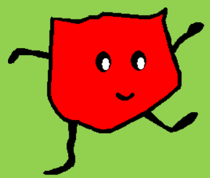


# CCT in JAPAN and CCT COLLABORATION with POLAND

**JUNE 2nd, 2014**


## Toru Namiki

- Japan Coal Energy Center (JCOAL)


# Contents

# I-1. JCOAL's Area of Activities (1)

JCOAL Japan Coal Energy Center

**Government of Japan**
Coal Division, Natural Resources and Fuel Department,
Agency for Natural Resources and Energy,
**Ministry of Economy, Trade and Industry (METI)**

- JOGMEC Japan Oil, Gas, and Metals National Corporation
- NEDO New Energy and Industrial Technology Development Organization
- JICA Japan International Cooperation Agency

- Coal Producing Countries
- Coal Using Countries

- International Agencies
(World Coal Association(WCA), IEA, etc.)

## JCOAL as "One-stop Shop for Coal"

**Information Collection & Sharing and Advisory Activities**
- Follow-up of Clean Coal Policy and Policy Recommendations
- Enhancement and exploration of JCOAL's Interorganizational Network
- Enhancement of Organizational Framework of Updated Information Collection and Sharing for Further Development

**Programs for Coal Resources Development**
- Coal Resources Survey

**Promotion of Clean Coal Technology Development**
- Coal Utilization Technology Development
- Coal Ash Utilization Technology Development
- Other R&D

**Programs for Technology Transfer to Overseas**
- Human Resources Development
- Clean Coal Technology Sharing and Transfer
- Support for Commercial Utilization Projects Overseas

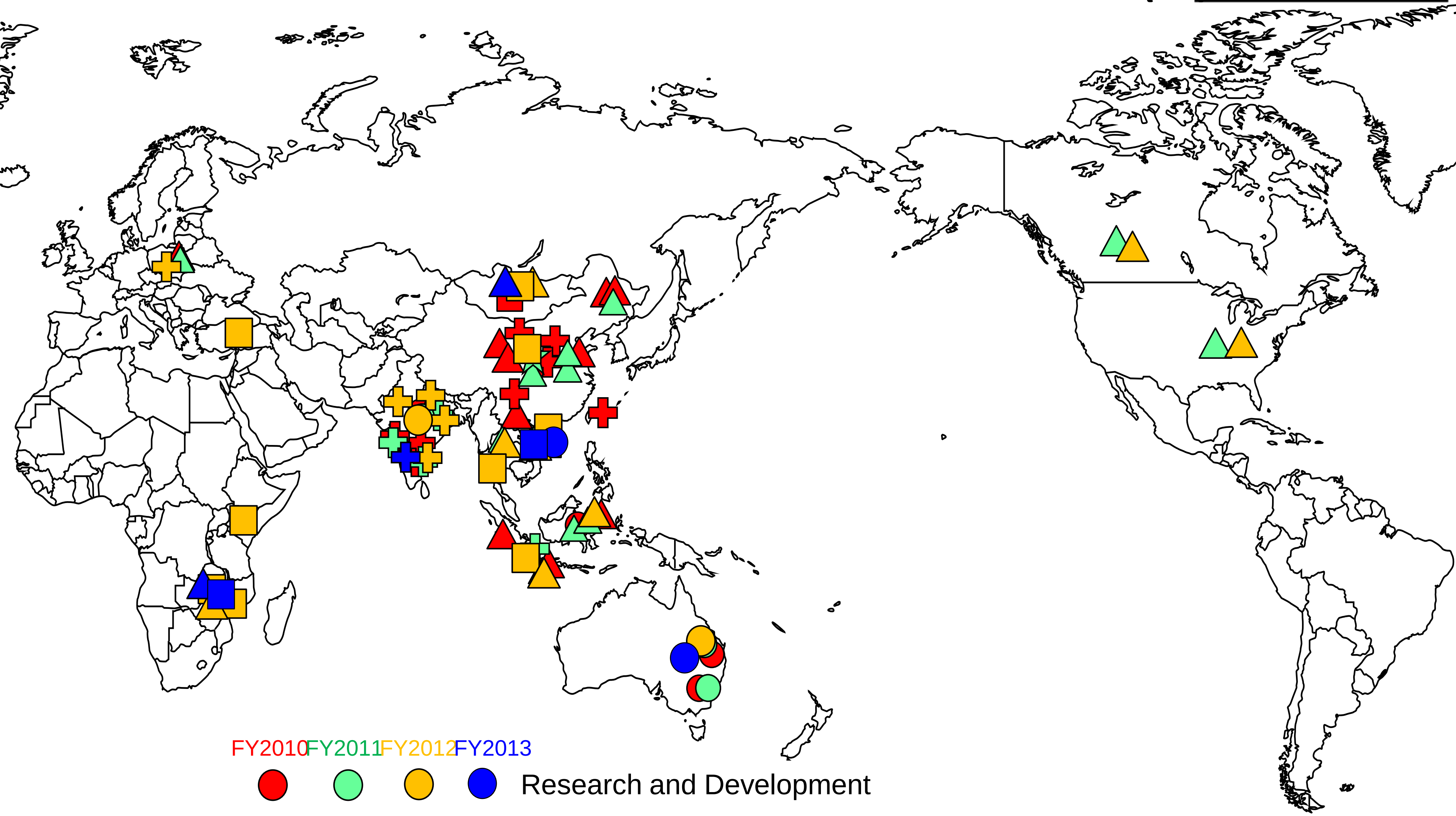
**Strategic Promotion of Prioritized Projects**
- Eco Coal Town Project
- Low Rank Coal Utilization Project
- IGCC, CCS and other CCS-related Projects

**Programs for Public Relations and Human Resources Development**
- Coal-related Public Relations Activities
- Projects for Domestic Human Resources Development

**115 Member Companies**

# Ⅰ-2. JCOAL's Area of Activities (2)

JCOAL Japan Coal Energy Center



FY2010 FY2011 FY2012 FY2013

Research and Development

Technical Exchange

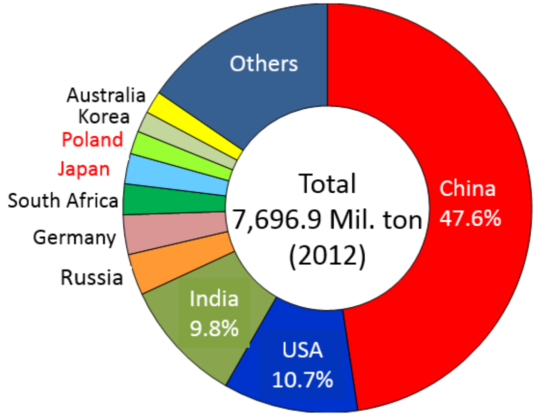
Geological Survey

Diagnosis

# Ⅱ- 1. Coal Consumption & Power Source in Japan

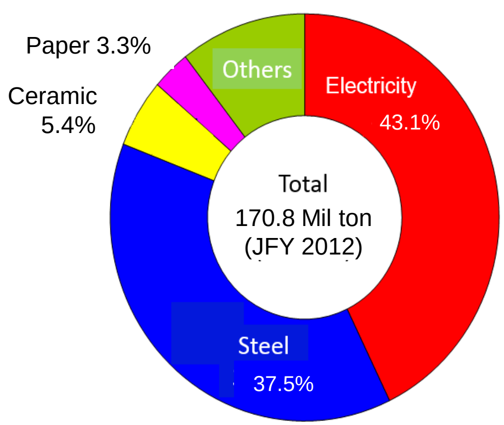
## World Coal Consumption

- Poland : 139.7 Mil.ton (1.8%)
- Japan : 183.8 Mil.ton (2.4%)



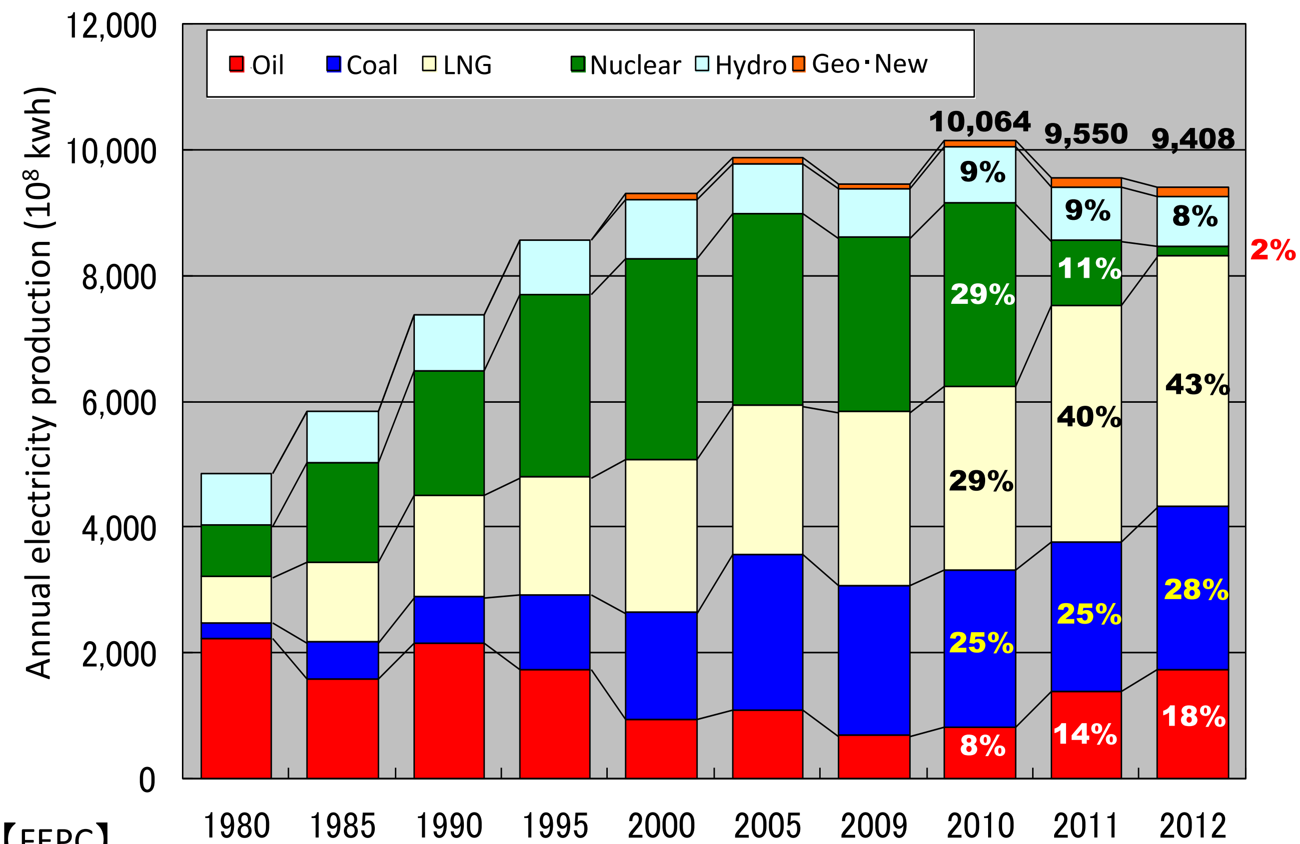

【IEA Coal Information 2013】

## Coal Consumption by Industry in Japan




【EDMC 2014】

## Electricity Production by power source in Japan




【FEPC】

# Ⅱ-2. JCOAL CCT Road Map

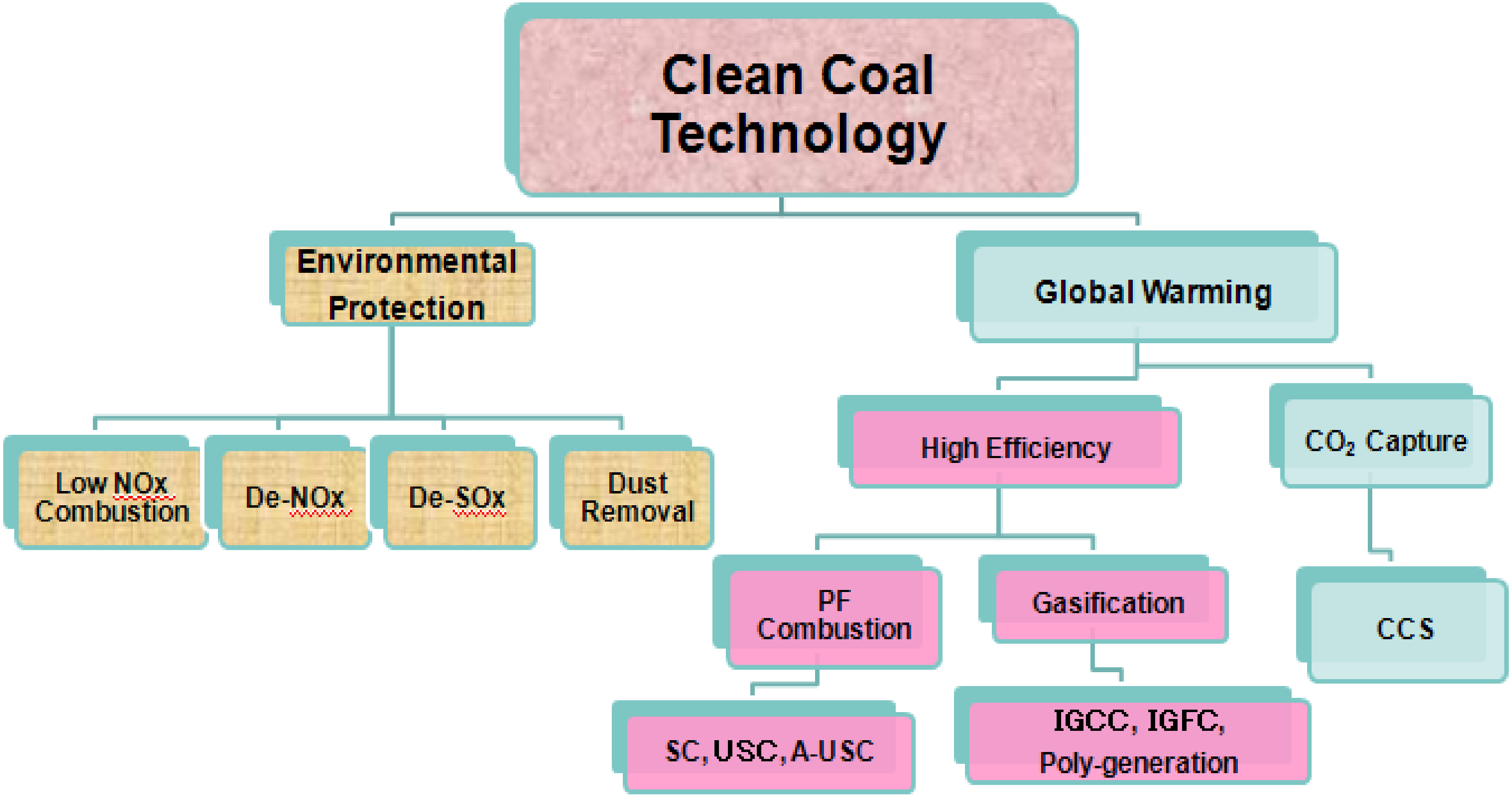
JCOAL Japan Coal Energy Center

| Technologies | | | 2020, 2030, 2040, 2050 | | | |
|---|---|---|---|---|---|---|
| High efficiency and low carbon | Power generation | ① A-USC | Commercial (700℃) | Commercial (800℃) | | |
| | | ② IGFC[1)] | IGCC demo. (Osaki) | Demonstration (Osaki) | Commercial | |
| | | ③ A-IGCC[2)] | Commercial (GT1700℃, 700℃ post A-USC | | | |
| | | ④ ABC[3)] | Commercial (<10%) | Commercial (>10%) | | |
| | Steel Industry | ⑤ Ferro Coke[4)] | Demonstration | Commercial | | |
| | | ⑥ COURSE50[5)] | min. blast furnace test | Blast furnace demo. | Commercial | |
| | CO2 capture | ⑦ $CO_2$ recycle IGCC | $O_2$-$CO_2$ Gasifier test | $CO_2$ Cycle Closed test | 300MWdemo. | Commercial |
| | | ⑧ Chemical Looping | Study of Reactor | 30MWPP test | 100MW demo. | Commercial |
| | | ⑨ Oxy-fuel combustion | Demonstration test | Commercial | | |
| | | ⑩ Post-Combustion | Demonstration | Commercial | | |
| | | ⑪ $CO_2$ Conversion | $CO_2$ Conversion test | Small scale test | Large scale demonstration | |
| Low rank coal utilization | Upgrading | ⑫Brown coal carbonization | PP test | Commercial | | |
| | | ⑬High efficiency fluidized bed drying | Bench P test | PP test | Commercial | |
| | Industrial utilization | ⑭ Hyper Coal[6)] | Demonstration | Commercial | | |
| | | ⑮ IGCC with renewable energy | Demonstration | Commercial | | |
| | | ⑯ TIGAR[7)] | Demonstration | Commercial | | |
| | | ⑰ ECOPRO[8)] | Demonstration | Commercial | | |
| Environmental protection | Low environmental burden | ⑱Low environmental burden (B, Se) | Standardization of analytical methods (JIS/ISO) | R&D of reducing tech. | | |

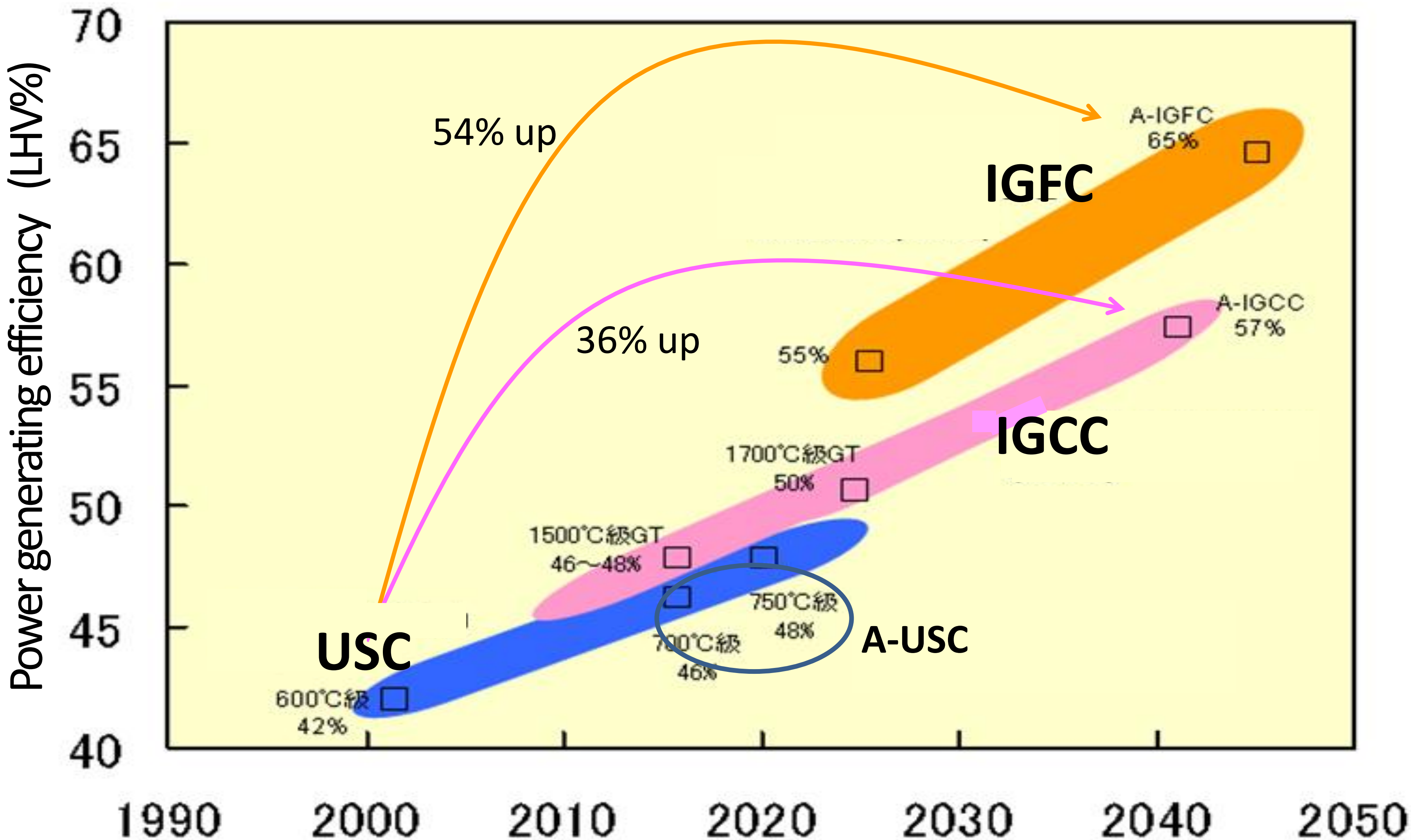
<Abbreviations>

1)IGFC: Integrated Gasification Fuel Cell Combined Cycle
2)A-IGCC: Advanced IGCC
3)ABC: Advanced Biomass and Coal Utilization Technologies
4)Ferro Coke: Coke made from low rank coal and iron ores
5)COURSE50: CO2 Ultimate Reduction on Steelmaking Process by Innovative Technology for Cool Earth 50
6)Hyper Coal: Non-ash Coal Made by Using Solvent Extraction
7)TIGAR: Twin CFB Gasifier Technology
8)ECOPRO: Coal Flash Partial Hydropyrolysis Technology

# Ⅱ-3. Clean Coal Technologies for Power Generation

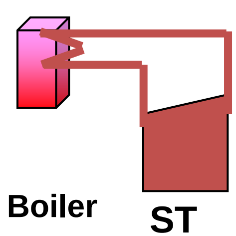
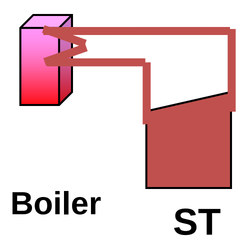


# Ⅱ-4. R&D on High Efficient Coal Power Generation in Japan



# Ⅱ-5. *Towards Higher Thermal Efficiency Development of Coal-fired Power Generation*

- **Pulverized Coal-Fired System (PCF)**： Efficiency upgrade by increasing steam temperature and pressure; A-USC（Advanced USC, 700℃ class）is under development
- **Integrated Coal Gasification Combined Cycle System (IGCC)**： Combined Gas turbine (GT) and steam turbine (ST) cycle; Higher thermal efficiency than PCF; Increasing the GT inlet gas temperature is necessary for efficiency upgrade
- **Integrated Coal Gasification Fuel Cell Combined Cycle System（IGFC）**： Triple combined cycle (GT+ST+FC); Higher thermal efficiency than IGCC

