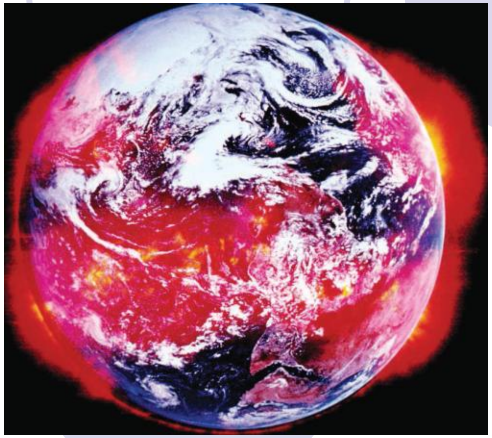
2nd U.S.-China Symposium on CO_2 Emission Control Science & Technology, Hangzhou China
28th -30th, May, 2008

Status of CCS in China



Prof. Zhongyang Luo

State Key Laboratory of Clean Energy Utilization
Zhejing University

29th May, 2008

Global CO_2 Emissions

Country	CO_2 Emissions (Million Tons Carbon)			
	1990	1997	2001	2010
USA	1345	1480	1559	1800
China	*620*	*822*	*832*	*1109*
Former USSR	1034	646	654	825
Japan	274	297	316	334
World	5836	6175	6522	8512

Source: Energy Information Administration/International Energy Outlook 2001

Global CO_2 Emissions from Fossil Fuel Use in 2006

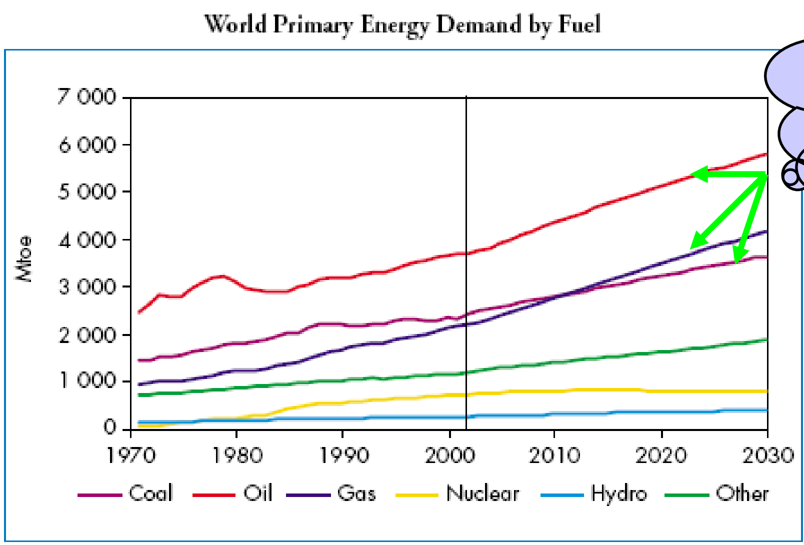
Country	CO_2 Emissions (1 million metric tons CO_2)	Percentage (%)
Total	28,160	100
USA	5,750	20.42
China	5,680	20.17
EU-15	3,330	11.72
Russia	1,620	5.75
Japan	1,210	4.3

But, according to the Netherlands Environmental Assessment Agency, it said that China produced 6,200 million tonnes of CO_2 in 2006, compared with 5,800 million tonnes from the USA. Britain produced about 600 million tonnes.

BP Statistical Review of World Energy, June 2007
(http://www.bp.com/sectiongenericarticle.do?categoryId=6914&contentId=7042803)

http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html

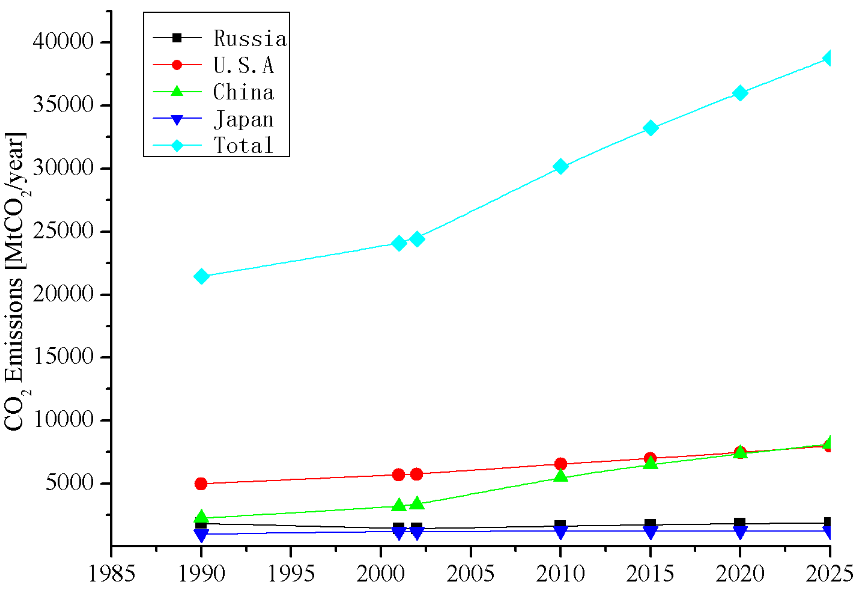
⌖ Global CO_2 Emissions in the Future



Fossil fuel will continue to dominate the global energy mix.

World Primary Energy Demand by Fuel from now to 2030 (*IEA Report, 2004*)

Global increase of total CO_2 emissions



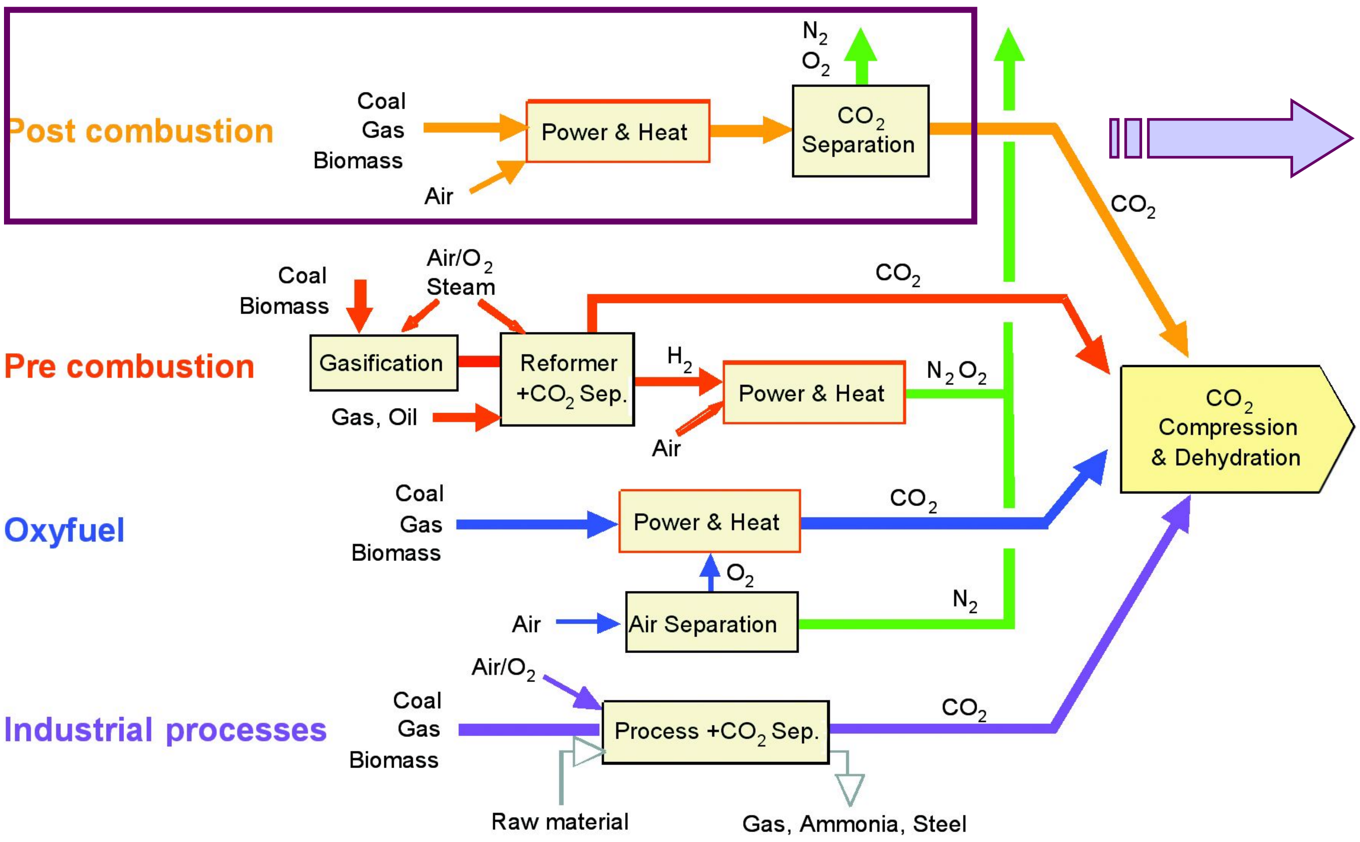
CO_2 Emission in China

Year	Total	Coal		Petroleum		Natural Gas	
	Million Tons Carbon	MtC	%	MtC	%	MtC	%
1990	620	514	82.9	98	15.8	8	1.29
1996	801	625	81.4	138	17.2	11	1.37
1997	822	661	80.4	148	18	12	1.46
2001	832	668	80.3	151	18.2	15.5	1.86
2010	1,457	1,115	76.5	277	19	65	4.46

In China, CO_2 capture from the coal-fired flue gases will be an effective way to control CO_2 emission in short term.

⌖ How to Control CO_2 Emission?

Overview of CO2 capture processes and systems



CO_2 capture in post combustion mode might be the best method to control CO_2 emission in the short term.

Resource: IPCC Special Report about CO_2 Capture and Storage,2001.

I Post-combustion CO_2 Capture Technologies

- **Absorption Methods**

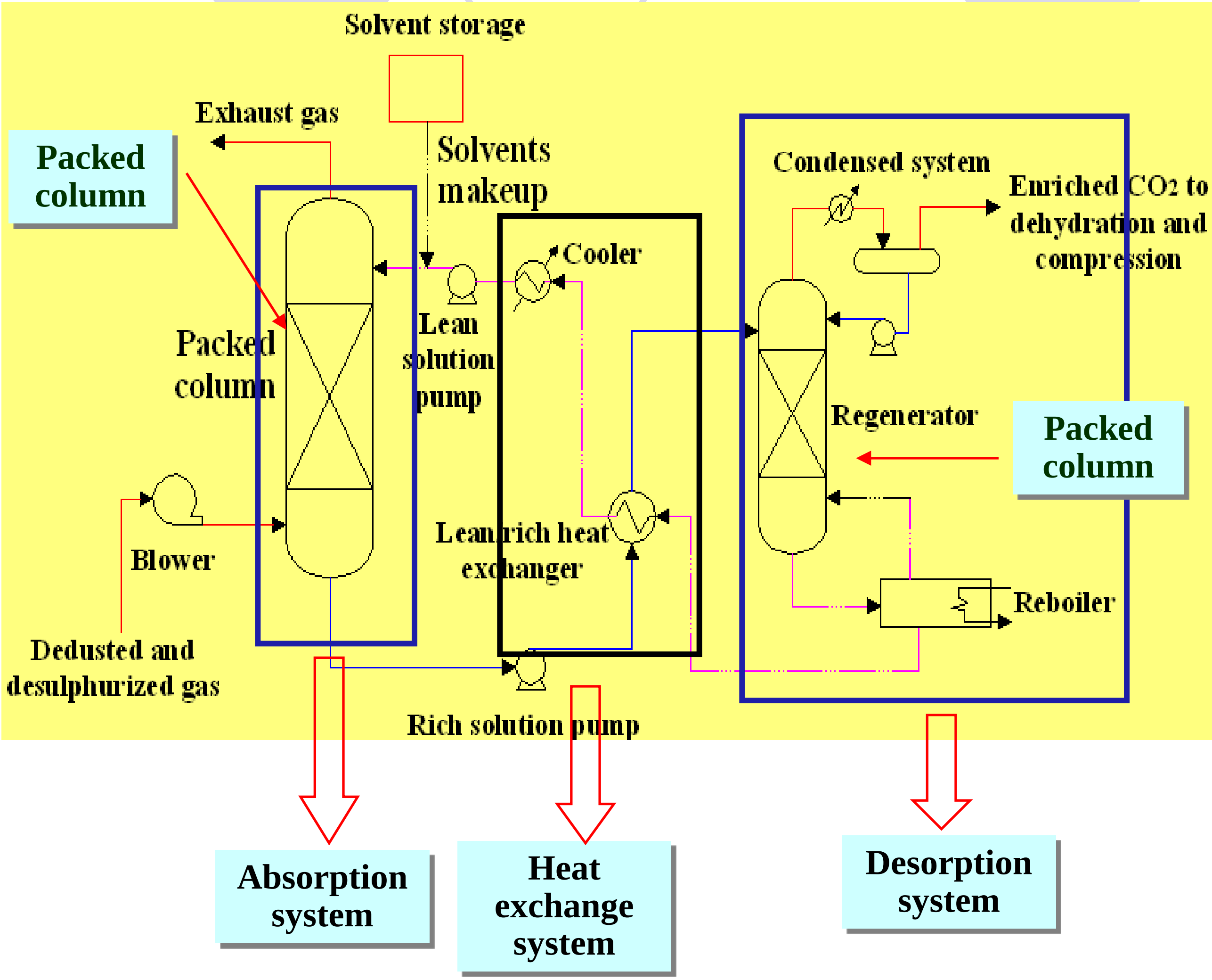
  Chemical absorption and physical absorption

- **Membrane technologies**

  Membrane separation and membrane gas absorption

- **Adsorption methods**
- **Cryogenic processes**

1. CO_2 Capture by Chemical absorption Method



Typical amine absorption process for CO_2 recovery from flue gas

The CO_2 absorption process generally consists of (1) <u>an absorption unit</u> where CO_2 is recovered from a gas phase into a liquid solvent and (2) <u>a heat exchange system</u> where rich solution is heated by lean solution before being pumped into desorption unit, and lean solution is cooled to a specific temperature value before being pumped into absorption unit; (3) <u>a desorption unit</u> where the absorption capability of the used solvent is recovered before being reintroduced to the absorption unit.

Research on chemical absorption in China

In China, so many institutes are now paying their attention on CO_2 separation using chemical absorption method, such as Najing University, Tsinghua University, Beijing University of Chemical Technology, Zhejiang University, Tianjin University, Nanjing University of Science and Technology, Huazhong University of Science and Technology, CAS and so on.

The research keystone:

- New Solvents (Provide equivalent or greater CO_2 absorption rates than MEA, adequate capacity for CO_2 and reduced cost of regeneration);
- New Packing or New Absorber;
- Kinetics and Dynamics of Solvents;
- Effects of some operating conditions on CO_2 removal performance.

Research on Absorbents by Chemical Absorption in China

Institute	Reactors	Absorbents	Gas	Some Results
Zhejiang University	Stirred-cell Absorber/Packed column	Blended absorption solution MEA, MDEA, PZ, Ammonia, PG, AMP, DEA, DETA and TETA	CO_2+N_2	Absorption rate and capacity of CO_2 can be remarkably enhanced by the system of aqueous MEA/MDEA and MDEA/PZ solutions.
Tsinghua University	Agitated kettle	Blended absorption solution of MDEA + Sulfolane	CO_2	Some kinetic data for absorption of CO_2 with the blended solvents of MDEA and sulfolane aqueous solution.
	Sieve-plate reactor	Ammonia…	CO_2+N_2	Effects of operating parameters on CO_2 removal efficiency; Analysis on dynamics.
Haerbin Engineering University	Disc column	Blended amine aqueous solution of TEA+DETA	CO_2	Absorption rate and CO_2 absorption capacity of blended amines
	Stirred absorption & desorption apparatus	MEA、DEA、MDEA and AMP	CO_2	CO_2 absorption and desorption rate of four kinds of solvents.
	Stirred-cell reactor	Seawater and MEA、DEA、TEA、MDEA、AMP、DETA、TETA、TEPA	CO_2	Using seawater and amines to form solvents can improve the CO_2 absorption performance.

Research on Absorbents by Chemical Absorption in China

Institute	Reactors	Absorbents	Flue gas	Some Results
Shanghai Jiaotong University	—	MDEA/ PZ and MDEA/DEA	CO_2	CO_2 absorption rate using MDEA/PZ or MDEA/DEA; the kinetic data of these solvents
Nanjing Agricultural University	Stirred-cell reactor	Aqueous MEA solution	CO_2	PH was measured during the absorption of CO_2 into aqueous of MEA at different conditions; Discussing the relationship between absorption time and depletion of amine concentration at different temperature and different pressure.
Anhui University of Science and Technology	Super-gravity bed with disks	Ammonia…	CO_2/N_2	Optimum structure of super-gravity bed with disks can be used to separate CO_2 from flue gas effectually.

Researches on CO_2 Absorption Using Chemical Absorption Method by ZJU

- **Experimental Apparatus**

  Structured packed column

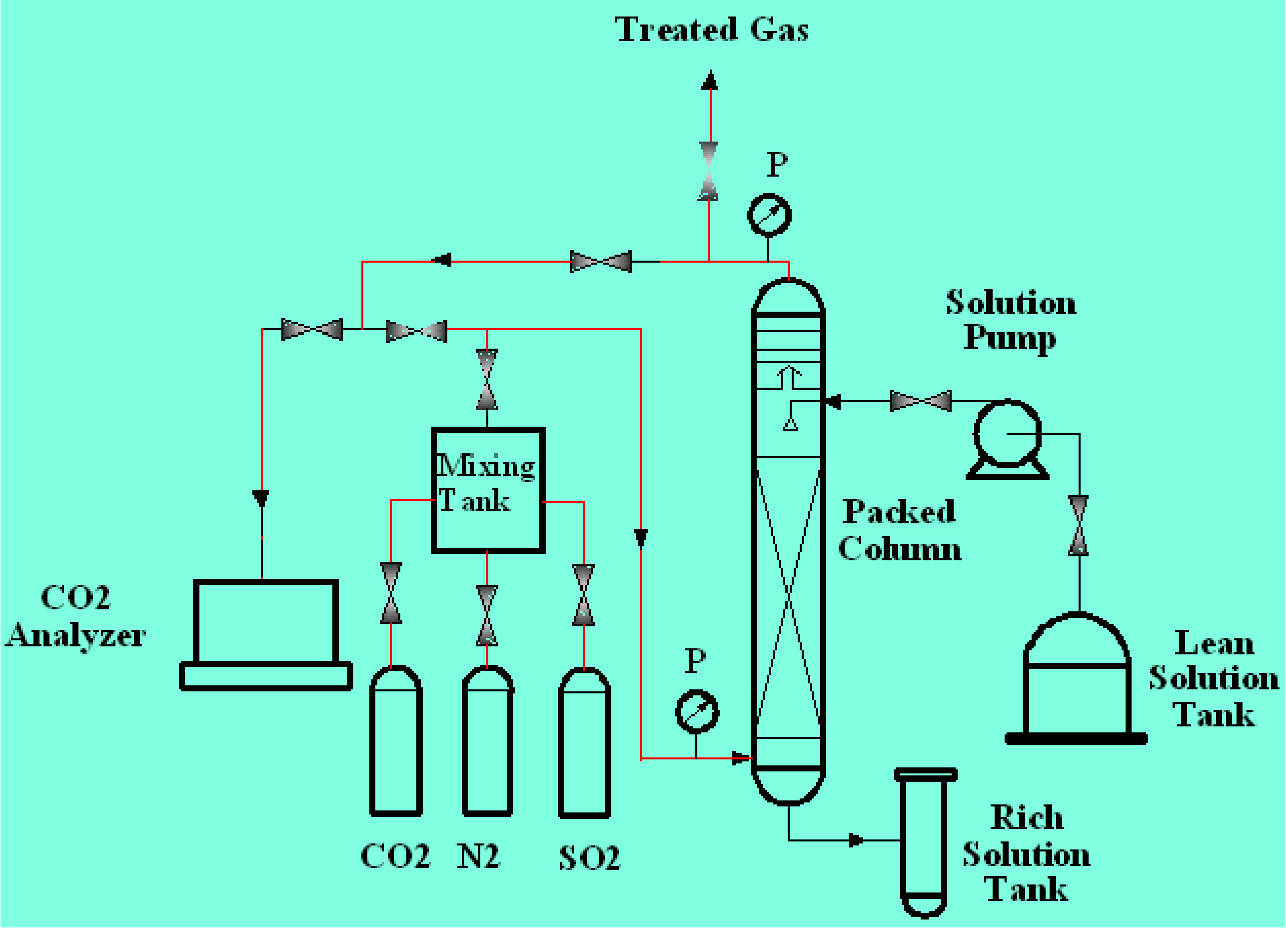
- **Absorbents**

  Single absorbents (MEA, DEA, AMP, PZ, MDEA, PG (Potassium Glycinate), Ammonia…); Blended absorbents (MEA/MDEA, MDEA/PG, MDEA/PZ, DEA/AMP…)

- **Operating Conditions**

  Flow rate, temperature, CO_2 concentration, SO_2 concentration, Additive concentration…

⌖ Experimental Setup



Experimental Setup of CO_2 Absorption by Packed Column

The simulated flue gas (CO_2/N_2/SO_2) was fed into the bottom of the packed column. At this point, the prepared absorbent solution from the lean solution tank was pumped to the top of the column at the desired flow rate by solution pump.

