Brief Introduction on Nakoso IGCC Demonstration plant Technology and its test results

January 24th 2012

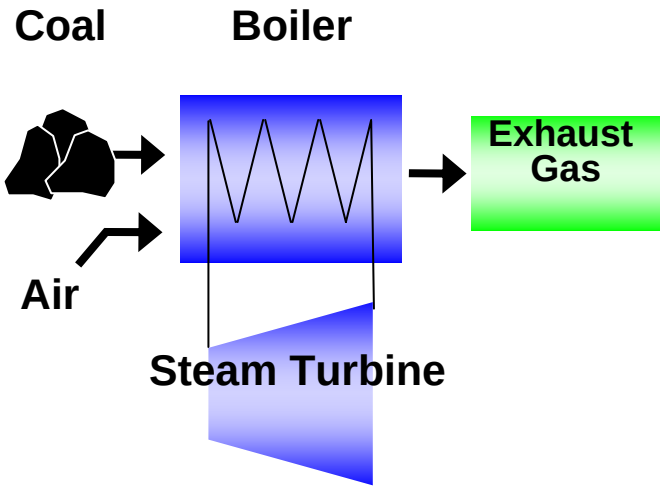
Tsutomu Watanabe

Clean Coal Power R&D., LTD

Basic Concept of IGCC

Conventional PCF

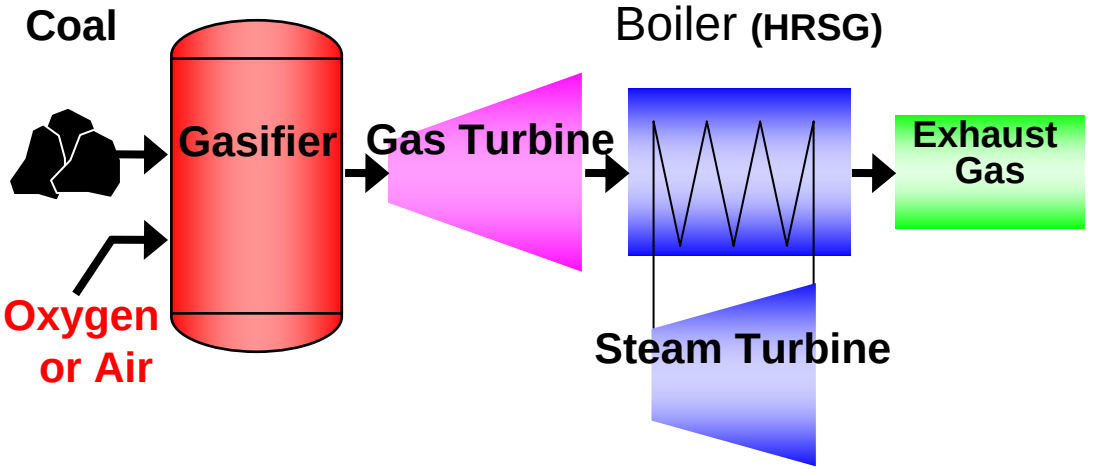
Boiler + Steam Turbine



PCF : Pulverized Coal Firing

IGCC

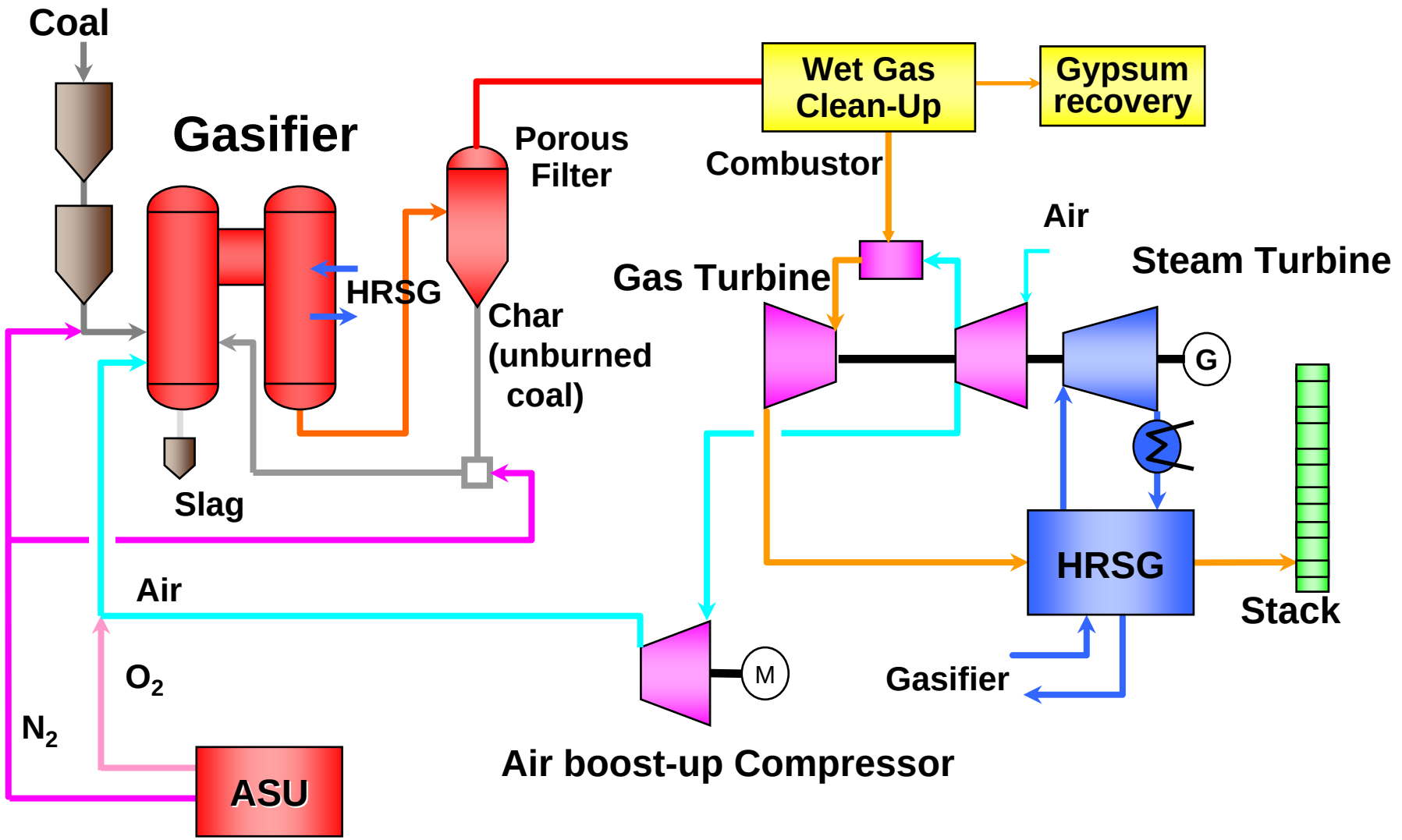
Boiler+Steam Turbine + Gasifier+Gas Turbine



IGCC : Integrated coal Gasification Combined Cycle

The thermal efficiency of IGCC is higher than that of PCF by using combined cycle power generation technology.
There are two types of IGCC, Oxygen-blown type and Air-blown type.

