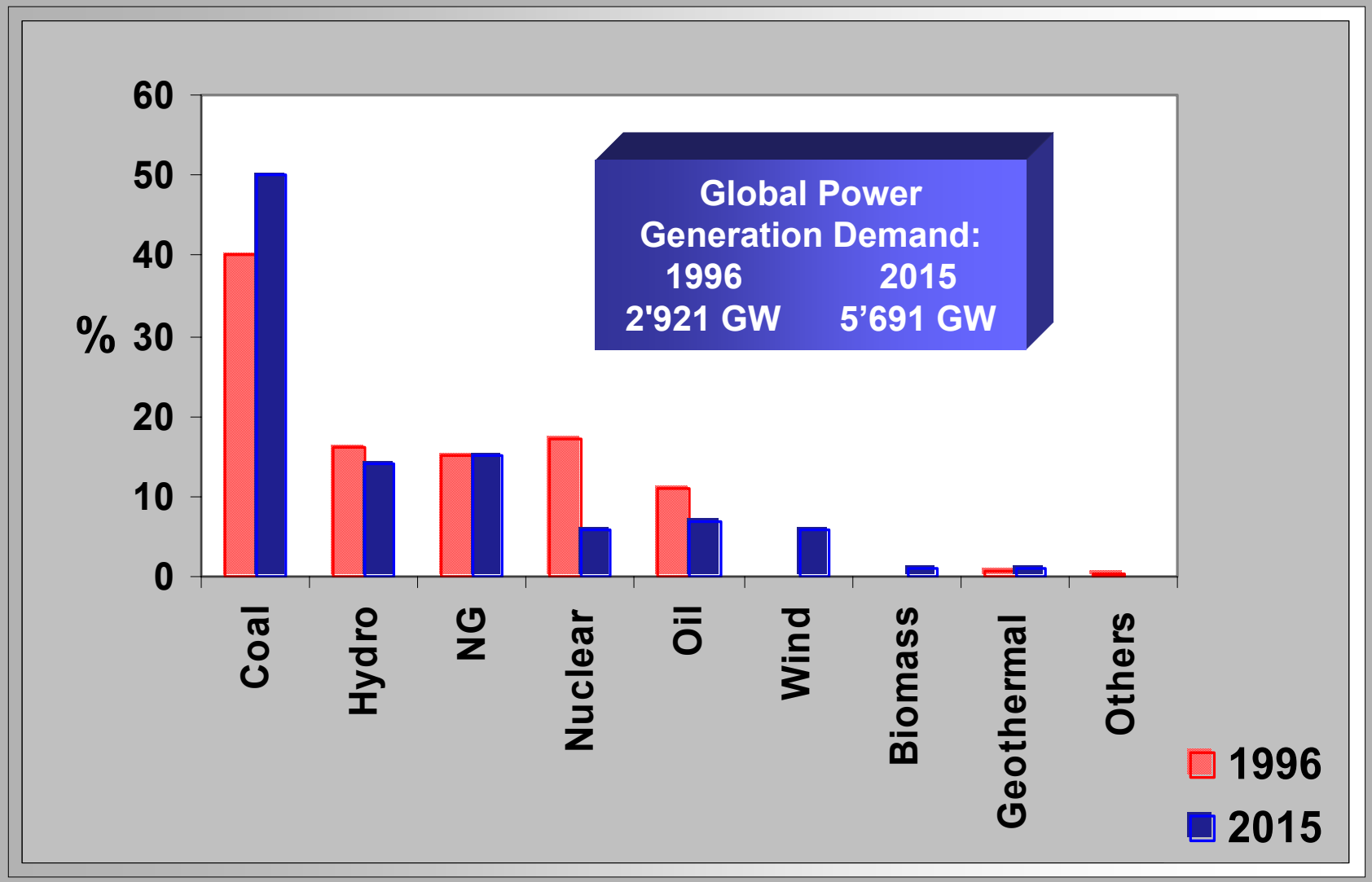
World Energy Consumption



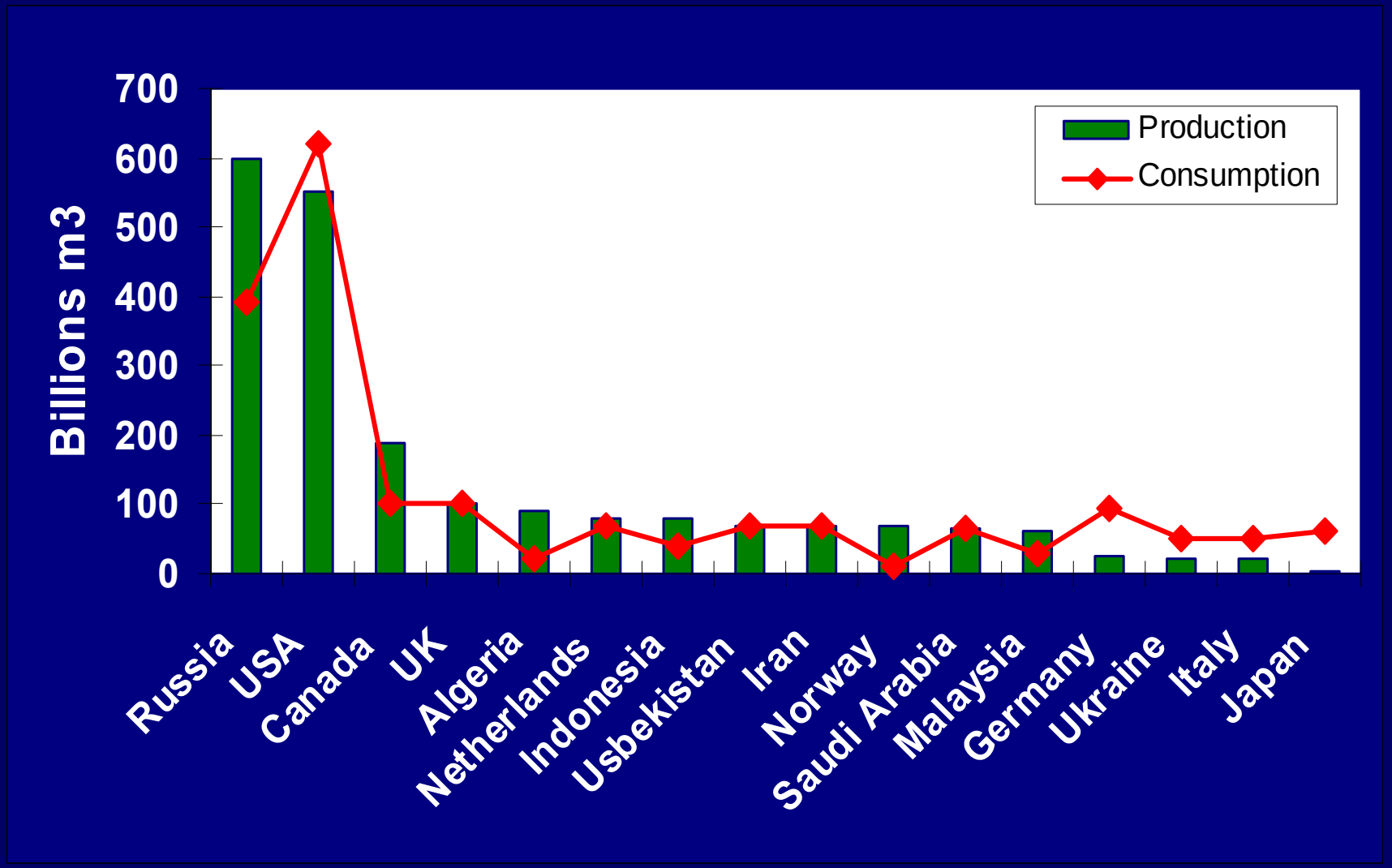

Worlwide Energy Consumption vs. Population
Consumption (%)
Population (%)
30
25
20
15
10
5
0
60
50
40
30
20
10
0
USA/CAN
S.+C. AMERICA
W+C.EUROPE
E.EUROPE/RUS
AFRICA
M.EAST
JAPAN
AUSTRALASIA
Energy Consumption
Population

- Increasing share of Independent Power Producers (IPPs) → preferring short-time investment return periods; guaranteed by the NG based technologies.
- Increasing pressure of environmental legislation in most countries → favors NG as the dominant choice in green-field projects.
- Worldwide deposits of NG are restricted → NG resources are enough for half century, while proven deposits of coal are sufficient for another 250 years.
- Costs of the NG distribution infrastructure investment and maintenance will be growing.
- Almost three quarters of NG resources are situated in countries with not very high political stability, like Middle East, Russia and other former Soviet Union States.
- Deposits of coal are distributed in many politically stable countries worldwide.
- New exploitation technologies, like underground gasification will amplify competitive power of coal.