In the column, the gas and liquid phases contacted countercurrently, and CO_2 was absorbed by the absorbents. The treated gas finally left from the top of column, and CO_2-rich solution was pumped from the bottom of column to the rich solution tank.

⌖ Structured packed column

Structured packed column: Perspex glass

Stainless steel silk screen packing

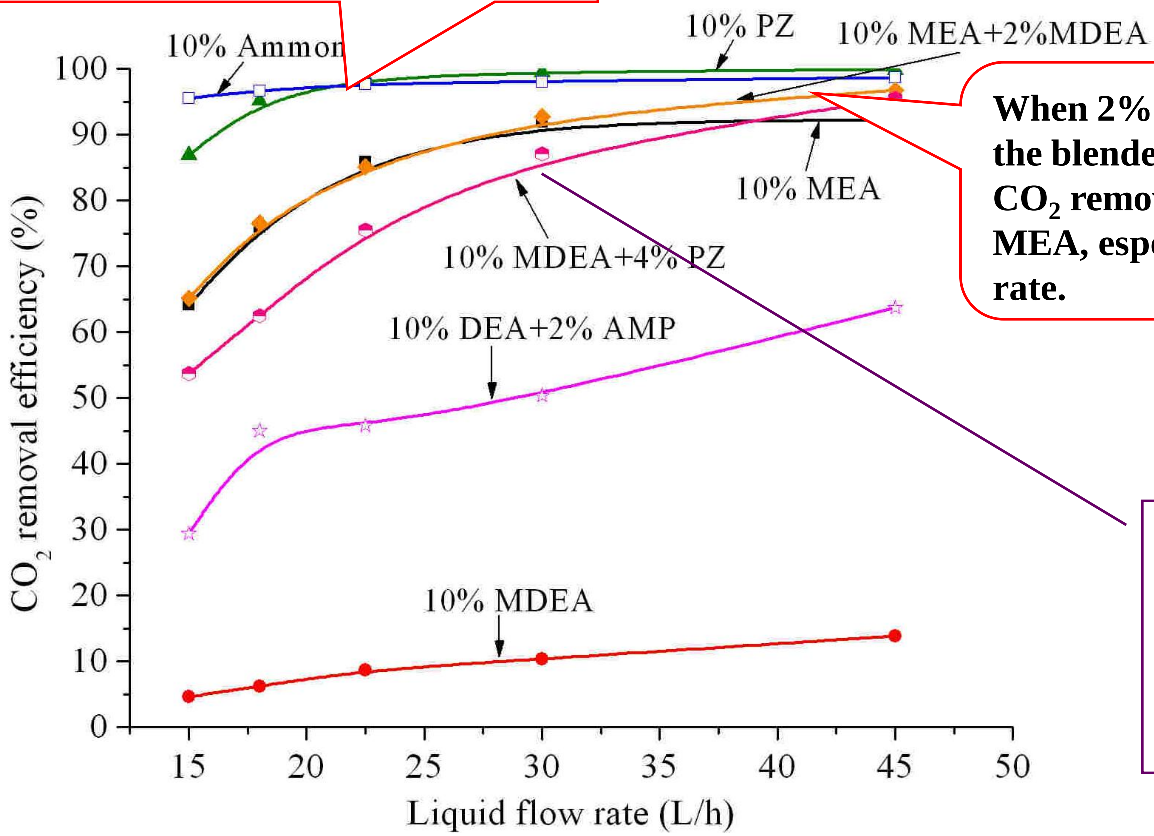
Structured packing was placed with each layer rotated with 90° with respect to the previous one.

Operating Parameters

Item		Characteristic Parameters
Packed column	Column I.D. (mm)	58
	Packing height (m)	0.6~1.35
	Packing size (mm)	φ58×50
	Specific area (m^2)	500, 700, 1000
Operating conditions	Gas flow rate (m^3/h)	1.8
	CO_2 concentration (%)	12~16
	SO_2 concentration (ppmv)	0, 500, 1000, 1500
	Gas temperature (℃)	Ambient
	Gas pressure (kPa)	~5
	Liquid flow rate (L/h)	15~45
	Liquid temperature (℃)	15~50
	Solvent concentration (w.t.%)	5~30
	Solvent type	Ammonia, MEA, PZ, MDEA, DEA, AMP

Some Useful Results

Ammonia and PZ have the best CO_2 removal performance compared with other absorbents.

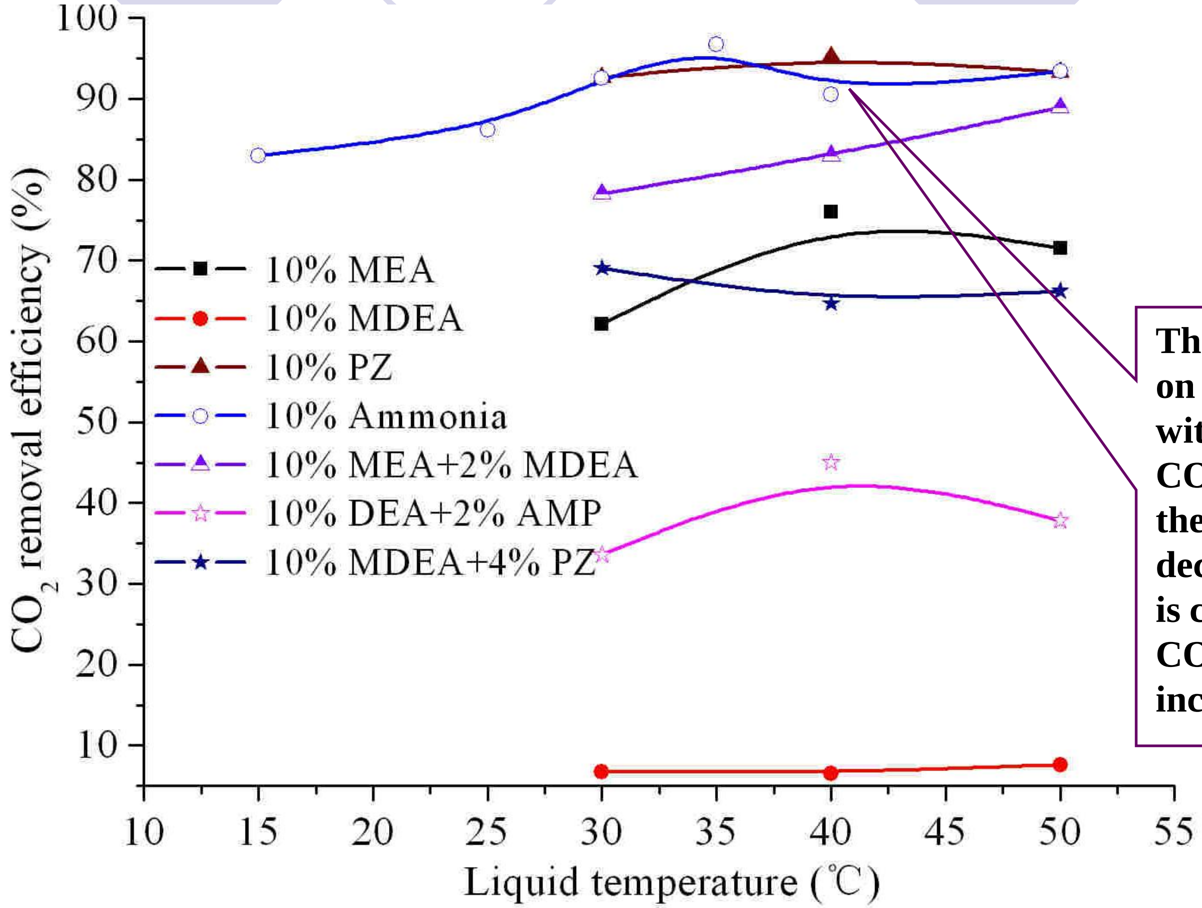


When 2% MDEA was added into MEA, the blended solvent has the slightly larger CO_2 removal performance than the single MEA, especially in the higher liquid flow rate.

Compared to the single MDEA, the CO_2 removal performance of MDEA/PZ solvent was increased greatly because of the active PZ.

Effect of liquid flow rate on CO_2 removal efficiency

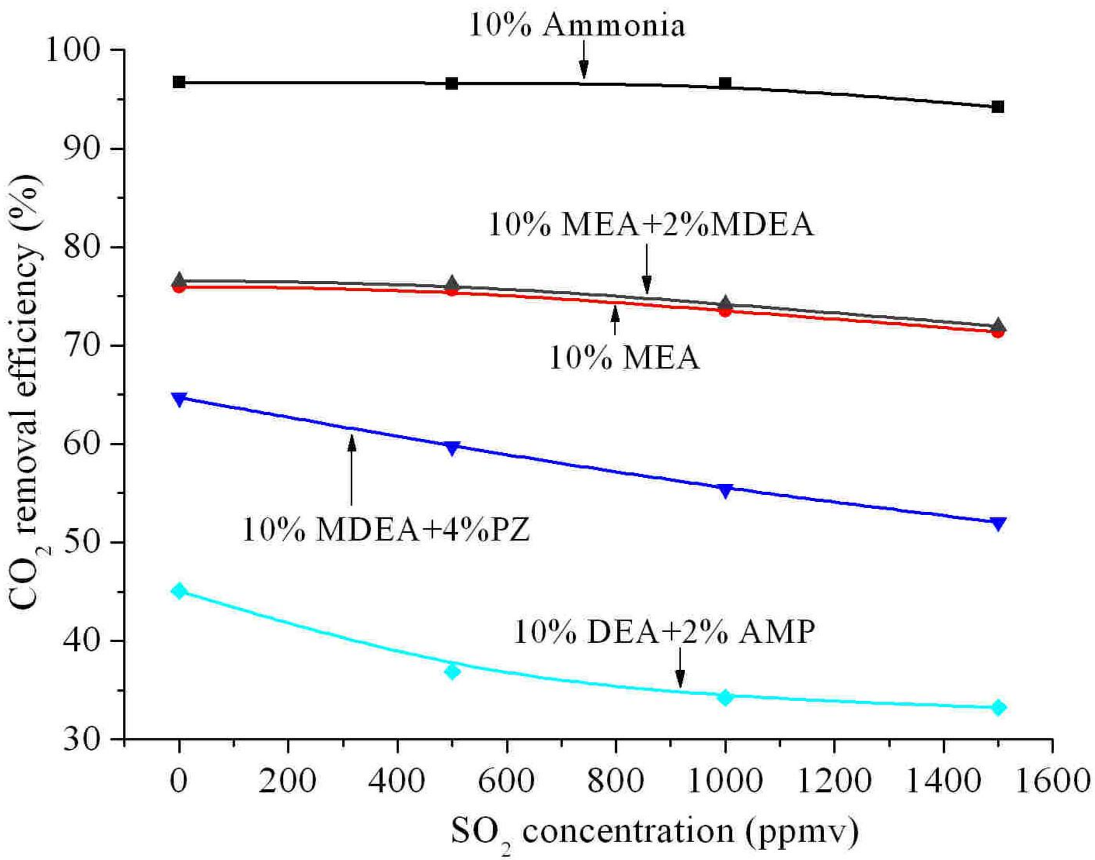
Effect of liquid temperature



The effect of liquid temperature on ammonia is not consistent with other solvents. Firstly, the CO_2 removal efficiency will reach the highest value, and then decrease. But, if the temperature is continuously increased, the CO_2 removal efficiency will increase again.

Effect of liquid temperature on CO_2 removal efficiency

Effect of SO_2



- **Results:** **The effect of SO_2 concentration on CO_2 removal efficiency is negative due to the competitive reaction between absorbent and SO_2 or CO_2. (Reaction rate between SO_2 and absorbent is higher than that between CO_2 and absorbent)**

- **Tendency:** **The extent of negative effect of SO_2 on CO_2 removal increases with the decrease of reaction rate between absorbent and CO_2. For example, the negative effect of SO_2 on DEA/AMP>MDEA/PZ>MEA>MEA/MDEA>Ammonia.**

Demonstration Plant of CO_2 Separation from Coal-fired Flue Gas in China

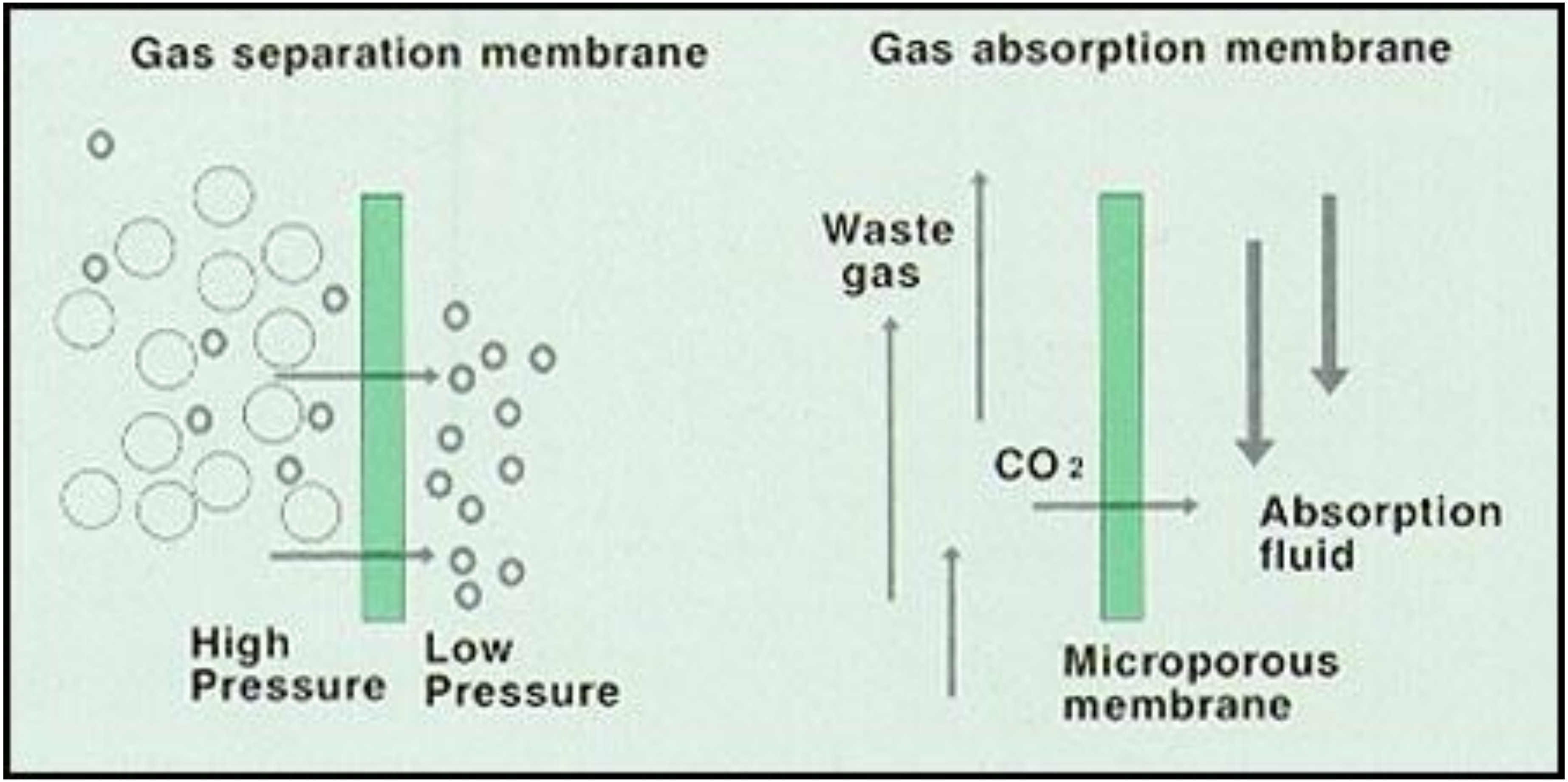
In Dec. 26th, 2007, the first demonstration project of CO_2 separation from coal-fired flue gas was started at Beijing Thermal Power Plant which is affiliated with China Huaneng Group. The demonstration project was supported by China Huaneng Group and Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO). The demonstration plant will be put into operation before the Opening date of Beijing Olympic Games.

Demonstration Plant of CO_2 Separation from Flue Gas

Technological Goals:

- **CO_2 Recovery Efficiency: >85%**
- **CO_2 Yields: up to 3000 ton/year**
- **CO_2 Purity after separation and purification: >99.5%**
- **CO_2 Consumer: Food service industry.**

⊕ 2 Membrane Technology for CO_2 Separation



Research on Membrane Separation in China

As the promising CO_2 capture technology, many researchers are now devoting their enthusiasms on it, such as CAS, Dalian University of Technology, Beijing Mining Institute, Tsinghua University, Beijing University of Chemical Technology, Zhejiang University, Tianjin University, Nanjing University of Science and Technology and so on.

The research keystone:

- New Separation Membranes (higher CO_2 selectivity or higher hydrophobicity);
- Mass Transfer Model;
- Effects of operating conditions on CO_2 removal performance;
- Effect of membrane wetting and plugging on CO_2 removal;
- Technologies to prevent the wetting and plugging problems (New membrane, new solvent…) .

Membrane Separation Research in China

Researchers	Membrane Modules	Solvents	Gas Phase	Main studies
Zhejiang University	Polypropylene (PP) hollow fiber membrane	Aqueous solutions of MEA, MDEA, PG and some blended amines	$CO_2/N_2/O_2$	The 5 Nm^3/h pilot-scale experimental system for CO_2 separation from flue gas was built and new absorbents were tested. Comparative analysis of membrane absorption and chemical absorption was also studied.
Beijing Mining Institute	Polypropylene hollow fiber membrane	Aqueous NaOH solution	CO_2/Air	Effects of operating conditions on the overall mass transfer coefficient were experimented, and a model to simulate the overall mass transfer coefficient was developed.
CAS	Polypropylene (PP) hollow fiber membrane…	Water, aqueous NaOH solution	CO_2 / N_2	Characteristics of membrane absorption process have been experimentally studied; New membranes were also tested.

Some Researchers on CO_2 membrane absorption

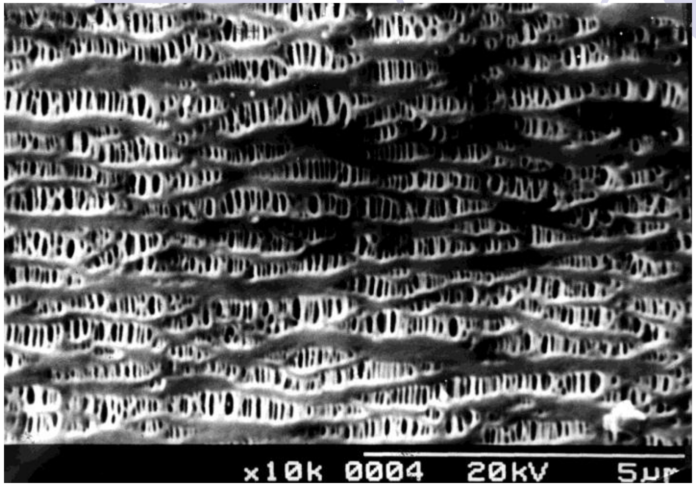
Researchers	Membrane Modules	Solvents	Gas Phase	Main studies
Tianjing University	Polypropylene (PP) hollow fiber membrane	Water, aqueous NaOH、MEA and AMP solutions	CO_2	The mathematical model of mass transfer in the membrane module.
Dalin University of Science and Technology	Polypropylene hollow fiber membrane	Water, aqueous NaOH and K_2CO_3 solutions	CO_2	The effects of some key operating parameters
Nanjing University of Science and Technology	Polypropylene hollow fiber membrane	Aqueous MDEA and MDEA/PZ solutions	CO_2 / N_2	The effects of some key operating parameters; effect of membrane pore wetting
Beijing University of Chemical Technology	Polypropylene hollow fiber membrane	Water, aqueous NaOH solution	CO_2/Air	The effects of some key operating parameters

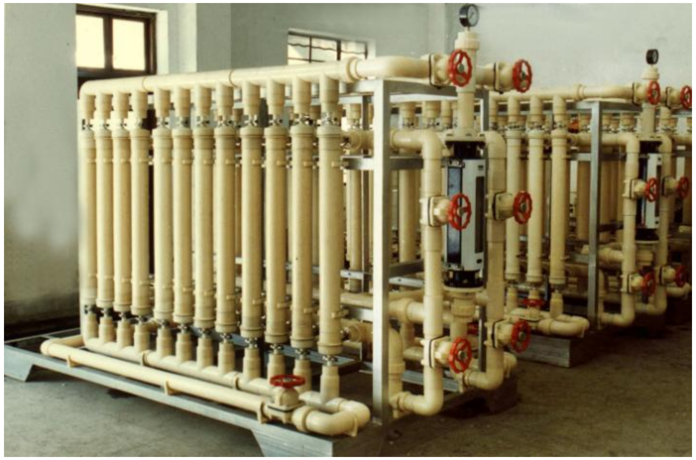
In China, most researches on CO_2 separation using membrane technology were focused on the experimental discussion and few pilot scale test facility was erected.

Membrane Gas Absorption Facility in ZJU

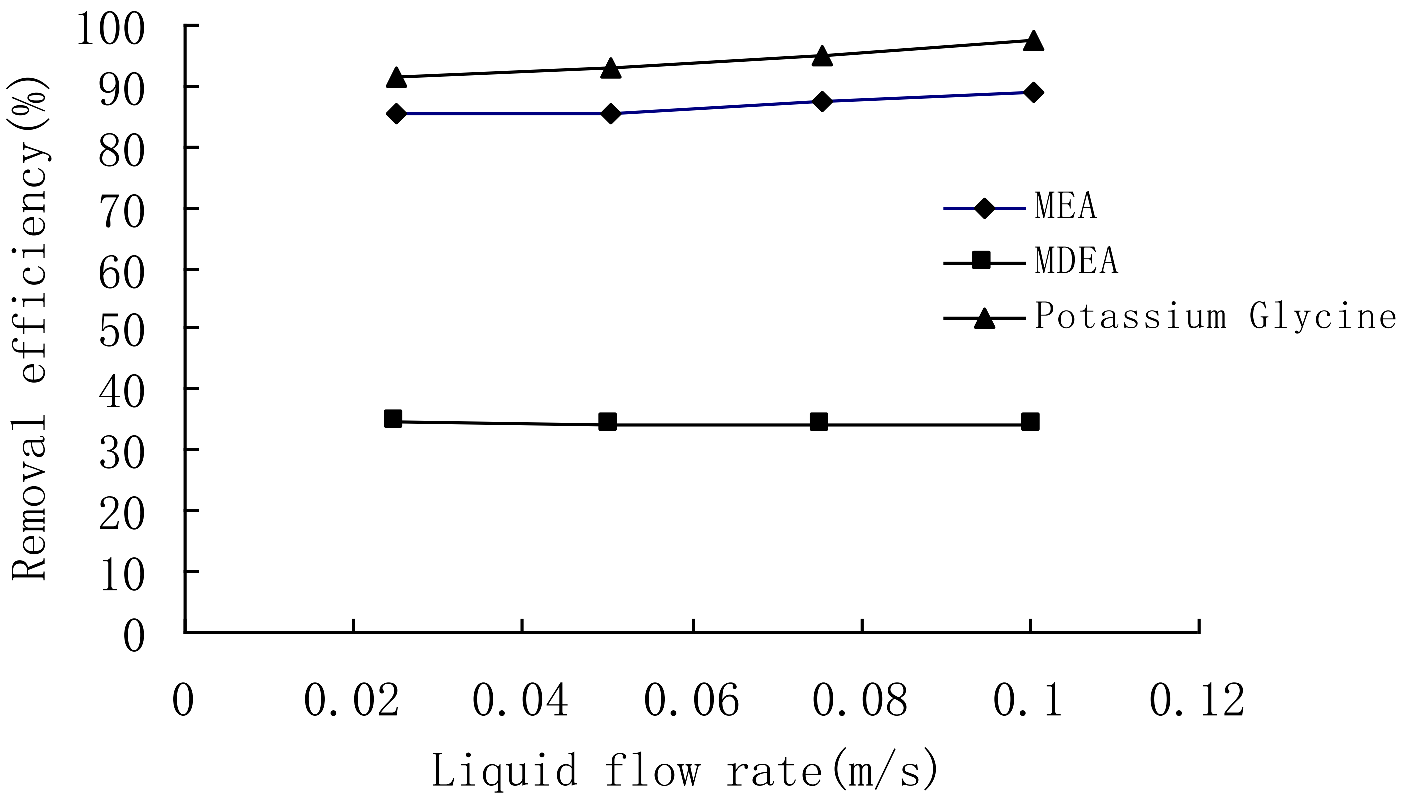
5 Nm^3/h

Characteristics of PP hollow fiber membrane



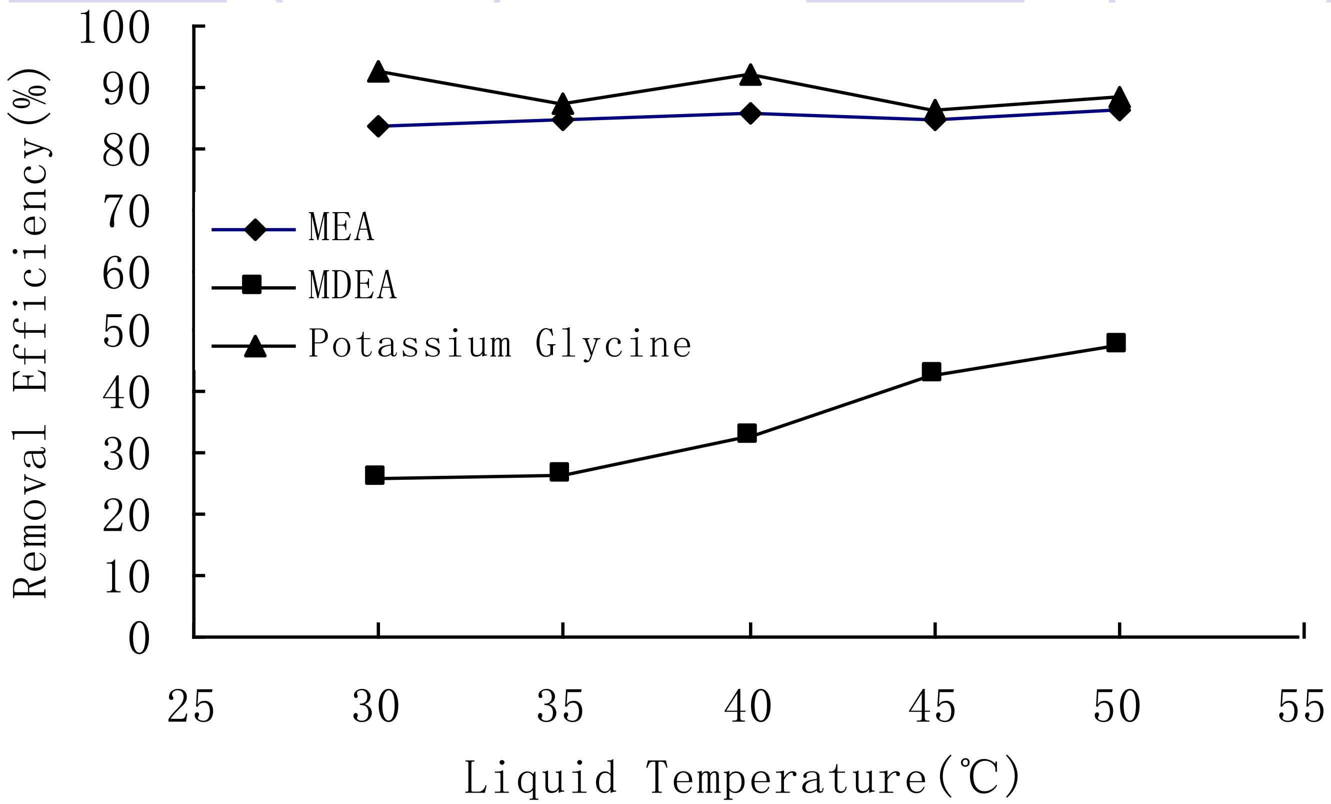


Results of CO_2 Capture from Flue Gas Using Membrane Contactors

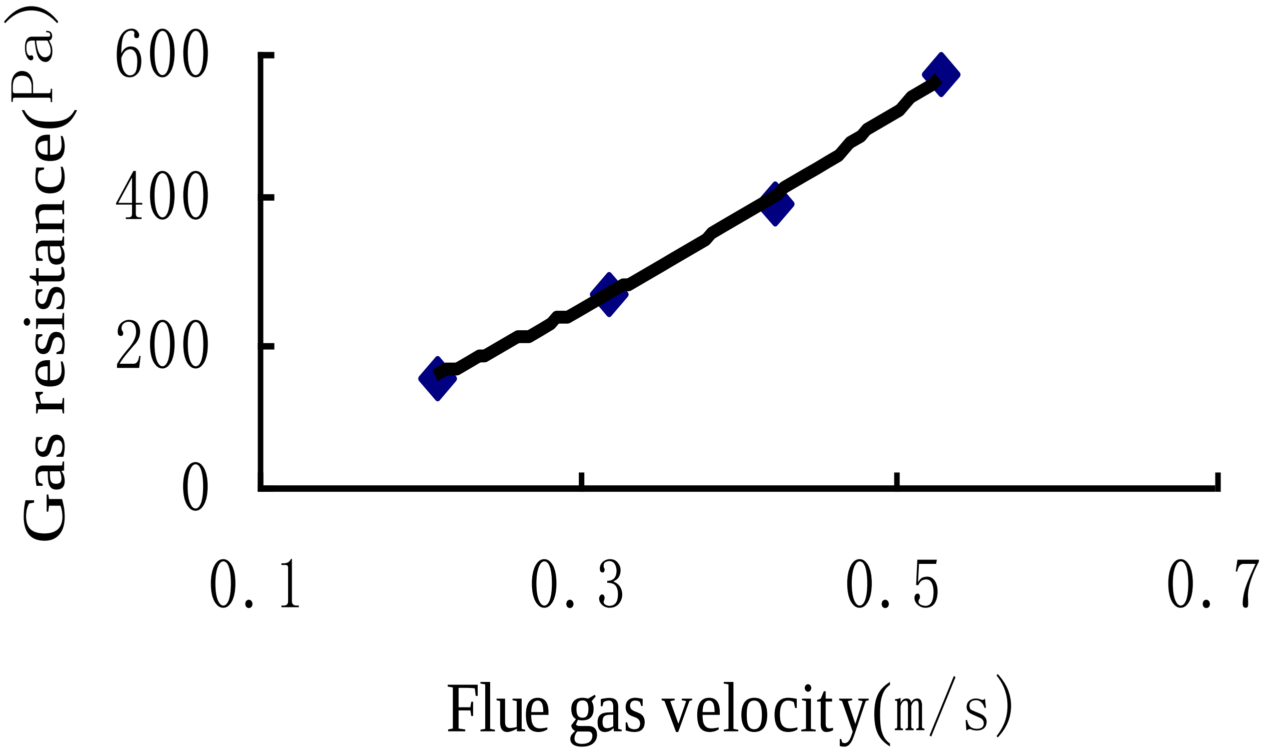


Influence of the absorption solutions on removal efficiency

(Flue gas: 0.211 m/s, absorption solution: 35 ℃, 3 mol/L)

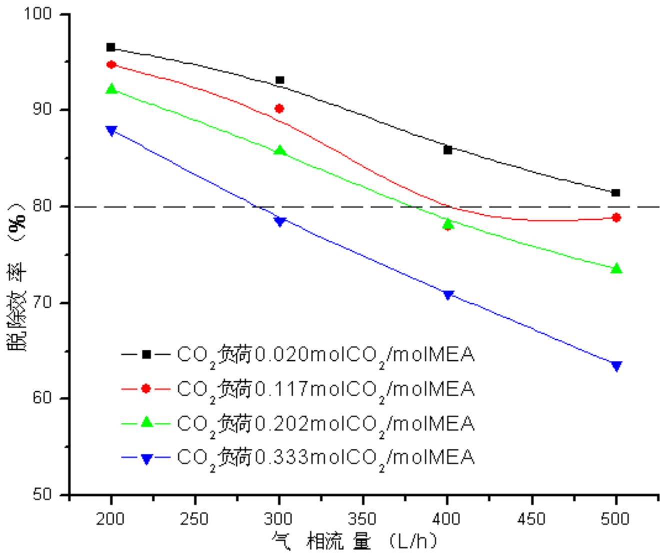


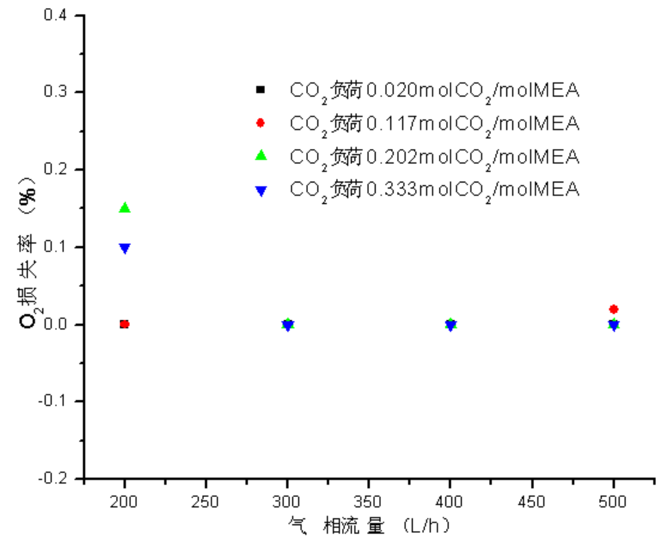
- **Influence of absorption solutions temperature on removal efficiency**
- **(Flue gas: 0.211 m/s, absorbent: 1 mol/L, 0.0503 m/s)**

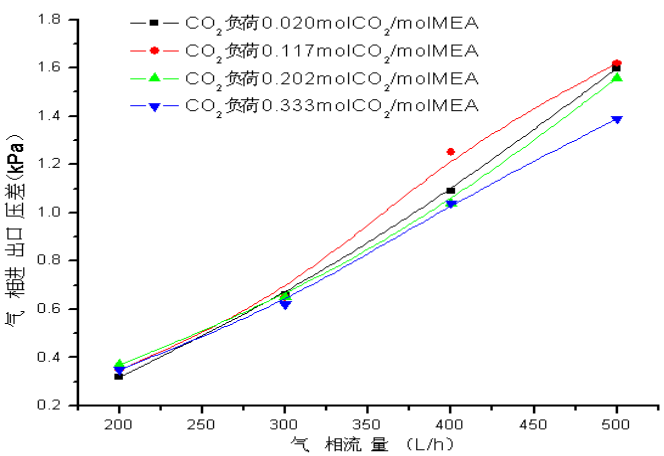


Gas pressure drop of membrane contactor

Results of CO_2 Capture from Low CO_2 Concentration Gas

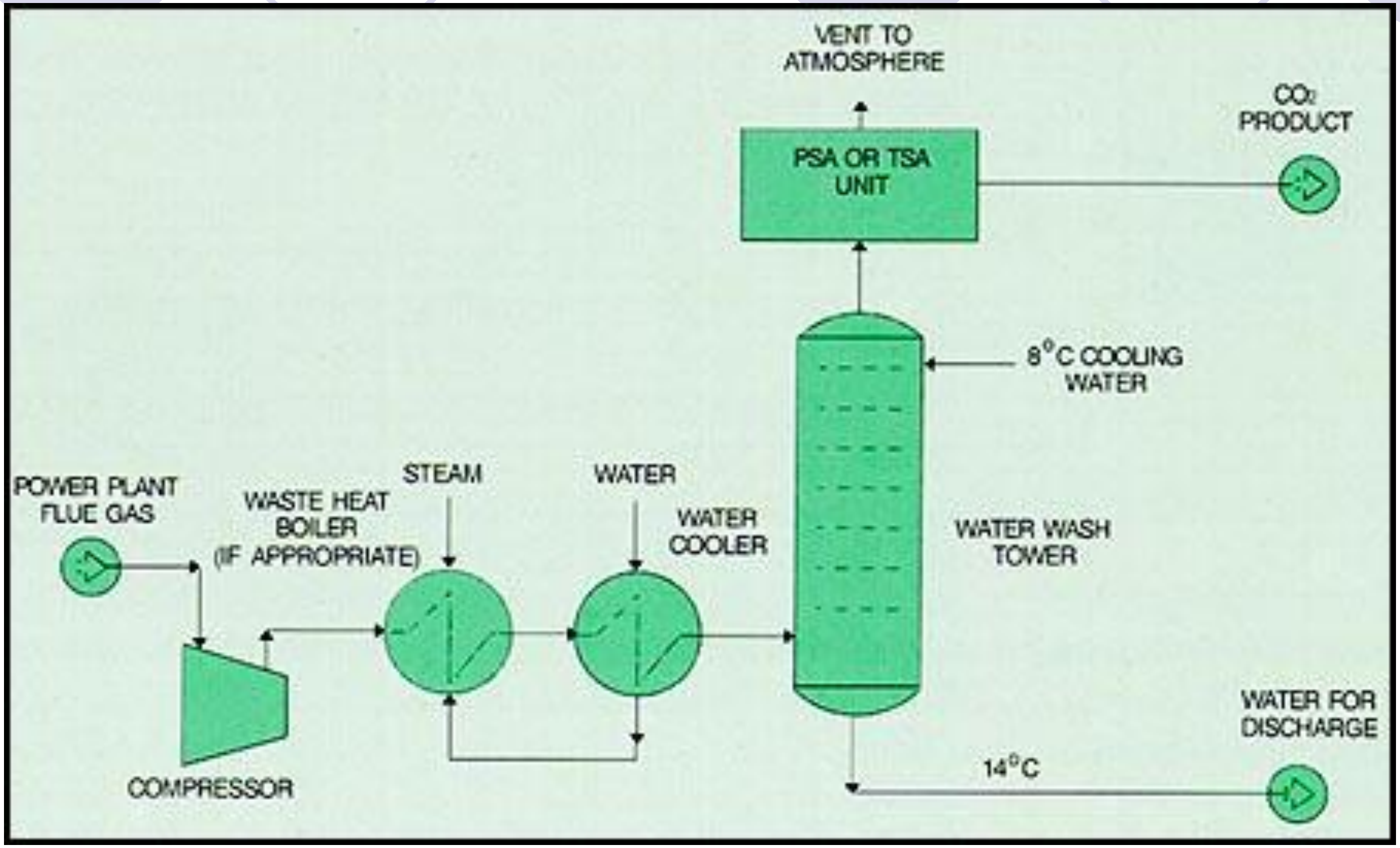






CO_2 recovery efficiency, O_2 loss rate and gas pressure drop (1% CO_2 Concentration)