Schematic diagram of Demonstration Plant



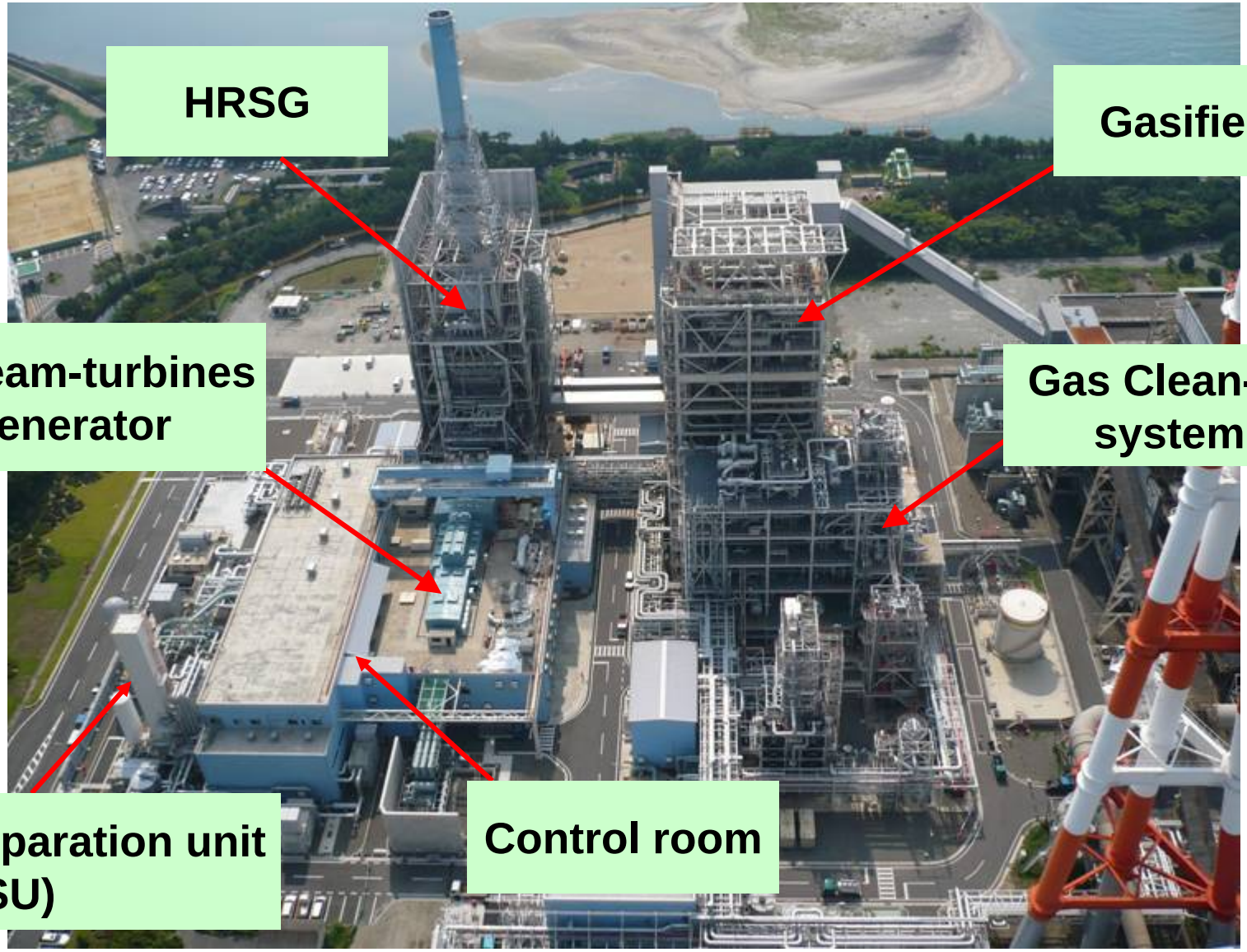
Purpose of ASU is to produce N_2 to pressurizing and transporting Coal and Char, and the ASU is very small.

Location of the demonstration plant

200km North from Tokyo city

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

Bird's-eye view of IGCC Demonstration Plant



Development history of air-blown IGCC in Japan

Shareholders of CCP are
10 major Utilities in Japan

Demonstration plant

CCP R&D Co.,Ltd.
1700t/d 250MW (2007-2010)