<table>
<tr><th colspan="2">① PCF</th><th>② IGCC（1500℃ class）</th><th>③ IGFC</th></tr>
<tr>
<td>Latest PCF<br>（USC)<br>
</td>
<td>700℃ class<br>(A-USC)<br>
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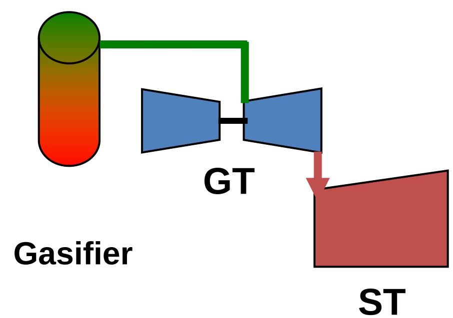
<td>
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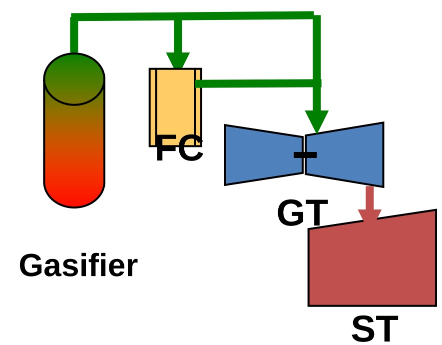
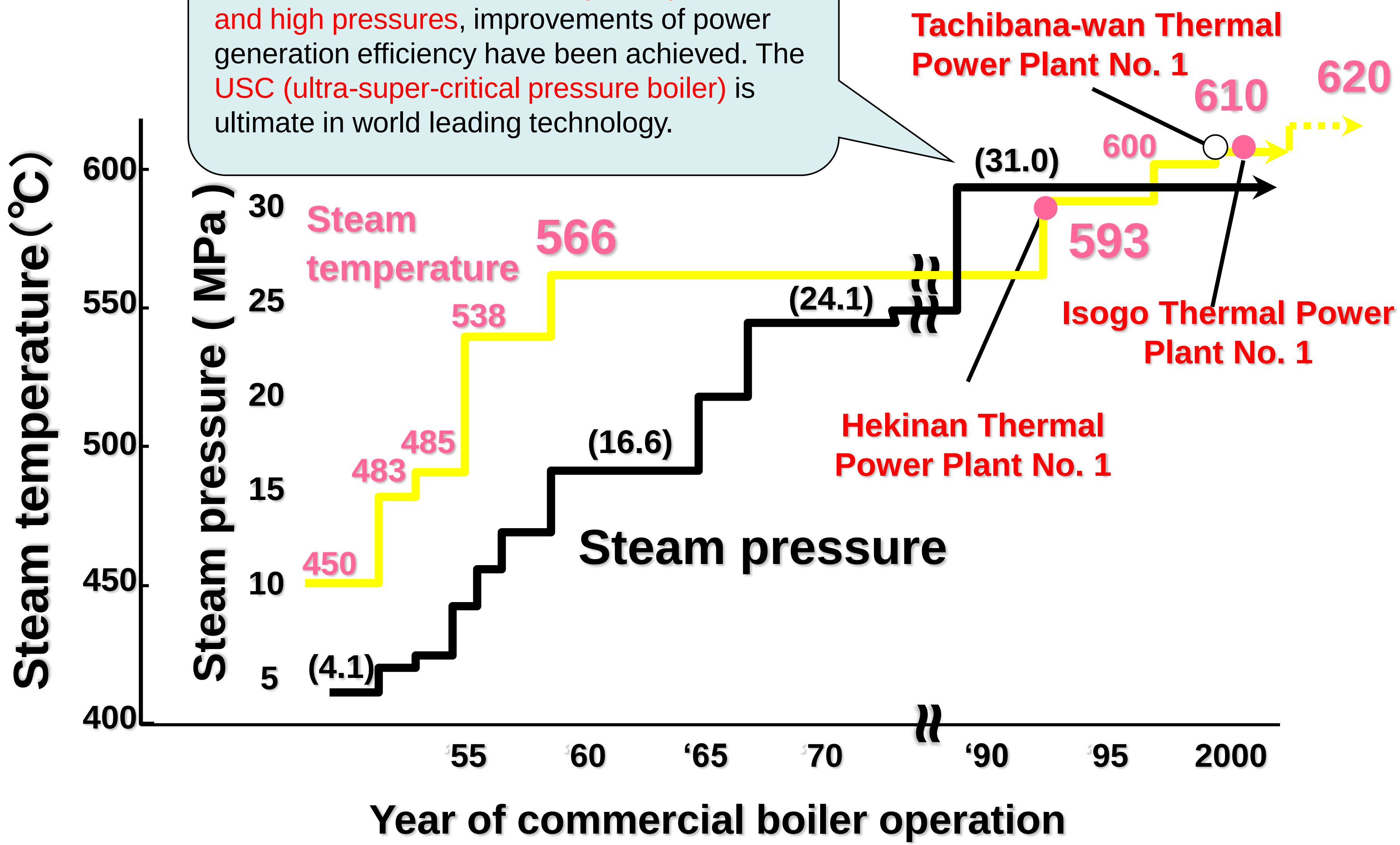
<td>
</td>
</tr>
<tr>
<td>Gross：42～43%<br>(HHV)<br>Net ：41%(HHV)<br>（Basis）</td>
<td>Gross：48%<br>Net ：46%<br>$CO_2$ reduction：<br>approx. 11%</td>
<td>Gross：51～53%<br>Net ：46～48%<br>$CO_2$ reduction:<br>approx. 13%</td>
<td>Gross：60%～<br>Net ：55%～<br>$CO_2$ reduction:<br>approx. 25%～</td>
</tr>
</table>

# Ⅱ-6. Changes in Japan's pulverized coal-fired thermal power generation technology

Due to the use of steam at high temperatures and high pressures, improvements of power generation efficiency have been achieved. The USC (ultra-super-critical pressure boiler) is ultimate in world leading technology.



# Ⅱ-7. Specifications of Nakoso IGCC Commercial Plant

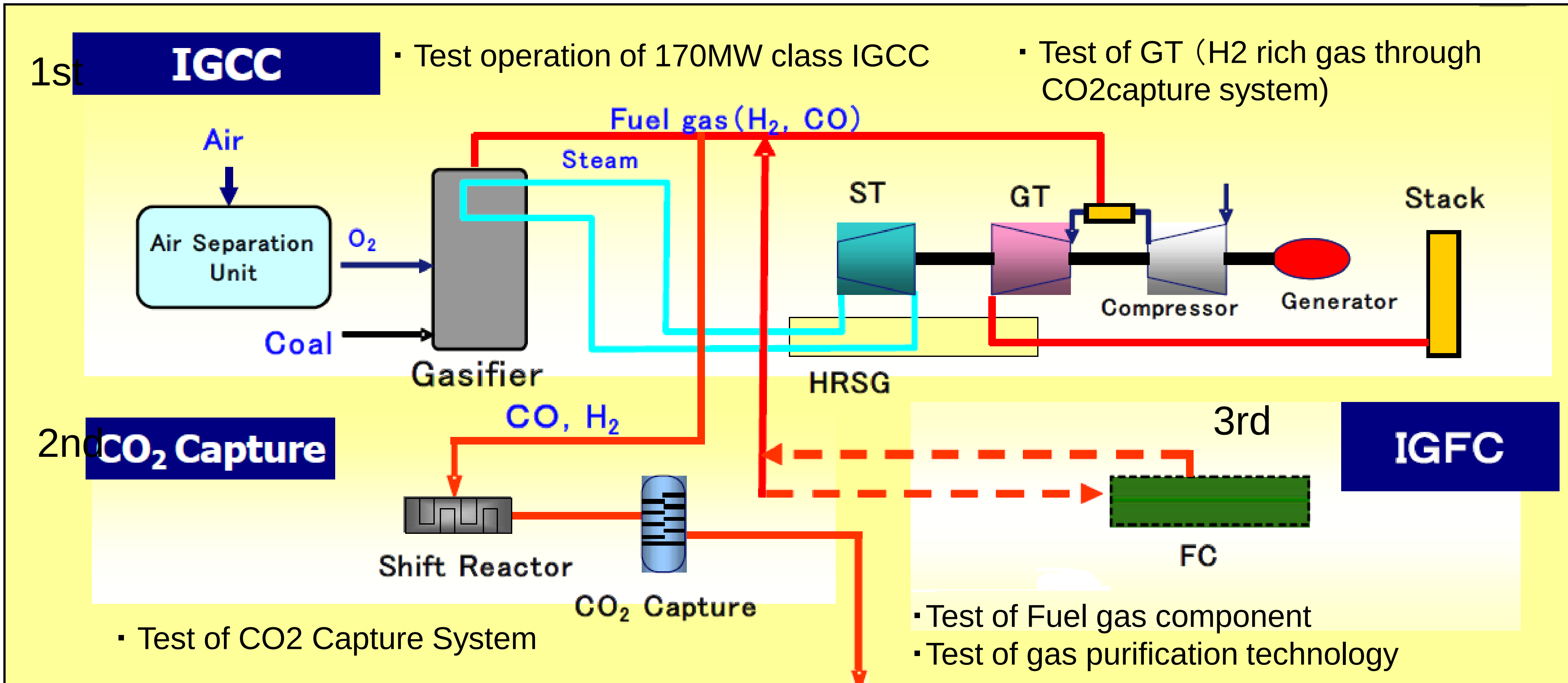
| | | | |
|---|---|---|---|
| Capacity | 250 MW gross | | |
| Coal Consumption | approx. 1,700 metric t/day | | |
| System | Gasifier | Air-blown & Dry Feed | |
| | Gas Treatment | Wet (MDEA) + Gypsum Recovery | |
| | Gas Turbine | 1200 °C class (50Hz) | |
| Efficiency (Target Values) | Gross | 48% (LHV) | 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/$m^3$N | |
| EPC | Mitsubishi Heavy Industries (MHI) | | |

* While target net thermal efficiency is 48～50% in commercial IGCC plant applying 1500 °C class gas turbine, 1200 °C class gas turbine was adopted to reduce the capacity of plant for economy as a test plant.

Source:“Progress in NAKOSO 250 MW Air-Blown IGCC Demonstration Project”, ICOPE-2013,October 24, 2013

# Ⅱ-8. Process Flow of Osaki CoolGen Demonstration Plant

IGCC Target efficiency : 40.5%（NET,HHV base）
SOx : 8pm, NOx : 5ppm, PM : 3mg/m3N (O2:16%)




CO2 Storage

# Ⅱ-9. Development step for Oxygen-blown IGCC

**EAGLE Project (J-POWER) <Pilot plant>**

Test Item : Pilot test of Oxygen blown Gasification and Carbon Capture Technology

IGCC Coal Feed Rate : 150 tons/day

$CO_2$ Capture

- Processed Gas Volume : 1,000 m3N/h
- $CO_2$ capture method : Chemical absorption test & Physical absorption test

↓

**Osaki CoolGen Project <Demonstration plant : 2017~2018 >**

Test Item : Large scale IGCC test of Oxygen blown Gasification and Carbon Capture Technology

IGCC Coal Feed Rate : 1,100 tons/day , Output :170MW class

$CO_2$ Capture : under planning

↓

**Oxygen blown IGCC commercial plant <Commercial plant>**

300 - 600MW class

# Ⅱ-10. History of Environmental Protection at Coal-fired Power Station

JCOAL Japan Coal Energy Center

1960 | 1970 | 1980 | 1990 | 2000

**Background**

**High Economic Growth**

**Oil Crisis**

***Transfer from Coal to Oil***

Transfer from Oil to Coal

**Serious environmental impact in industrial area (Kawasaki, Yokkaichi) (particulate, Sox)**

Photochemical smog in urban area (NOx)

PM10 and NOx in urban area (Vehicles)

PM2.5 (Vehicles)

**Environmental Policy**

**1963 Law for Regulation on Emission of Particulates**

**Agreement on Environmental Protection between local authority and company**
- **Plan for air pollution control (additional regulatory standard)**
- **Observation at emission resource by telemeter**

**Ex) agreement for Isogo No.2, JPOWER**
**SOx<=60ppm, NOx<=159ppm, particulate <=50mg/m3N(spontaneous value) (1964)**

**SOx<=10ppm, NOx<=13ppm, particulate≦5mg/m3N (spontaneous value) (2010)**

**1968 Air Pollution Control Law**

- **Principle of responsibility by polluter (ex. imposition due to SOx emission)**
- **Finance with low interest for environmental protection investment**

**Regulation of NOx emission by five stages, starting from 450ppm (1973) to 200ppm (1983)**

**1993 The Basic Environment Law**

**1997 Environmental Impact Assessment Law**

**1993 Standard for PM10**
**day average<=0.10mg/m³**
**hour average<=0.20mg/m³**

**2009 Standard for PM2.5**
**Day average<=15μg/m³**
**hour average<=3 5μg/m³**

# Ⅱ-11. History of Environmental Protection at Coal-fired Power Station

JCOAL Japan Coal Energy Center

1960 1970 1980 1990 2000 2010

## Environmental protection Technology

- **Use of low-sulfur coal**
- **Tall and/or collective stack**

**De-NOx**

1970- Burning Technology for Low-NOx Emission

Two-stage burning(1970-), Low-NOx Emission Boiler(1970-), Burner with Low-NOx Emission (1975-)

1977- selective catalytic reduction process for de-NOx

**De-SOx**

1975- High-efficient de-SOx by gypsum process

Twin tower Method → Single tower Method → Larger Capacity

Removal of mercury
Removal of elements of small mass

**Particulate collection**

1966- Introduction of high-efficient Electrostatic Precipitator particulate Collector

