Clean coal technology required for the future and development of IGCC technology.

November 10, 2009

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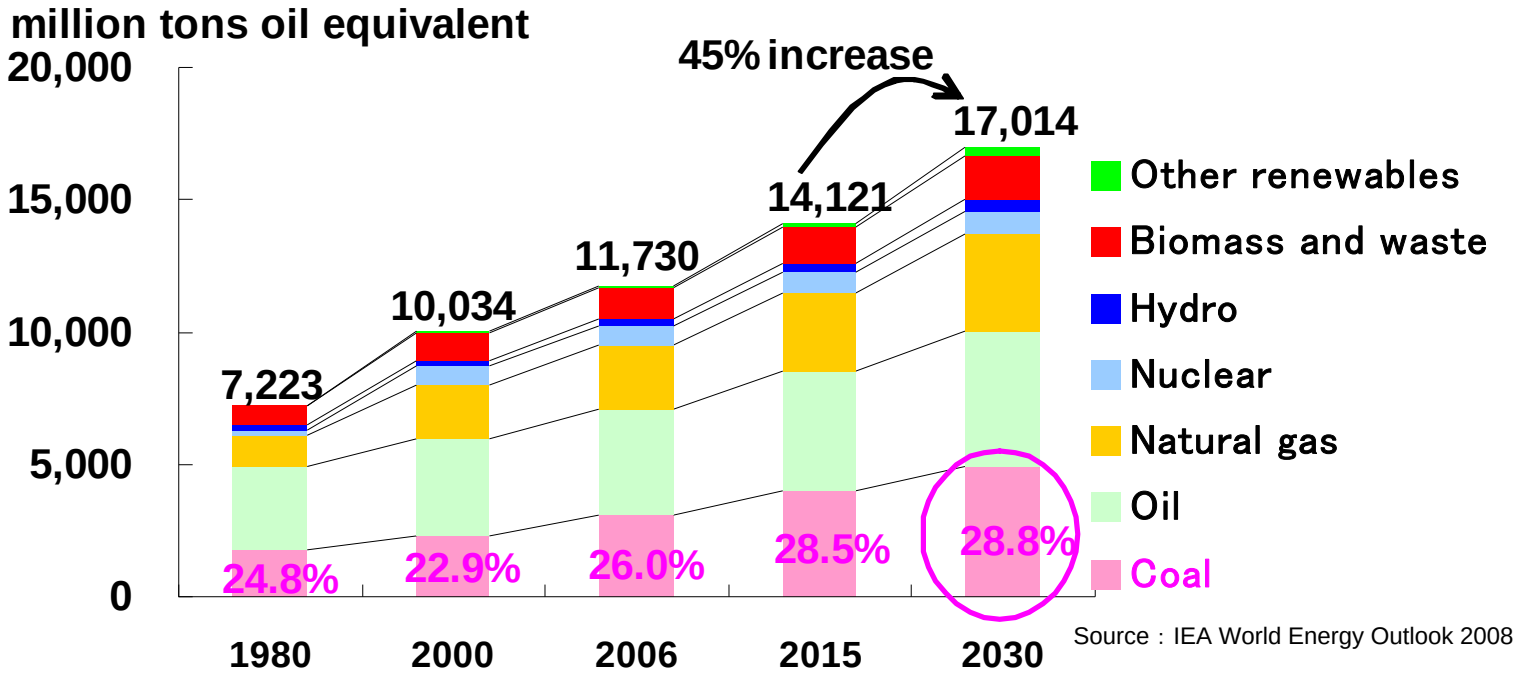
Coal demand growth in the world

Forecast of world primary energy demand by fuel



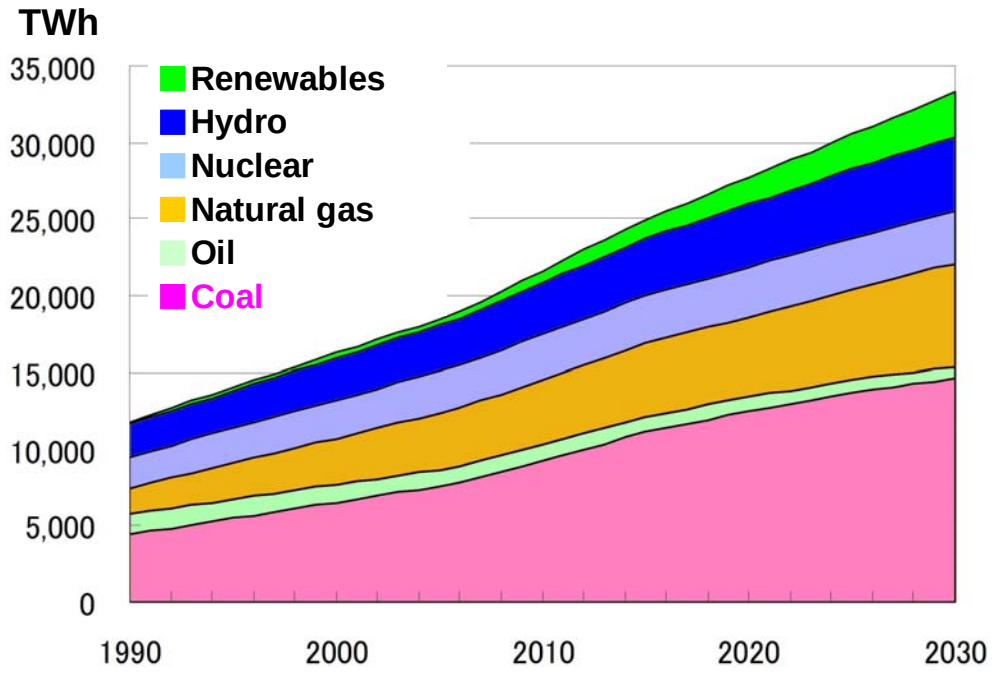
Source：IEA World Energy Outlook 2008

- In 2030, total primary energy demand would be 45% higher in the world.
- The share of coal in global primary energy demand would reach about 30% in 2030 according to the IEA prospect.

The coal utilization is expected to be expanded to cope with economic growth in the world.

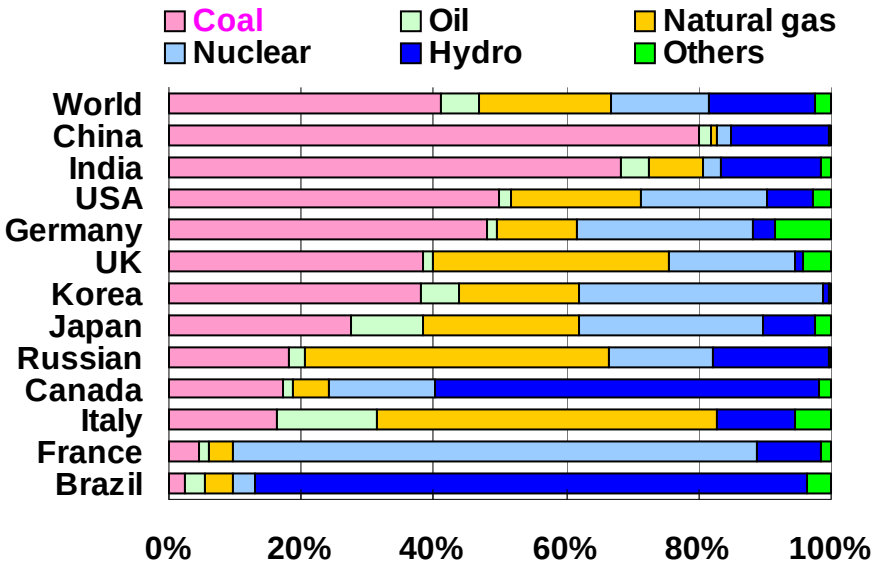
Status of coal fired power in the future

Forecast of power generation by fuel



Source：IEA World Energy Outlook 2008

Fuel mix in power generation



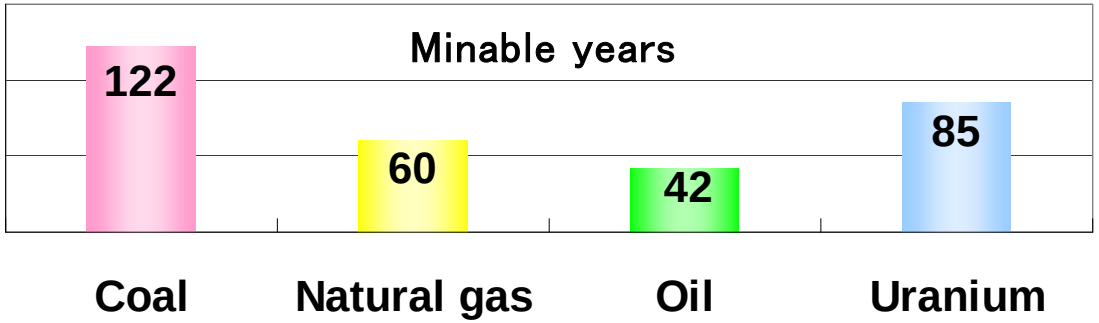
Source：FEPC Nuclear & Energy 2009

The share of coal fired power in total generation is expected to increase from 41% at present to 44% in 2030.

Coal fired power would play a major role in electric power section.