Pilot plant

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

Process development unit

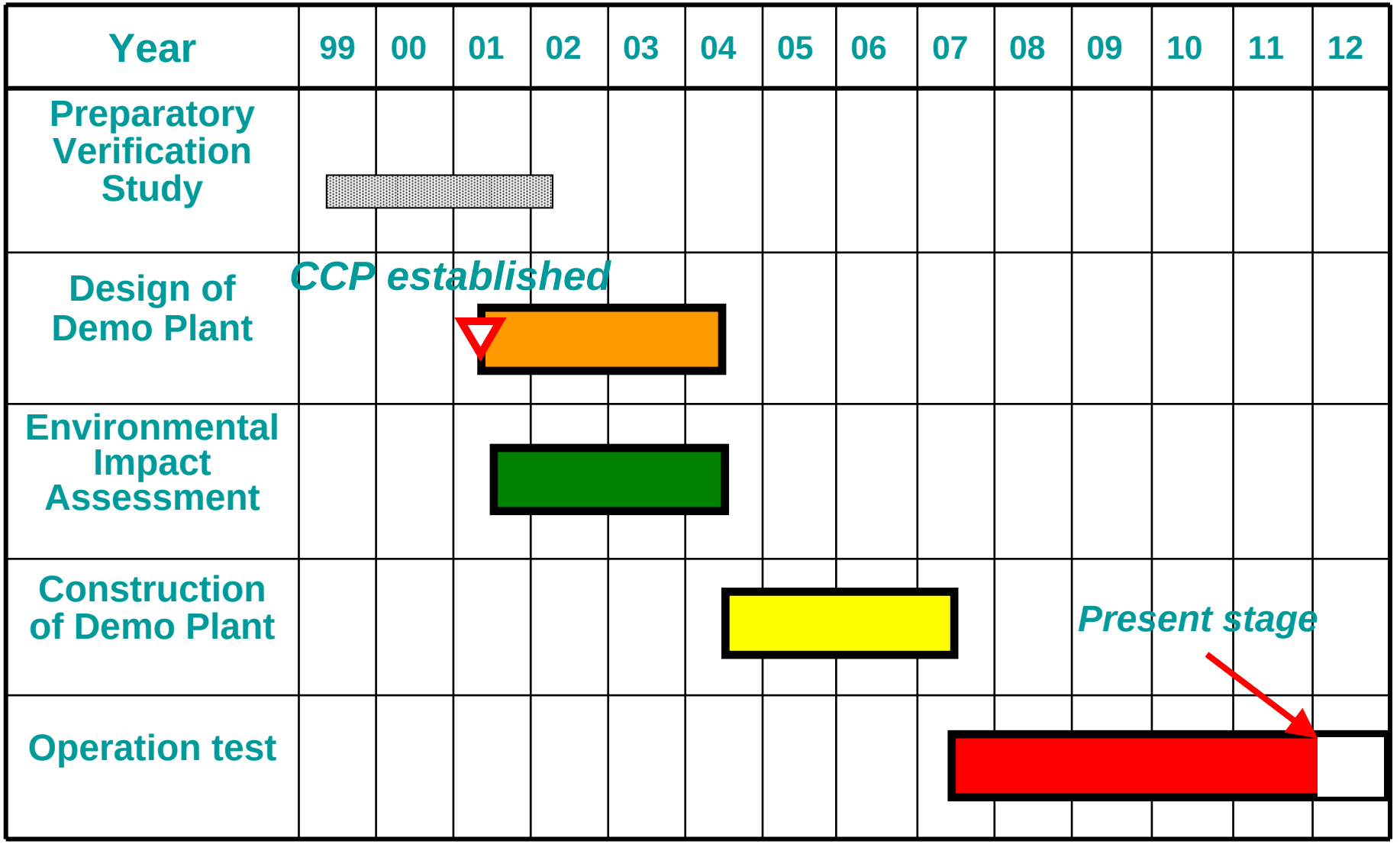
CRIEPI-MHI 2t/d(1983-1995)

Confirmation test plant

MHI Nagasaki 24t/d (1998-2002)

CRIEPI: Central Research Institute of Electric Power Industry

Demonstration Project Schedule

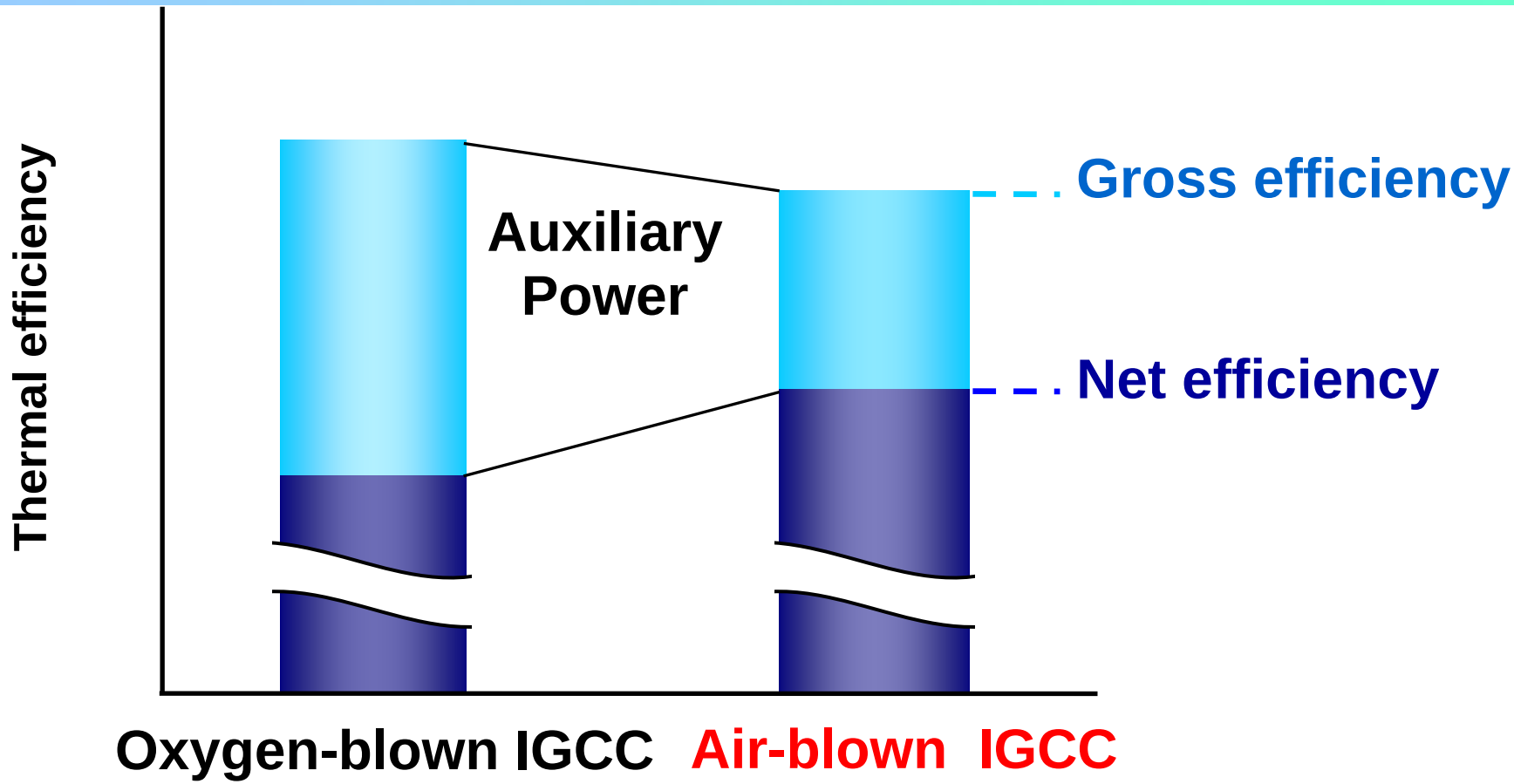


Operation test was started in September, 2007.

