

Research Institute of Petroleum Exploration & Development, PetroChina

Author Biography



- ◆ **Pingping Shen, Male, Former vice-president of PetroChina ,a senior engineer from Research Institute of Petroleum Exploration & Development, PetroChina, a tutor for Ph.D Candidate, also an expert who is provided special allowance by the government. He worked as a routine executive member of the fourth session council for Chinese Petroleum Society, and now works as the director of Chinese Petroleum Engineering Society.**
- ◆ **E-Mail:spp@petrochina.com.cn**
- ◆ **Publications: 6 monographs, 60 domestic or oversea published papers**
- ◆ **Researching experiences: He has engaged in the research work of EOR for a long time, and has finished several research projects either national or from PetroChina as a manager, which including: Research for enhanced oil recovery. 973 project (The National Basic Research Program) named ‘Basic Research for Enhanced Oil Recovery in A Large Scale’. Potential evaluation for EOR in China oil field and development stratagem. Potential and corresponding plan for tertiary recovery in oil field. He is chief scientist of ”973” project for CCS-EOR.**





China Utilization of Greenhouse Gas as Resource in EOR and Storage It Underground

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Research Institute of Petroleum Exploration & Development, PetroChina

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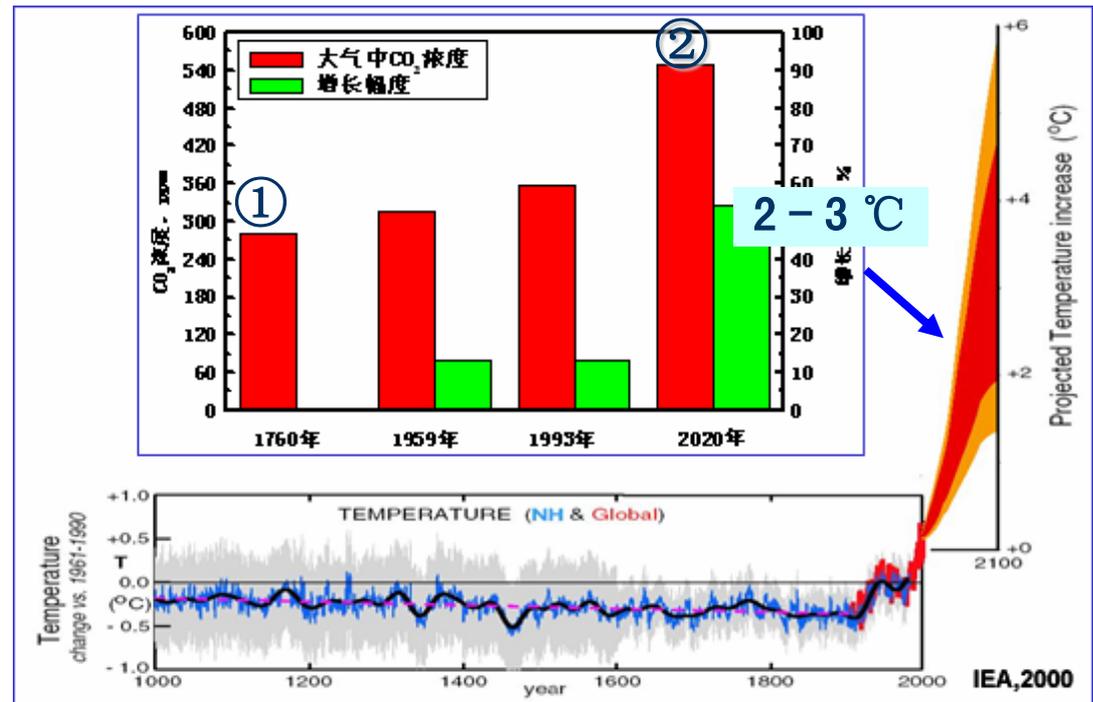


I .Introduction

1.Reduction of Green House Gas Emission---A topic concerned around the world nowadays

①The concentration of CO₂ in the atmosphere is **280ppm** before Industrial Revolution.

②IPCC indicates that the concentration of CO₂ would reach to **550ppm** in 2020, with **54%** increasing than 1993, if there were no effective treatment.





I .Introduction

1.Reduction of Green House Gas Emission---A topic concerned around the world nowadays

- **Reduction of green house gas emission was concerned by international community**

Kyoto Protocol was signed by international community, which ask developed countries for decreasing green house gas emission by 5.2%, comparing that in 1990. China, earnestly declared that we have approved the protocol as a developing country.

- **Chairman Hu Jingtao made a speech in Eight Country Conferences in August, 2005, which pointed out that China having the sense of responsibility, will take a series measures, which are beneficial for reducing the emission of green house gas, for dealing with climate change.**



I .Introduction

1.Reduction of Green House Gas Emission---A topic concerned around the world nowadays

- China concerns about reduction of green house gas emission

For CO2 emission, China is located at the **2nd place** in the world now, and is predicted to be the **1st one** around 2025.