⊕ 3 Adsorption of carbon dioxide

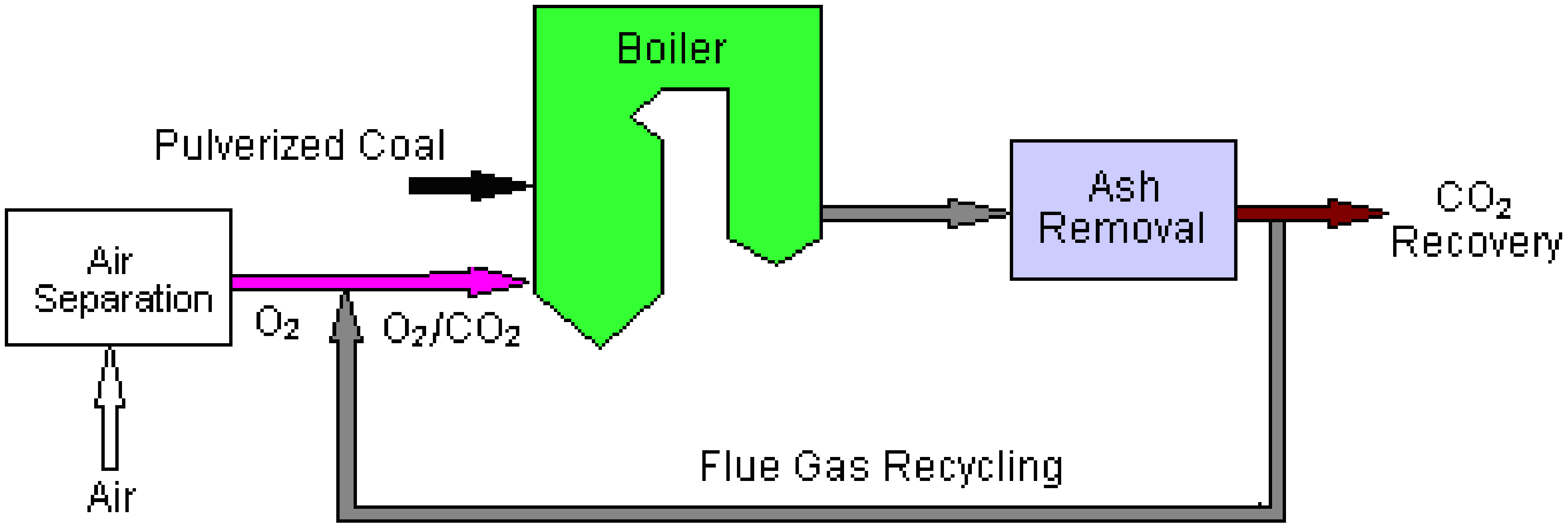


Adsorption is based on the inter-molecular attraction between the gas molecular and the active sites on the surface of adsorbent. The adsorbent is made up of some special solid, such as zeolite, active carbon and molecular sieve.

Research on CO_2 adsorption in China

- **China University of Mining Technology prepared the active carbon using anthracite as the feed coal used in separating CO_2. This active carbon have a long adsorption time and a great adsorption capacity.**
- ***Nanjing Chemical Institute* researched the adsorption using zeolite, active carbon and molecular sieve in 1991. There are more than 100 apparatus have been applied and the scale is more than 60000m^3/h. The apparatuses are mainly used in purification of CO_2, H_2S, NO_X, H_2, and natural gas and removal of some toxic substance.**

II Oxy-fuel Combustion

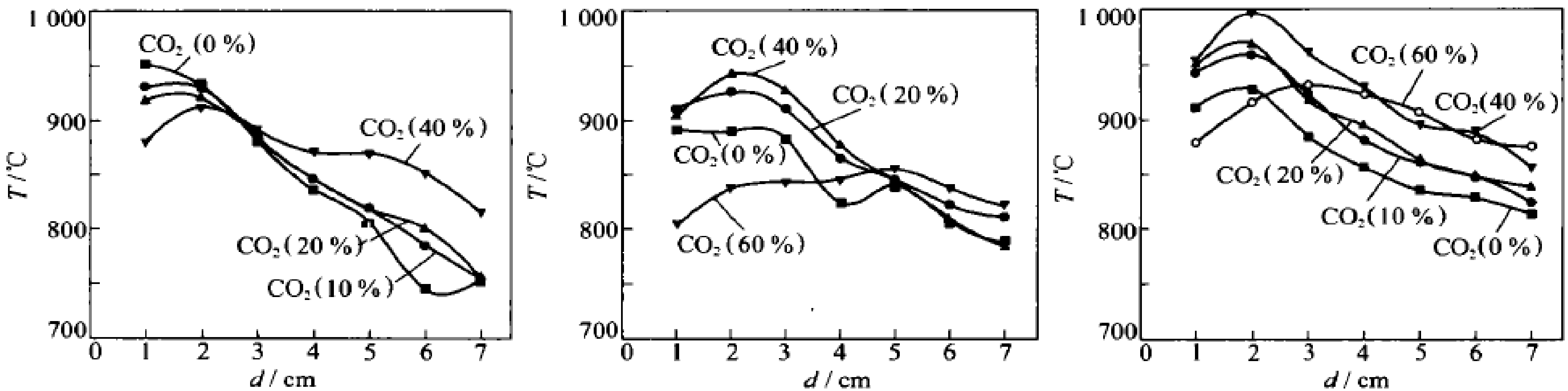


Typical Oxy-fuel combustion process

Research on Oxy-fuel Combustion in China

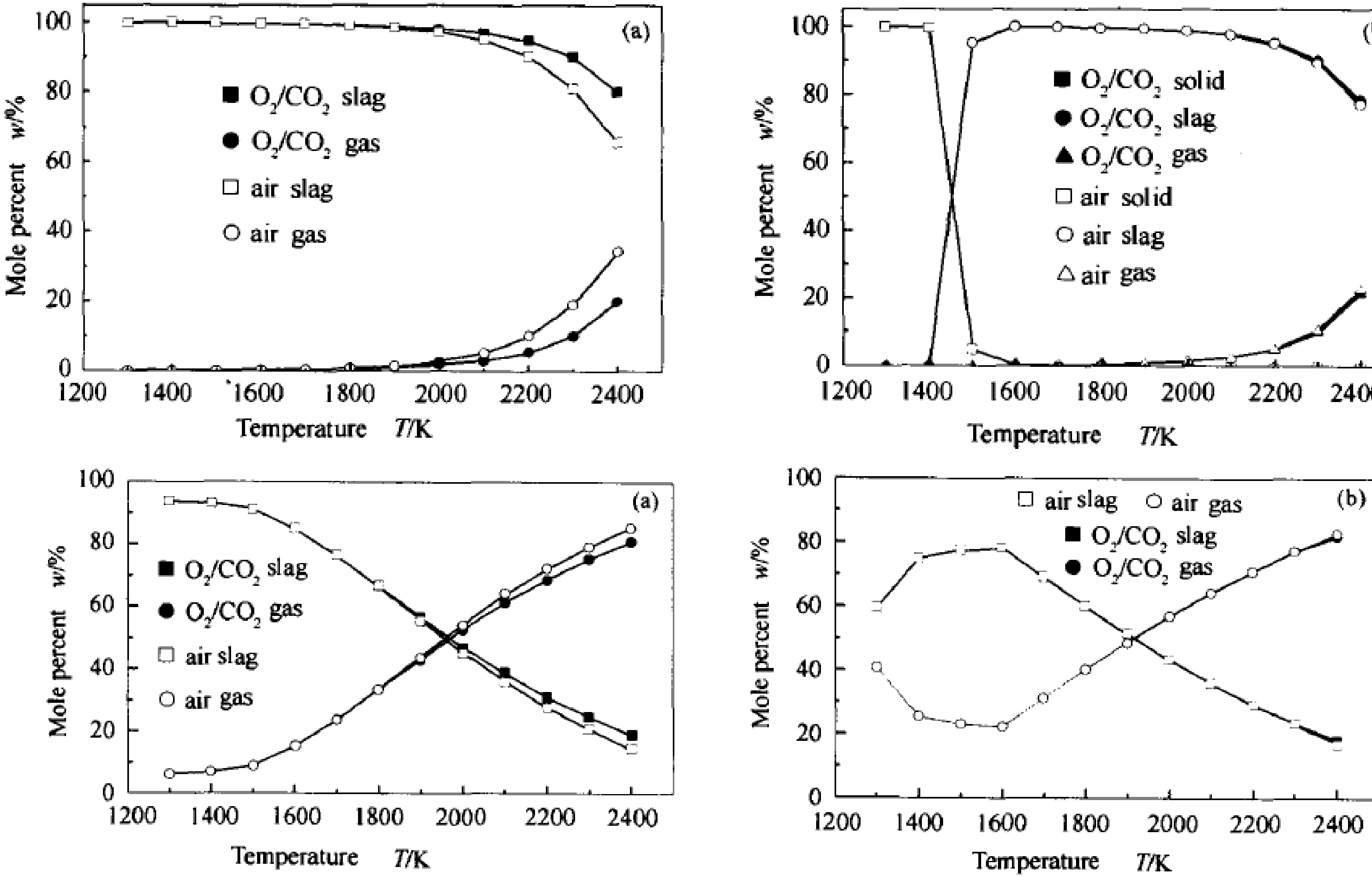
- **Southeast University**: Characteristics of Pulverized Coal Combustion in O_2/CO_2 Mixtures; Thermodynamics analysis; Pollutant Control…
- **North China Electric Power University.** Based on the experiments of characteristics of coal combustion and pollutant emissions under the oxy-fuel conditions using an entrained-flow reactor, they reported the decrease of SO_2 and NOx emissions.
- **Huazhong University of Science and Technology** studied the desulfurization under the condition of oxy-fuel combustion in a vertical tube electrical heating reactor and a small oxy-fuel combustion test system was built.
- **Zhejiang University** studied the oxy-fuel combustion with the CFB.
- Tsinghua University
- Chongqing University
- …..

Oxyfuel Combustion Research by Huazhong University of Science and Technology



Effect of air excess coefficient (λ) on temperature characteristics of CH_4 flame under O_2/CO_2 atmosphere.

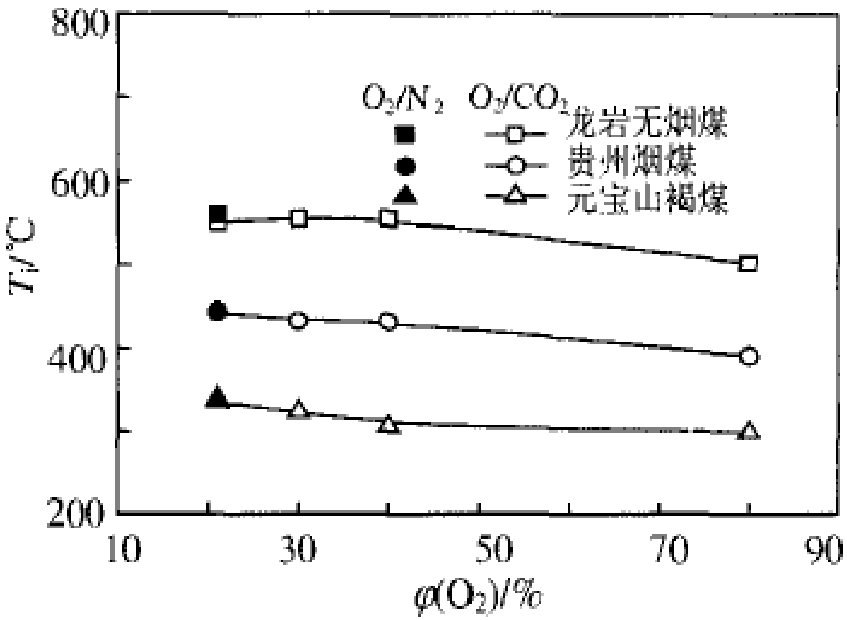
(Left: λ=0.8; Medium: λ=1; Right: λ=1.1)



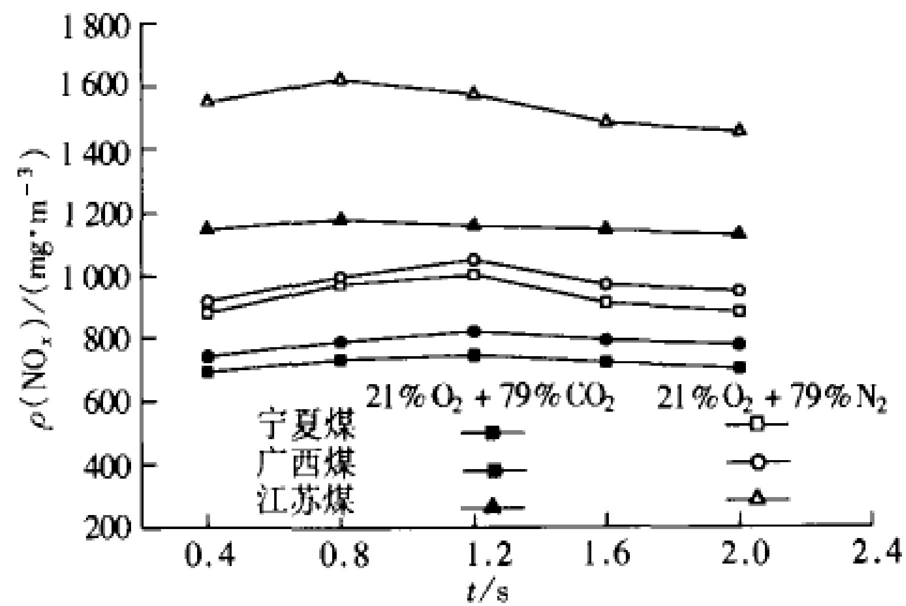
Equilibrium distributions of Fe and Na under different atmospheres.

(a: reducing condition; b: oxidizing condition)

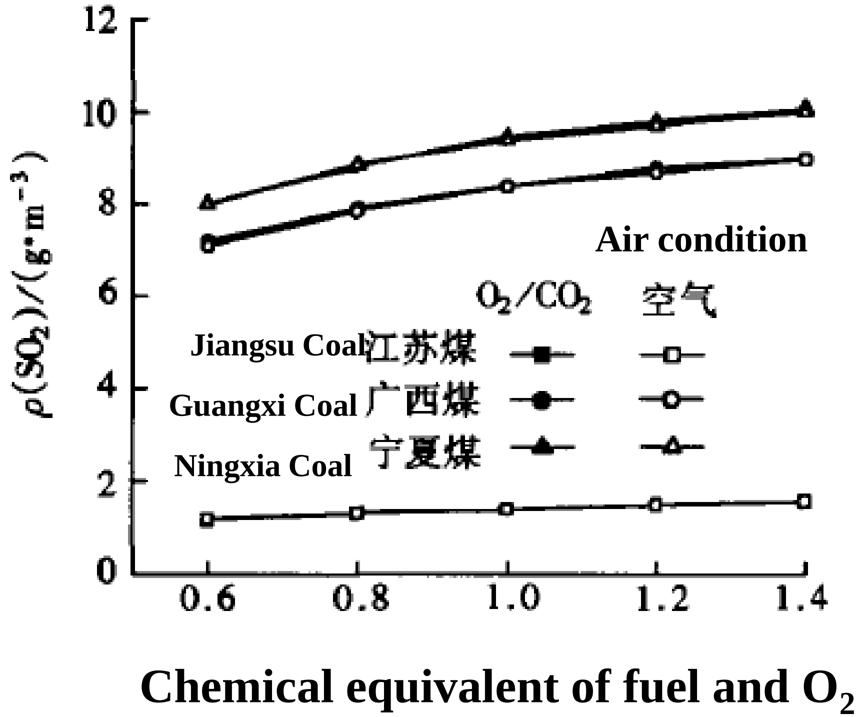
Oxyfuel Combustion Research by Southeast University and North China Electric Power University

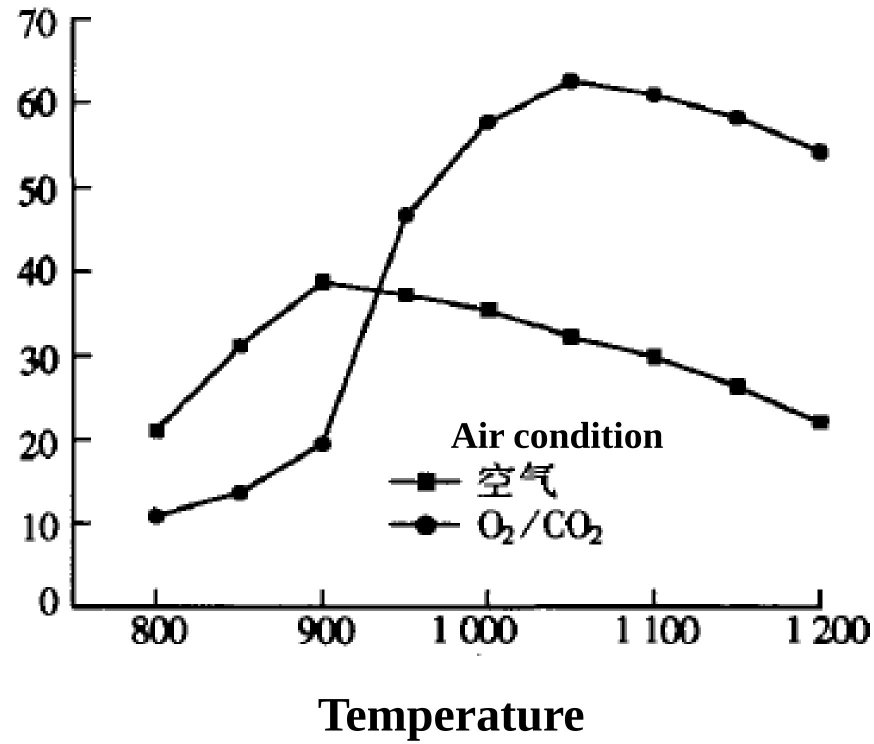


Effect of O_2 content on burnout temperature (T)