Coal IGCC Projects in the world

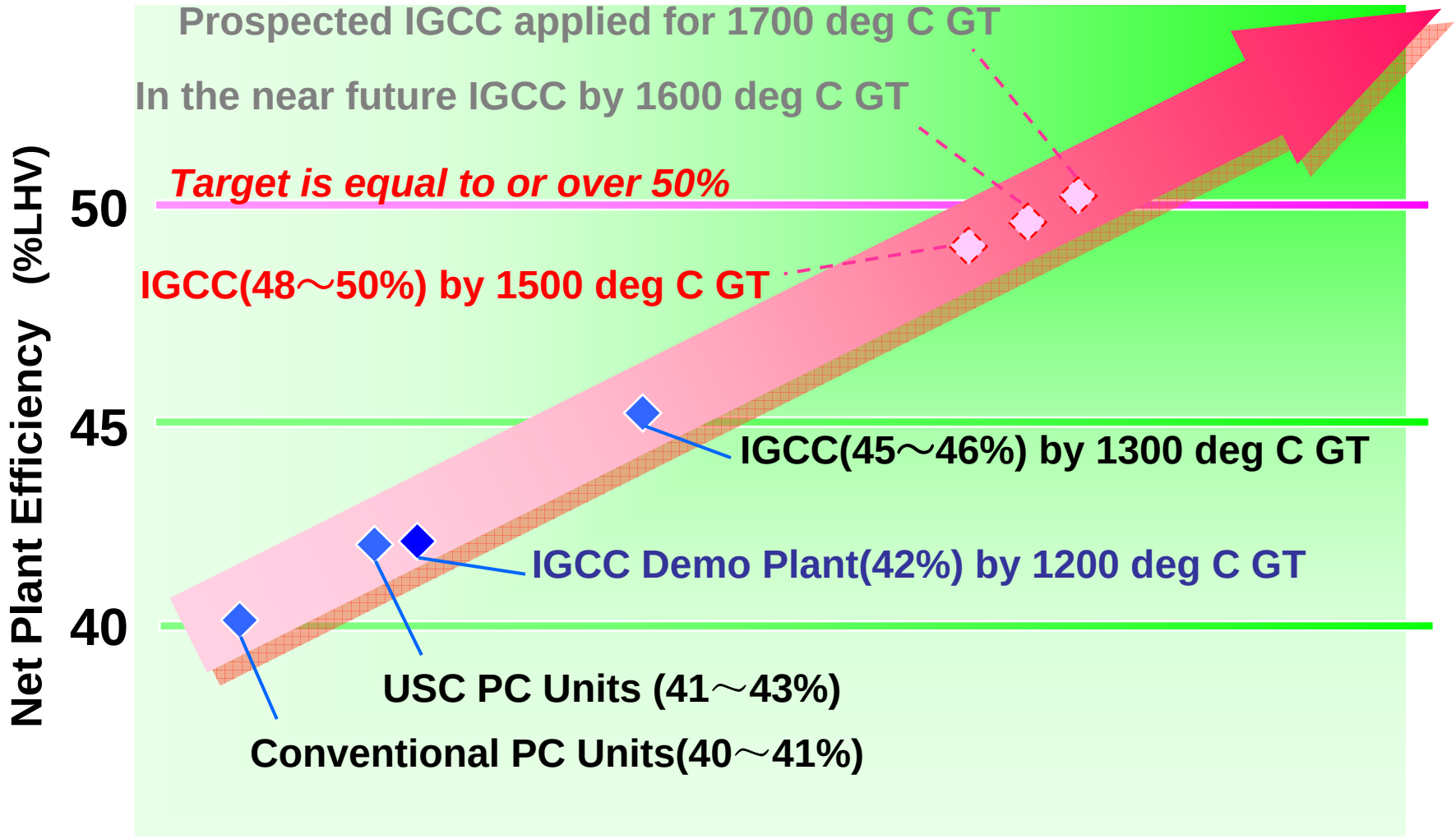
Projects Site	Buggenum Netherland	Puertollano Spain	Wabash River USA	Tampa USA	Nakoso Japan
Gasifier type	O_2-blown Dry-feed Shell	O_2-blown Dry-feed Penflo	O_2-blown Slurry-feed E-Gas™	O_2-blown Slurry-feed GE	Air-blown Dry-feed MHI
Coal consumption	2,000 t/d	2,600 t/d	2,500 t/d	2,500 t/d	1,700 t/d
Gross output	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 Air-blown IGCC in Efficiency