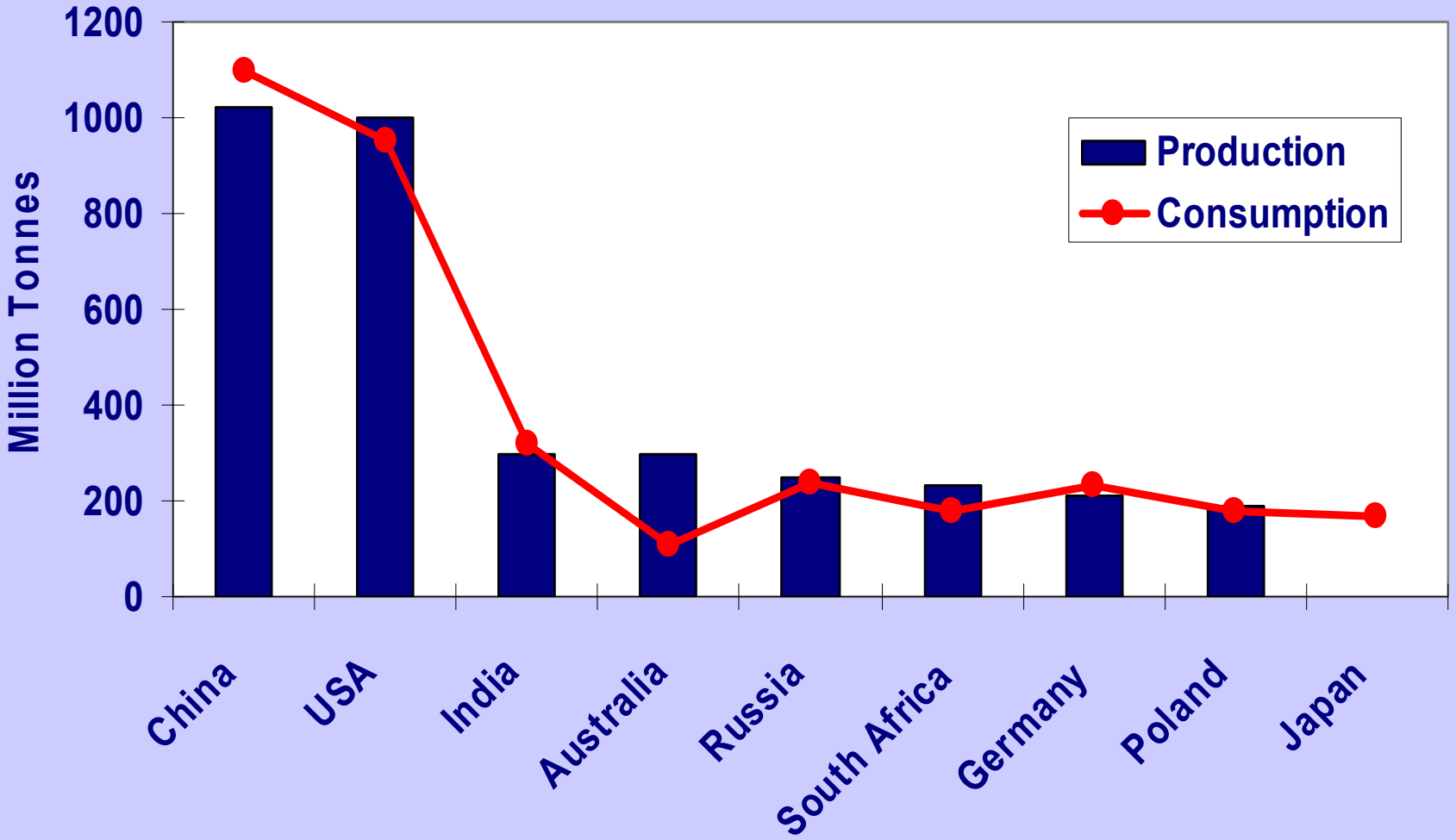
Fuel Scenario 1996 - 2015



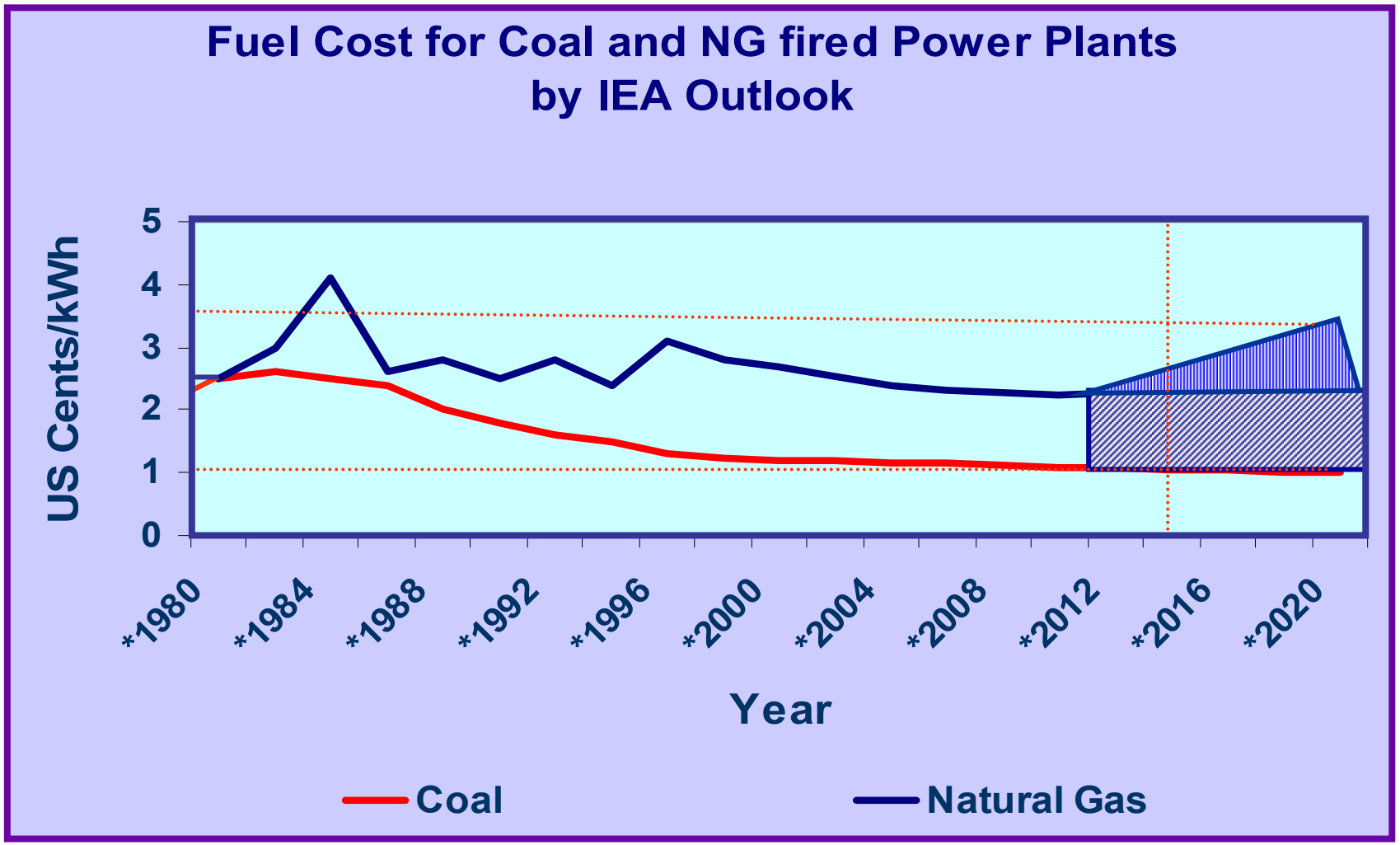
NG Production vs. Consumption in Year 2000

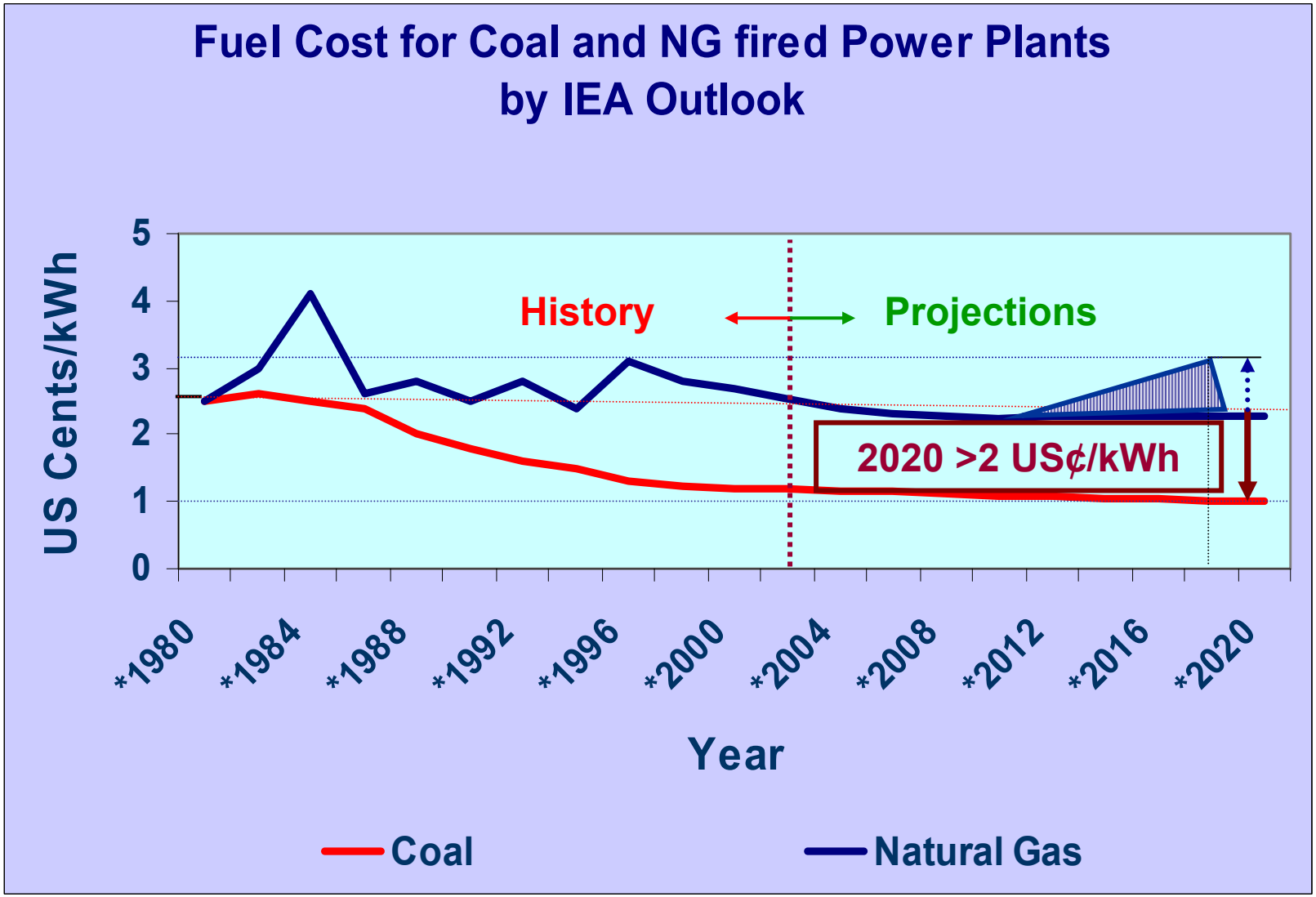


Coal Production vs. Consumption in Year 2000



Equilibrium between Natural Gas & Coal



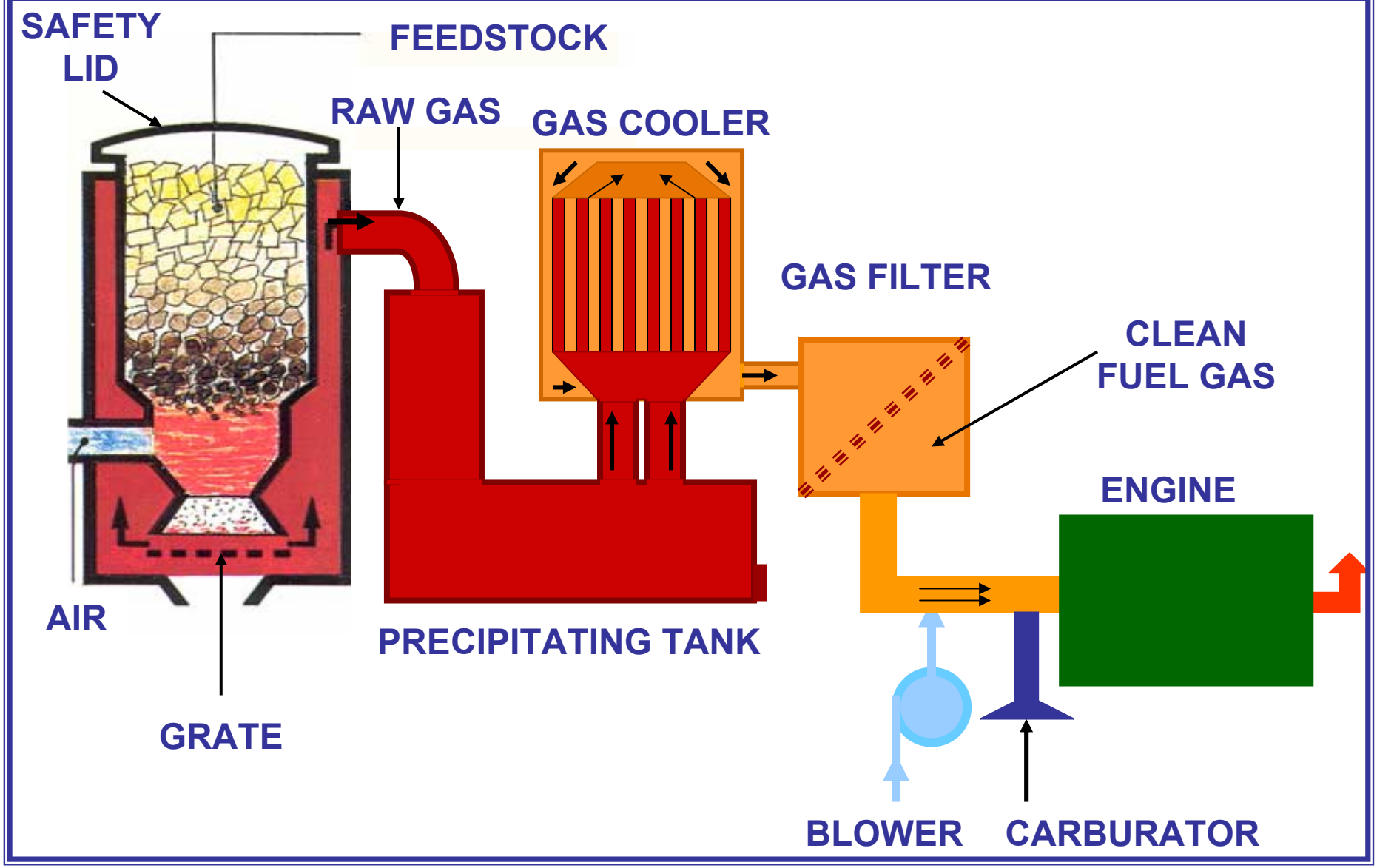

Fuel Cost for Coal and NG fired Power Plants
by IEA Outlook
US Cents/kWh
5
4
3
2
1
0
History
Projections
2020 >2 US¢/kWh
*1980
*1984
*1988
*1992
*1996
*2000
*2004
*2008
*2012
*2016
*2020
Year
Coal
Natural Gas