Characteristic of NO_X emission (ρ) under O_2/CO_2 condition

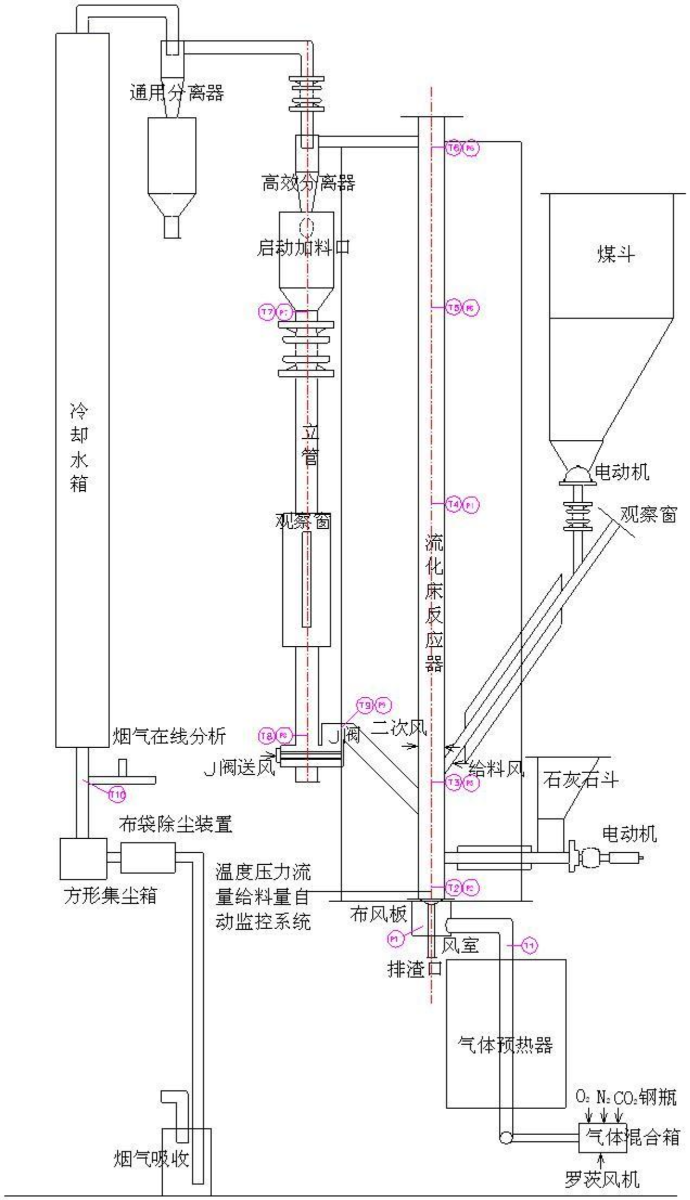




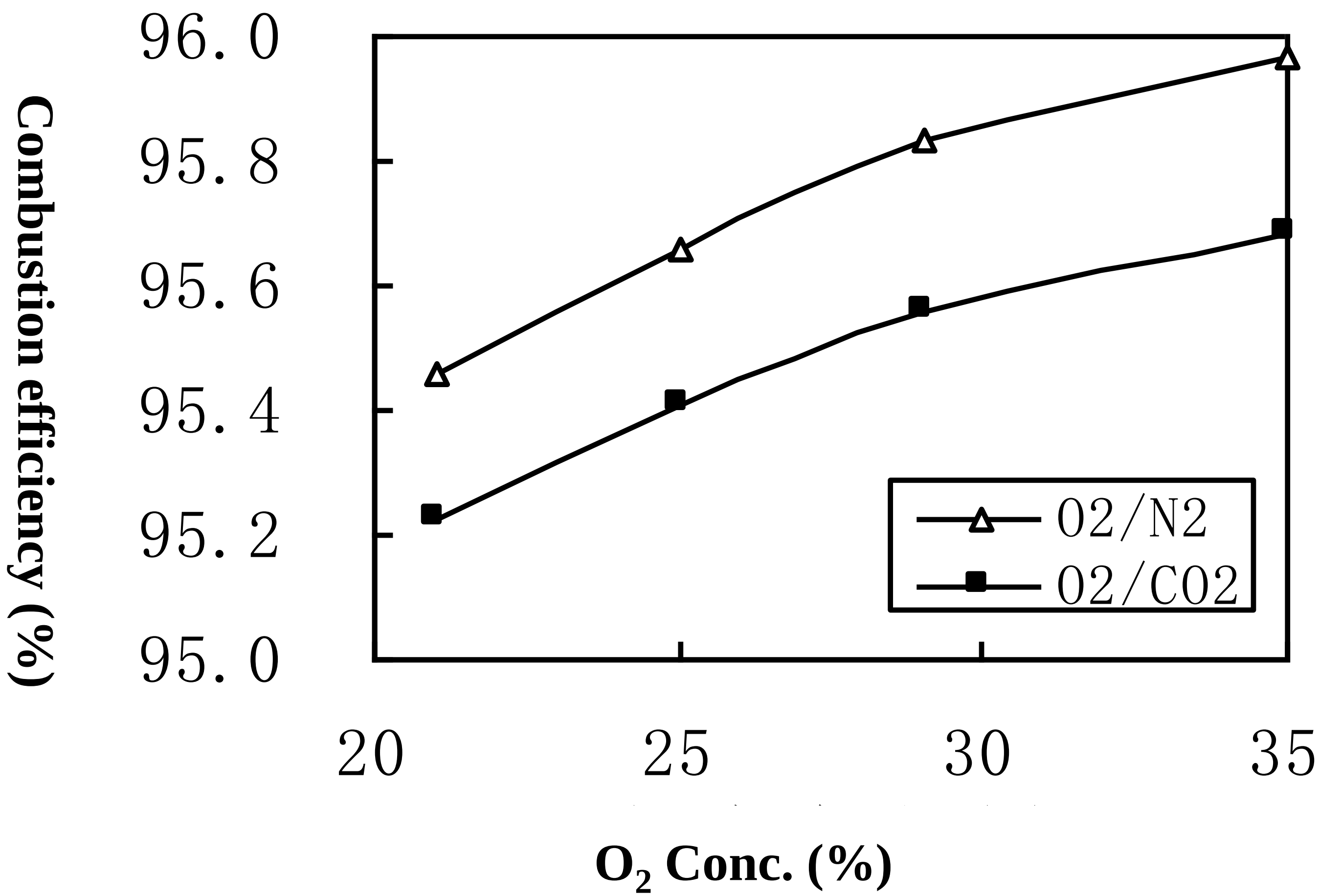
Effect of fuel/O_2 chemical equivalent on SO_2 emission

Effect of temperature on SO_2 removal efficiency

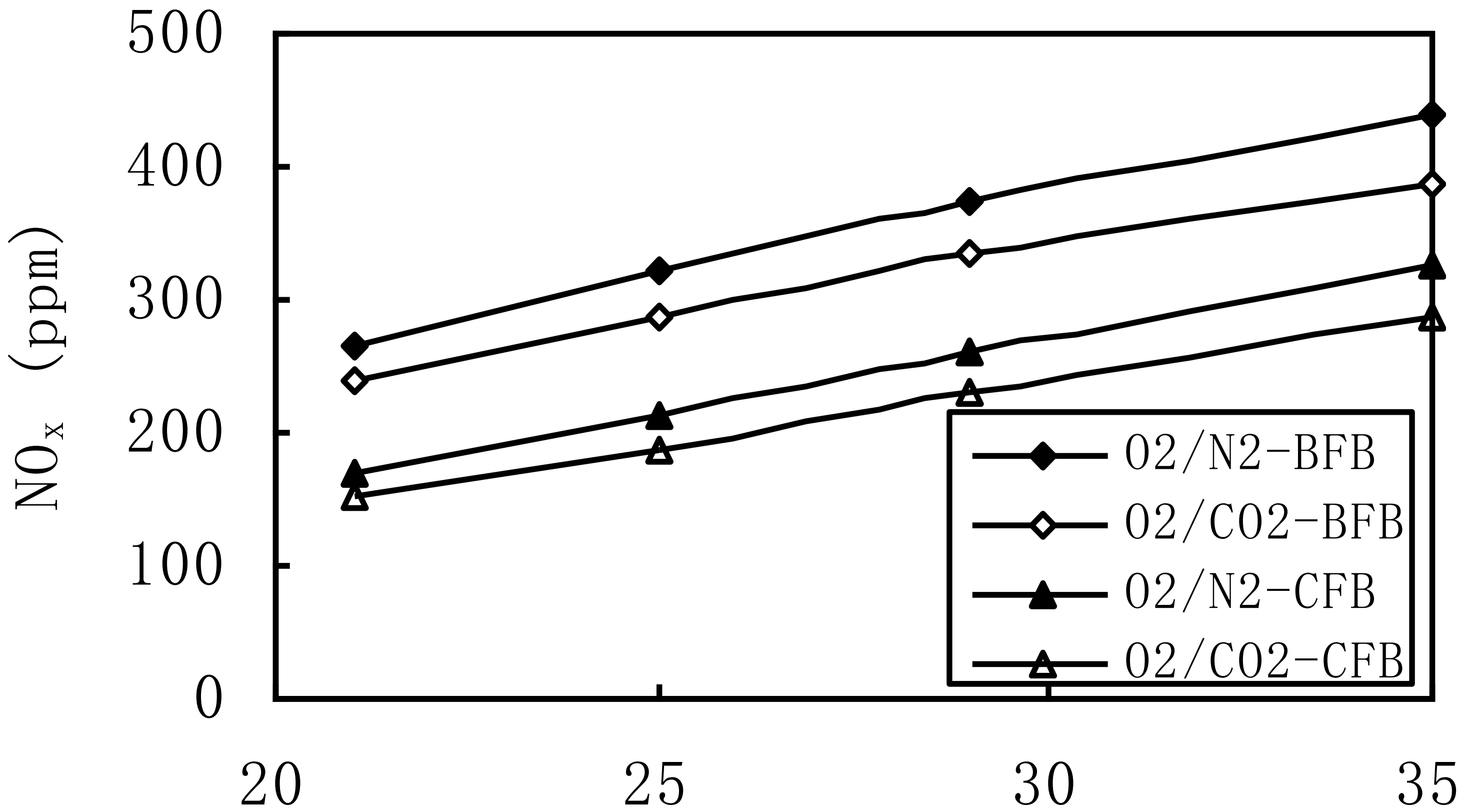
Oxyfuel Combustion Test-facility in ZJU



Oxy-fuel Combustion Efficiency

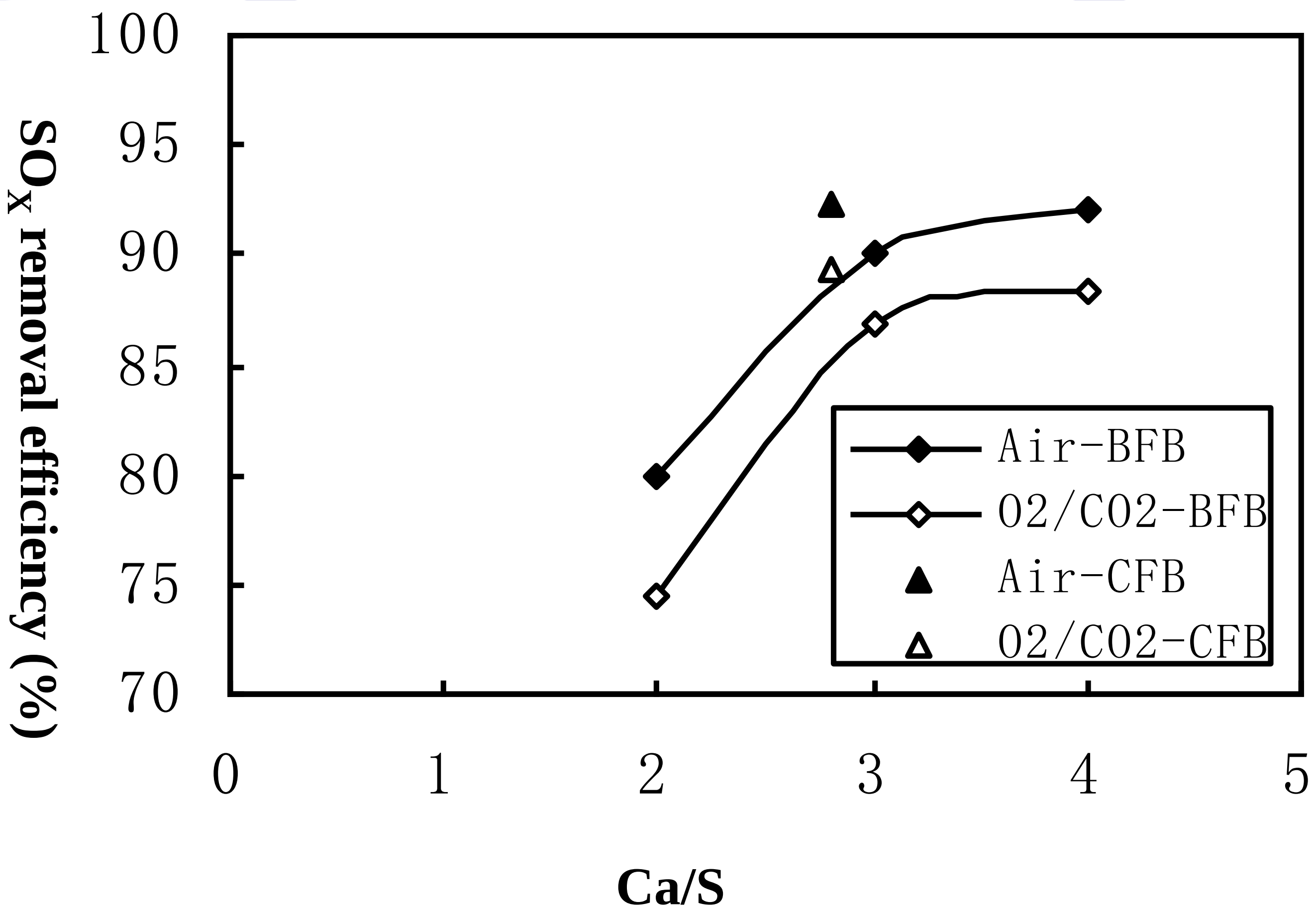


Emission of O_2 Content on NOx Emission



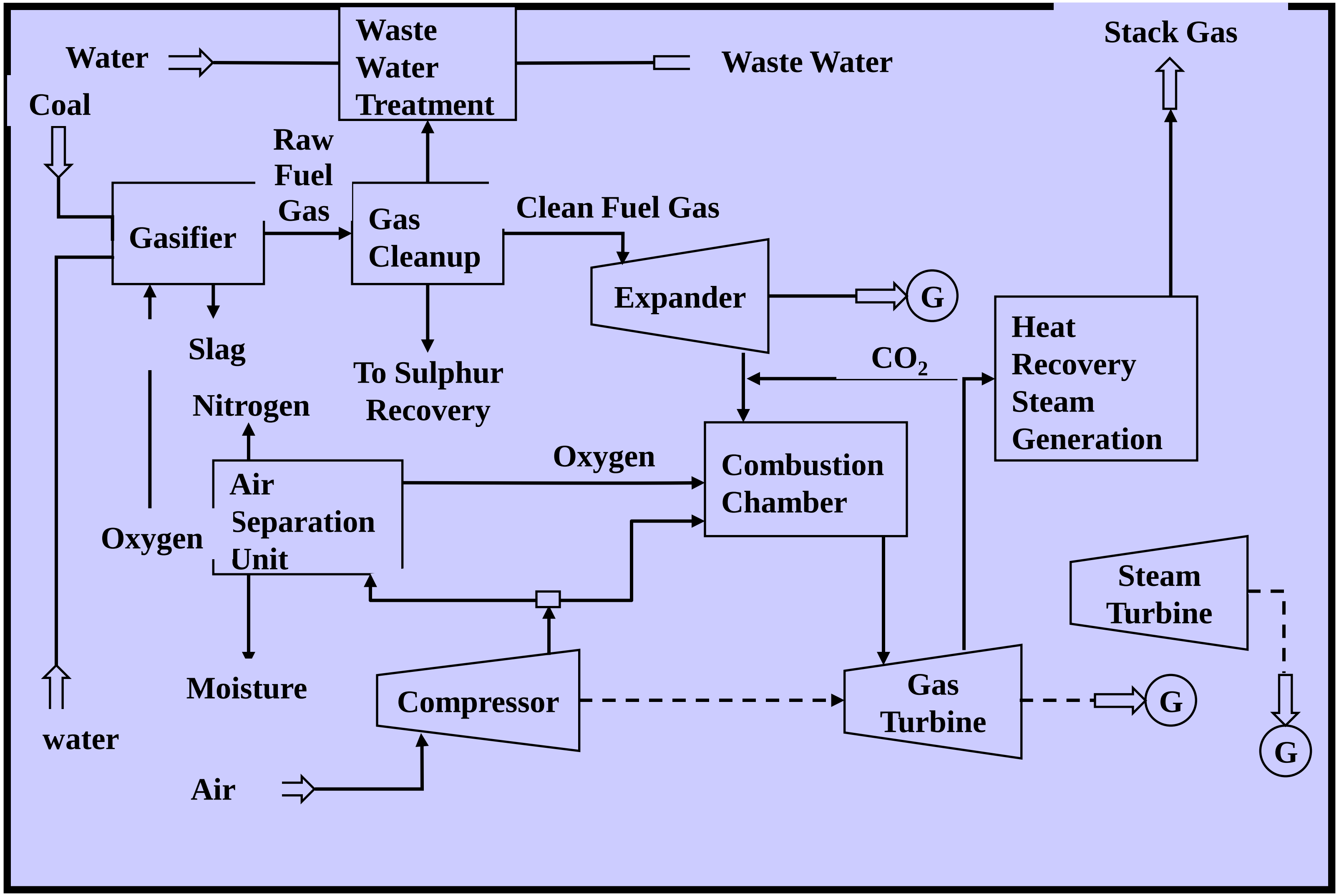
O_2 Conc. (%)