**Low temp. circum. (130℃)** **High temp. circum. (350℃)**

Optimization with De-SOx tech. (2000-)

**Low-Low temp. circum. (90℃) (2005-)**

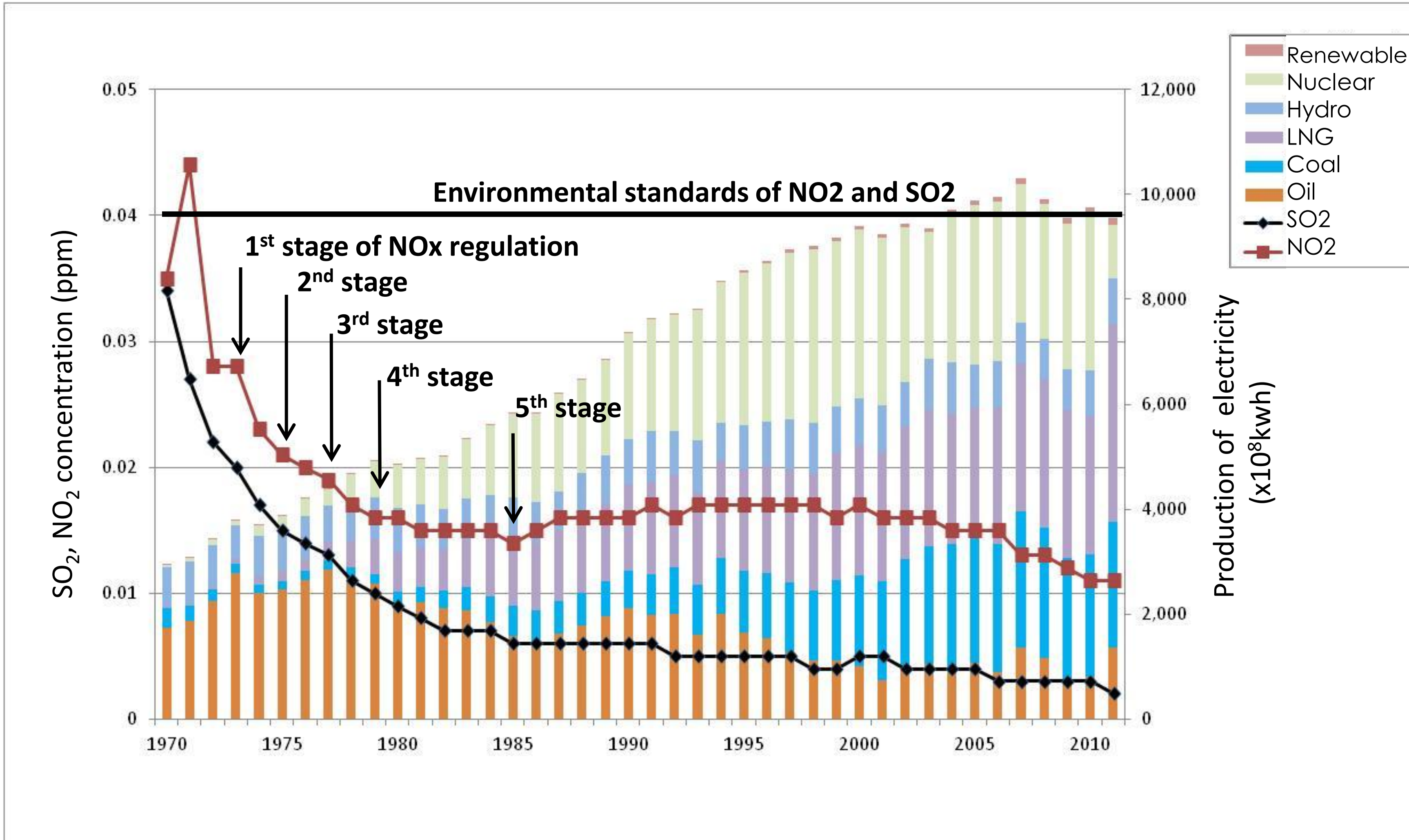
**Low-$CO_2$ emission (High efficient generation)**

Sub-critical (40-43%) → Super Critical (42-44%) → Ultra Super Critical (43-45%) → Advanced Ultra Super Critical (46-48%)

IGCC (40-48%) → IGFC (55-%)

# Ⅱ-12. Environmental Monitoring of $SO_2$ and $NO_2$

- Environmental protection for SO2 emission from factories completed in 1970's
- Environmental protection for NO2 emission from factories completed in 1980's



# Ⅱ-13. Efficiency Upgrade by Plant Replacement (Isogo Power Station)

Old Isogo, Startup:1967

New Isogo No.1, Startup: 2002
New Isogo No.2, Startup: 2009

**Three Purposes**

- ◇ **Output Upgrade**
- ◇ **Environmental Upgrade**
- ◇ **Efficiency Upgrade**

| | Old | New |
|---|---|---|
| ◆ Output | 530MW ( 265MW×2 ) | 1,200MW ( 600MW×2 ) |
| ◆ SOx | 60 ppm | 20 ppm (10) |
| NOx | 159 ppm | 20 ppm (13) |
| Dust | 50 mg/m$^3$N | 10 mg/m$^3$N (5) |
| ◆ Steam condition | Sub-critical | Ultra Super Critical (USC) |
| Efficiency | 38% (Gross%; HHV) | 42～43% (Gross%; HHV) |
| **$CO_2$ Emissions** | **100** | **83** ※ |

( ):No. 2

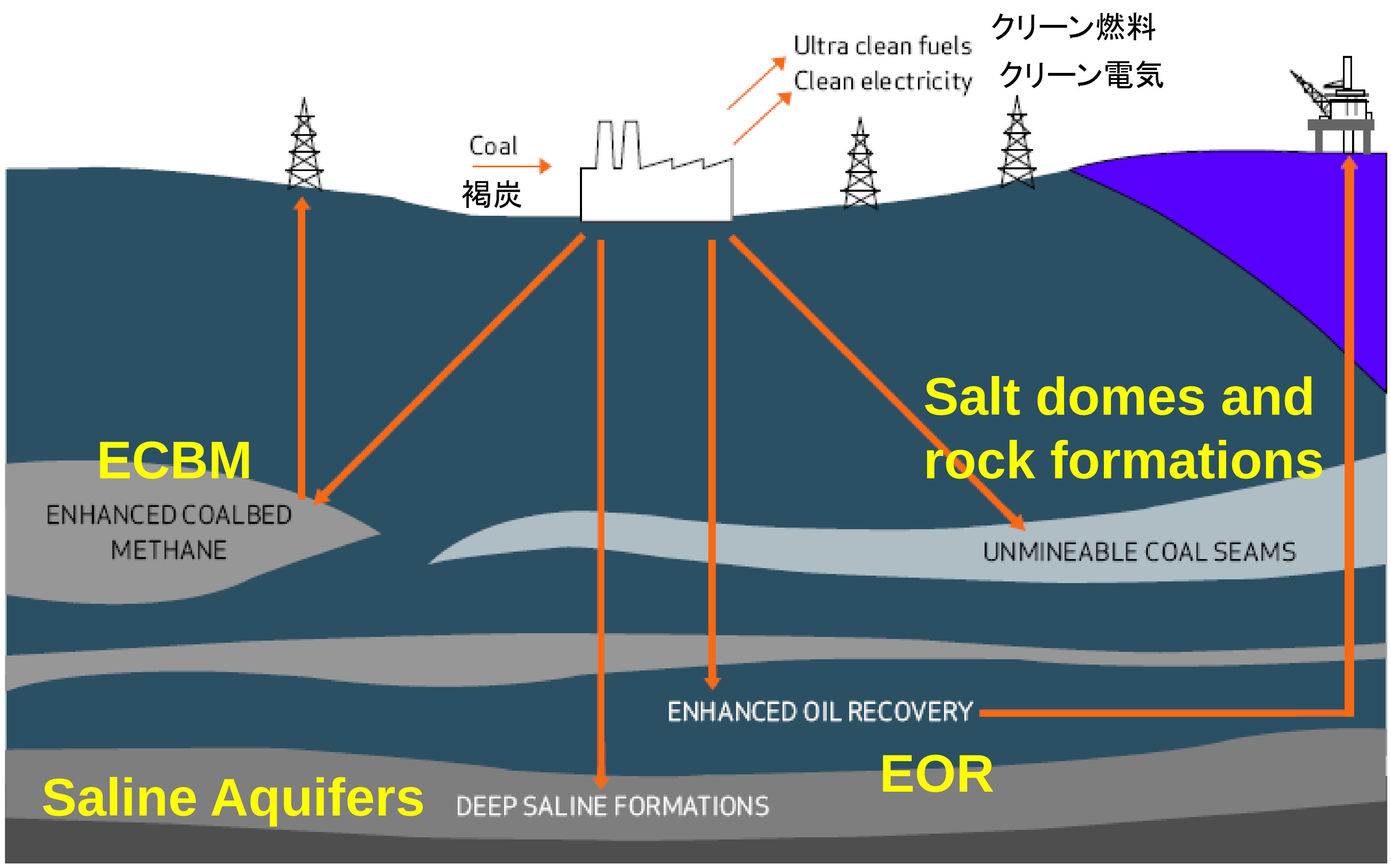
※ A comparison of the $CO_2$ emission per gross output (kWh) with an old plant (100 basis).

# Ⅱ-14. Present State of Japanese Exhaust Gas Cleaning Technology (Isogo Power Station)

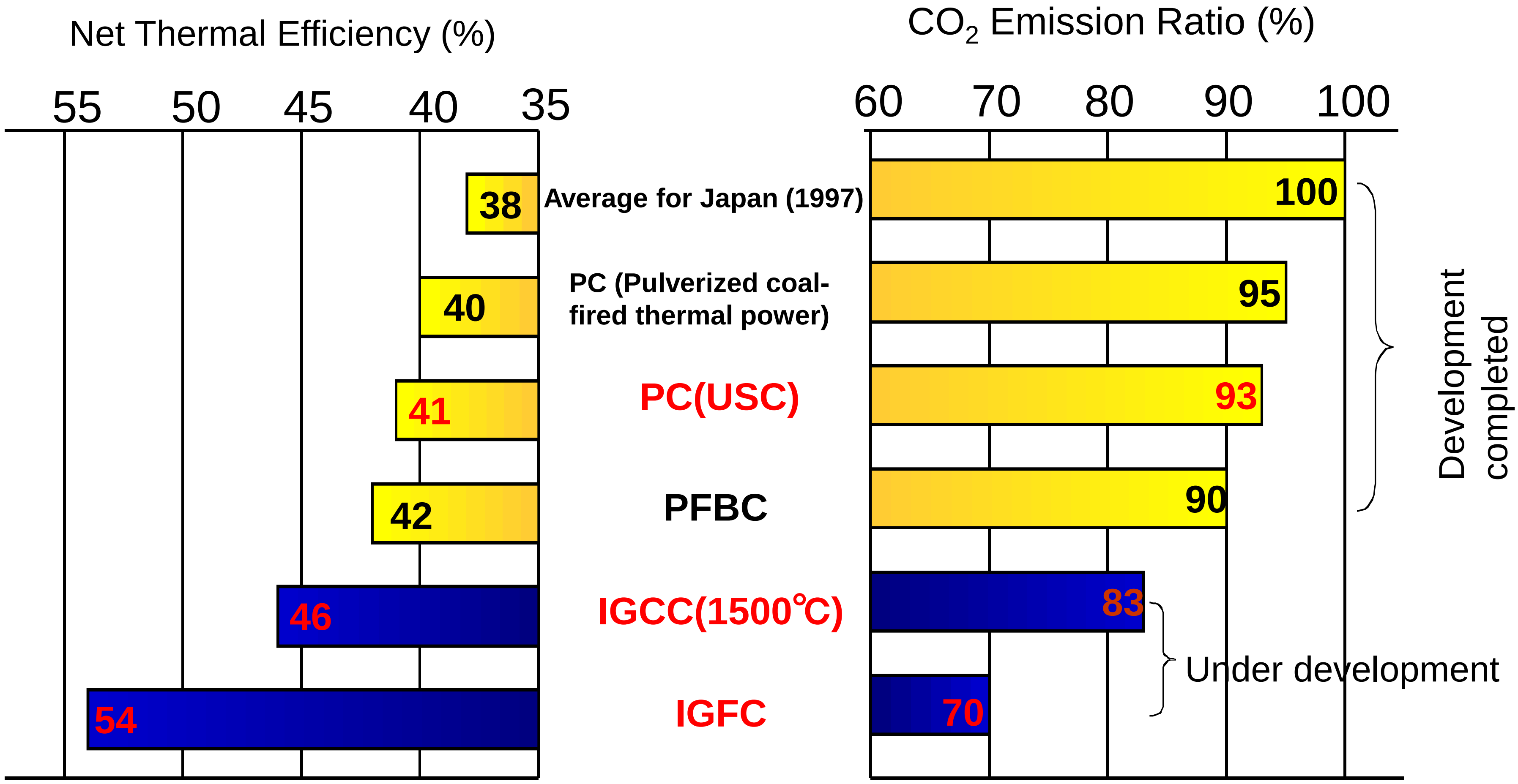
World leader reaching three 10s

| | Former No. 1 and No. 2 Plants | New No. 1 Plant | New No. 2 Plant |
|---|---|---|---|
| Flue gas emission (wet gas, m3N/h) | 1,972,000 | 2,000,000 | 1,992,000 |
| NOx concentration (ppm) | 159 | 20 | 13 |
| Particurate concentration (mg/m3N) | 50 | 10 | 5 |
| SOx concentration (ppm) | 60 | 20 | 10 |