Coal Gasification

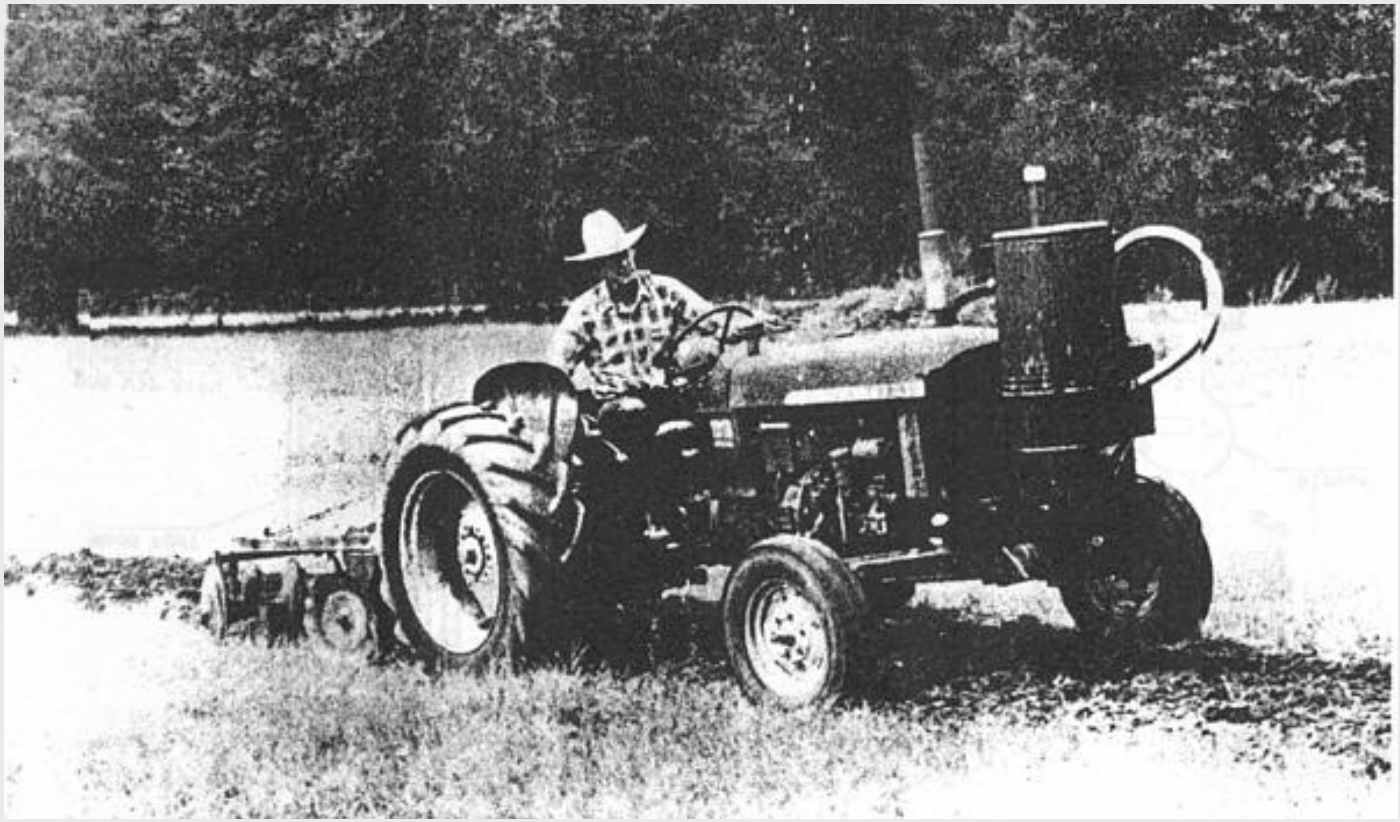
- Gasification has been known for more than 200 years.
- First record of its commercial application origins from the year 1830.
- Primitive coal gasification systems supplied town gas in many countries worldwide more 100 years ago.
- Gasification industry produced coal and wood based transportation gaseous fuel in many European countries during World War II.

In 1847 coal gas producing company supplied town gas for 100 public street lights for Cape Town in South Africa. The primeval darkness that has brooded over South Africa was dispelled, and the streets of Cape Town were illuminated with the long promised brilliancy of town gas.