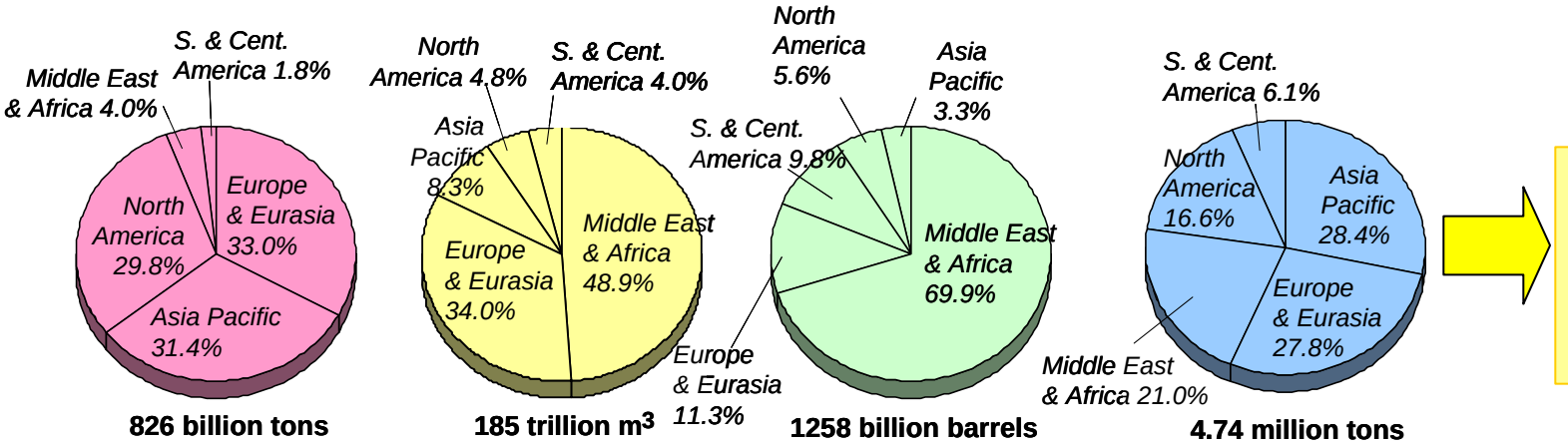
Why coal fired power? ➡amount and distribution of energy resources

●Amount of reserves



Amount of coal reserves is relatively large

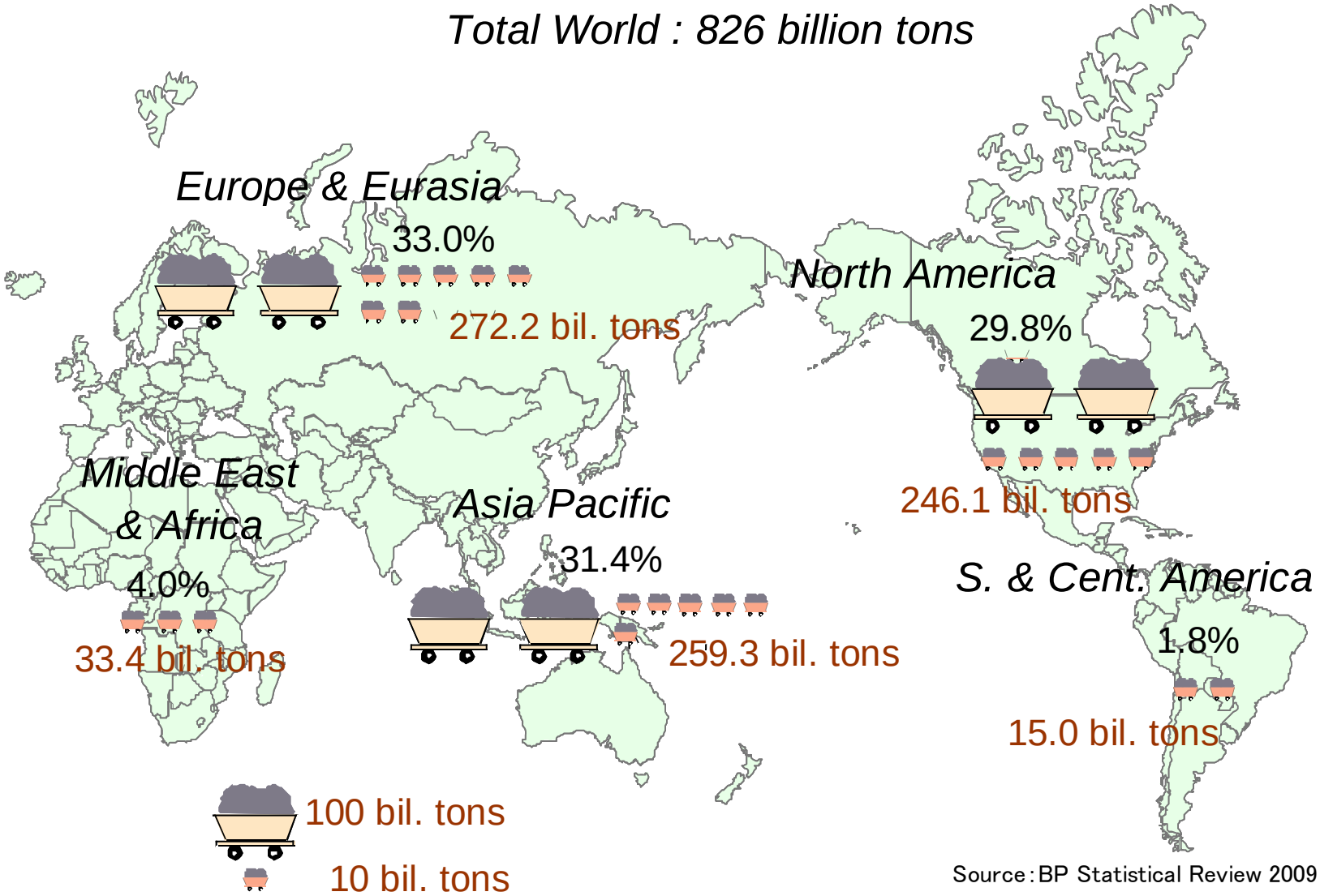
●Distribution of reserves



***Coal is* evenly distributed**

Source：BP Statistical Review 2009
URANIUM 2007

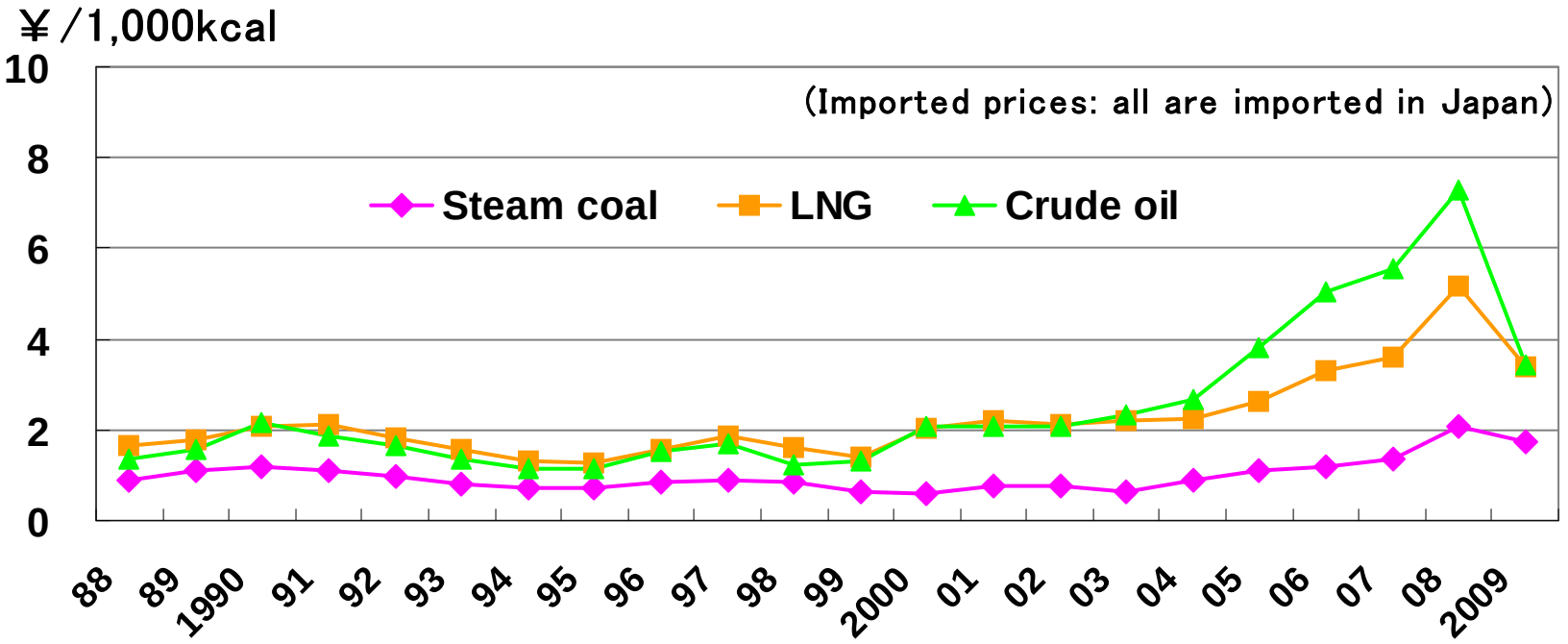
Main reserves of coal in the world



Source：BP Statistical Review 2009

Why coal fired power? ➡ Stability of price

Trend of the prices of fossil fuel in Japan



until August, 2009

Source: Ministry of Finance / Trade Statistics of Japan

Coal price is expected to be stable , compared with other fossil fuel prices .

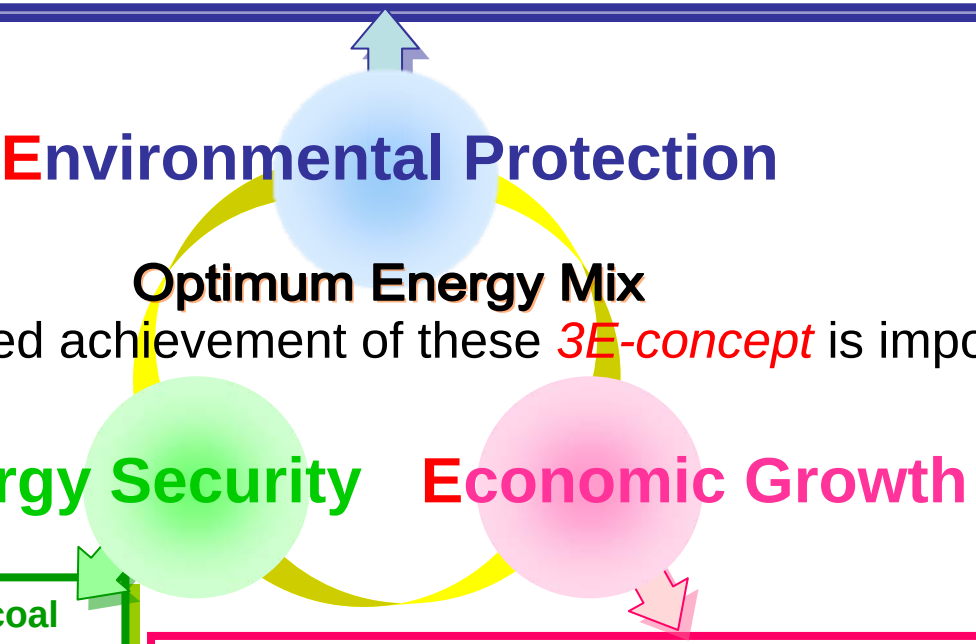
Why coal fired power? ➡ 3E-concept for energy utilization

- Relation between energy mix and coal utilization -

Reduction in SOx, NOx, Particulate and CO2 emissions.