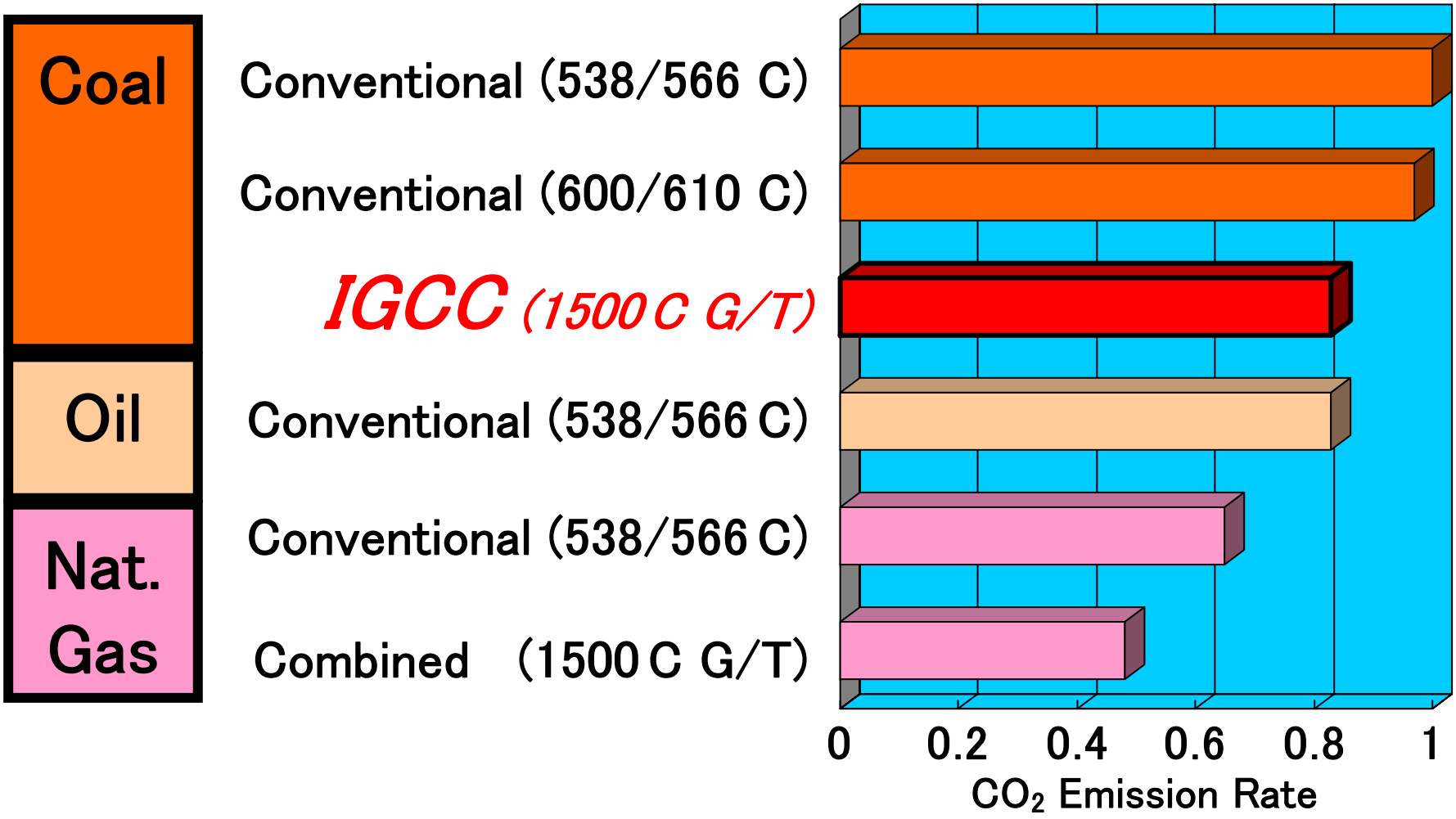
Air-blown IGCC applied in Nakoso is expected to realize high thermal efficiency compared with oxygen-blown IGCC.

Thermal efficiency Improvement



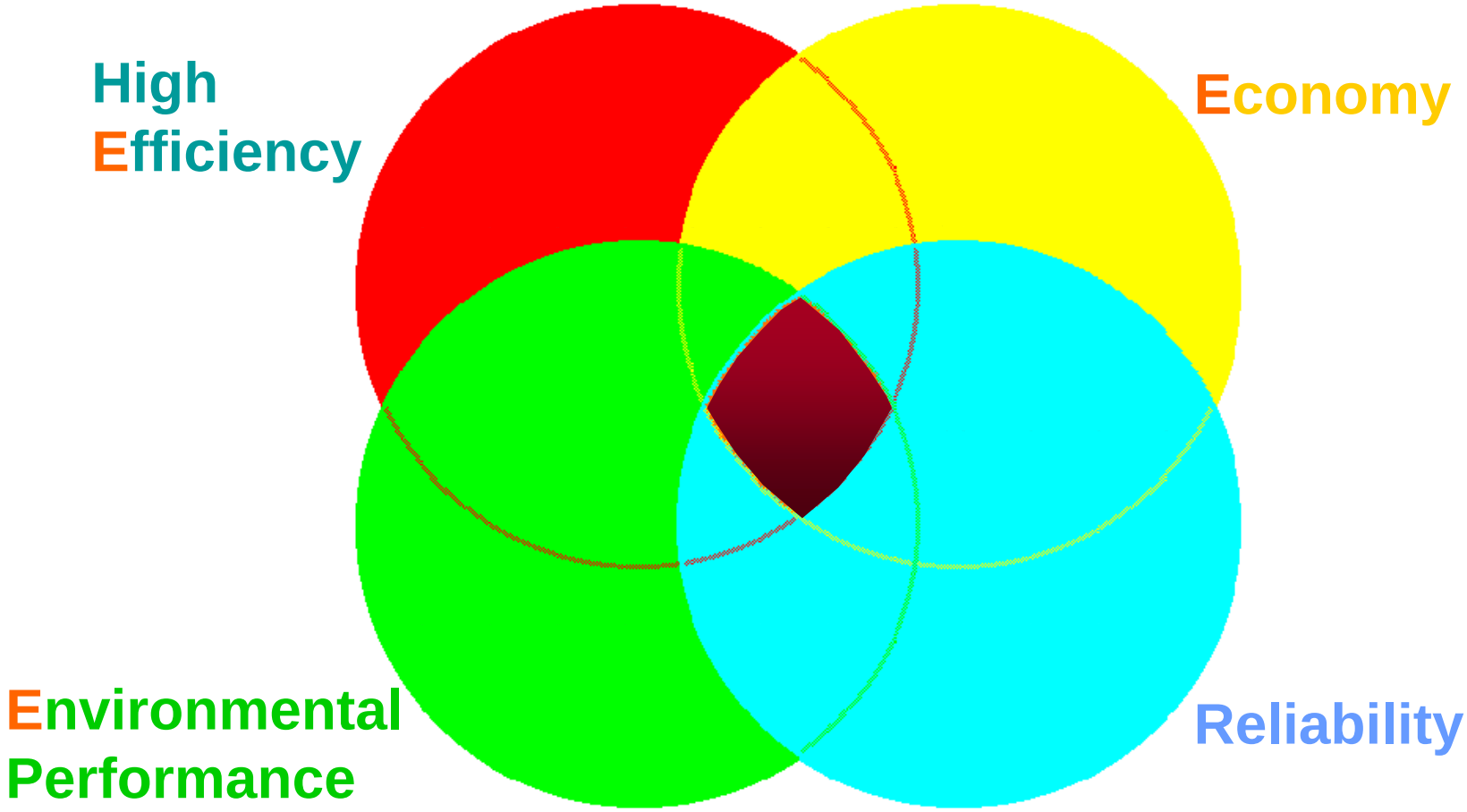
Thermal efficiency improves with the advancement of high temperature gas turbine combined cycle technology.