# Ⅱ-15. Storage of CO2

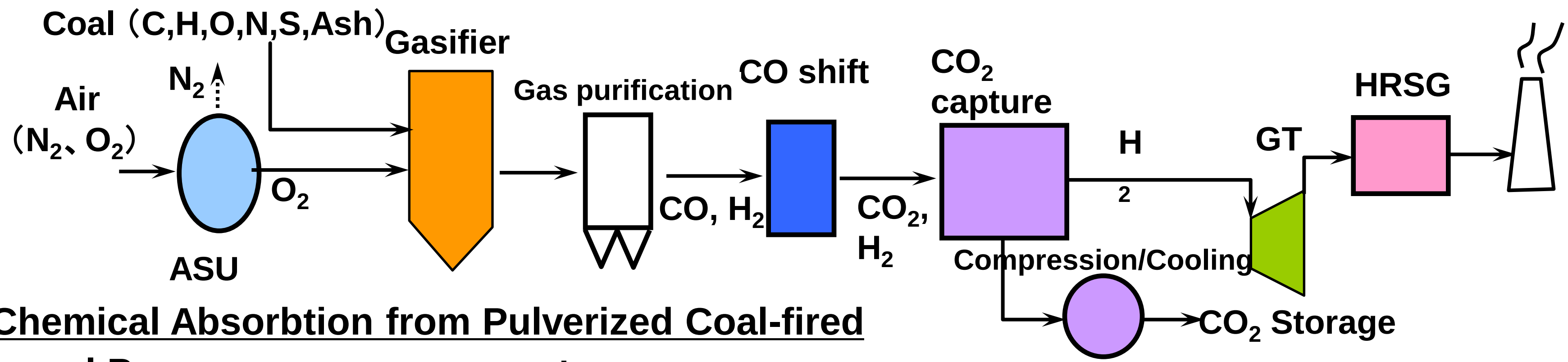


# Ⅱ-16. Efficiency of Japan's coal-fired power plants and $CO_2$ Formation Ratio

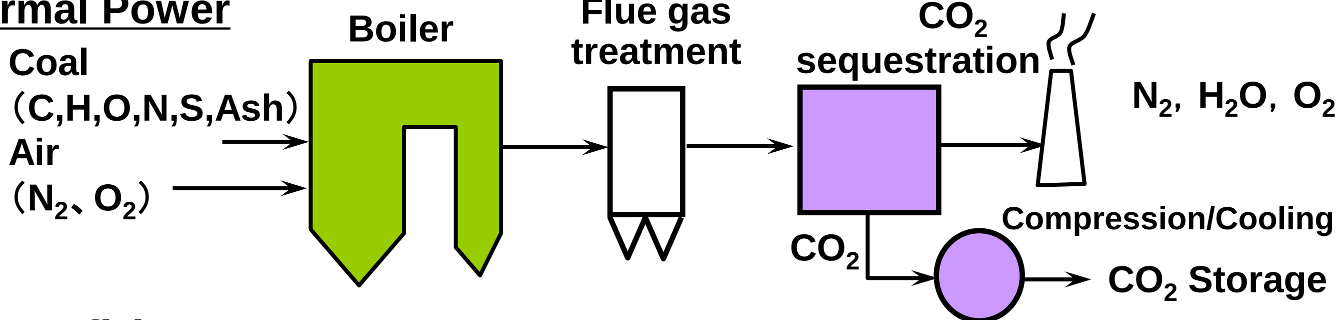


# Ⅱ-17. $CO_2$ Capture from Coal-fired Thermal Power Plant

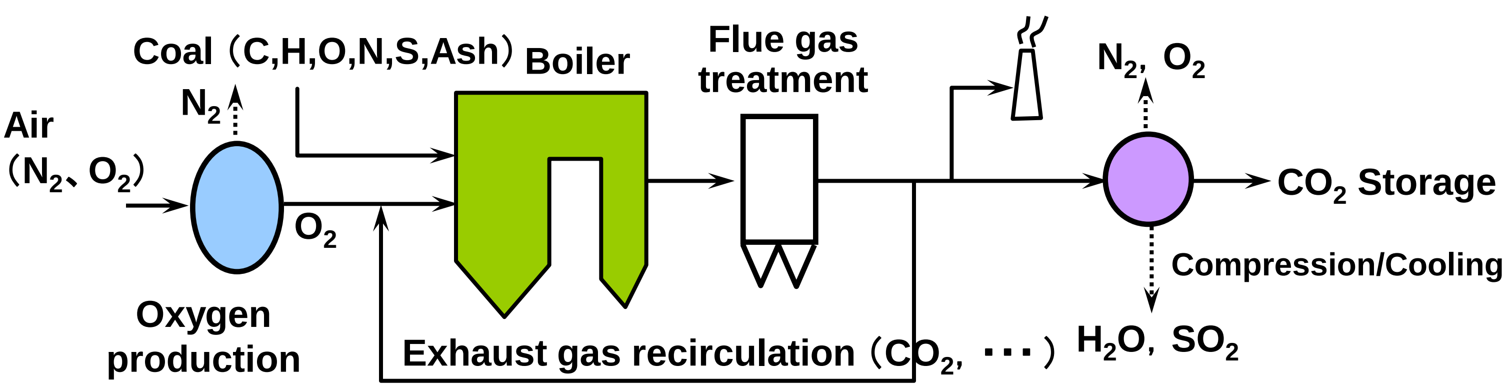
## 1. Capture from coal gasification




## 2. Chemical Absorbtion from Pulverized Coal-fired Thermal Power




## 3. Oxy-firing



# Ⅱ−18. Japan-Australia Callide-A Oxy-fuel Project outline

JCOAL Japan Coal Energy Center

**Demonstration of 30MWe coal fired power plant with CCS by Oxy-fuel technology**

**Callide-A: 4 x 30 MWe (Use one unit)**
**Evaporation: 123 t/h steam**
**4.1 MPa/460°C**
**Operation terminated 2002**
**Flue gas treatment / Fabric filter (without DeNOx / DeSOx)**

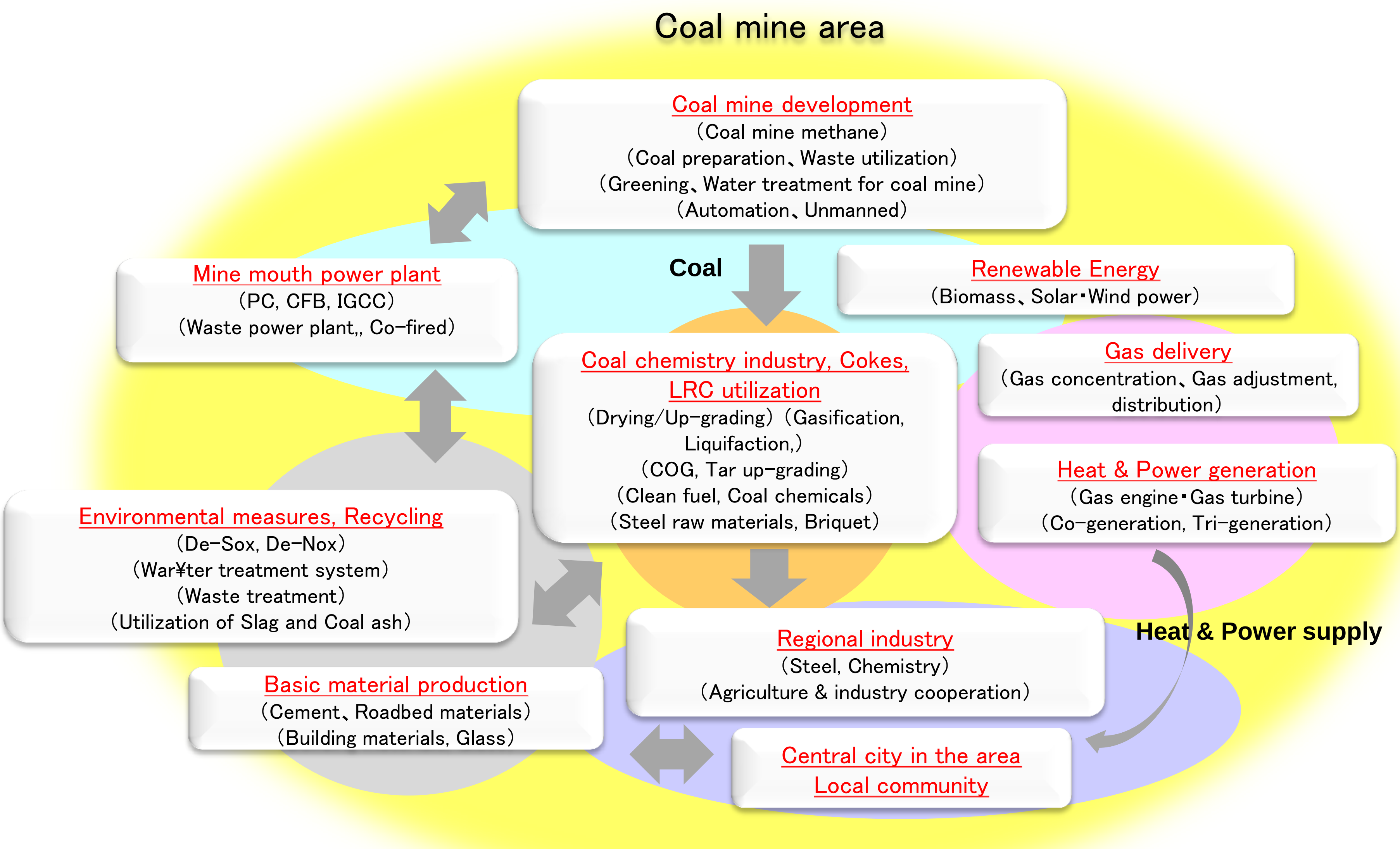
**Partners**
**CS Energy, Xstrata, Schlumberger**
**JPOWER,IHI, Mitsui & Co, JCOAL**

**CO2 storage site area (app.300km far east from Callide-A)**

**Callide-A Power Plant**

Callide
OxyFuel Project

# Ⅱ-19. outline of Clean Coal Town Planning




Basic concept of the low carbon and resources circulation type coal mine area (Clean coal town)

# Ⅱ-20. Clean Coal Town Project － Overview －

- The objective of the project is to promote the effective utilization of coal resources in the coal producing country, and to contribute to the development of the coal industry while considering to environmental burden. Specifically, it is to develop a coal-related industrial chain (Clean Coal Town) which efficiently combines coal-fired power generation and coal chemical industry and so on to utilize the coal, focusing on a model coal mine.
- Japanese clean coal technology, from the upper stream to the down stream, contribute to the optimizing of productive efficiency, utilizing resources and the environmental conservation regarding energy flows and material flows.

