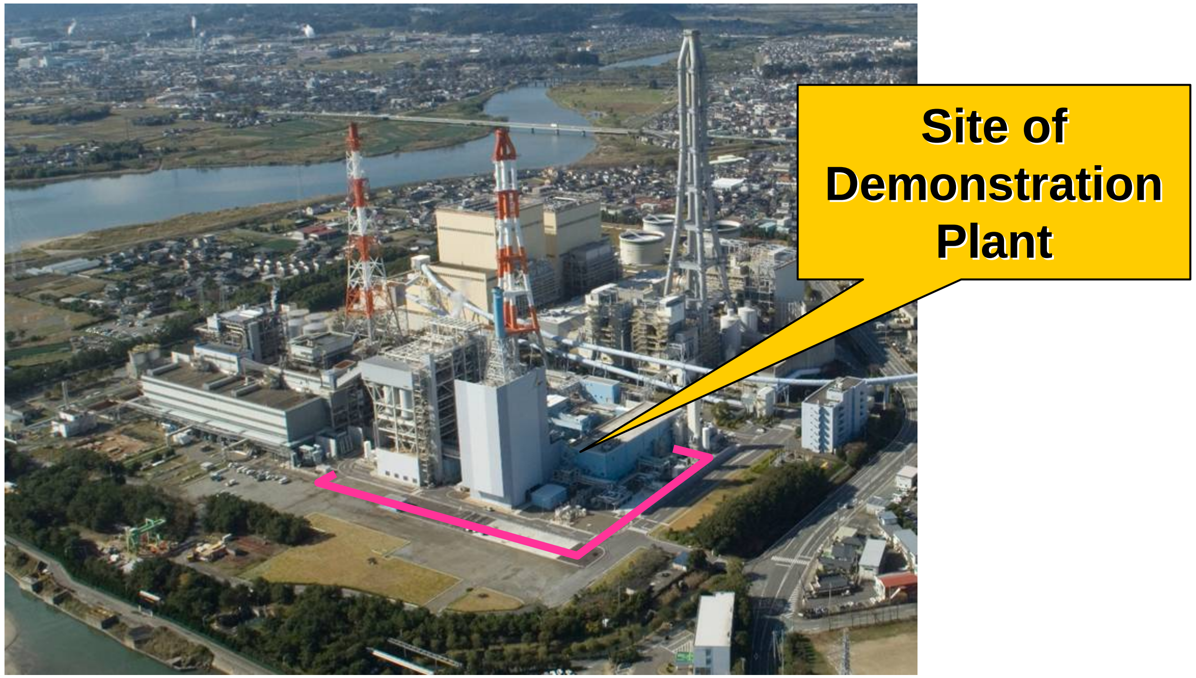
Progress in Japanese Air-blown IGCC Demonstration Project Update

April 26th, 2012

Clean Coal Power R&D Co., Ltd.

Location of demonstration plant

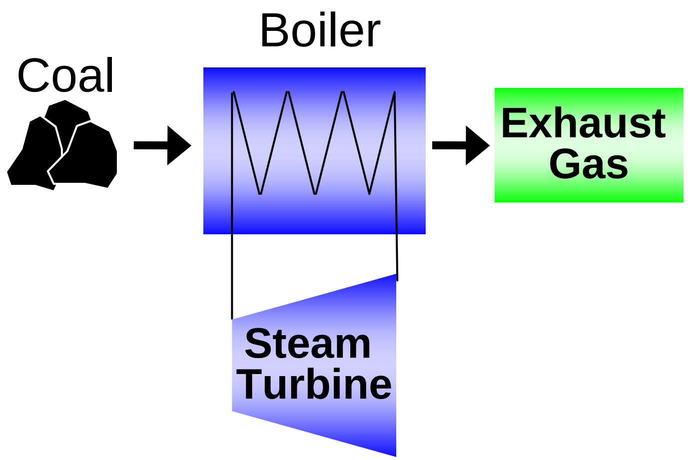


Located within the NAKOSO Power Station
of JOBAN JOINT POWER CO.,LTD.