CO2 Emission by Fuel and Cycle



Target of IGCC development

Well coordinated combination of 3E +reliability



IGCC Operating Hours

(As of January 15, 2012)

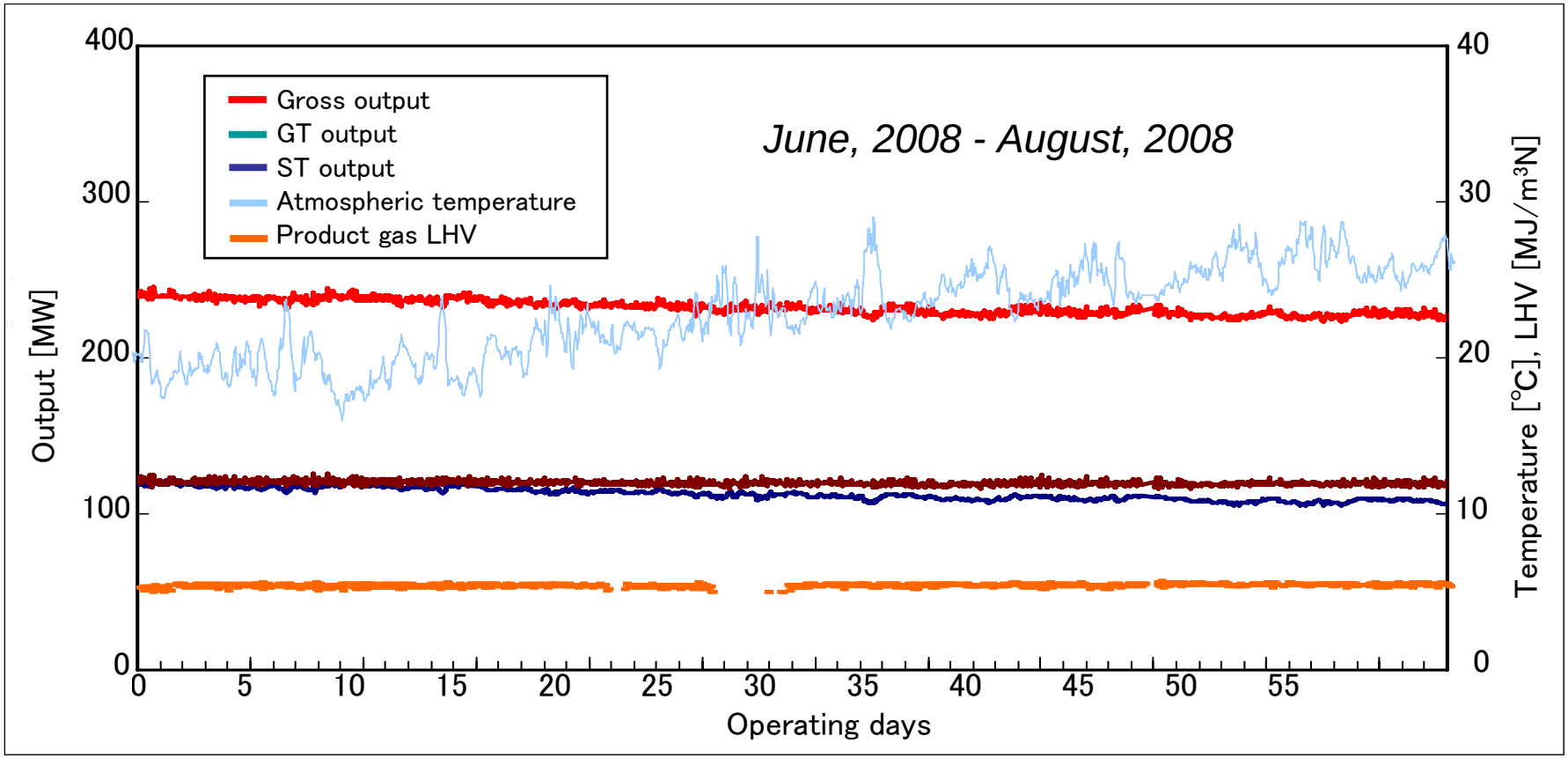
Operating Time	**GT Operation by Syngas**	**14,000 hrs**
	Gasifier Operation	**14,122 hrs**
Power Generation	**Cumulative gross output**	**2,789GWh**

Summary of Targets & Achievements

	Targets	Results	Status of Achievement	Future plan
Safe and Stable Operation	250MW	250MW	Achieved	—
Long Term Continuous Operation	>2000hr	2238hr	Achieved	—
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) Russia (B) USA (SB) Indonesian (SB) Columbia (B)	Achieved	Increase in coal Types
Start-up Time	<18hr	15hr	Achieved	—
Minimum Load	50%	36%	Achieved	Decrease in minimum load
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.

Test results: Reliability

Output of 2000 hours reliability test in 2008 summer

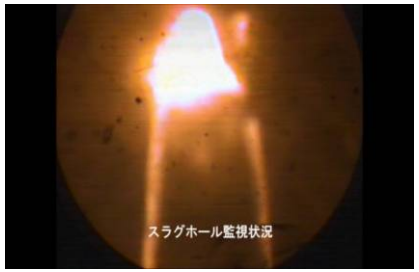


- **Capability of stable power generation at rated power was confirmed.**
- **2000hours continuous operation was achieved in the first year.**

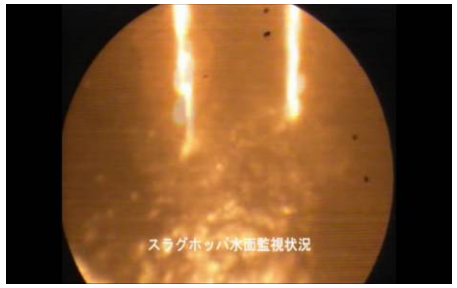
Test Results: System Safety and Stability

Slag hole blockage has never been experienced.
The molten slag is constantly flowing, keeping the gasifier in very stable condition.

