

**The Kazakhstan Green Bridge Initiative Conference 2016**  
**Critical Element of the Green Bridge Initiative:**  
**Advanced Fossil Fuel Technologies**



**Clean Coal Technology**  
**for the Future Power Generation**  
**~~~Experiences in Japan~~~**

**Astana, Kazakhstan**  
**9 March, 2016**

**Keiji MAKINO**  
**Senior Fellow**  
**Japan Coal Energy Center**

**121 Associations  
(As of March 2016)**

# JCOAL



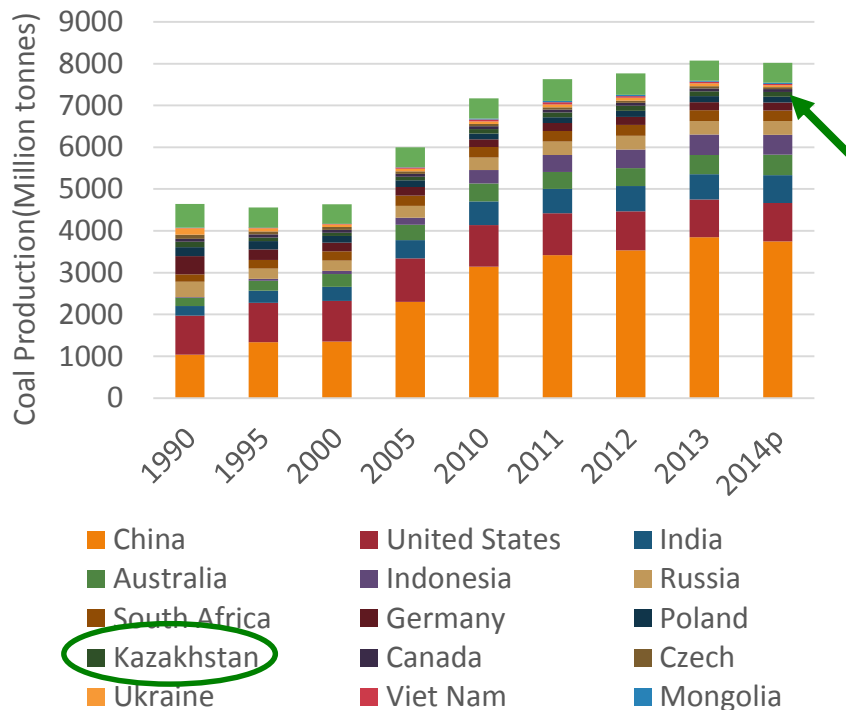
# **CONTENTS**

- 1. Coal Now ~~Situation of Japan~~**
- 2. What is Clean Coal Technology?**
- 3. Coal Preparation**
- 4. Environmental Protection**
- 5. Global Warming**
  - 5.1 High Efficiency**
  - 5.2 CO<sub>2</sub> Capture**
  - 5.3 Biomass Co-Combustion**
- 6. Utilization of Coal Ash**
- 7. Japanese Roadmap of Clean Coal Technology R&D**
- 8. Lastly-----**

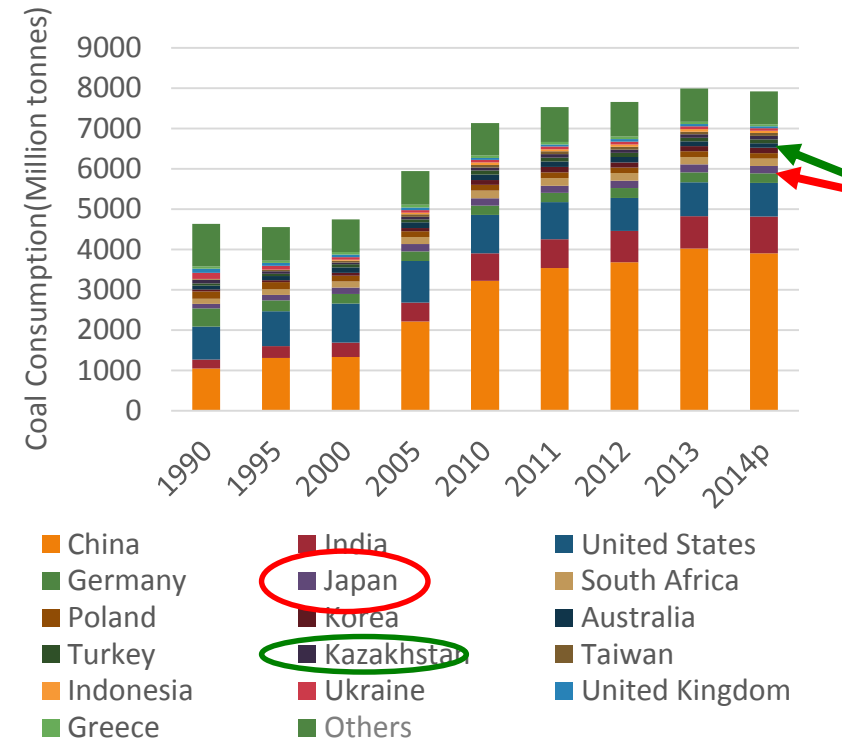
# 1. Coal Now –Situation of Japan--

## World Coal Production and Consumption

World Coal Production  
IEA Coal Information 2015

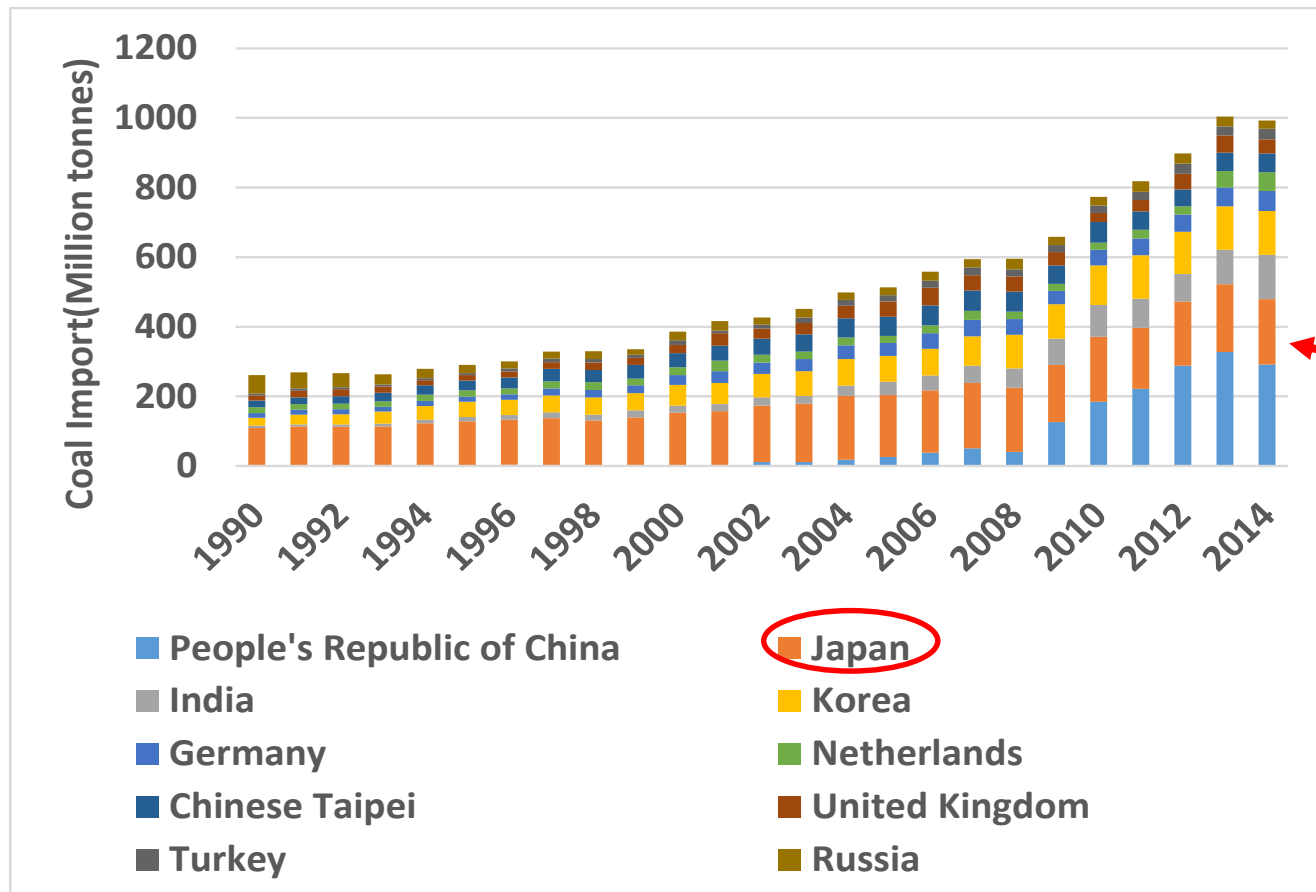


World Coal Consumption  
IEA Coal Information 2015



IEA Coal Information 2015

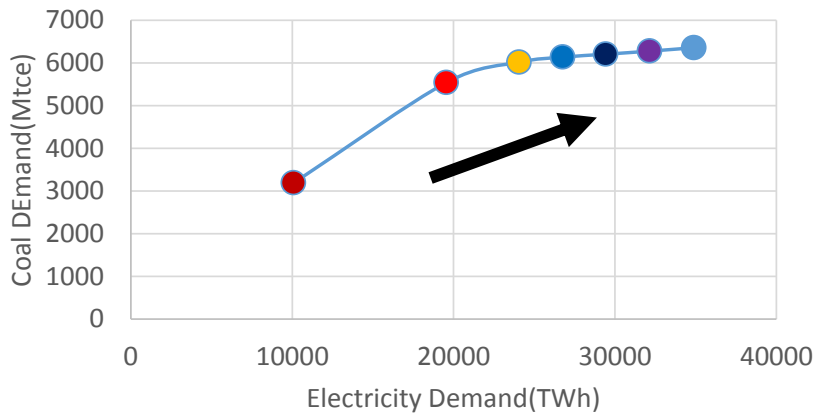
# World Coal Import



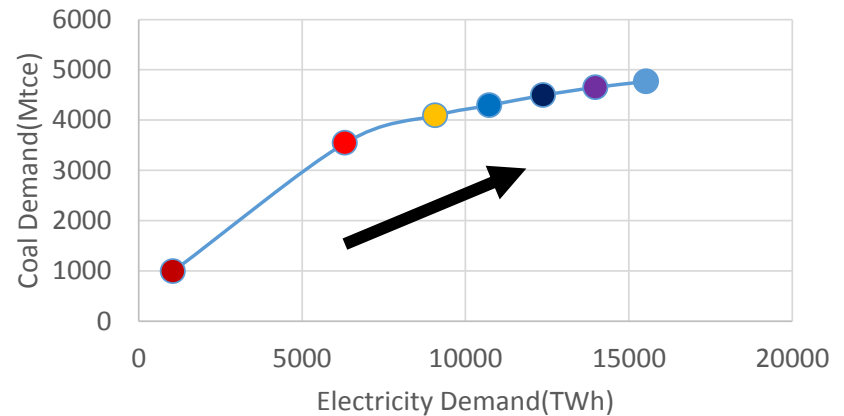
**IEA Coal Information 2015**

# Coal and Electricity Demand

World Electricity and Coal Demand

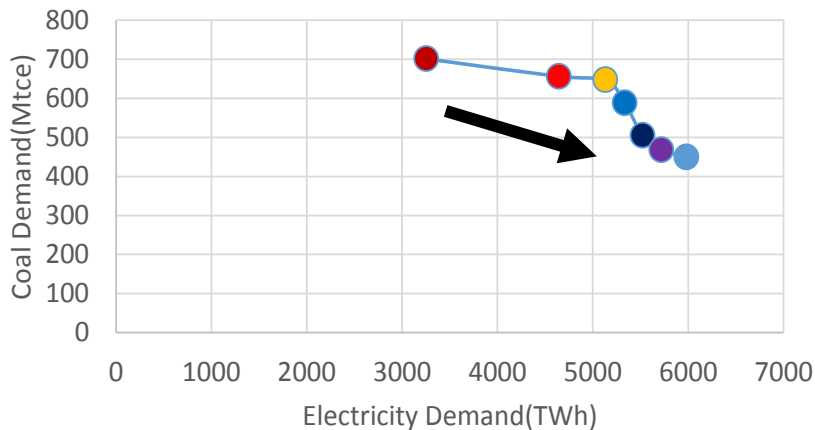


Asia Electricity and Coal Demand

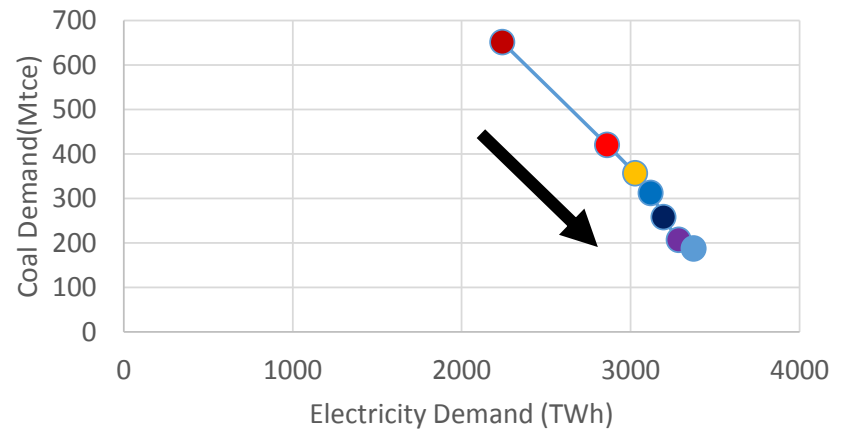


**Trend for 50 years : 1990, 2012, 2020, 2025, 2030, 2035, 2040**

America Electricity and Coal Demand

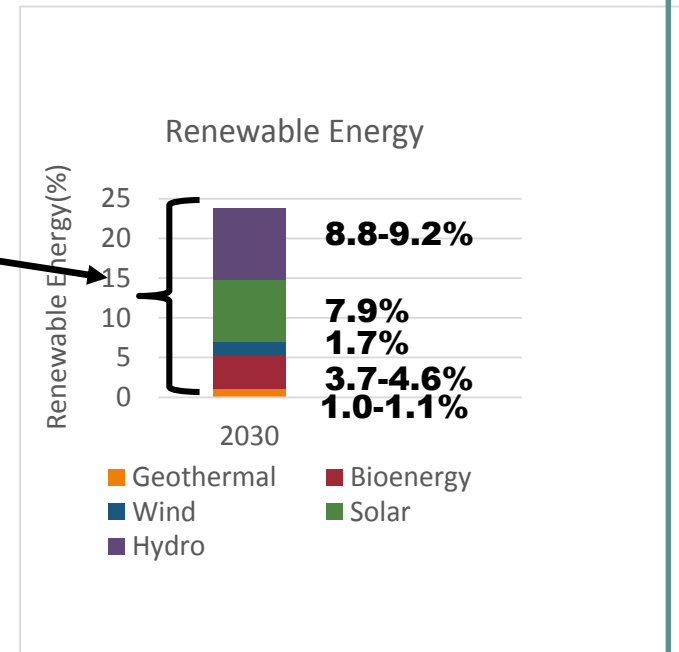
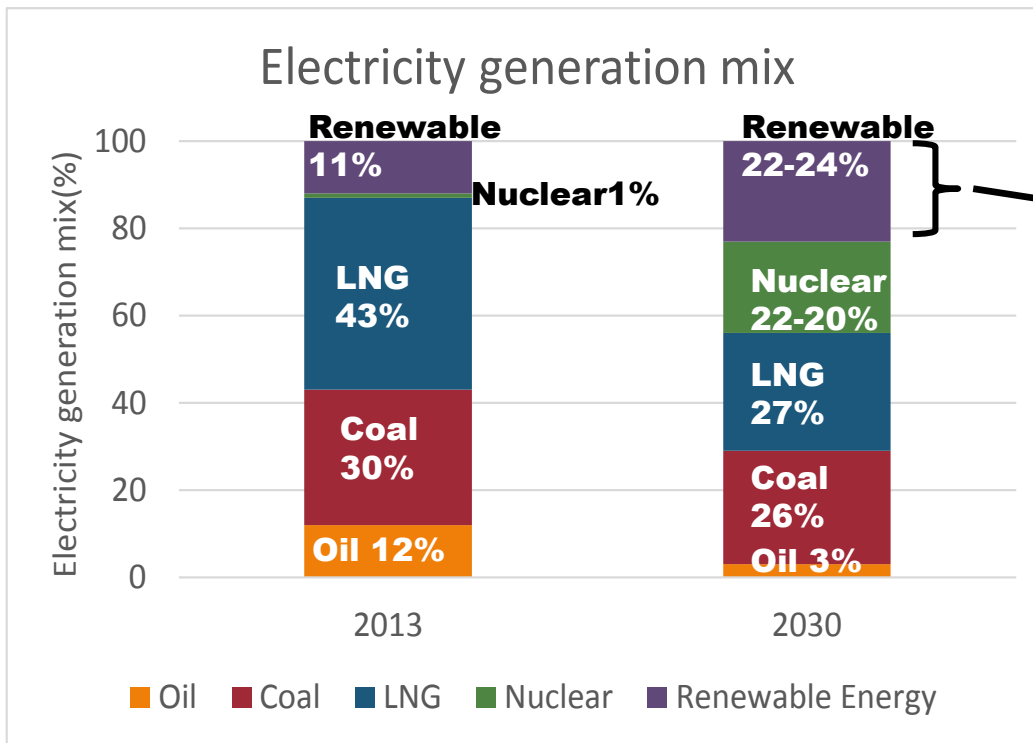


Europe Union Electricity and Coal Demand



# Electricity Generation Mix of Japan

- **July 2015, Japan's New Energy Mix towards 2030 was decided.**
- **The basic policy of "Energy Mix" is to realize a balanced power source composition, while achieving 3E+S(Safety, Energy Security, Economic efficiency and Environment ).**
- **Coal is positioned as the important energy source to be used while the environmental burden.**



**METI Website**

## **2. What is Clean Coal Technology ?**



## 2. Clean Coal Technology

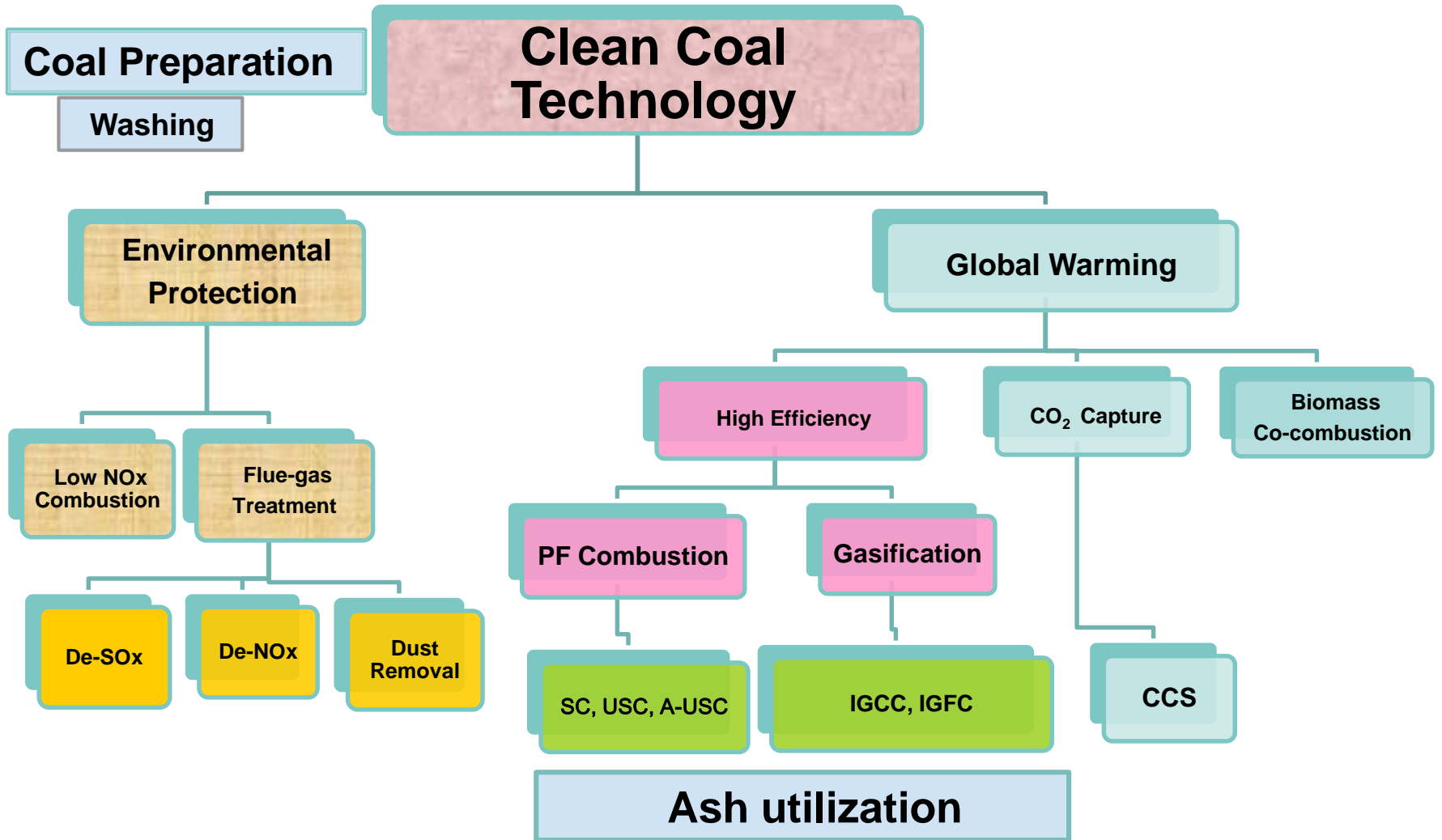
### Components of Coal and Emissions

Component	Molecule	Content(%)	Emission	Problems	Countermeasures
Carbon	C	70-75	CO <sub>2</sub>	Global Warming	High efficiency, CCS
Hydrogen	H <sub>2</sub>	around 5	Steam	None	
Oxygen	O <sub>2</sub>	around 8	Support combustion	None	
Nitrogen	N <sub>2</sub>	0.2-3	NO <sub>x</sub>	Problems to respiratory organ	De-NO <sub>x</sub> (SCR)
Sulphur	S	0.1-5	SO <sub>x</sub>	Problems to respiratory organ	De-SO <sub>x</sub>
Ash	SiO <sub>2</sub> , Fe <sub>2</sub> O <sub>3</sub> , Al <sub>2</sub> O <sub>3</sub> , etc.	15-50	Fly ash	Problems to respiratory organ	EP, Bag Filter, Cyclone Separator
Heavy metals	Hg, Cl, F, Cd, Se, Pb, etc.		Heavy metals	Health Problems	Activated Carbon, Wet Scrubber

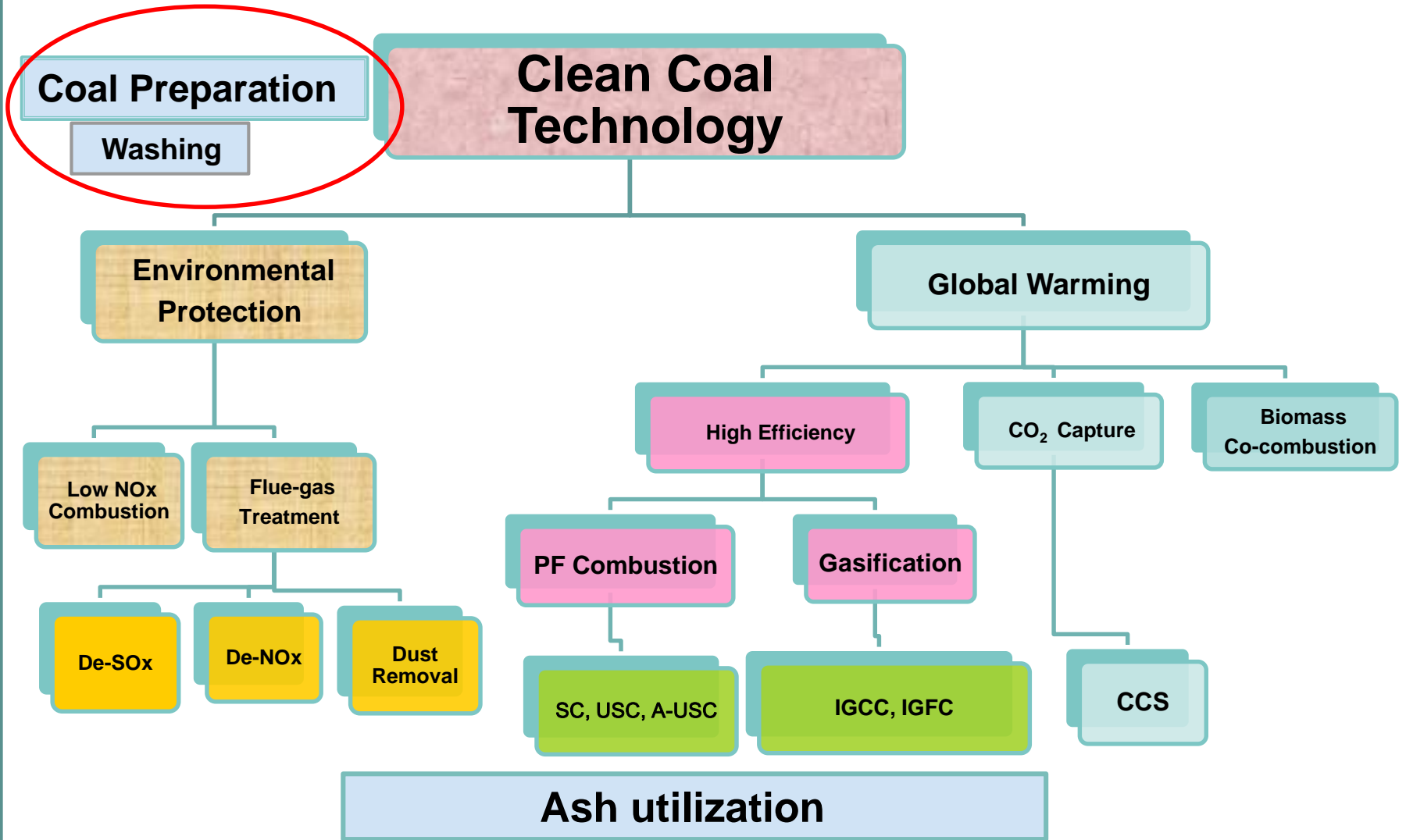
### Clean Coal Technology

==== Remove emissions from flue gas

# Clean Coal Technology



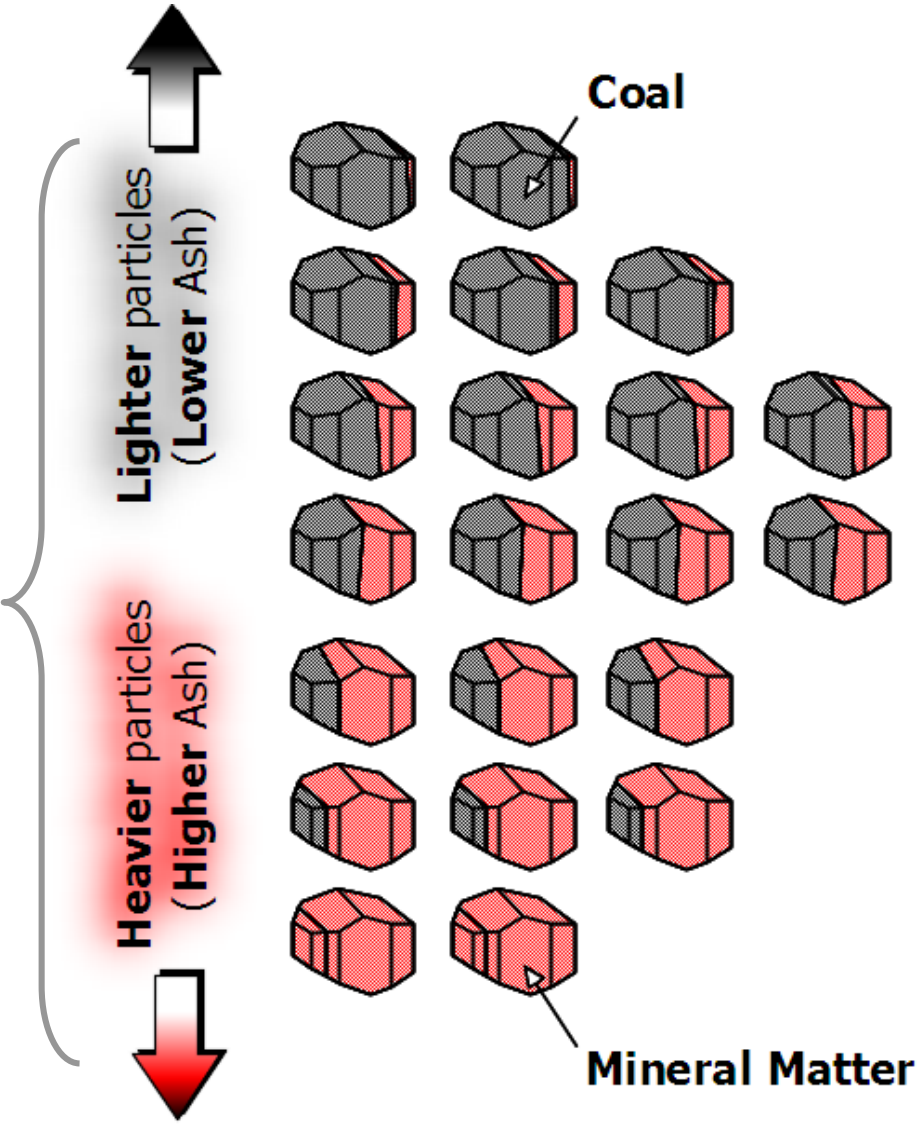
# 3. Coal Preparation



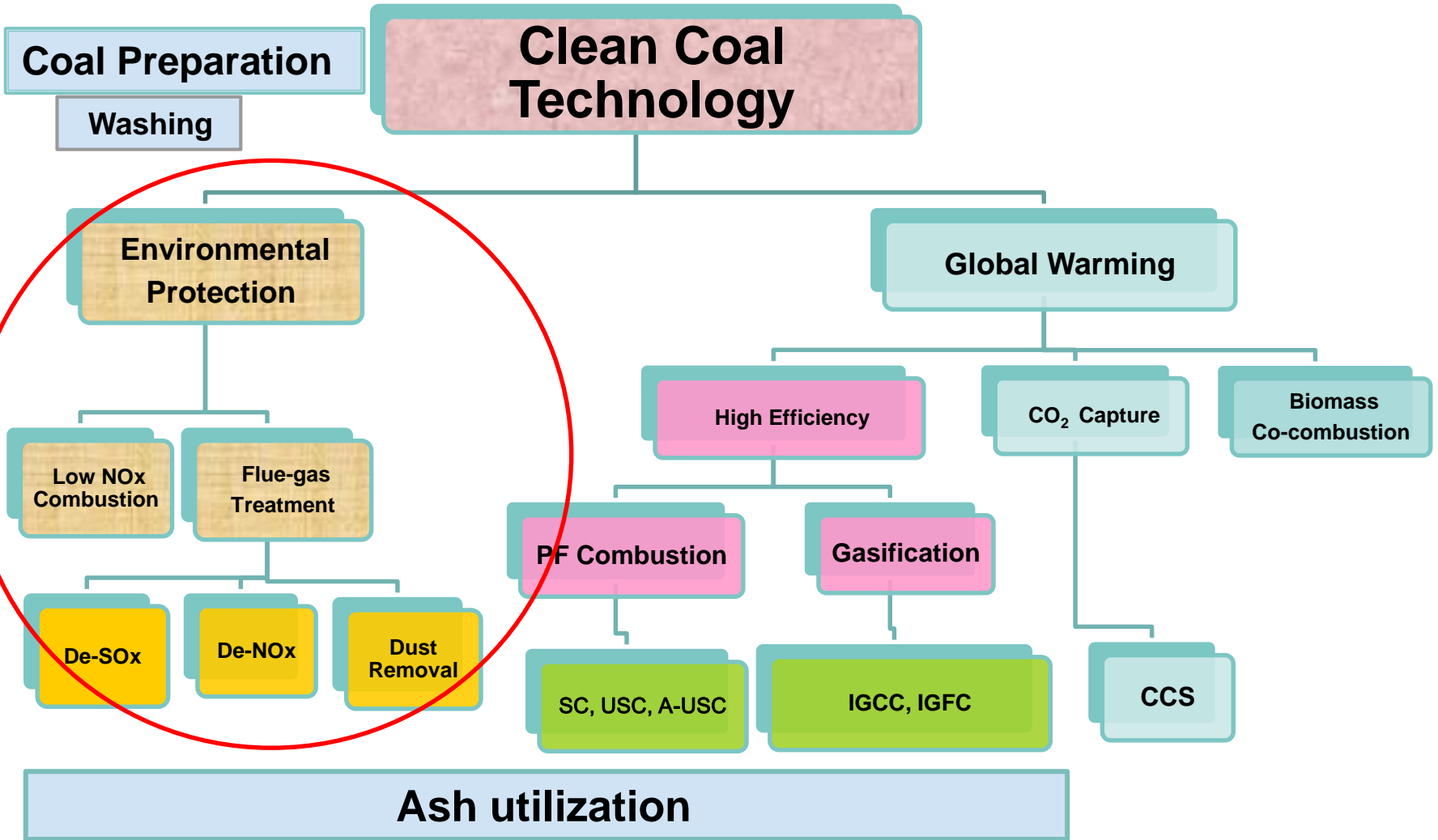
**Mined Coal =  
Coal + Mineral Matter**



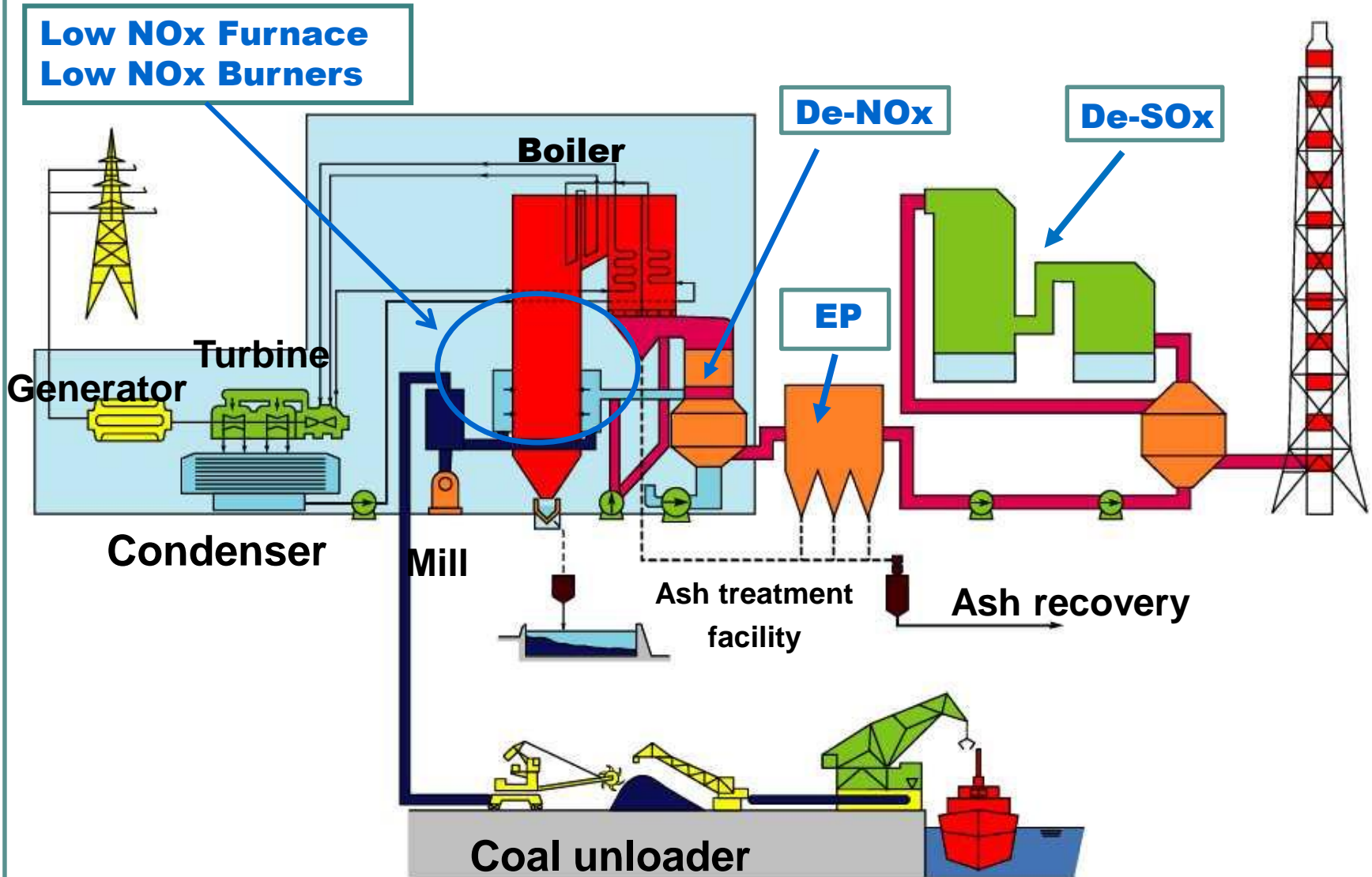
**Separate coal and mineral by heavy medium or dry-system**



# 4. Environmental Protection



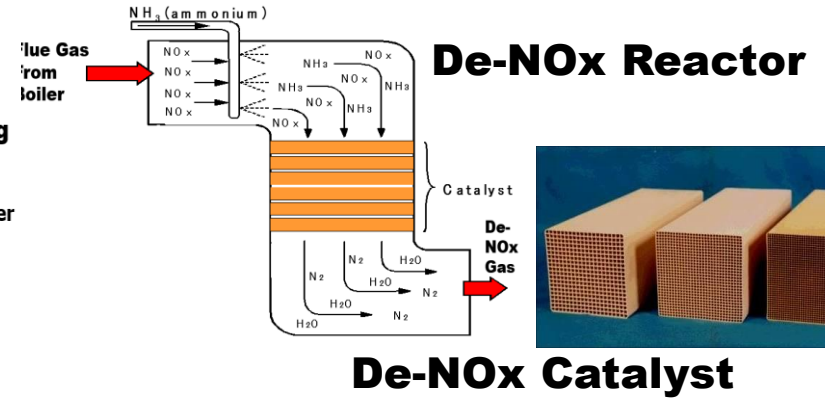
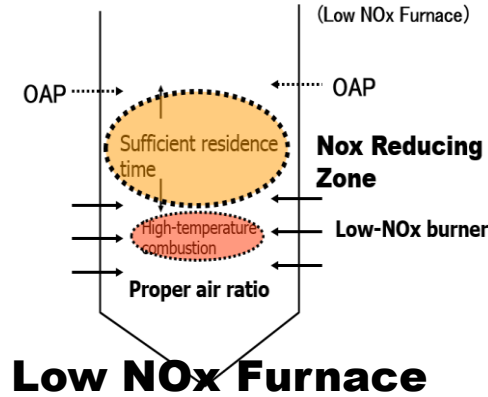
# Environmental Protection of Coal Fired Power Station



# Flue Gas Treatment Facilities



**Low NOx Burner**

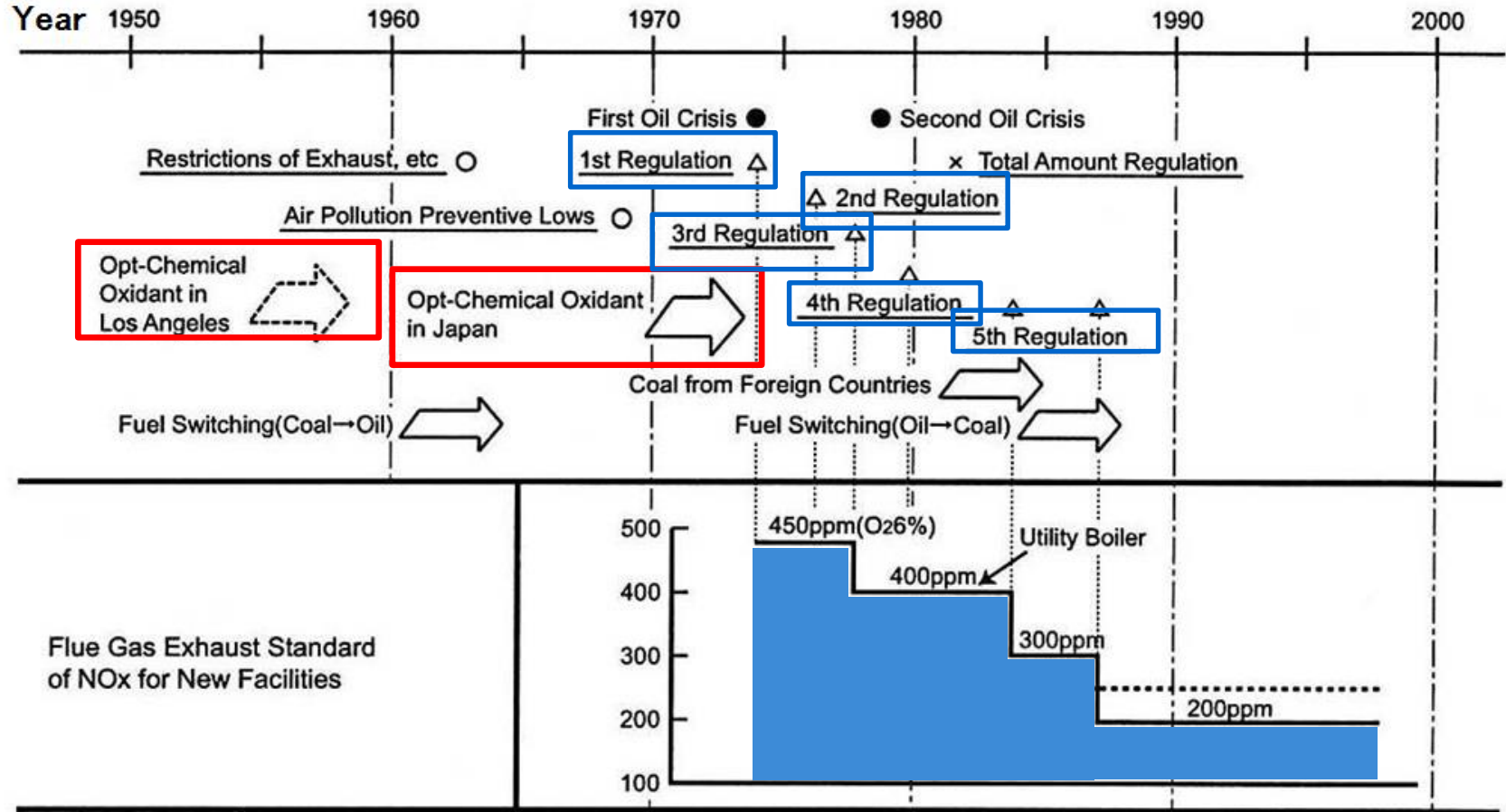


**De-SOx Facility**



**Electrostatic Precipitator**

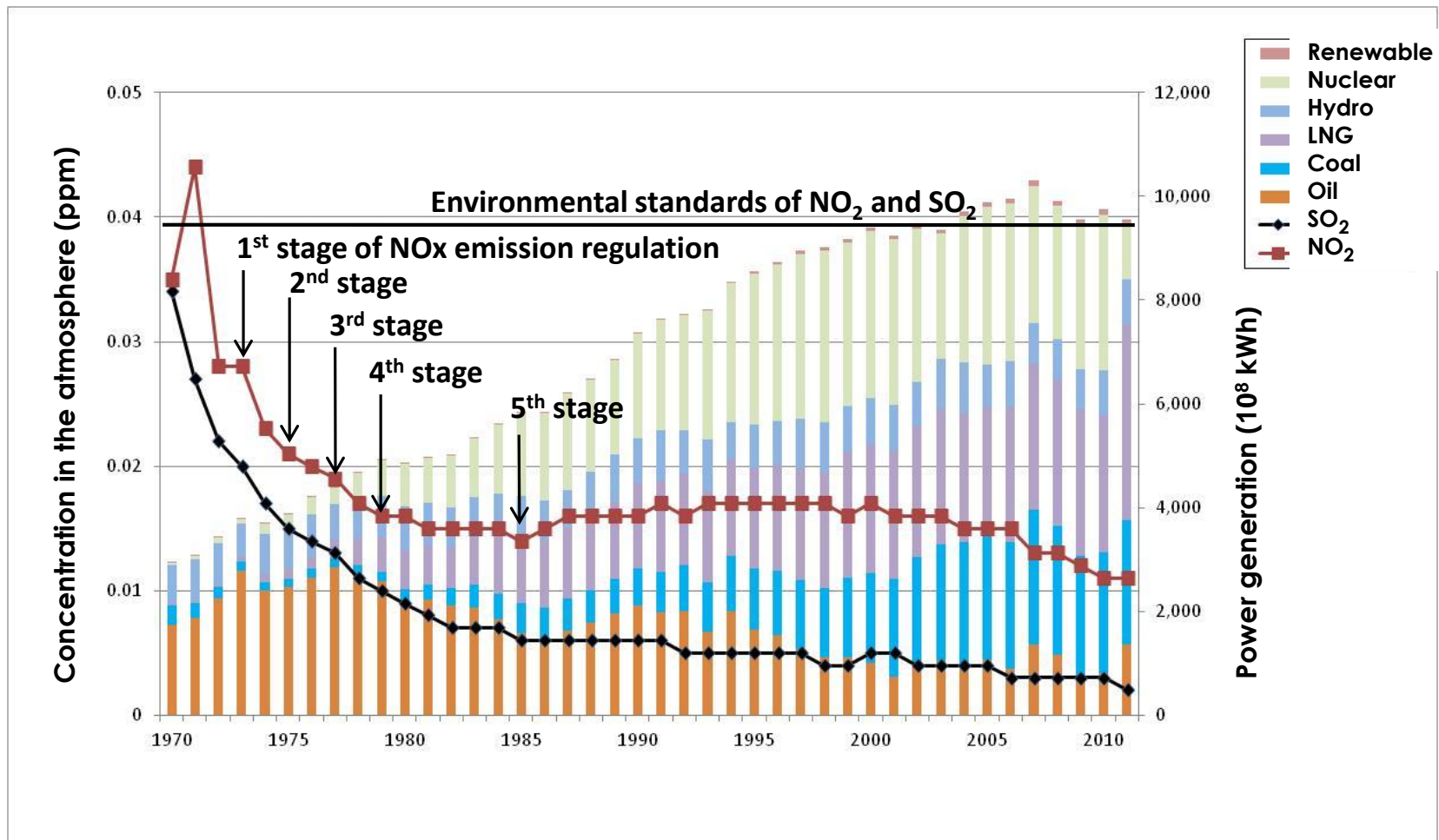
# Japanese History of NOx Regulation





# Environmental Monitoring of SO<sub>2</sub> and NO<sub>2</sub>

- Environmental protection for SO<sub>2</sub> emission from factories completed in 1970's
- Environmental protection for NO<sub>2</sub> emission from factories completed in 1980's



# Drastic Change of Air Pollution in Japan



**Tokyo industrial area 1955**



**Tokyo industrial area 1970**

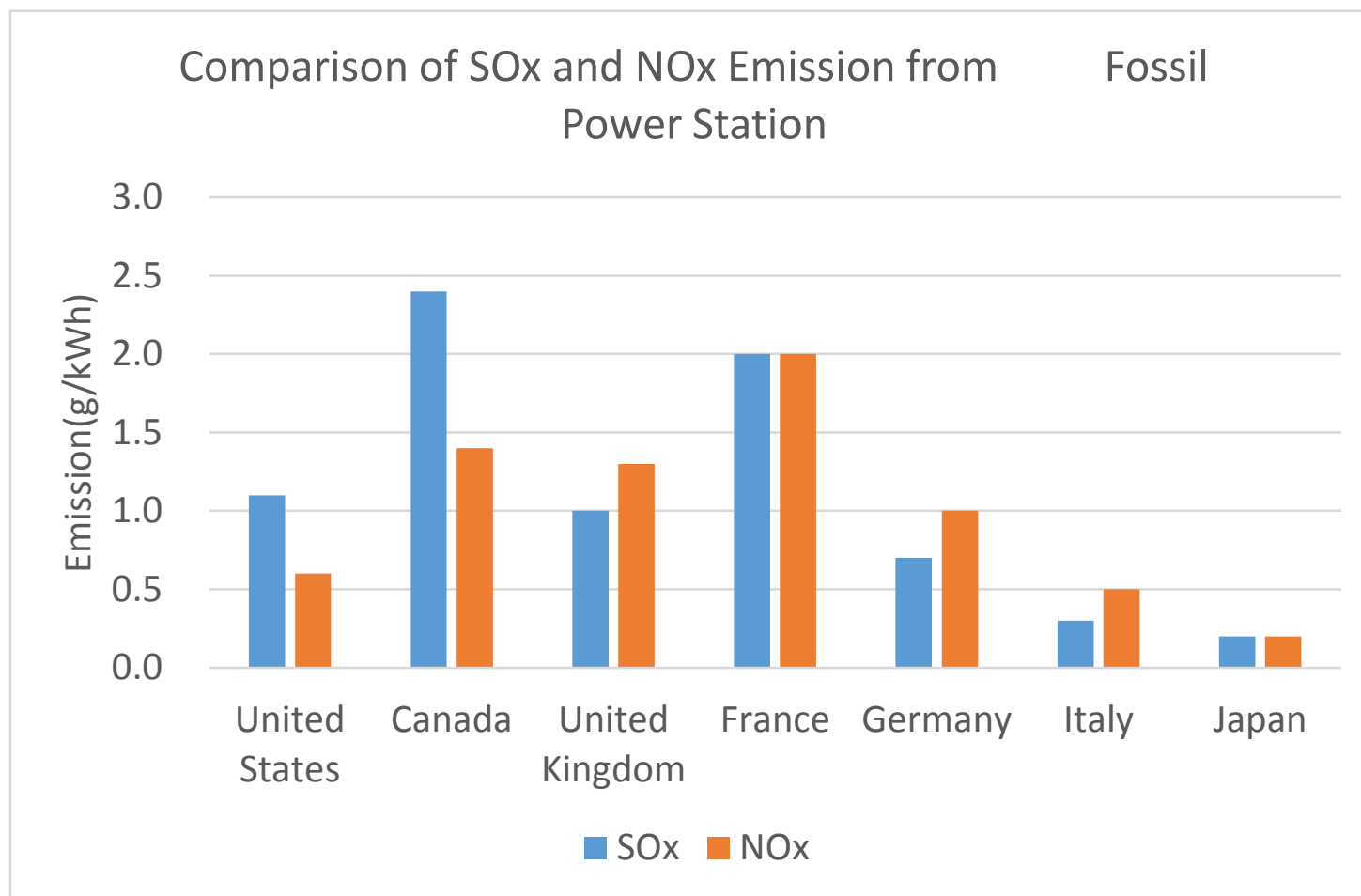


**Present Tokyo**

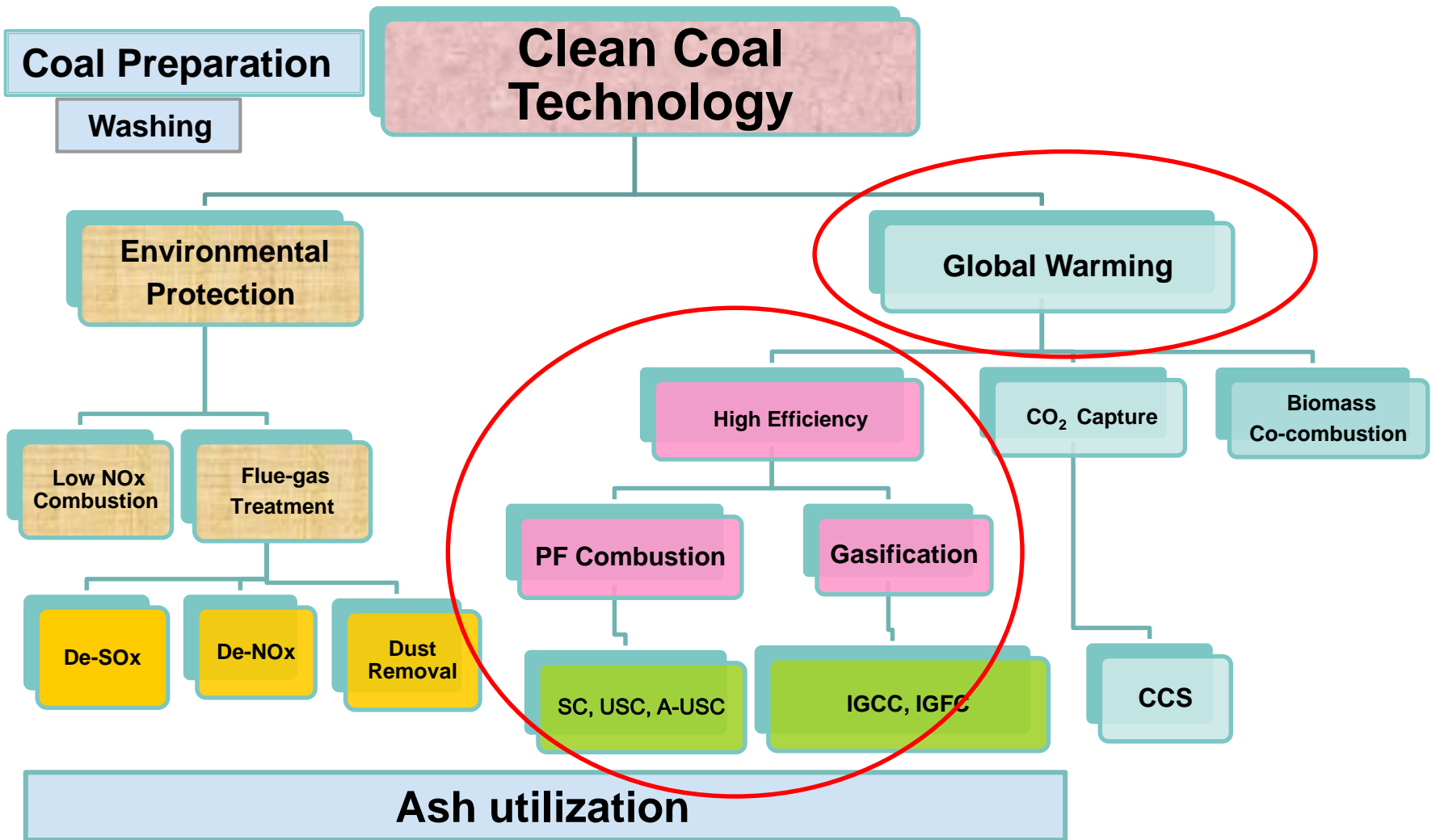


**Tokyo industrial area 1970**

# NOx and SOx emission levels in Power Generation by country



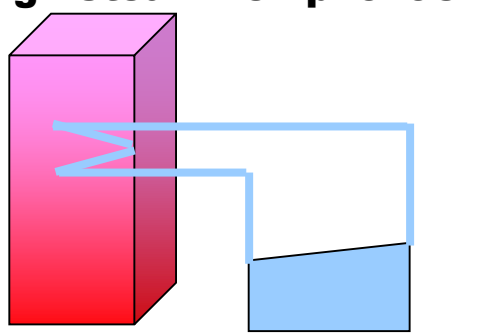
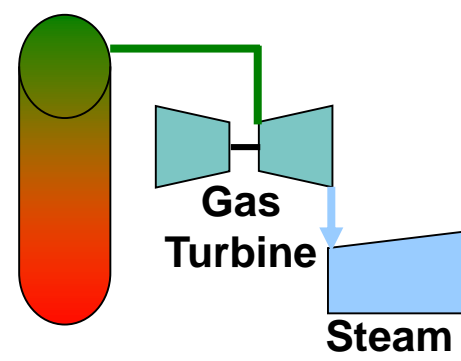
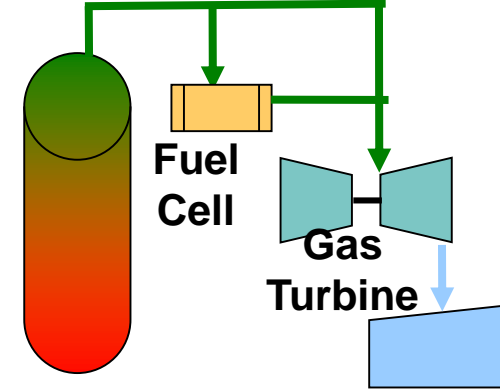
# 5. Global Warming



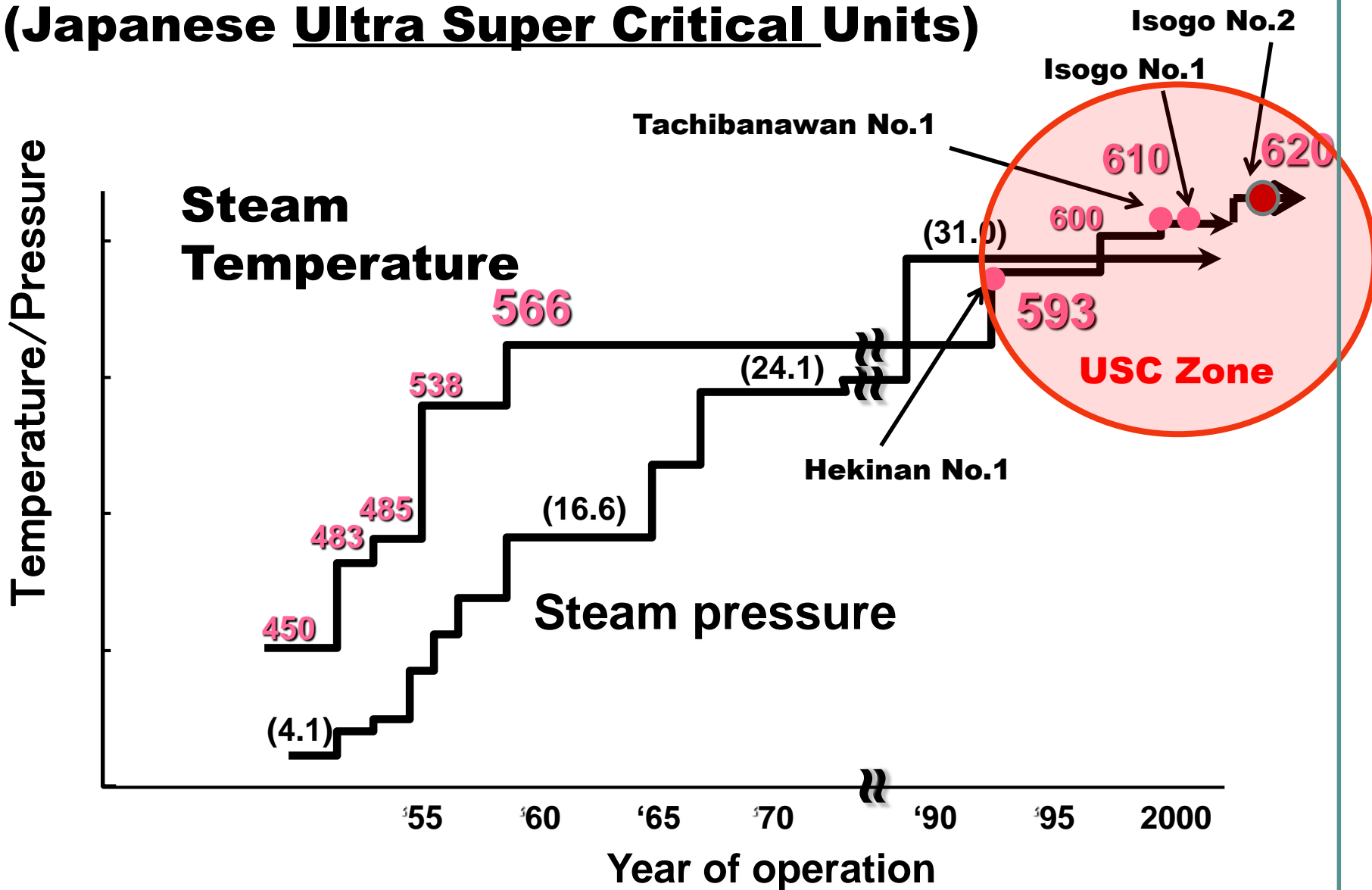
# 5.1 High Efficiency

## High-Efficient Coal Fired Power Generation

**Efficiency: HHV Basis**

Pulverized Coal (USC)	IGCC (1500C Class Gas Turbine)	IGFC
<p><b>High Steam Temp: 620C</b></p>  <p>Boiler      Steam Turbine</p>	 <p>Gasifier      Gas Turbine      Steam Turbine</p>	 <p>Gasifier      Fuel Cell      Gas Turbine      Steam Turbine</p>
<p>Gross Efficiency :44%</p> <p>Net Efficiency :41%</p> <p><b>Commercialized</b></p>	<p>Gross Efficiency :49%</p> <p>Net Efficiency :46%</p> <p><b>Commercialized</b></p>	<p>Gross Efficiency :60%</p> <p>Net Efficiency :54%</p> <p><b>Under Development</b></p>

# Steam Temperature Increase of Boiler (Japanese Ultra Super Critical Units)



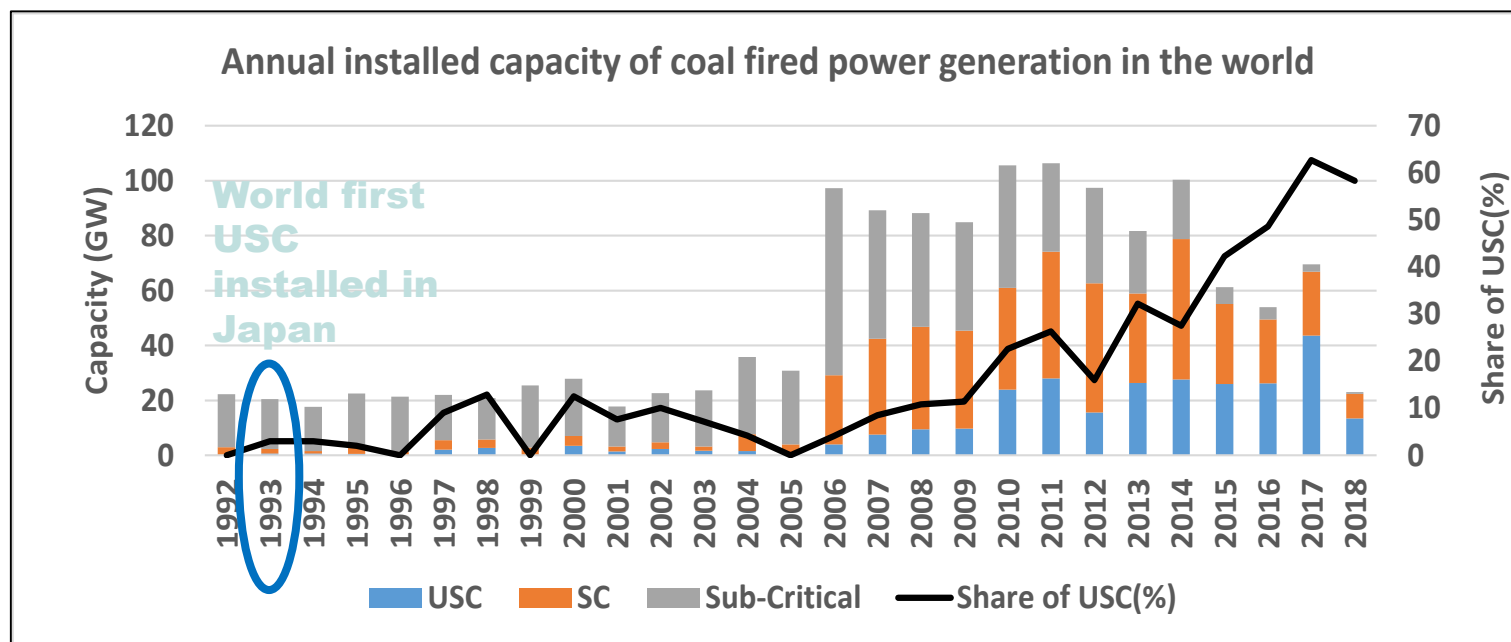
# **World Highest Efficient Coal fired Power Station ---Isogo No.2 600MW 600/620C USC (Japan)---**



**Efficiency :**  
**Gross 44%**  
**Net 41%**  
**(HHV Basis)**

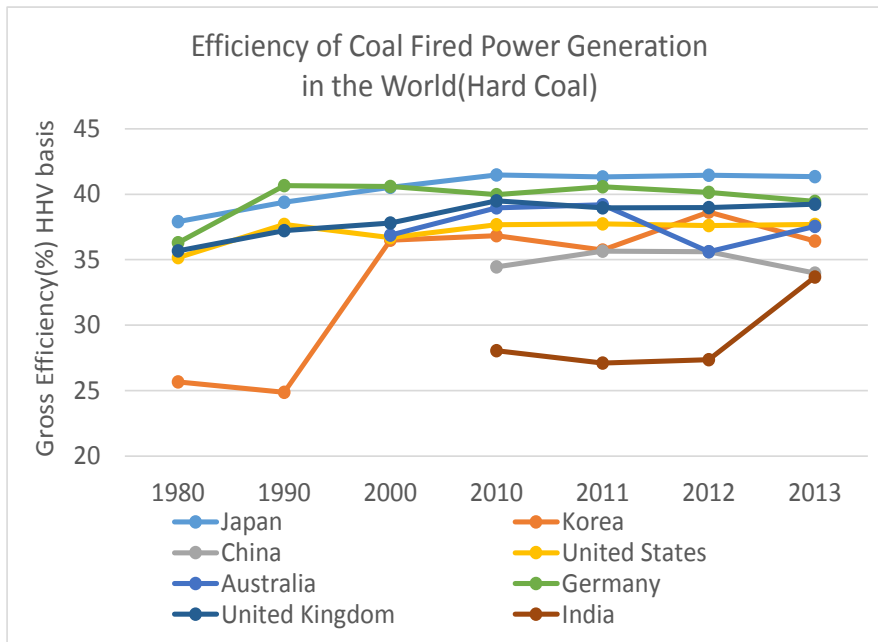
# Installation of USC in the World

- **First Ultra Super Critical Unit (USC) was installed in Japan in 1993.**  
**Since then, USC is increasing RAPIDLY and Super-Critical and Sub-Critical units are decreasing.**
- **60% of recent installation is USC in the world.**  
**SC is less than 10% and Sub-Critical is small number.**
- **Countries where USC were already operated:-**  
**Japan, Germany, Italy, Poland, Czech Republic, Netherland, Slovenia, USA, China, Korea, Taiwan, Malaysia,**
- **Countries where USC is planned:-**  
**Greece, Indonesia, India, Philippines, Morocco, Vietnam**

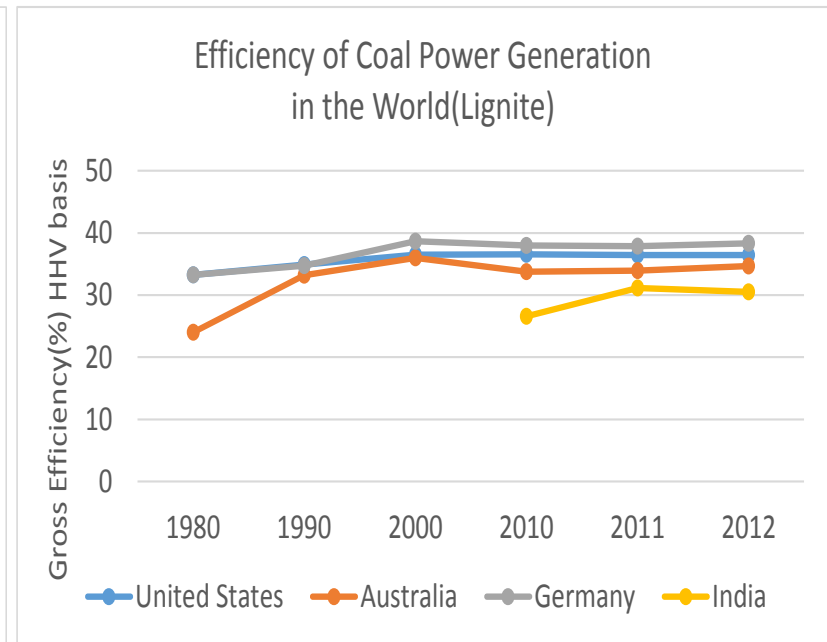




# Efficiency of Coal Power Generation of Various Countries (HHV, Gross)



Hard Coal

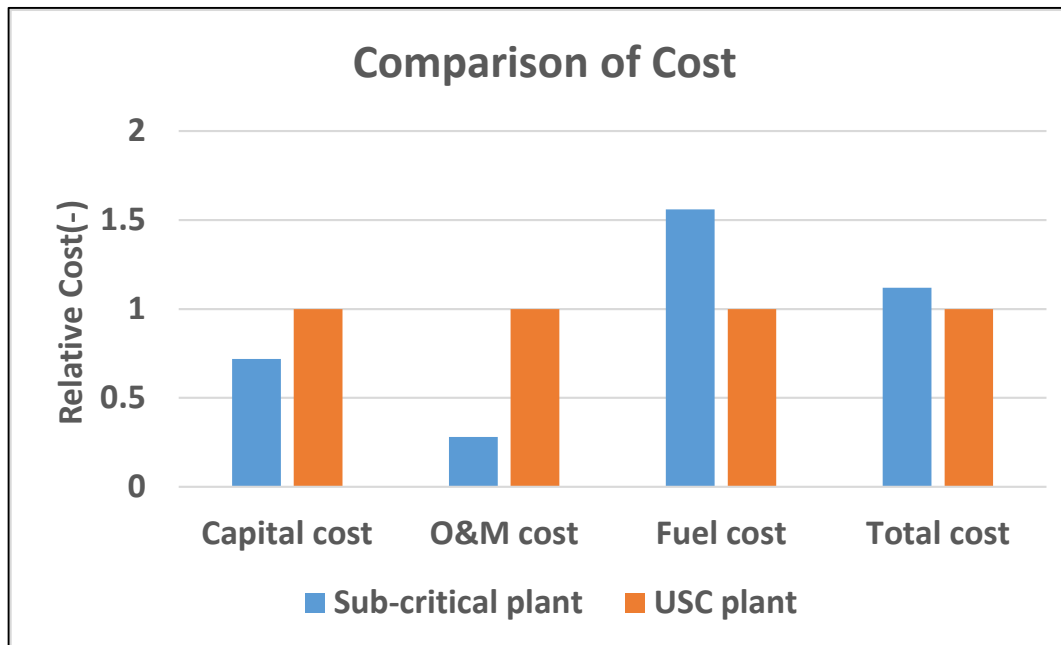


Lignite

# Life Cycle Cost of USC

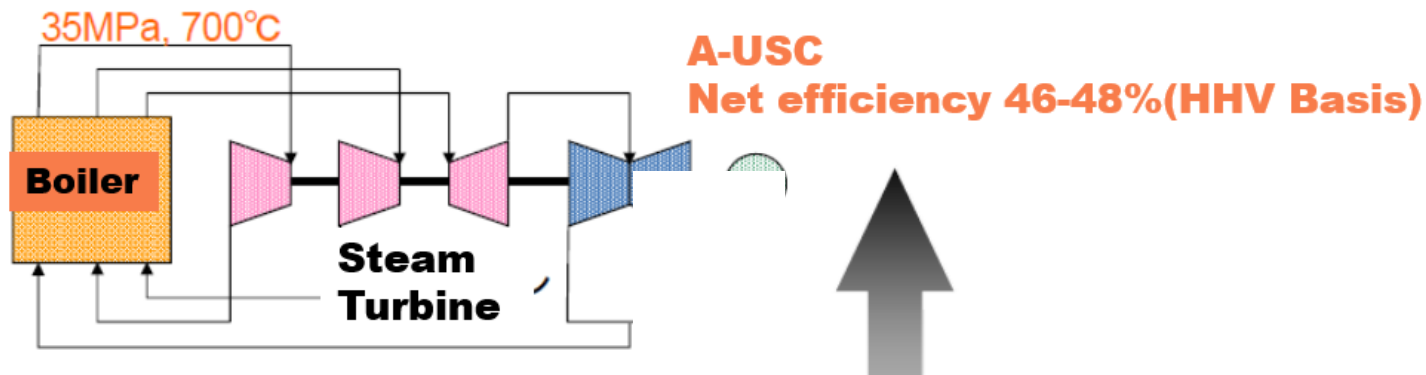
- **Total cost of USC is smaller when compared with Sub-Critical unit, when studied about the case in developing country.**
- **Conditions of estimation:-**

	Net thermal efficiency	Load factor	Data source
USC	0.4	0.8	CRIEPI
Sub-Critical	0.26	0.73	ECOFYS 2013



# Advanced USC (A-USC)

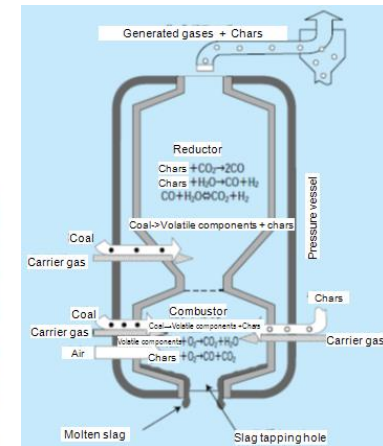
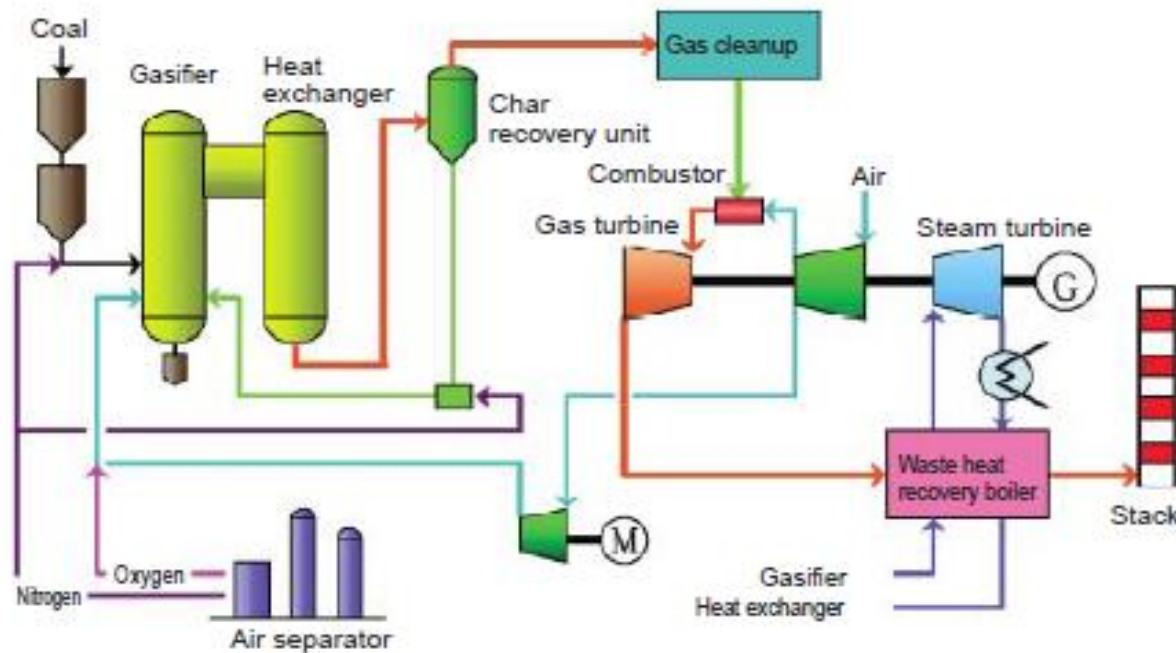
- **Japan 2012**  
700 degree C, 500MW Class



- **India 2011**  
700 degree C, 800MW
- **EU 2021**  
700 degree C, 540MW
- **USA 2021**  
760 degree C 35MPa Developed by NETL
- **China 2011**  
700 degree C, Double Reheat

# System flow of IGCC

## (Nakoso 250 MW IGCC)



### New IGCC (Website)

- **Osaki CoolGen 170MW : Operation: 2017**
- **Nakoso About 540MW : Start of construction 2016(Planned)  
Start of operation Early 2020(Planned)**
- **Hirono About 540MW : Start of construction 2016(Planned)  
Start of operation Early 2020(Planned)**

# Development of IGCC

## Japanese IGCC

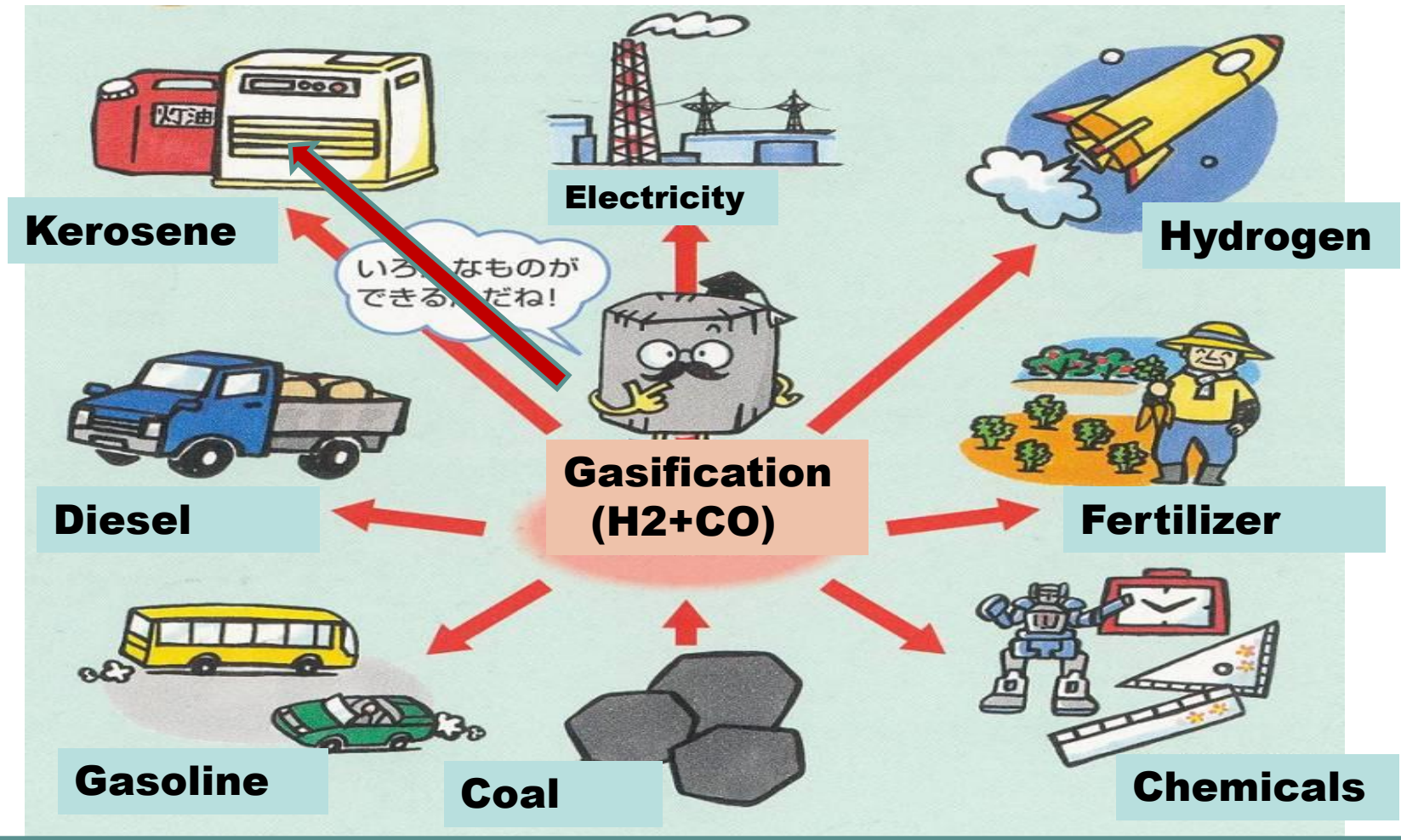
- **Nakoso NO.10 : 250MW**  
**Commercial Operation : April 2013**
- **Osaki CoolGen : 170MW**  
**Operation: 2017**

## New IGCC plan(Website of Nakoso and Hirono)

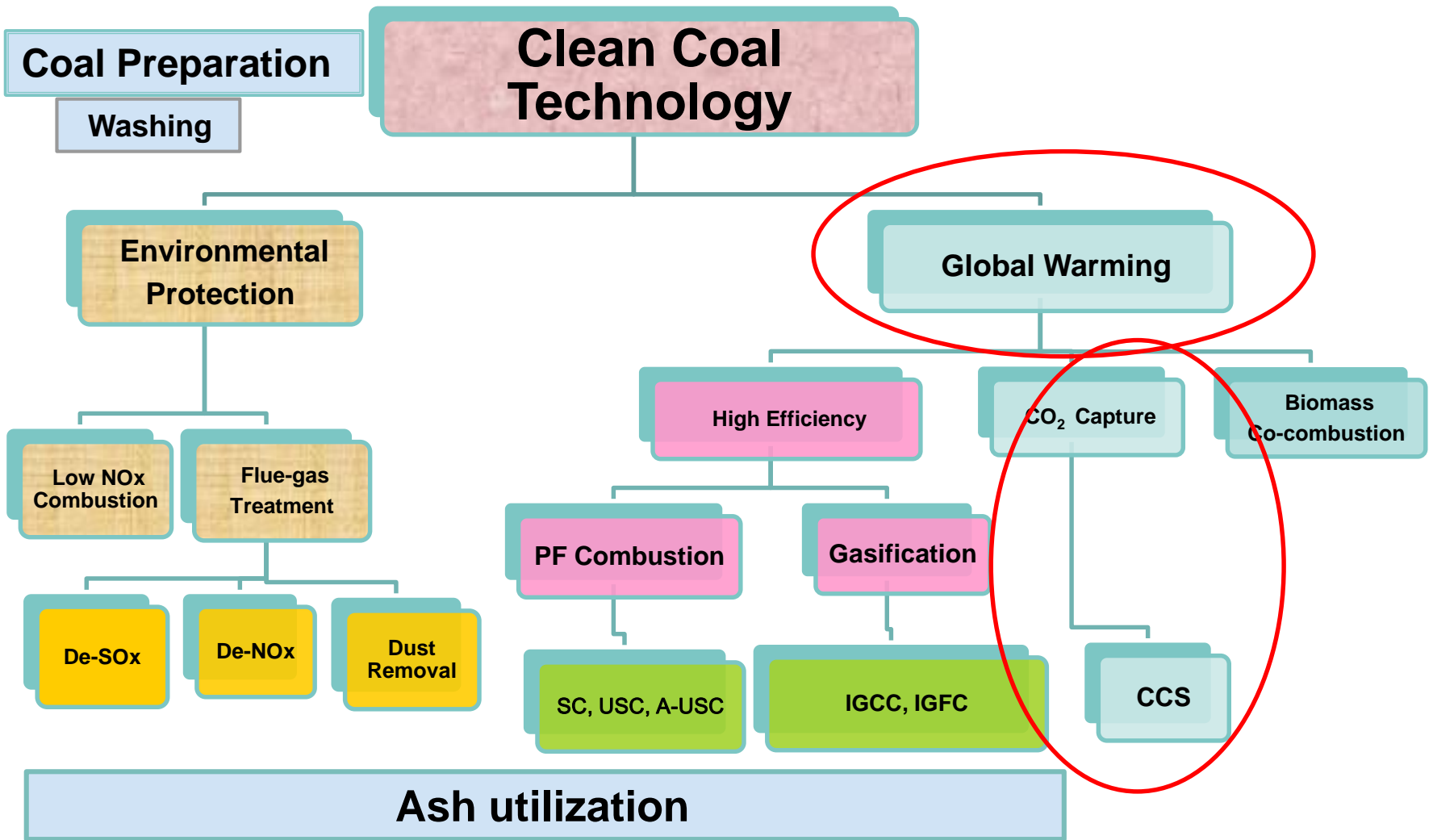
- **Osaki CoolGen 170MW : Operation: 2017**
- **Nakoso About 540MW : Start of construction 2016(Planned)**  
**Start of operation Early 2020(Planned)**
- **Hirono About 540MW : Start of construction 2016(Planned)**  
**Start of operation Early 2020(Planned)**

# Reference

## Produce Chemicals from Coal Gasification

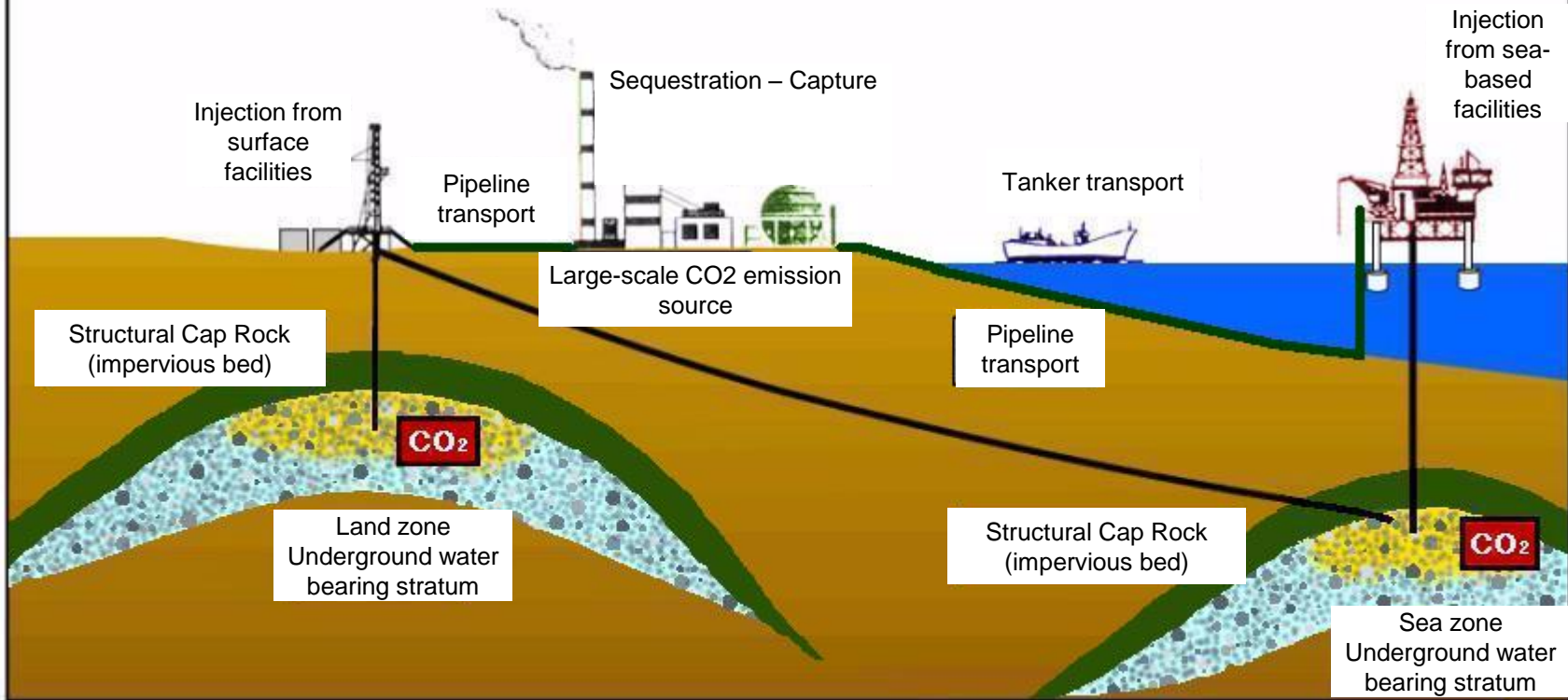


# 5.2 Carbon Capture and Storage



CCS 2020

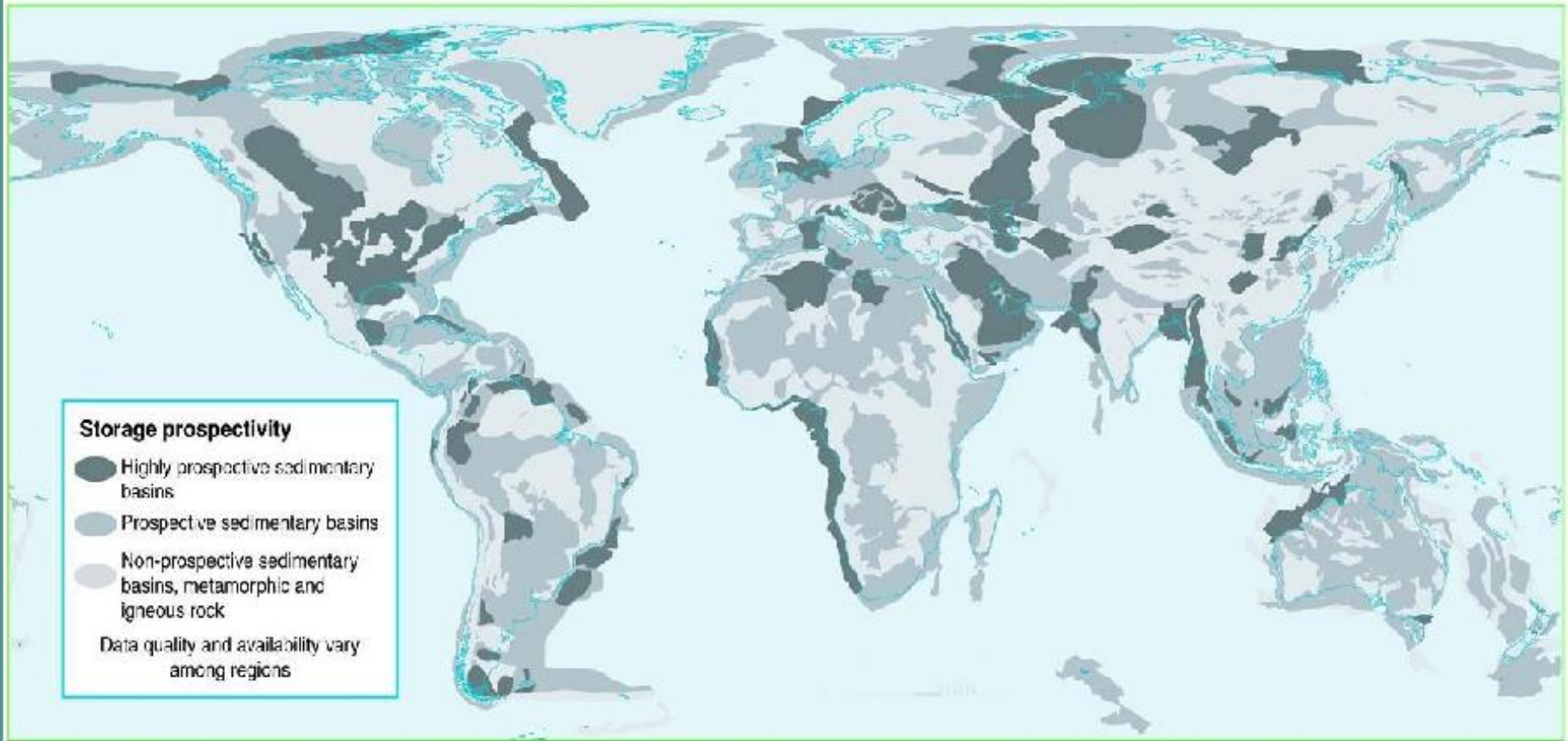
## No less important is “High Efficient Power Generation + CCS”





# Distribution of Storage Capacity (IPCC Special Report)

Prospective areas in sedimentary basins where suitable saline formations, oil or gas fields, or coal beds may be found.



# CO<sub>2</sub> Injection Point



**Sleipner**



**Snøhvit**



**Weyburn**



**In-Salah**

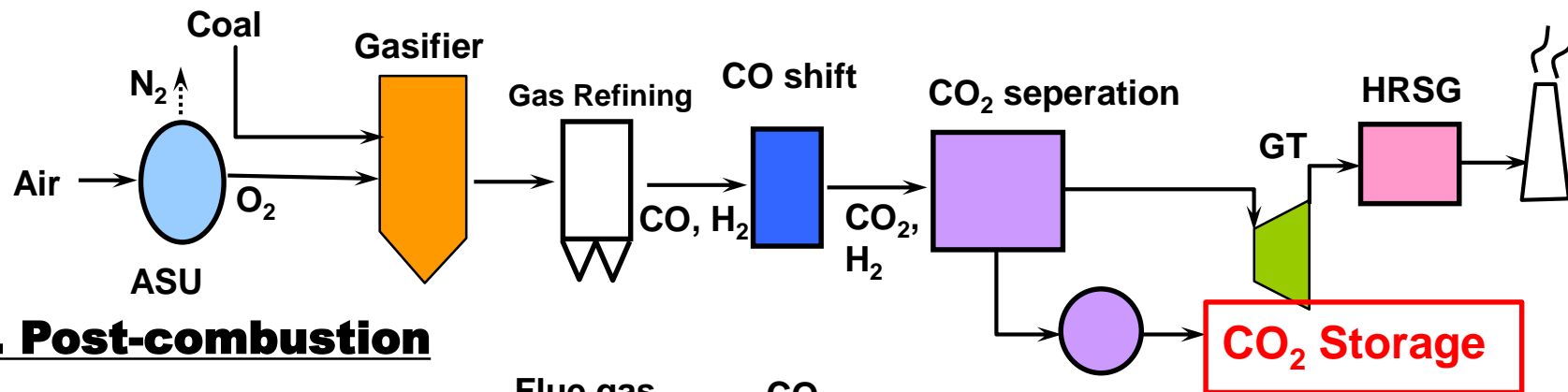
**(CO<sub>2</sub> from Coal Gasification)**



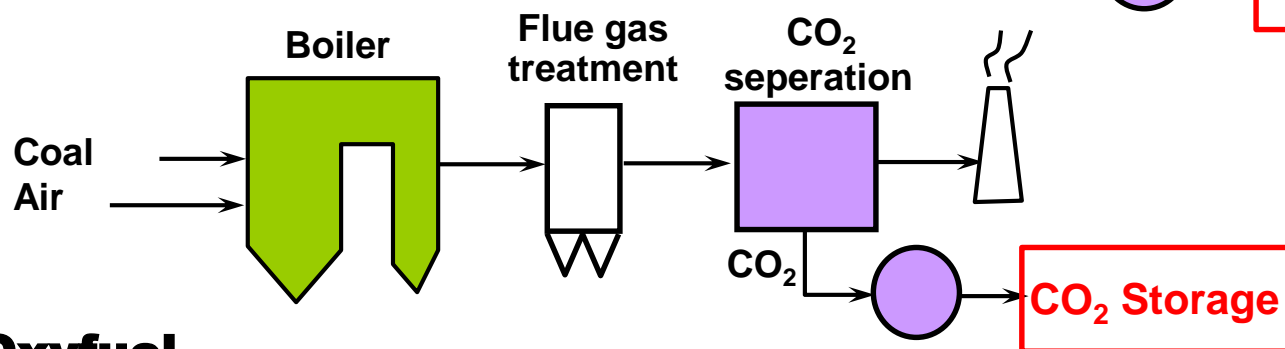
**SaskPower  
Boundary Dam (CO<sub>2</sub> from Coal firing)**

# CO<sub>2</sub> Capture from Coal-fired Power Plant

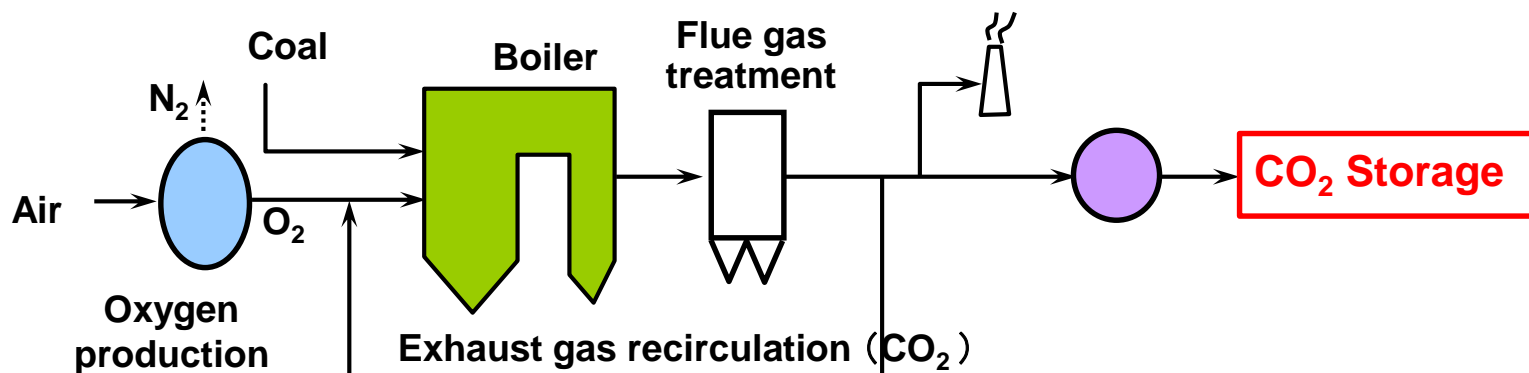
## 1. Pre-combustion



## 2. Post-combustion



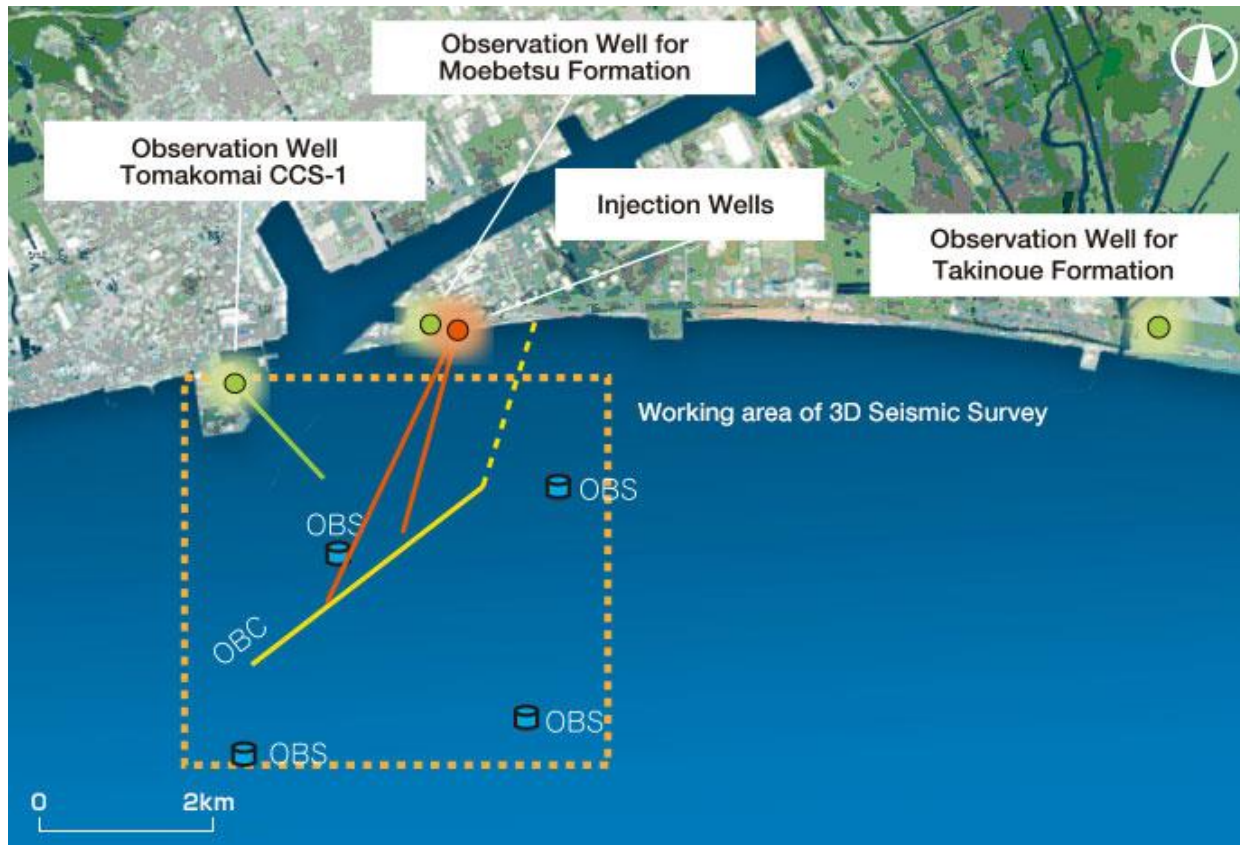
## 3. Oxyfuel



# Japanese CCS Demonstration Project

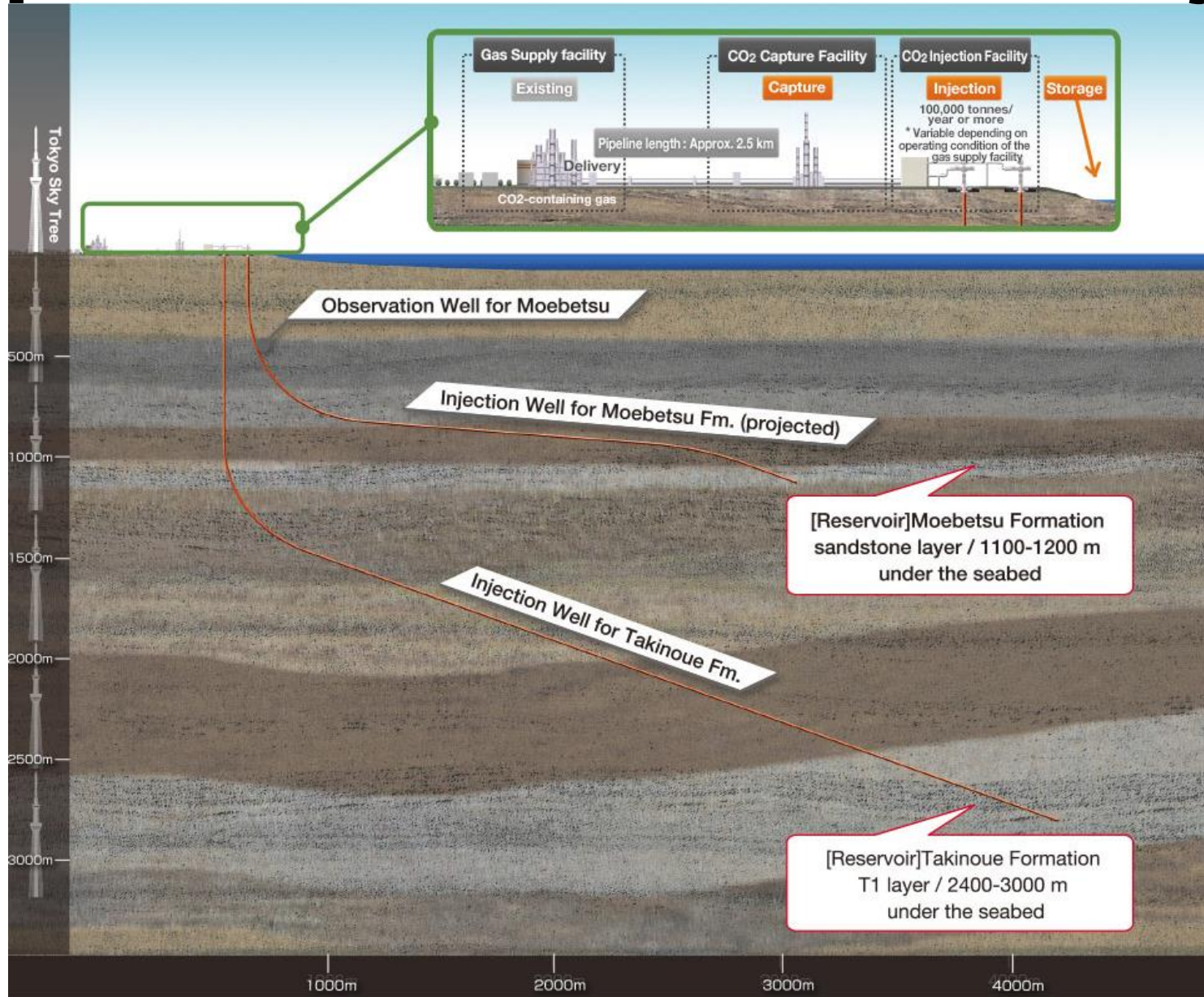
- **Place: Tomakomai(Japan)**
- **Injection capacity : 0.1Mt-CO<sub>2</sub>/year**
- **Schedule : Project start 2008**

**Injection 2016-2018**

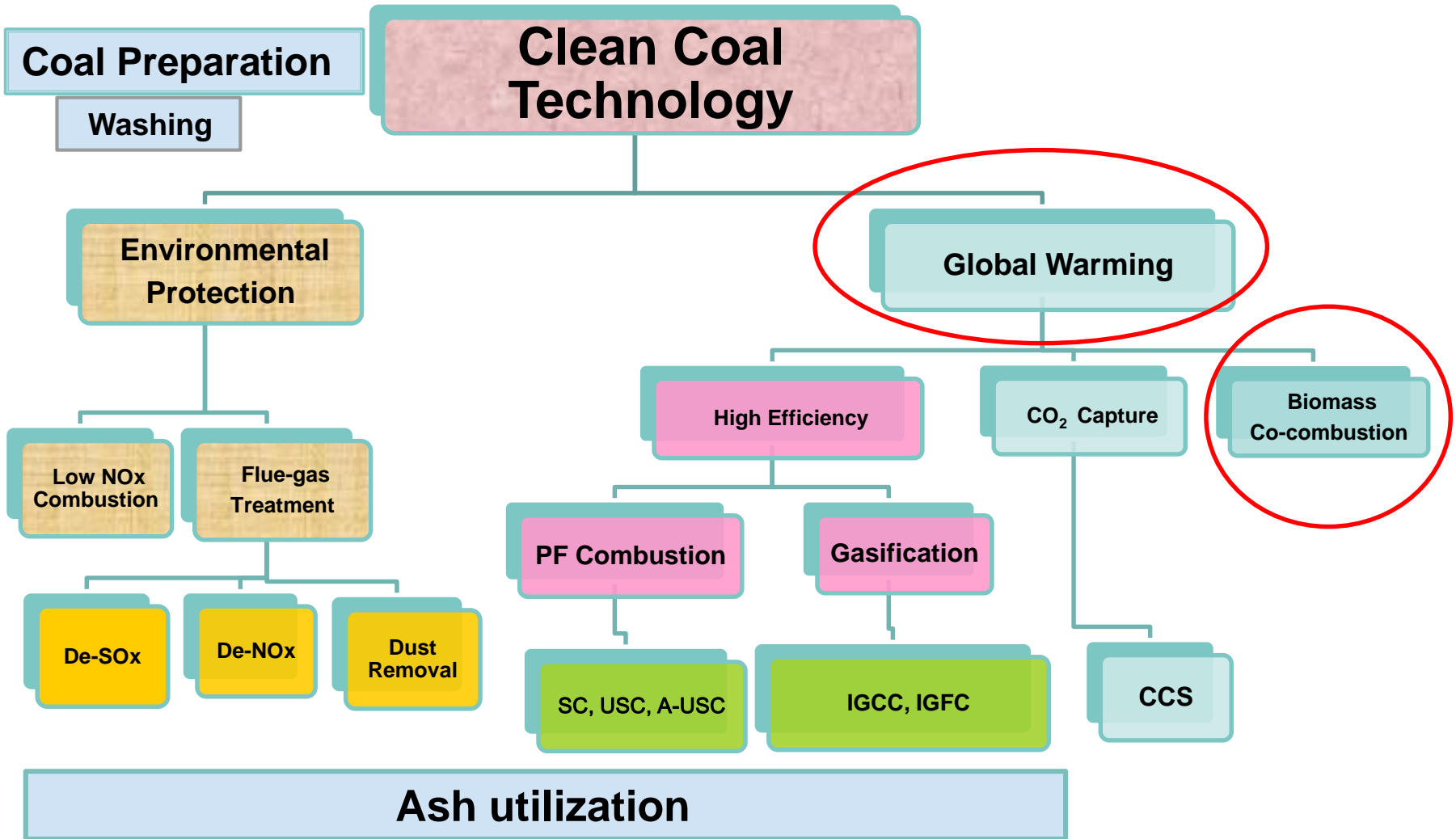


**Tomakomai CCS Website**

# Japanese CCS Demonstration Project



# 5.3 Biomass Co-combustion



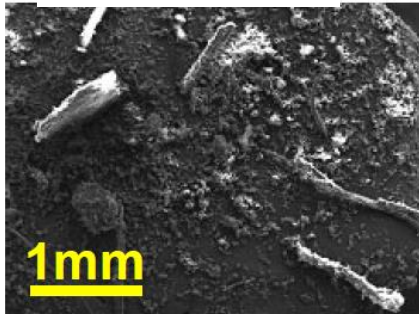
# Pulverization Biomass with Coal

## SEM



## Pulverization coal/biomass

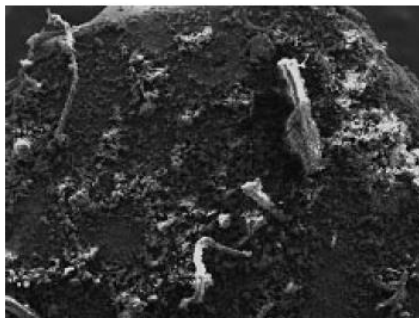
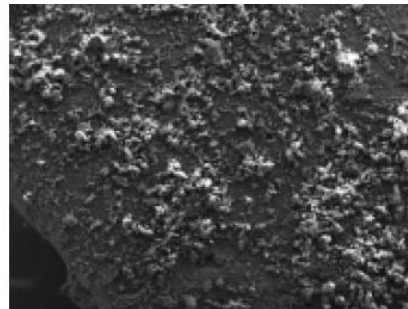
**Cedar bark**



**Pine tree bark**



**Newlands coal**

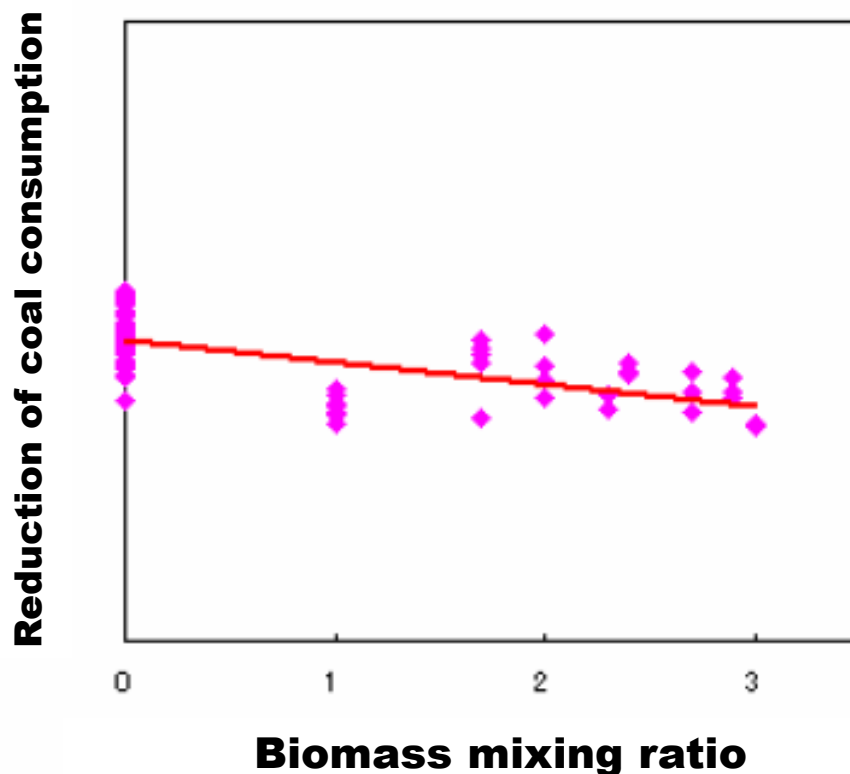


**Cedar chip**



**Saw dust of pine tree**

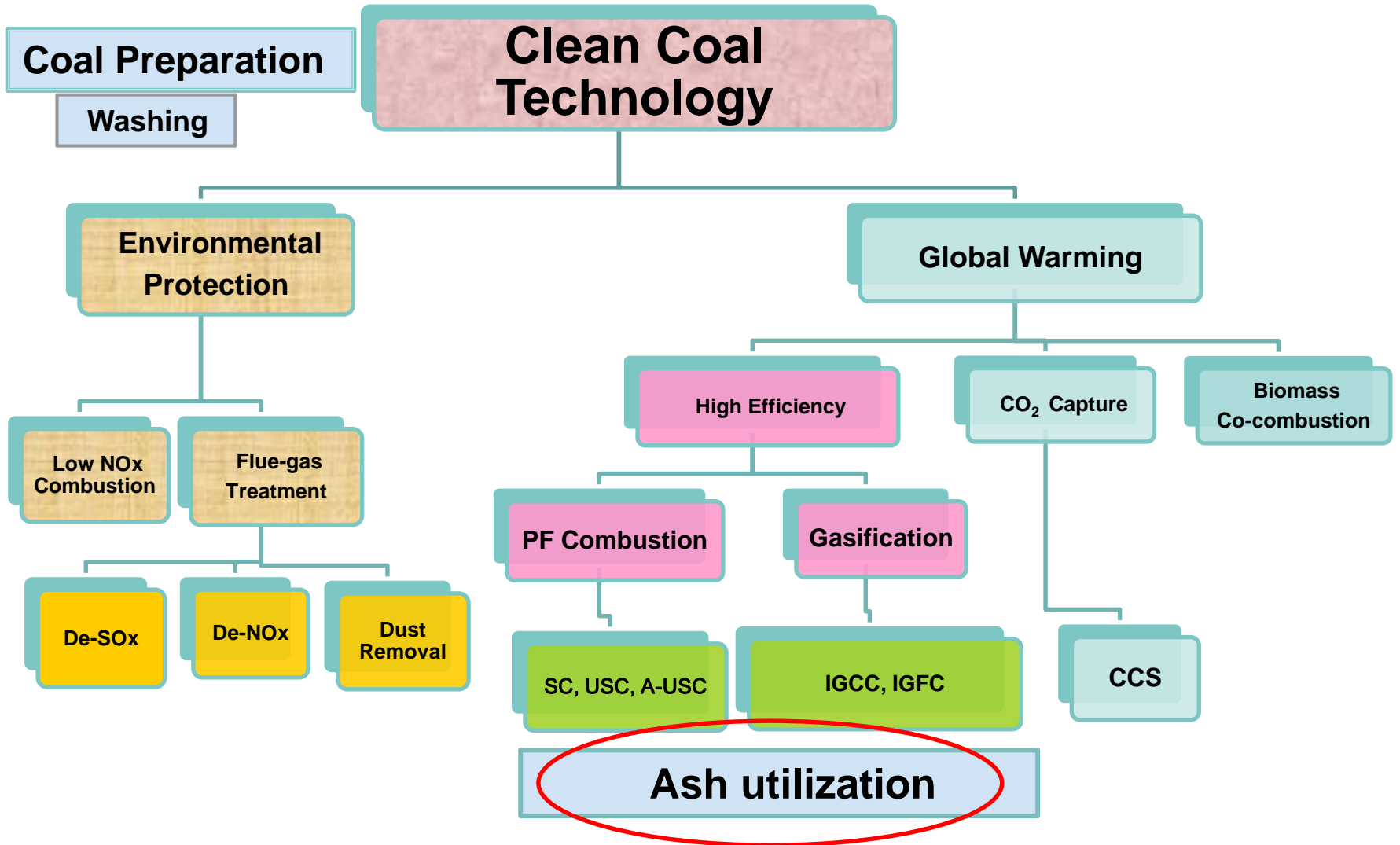
# Reduction of Coal Consumption with Biomass mixing



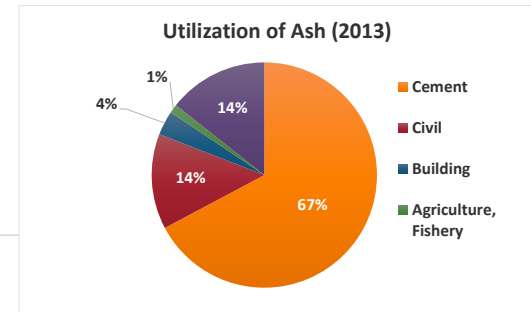
**Coal technology conference(Shikoku Power)**



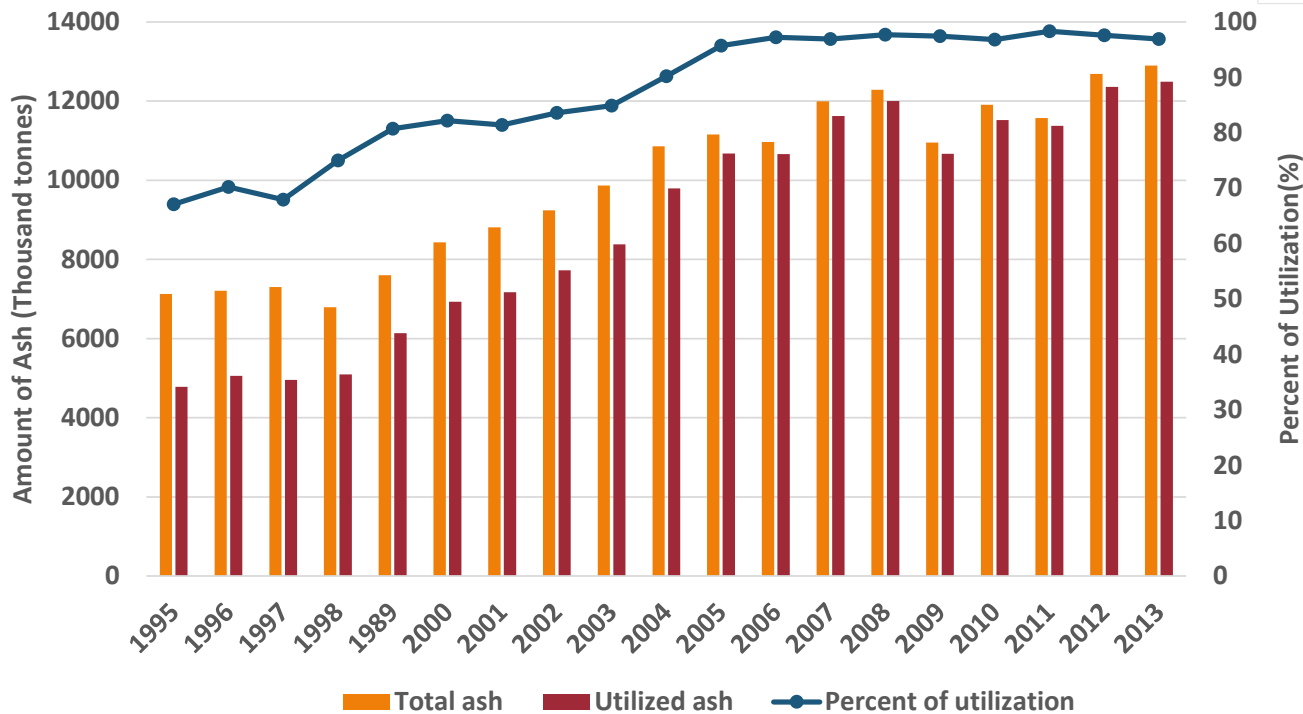
# 6. Utilization of Coal Ash



# Amount and Utilization of Ash from Boiler in Japan



Utilization of Ash from Power Stations

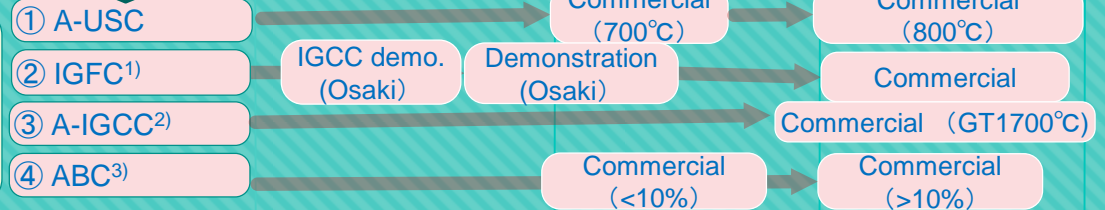


# 7. Japanese Roadmap of Clean Coal Technology R&D

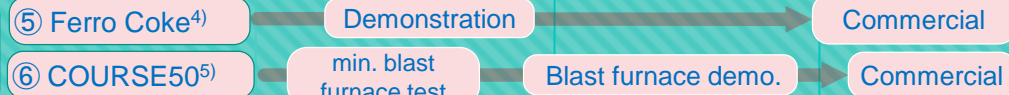


High efficiency and low carbon

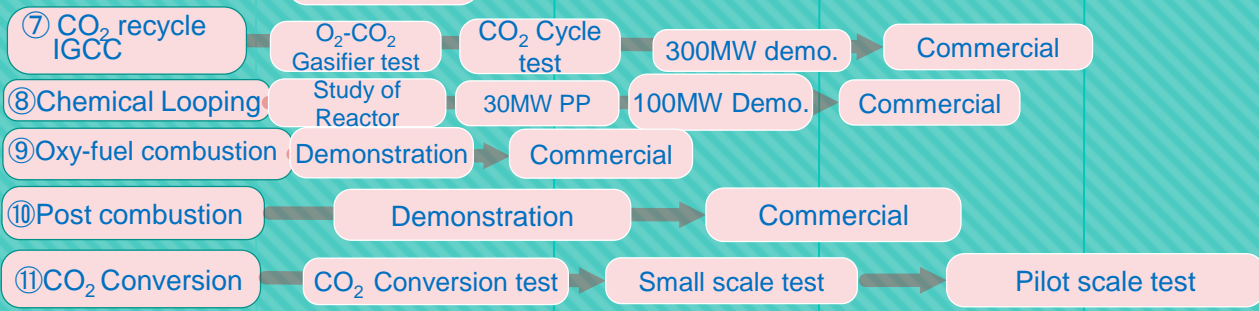
Power generation



Steel Industry

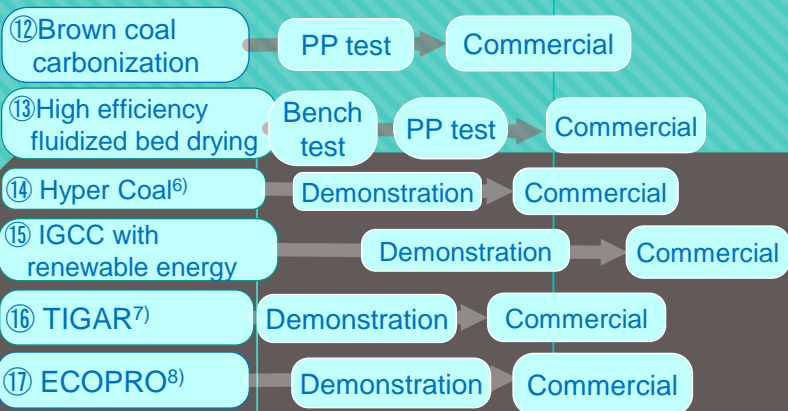


CO2 capture



Low rank coal utilization

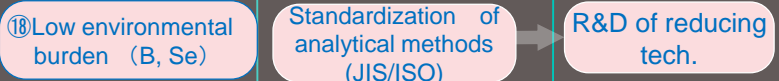
Upgrading



Industrial use

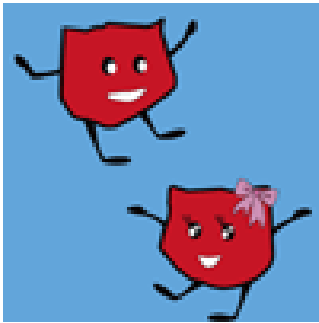
Environmental protection

Low environmental burden



## 8. Lastly-----

- **Coal should be used as a main fuel in the future.**
- **Especially, non-OECD countries will use more coal for their economic growth than OECD countries.**
- **However, consideration should be paid to reduce air pollution and CO<sub>2</sub> emission in order to continue using coals.**
- **Now, Clean Coal Technology is essential.**
- **Japan will contribute in the world for use of clean and high efficient coal power generation.**



**Thank you  
for your attention.**