System Feature of IGCC

Conventional PCF

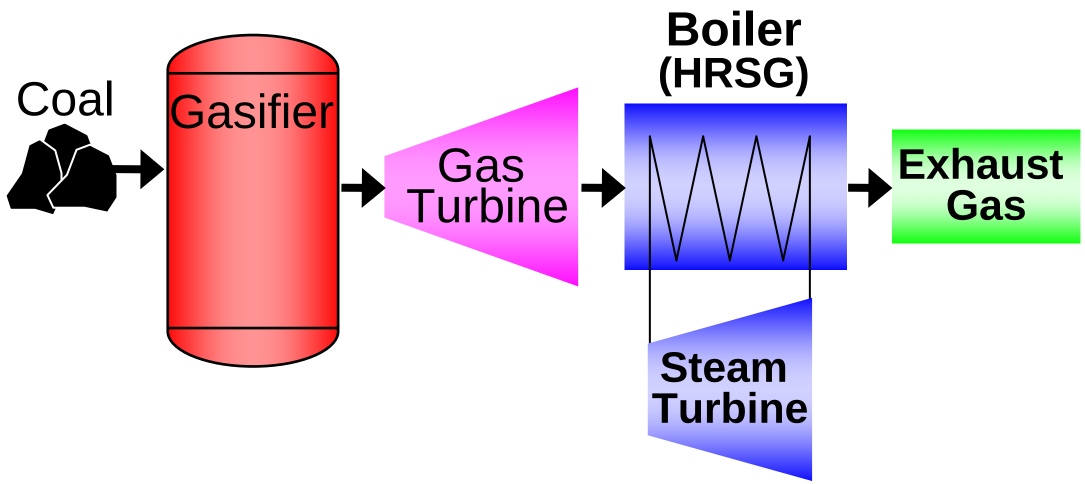
Boiler + Steam Turbine



PCF : Pulverized Coal Firing

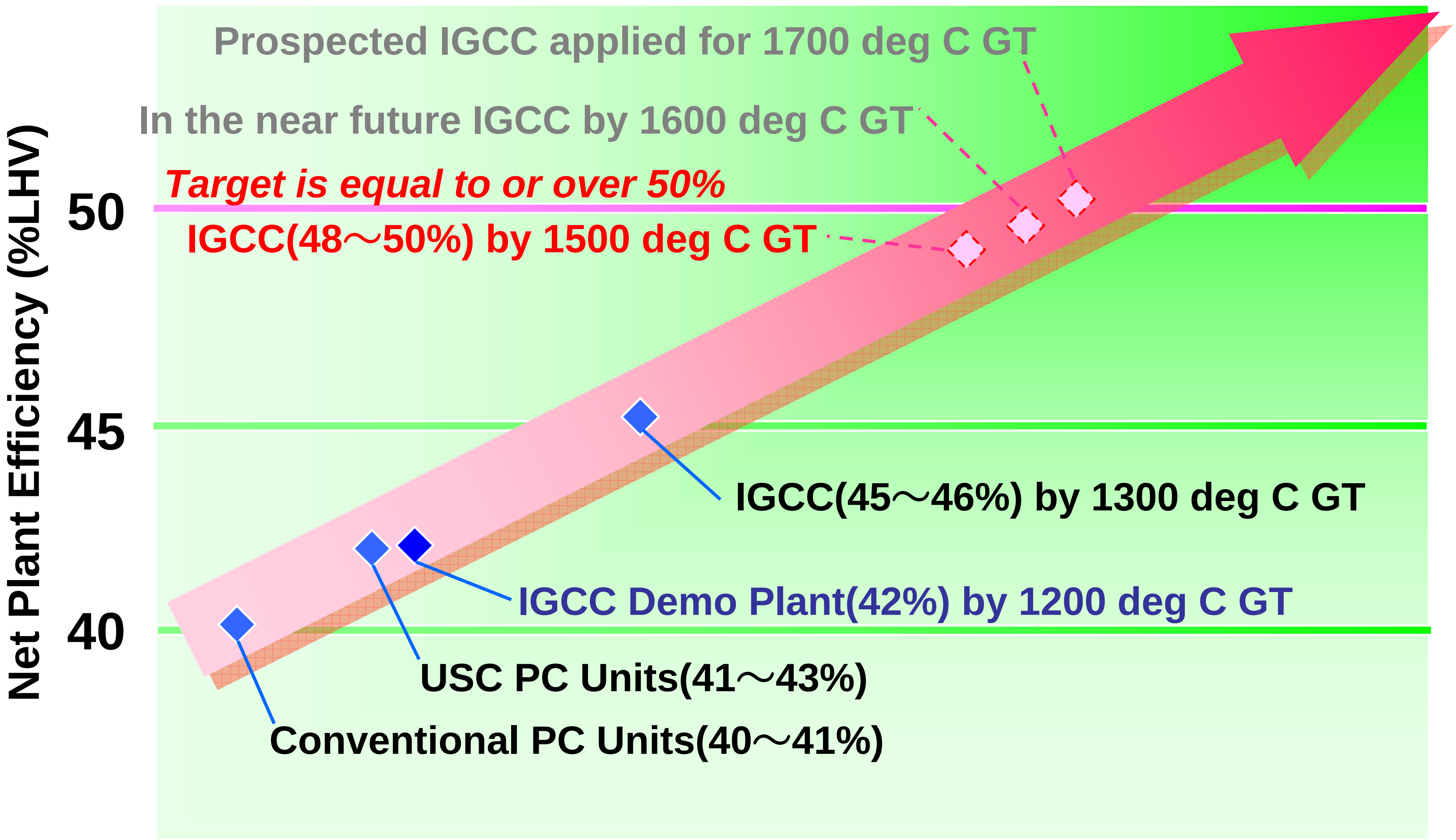
IGCC

Boiler + Steam Turbine
+ Gasifier + Gas Turbine



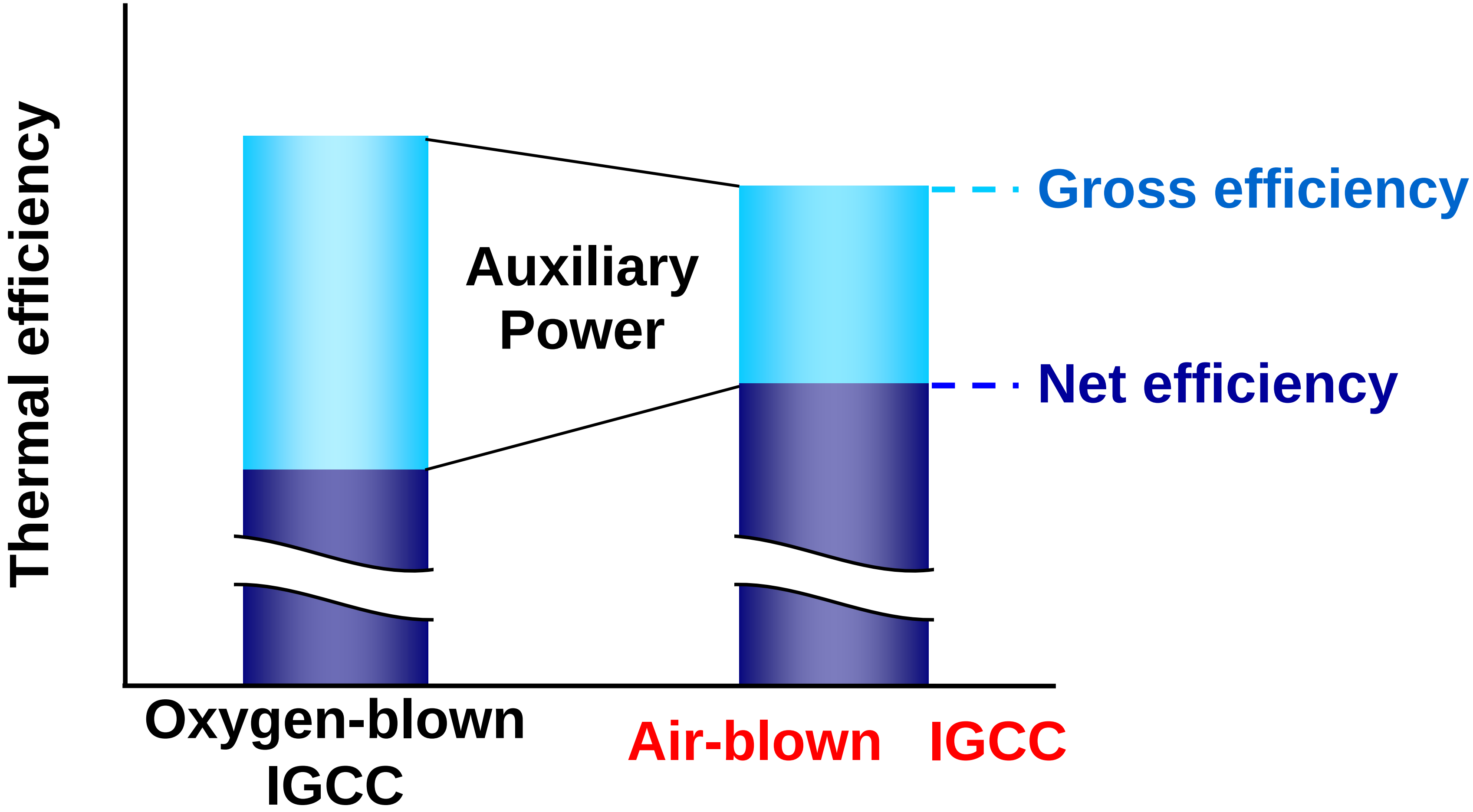
IGCC is a new power generation system aiming at higher efficiency than conventional coal-fired systems by integrated coal gasification with combined cycle power generation technology.

Thermal efficiency Improvement



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

Advantage of Air-blown IGCC in Efficiency



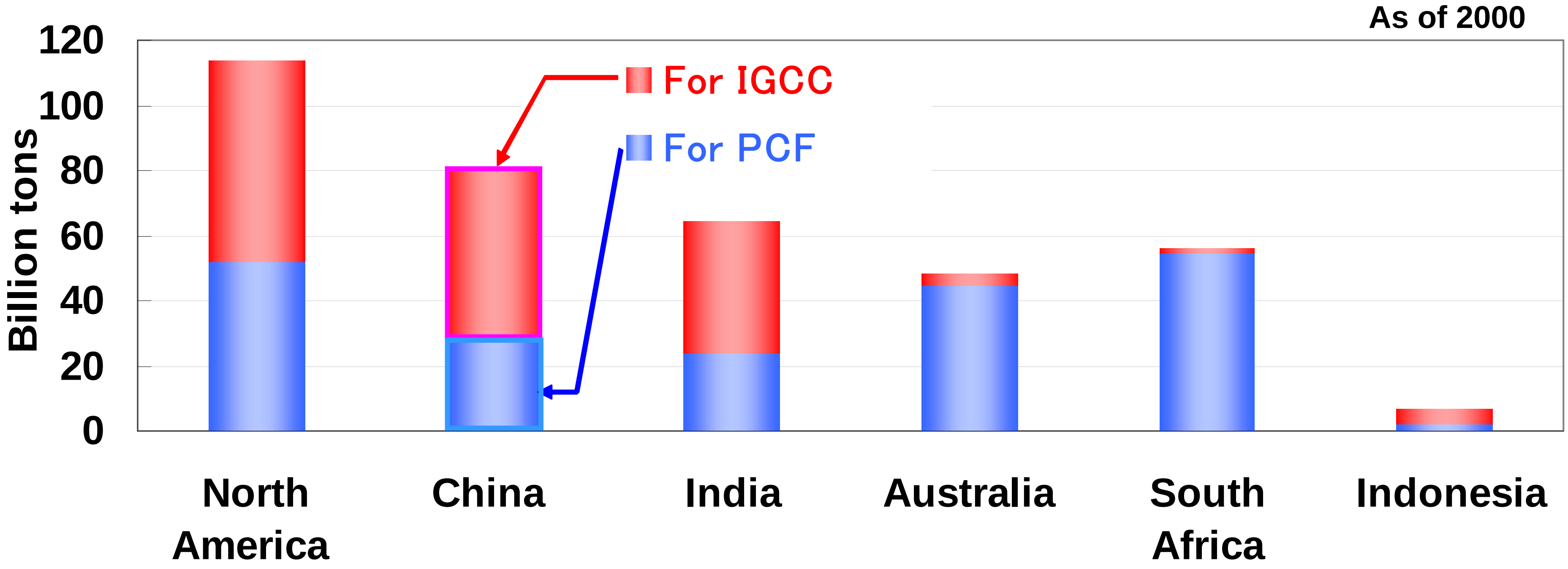
Air-blown IGCC applied in Nakoso is expected to realize high thermal efficiency compared with oxygen-blown IGCC.

Coal IGCC Projects

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 1,100degC-class	335 MW 1,300degC-class	297 MW 1,300degC-class	315 MW 1,300degC-class	250MW 1,200degC-class
Demonstration test start	Jan. 1994	Dec. 1997	Oct. 1995	Sep. 1996	Sep. 2007

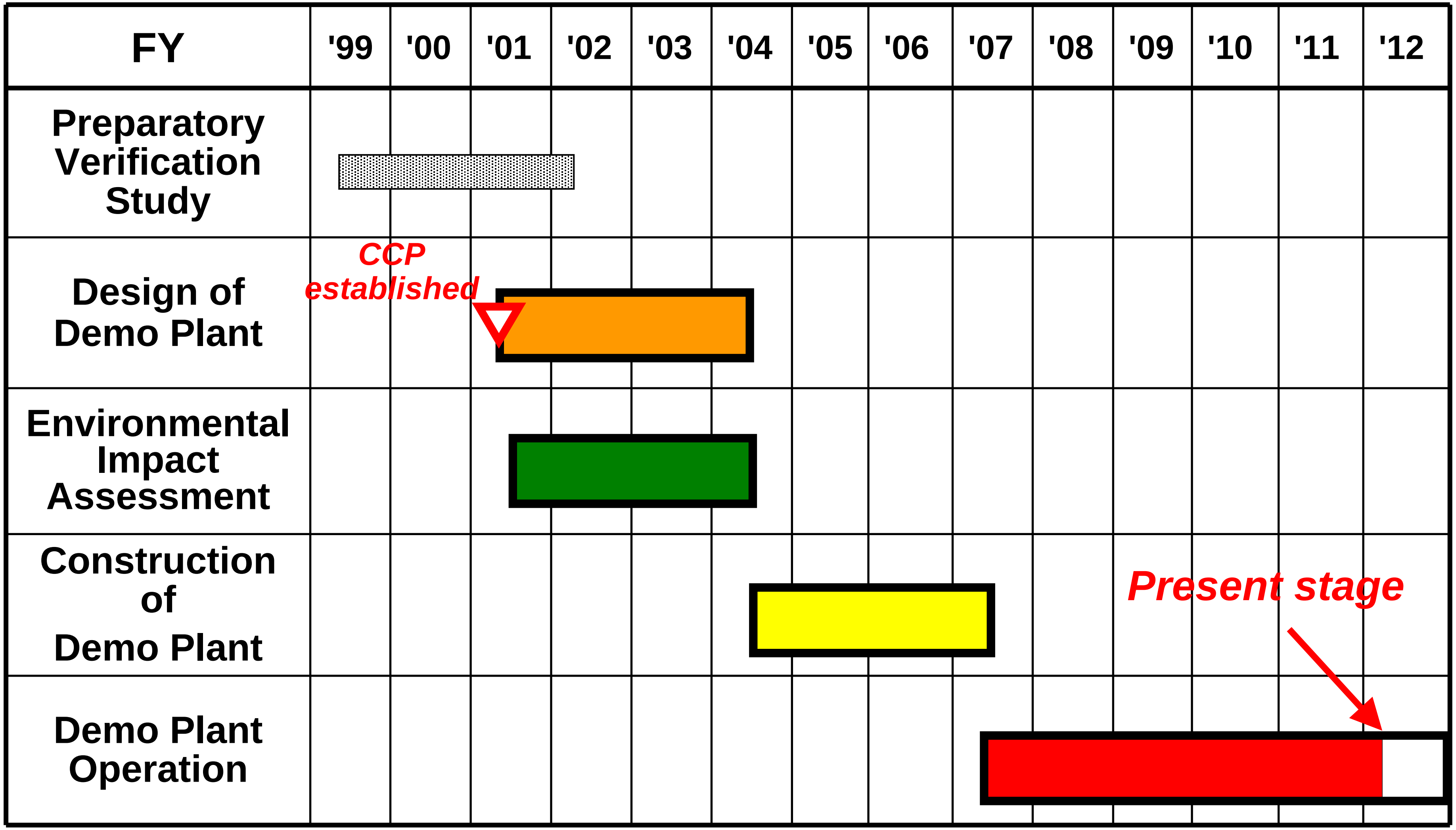
Advantage of Japanese IGCC in increase in kinds of coal