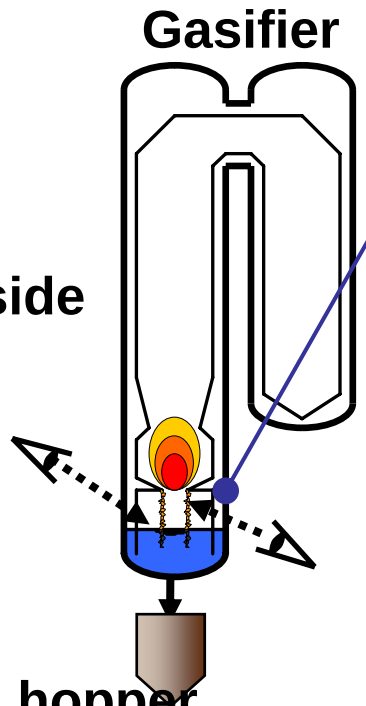
<Stable streams of molten slag >



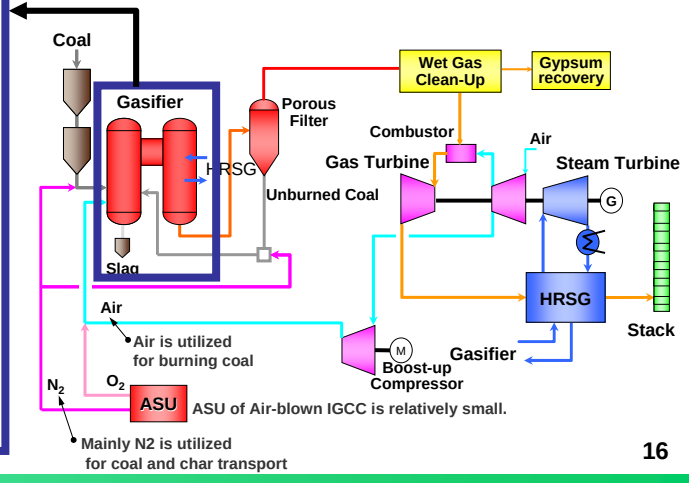
Slag hole view from lower side



Surface of the water in slag hopper



Slag condition monitor
>Image analysis device
>Sound monitoring system



Test Results: Plant performance

		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
Net Efficiency (LHV)		42 %	42.4 %(42.9%)
Syngas LHV		4.8 MJ/m^{3}N	5.2 MJ/m^{3}N
Composition	CO	28.0 %	30.5 %
	CO2	3.8 %	2.8 %
	H2	10.4 %	10.5 %
	CH4	0.3 %	0.7 %
	N2etc.	57.5 %	55.5%
Environmental Performance		<Target >	
(16% O2 Corrected)	SOx	8 ppm	1.0ppm
	NOx	5 ppm	3.4 ppm
	Particulate	4 mg/m^{3}N	<0.1 mg/m^{3}N

Full load (250MW) operation was achieved in March 2008. Stable and continuous full load operation as well as design plant performance was confirmed.