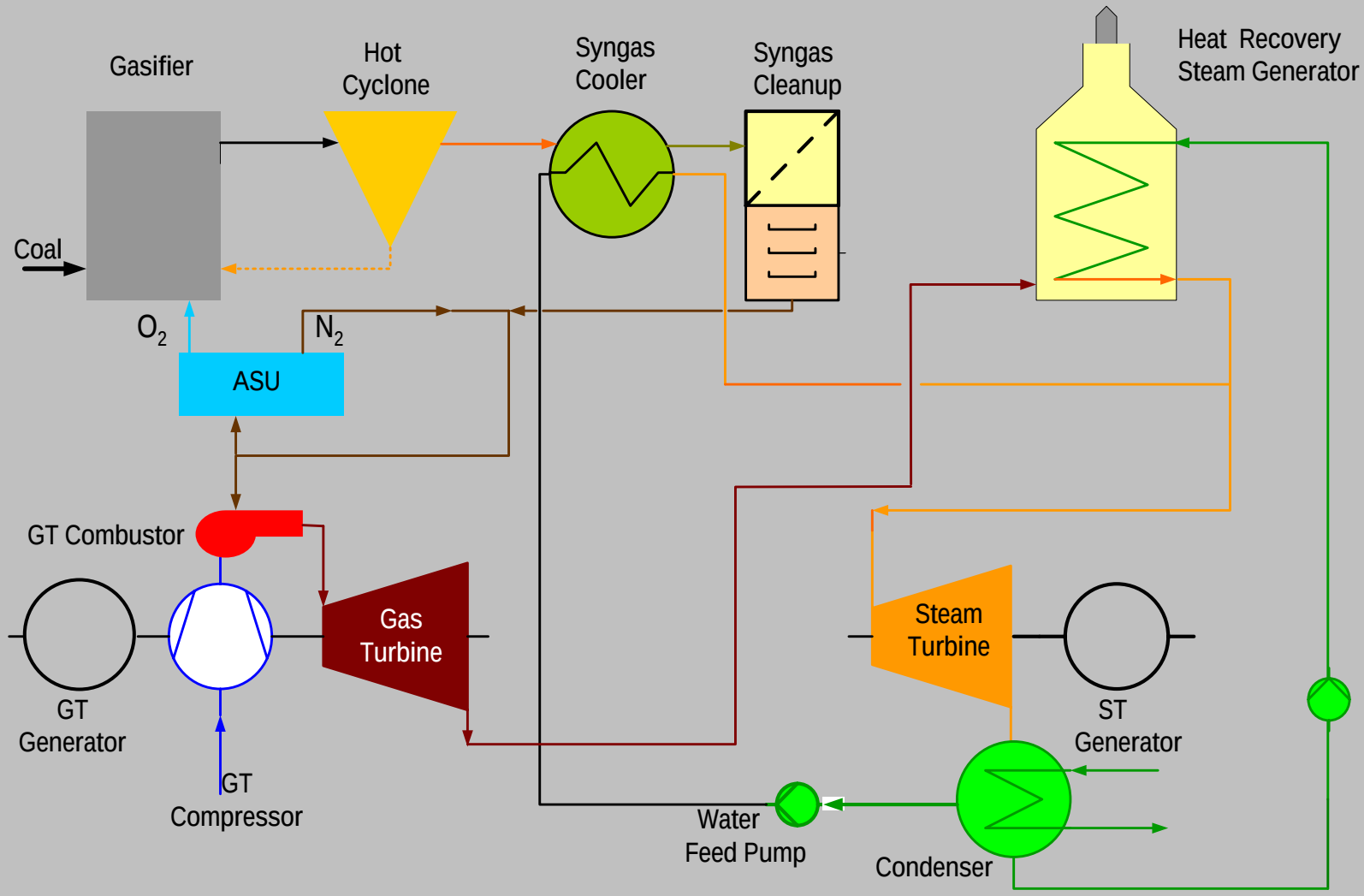
WORLD WAR II - GASIFIER



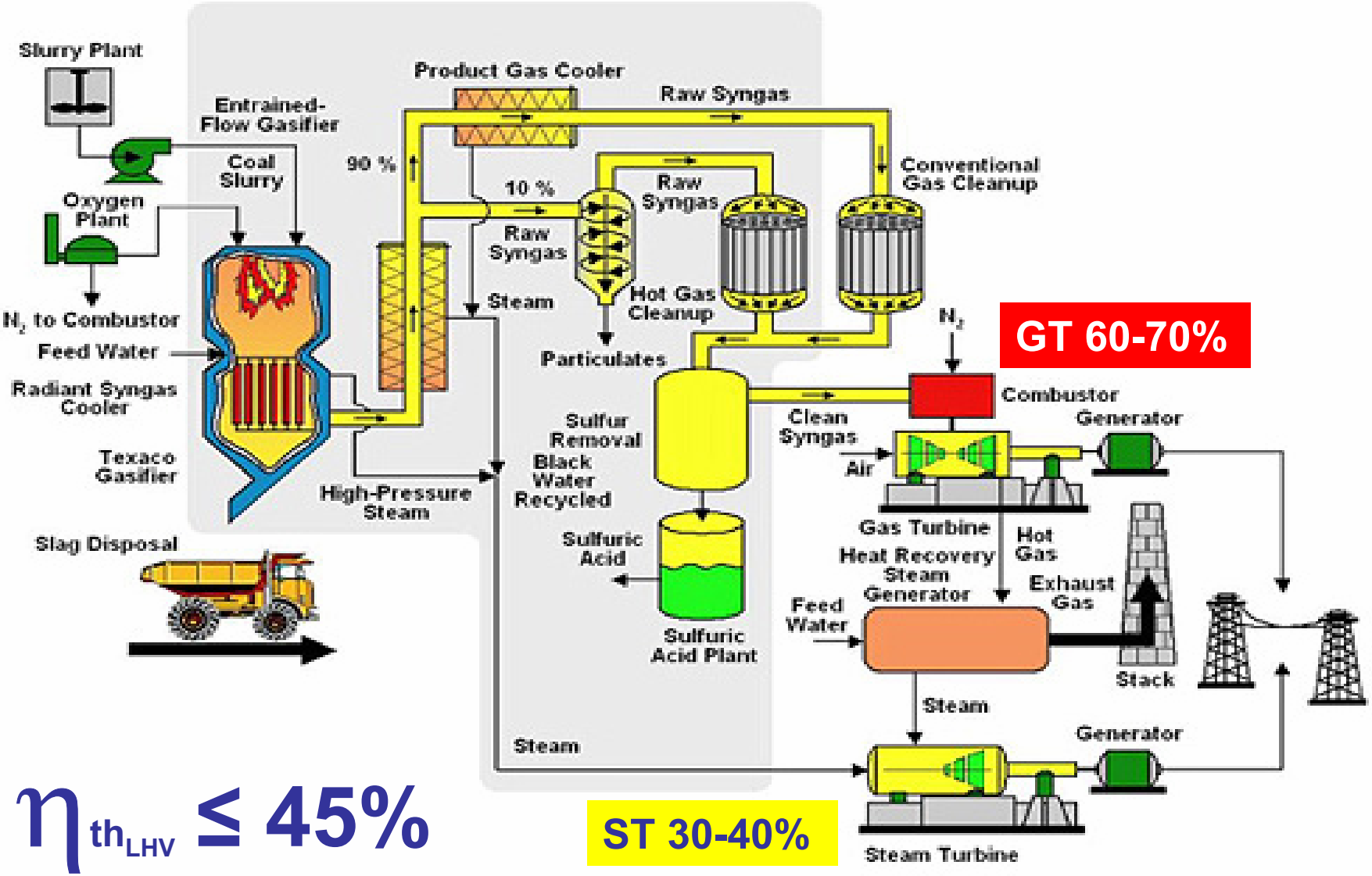
Tractor fueled with wood gas

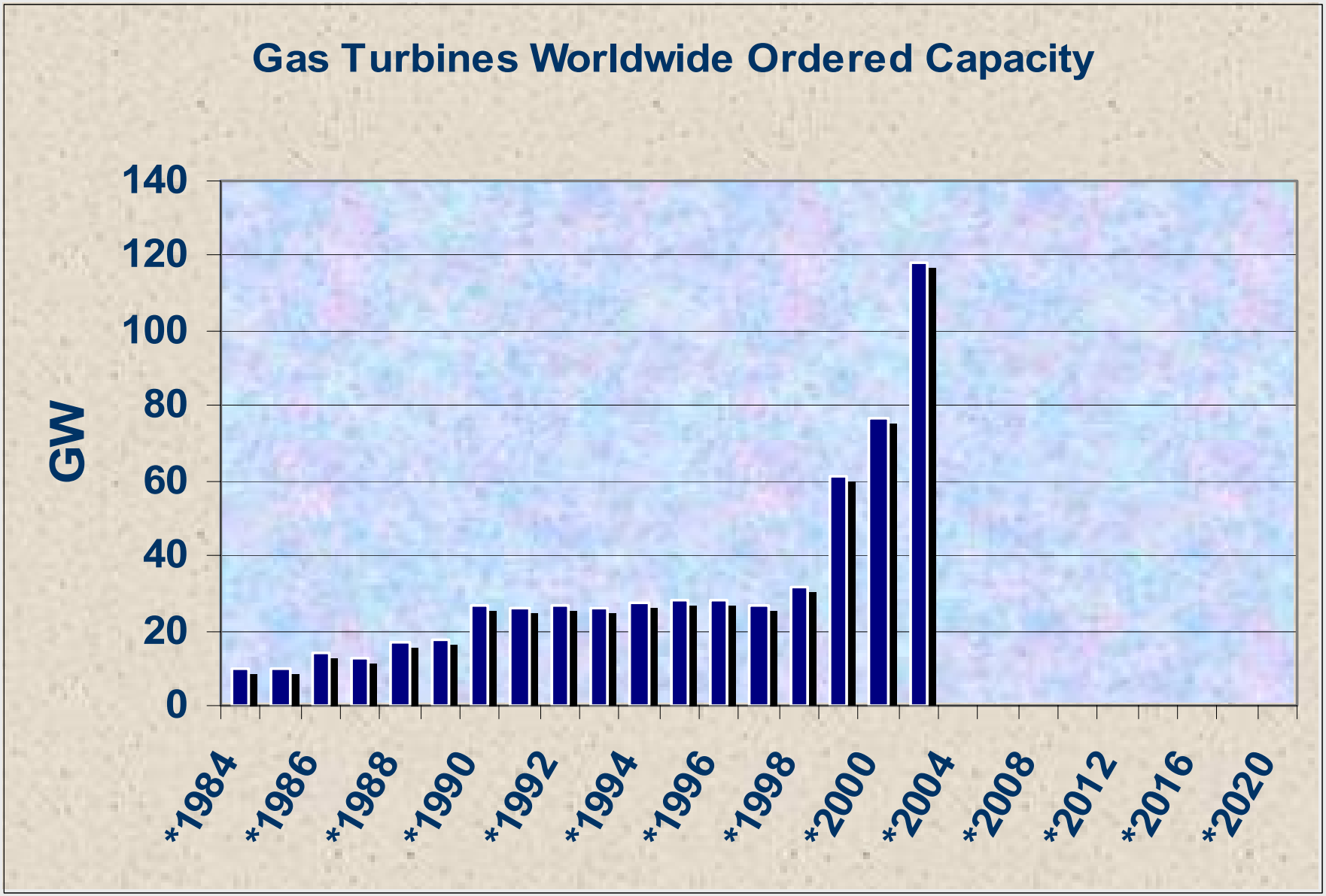


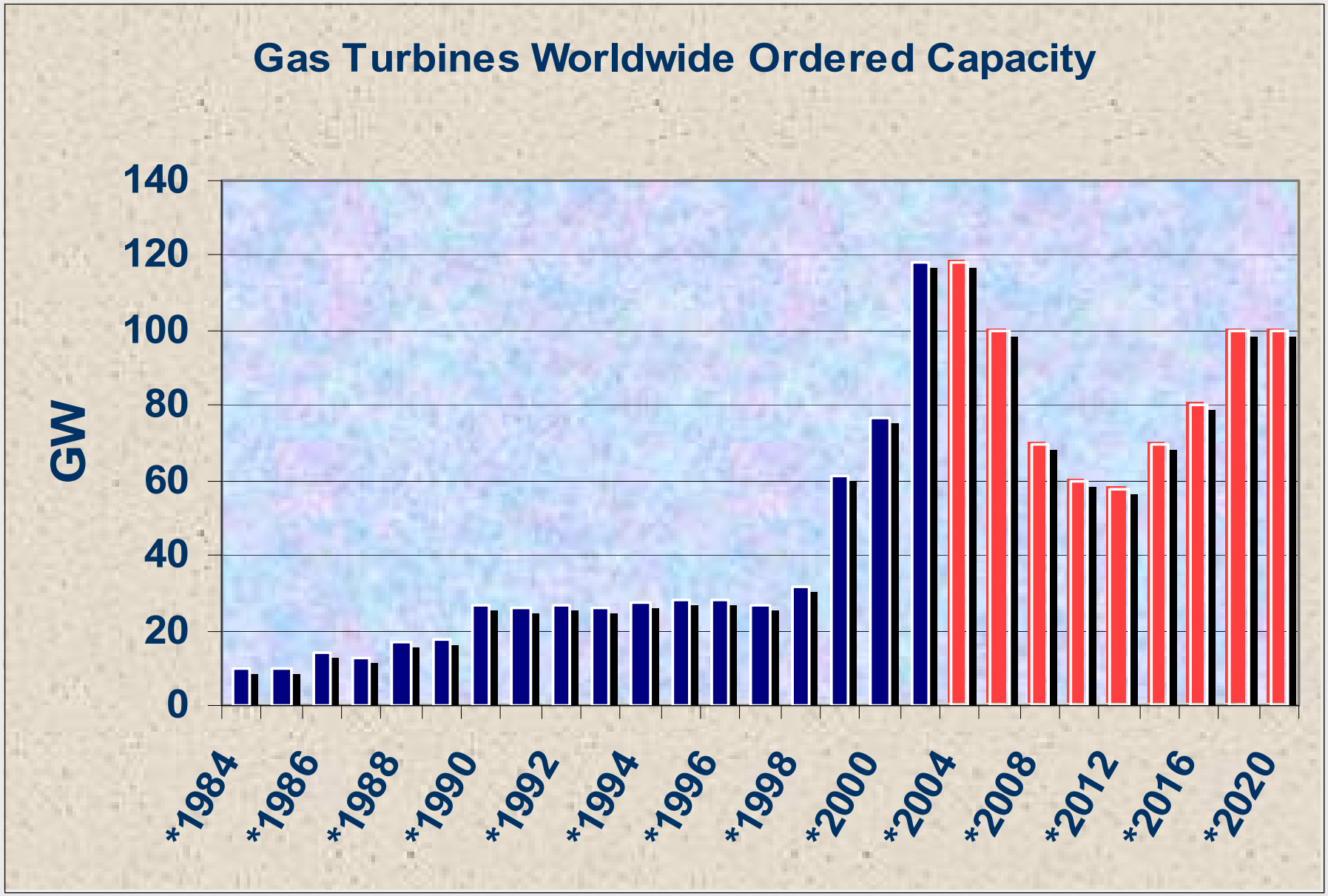
IGCC plant with Cold Gas Cooling System



IGCC Flow Diagram




Gas Turbines Worldwide Ordered Capacity
GW
140
120
100
80
60
40
20
0
*1984
*1986
*1988
*1990
*1992
*1994
*1996
*1998
*2000
*2004
*2008
*2012
*2016
*2020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0
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*1986
*1988
*1990
*1992
*1994
*1996
*1998
*2000
*2004
*2008
*2012
*2016
*2020

- IGCC systems can be built down to 100 – 150 MW modules, allowing flexibility in capacity expansion and lower unit costs than onsite fabrication.

- Efficiencies approaching 50%, >99% SO2 removal, and NOx <50ppm, normally im-practicable with any other solid fuel fired technology, are potentially possible.

Coal Gasification Technologies

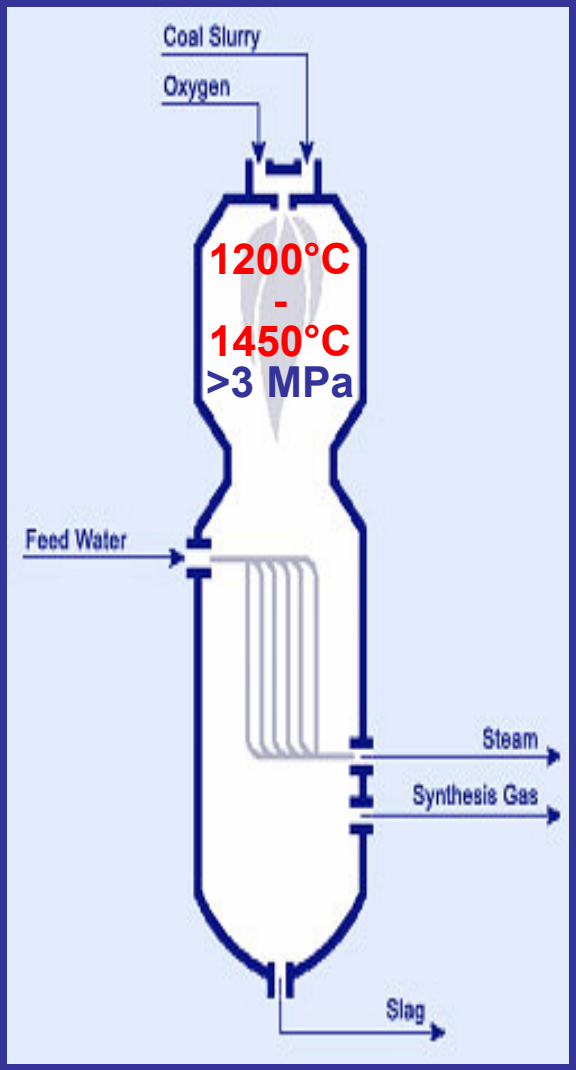
Coal gasification is a process that converts coal into syngas at high temperature and elevated pressure in the presence of oxygen and steam.

- Lurgi Dry Ash Gasifier
- Texaco Entrained Flow Gasifier
- E-GAS Entrained Flow Gasifier
- Shell Entrained Flow Gasifier

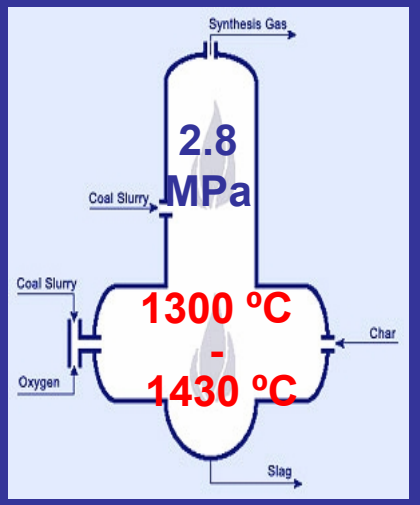
- PRENFLO Entrained O_2 Blown Gasifier
- KRW Fluidized-Bed Gasifier
- Kellogg Transport Gasifier
- British Gas/Lugi Fixed-Bed Gasifier