SO_X Removal Efficiency



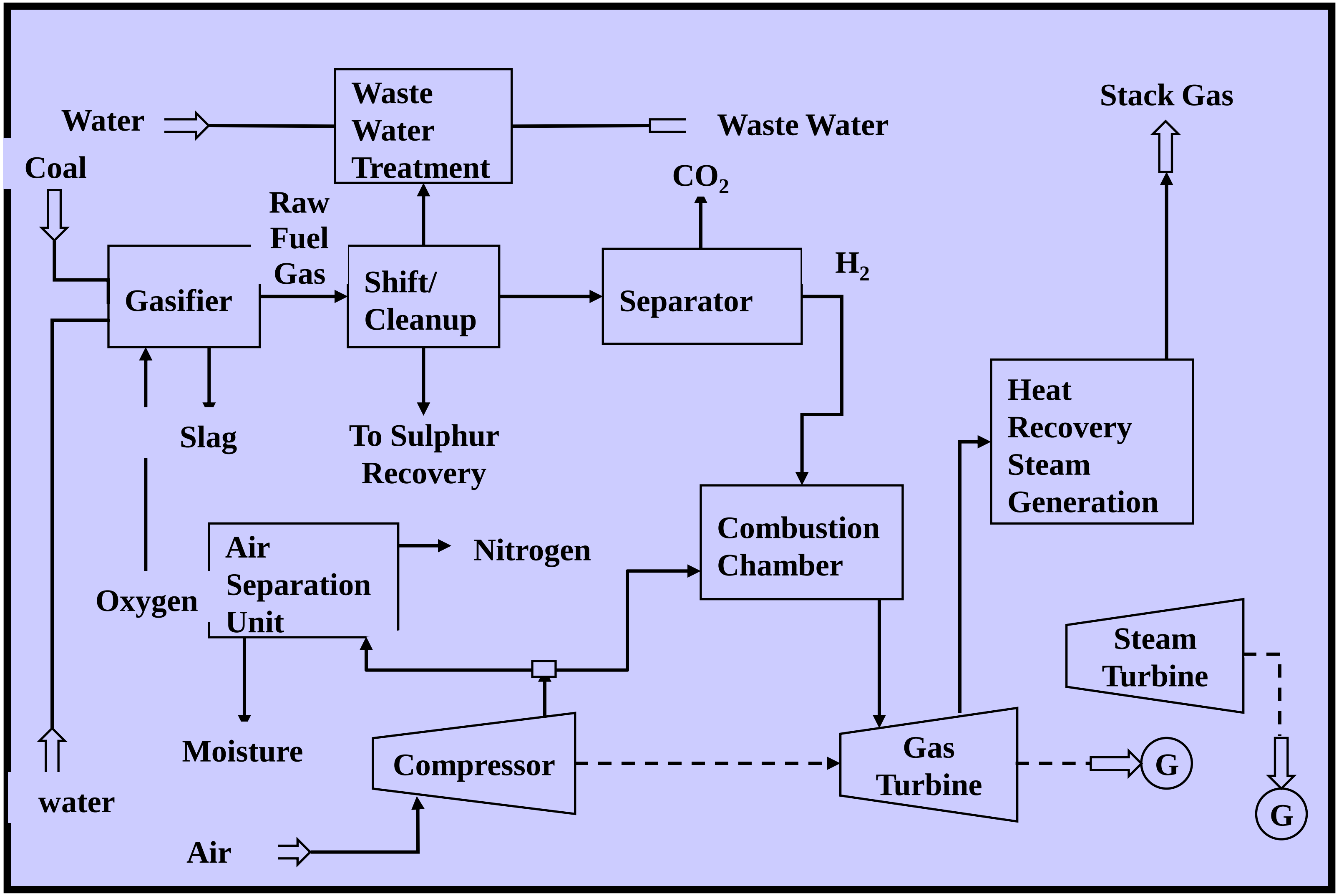
III-1 IGCC with CO_2 separation

Scheme1: IGCC with CO_2 Separation after combustion



III-2 IGCC with CO_2 separation

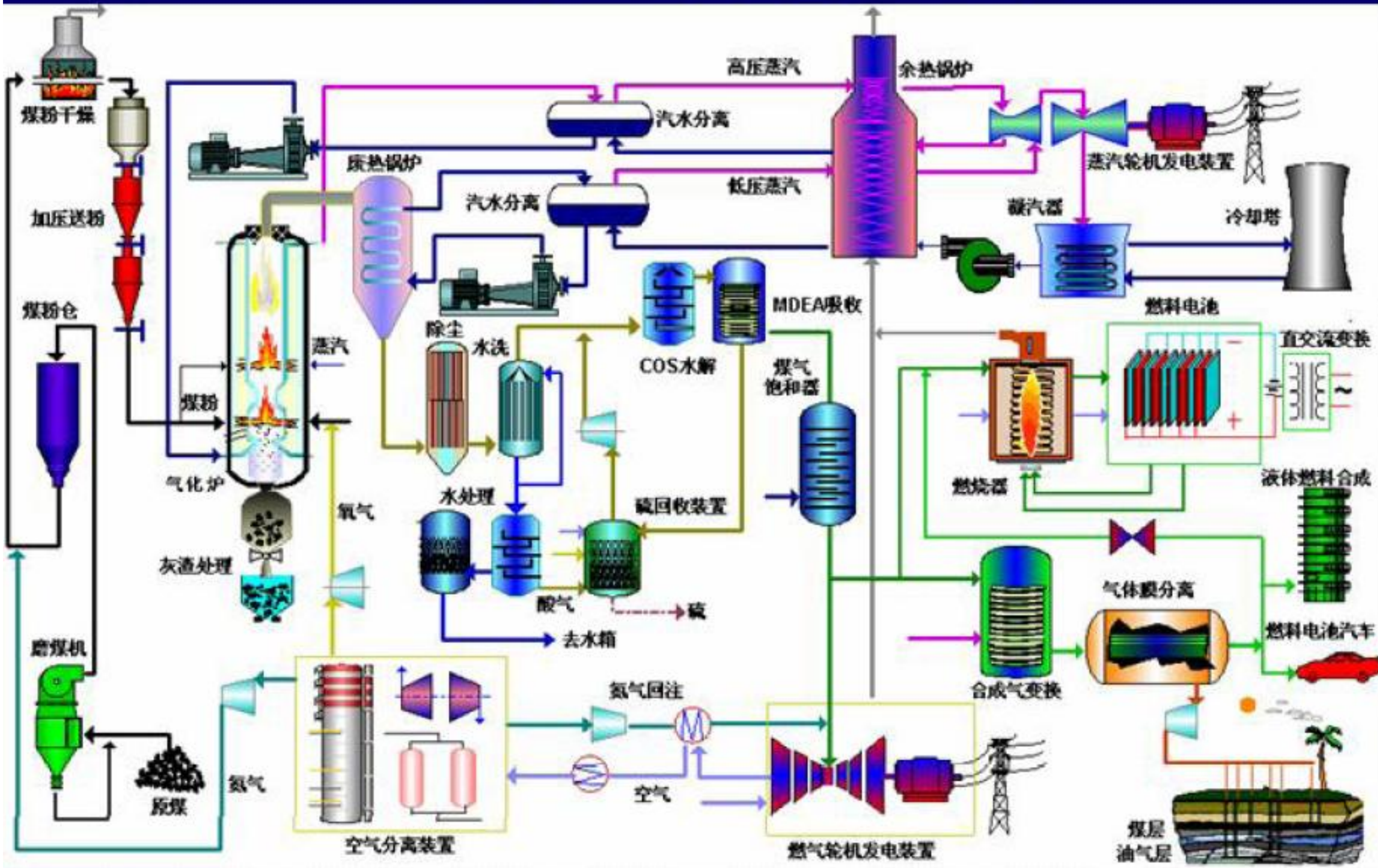
Scheme2: IGCC with CO_2 Separation before combustion



GreenGen's 400 MW Demonstration Project with H_2, Electricity Production and CO_2 separation in Tianjin

The Flow Sheet of GreenGen

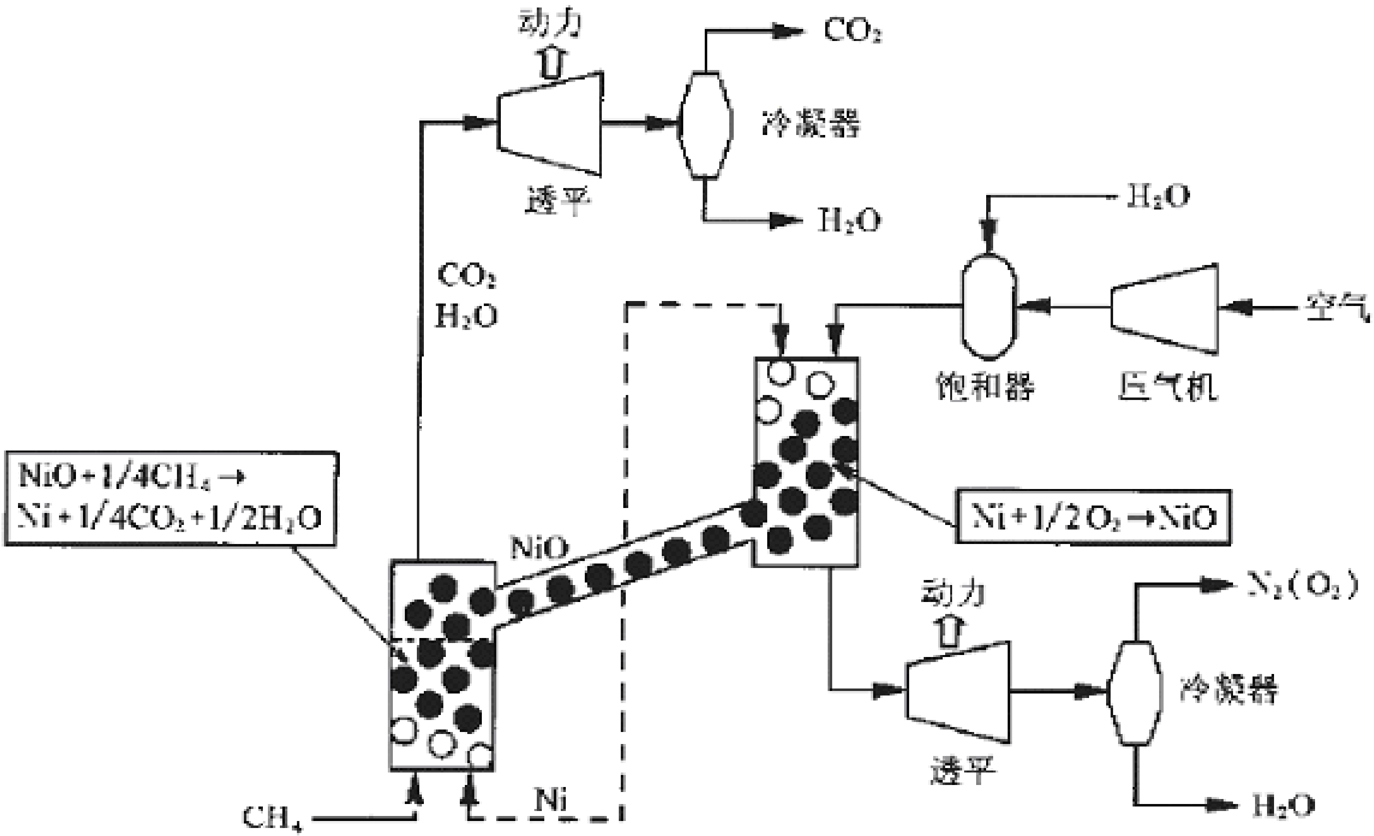
TPRI



Technological goals of GreenGen

- To complete industrial demonstration project of 400MW before 2020
- Generation efficiency up to 55%-60%
- SO_2 and NOx emission less than $20 mg/Nm^3$
- PM2.5, Hg and VOC near zero discharge
- Over 80% of CO_2 separated and treated
- Byproducts effectively utilized
- Acceptable cost

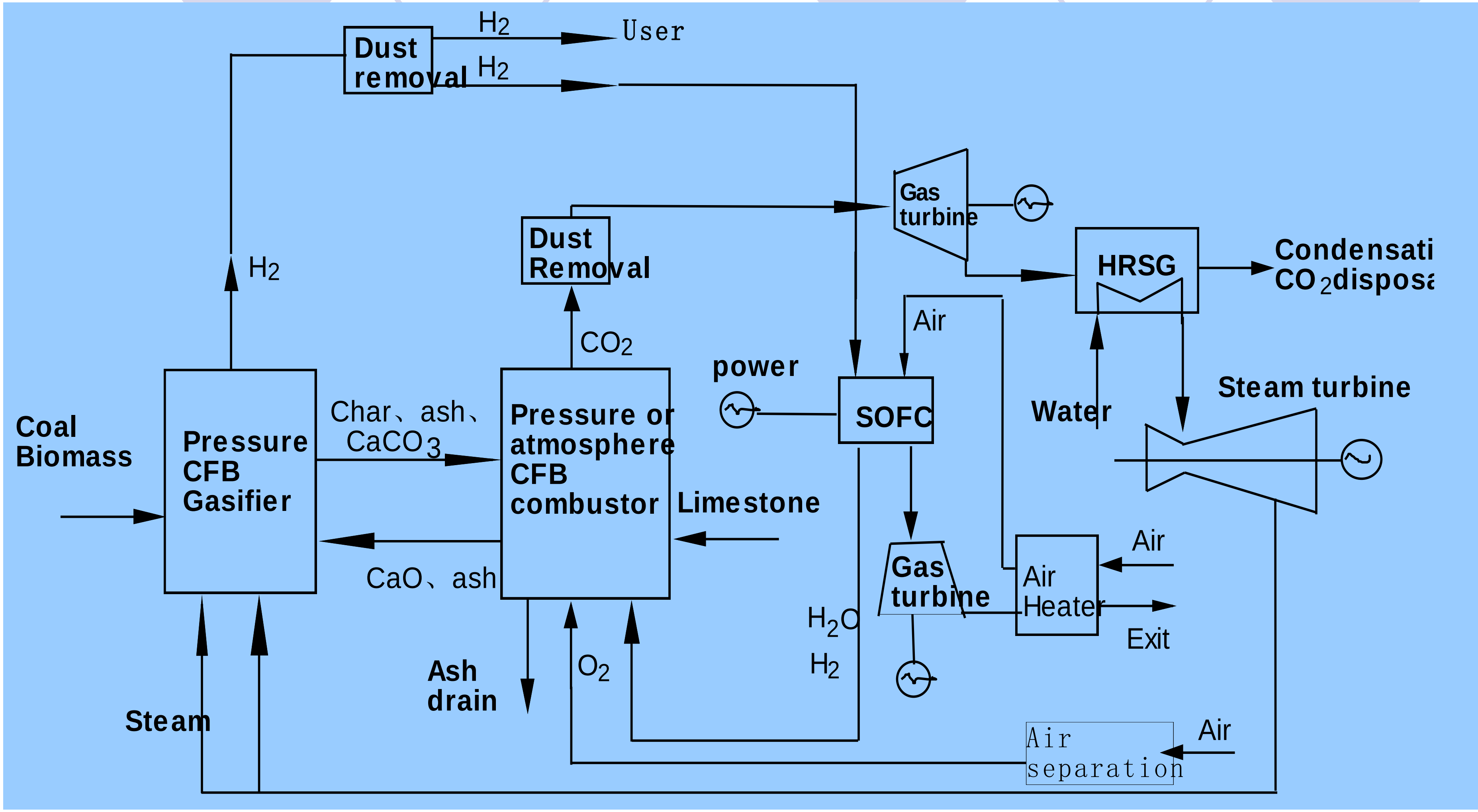
IV Chemical-looping Combustion



Research on Chemical looping Combustion system

- **Institute of Engineering Thermophysics studied the chemical looping combustion technology combined with the saturation for air combustion turbine using $NiO/NiAl_2O_4$ as oxygen carriers.**
- **Southeast University studied the high rate power generation and CO_2 separation with gasify, chemical looping combustion and combined cycle technologies using Fe_2O_3,Fe_3O_4 as oxygen carriers.**
- **Zhejiang University also studied the chemical looping combustion.**

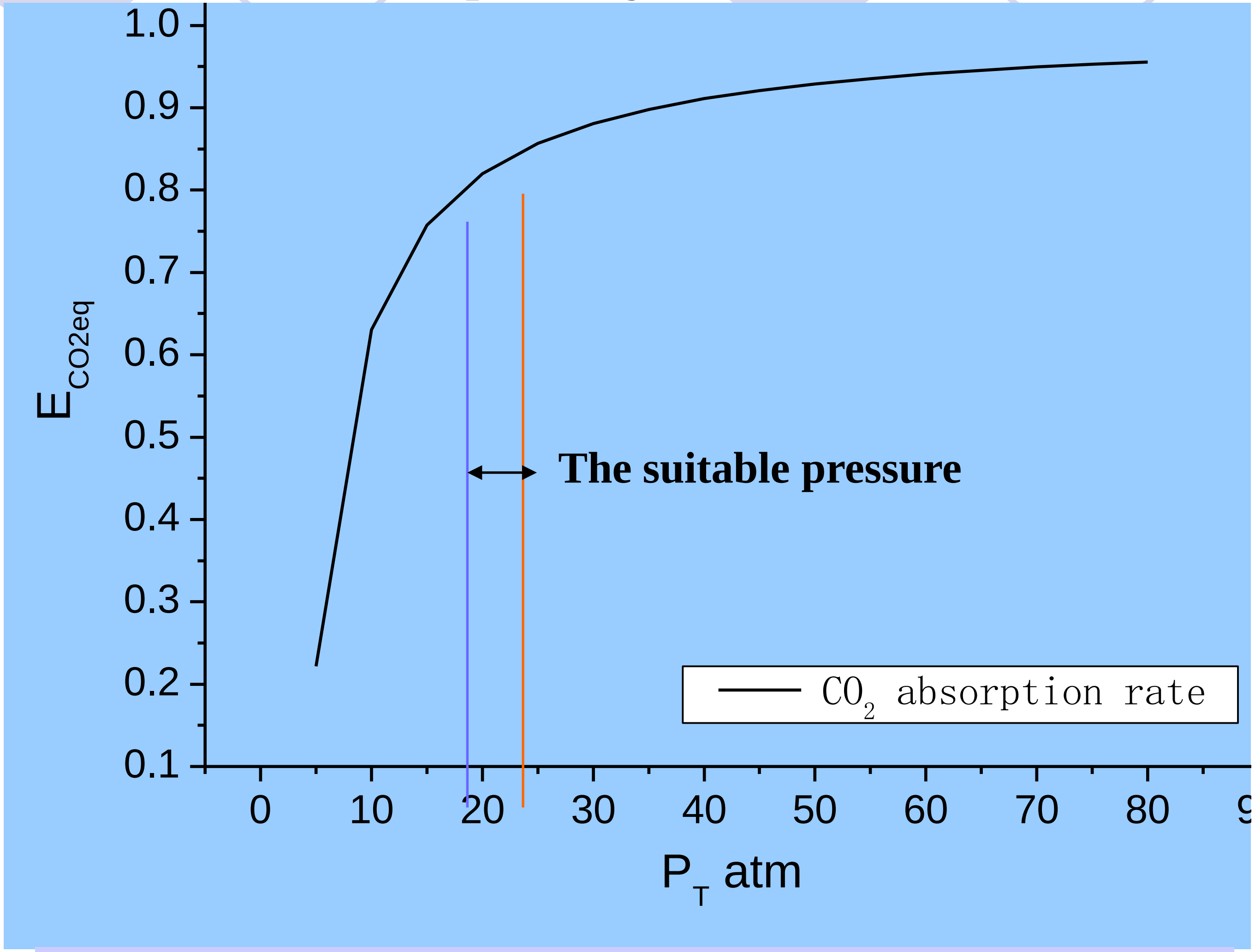
V Near Zero Emissions Coal Utilization Technology to Produce H_2 in ZJU