Data of CO2 Emission in the World(IEA,2000)

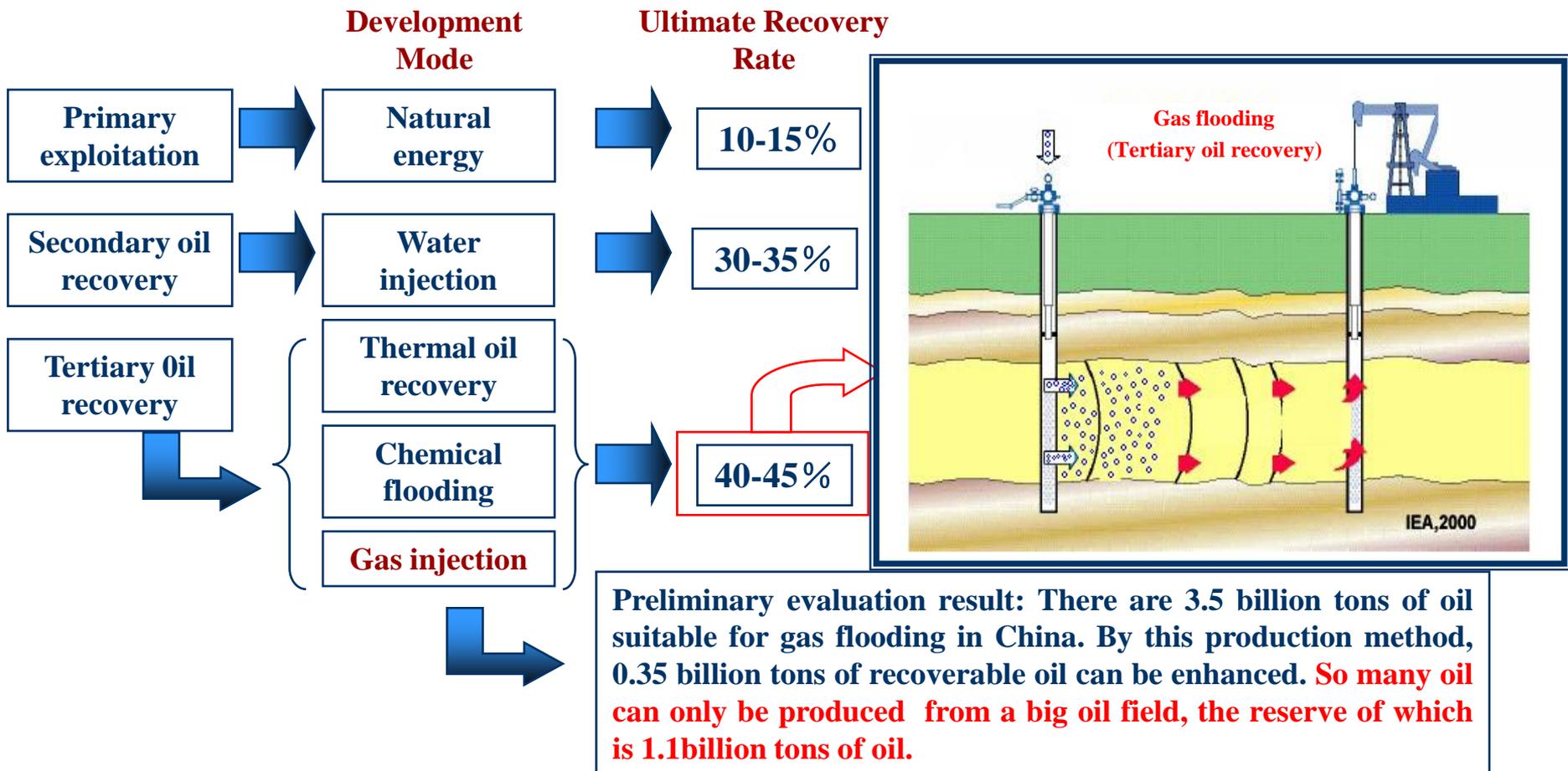
Country	Emission of CO2 (100million tons)	Ratio(%)
U.S.A	48.81	23.72
China	26.68	12.97
Russia	21.03	10.22
Japan	10.93	5.31
Germany	8.78	4.27
India	7.69	3.74
Ukraine	6.11	2.97
U.K.	5.66	2.75
Canada	4.10	1.99
Italy	4.08	1.98
France	3.62	1.76
Poland	3.42	1.66
Other country	51.93	25.24
Total	205.74	100.00