Entrained Flow Gasifiers

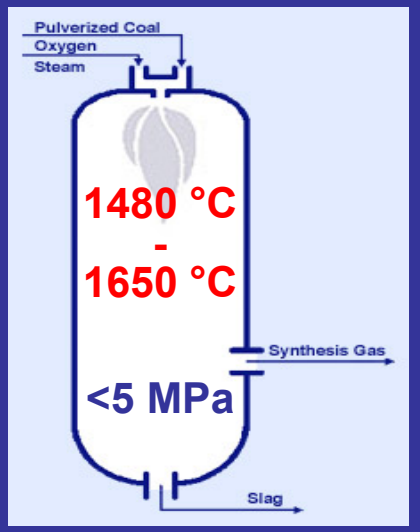
TEXACO



E - GAS

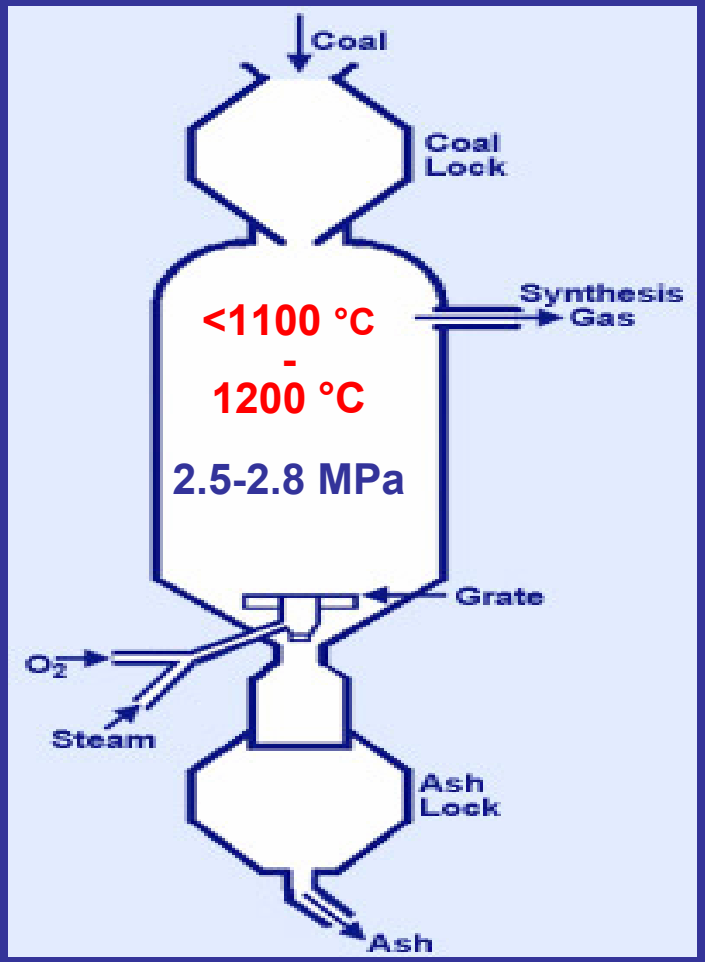


SHELL

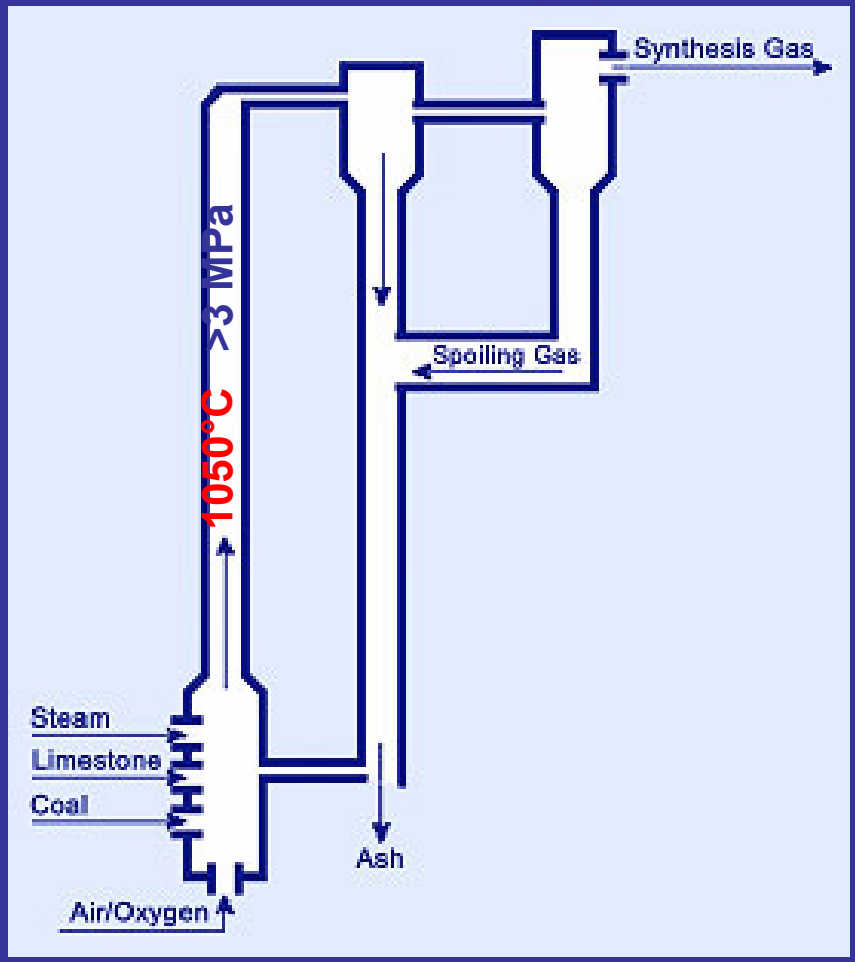


Coal Gasifiers

Lurgi Dry Ash

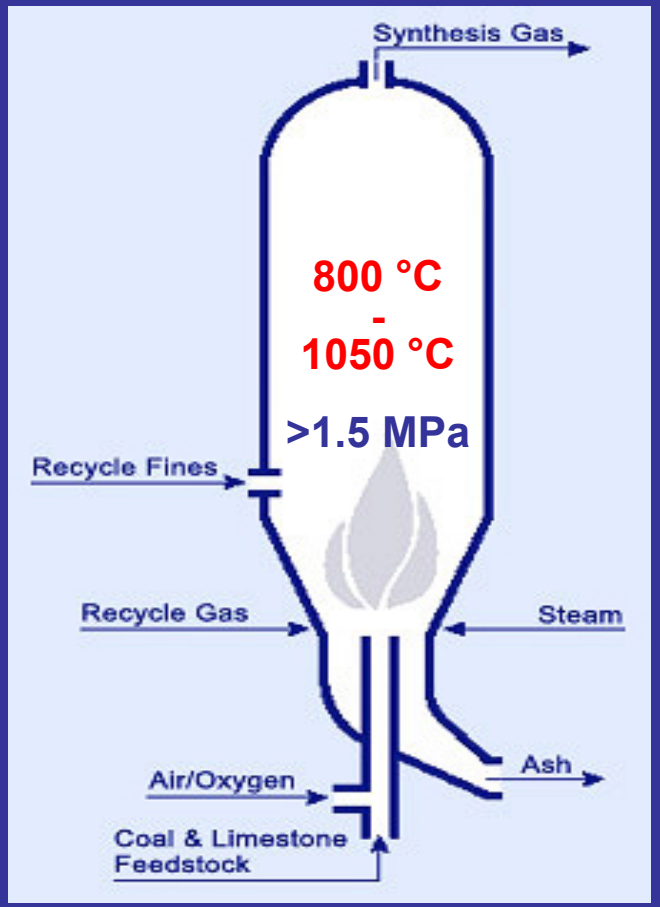


Kellogg DryTransport

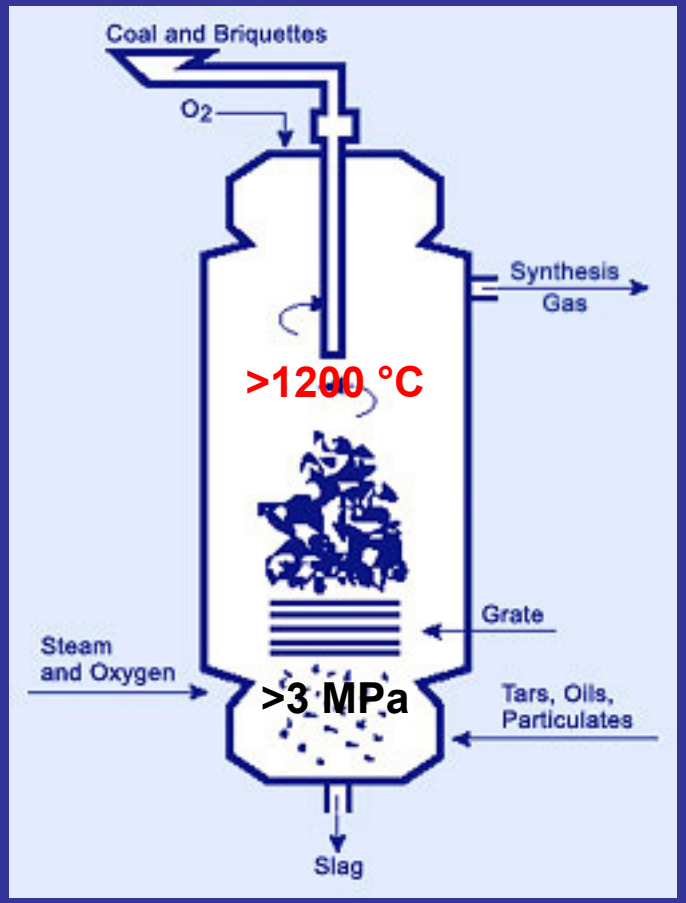


Coal Gasifiers

KRW Fluidized Bed



British Gas-Lurgi Fixed Bed



Underground Coal Gasification

This technique can be applied to generate energy from coal seams occurring deep below the surface generally not amenable, technically or economically, to extraction with known mining techniques.

Phased IGCC Construction

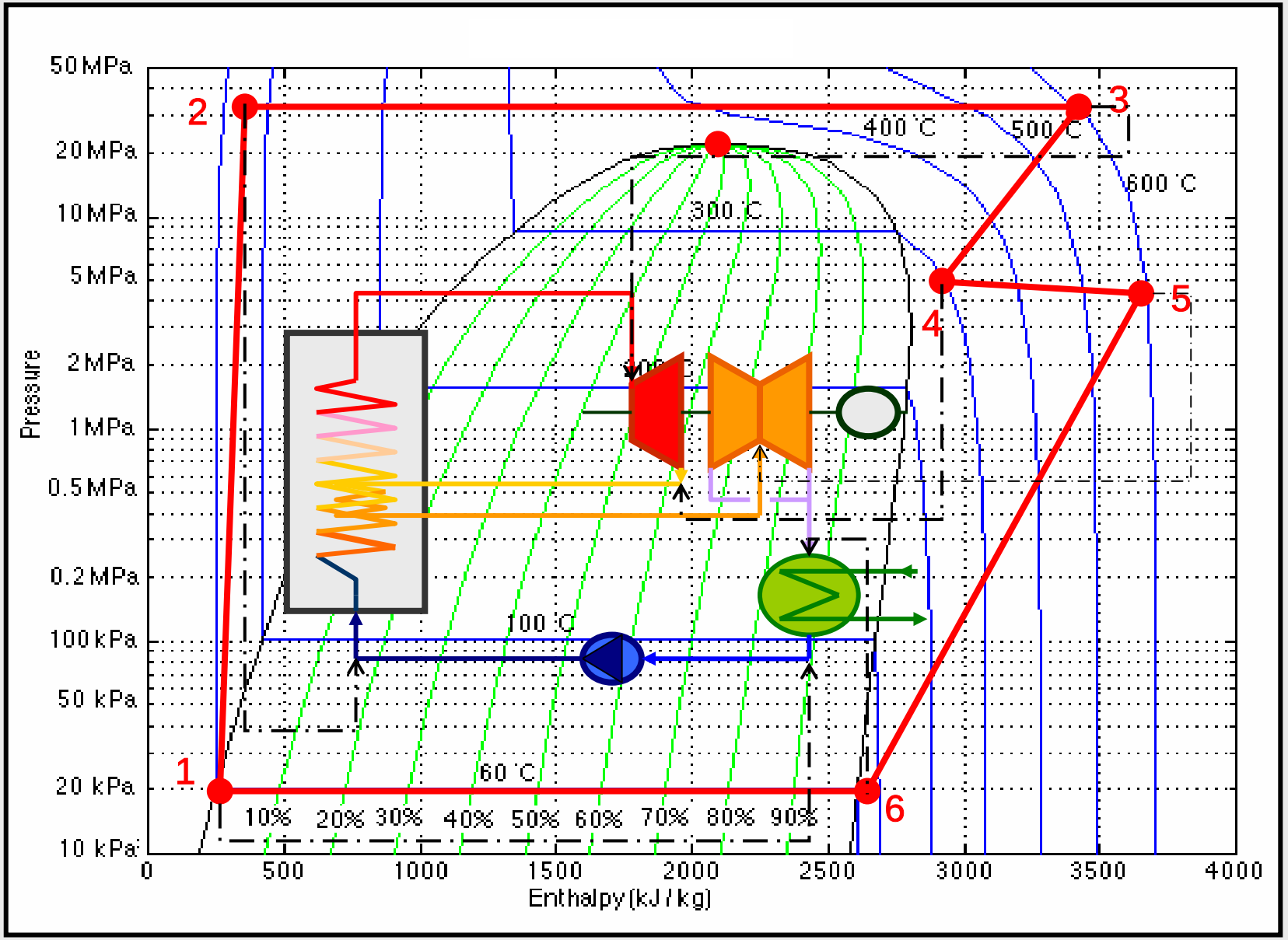
- Phase I - To produce ultra clean power
- Phase II+III - To produce CO_2 and H_2

In the first phase a state-of-the-art IGCC plant would be built with space left for the addition of syngas shift reactors and CO_2 removal and compression for use or disposal when that is needed to meet future CO_2 emission requirements.