System Design for 400MW Plant	
Coal feed rate（kg/s）	18.35
Operation Pressure（bar）	25
Temperature in the gasifier（K）	1123
Heat loss of the gasifier （kJ/s）	3120.93
Coal gasification ratio	0.7
Hydrogen production rate（kmol/s）	1.42
Pressure in combustor（bar）	25
Temperature in the combustor（K）	1223
Limestone supplement（kg/s）	4.25
Fuel utilization ratio in the SOFC（％）	85
Oxygen utilization ratio in the SOFC（％）	51
Power generation from the SOFC（kW）	269208.48
Efficiency of gas turbine cycle（％）	59
Power generation from the gas turbine（KW）	152115.31
Power generation from the steam turbine cycle,kw	3956.7
Power consumption of the air separation（kW）	25955
Power consumption of the air compressor, kw	99821.12
Net Power generation（kW）	413538.88
System efficiency（％）	66.52

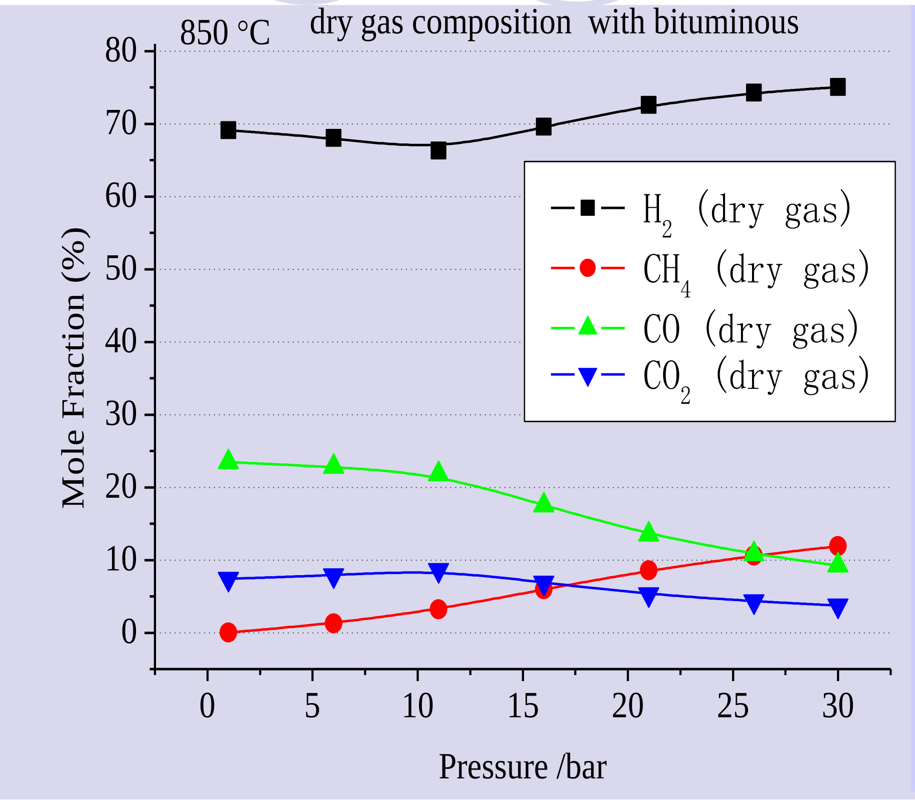
Effect of pressure on carbonation reaction rate

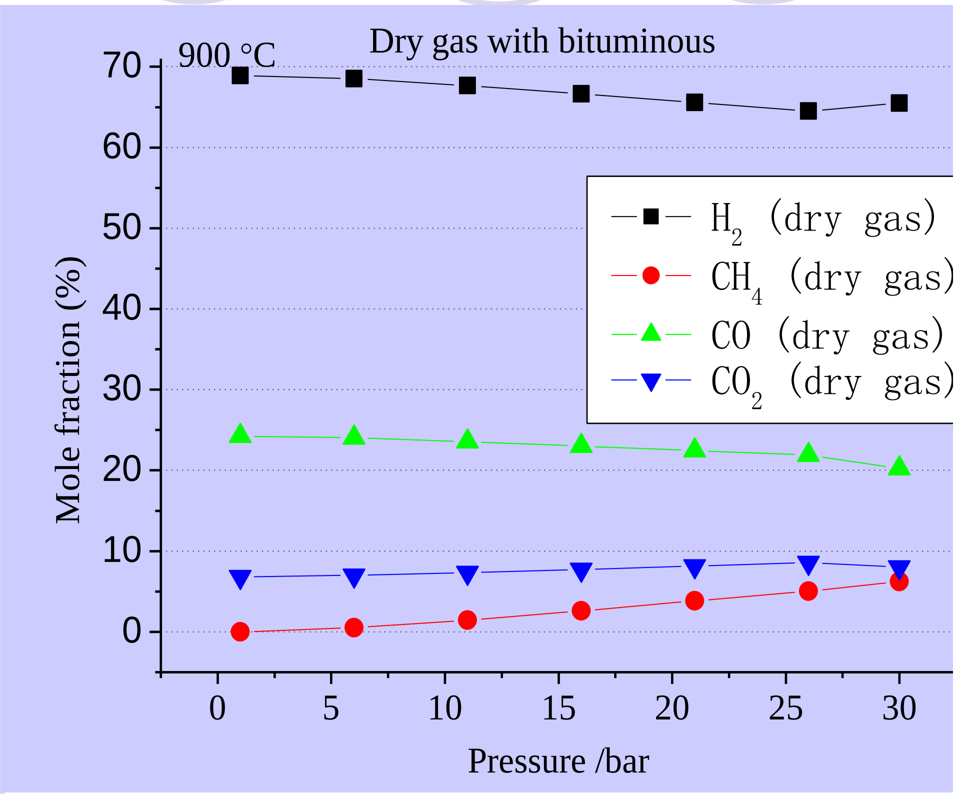
$CaO+CO_2=CaCO_3+178.1kJ/mol$



Suitable pressure range may be 20-30 bars

Effect of Pressure on Dry Gas Composition



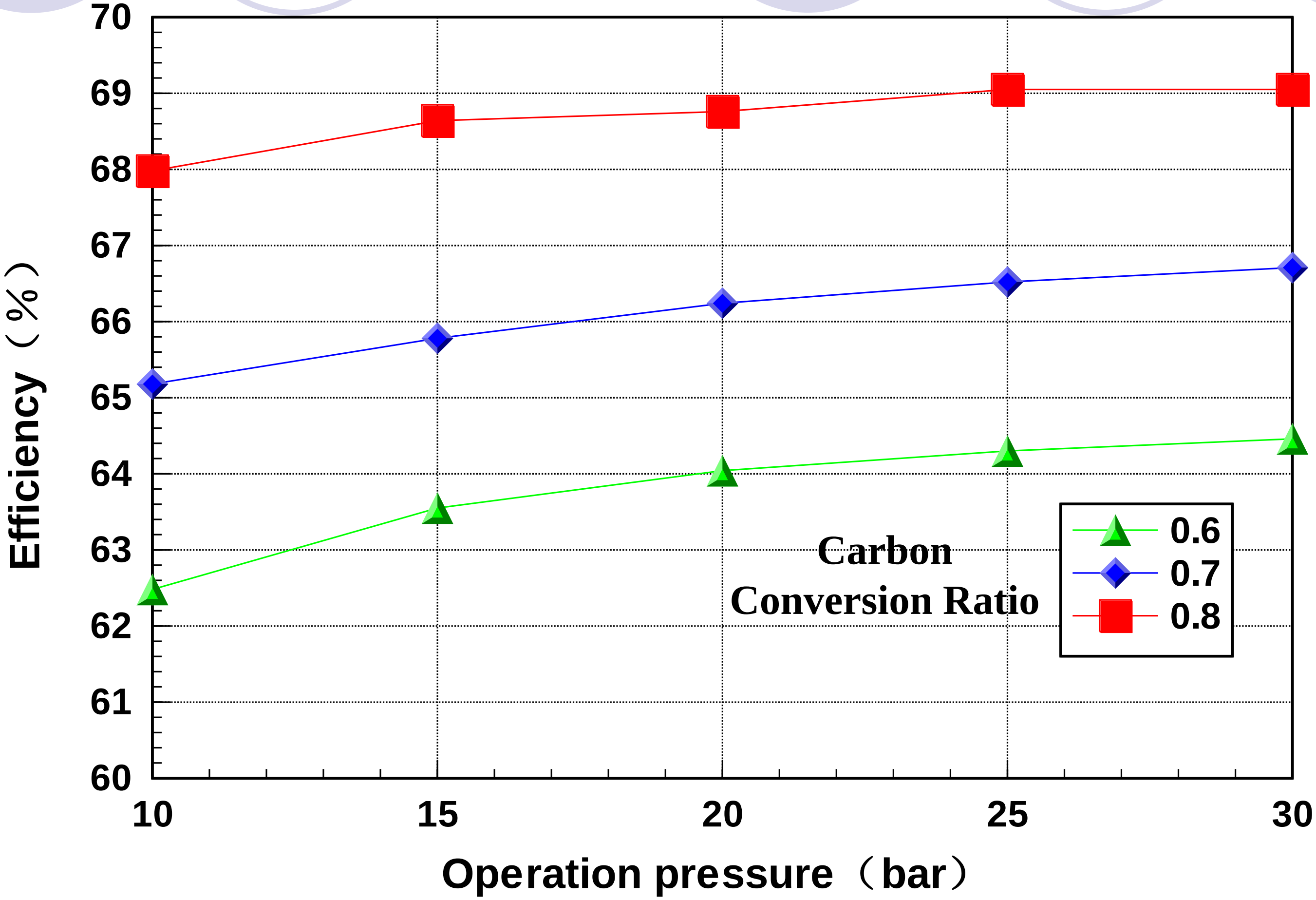


Bituminous coal

Reaction temperature: 850℃ (left), 900 ℃ (right)

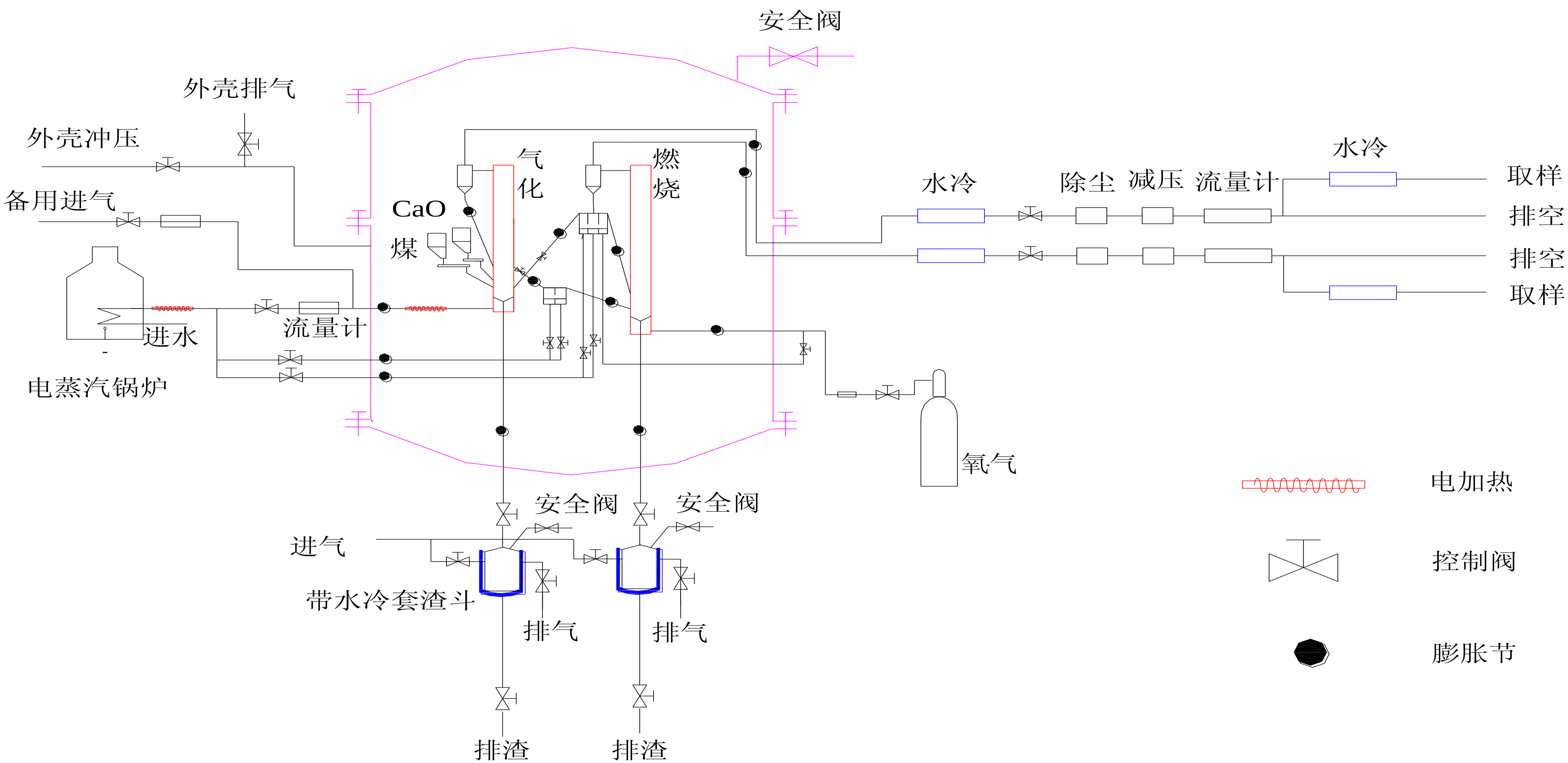
C:H_2O:CaO=1:2:1

Effect of Operation Pressure



System efficiency versus operation pressure under different carbon conversion ratio

Near Zero Emissions Coal Utilization Facility in ZJU



0-30bar, 1000℃

VI CO_2 Utilization and Fixation

Characteristics of Sequestration Methods

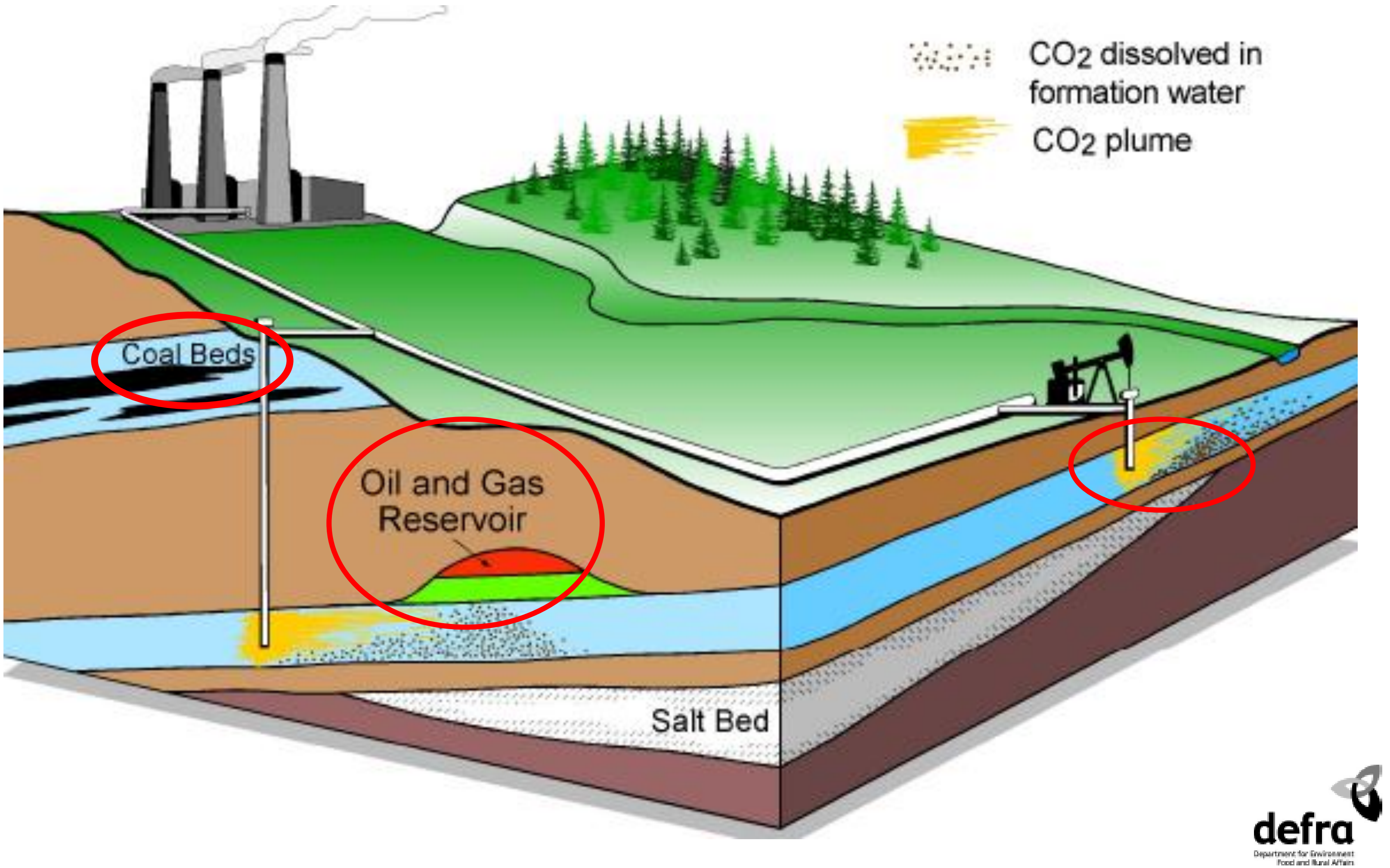
- **Underground Geological Storage**
  - CO_2 can store underground in a long time;
  - EOR technology can reduce the cost of CCS;
  - Selection of suitable storage site and monitor of CO_2 leakage are essential.

- **Ocean Storage**
  - Research phase
  - Immature Technology
  - Higher Cost
  - Unclear Effect of CO_2 on Ocean Ecological Environmenta l in long term

- **Mineral Carbonation**
  - Higher Cost;
  - Immature Technology;
  - Long Storage time.