Amount of coal that can be used in Japan



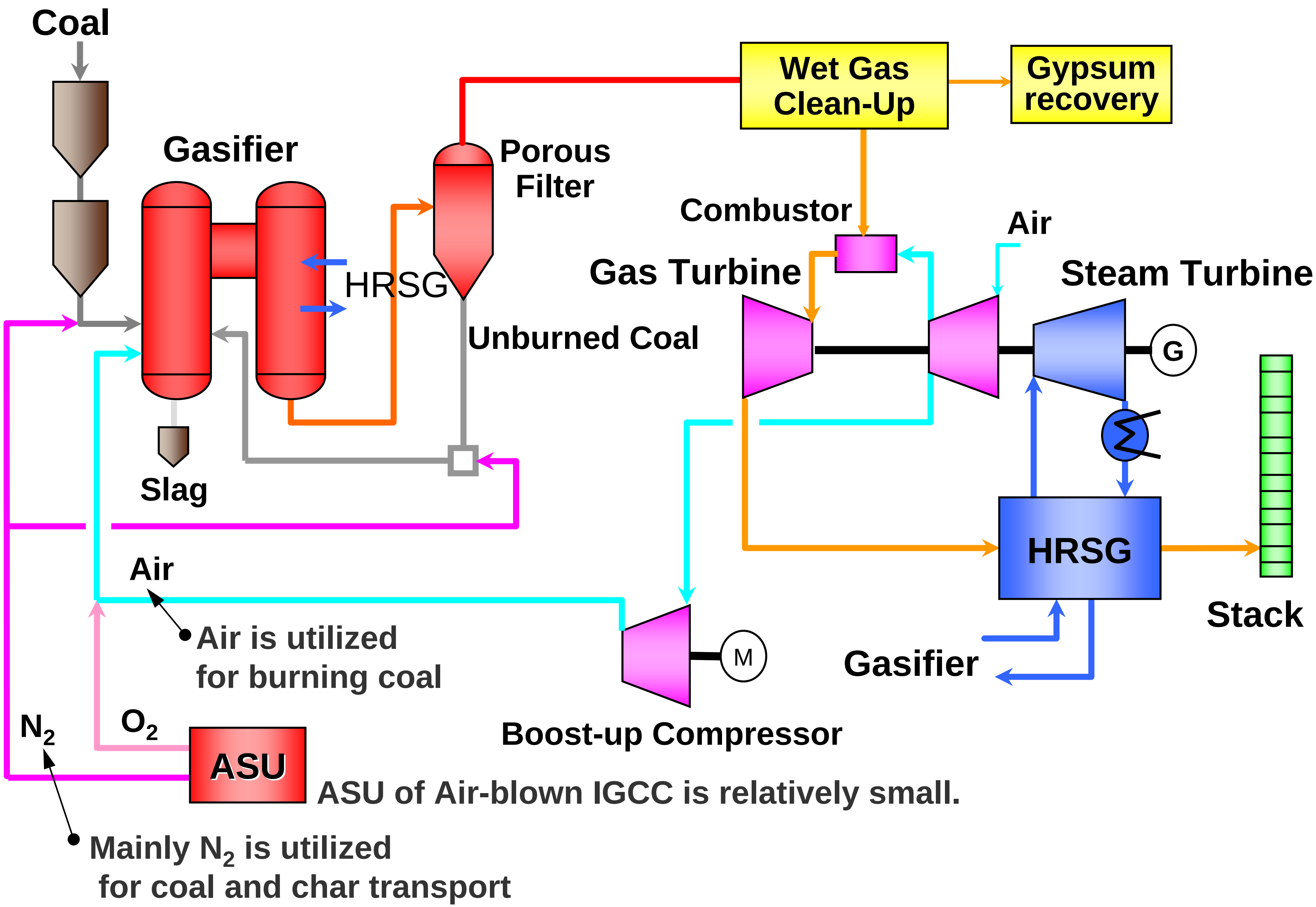
•**Low rank coal use could be increased because IGCC utilizes different type of coals.**

Demonstration Project Schedule

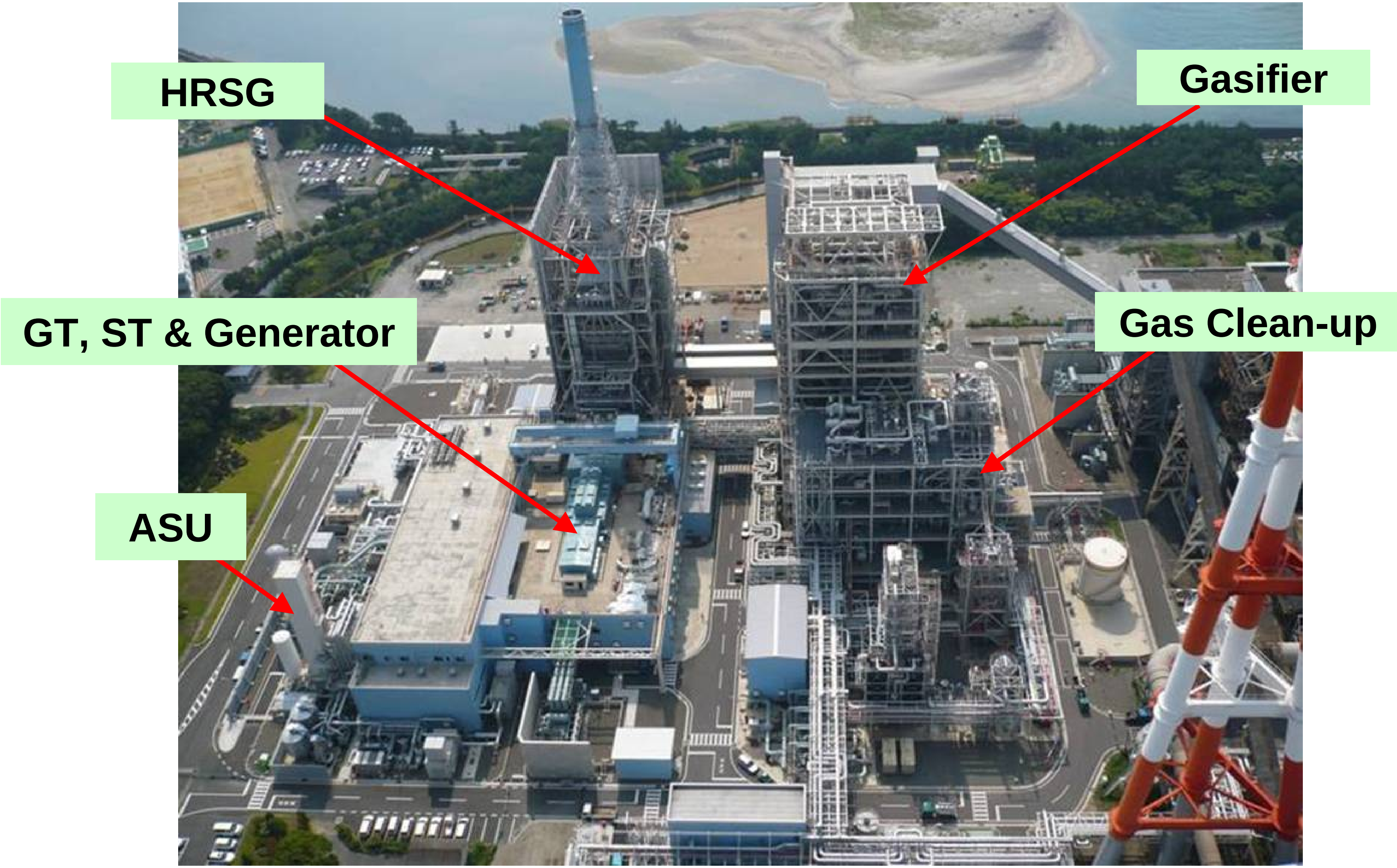


The construction work finished in September 2007.
The remaining demonstration period is just one year.

Schematic diagram of Demonstration Plant



Bird's-eye view of IGCC Demonstration Plant



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 deg C-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 deg C class gas turbine, 1200 deg C-class gas turbine was adopted to reduce the capacity of plant for economy.