At the same time H_2 purification, storage and transportation facilities could be added to supply hydrogen for distributed generation and vehicular transportation.

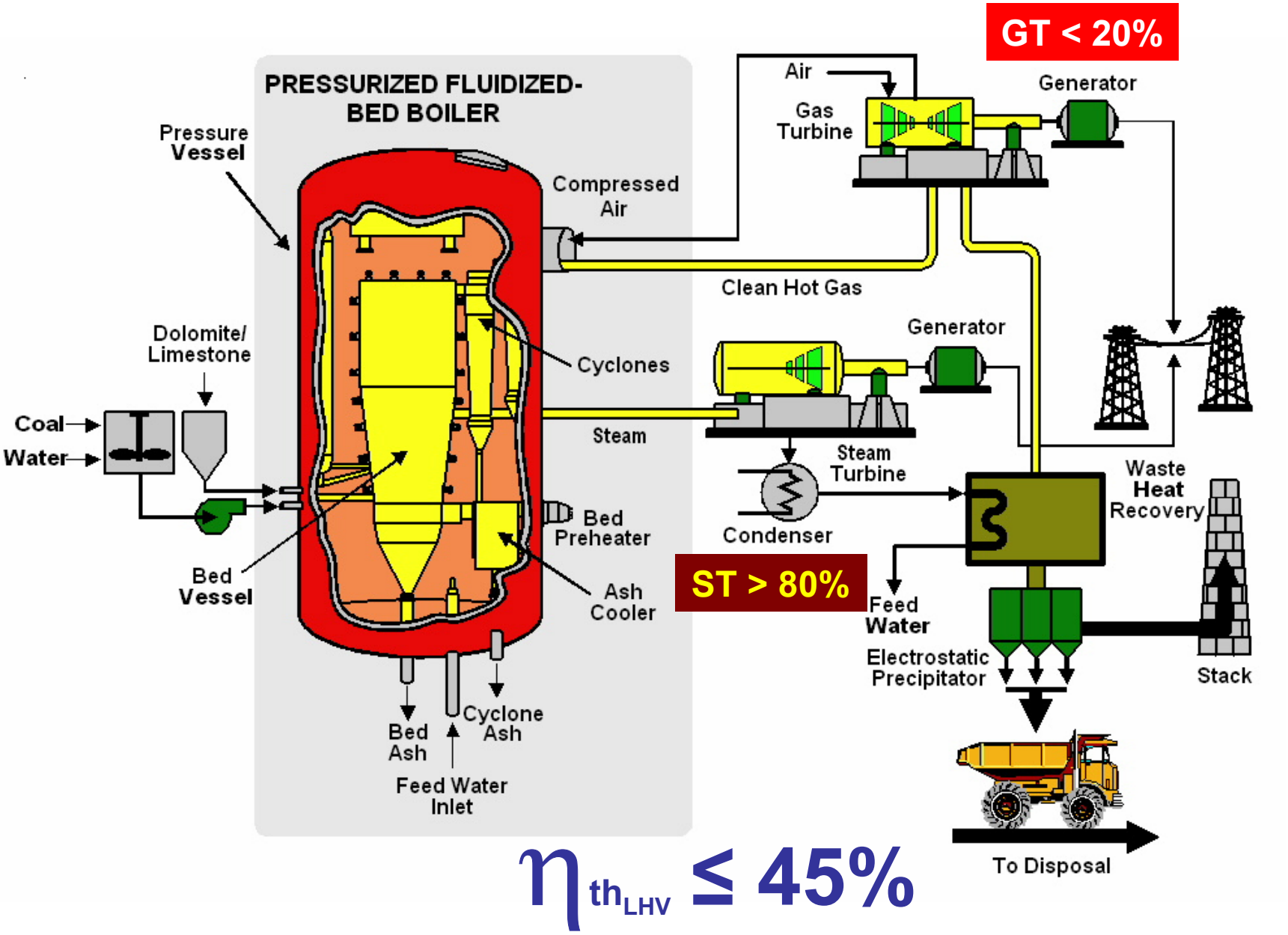
Another Advanced Clean Coal Technologies

- **SC and USC Steam Conditions**


50 MPa
20 MPa
10 MPa
5 MPa
2 MPa
1 MPa
0.5 MPa
0.2 MPa
100 kPa
50 kPa
20 kPa
10 kPa
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
Enthalpy (kJ / kg)
400 °C
500 °C
600 °C
300 °C
100 °C
60 °C
10%
20%
30%
40%
50%
60%
70%
80%
90%
1
2
3
4
5
6

Another Advanced Clean Coal Technologies

- SC and USC Steam Conditions
- Pressurized Fluidised Bed Combustion


GT < 20%
PRESSURIZED FLUIDIZED-BED BOILER
Pressure Vessel
Air
Gas Turbine
Generator
Compressed Air
Clean Hot Gas
Dolomite/ Limestone
Coal
Water
Cyclones
Steam
Generator
Steam Turbine
Condenser
Waste Heat Recovery
Bed Preheater
Bed Vessel
Ash Cooler
ST > 80%
Feed Water
Electrostatic Precipitator
Stack
Bed Ash
Cyclone Ash
Feed Water Inlet
To Disposal
$\eta_{th_{LHV}} \leq 45\%$

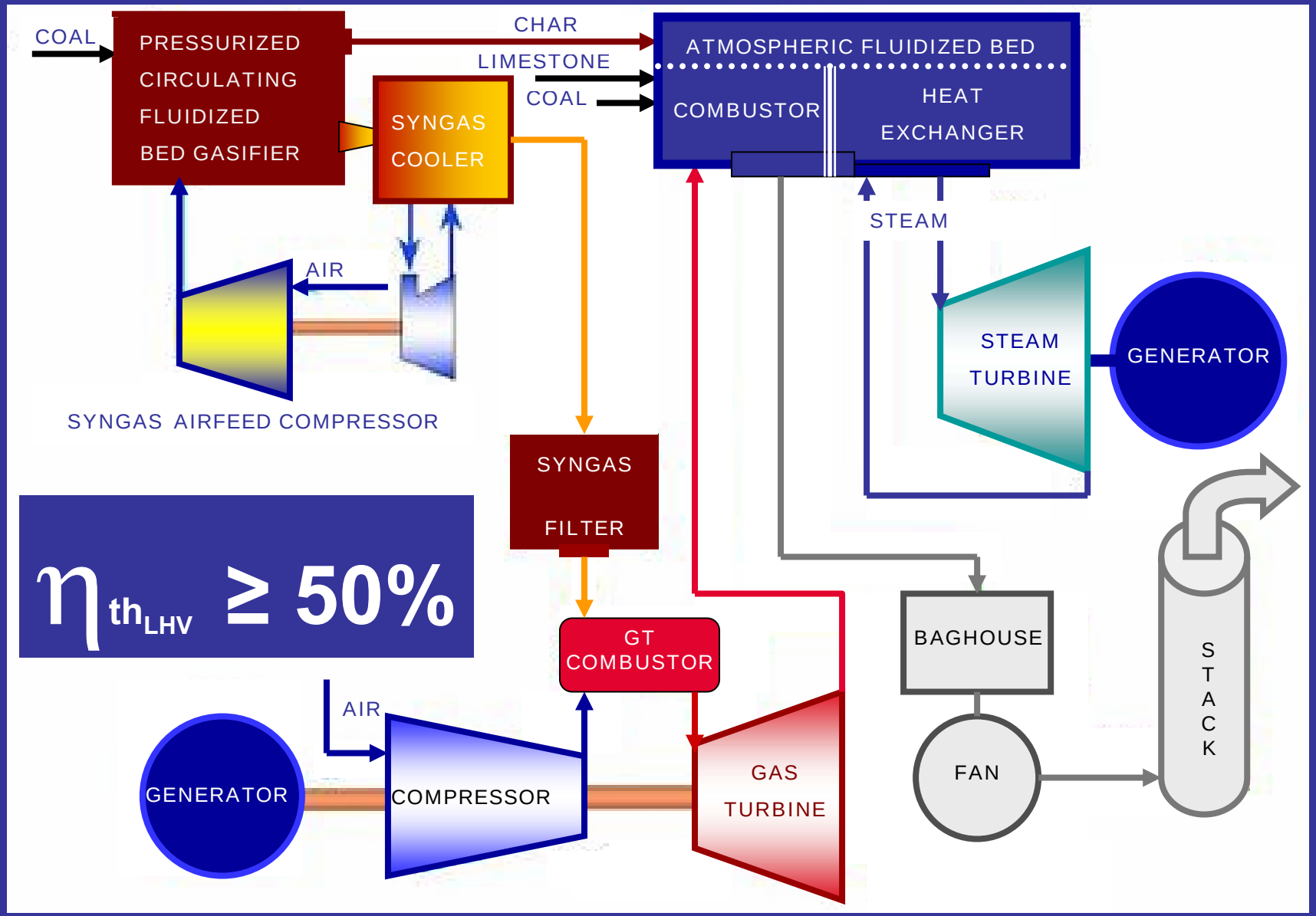
Another Advanced Clean Coal Technologies

- SC and USC Steam Conditions
- Pressurized Fluidised Bed Combustion
- Hybrid Combined Cycle

Hybrid Combined Cycle (HCC)

- Technology currently under development;
- Combination of both, gasification and combustion technology, using coal in a two-stage process;
- First stage gasifies the majority of the coal and runs a GT;
- Second stage combusts the residual char mixed with coal to produce steam for ST drive;
- Waste heat from GT can be utilized in heat recovery steam generator to generate additional steam for ST.

Hybrid Combined Cycle (HCC)



Another Advanced Clean Coal Technologies

- SC and USC Steam Conditions
- Pressurized Fluidised Bed Combustion
- Hybrid Combined Cycle
- Direct Coal fired Combined Cycle

Direct Coal fired Combined Cycle (DCCC)