Test results: Fuel Flexibility

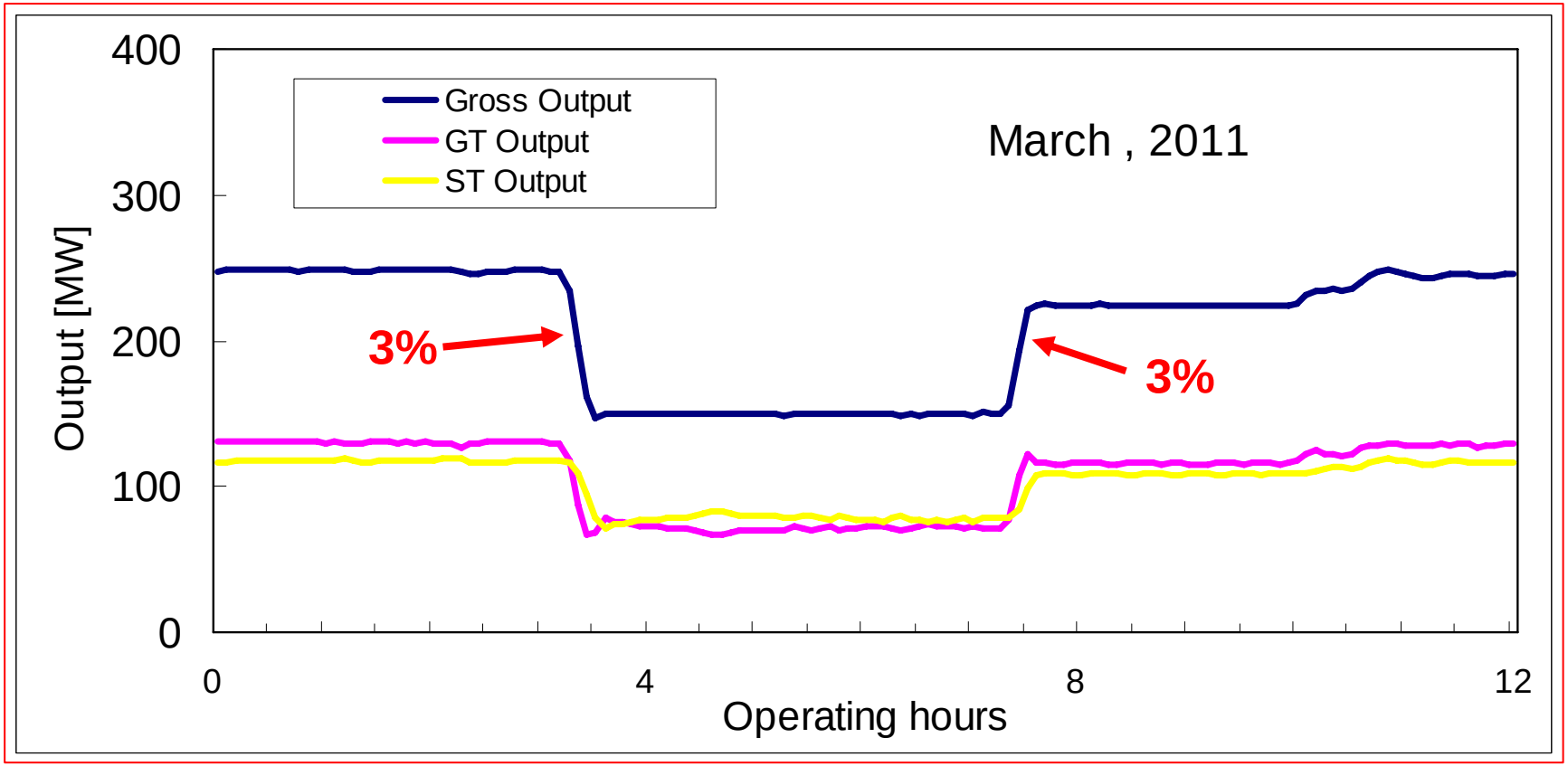
Properties of coal used in 2009, 2010

		#1 (design coal) Chinese Shenhua Jan, 2009	#2 North American PRB Feb, 2010	Indonesian Coal	
				#3 (A) Mar, 2009	#4 (B) Sep, 2010
Gross Calorific e (air dry)	kJ/kg	27,120	26,670	26,370	23,010
Total Moisture (as received)	wt%	15.4	25.3	21.7	29.7
Total Sulphur (air dry)	wt%	0.25	0.39	0.25	0.12
Proximate Analysis (air dry)					
Inherent Moisture	wt%	7.5	8.0	7.9	17.1
Fixed Carbon	wt%	51.3	47.4	45.2	37.8
Volatile Matter	wt%	32.3	39.1	42.5	41.6
Ash	wt%	8.9	5.5	4.4	3.5
Fusibility of Coal Ash					
Flow Temperature	deg C	1225	1420	1260	1230

Bituminous coal and sub-bituminous coal have been used at the Demo Plant. Test for Columbian and Russian coal was finished recently.

Test results: operational capability

Load Change Rate



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

Study results (still under way): Economy

Evaluation 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 initial 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.

We conduced maintenance outage by law this year, we are analyzing the cost for the estimation at commercial stage .

Study results: Required space

Space of IGCC Demonstration plant

250MW

Space of IGCC Commercial plant

About 1140MW
(570MW ×2 unit)

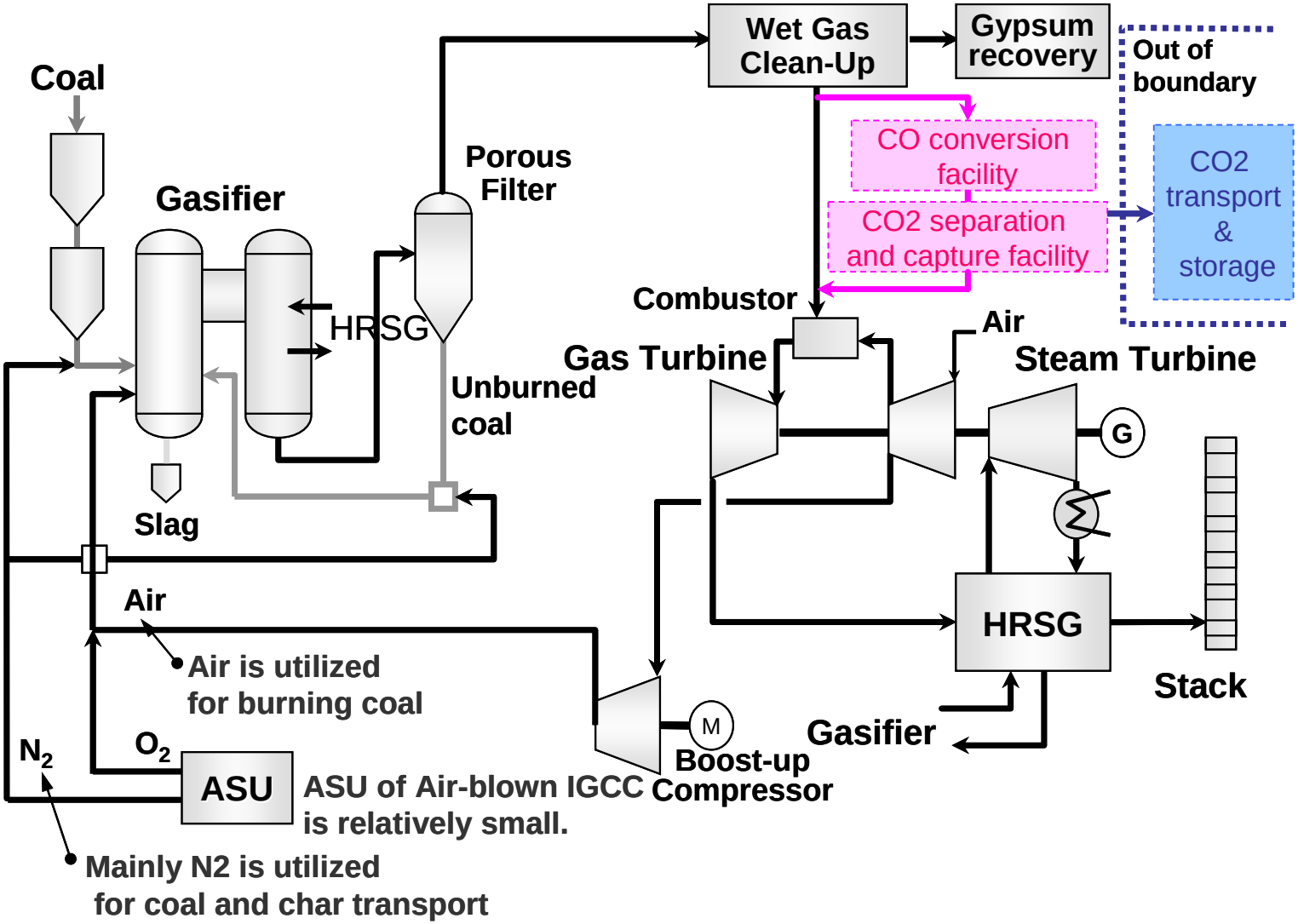
Space of PCF plant
(with FDG)

1000MW
(1000MW ×1 unit)

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

New Subject under consideration

Japanese government is now conducting feasibility study of CCS application utilizing the Nakoso IGCC plant, which would reduce the CO2 emission.



Regarding the Earthquake on March 11th

Nakoso IGCC incurred severe damages mainly because of the tsunami

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

Recovery Process after the disastrous earthquake

- *March 11th* 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 middle April and end of June*
  Restoration work continued
- *July* Test and adjusting and *started the operation 28th*
- *After August 10th*, Continuous operation for 2238hours
- *After December 1st Continuous operation until now*

Some Remarks

- New technology development is one of the key issues for energy sector to meet the needs of the society
- In generation field, IGCC is a good candidate for fulfilling the requirements of coal generation such as on environment, economy, energy security in coming years
- Air-blown IGCC developed in Japan is showing its capability and potential for future
- It would be rewarding to share the experiences in the related area between India and Japan

More information is available in our Home Page site

Clean Coal Power R&D