### 1st Step: Preliminary Studies

- Current status of coal industry
- Understanding of needs and collect information of the candidate coal mining area
- Collect information on Japanese seeds
- Building basic concept of projects
- Selection of target area

### 2nd Step: Create a Basic Plan in the Target Area

- Target setting ($CO_2$ reduction, energy saving, economics, etc.)
- Evaluation of effects of seeds technology introduction
- Making a master plan for target area

### 3rd Step: Creating the Execution Plan

- Business proposals
- Building a business model (Project implementation system, policy tools, finance schemes, etc.)
- Pre-FS
- Building action plan

# Ⅲ-1. Recent Activities in Clean Coal Technologies between Poland and Japan

JCOAL Japan Coal Energy Center

2009.12 Polish - Japanese CCT Seminar at Katowice

2010. 9 JCOAL signed the MOU with GIG and IChPW to pursue collaborative work.
(GIG ; Glowny Instytut Gornictwa, IChPW ; Instytut Chemicznej Przerobki Wegla)

2011. 3 1st CCT Technical Exchange Program in Poland

2011.11 2nd CCT Technical Exchange Program in Poland

2012. 9 3rd CCT Technical Exchange Program in Japan

2012. 9 JCOAL signed the MOU with PGE to pursue diagnosis work.
(PGE ; Polska Grupa Energetyczna Spółka Akcyjna)

2013.10 JCOAL signed the MOU with NCBiR to pursue collaborative work.
(NCBiR ; Narodowe Centrum Badań i Rozwoju)

2014. 6 Polish - Japanese clean coal seminar at Warszawa

**These activities priority areas are High efficiency coal-fired power station, IGCC, CCS and other innovative technologies.**

↓

**Realization of CCT Collaboration project between Poland and Japan.**

# Ⅲ-2. WORK PROCESS for Realization of Bilateral CCT collaboration project

- **STEP 1**
  - **Proposals on CCT collaboration from Poland**

2012 FY

- **STEP 2**
  - **SURVEY on Japanese Candidate Technology**

========================================

- **STEP 3** 2013 FY
  - **Presentations and Proposals on CCT collaboration by Japanese experts in Poland････4 times – 8 Themes**

  2014 FY ⇒⇒⇒

========================================

- **STEP 4**
  - **Developing collaboration plan through discussion between Poland and Japanese experts**
    1) **Possibility of Feasibility Study for the site**
    2) **R&D Collaboration**

# Ⅲ-3. Candidate of Clean Coal Technology for collaboration between Poland and Japan

JCOAL Japan Coal Energy Center

**<Ongoing>**

- **TIGAR coal gasification process : IHI-IChPW**
- **Fundamental drying tests using Polish lignite : Tokyo Univ.-AGH**
- **CMM Concentration System : Osaka Gas-KW, KHW**

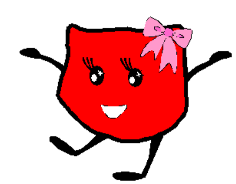
**< Looking for the counterparts >**

- **Mercury removal technology : BHK-**
- **VAM/CMM Utilization in KAWASAKI Engines : KHI-**
- **CO2 utilization technology : Tokyo University of Science -**
- **Quick and Low Temperature Drying Technology : BHK-**
- **UBC （Upgraded Brown Coal)：KOBELCO-**

**<Reviewing>**

- **Hyper-coal as alternative use of cokes : KOBELCO**
- **Lignite catalytic gasification to produce FT synthesis gas in single direct step:AIST**
- **Survey on appropriate area for lignite-derived hydrogen chain in Poland:KHI**
- **CRADLE (Coal Rapid Air Dry Leading Equipment)：BHK**
- **Others**


# Dziękuję bardzo



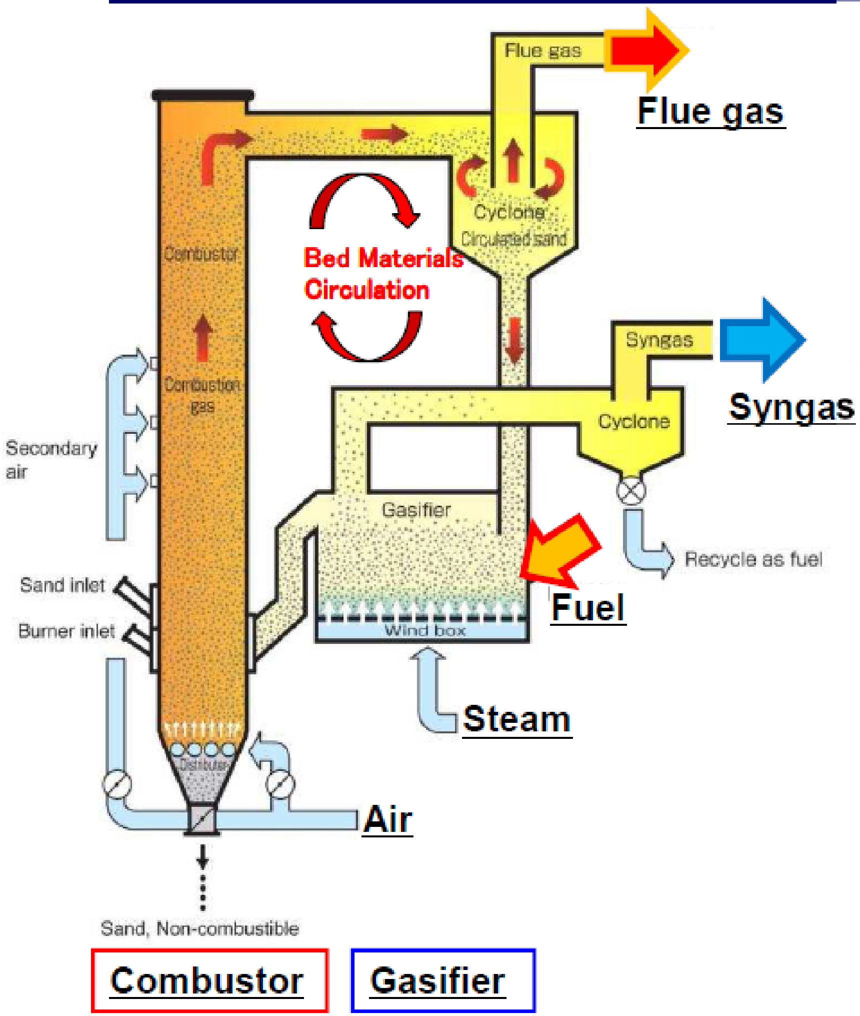
# <References>

- Gasification Technology  of TIGAR ®
- Fundamental drying tests using Polish lignite at Tokyo University (Photos from the laboratory)
- Utilization of CMM with CMM Concentration Technology
- UBC Process for Low CO2 Emission Power Generation
- Steam Tube Dryer (STD)
- Mercury removal technology
- VAM/CMM Utilization in Kawasaki Engines
- Hyper-Coal
- Survey on appropriate area for lignite-derived hydrogen chain in Poland

<Reference>

# Gasification Technology of TIGAR®

■ ***We used our experience in CFB boiler to develop the TIGAR®***






Circulating fluidized bed gasifier system

- Bubbling fluidized bed gasifier
- Circulating fluidized bed (CFB) combustor
- Isolated by using loop seal

Gasifier

- Steam is used as gasification agent
- VM and a part of gasified char
- High calorific value
  (Less contamination of N2 and Air)
- No need to produce O2

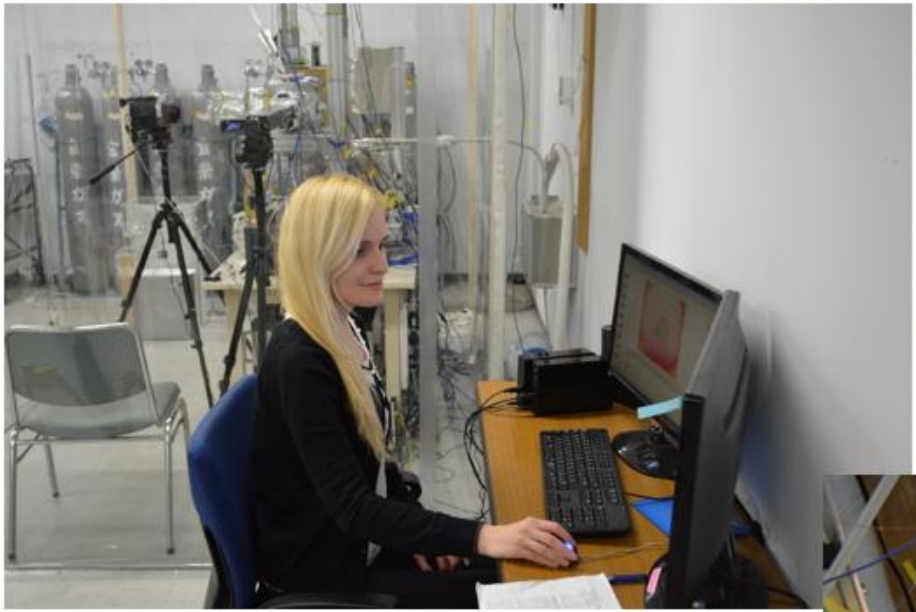
Combustor

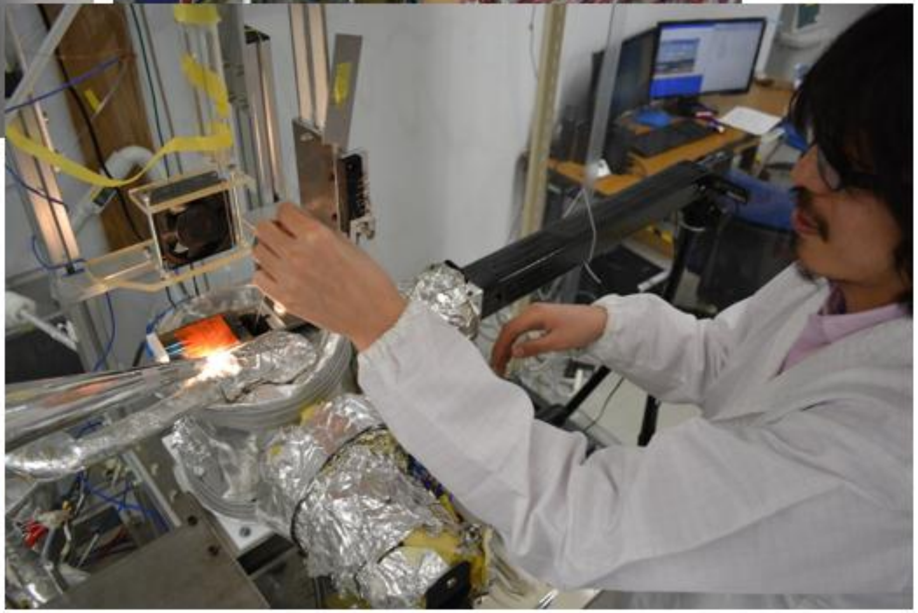
- Remaining char is combusted with Air
- Heated bed materials can keep the gasifier at a certain Temp.