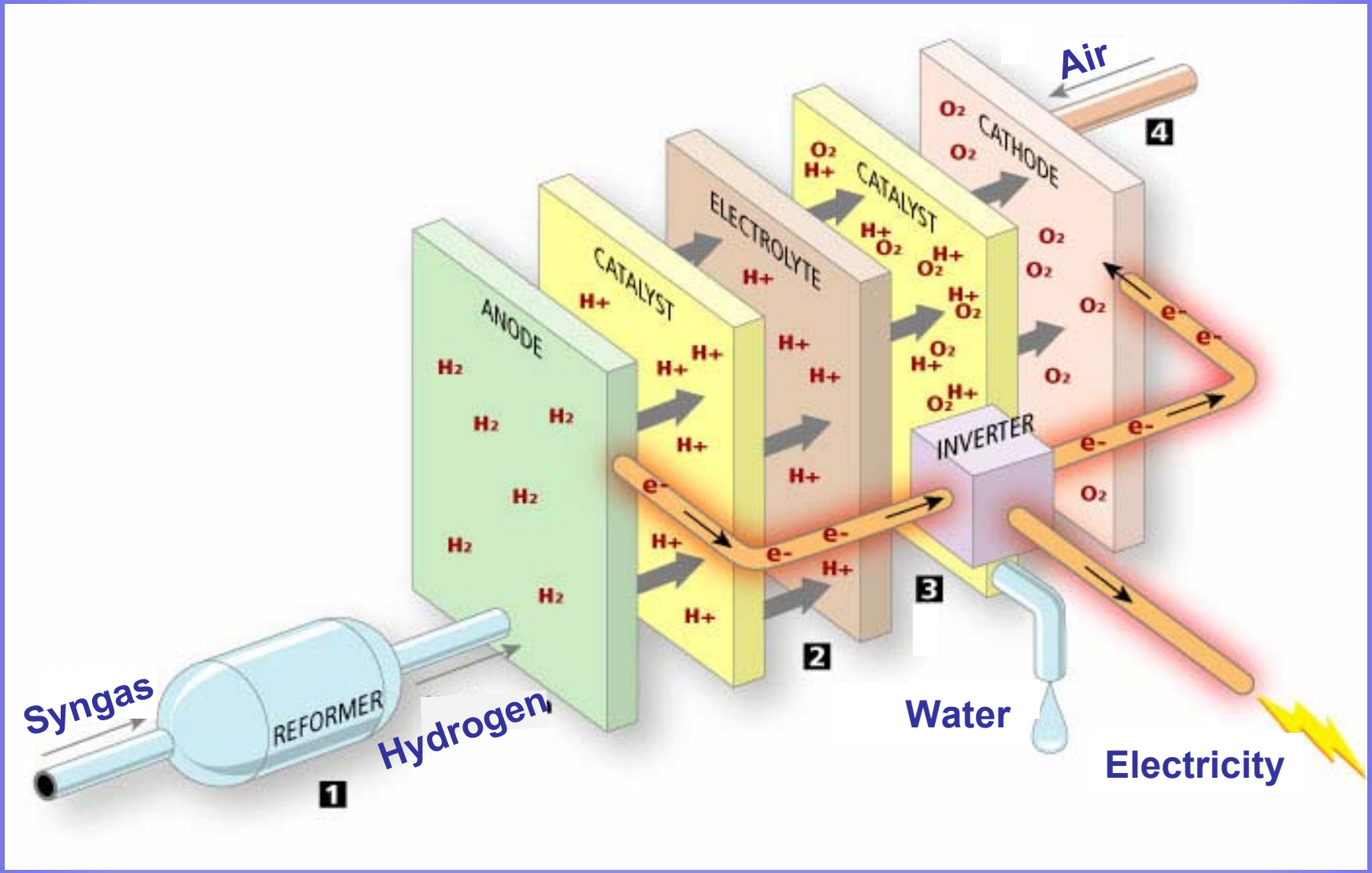
Main problem areas: → Coal quality
→ Combustion technology.
→ Price

- ✓ GT accept only high purity, chemically cleaned ultra clean coal;
- ✓ The residual ash must be reduced to less than 0.2% of the coal;
- ✓ Ash particles to be less than 5µm in size;
- ✓ The coal must contain extremely low levels of alkali metal such as sodium and potassium;
- ✓ High pressure (18-30 bar) slagging coal combustors must allow removal of residual ash as a liquid prior to entering the GT;
- ✓ The hot gas clean up must take place above the ash melting temperature (1400-1600ºC) and high pressure (> 18 bar);
- ✓ Estimated costs would be twice those of NG-fuelled CCGT power plant;
- ✓ DCCC is not yet a proven technology.

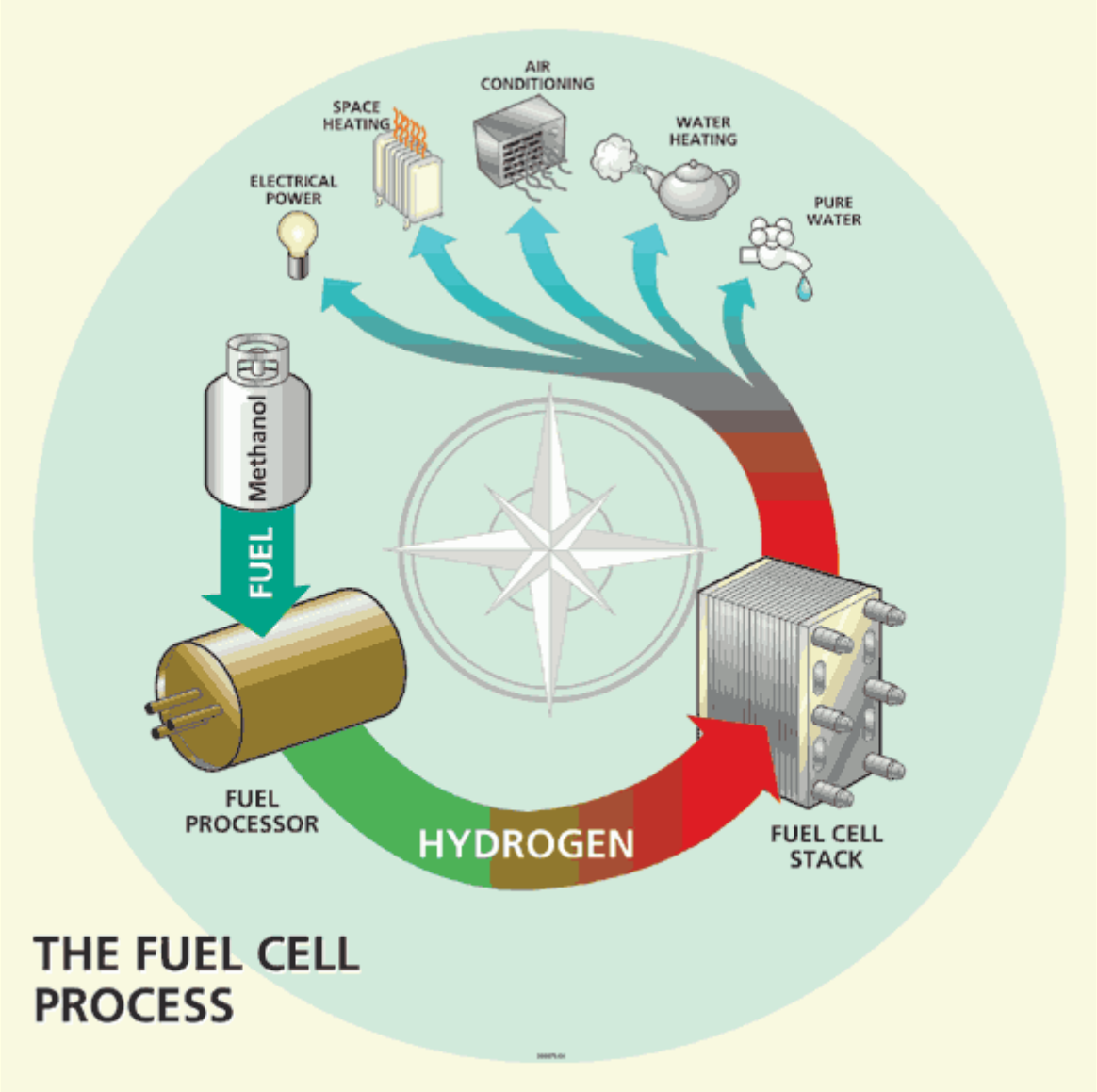
Another Advanced Clean Coal Technologies

- SC and USC Steam Conditions
- Pressurized Fluidised Bed Combustion
- Hybrid Combined Cycle
- Direct Coal fired Combined Cycle
- Fuel Cell

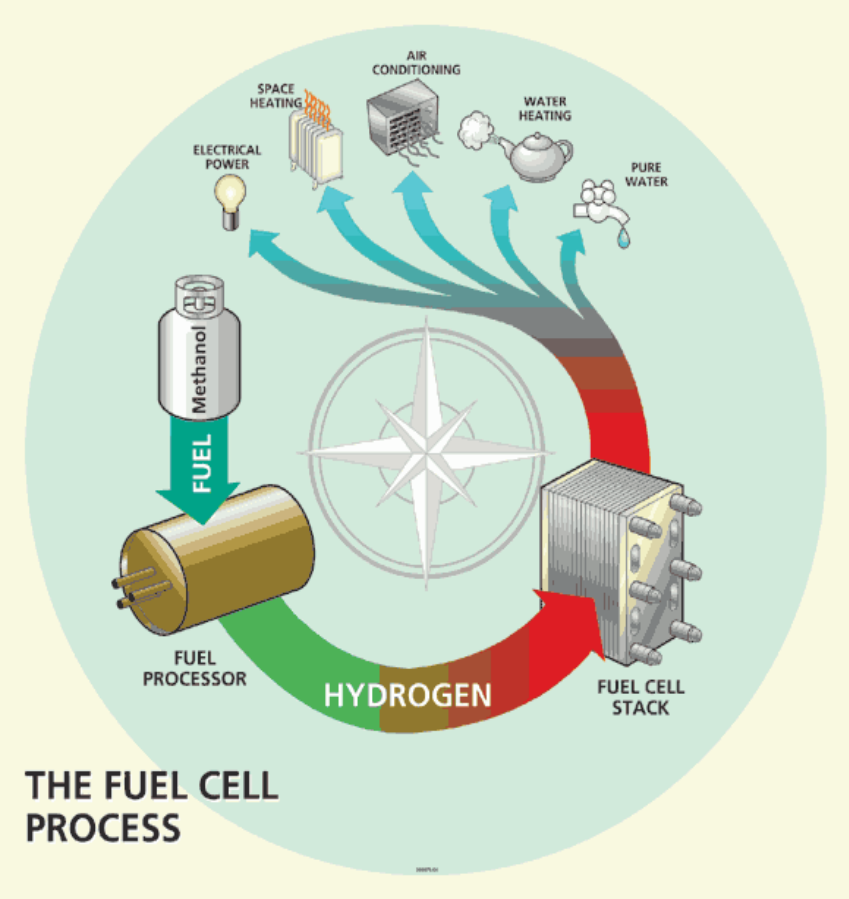
Fuel Cell


Air
CATHODE
CATALYST
ELECTROLYTE
CATALYST
ANODE
INVERTER
Syngas
REFORMER
Hydrogen
Water
Electricity
1
2
3
4

Fuel Cell


AIR CONDITIONING
SPACE HEATING
WATER HEATING
ELECTRICAL POWER
PURE WATER
Methanol
FUEL
FUEL PROCESSOR
HYDROGEN
FUEL CELL STACK
THE FUEL CELL PROCESS

Fuel cell


AIR CONDITIONING
SPACE HEATING
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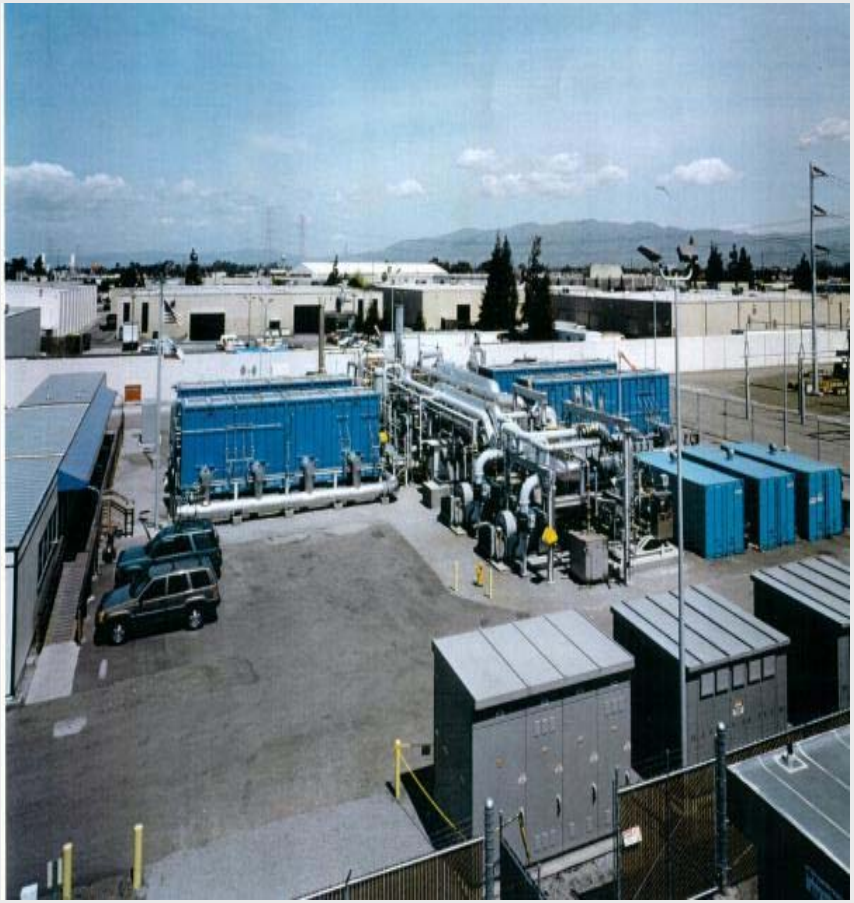
PURE WATER
Methanol
FUEL
FUEL PROCESSOR
HYDROGEN
FUEL CELL STACK
THE FUEL CELL PROCESS