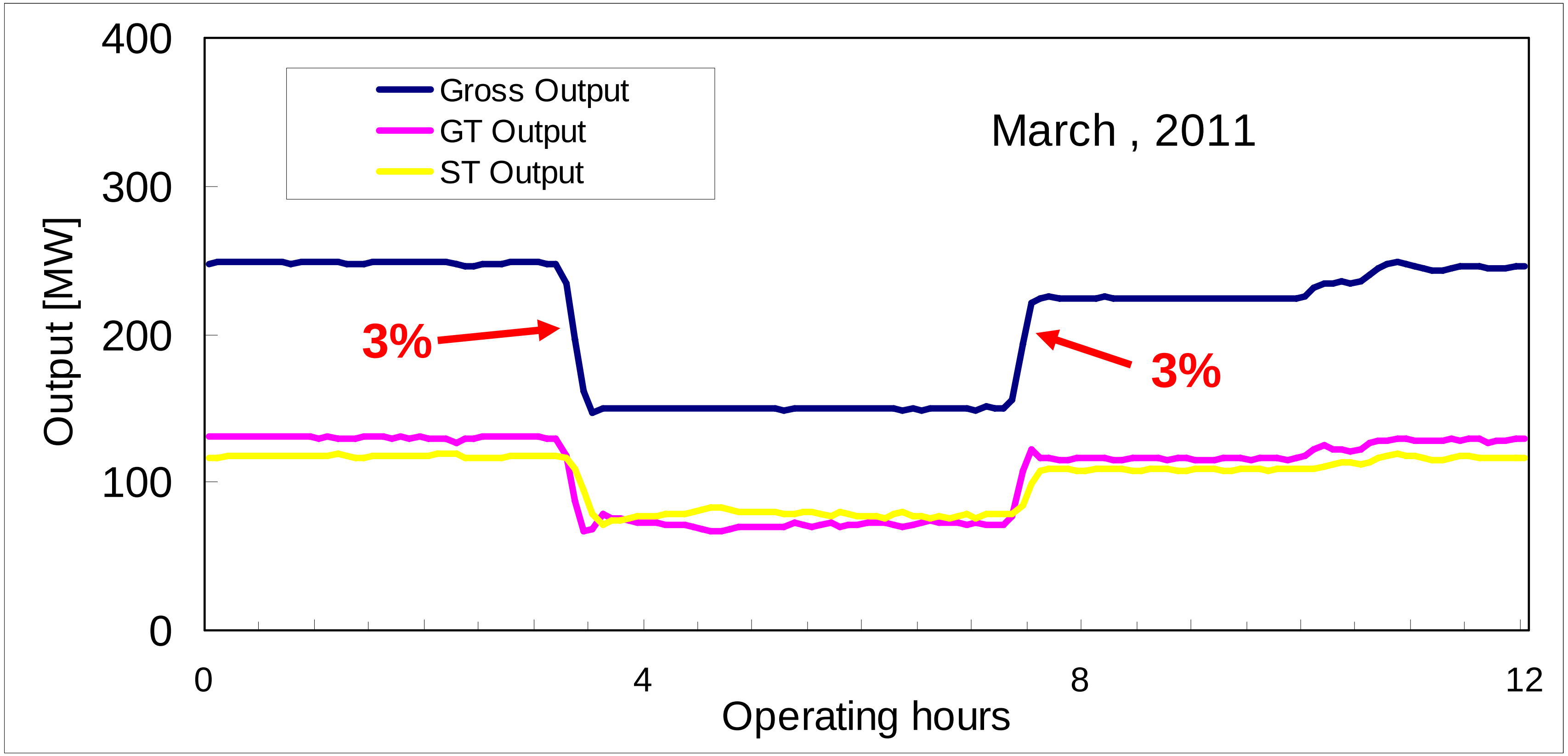
Outline of Demonstration Test Program

No.	Item	Goal
1	System Safety and Stability	Safe and stable operation to be verified during start-up, operation and shutdown
2	Reliability	2,000 hours continuous operation (equivalent to 3 months operation)
3	Fuel Flexibility	Several types of coals to be used for the design of future commercial IGCC
4	High Efficiency	Achievement of target efficiency
5	Durability	Durability of components and auxiliaries to be examined by inspection after long-term operation
6	Economy	Evaluation of economy of commercial IGCC by the results of construction, operation and maintenance of Demonstration Plant

Status of Targets & Achievements

	Targets	Results	Status of Achievement	Future plan
Safe and Stable Operation	250MW	250MW	Achieved	
Long Term Continuous Operation	>2000hr	2238hr (After tsunami)	Achieveded	
Net Thermal Efficiency	>42% (LHV basis)	42.9%	Achieved	
Carbon Conversion Rate	>99.9%	>99.9%	Achieved	
Environmental Performance	SOx <8ppm NOx <5ppm Dust <4mg/m3N	1.0ppm 3.4ppm <0.1mg/m3N	Achieved	
Coals	Bituminous (B) Sub-bituminous (SB)	Chinese (B) USA (SB) Indonesian (B,2SB) Russian(B) Columbian(B)	Achieved	Increase in coal Types (2B,1SB is scheduled)
Start-up Time	<18hr	15hr	Achieved	
Minimum Load	50%	36%	Achieved	Reduce load of fuel change
Load Change Rate	3%/min	3%/min	Achieved	
Durability & Reliability & Maintainability	Evaluate during 5000hr test	5013hr in one year, No serious damage	Almost achieved	Maintenance interval Evaluation, Higher availability
Economy estimation	Less than or equal to PCF power generation cost	Construction cost and operation cost was estimated.	Under study	Maintenance cost Evaluation etc.

Load Change Rate



Load change rate of 3%/min which is compatible with conventional PCF in Japan, was realized by adjusting the operation parameters.

No.1:System Safety and Stability (1)+No.4:High Efficiency

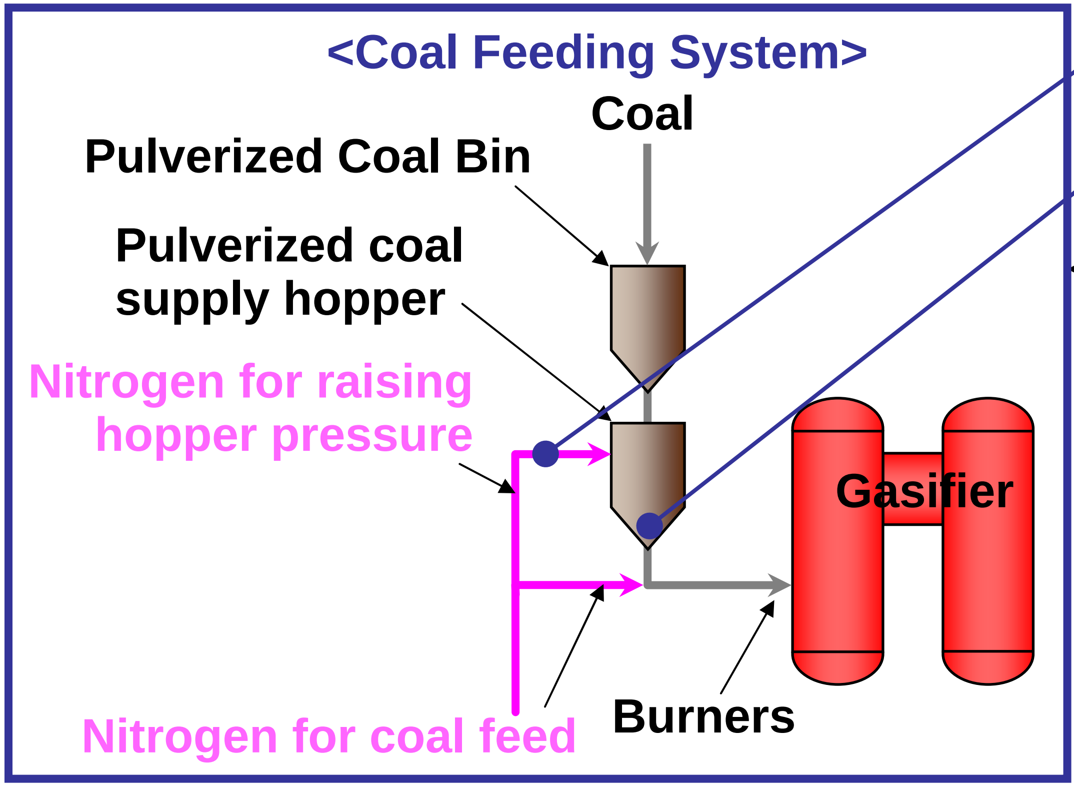
Result of plant performance test in March 2008

	Design values	Results
Atmospheric Temperature	15degC	13.1degC
Gross Output	250 MW	250.0 MW
Gas Turbine Output	128.9 MW	124.4 MW
Steam Turbine Output	121.1 MW	125.8 MW
Cold Gas Efficiency of Gasifier		75.3 %
Carbon Conversion Rate	> 99.9 %	> 99.9 %
Net Efficiency (LHV)	42 %	42.4 %(42.9%)
Syngas LHV	4.8 MJ/m³N	5.2 MJ/m³N
Composition CO	28.0 %	30.5 %
CO_2	3.8 %	2.8 %
H_2	10.4 %	10.5 %
CH_4	0.3 %	0.7 %
N_2 & Others	57.5 %	55.5%
Environmental Performance (16% O_2 Corrected)	<Target values>	
SOx	8 ppm	1.0ppm
NOx	5 ppm	3.4 ppm
Particulate	4 mg/m³N	<0.1 mg/m³N

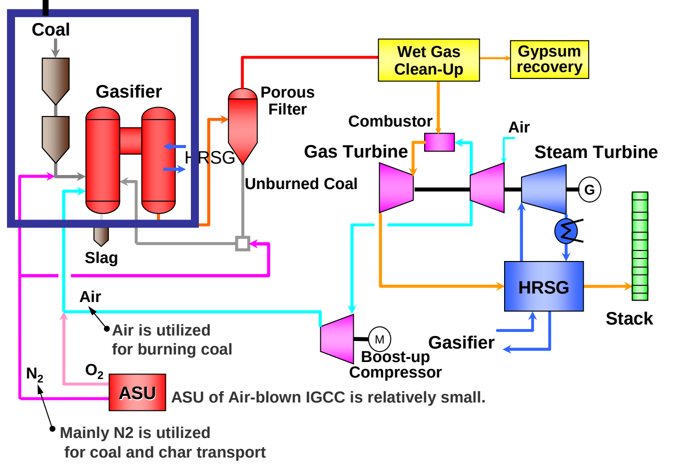
To apply this technology for renewal of old low-efficiency pulverized coal-fired power stations is the most effective and practical way to stop global warming and save resources.

Improvement of dry coal feeding system

Unsteady coal feeding caused a difficulty on gasifier operation at trial operation in 2007.
The problem was solved by modification of coal feeding system and operation of IGCC system became stable.



Modification system
>Improvement of pressurization control of the hopper
>Improvement of fluidization in the bottom cones of the hopper

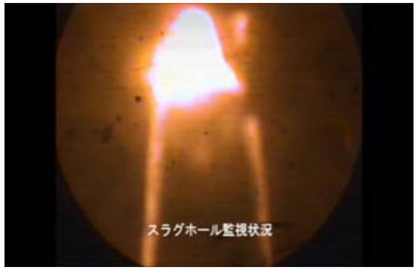


No.1:System Safety and Stability (3)

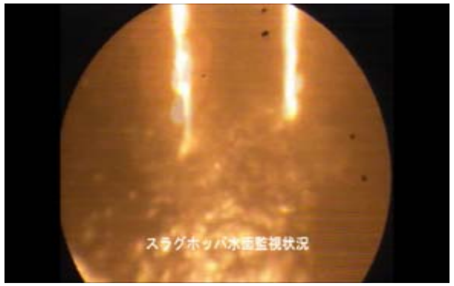
Development of the slag condition monitoring system

Slag hole blockage has never happened during operating test .
The flow of molten slag is constant, which means that the gasifier is operating in a very stable condition.