- Use of existent air pollution control technologies（desulfurization facility, denitrification facility, electric precipitator）
- CO2 reduction technology is expected to advance.

⇒Advances of the technology in the future has already been incorporated.



The balanced achievement of these *3E-concept* is important.

Increase of kinds of usable coal

- Use of low rank coals

Use of CO2 free fuel

- coal fired power with biomass fuel

Highly effective energy utilization

- Improvement of existing power station facilities and improvement of efficiency by optimization of operation would be expected.
- Replacement of existing superannuation facilities with highly effective facilities
- Development of highly effective technology for coal utilization.

Technical issues to respond to expectation of coal utilization
⇒ Development of clean coal power technology

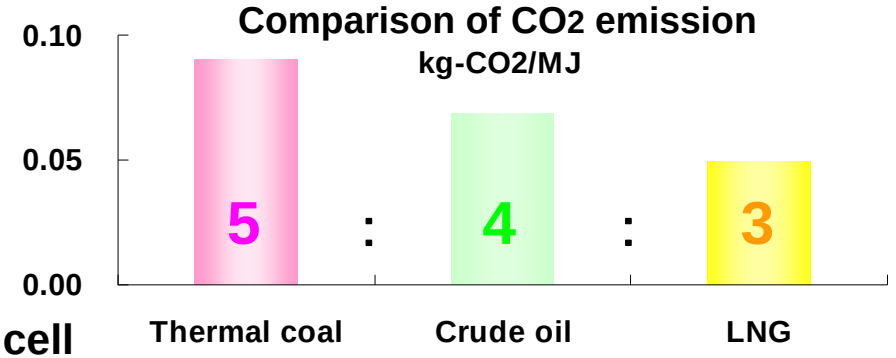
The expectation for coal use for the future is great. Technological development to respond to the expectation is to be achieved

●Environmental Protection technology compatible with Economic Growth

Reduction in CO_2 emission

Method1: Improvement of thermal efficiency

- **Combustion technology (USC, A-USC)**
- **Coal gasification technology (IGCC,(→ IGFC ＊)) ＊IGCC with fuel cell**



Method2: CO_2 capture and storage

- **CO_2 capture technology (pre-combustion + conventional plant or IGCC) and (post-combustion + conventional plant), etc.**
- **CO_2 storage technology could be applied to all the fossil fuel**

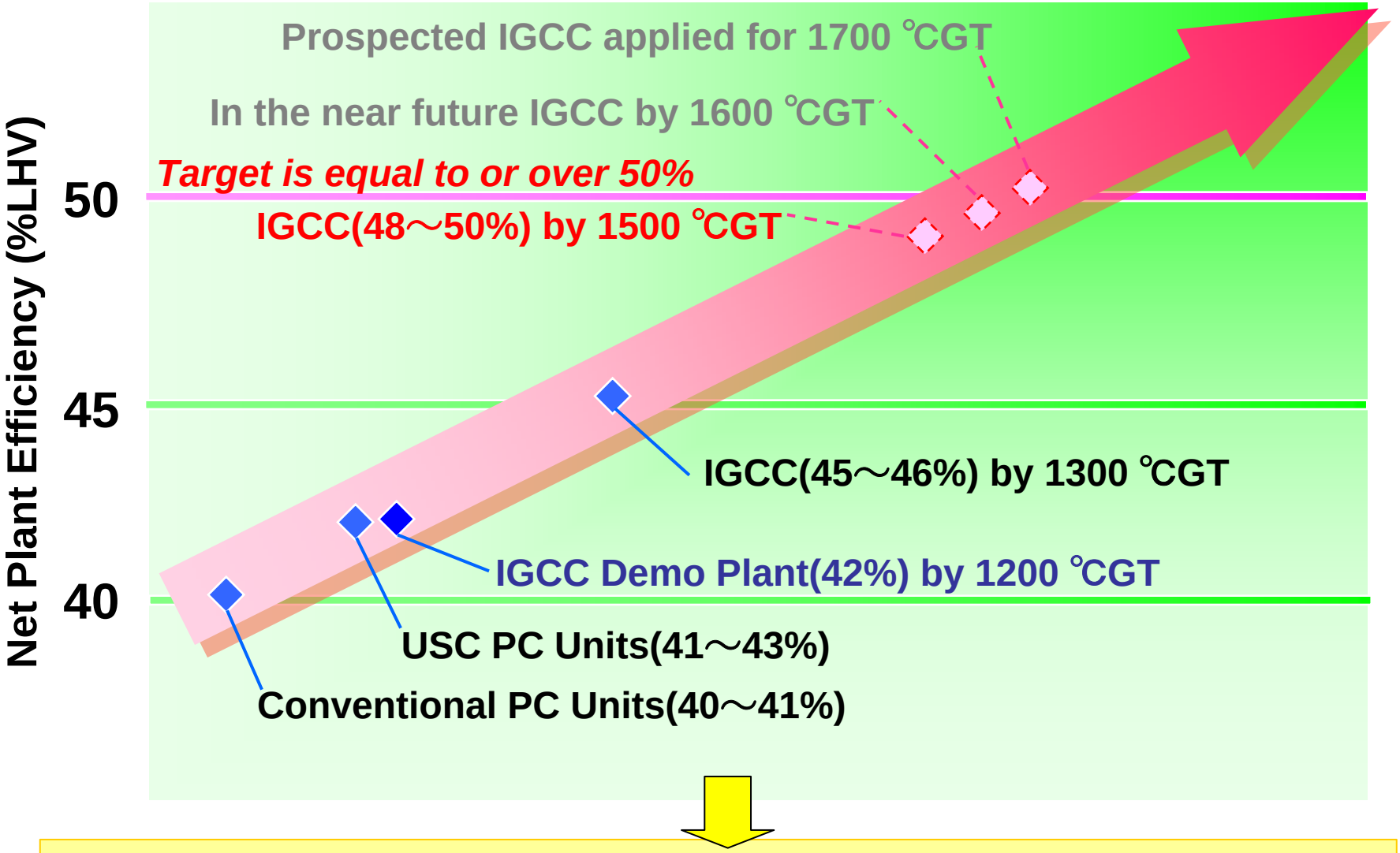
●Energy Security

Use of low rank coals that is hardly used in conventional coal fired plants.

- **Coal gasification technology (IGCC)**
- **others?**

IGCC is an effective option to solve the technical issues realize 3E concept.

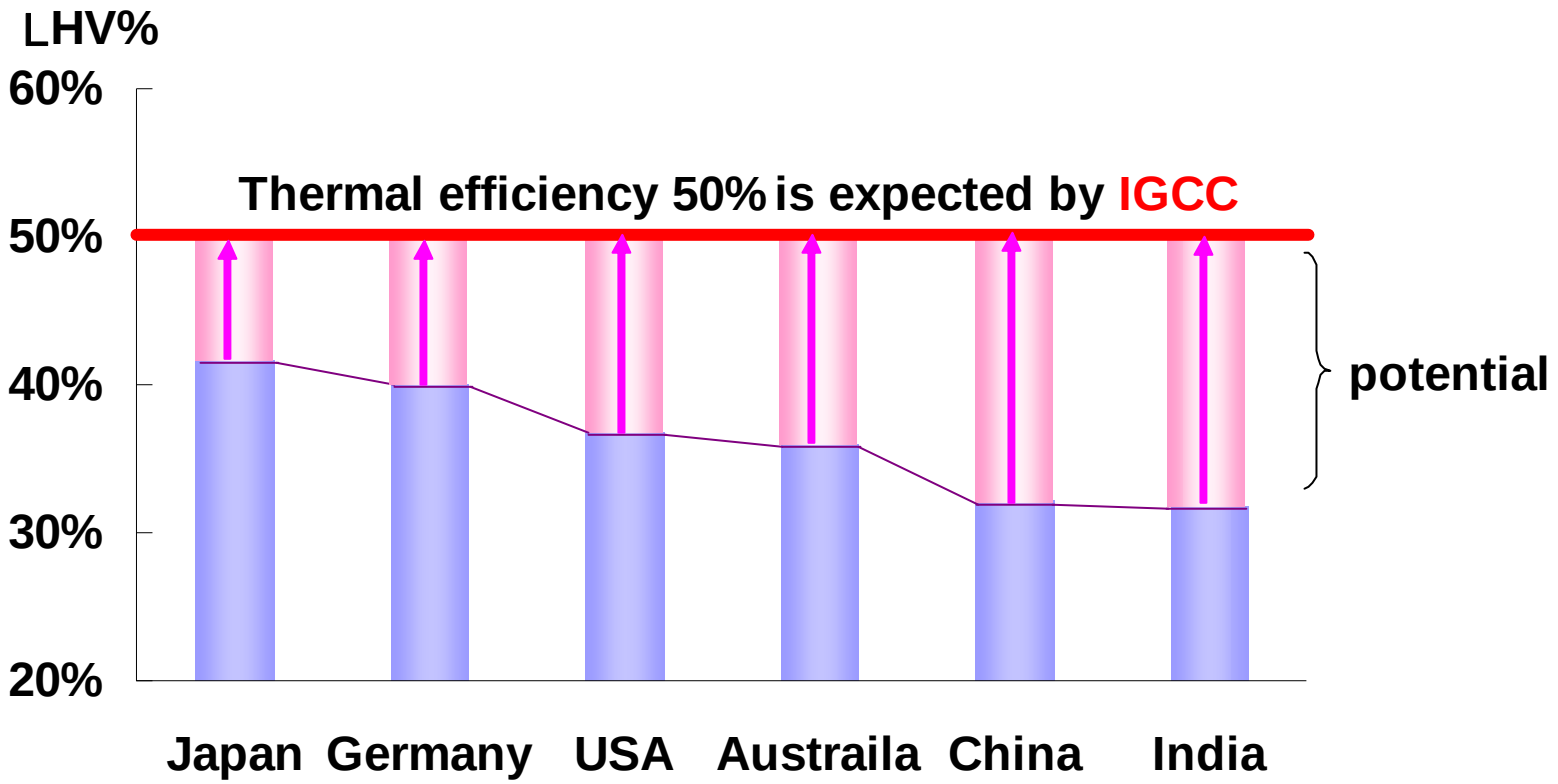
IGCC technology : Thermal efficiency Improvement



Thermal efficiency improves in cope with high temperature gas turbine combined cycle technology.

IGCC technology : Effect of thermal efficiency Improvement

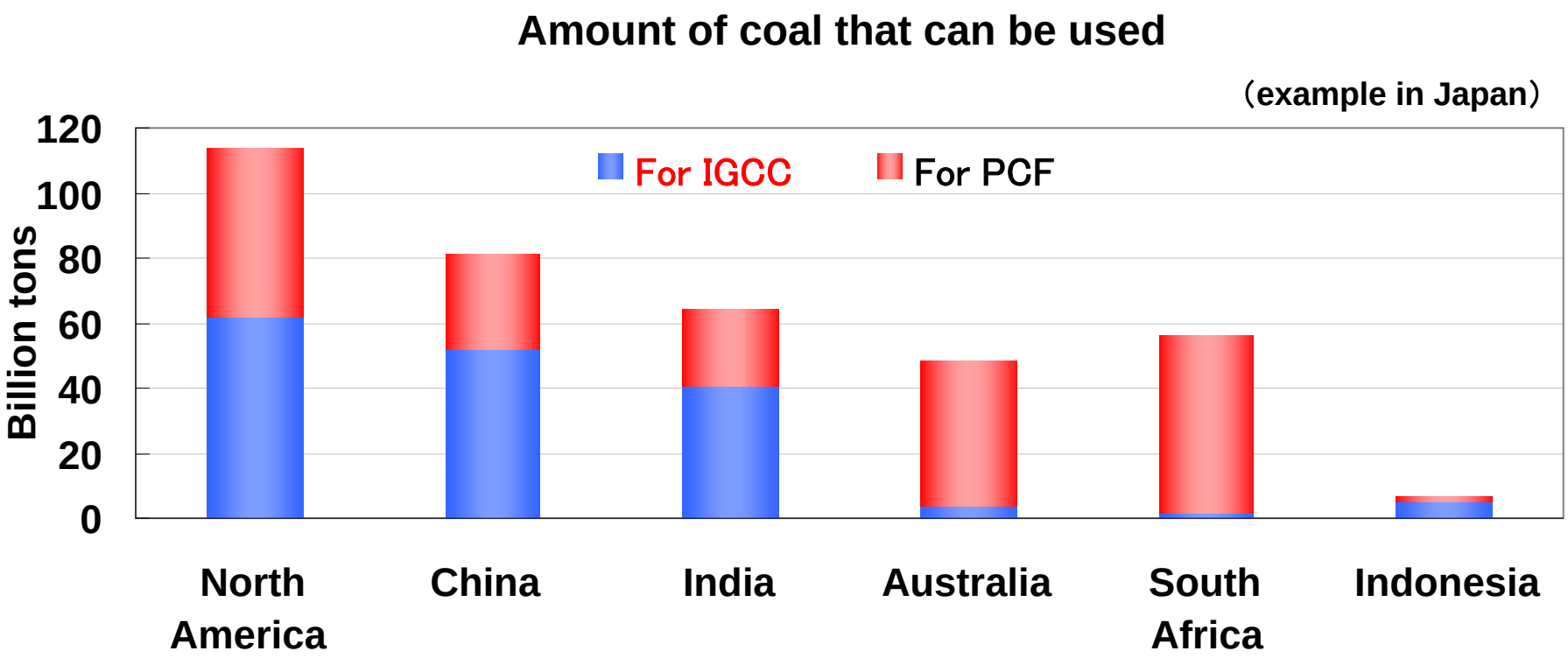
Thermal efficiency of coal fired power stations in the world（2006）



Source: ECOFYS,“INTERNATIONAL COMPARISON OF FOSSIL POWER EFFICIENCY”(2008)

Large potential of improvement in coal fired power efficiency by IGCC though upper assumption would not be practical at present.

IGCC technology : Increase in kinds of coal



- Low rank coal use could be increased because IGCC utilizes different type of coals.
- Biomass fuel can be also used for IGCC.

Relation between CO_2 capture technology and IGCC

CO_2 capture technology

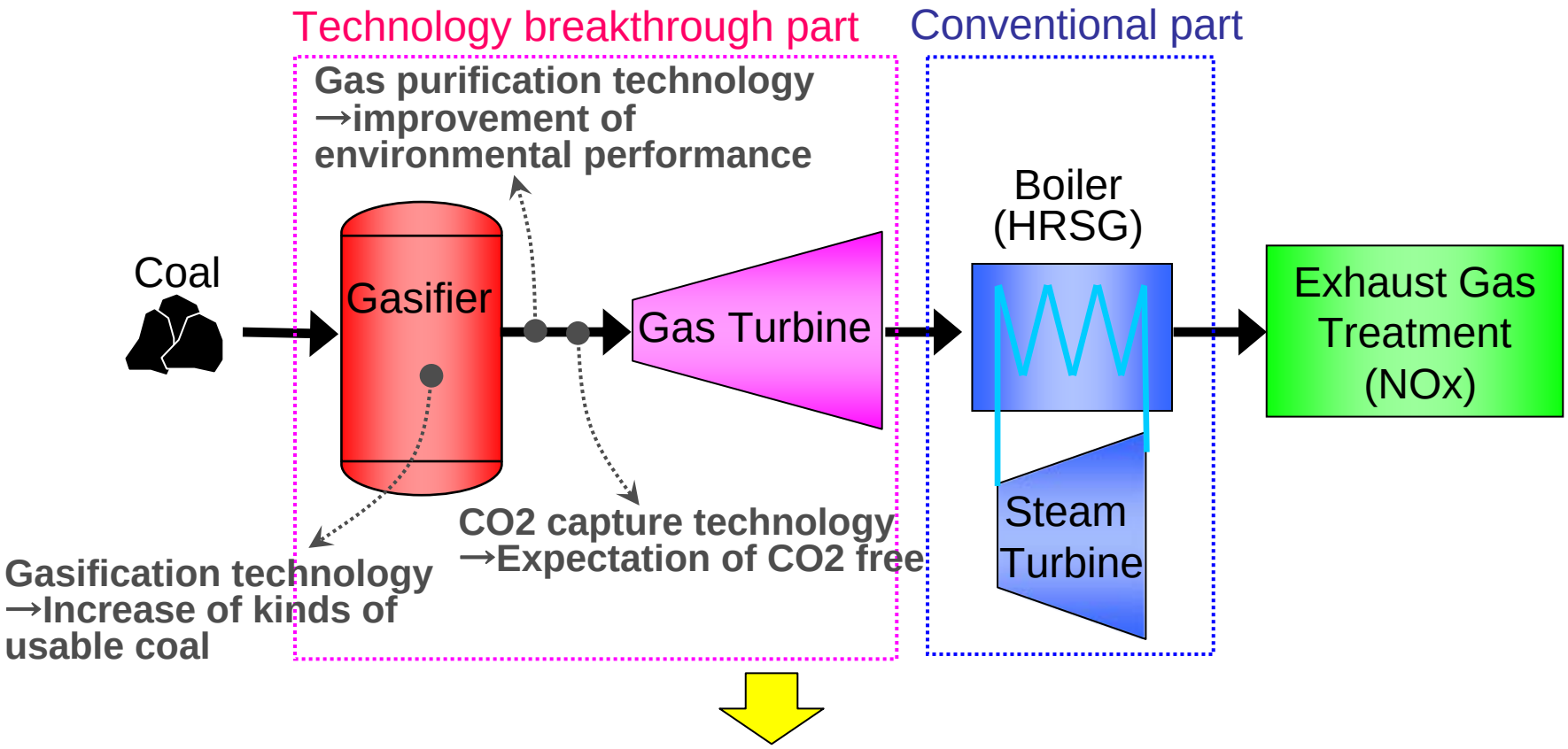
'pre-combustion type' and 'post-combustion type', etc.

- **IGCC applying pre-combustion technology could compensate the thermal efficiency decrease caused by CO_2 capture, because of the high efficiency power generation.**
- **Although effectiveness should be studied , application of post-combustion type might be possible.**
- **It would depend on technological development in the future what type of CO_2 capture technology is the best for IGCC.**
- **Moreover, highly effective and zero emission power generation would be achieved by combining IGFC (IGCC with fuel cell) with CCS by application of pre-combustion technology.**
  ⇒It would be matter for long-term technological development

Introduction : Fundamental concept of IGCC System

IGCC: Integrated Coal Gasification Combined Cycle

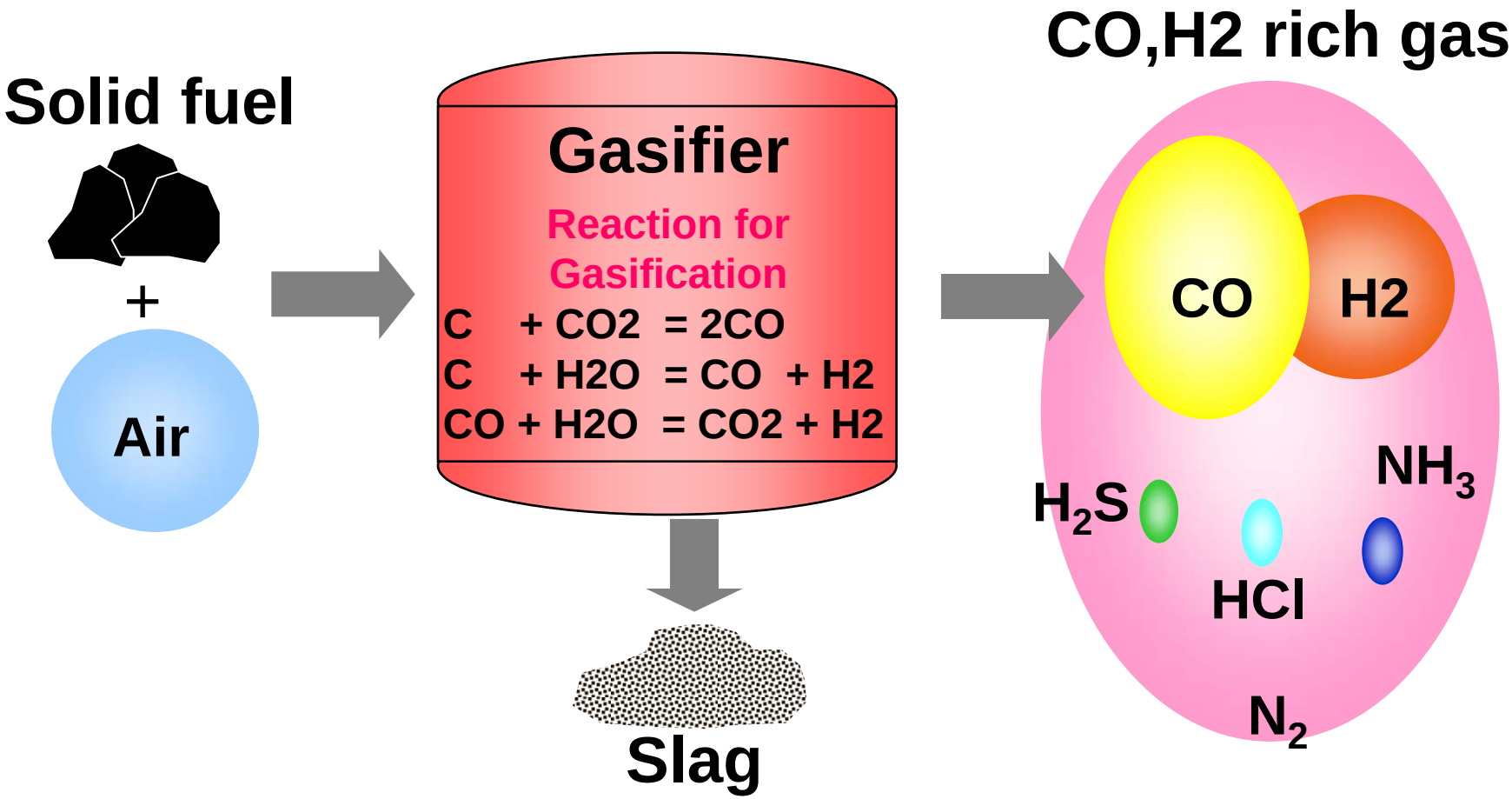
IGCC is a new power generation system aiming at higher efficiency than conventional coal-fired systems by integrated coal gasification with combined cycle power generation technology.



Various clean coal power technologies are applied to IGCC.

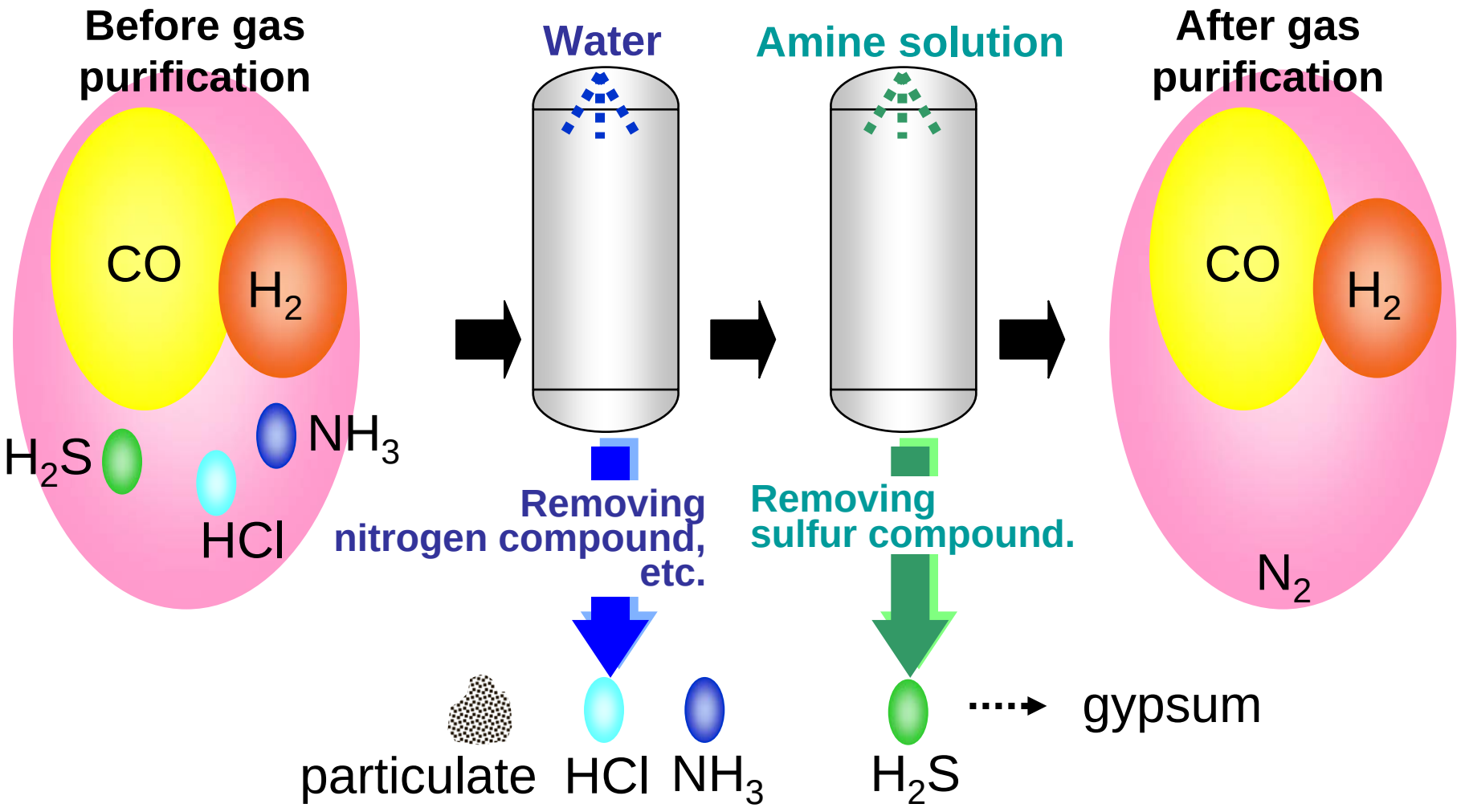
Introduction : Gasification technology

- Coal with low ash melting temperature hardly used in conventional stations, could be used in IGCC. Low rank coal and biomass fuel could be also usable.
- Volume of waste is reduced by half in IGCC, compared with conventional stations becasue coal ash is discharged from the gasifier as glassy slag.



Introduction : Gas purification technology

Gas purification facility of IGCC removes sulfur compound and nitrogen compounds, etc. Exhaust of SOx, NOx and particulate to the atmosphere is decreased.