Operate under atmospheric pressure

JCOAL Japan Coal Energy Center

# Photos from the laboratory



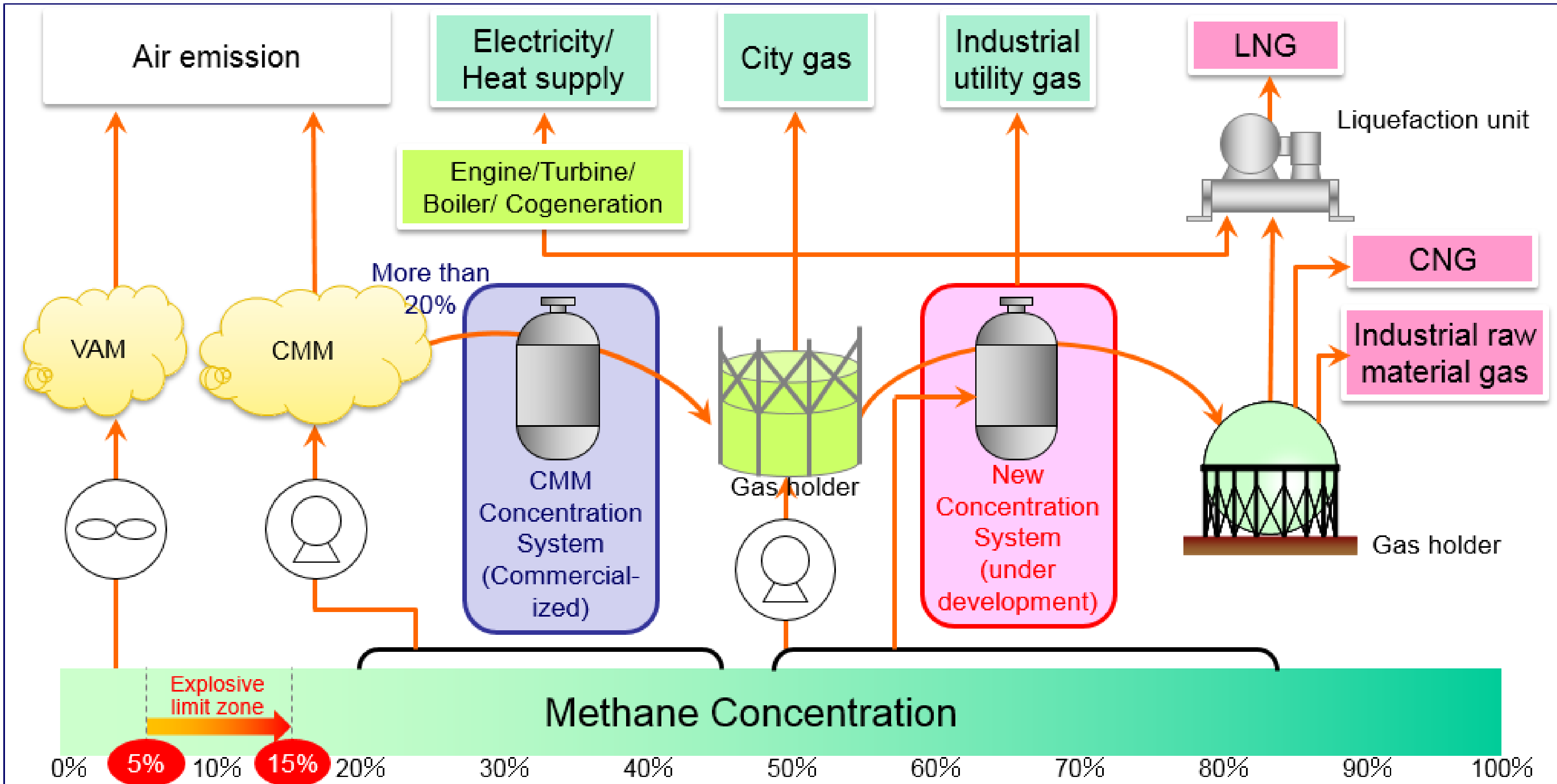


<Reference>

# Utilization of CMM with CMM Concentration Technology

- Utilization of concentrated CMM (around 50% $CH_4$) as regional city gas
- Utilization of concentrated CMM (over 90% $CH_4$) as natural gas

**Extended use of CMM by applying CMM concentration technology**



# UBC Process for Low CO2 Emission Power Generation

**KOBELCO**
*-Upgrading the Future-*

## UBC (Upgraded Brown Coal) Process at a Glance

- Developed by Kobe Steel, Japan with METI back-up.
  (METI: Ministry of Economy, Trade and Industry of Japan)
- Removes moisture completely from lignite of which total moisture is as high as 60% by highly energy efficient Coal – Oil Slurry Dewatering. (Oil is recycled)
- Large Scale Demonstration plant (600 UBC-ton/day) completed successful operation
- UBC product can be in the form of;

i) Briquette for long distance transportation
(Product moisture: 8-10% which is equilibrium after open yard storage)
ii) Powder (without briquetting) for direct feed to adjacent power station
(Product moisture: 0% which is right after upgrading)

**<UBC is the only technology that removes moisture completely.>**
**<Boiler test of UBC powder confirmed;**
**- great efficiency improvement in power generation, and**
**- good combustibility at normal USC plant.>**

## Low Investment Solution for CO2 Reduction

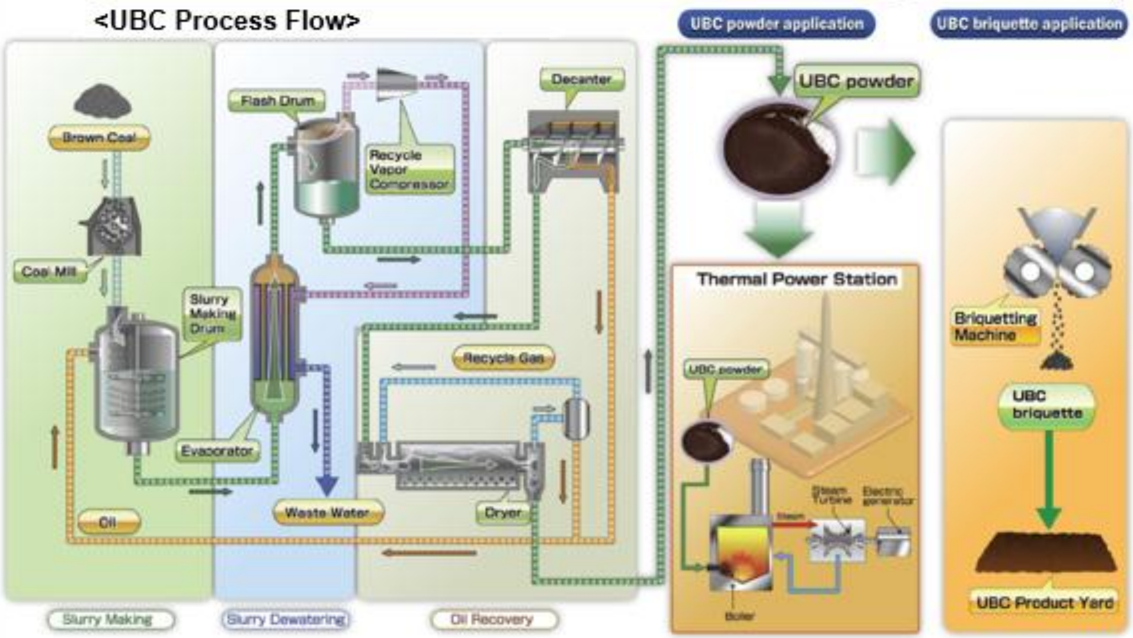
**Efficiency Improvement from Conventional Lignite-fired Power Plant**

| | Power Generation Efficiency (Sending End) | Improvement from Conventional | Remarks |
|---|---|---|---|
| **Conventional Power Generation** | | | |
| Lignite-fired Sub-Critical Plant | 29.2% | NA | Data from operating plant |
| **UBC based Power Generation** | | | |
| ① Integrated UBC-fired Sub-Critical Plant | 32.6% | 11.8% | Energy used for UBC plant is deducted |
| ② Integrated UBC-fired Ultra Super Critical Plant | 34.5% | 18.2% | Energy used for UBC plant is deducted |
| ③ Non Integrated UBC-fired Ultra Super Critical Plant | 40.6% | 39.4% | Energy used for UBC plant is not deducted |

* Lignite: TM 52%, 2,830kcal/kg, UBC Powder: TM 0%, 5,900kcal/kg.
* Efficiency: HHV Basis

UBC technology improves energy efficiency, thus
i) Reduces CO2 emission.
ii) Extends lignite mine life. (less lignite consumption)
iii) Makes operating cost lower.

### <UBC Process Flow>




# <Reference> Steam Tube Dryer (STD)

## Features

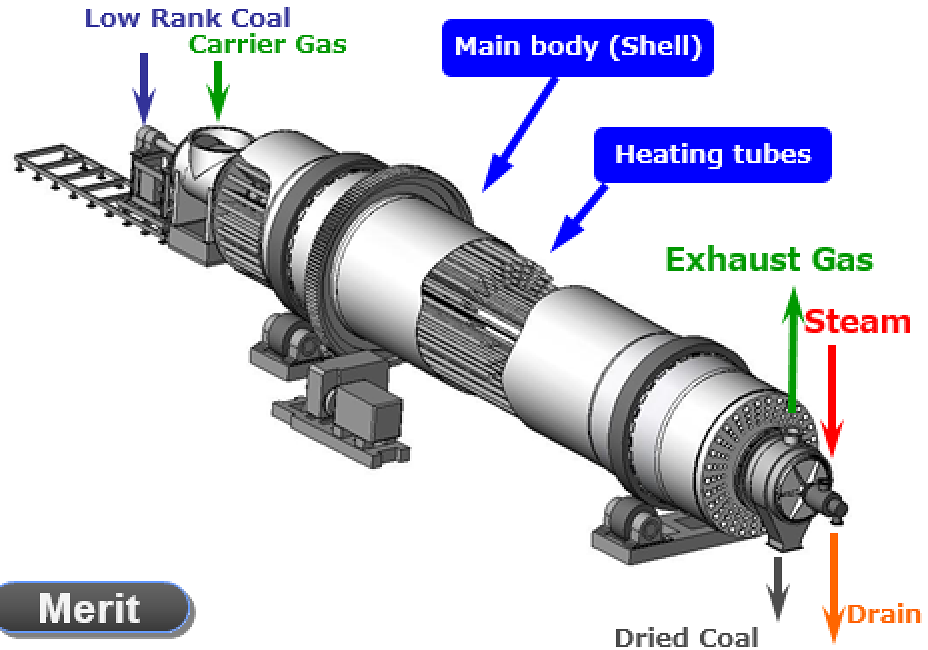
**1. Proven technology**
: TSUKISHIMA KIKAI CO. LTD (TSK) has supplied more than **500 sets** for various applications.

**2. Large capacity**
: Maximum capacity is **500t/h by one dryer** as coking coal.
*Coal moisture range ; 10 › 6%

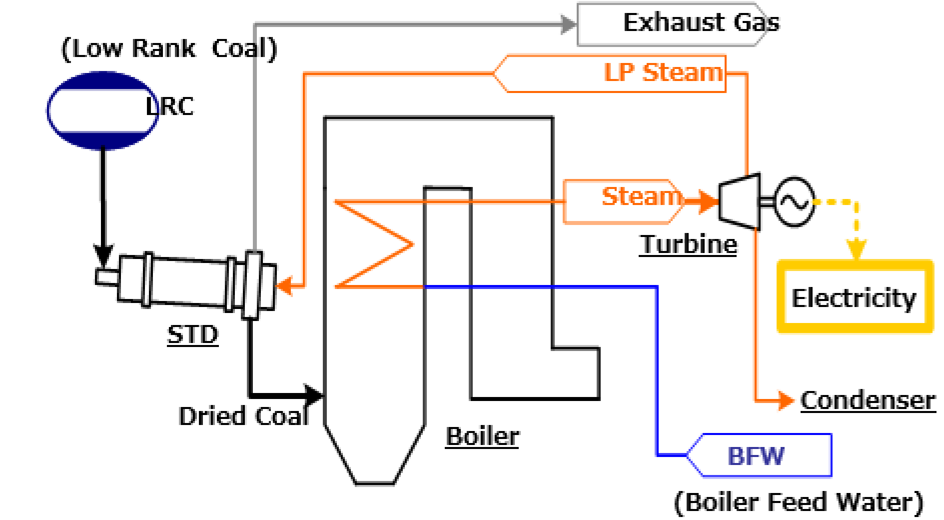
**3. Reliable operation**
: **1 year continuous operation** can be achieved without major maintenance or shutdown.

**4. Low pressure steam**
: **Low pressure steam** such as extract steam from turbine at power plant **can be utilized as heat source of STD**

## Configuration




## Application for Power plant




Source: Website of Tsukishima Kikai Co., Ltd.

## Merit

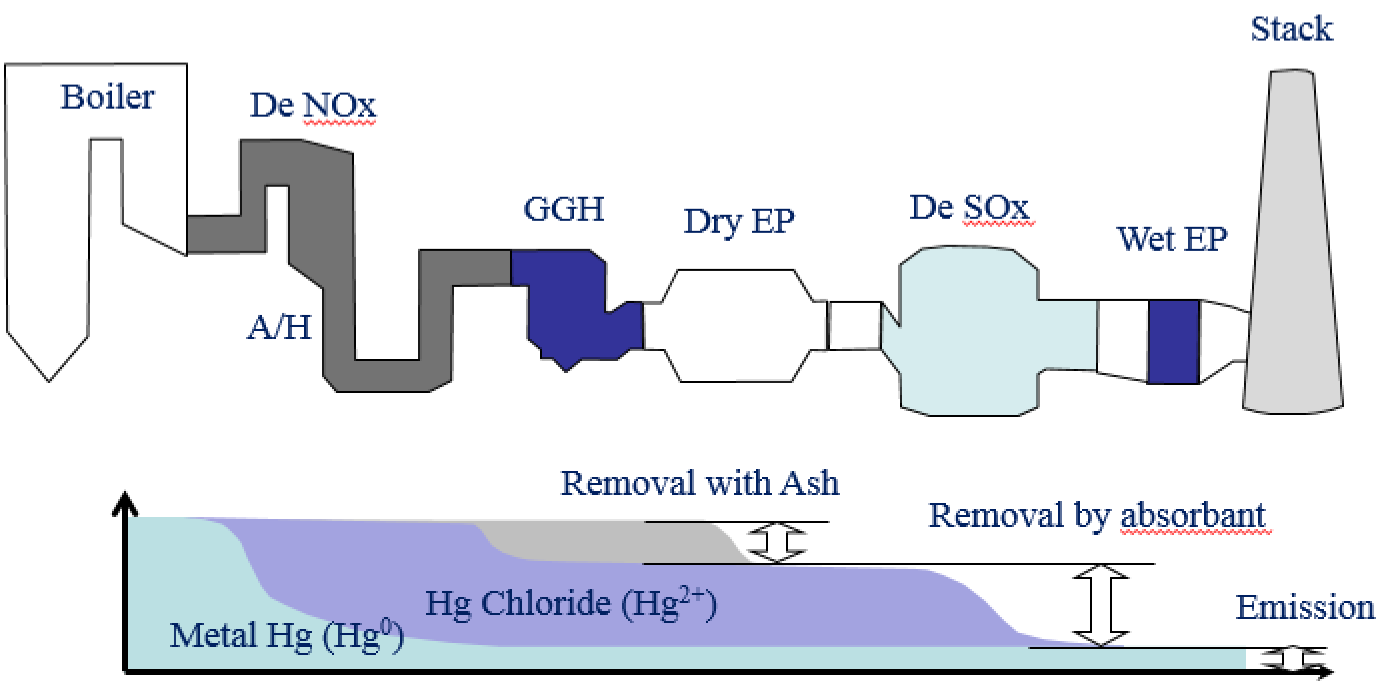
1. Recovery of generation capacity in Power Plant
2. Reduction of Fuel cost
3. Expansion of Low Rank Coal Utilization

## Commercial plant for coking & thermal coal

<Reference>

# Mercury removal technology

## Schematic Removal model of Mercury in Coal-Fired Power Plant

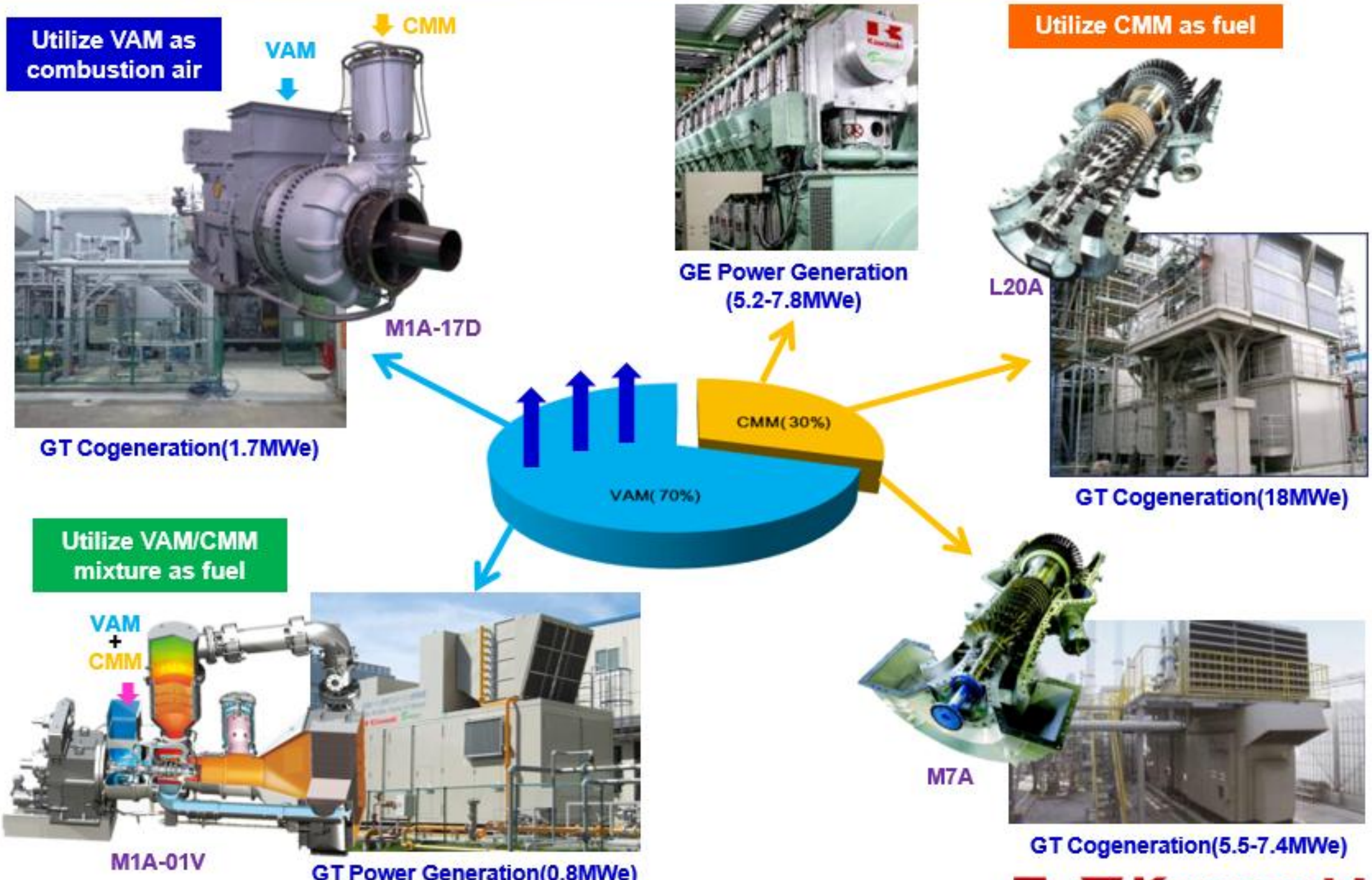



- Mercury in coal is converted to metal Hg during combustion.
- Metal Hg is converted at De-NOx Cat. to Chloride compound which is water soluble.
- Hg Chloride is removed with ash particle as well as De-SOx absorbant.

Source: Website of **Babcock-Hitachi K.K.**

<Reference>

# VAM/CMM Utilization in Kawasaki Engines

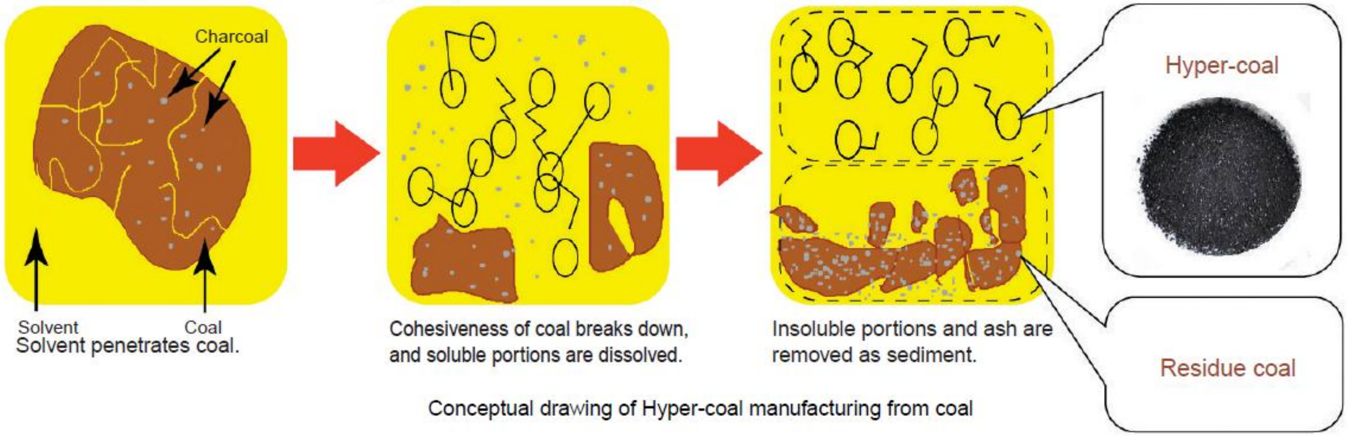


<Reference>

# Hyper-Coal

-Upgrading the Future-

A solvent with a high affinity to coal is applied during the ash extraction process. Ash present in the coal is removed from the solution though the use of a solid-liquid separation technology. Once the solvent is removed from the solution, the final product, Hyper-coal, has little ash content.




Conceptual drawing of Hyper-coal manufacturing from coal

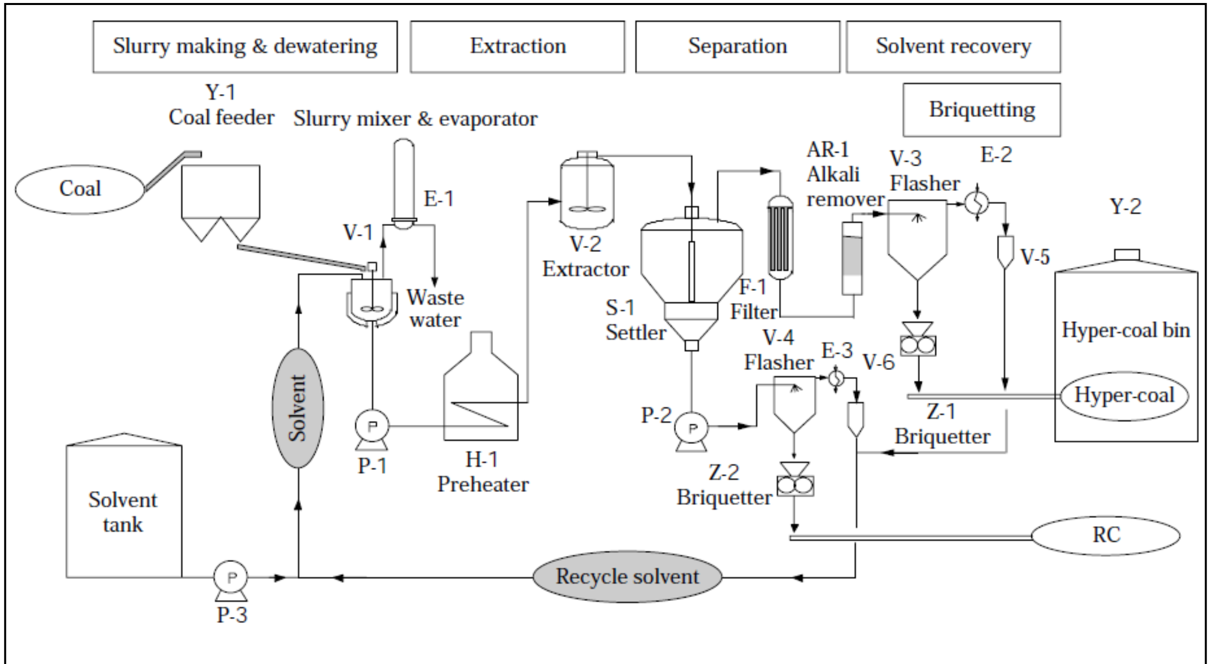



**Fig. 1** Schematic flow diagram of hyper-coal process

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# Survey on appropriate area for lignite-derived hydrogen chain in Poland



<Reference>