<Stable streams of molten slag >

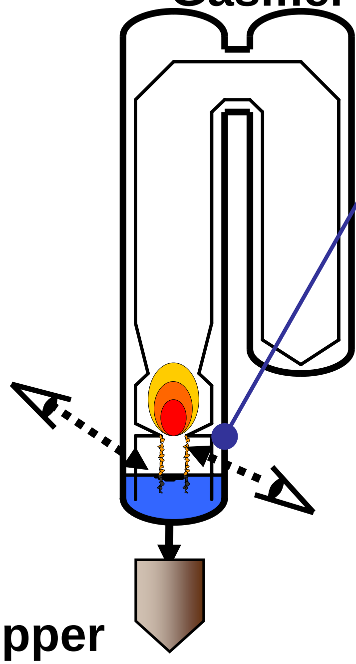


Slag hole view from lower side

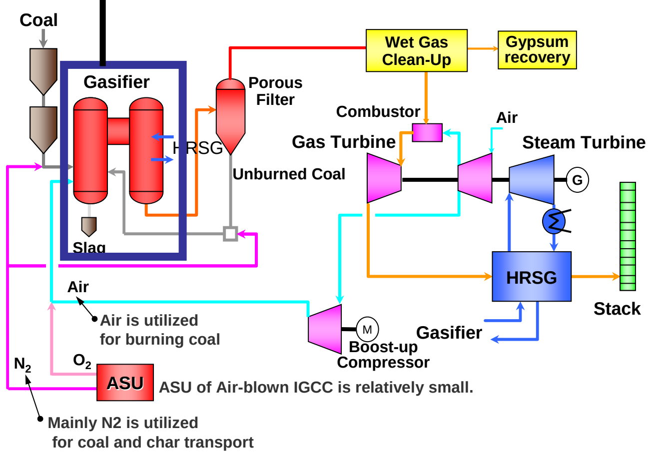


Surface of the water in slag hopper

Gasifier

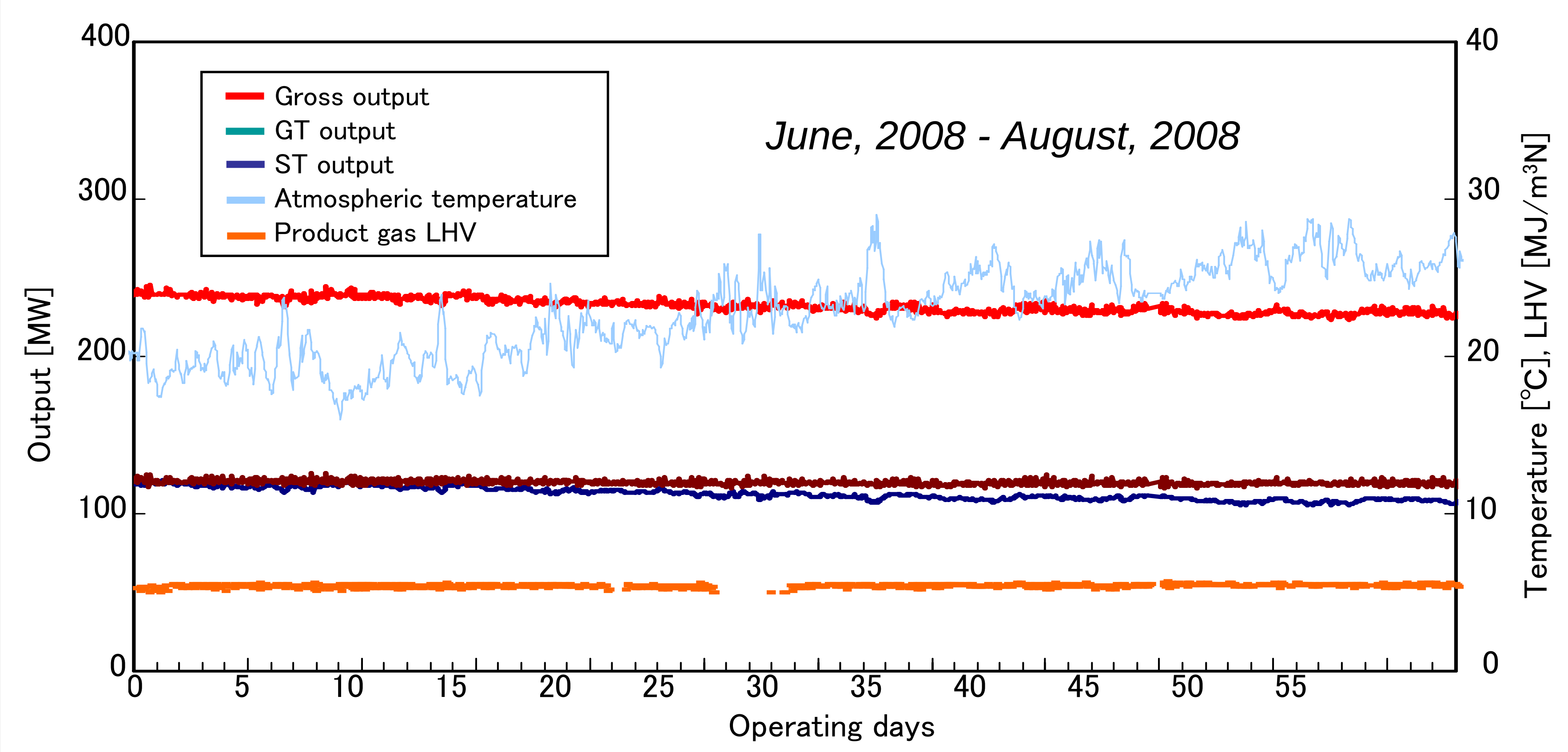


Slag condition monitor
>Image analysis device
>Sound monitoring system



No.2:Reliability

Trend data of long term reliability test conducted in 2008 summer



- Capability of stable power generation was confirmed.
- 2000hours continuous operation was achieved in the first year.
  - >Total operating hours reached 2,039hours.

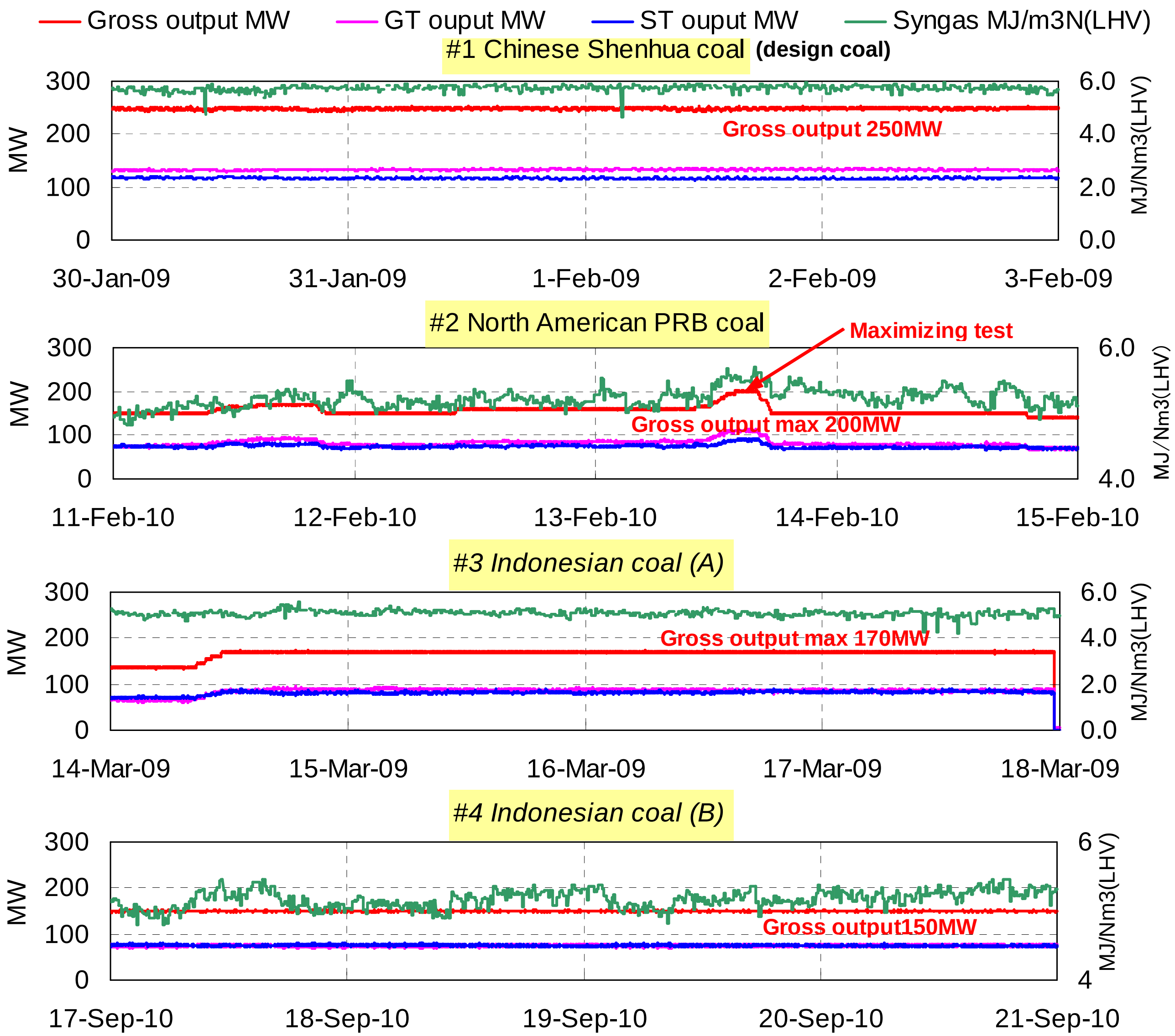
No.3:Fuel Flexibility (1)

Properties of coal used in 2009-2012

		#1 Chinese Shenhua Coal Jan, 2009 (design coal)	#2 North American PRB coal Feb, 2010	#3 Indonesian (A) Mar, 2009	#4 Indonesian (B) Sep, 2010	#5 Colombian Sep, 2011	#6 Russian Dec, 2011	#7 Indonesian (C) Jan, 2012
Gross Calorific Value (air dry)	kJ/kg	**27,120**	**26,670**	**26,370**	**23,010**	**28,090**	**26,560**	**29,620**
Total Moisture (as received)	wt%	**15.4**	**25.3**	**21.7**	**29.7**	**14.7**	**10.8**	**8.4**
Total Sulphur (air dry)	wt%	**0.25**	**0.39**	**0.25**	**0.12**	**0.76**	**0.34**	**0.62**
Proximate Analysis (air dry)								
Inherent Moisture	wt%	**7.5**	**8.0**	**7.9**	**17.1**	**1.8**	**3.7**	**2.7**
Fixed Carbon	wt%	**51.3**	**47.4**	**45.2**	**37.8**	**49.0**	**44.8**	**43.9**
Volatile Matter	wt%	**32.3**	**39.1**	**42.5**	**41.6**	**35.6**	**38.2**	**44.9**
Ash	wt%	**8.9**	**5.5**	**4.4**	**3.5**	**13.6**	**13.3**	**8.5**
Fusibility of Coal Ash								
Flow Temperature	deg C	**1225**	**1420**	**1260**	**1230**	**1390**	**1450**	**1570**