I .Introduction

2.CO2 can be used for Enhancing Oil Recovery

● The potential for EOR in developed oil field is great

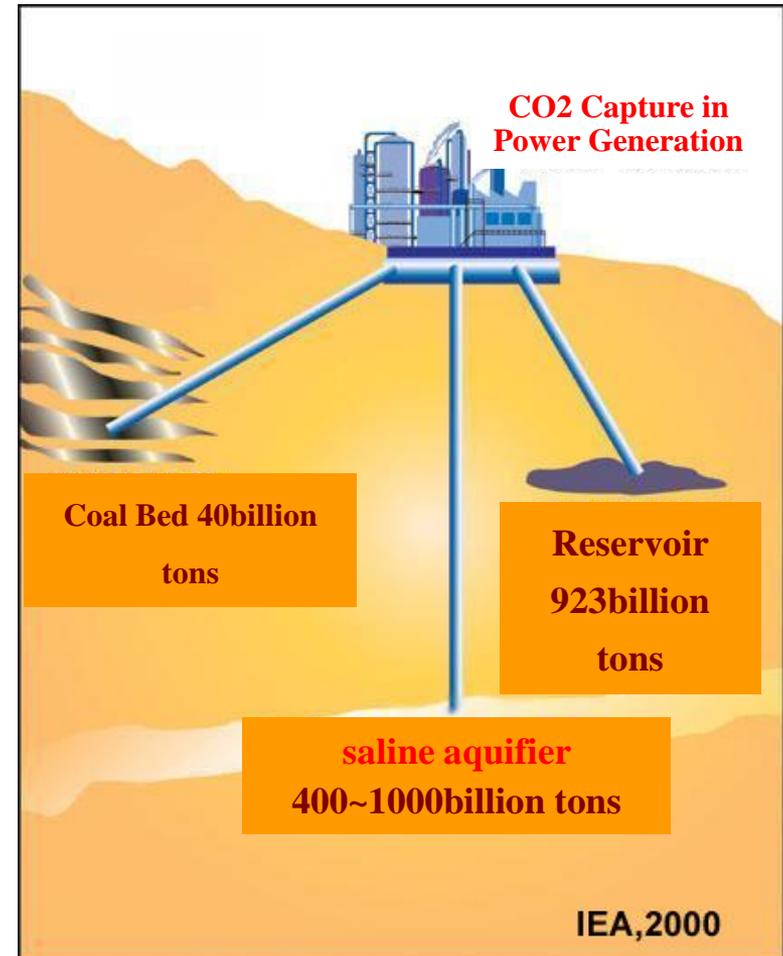




I .Introduction

3.The ideal underground storage site for CO₂

- depleted oil or gas reservoir , deep saline aquifer , Unminable coal beds Ideal Place for CO₂ Storage
- 923 billion tons of CO₂ can be stored in reservoir, which is 45% of global cumulative emission in 2050.





I .Introduction

4.Effective and cheap CO₂ Capture and purification technology

CO₂ emission mainly come from
**power generation and industrial
production (coal)**

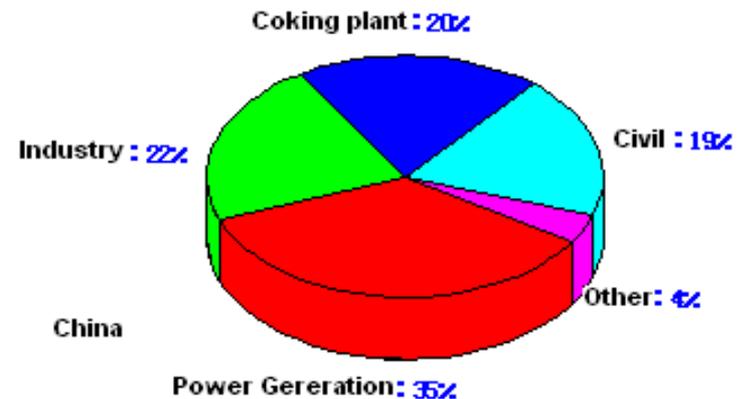
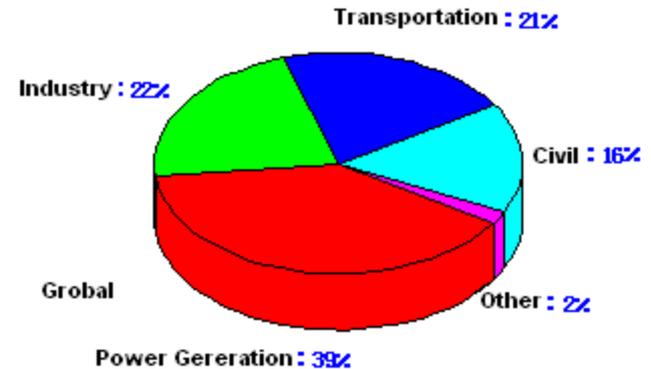
Global: Power generation 39% Industrial production 22%

China :Power generation 35% