The technology development and perspective of clean coal in Taiwan

Jan 16th, 2007

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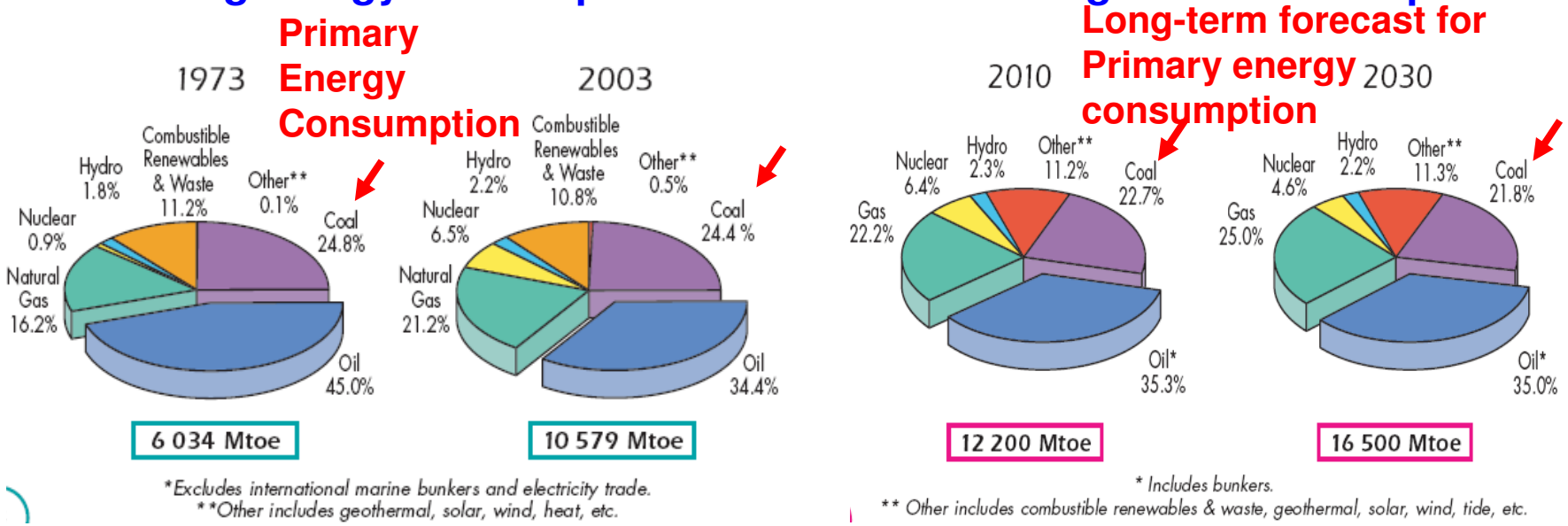
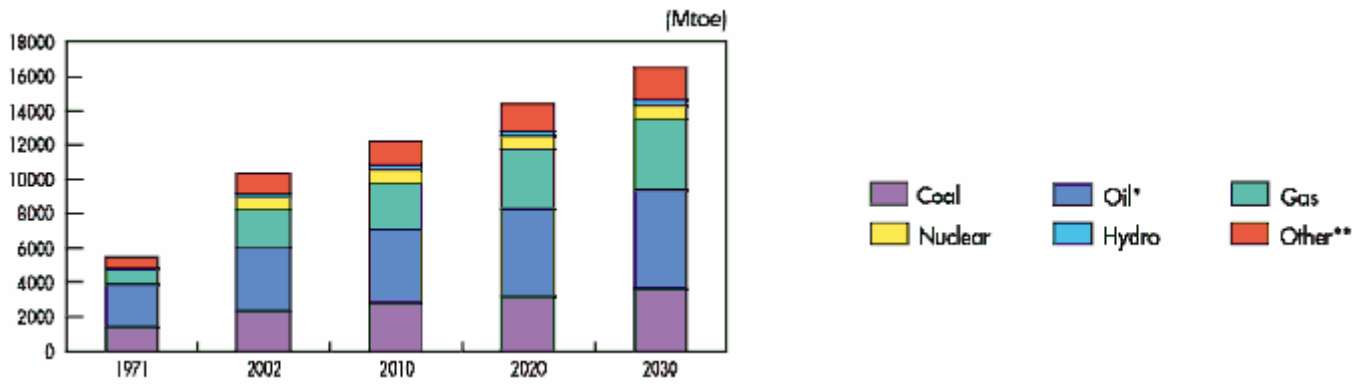
1.International coal usage—World Primary Energy supply

■Coal consumption increase %. It is not a significant increase, however, increasing energy consumption will still result in large coal consumption.





Source：Key World Energy Statistics 2005, IEA

1.International coal usage—international energy technology development

1 International power generating technology long-term development forecast

❖Business As Usual (BAU)

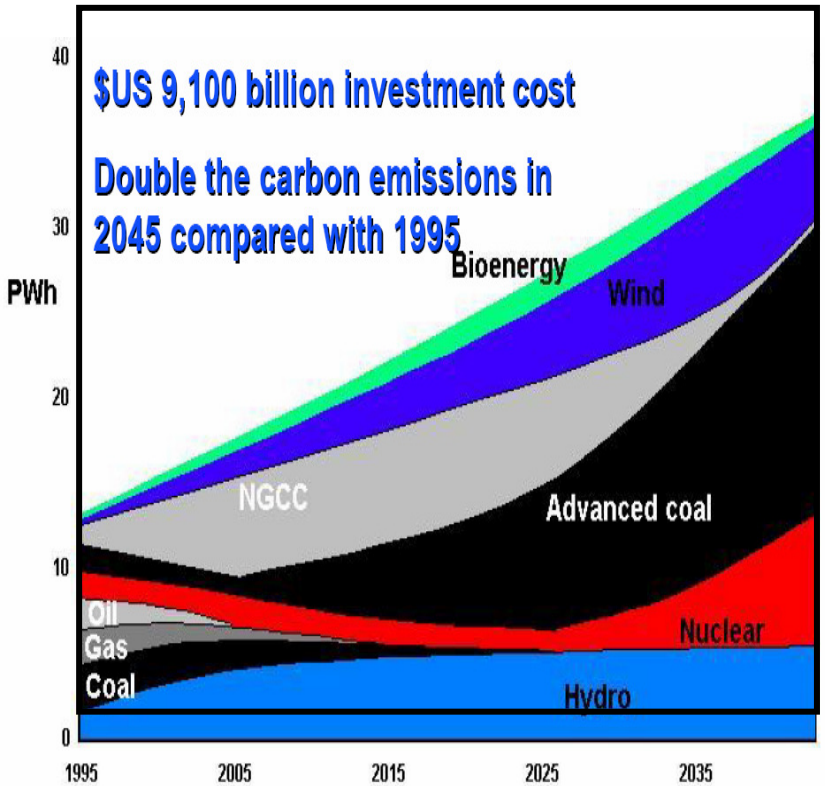
❖Potential energy technology in 2045 (Power generation percentage)

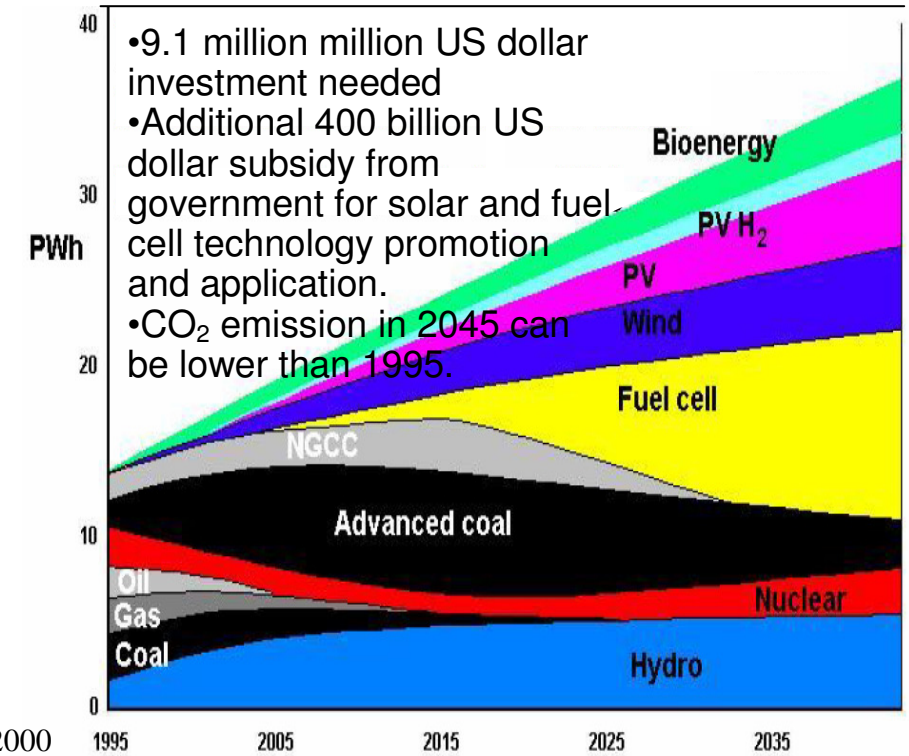
- **Advanced Coal (45.8%)**
- **Nuclear (20.3%)**
- **Hydro (15.5%)**
- **Wind (14.8%)**
- **Bioenergy (2.4%)**
- **NGCC (1.2%)**

❖Scenario analysis when actively developing various new energy technology

❖Potential energy technology in 2045 (Power generation percentage)

- **Fuel Cell (30.1%)**
- **PV+PVH$_2$ (18.1%)**
- Hydro (14.5%)
- Wind (13.3%)
- Bioenergy (8.4%)
- Advanced Coal (8.4%)
- Nuclear (7.2%)



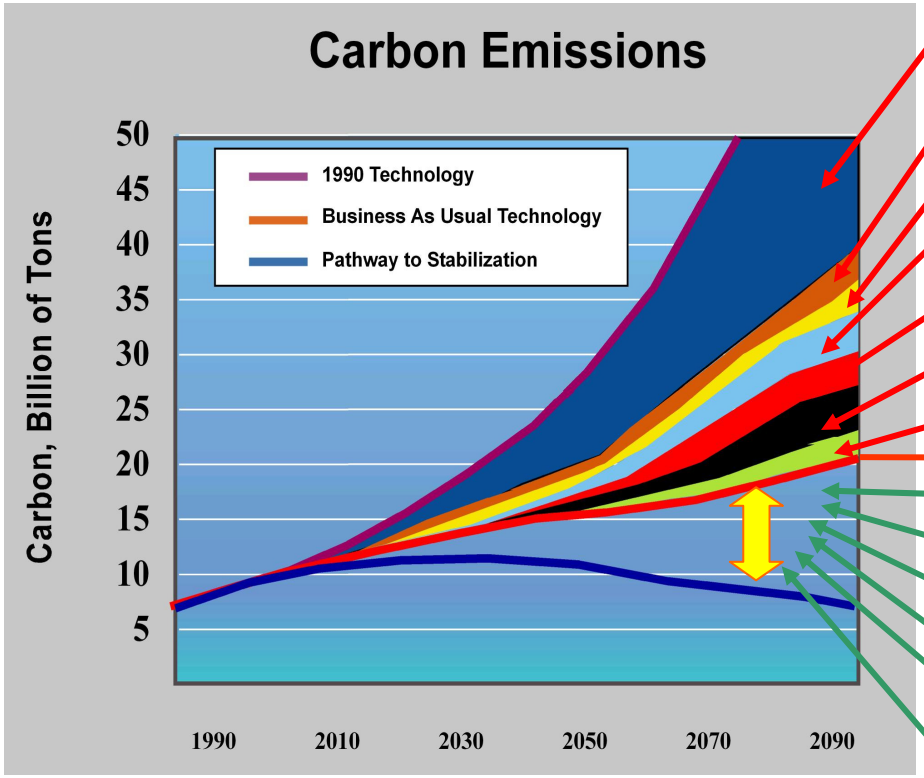


Source：Experience Curves For Energy Technology Policy, IEA2000

1.International coal usage—international energy technology development

2 Technology development regarding global CO2 emission reduction

- Energy related new technology development and untilization play a key role regarding to GHG reduction.
- Improving energy saving, renewable energy and clean energy technology based on BAU.
- Need further innovation and advanced technology to stablized into 550 ppm



Improving energy efficiency and lower demands (energy saving lighting/air-conditioning/building energy saving/transportation energy saving)

Promote and improve solar energy conversion efficiency

Promote wind power

Increase nuclear power

Increase Natural gas power

Promote Clean Coal Technology

Promote Biomass energy utilization

Research and promote advanced biomass energy utilization

Research and promote CO_2 capture and storage

Fossil fuel with CO_2 treatment and hydrogen power utilization

Conduct advanced nuclear power generation

Improving solar/wind power utilization rate

Highly improving technology and increase energy efficiency and lower demands (LED lighting/advanced air-con/building integrated design…)

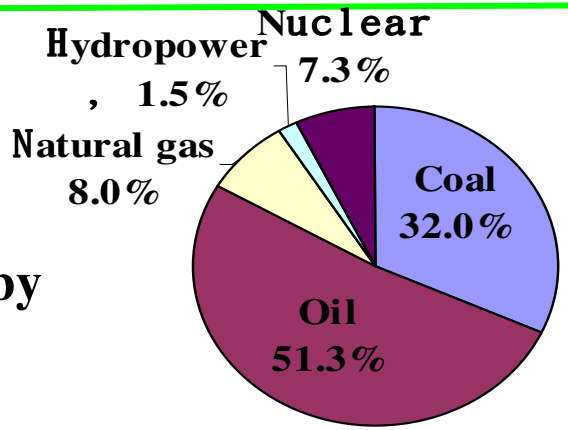
BAU

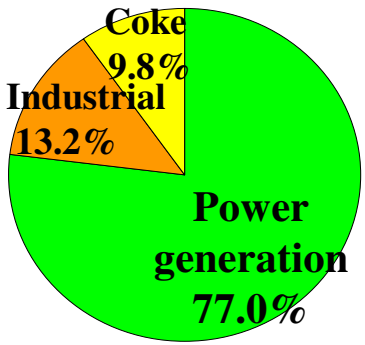
STG

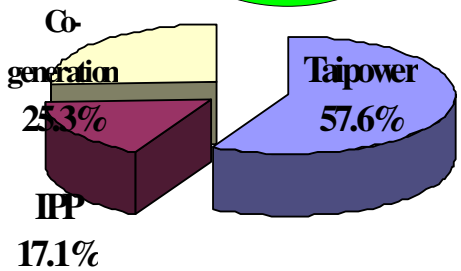
Source： Battelle, APEC Workshops 2004

2.Coal Usage in Taiwan

- **Coal usage was 32% among total energy consumption (Oil:51.3%，Gas:8%，hydro:1.5%，nuclear:7.3%)**
- **Increasing consumption, almost 60,000,000 tons by the year of 2005:**
  - 86.6% Coal→fuel ； 13.4% Coal→material
  - 77% were mainly utilized on power generation
- **Power was mainly from coal-fired in 2005**
  - Installed capacity reached 43,121 MW, coal-fired accounted for 27.2%(not including 7,014MW from cogeneration)
  - Coal-fired accounted for 38.6% of actual power generation (not including18.7% from cogeneration)
- **New installed capacity construction plan**
  - Expected new installed capacity about 26,202MW, 10,700MW will be coal-fired plant, accounts for 40.8%
  - Coal-fired plant reach 46~47% in 2020 and 48~50% in 2025.







Coal usage comparison between power sectors

Source: Energy statistics-monthly report, BOE, 2006 Mar

3.International clean coal technology development

-Scope and major development of clean coal technology

Clean coal technology

Combustion pollution control

- Particulates—Particulates removal technologies(Electrostatic Precipitator、Baghouse removal efficiency have reached=99.5%), mature technologies.
- SO_2—Flue Gas Desulfurization (Efficiency has reached 95%, have technical ablility domestically), mature technology.
- NOx—SCR (efficiency has reached 90%, capable to design and construct domestically), mature technology.
- Heavy Metal(Hg)— under development

Industrial application

- Steel and iron industry— Produce CO as reducing agent through gasification technology, syngas can be used as fuel substitute.
- Petrochemical industry— Produce chemicals
- Industrial part gasification plant— Produce CO、H_2 through gasification to provide clean and low cost syngas.
  - —Directly used as fuel, replace NG and fuel oil.
  - —Co-generation
  - —Transferring methanol or hydoren fuel

Fuel switch

CO_2 reduction

- Existing unit: efficiency increase 1~2%
- Mixing biomass to reduce about 5%
- Replacing old plant to reduce about 10~20%

CO_2 reduction and capture

CO_2 capture

- After combustion —CO_2 can be absorbed chemically (MEA) and physically which are both financially matured.
- Before combustion —Gasification, CO_2 are 40~60%, capture cost are lower. If integrated with H2 generation process, can produce >90%CO_2 through PSA or membrane separation.
- Oxygen-rich Combustion—directly produce >90% CO_2, under development internationally, high difficulty.

High efficiency power generation

- Super critical pulverized coal combustion(SC)—246~250bar/600℃/610℃, power plant efficiency has reached 43~44%(LHV) comparable to IGCC, owned by big plant from US、Japan、Europe, highly matured technology.
- Ultra supercritical pulverized coal combustion(USC)—280~300bar, 600℃/620℃ about 45%(LHV), still under certification, reaching 375bar, 700℃/720℃, efficiency can reach 50%(LHV). Japan and Europe is leading now.
- Pressurized Fluidized Bed coal combustion(PFBC)— efficiency about 42~43%(LHV) comparable to IGCC, Japan and Europe are leading at this technology but future efficiency improvement are not good as IGCC, thus valued low.
- Integrated Gasification Combined Cycle(IGCC)— efficiency 42~45%(LHV), have potential to reach 52%(LHV), US and EU take the lead, Japan is also developing actively.
- Integrated gasification fuel cell (IGFC)— efficiency to reach 60%, high difficulty in large size utilization.

Gasification technology produce syngas consist mainly of CO and H_2 to be raw material

- Liquid fuel (Methanol or DME)— better be utilized in IGCC or industrial park gasification plant, transferring syngas to liquid fuel in storage during off peak time.
- H_2 production— Cheap future hydrogen fuel source, domestic energy is capable to transfer vapor and separate gas.
- F-T fuel—more suitable to coal producing area, transfering to F-T fuel.

3.International clean coal technology development

-International clean coal technology development plan

USA	EU	Japan
CCT roadmap、Vision21、FutureGen	PowerClean	CCT Strategy、EAGLE
● **Short-term goals** are to control SO_x、NO_x、Hg emission and lower carbon emission factor, maintain existing plant operation and prepare to upgrade to zero-emission. ● **Long-term goal** is to construct zero-emission power plant through the research of IGCC, advanced material, high efficiency hybrid system and CCS technologies. ● Clean Coal Technology〔10 years from 2001〕、Vision 21〔15 years from 2001〕、**FutureGen**〔10 years from 2003〕and so on to support fuel cell、gasification、H_2 production、turbine、system integration、and CCS technologies.	● **Ultra supercritical pulverized coal combustion** net efficiency has reached 47 ~ 50 %(LHV), future development focus on high-temperature material comparable to Japan as the leading role and intergrate almost-zero CO_2 emission technology. ● **Pressurized Fluidized Bed coal combustion** is mature technology around 300 MW, going to implement on 600 MW, future goal is 600 ~ 800 MW, and derive CO_2capture technology. ● Several **IGCC** power plants are operating, operation rate is below 85 %, stability is the main limit. Research is gaining support from EU commission continuously.	● Major research on the reactor material in the area of **supercritical pulverized coal combustion.** ● **IGCC** development is the major current concern. ● **Gasification integrate with fuel cell** is the long-term research goal. ● The major technology before 2020 is to improve efficiency, expecting **zero-emission** after 2030.

Source：CCT2005, IEA Clean Coal Conference, Sardinia, Italy, 10 - 12 May 2005

3.International clean coal technology development

-Commercialized Operational IGCC plan over the world

Power Plant／Nationality	Start year	Power generation MW	Fuel	Application	Gasifier／Combined cycle
Nuon(Demkolec)/Netherland	**1994**	**250**	**Coal**	**Power generation**	**Shell-O_2/Siemens V94.2**
Wabash/USA	**1995**	**260**	**Coal**		**Conoco Phillips-O_2/GE 7FA**
Tampa Electric/USA	**1996**	**250**	**Coal**		**GE/Texaco-O_2/GE 7FA**
EI Dorado/USA	1996	45	Oil coke	Co-generation	GE/Texaco-O_2/GE 6B
SUV/Czech	1996	350	Coal/Oil coke		Sasol Lurgi-O_2/GE F9E
Schwarze Pumpe/Germany	1996	40	Lignite/Waste	Power generation/ Methanol	BGL-O_2/GE 6B
Shell Pernis/Netherland	1997	120	Bottom oil	Cogeneration/ H_2	Shell/Lurgi-O_2/GE 6B
Puertollano/Spain	**1998**	**300**	**Coal**	**Power generation**	**Prenflow-O_2/Siemens V94.3A**
ISAB/Italy	2000	520	Bitumen	Power generation/ H_2	GE/Texaco-O_2/Siemens V94.2
Sardinia /Italy	2001	545	Bottom oil	Cogeneration/H_2	GE/Texaco-O_2/GE 109E
Chawan/Singapore	2001	160	Oil coke	Cogeneration/H_2	GE/Texaco-O_2/GE 6FA
API/Italy	2002	280	Bottom oil	Power generation/ H_2	GE/Texaco-O_2/KA 13E2
Delaware/USA	2003	160	Oil coke	Power generation	**GE/**Texaco-O_2/GE 6FA
Negishi/Japan	2003	342	Bitumen		GE/Texaco-O_2/MHI 701F
AGIP/Italy	2006	250	Residue oil	Cogeneration/H_2	Shell-O_2/Siemens V94.2K
Total(MW)		3,872			

IGCC energy availability in commercialized oil refinery are usually below 70% during the first and second year, but can reach 90% after three years. However, IGCC using coal as raw material is not able to reach 85% until now.

Source：IGCC and Gasification, GAS TURBINE WORLD: January-February 2006

4.Taiwan clean coal technology-current development

- **BOE have focused on clean coal technologies since 1987 and completed the research toward combustion pollution control**
  - **Low NOx Burner**：2.5MW Burner，Coal-fired NO_x<250ppm
  - **Flue gas desulphurization**：Removal Efficiency>95%
  - **SNCR de-NOx**：Removal efficiency >50%
- **IGCC technology development and introduction since 1998**
  - Clean coal power generation technologies：IGCC、PFBC、SC
  - IGCC technologies analysis：air seperation、coal gasifier、coal gas clean- up and integrated combined cycle.
  - Introduction strategies
- **2000~2001 clean coal technology application introduction plan**
  - Clean coal technology application in **power generation**
  - Clean coal technology integration and incentives plan and development：「Clean coal power generation incentives recommendation」and「Clean coal technology subsidy draft direction」
  - Clean coal technology application plan in **energy intensive** industries：Iron and steel、Petrochemical、Synthetic fibers and pulp and paper industry.

4.Taiwan clean coal technology-current development

Multiple fuel gasification technologies development (2002～2005)

- ITRI built 2 ton/day Entrained Bed gasifier system, maximum operational pressure 15bar, Dry- feed, Oxygen-blown。
- Without heat recovery, gasification efficiency and carbon conversion rate can reach 70% and 88%, respectively.
- Built IGCC modeling and diverse application evaluation method.
- Technology can apply to power generation、Iron and steel、Petrochemical、synthetic fiber、Pulp and paper industries.

Major development 2006~2009

Multiple feeding gasification technology

- Solid dry feed
- Liquid feed

Syngas conversion application

- Liquid methanol fuel
- H_2 Production and CO_2 seperation

Syngas clean-up technology

- High temperature desulfurize and dust removal
- CaO capture CO_2

Syngas application demonstration and introduction

- Combustion and power generation
- Industrial park gasification demonstration plant

4.Taiwan clean coal technology-current development—Taiwan IGCC development evaluation

- The best of commercialized gasification technology application in Taiwan is from Texaco residue oil gasification plant in Chinese Petroleum Corporation Kao-Hsiung plant. Original design was to use residue oil as fuel, but now heavy oil is the major feed. It mainly provides downstream acetic acid production and hydrodesulfurization. Formosa Petrochemical Corp. built light oil gasification plant in Mai-Liao at 2005, producing CO and H2 as petrochemical material.
- As for advanced IGCC technology, evaluation commissioned by Taipower Company was made at 1995 to determine the feasibility replacing current gas turbine with IGCC. In 2002, a commissioned research about the feasibility installing IGCC in Chang-Bin Industrial Park was completed. The project includes three 320 MW capacity units. Net efficiency under ISO can reach 40.6% (HHV),and gasifier used entrianed bed.
- Future implementation timing should consider the reliability and cost of IGCC technology.

5.Taiwan clean coal technology-future development

- **Recent new and remodeled coal-fired unit should give priority to utilize supercritical and ultra-supercritical units.**
- **Coal IGCC technology is still at the stage of commercialized exemplary, should be introduce step by step.**
- **Introduce large coal gasification plant into industrial park as an application demonstration. Centralized providing syngas fuel and process steam to help the integration and utilization of regional energy which result in energy efficiency improvement.**
- **Build up the ability to plan and design small-mid coal gasification plant**
  - High Temperature Gaseous clean-up technology
  - Convert syngas to liguid fuel or produce H_2,CO_2 capture and sequestration

5.Taiwan clean coal technology-future development

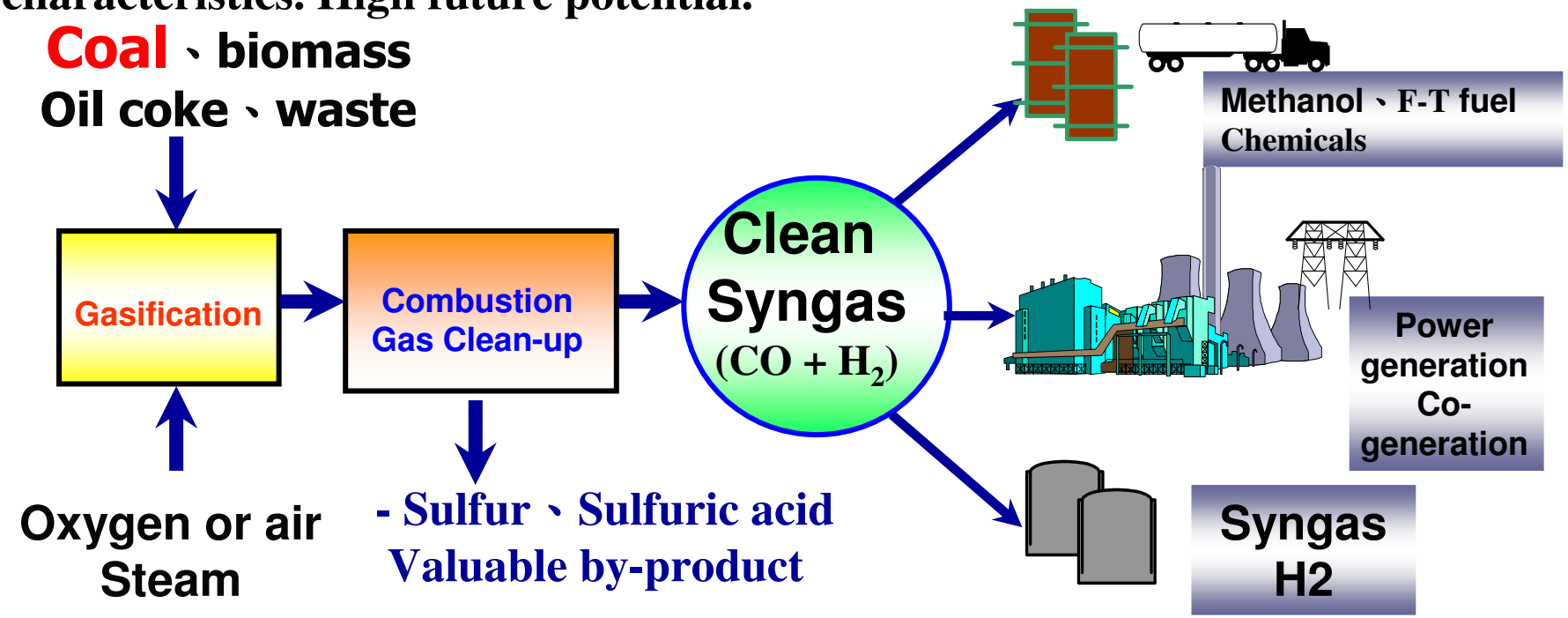
— Major technologies introduction strategies and development schedule

- **Key Technologies關鍵核心技術**
  - Coal Gasification will be important key technology for future clean energy. Short and mid-term：Build gasification key technologies.
  - Mid and long-term：Implement syngas gasification conversion technology development.
  - Future：Integrate gasification and fuel cell (IGFC, IGCC+FC), Hydrogen production and zero-emission will be major research area.

5.Taiwan clean coal technology-future development

— Multiple gasification technologies as the key development

- **Lower the reliance from oil to increase energy safety.**
- **Gasification technology** can allow various flexible feeding choices, and syngas production can be used in multiple places, ex. Power generation、Syngas fuel、Convert to liquid fuel and hydrogen production…etc.
- Mid and small size gasification technology to fit in domestic industrial characteristics. High future potential.



5.Taiwan clean coal technology-future development

— Major technologies introduction strategies and development schedule

- **Clean coal technology introduction and promotion**
  - Regarding to the decommission of old power plants and improve power plant efficiency to constraint CO2 emission
  - Short and mid-term：Install supercritical and ultra-supercritical pulverized coal fired boiler which have higher efficiency
  - Mid and long-term：International technology cooperation to build large scale IGCC demonstration plant and understand the operational technology to develop the experience basis for future IGCC introduction
- **Industrial applicable gasification technology introduction and promotion for Industrial Application**
  - Clean coal technology utilization by industry, taking multiple syngas utilization as the main goal, in addition to co-generation plan, also provide clean syngas as fuel to replace original fuel.
  - Short and mid-term：build low cost gasification technology, coordinate gasified coal demonstration plant group in industrial park, evaluate feasibility of coal gasification demonstration plant in industrial park and its installation permit.
  - Mid and long-term：Install coal gasification demonstration plant, provide clean and low cost syngas fuel to replace natural gas and fuel oil.
  - Future：Combine H2 production and CO_2 capture and storage to build multiple syngas utilization and zero-emission industrial park.

5.Taiwan clean coal technology-future development
--Technology research and development strategies

- **Technology introduction：belong to large coal gasification plant and power plant**
  - Feasibility evaluation、plan and design、key equipment.
- **International and academic cooperation：part of key technology for small coal gasification plant**
  - Small gasification system design and model、CO_2 capture and separation、advanced syngas conversion reactor and catalyst technologies…etc.
- **Technology development： technology under domestic independent development can be viable**
  - Coal gasification control technology、high-temperature syngas purification、syngas convert to methanol and H2 production、syngas combustion and power application 、zero pollution hydrogen fuel power generation.
- **Technology services：utilize resource from project to help industry**
  - Technical information collection、Industrial cooperation coordination、large coal gasification demonstration plant installation.

6.International CO2 capture and storage technology development

CO_2 capture：

- Objectives：Sequestrate and capture CO_2 from the emission source for future reuse or storage.
- Target emission source：
  - **Flue gas from combustion process.**
  - **Synthesis gas (syngas) from oxygen-enriched combustion/gasification process.**
  - **Other high concentration CO2 emission source from industrial process**
- Capture method：
  - **CO_2 absorption/adsorption、membrane and other physical or chemical capture method.**
  - **CO_2 capture and combustion process improvement and integration**

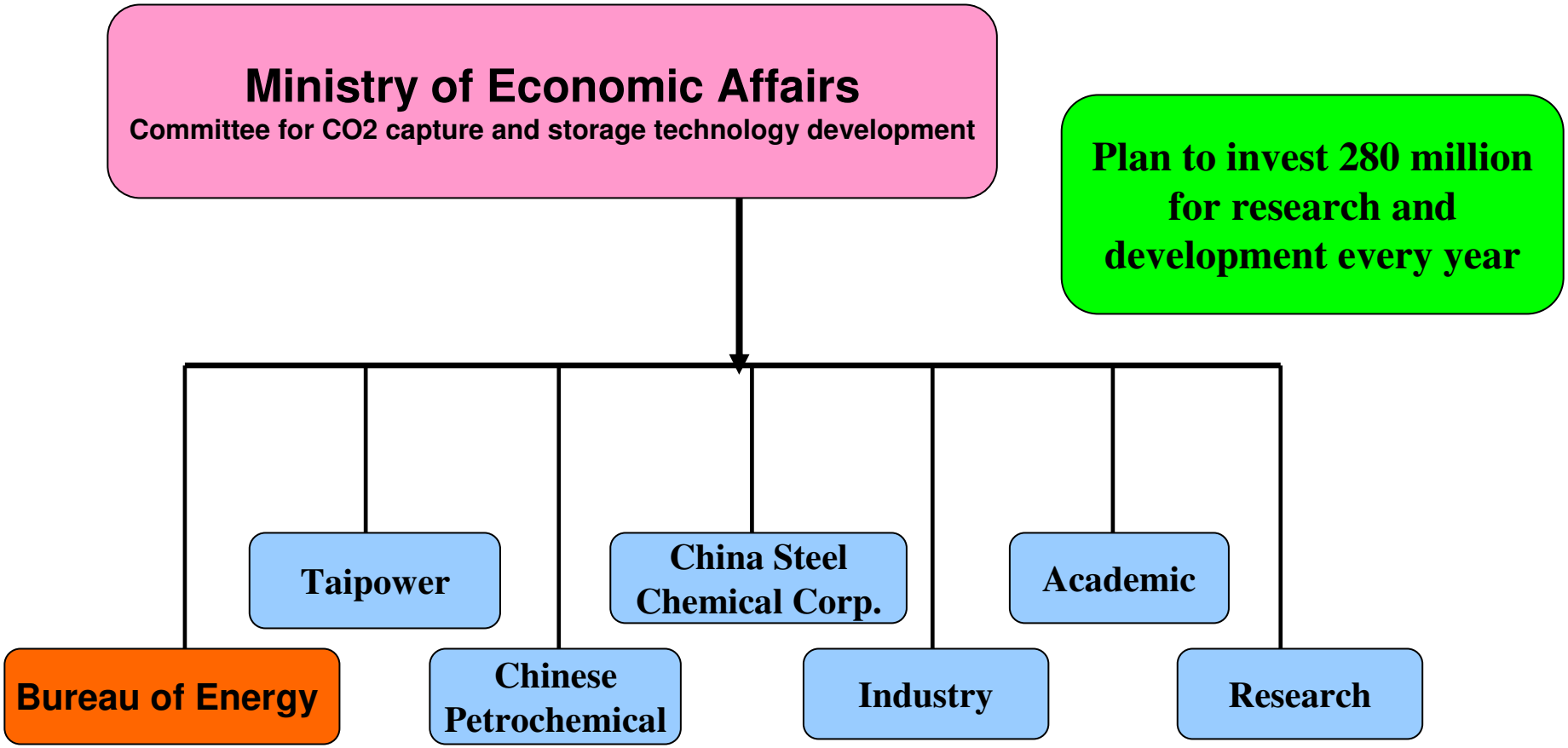
CO_2 storage technologies

- Goal：Stable CO_2 storage over a hundred year.
- Storage method：
  - **Geological Sequestration**
    - Inject CO_2 into deep and safe geological location；certain technology is currently the most feasible way to largely stored CO_2.
  - **Terrestrial Sequestration**
    - Biological sequestration生物封存：through plants and soil to naturally absorb CO_2 emission Chemical sequestration：combined CO_2 with another element to become a stable solid matter
  - **Ocean Sequestration**
    - Inject CO_2 into deep ocean；although ocean can store large amount of CO_2, due to CO_2 movement under the sea, both ocean current and biological effects need to be carefully studies and evaluated for a longer-term

7.Taiwan CO_2 capture and storage technology development plan

- Short-term、Mid-term：
  - **Take CO_2 Capture, combustion improvement and CO_2 reuse technologies research as the main direction, practically facilitate industry to reduce CO_2 emission.**
  - **Investigate and evaluate domestic geologic storage potential, to collect important information for future storage location and potential planning.**
- Mid-term、Long-term：
  - **Through geologic storage technology, largely removing captured industrial CO_2 emission to elevate competency for domestic industry.**

7.Taiwan CO2 capture and storage technology development plan
—MOEA working group



8.Conclusion

- Under the limited condition of fossil fuel, coal utilization will still be the major source of energy. Clean Coal technology and CO2 reduction technology responding to global concern will be beneficial basis for international industry development and also the direction for related domestic industry.
- Government should proactively facilitate domestic green-coal industries. Cooperate with domestic industry through policy, technology exploration, and incentive measures to develop another beneficial industry.
- Government should clearly set up policy goal for domestic clean coal technology and clarify with technology developing schedule to direct domestic research ability into certain technical area.
- During the initial development stage, it is recommended to introduce technology through international cooperation and encourage participation of domestic industry.
- CO_2 capture and geologic storage are internationally concerned to be highly potential CO_2 reduction mechanism and major research direction. It is recommended to actively participate international cooperation to understand the most updated development and technologies.

Thank you