- **Biological Storage**
  - Short Storage time
  - Higher Cost

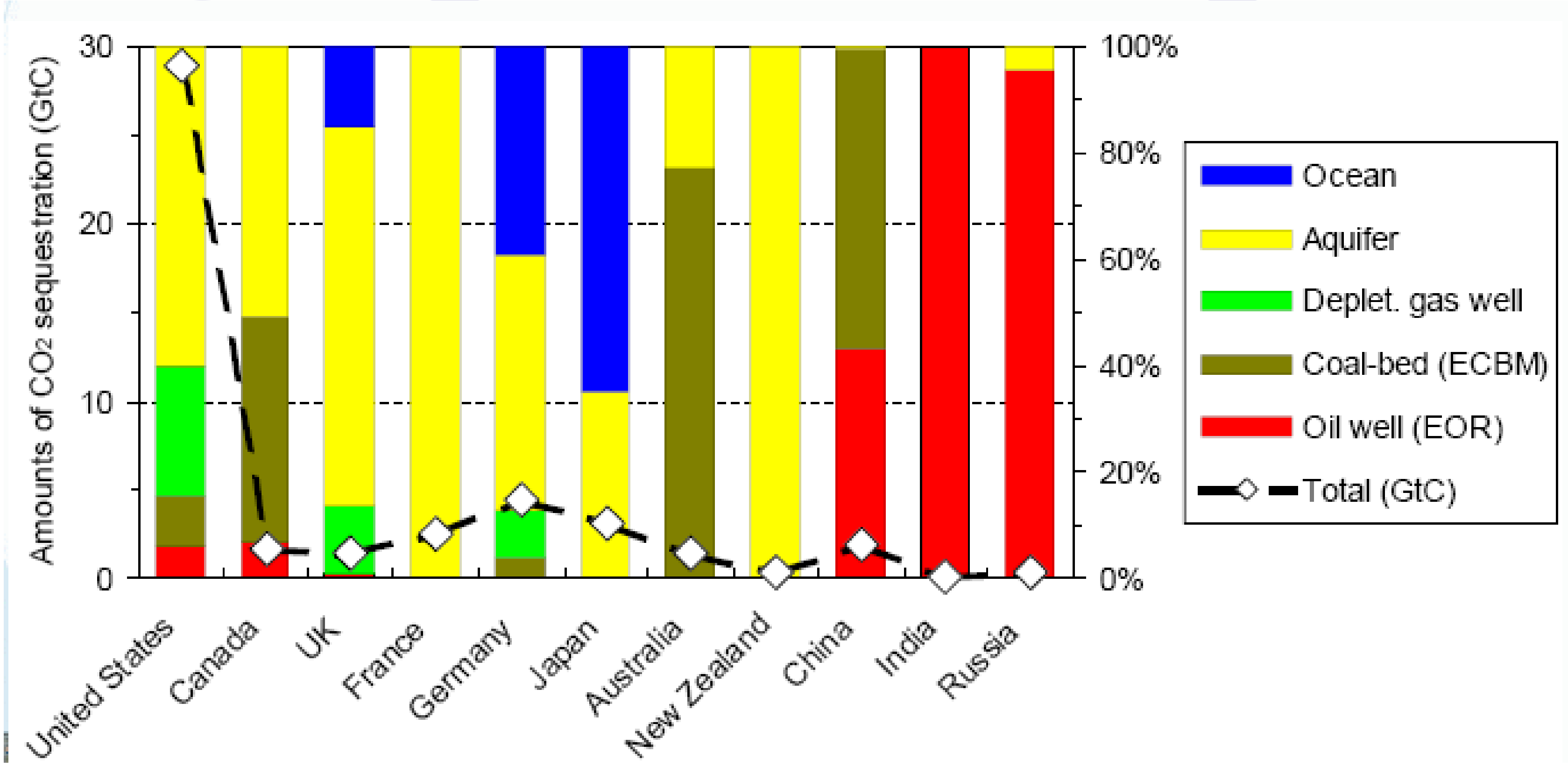
1. Underground Geological Storage in Oil & Gas Reserviors,Coals & Saline Aquifers



1. Underground Geological Storage

- **Aquifers**
- **Oil Fields（CO_2-EOR, enhanced oil recovery）**
- **Natural Gas Fields（CO_2-EGR, enhanced gas recovery）**
- **Coal Bed（CO_2-ECBM, enhanced coal beds methane）**
- **CO_2 injected into depleted oil & gas fields, aquifers and coal beds which can not be exploited can be stored in a very long time, but the revenue may be low.**
- **The operations that CO_2 was directly injected into the exploiting oil or gas fields and coal seams can not only reduce the CO_2 emissions, but also increase the recovery efficiency of oil, gas and coal seam gas (Win-win situation between Revenue and environmental protection)**

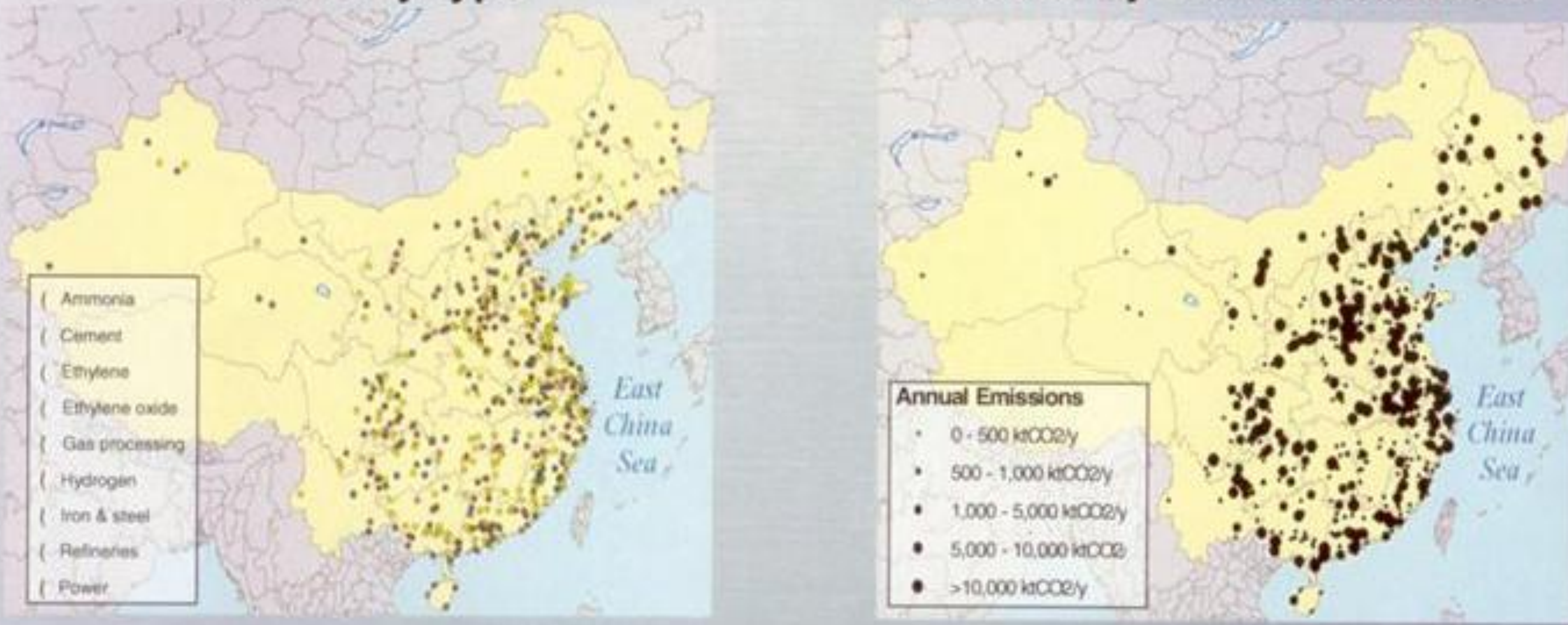
Options and Deploy Scale of Underground Storage in China



(Cited from Institute of Rock and Soil Mechanics, Chinese Academy of Sciences)

CO_2 Storage Capacity In China

Sources by type — Sources by annual emissions

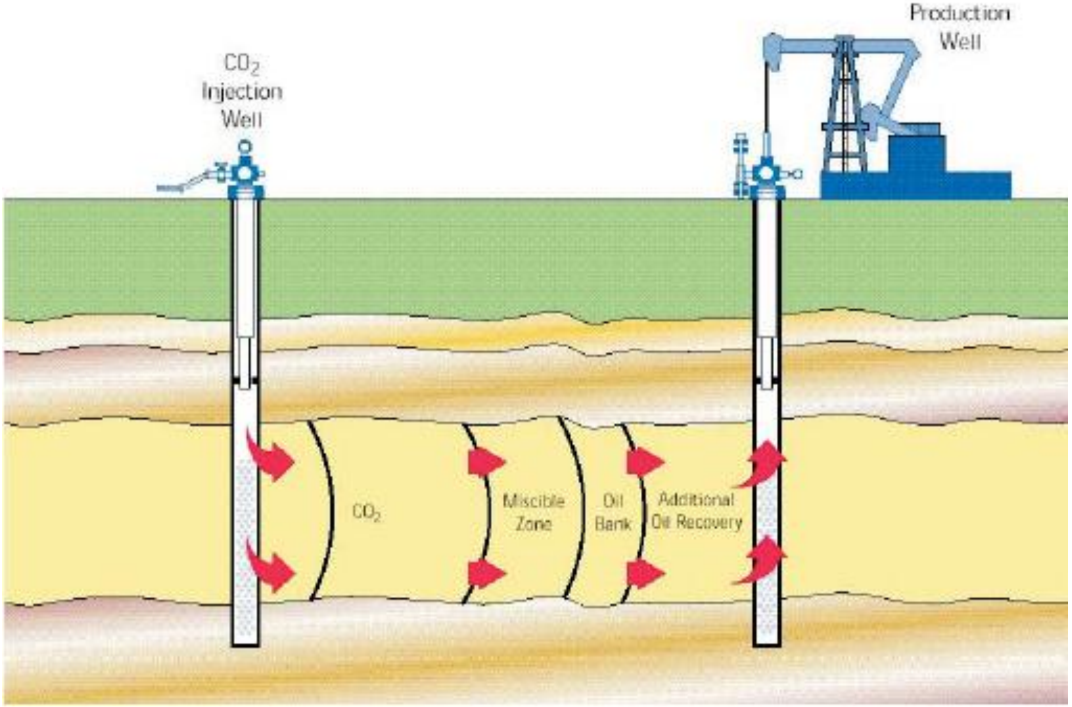


26 $GtCO_2$ storage capacity identified in the literature within Chinese coal-beds, depleted oil and gas fields

360 $GtCO_2$ storage capacity in deep saline formations in China estimated by Dooley and Friedman (2004)

CO_2 Enhanced Oil Recovery (EOR) in China

- CO_2 separated is mainly applied in enhanced oil recovery (EOR).
- EOR can not only increase the oil field production, but also prolong the oil field production period.
- Study have been made on EOR in China.



Research of CO_2 -EOR in China

Project	Scale of project	Start date	Storage type
Daqing Oil Field	Pilot	1990	CO_2-EOR
Jiangsu Oil Field	Pilot	1998	CO_2-EOR
Liaohe Oil Field	Pilot	2001	CO_2-EOR
Zhongyuan Oil Field	Pilot		CO_2-EOR
Jilin Oil Field	Pilot	1994	CO_2-EOR
Shengli Oil Field	Pilot		CO_2-EOR

Application Project of CO_2 -EOR in China

- December, 2006. CO_2 was injected into the No. 9711 and 9117 wells to recover oil by Gas Production Branch of Daqing Oil Field.

- 12nd, June, 2007. In the Tuha oil field, CO_2 with 90 m^3 volume was successfully injected into the oil field to recover oil. The operation was lasted about 2 hours.

- 12nd, November, 2007. In the Kongdian Oil Field which is affiliated with Dagang Oil Field Company, CO_2 was successfully used to enhance the oil yield at the Yang 7-13-2 well. The operation was lasted about 1.5 years, and the oil output was increased from 2 ton/day to 10 ton/day.

- January, 2007. The best mining technology was awarded to Liaohe Petroleum Exploration Bureau because of their enhanced oil recovery technology using flue gas, which can increase the oil recovery by 10%~20%.

Application Project of CO_2 -EOR in China

Jilin Oil Field, China National Petroleum Corporation

August, 2007. The project, "Research on Exploitation of Natural Gas with Higher CO_2 Concentration, CO_2 storage and Comprehensive Utilization of Resources in Jilin Oil Field", was started.

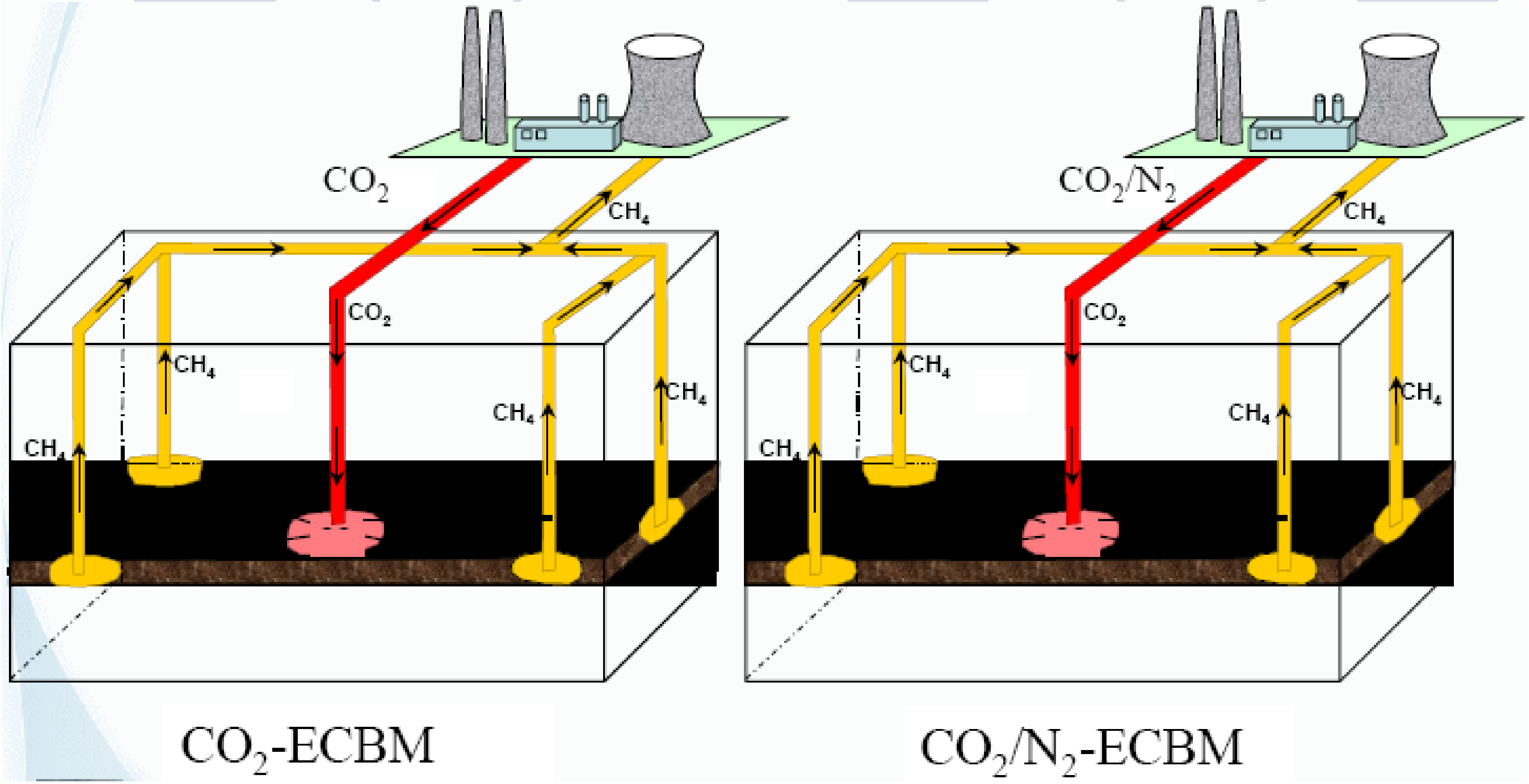
Application Project of CO_2 -EOR in China

Zhongyuan Oil Field, SINOPEC

February, 2008. The experimental project of CO_2-EOR in Zhongyuan Oil Field was started. The project will be implemented by Exploration and Exploitation Institute, Petroleum Production Institute and Second Petroleum Production of Zhongyuan Oil Field.

Goals: Using CO_2 to enhance the oil recovery.

CO_2-ECBM Concept



(Cited from Institute of Rock and Soil Mechanics, Chinese Academy of Sciences)

CO_2 Underground Geological Storage in China

Project	Scale of project	Start date	Storage type
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Zhongyuan Oil Field	Pilot		CO_2-EOR
Jilin Oil Fiedl	Pilot	1994	CO_2-EOR
Shengli Oil Field	Pilot		CO_2-EOR
Qinshui Coal Field	Pilot	2003	CO_2-ECBM
Pingdingshan Coal Field	Pilot	2006	G-ECBM

2. Other CO_2 Utilization Technologies

- ***Physical Applications:*** **CO_2 can be used to act as (1) the <u>refrigerating medium</u>; (2) <u>extinguishing agent</u>; (3) <u>supercritical extractant</u> to purify the Chinese traditional medicine and spice; (4) <u>working substance</u> in low-temperature heat power station。CO_2 also can be used for <u>food storage</u> and <u>gas shielded welding</u>.**
- ***Chemical Applications:*** **CO_2 may be the perfect materials which can be used to synthesize the new chemical compounds such as <u>urea</u>, <u>methanol</u>, <u>pure caustic soda</u>, <u>polycarbonate</u>, <u>salicylic acid</u> and <u>propylene carbonate</u>, synthesize the <u>liquid hydrocarbon</u> combined with CH_4 and synthesize the <u>gasoline</u> combined with H_2. CO_2 also can be used in <u>water treatment</u>.**
- ***Biological Fixation:*** **Using some suitable algae (microalgae) and bacterium to fix CO_2.**

CO_2 Productions

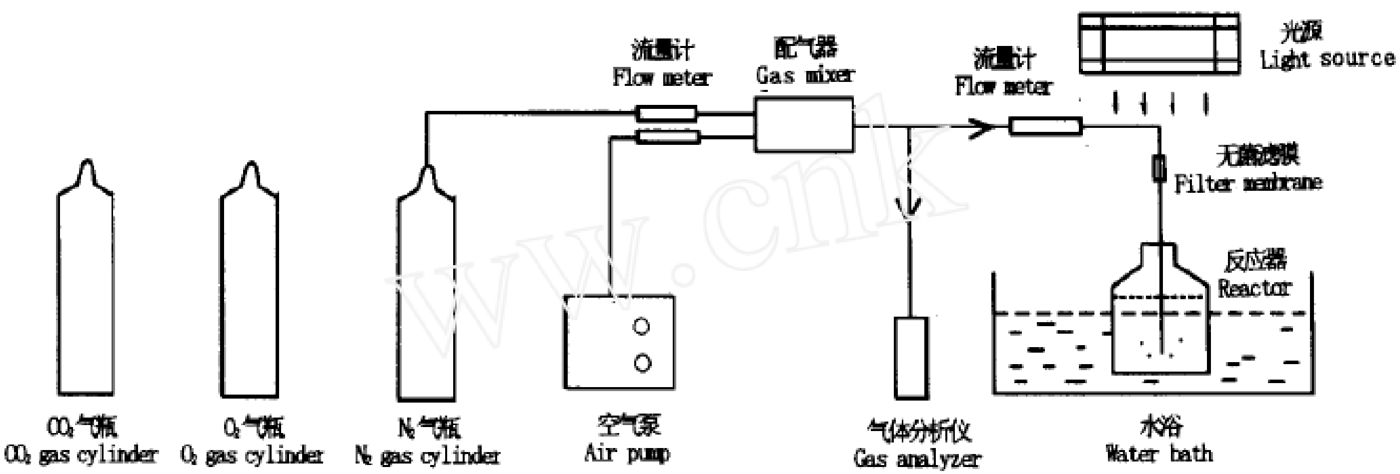
Carbon dioxide copolymer

Ammonia bicarbonate

Sodium carbonate

CO_2 Fixation by Microalgae

- ***Zhejiang University*** **have screened the blue algae and green algae under high temperature and high concentration CO_2 and studied the highly active membrane-based algae-light reactor.**
- ***Northeastern University*** **studied the CO_2 separation by algae and cultured the algae mixture samples using flue gas. They also isolated the useful algae species: ZY-1.**



培养特性测试实验装置图

Diagram of the experimental apparatus of determining the cultural characteristics

CO_2 as Fertilizer of Plant

If CO_2 concentration increases from 355 ppm to 675 ppm, tomato yields are increased by about 30%, sugar beet yields are increased by about 22%.

VII Conclusion

- Many researches on CO_2 capture have been made and many fruits have been got in China;
- Few demonstration projects of CCS in China;
- Demonstration project must be supported by government.
- International cooperation on CCS need to be enhanced.

Thank you for your attentions!