Another Advanced Clean Coal Technologies

- SC and USC Steam Conditions
- Pressurized Fluidised Bed Combustion
- Hybrid Combined Cycle
- Direct Coal fired Combined Cycle
- Fuel Cell
- Magneto Hydrodynamics

Magneto Hydrodynamics (MHD)

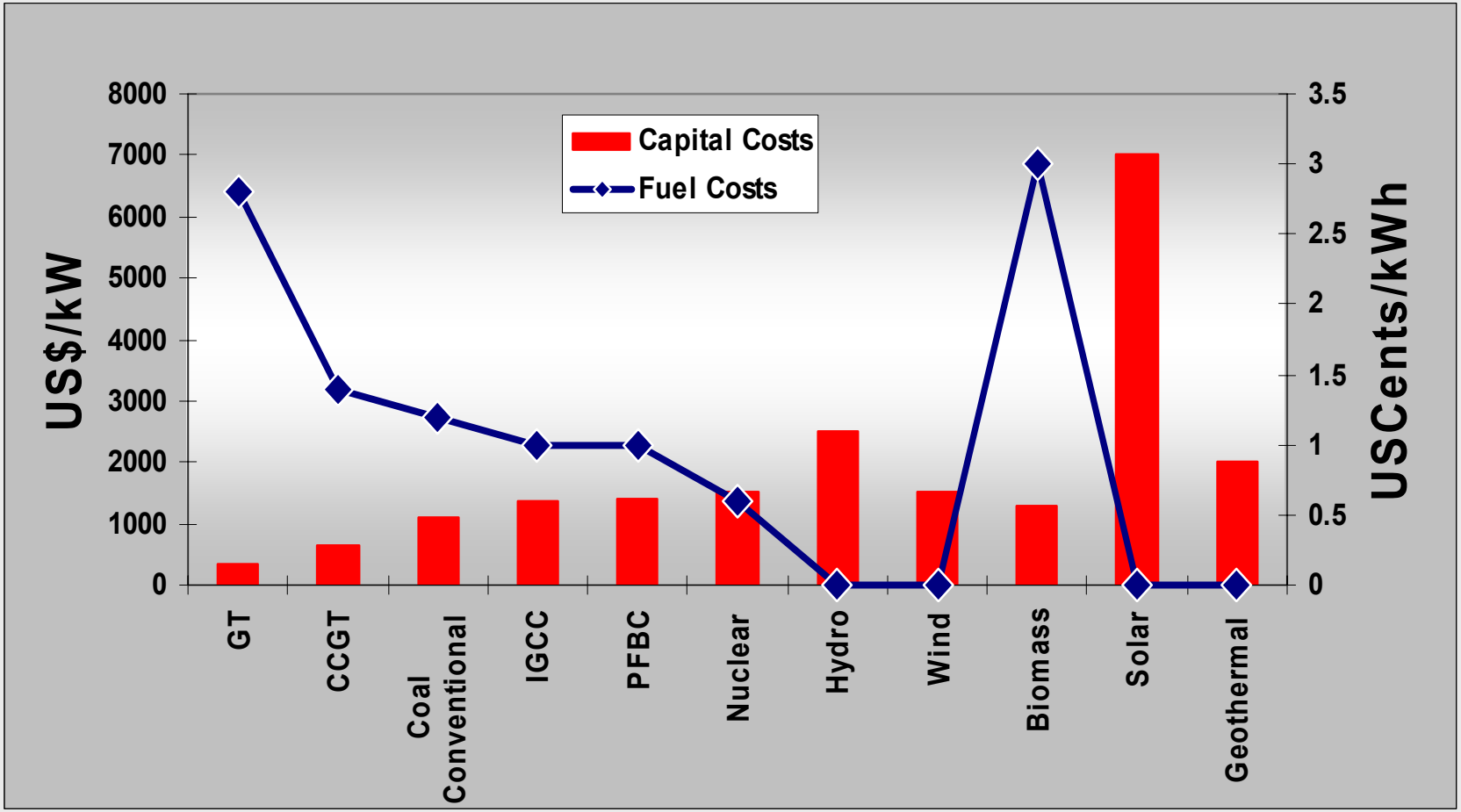
- MHD generators convert fuel directly into electric energy;
- MHD generator produces hot, ionized (electrified) gases by burning coal or other fuels at high temperatures;
- Ionized gases are forced through a duct in a magnetic field, where they produce an electric current which is drawn off by electrodes;
- MHD generators are more efficient than typical steam powered devices, also once the gas passes through the collection ducts it can be used to run a turbine to produce additional electricity;
- Until the technology is refined, we will not see MHD generators in commercial operation.

Technological & Commercial Constraints

If the energy generated from an IGCC plant is to compete with energy price generated from NG CCGT power plant, it will have to tolerate a maximum capital cost of 650 US$/kW for a stand alone power generation unit.

650 US$/kW is the current estimated cost of a state-of-the-art NG fired CCGT power plant in 2005, whereas a fully mature IGCC plant would probably cost in the range of 1'100 to 1'400 US$/kW and the first generation IGCC power plant will cost over 1'500 to 2'000 US/kW

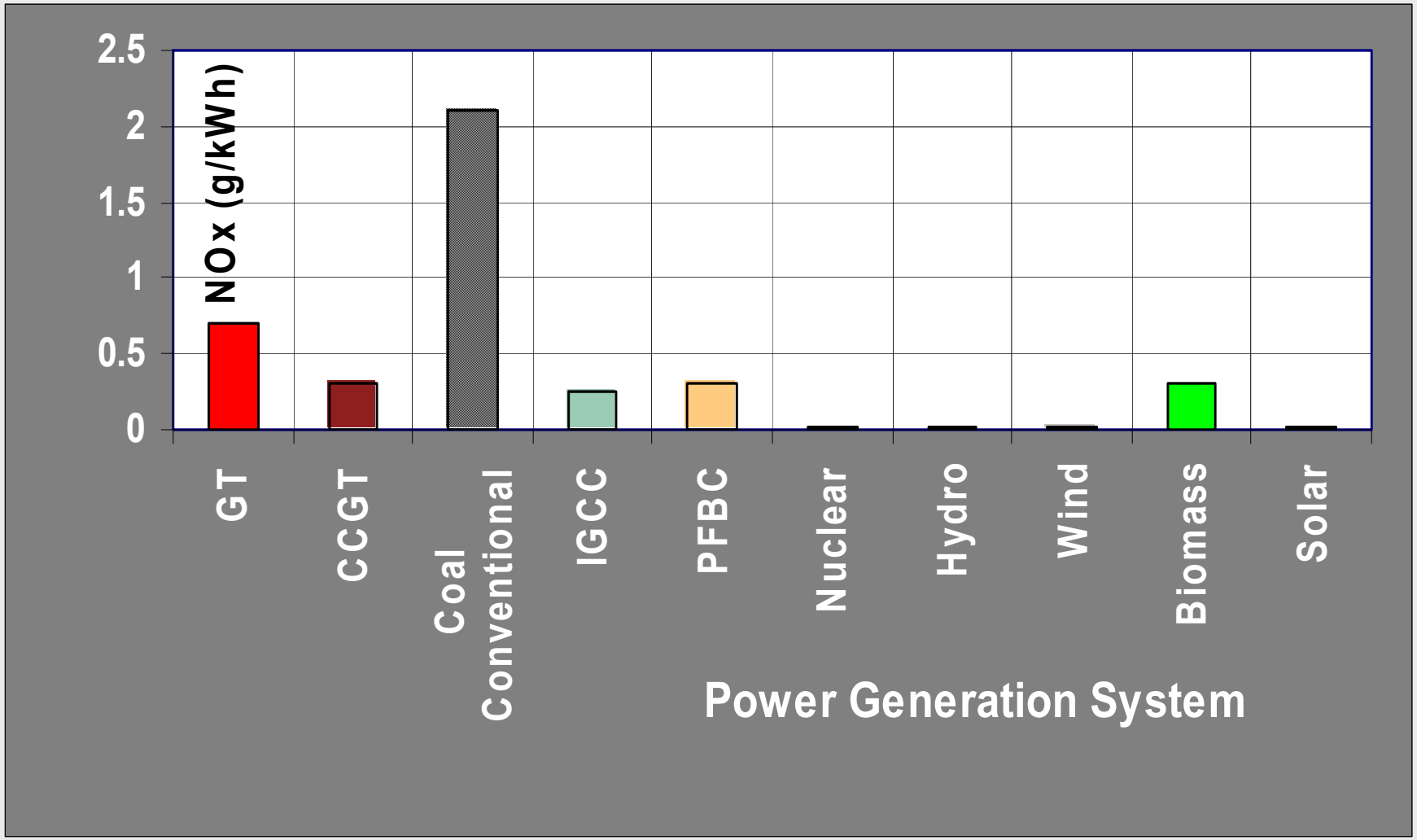
Specific Capital Costs vs. Fuel Costs for Miscellaneous Power Generation Systems



How to reduce specific capital costs for IGCC power plants in SEA?

- Use most advanced, large heavy duty GTs available;
- Standardize and modularize the equipment;
- Decrease overhead expenditures;
- Maximize the local content;
- Rationalize measures for construction and installation;
- Increase economy of scale (specific costs for larger; installations are lower);
- Locate the power plant near to fuel source.

Specific NOx Emissions from selected Power Generation Systems



SELECTED IGCC POWER PLANTS

Id. No.	Project	Location	Gasification Technology	Fuel	Efficiency (%)	Total Power Output (MW)	Start of Commercial Operation	Capital Costs (US$/kW)
P1	SUV / EGT	Litvinov, Czech Republic	Lurgi	Lignite		350	1997	
P2	Elcogas SA	Puertollano Spain	Prenflo-O_2	Coal & Petcoke	42.7	335	1997	2900
P3	Tampa Electric	Polk City USA	Texaco	Coal	40.0	316	1996	2000
P4	PSI/ Destec	Wabash River USA*)	E-GAS	Coal & Petcoke	39.7	260	1995	1600
P5	Willem Alexander	Buggenum Netherlands	Shell	Coal	41.3	253	1994	2110
P6	Lakeland Water/DOE	Lakeland USA	ACFBCC	Coal		240	2007	
P7	Steag Kellerman	Lunen	BGL	Coal	31.7	170	1969	
P8	LGTI	Plaquemine	E-GAS	Western Coal	36.0	160	1987	2140
P9	SCE Cool Water	Cool Water USA	Texaco- O_2	Coal	31.2	100	1984	4890
P10	Sierra Pacific	Pinon Pine USA	KRW-air	Lignite	38.0	99	1996	2300
P11	Schwarze Pumpe	Cottbus Germany	Lurgi-O_2/BGL	Coal / Wastes		75	1995	
P12	Vresova	Vresova Czech Republic	HTW	Lignite		376	1996	

- IGCC is still in early stage of commercialization. Current commercial demonstration projects are associated with technical risks and higher cost;
- Several demonstration power plants with capacity up to 400 MW are in operation or under construction.
- Commercial availability of larger units is not expected before 2005;
- The primary constraints to the application of IGCC power plants in developing countries are that the technology needs further demonstration;
- IGCC installation costs are higher than those of competing technologies;
- Environmental regulations in many developing countries still do not require the high SO_2 removal and low-NOx emissions achieved by IGCC.
- Current IGCC coal gasification projects require subsidization from various national & international entities and supporting programmes.

- IGCC technology it is one of the advanced coal utilization technology with high efficiency and low environmental emissions including $CO_{2;}$
- It has a large potential to reduce Greenhouse Gas Emissions in the long term;
- Modern coal gasification technology uses low quality coal or lignite which is abundant in many Asian countries such as India, Indonesia and China;
- Combination coal gasification with advanced, large heavy duty, GTs and with steam-bottoming cycle with once-through heat recovery steam generator operating under supercritical steam parameters resulting in unbeaten efficiency;
- Reusable process media remove sulphur from syngas prior to combustion in the GT;
- By contrast, conventional steam power plants with flue gas desulphurization techniques as well as PFBC power plants use limestone, dolomite, or other sulphur sorbents. These substances require disposal.


Clean coal technologies are a family of new technological innovations that are environmentally superior to the technologies in common use today.
Thank you.