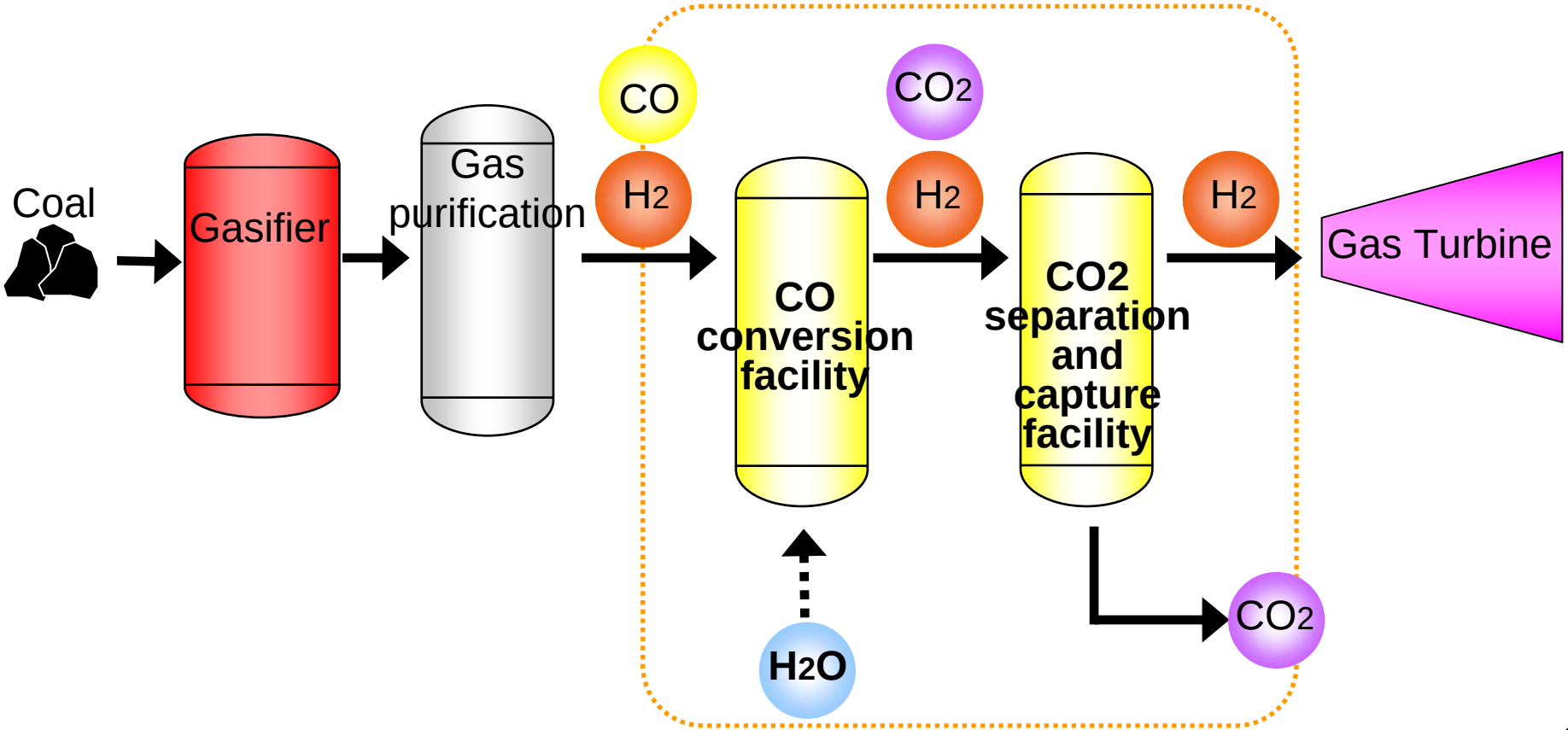


IGCC + CO_2 capture by pre-combustion technology

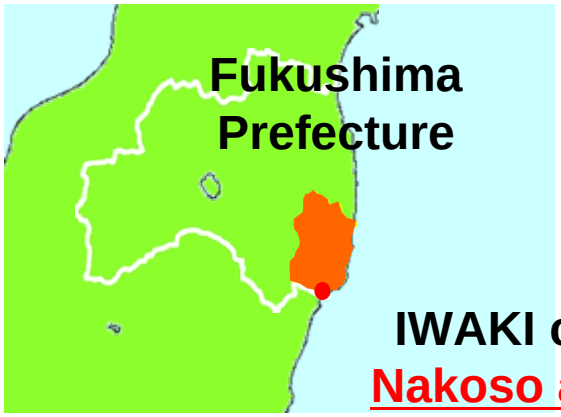
IGCC + CO2Capture (pre-combustion Type)

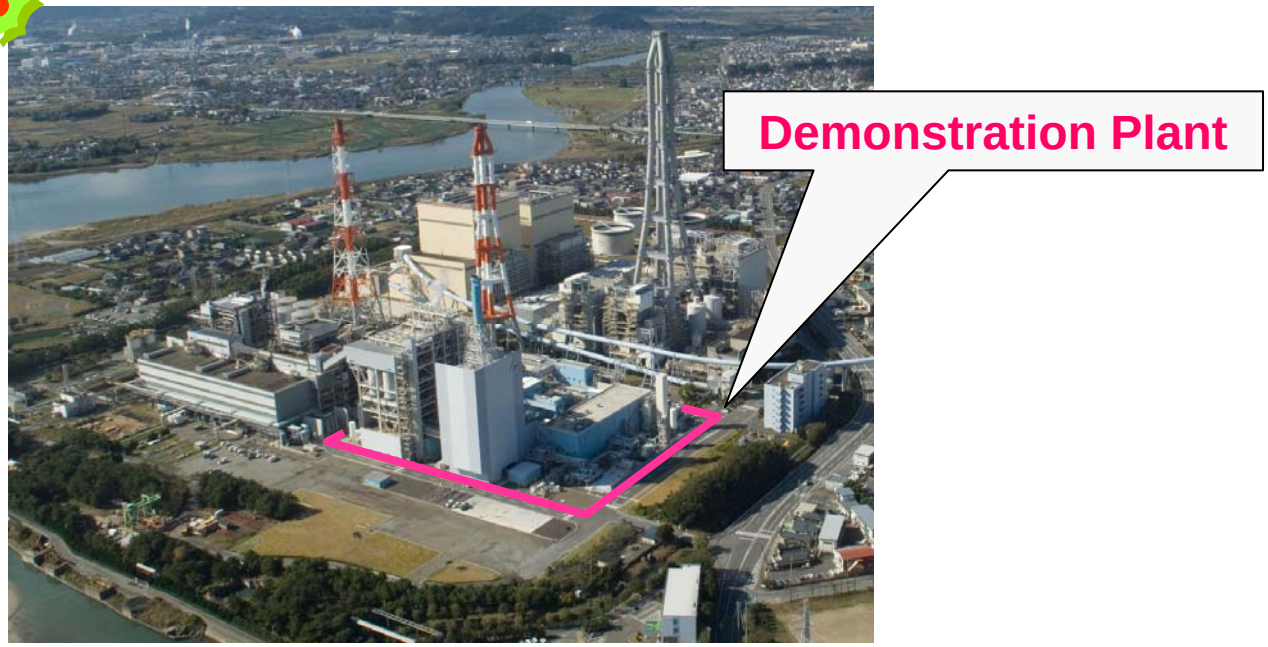
CO is converted into CO_2 by injecting steam(H_2O) into the fuel gas before combusting in the gas turbine

CO_2 is collected through CO_2 separation and capture facility.



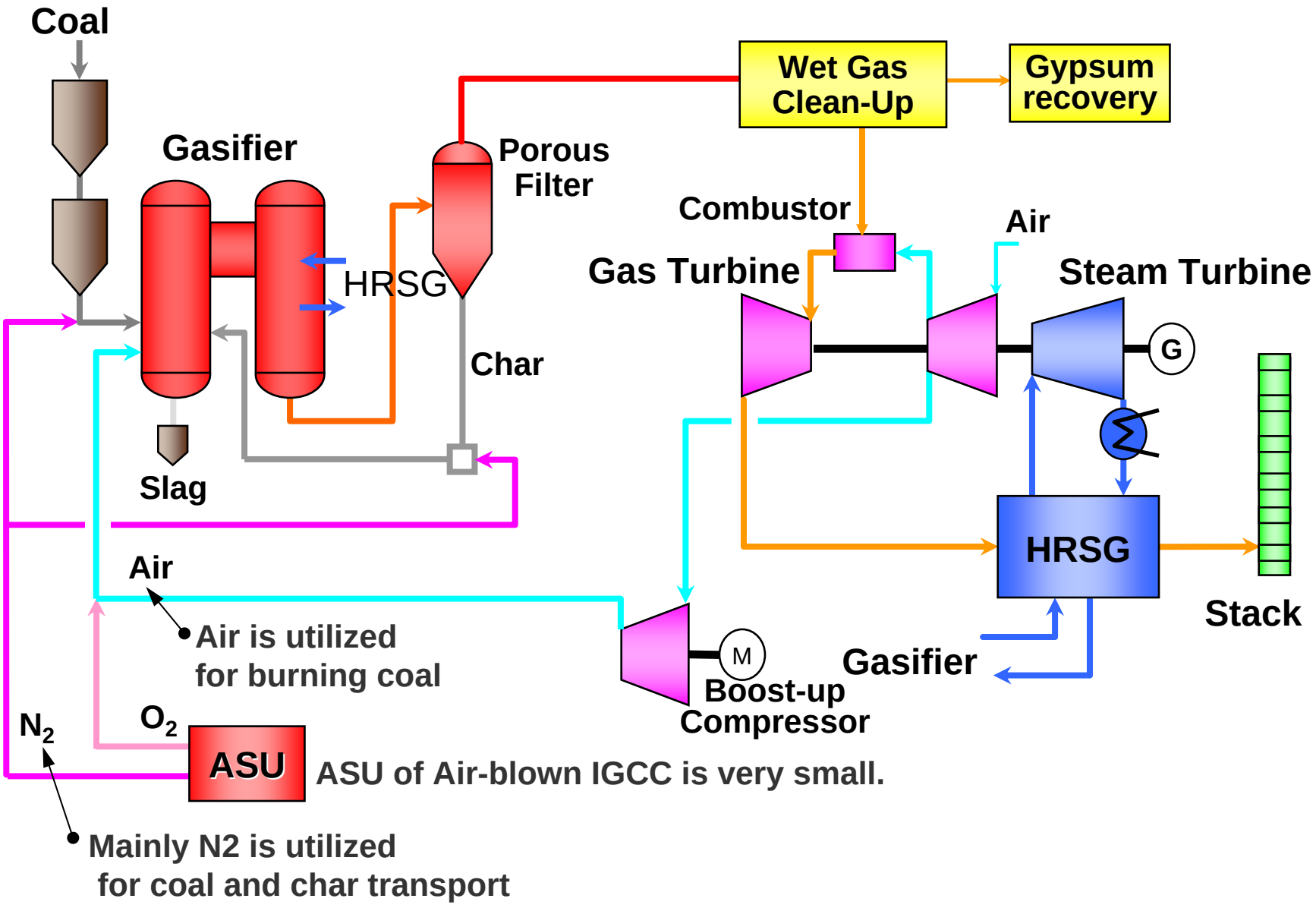
IGCC project in Japan : Location of demonstration plant





Located within the NAKOSO Power Station of JOBAN JOINT POWER CO.,LTD.