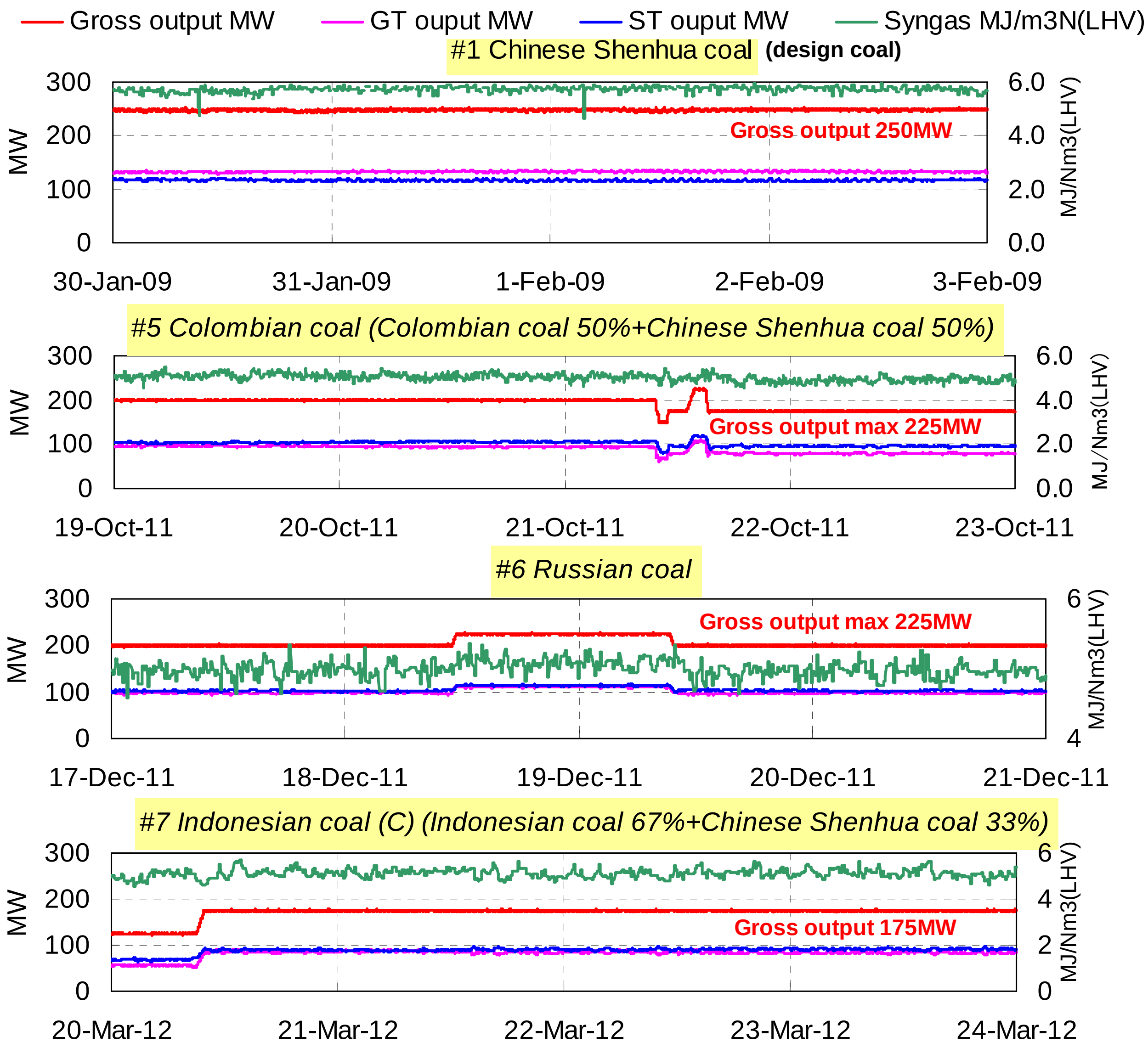
Bituminous coals and sub-bituminous coals were applied and recently Columbian and Russian coal were also successfully tested

No.3:Fuel Flexibility (2) ; Test result (1)



Stable power generation using various coals was confirmed.

No.3:Fuel Flexibility (2) ; Test result (2)



Stable power generation using various coals was confirmed.

No.5:Durability (1)

The durability test was executed from June, 2009 to June, 2010.
>Total operating hours reached 5,013hors

Some shut-downs during durability test were experienced principally by the auxiliary facilities incidents as shown in the following table. And, defect of facilities was not found by inspection after the durability test.

Item of Incident	System	Root Cause	Cure
1.Leakage from Gland packing of Rotary Valve below Porous Filter	Char Recycle System	Inadequate tightening of a packing caused the gas leakage from the ground.	Proper control of tightening the packing at the ground
2.Trip of Slag Discharge Conveyor	Slag Treatment System	Scraper of the drag chain conveyor meandered and stuck onto the gutter of the bottom plate, and caused overloading of the conveyor motor.	Improvement of the conveyor structure
3.Leakage of Coal from the Pulverized Coal Collector	Pulverized Coal Supply System	Filter cloth tore and pulverized coal accumulated in the bag filter was oxidized and increased in temperature.	Monitoring device added and operation procedure improved
4.Leakage of No.2 Extraction Air Cooler Tube	Gasifier Air Supply System	Inadequate and irregular tube material selection caused corrosion. Air leaked to the condenser and resolved oxygen concentration in condensate water increased.	Tube material correctly changed
5.Leakage of Char Gasifier Burner Cooling Tube	Gasifier	Inadequate positioning of the burner front edge caused erosion of the burner cooling tube	Proper control of positioning the burner front edge

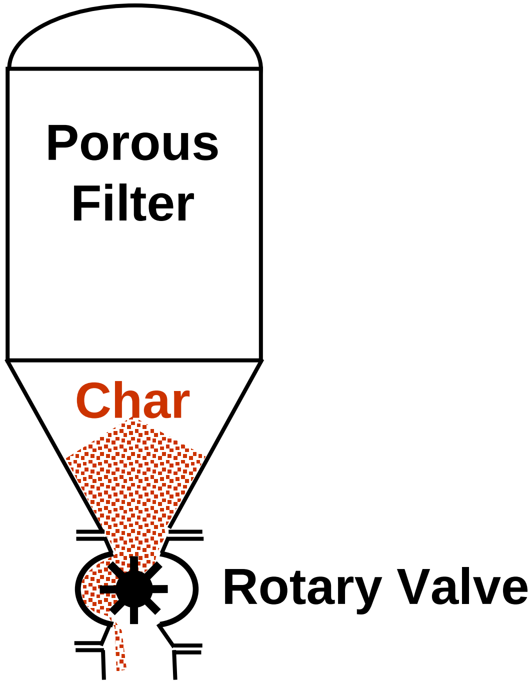
Char leakage from rotary valve under the porous filter

Cause

Tightening shortage of gasket

Solution

Proper tightening of gasket



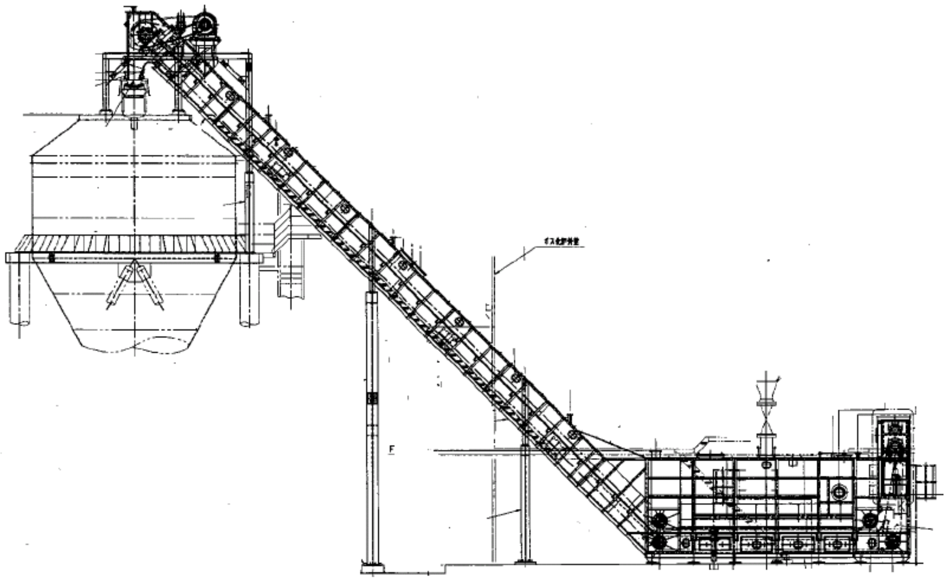
Breakdown of slag conveyer

Cause

Slag conveyer meandered, and parts were damaged.

Solution

The structure of the bottom plate of the conveyer was changed.



Pulverized coal leakage from bag filter

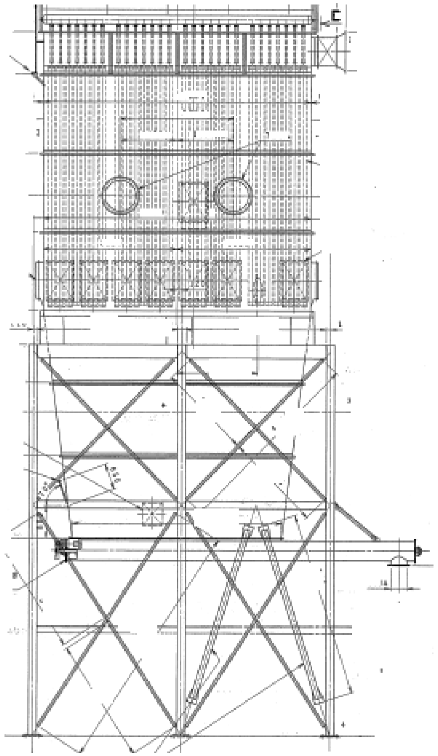
Cause

The bag filter was damaged.

Leakage was occurred by the breakage of bag filter.

Solution

The pulverized coal leakage monitor was set up.



Pulverized coal leakage from bag filter

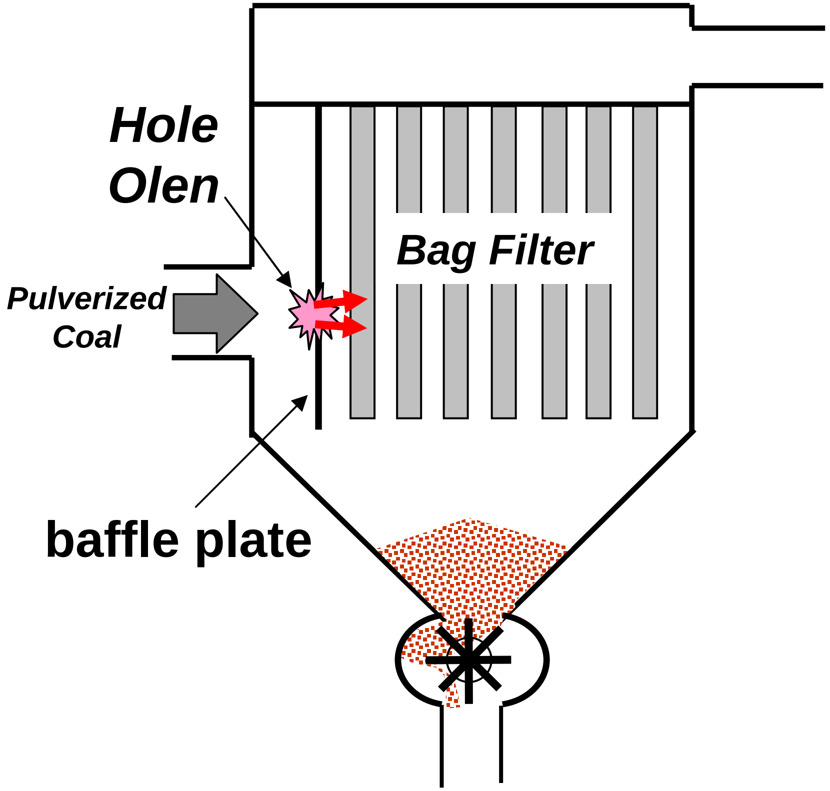
Cause

The bag filter was damaged.

Leakage was occurred by the breakage of bag filter. The hole open in the baffle plate in the pulverized coal entrance part.

Solution

The range of target plate in pulverized coal entrance baffle plate was expanded .



No.5:Durability (6)-*The major causes of outages (5)*

No2 Bleed Air Cooler Tube Leakage

Cause

No2 Bleed Air Cooler Tube was damaged.
Leakage was occurred by the Stress corrosion cracking.

Solution

The tube material was changed to titanium.

No.5:Durability (7)-The major causes of outage (6)

Auxiliary facility incident-5

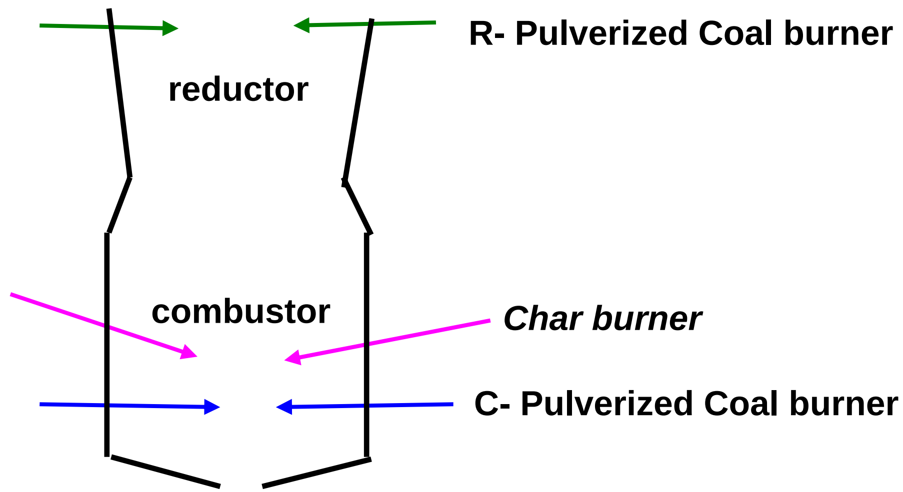
Leakage of Char Gasifier Burner Cooling Tube

Cause

The char accompanied by the secondary air eroded the burner cooling water tube.

Countermeasure

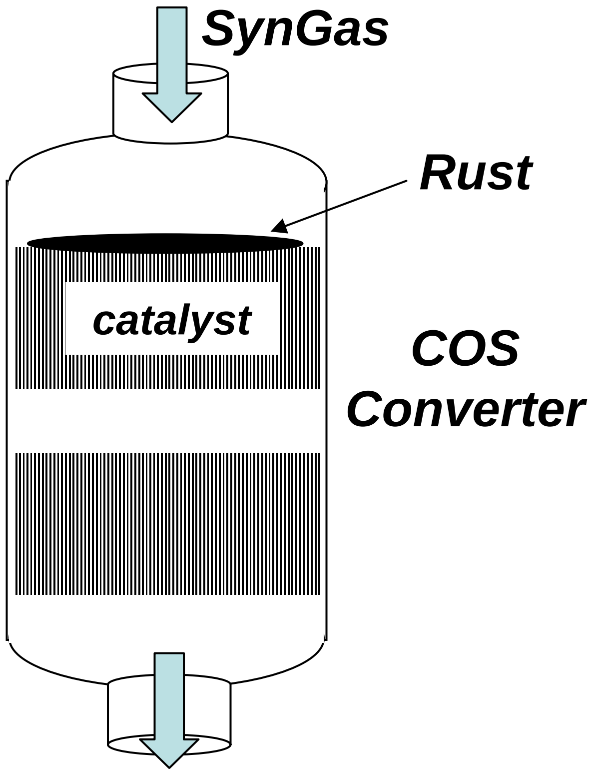
The disposition of the burner was adjusted.



COS Converter Pressure Drop Increase

Cause

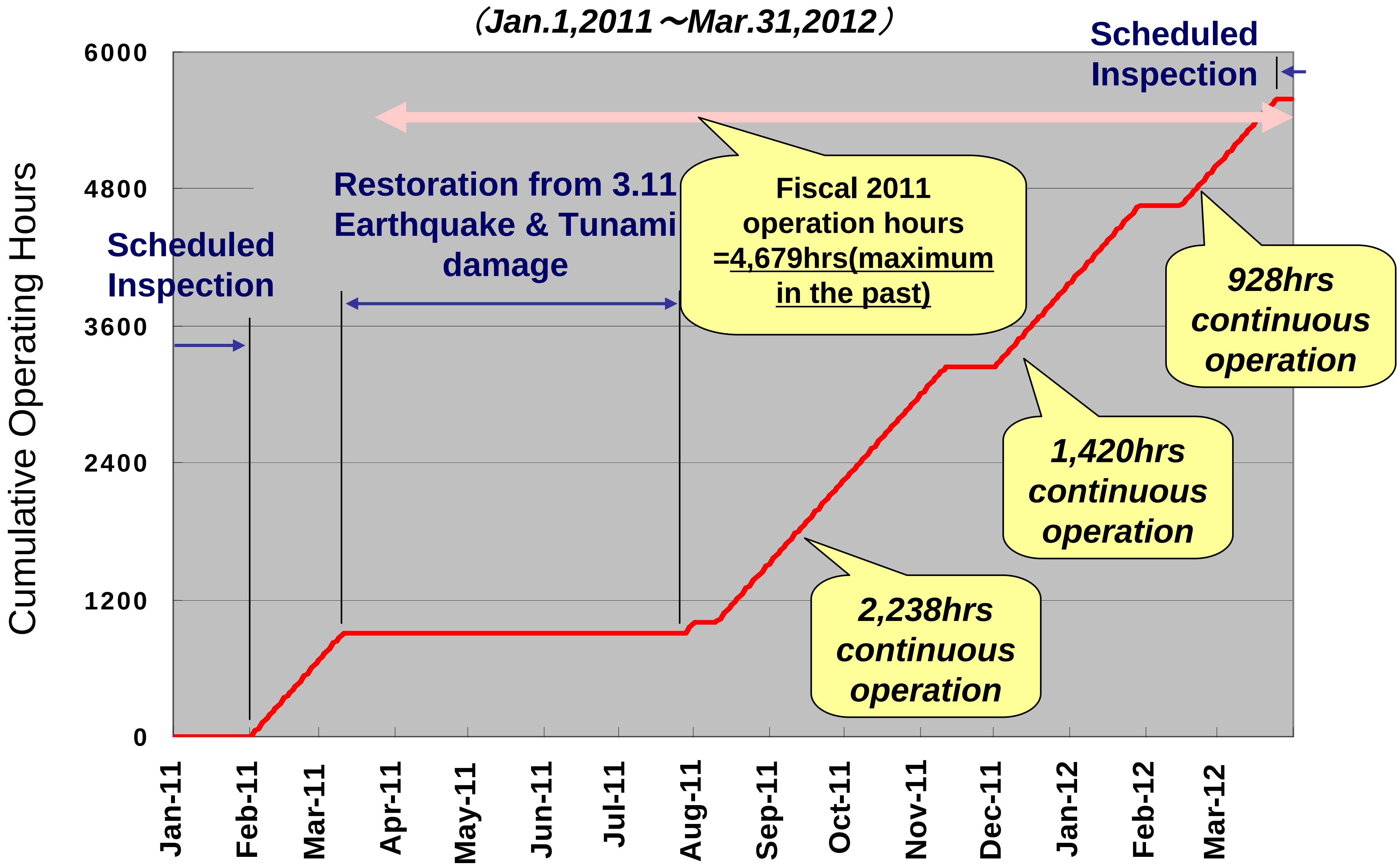
The piping rust piled up in the upper part of the COS converter catalyst.



Solution

The chamber that collected the piping rust was set up in the inside of the COS converter.

No.5:Durability (8): High availability after Tsunami



After the restoration from disaster, Nakoso IGCC is keeping high availability.

No.6:Economy (1)

Evolution on economy of commercial IGCC is under way based on the results of construction, operation and maintenance of demonstration plant.

Power generation cost/kWh =

construction cost + operating cost + maintenance cost +carbon-emissions tax

①IGCC > PCF

②IGCC < PCF

③IGCC ≒ PCF

④IGCC < PCF

Economy estimation

①Construction cost is to be almost 20% higher than conventional PCF at commercial stage. Cost-reduction in facility is under study such as reducing the components, reflecting the various test results.

②Fuel cost mainly consisting operating cost could be almost 20% lower than PCF at commercial stage because of higher efficiency.

③Maintenance cost is under study while conducting maintenance work in the plant.

Target power generation cost of commercial IGCC is less than or equal to that of conventional pulverized coal firing plant.

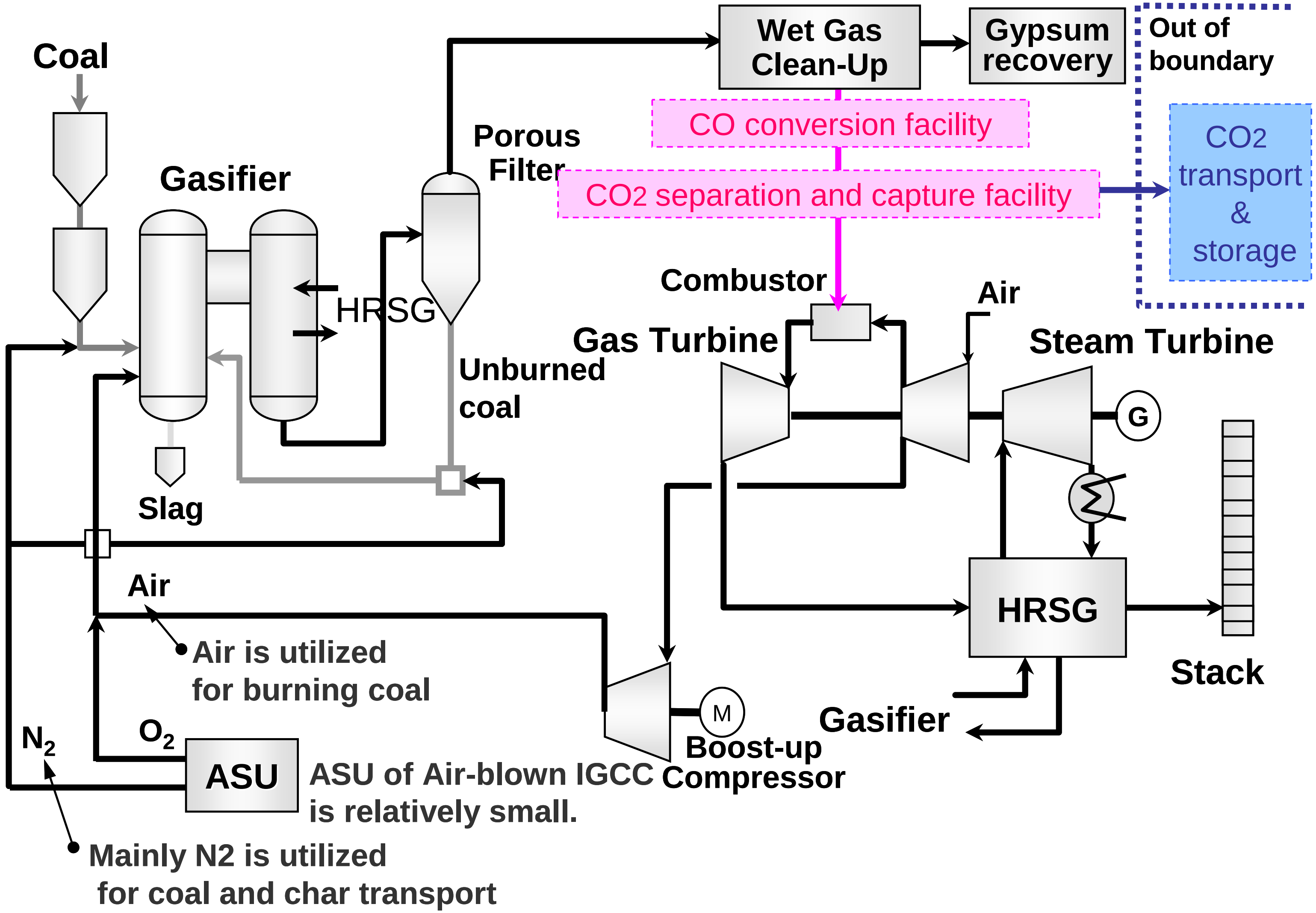
No.6:Economy (2) (Example of the required space)

Space of IGCC Demonstration plant	250MW
Space of IGCC Commercial plant	About 1140MW (570MW ×2 unit)
Space of PCF plant	1000MW (1000MW ×1 unit)

The space of IGCC at commercial stage is expected to be equal or smaller than that of conventional PCF plant.

Other information(1):Subject after the operation test

Japanese government has finished conducting feasibility study of CCS application utilizing the Nakoso IGCC plant.



Nakoso IGCC incurred severe damages mainly because of the tsunami *on March 11, 2011.*

(strong jolts did not bring about fatal damages to the facilities)

IGCC

Other information(3): Recovery Process after the disastrous earthquake

- *March 11th*, 2011 IGCC System halted its operation safely
  A lot of facilities were submerged
  No fatal damage in the main IGCC system
- *In March* Minimum personnel stationed while preparing for the worst case of the nuclear accident
- *Early April* Starting the restoration work
  (on April 11th and 12th, additional strong jolts)
- *Between mid April and end of June*
  Restoration work continued
- *July* Test and adjusting and *started the operation on 28th*
- *After August 10th*, Continuous operation for 2238 hours
- *Fiscal 2011 ,* Total operation hours = 4,679hours

Concluding Remarks

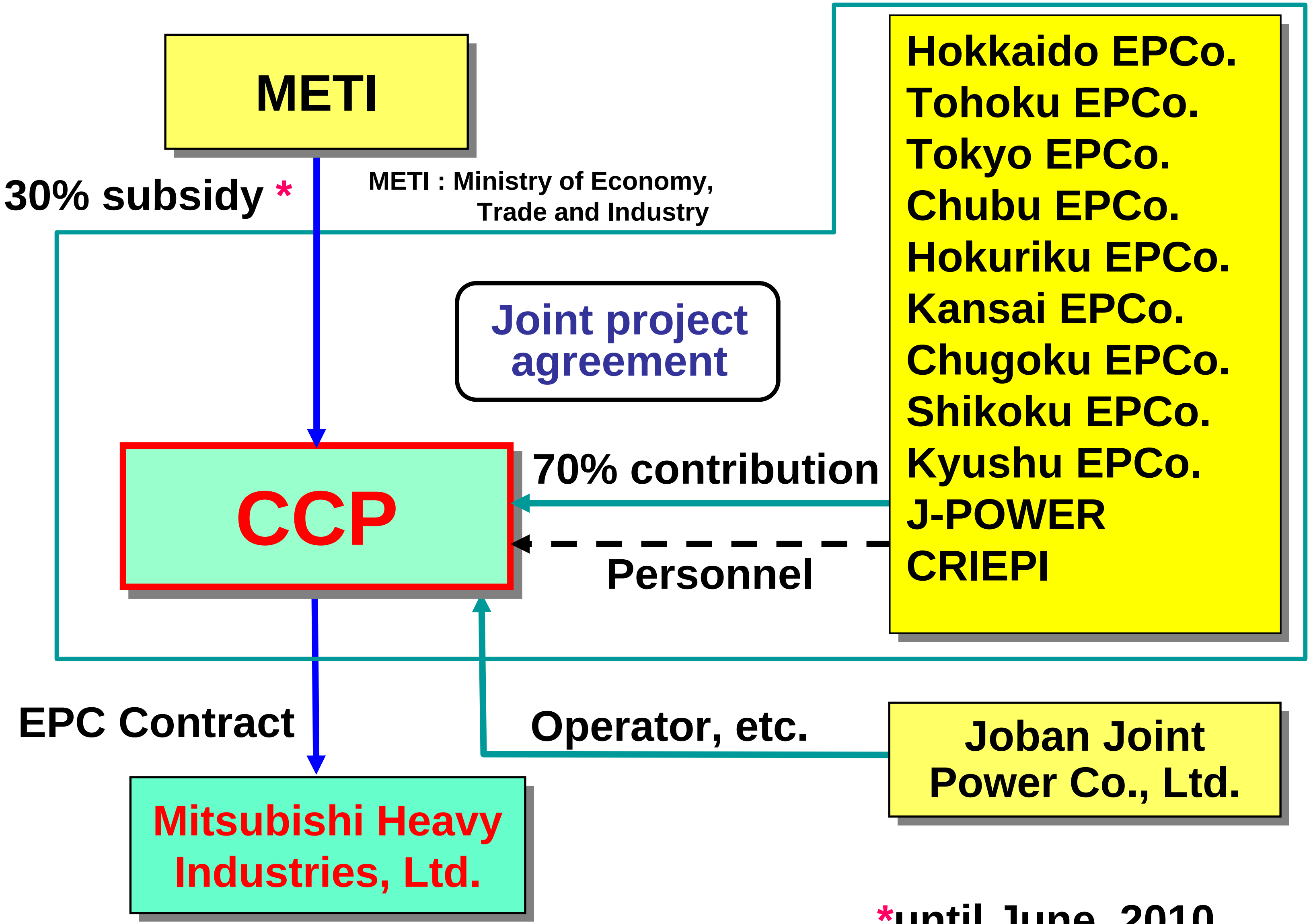
- ***Japan has continued to develop air-blown IGCC more than 28 years, and now is the final stage of the development.***
- ***Our demonstration test has been proceeded almost on schedule. Various findings for commercial IGCC plant were obtained through these operation tests.***
- ***CCP will enhance higher operability and expand the coal flexibility further.***
- ***And CCP will finalize the air-blown IGCC with high efficiency, high reliability and competitive price. And contribute to the global warming problem as well as the reduction of fuel consumption.***
- ***CCP believes that there must be much demand for this Air-blown IGCC system in Korea that is exactly suitable for mono-generation system ,not for chemical production or poly-generation***

Thank you for your attention.

More information is available in our Home Page site

Clean Coal Power R&D

Attachment (1):Relation among stake holders



*until June, 2010.

Demonstration plant

CCP R&D Co.,Ltd.
1700t/d 250MW (2007-2013)

Pilot plant

IGC Research Association
200t/d Equivalent to 25MW (1991-1996)

Process development unit

CRIEPI-MHI 2t/d(1983-1995)

Confirmation test plant

MHI Nagasaki 24t/d (1998-2002)

CRIEPI: Central Research Institute of Electric Power Industry

Attachment (3):Information on Clean Coal Power R&D Co., Ltd.

1. ***Date of Establishment :*** ***June 15, 2001***

2. ***Business Activities :***

   Test and Research of IGCC through Design, Construction and Operation of Demonstration Plant.

3. ***Shareholders :***

Hokkaido EPCo	***Kansai EPCo***
Tohoku EPCo	***Chugoku EPCo***
Tokyo EPCo	***Shikoku EPCo***
Chubu EPCo	***Kyushu EPCo***
Hokuriku EPCo	***Electric Power Development Co.***

4. ***IGCC Development Coalition :***

   Above EPCOs + Central Research Institute of Electric Power Industry (CRIEPI)