IGCC project in Japan : Schematic diagram of the IGCC



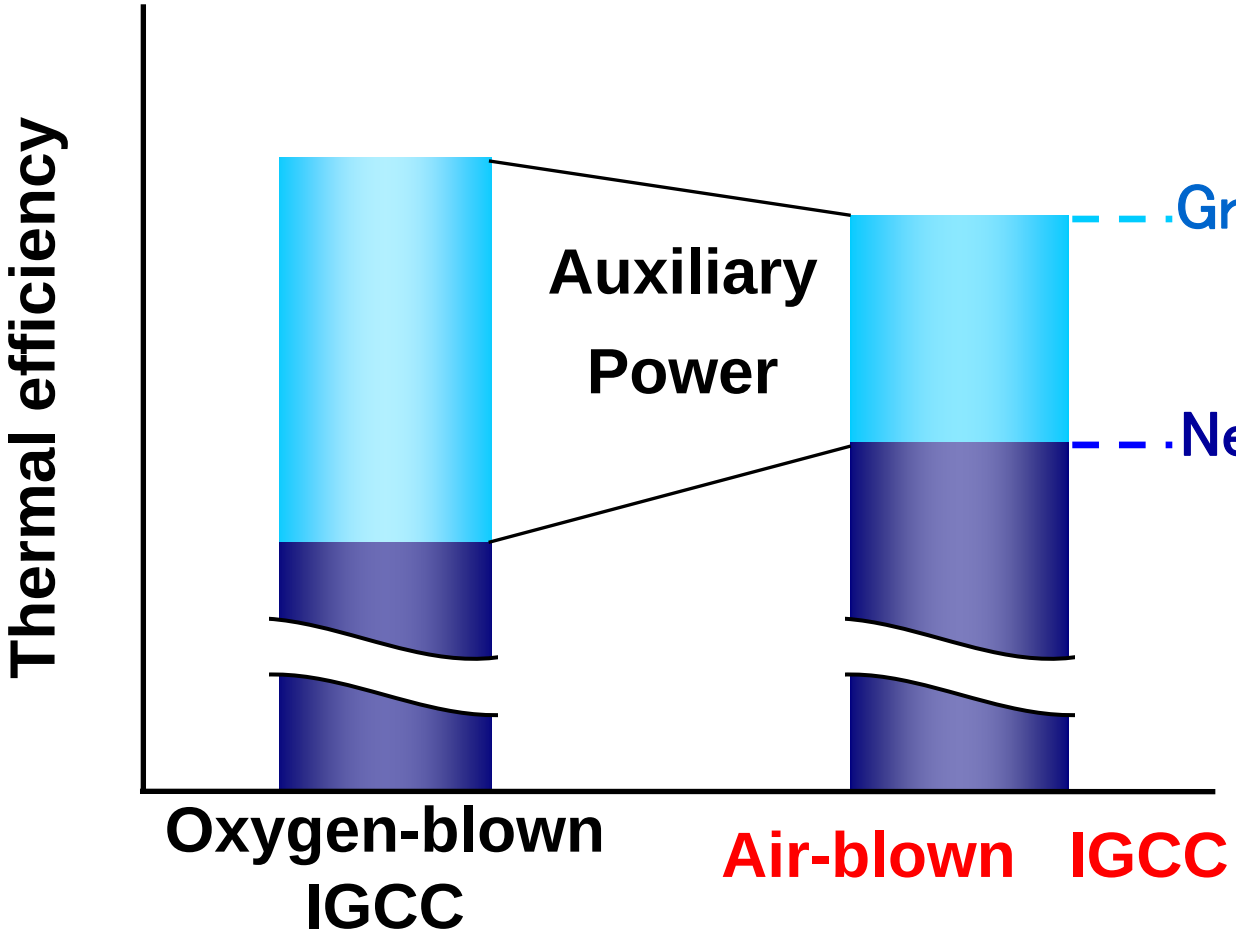
Comparison among IGCC Projects

IGCC projects with O2-blown type have been executed all over the world while air-blown type IGCC is adopted in Nakoso.

Projects Site	Buggenum Netherland	Puertollano Spain	Wabash River USA	Tampa USA	Nakoso Japan
Gasifier type	O_2-blown Dry-feed (Shell)	O_2-blown Dry-feed (Plenflo)	O_2-blown Slurry-feed (E-Gas™)	O_2-blown Slurry-feed (GE)	Air-blown Dry-feed (MHI)
Coal consumption	2,000 t/d	2,600 t/d	2,500 t/d	2,500 t/d	1,700 t/d
Gross output (GT)	284 MW (1100℃-class)	335 MW (1300℃-class)	297 MW (1300℃-class)	315 MW (1300℃-class)	250MW (1200℃-class)
Demonstration test start	Jan. 1994	Dec. 1997	Oct. 1995	Sep. 1996	Sep. 2007

Advantage of Air-blown IGCC

Air-blown IGCC applied in Nakoso is expected to realize high thermal efficiency compared with oxygen-blown IGCC



Specification of Nakoso IGCC

Capacity	250 MW gross		
Coal Consumption	approx. 1,700 metric t/day		
System	Gasifier	Air-blown & Dry Feed	
	Gas Treatment	Wet (MDEA) + Gypsum Recovery	
	Gas Turbine	1200℃-class (50Hz)	
Efficiency (Target Values)	Gross	48% (LHV)	46% (HHV)
	Net	42% (LHV) *	40.5% (HHV)
Flue Gas Properties (Target Values)	SOx	8 ppm	($16\%O_2$ basis)
	NOx	5 ppm	
	Particulate	4 mg/m^3N	

* While target net thermal efficiency is 48～50% in commercial IGCC plant applying 1500℃ class gas turbine, 1200℃-class gas turbine was adopted to reduce the capacity of plant for economy

Status of operating test on Nakoso IGCC

- Construction of demonstration plant was completed in September, 2007
- Operating test started after the completion.
- Operating test is still going on and will end in March, 2011.

The main results of operating test at present

- Result value of net thermal efficiency is 42.9%LHV (target value is 42%)
  ⇒Highly efficient operation was achieved.

- The amount of SOx, NOx and particulate emission is less than designed value.
  ⇒Environmental performance was satisfied with the design.

- 2,000hours continuous operation was achieved in the first year.
  ⇒Reliability was confirmed.

- Stable operation with bituminous coal (China) and subbituminous coal (USA, Indonesia) was confirmed.
  ⇒Several kinds of coal were tested to increase the flexibility.

Status of operating test on Nakoso IGCC

Remaining items in the test

- 5,000 hour durability test is continuing until March 2010.
- Additional kinds of coal flexibility test
- Operational optimization tests

Subject after the operation test

- Japanese government is now conducting feasibility study of CCS application utilizing the Nakoso IGCC plant.

CONCLUDING REMARKS: Regarding IGCC

- **Development of clean coal power technology is a key factor to solve the global warming issue while pursuing 3E concept. Therefore, in Japan, entire electric power utilities are involved in the IGCC technology development. .**

- **Wide market expansion regarding the technology is expected in the developing country and the advanced country including BRICS. It seems that international technological competition would advance.**

- **Each country would hopefully work positively regarding IGCC technology to achieve worldwide economic growth and 3E simultaneously.**

- ***CCP R&D* would like to join the effort and contribute to the technological progress.**

CONCLUDING REMARKS: In General

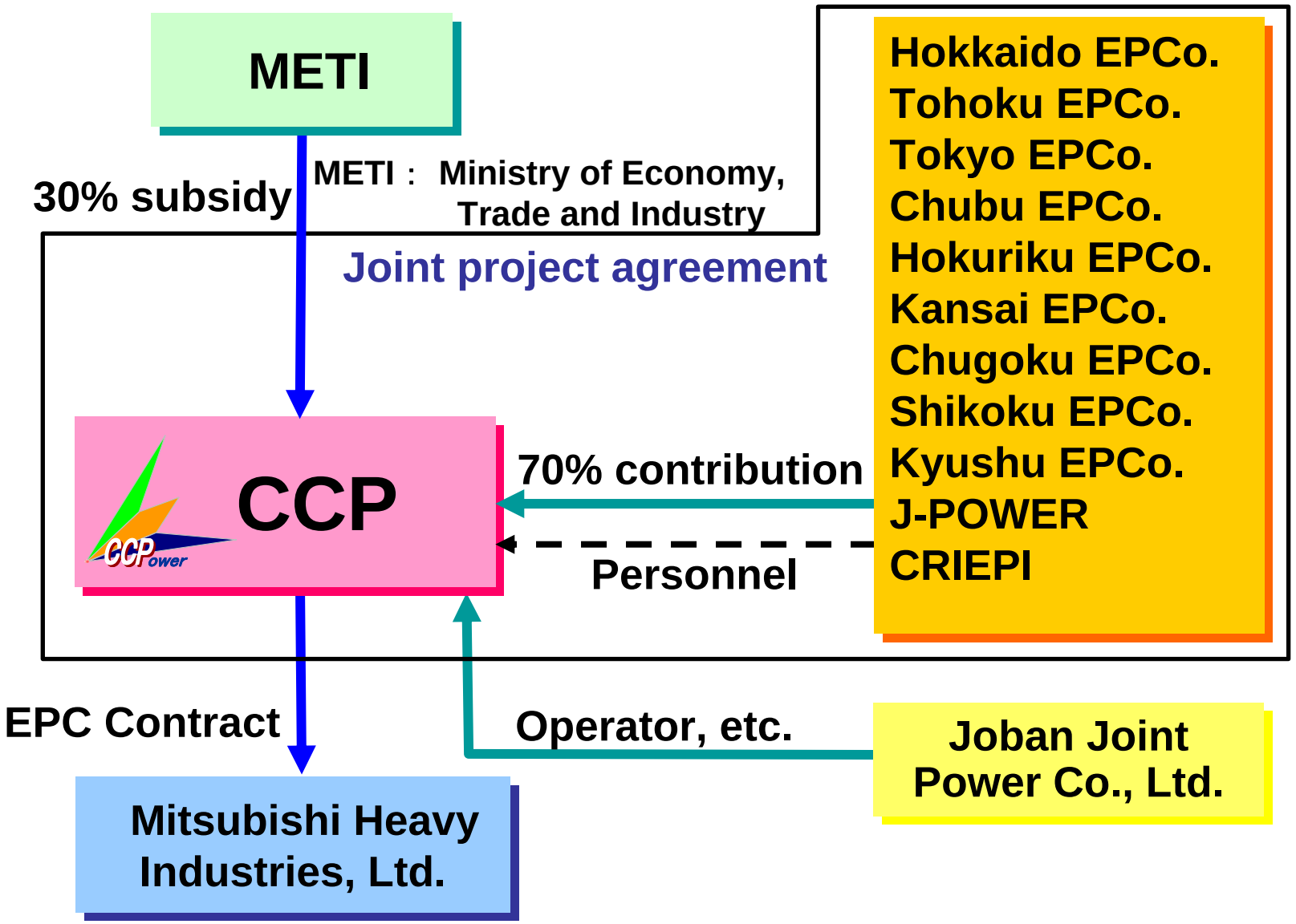
- It will be necessary for the electric power industry to develop the technology of the combination with ready-made technologies, new technologies and other industry (Regarding IGCC; Chemical industry) technologies in the future.

- For realizing good combination, Integrated technological control and measures with such as the cost reduction of individual elements while achieving reliability improvement

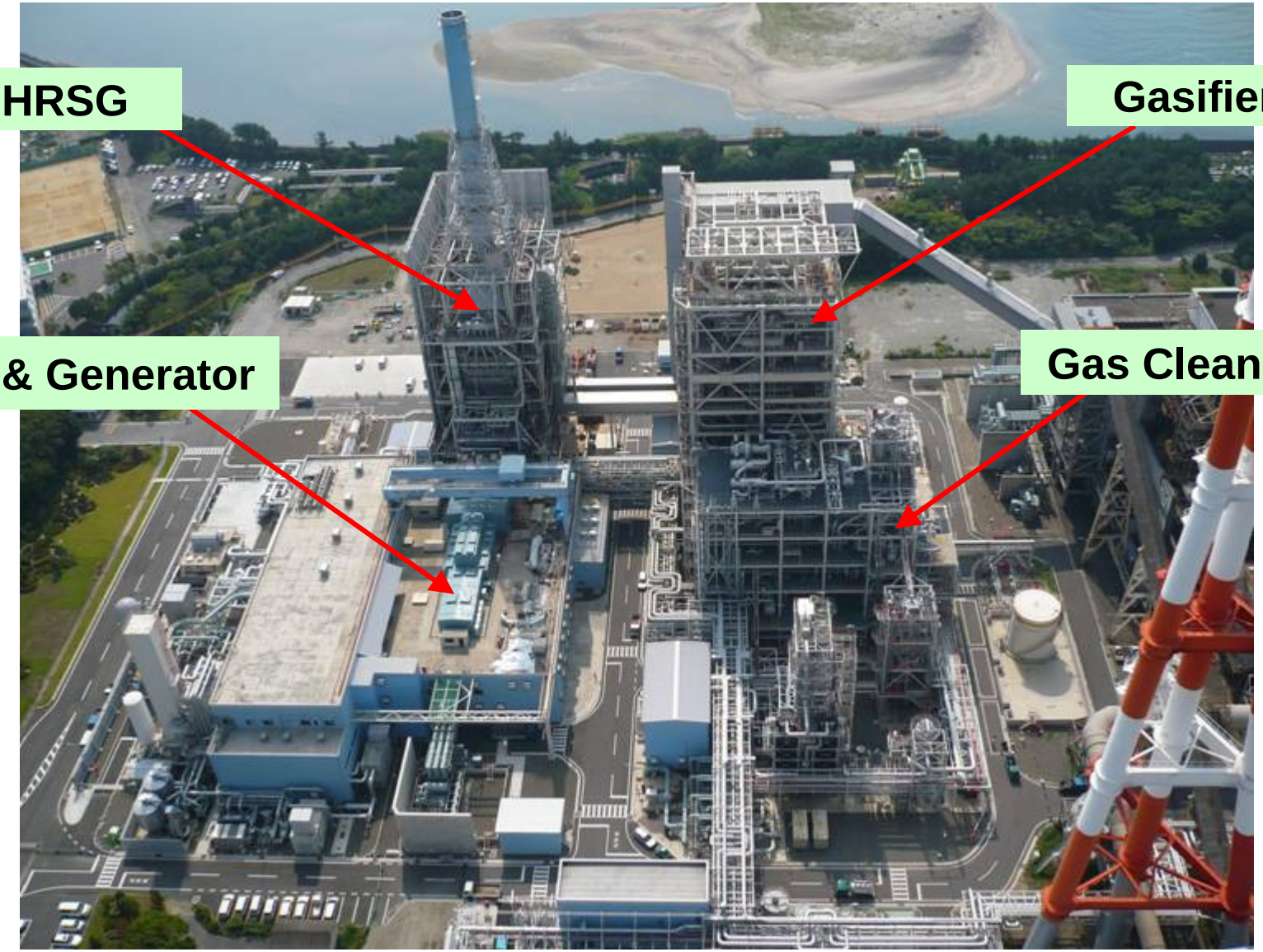
- IGCC is the typical example, and the integrated system consists of considerably complex elements.

- IGCC would hopefully become a good example for such efforts on the technological development of overall system and each element.

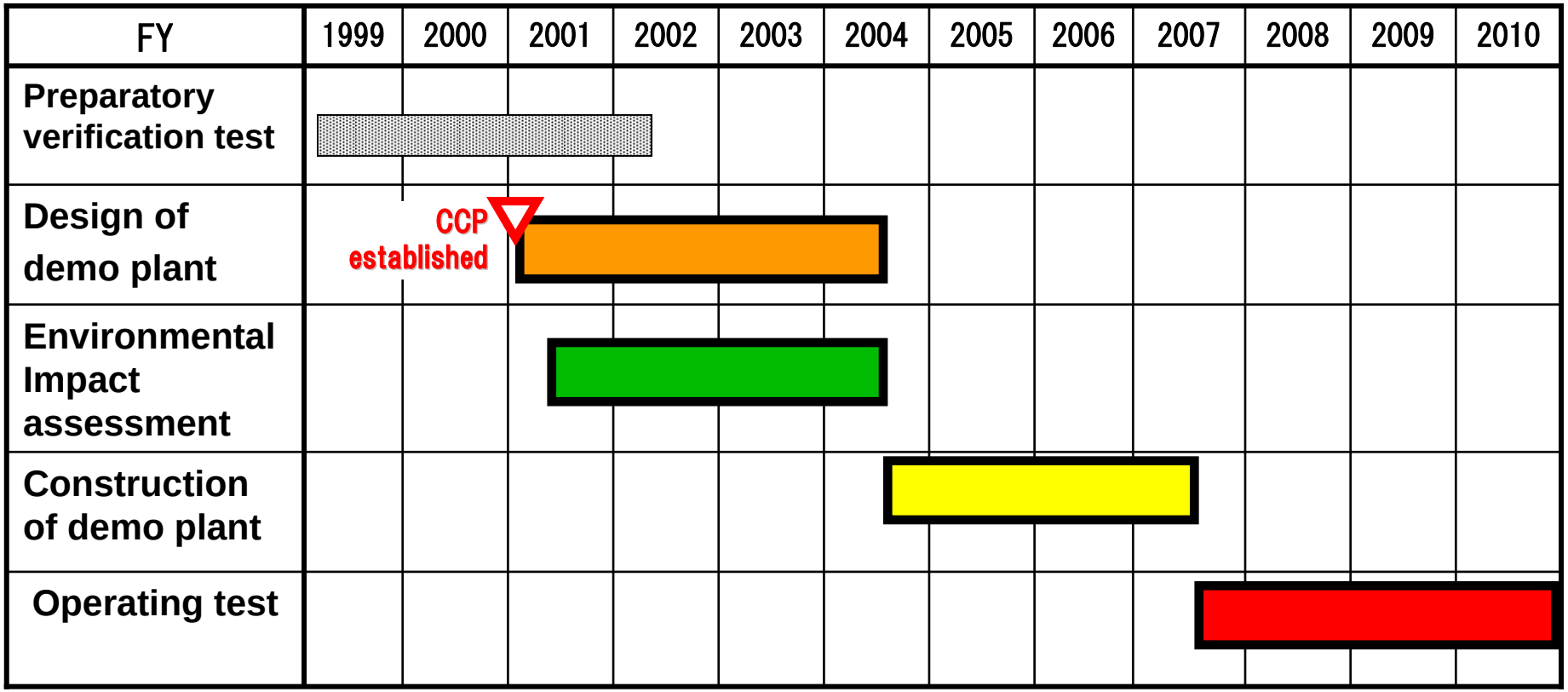
Attachment 1: *Demonstration Project Scheme*



Attachment 2: View of IGCC Demonstration Plant



Attachment 3: Demonstration Project Schedule



The construction work finished in September 2007, and the test operation has been executing now.

Attachment 4: *Status of Targets & Accomplishments*

	Target	First year	Second year	Third year
Safe and Stable Operation	250MW	250MW		
Long Term Continuous Operation	>2000hr	2039hr (1568+471hr)		
Net Thermal Efficiency	>42.5% (LHV basis)	42.4%	42.9%	
Carbon Conversion Rate	>99.9%	>99.9%		
Environmental Performance	SOx <8ppm NOx <5ppm Dust <4mg/m3N	1.0ppm 3.4ppm <0.1mg/m3N		
Coals	Bituminous Sub-bituminous	Chinese	Chinese, PRB & Indonesian	expand coal flexibility
Start-up Time	<18hr	20hr	15hr	
Minimum Load	50%	50%		
Load Change Rate	3%/min	1.2%/min	(no try)	3%/min
Durability & Maintainability	Evaluate during 5000hr test		(in progress now)	5000hr evaluation

Attachment 5: Optimization Test Results

	Design values	Results
Atmospheric Temperature	15°C (59 degF)	9.9°C (50 degF)
Gross Output	250 MW	248.8 MW
Gas Turbine Output	128.9 MW	130.4 MW
Steam Turbine Output	121.1 MW	118.4 MW
Net Efficiency (LHV)	42.5 %	42.9 %※
Cold Gas Efficiency of Gasifier	73 %	77 %
Carbon Conversion Efficiency	>99.9 %	>99.9 %
Syngas LHV	4.8 MJ/m3N	5.6 MJ/m3N
Composition CO	28.0 %	31.9 %
CO2	3.8 %	2.7 %
H2	10.4 %	10.0 %
CH4	0.3 %	1.4 %
N2 & Others	57.5 %	54.0 %
Environmental Performance (16% O2 Corrected)	<Target values>	
SOx	8 ppm	0.5 ppm
NOx	5 ppm	3.9 ppm
Particulate	4 mg/m3N	<0.1 mg/m3N

※Correction value at 15℃

Attachment 6: Operating Results

(As of October 31, 2009)

Operating Time	GT Operation by Syngas	4,911 hrs
	Gasifier Operation	5,008 hrs
Power Generation	Cumulative gross output	1,010 GWh
Fuel Consumption	Cumulative coal consumption	332 kton (metric)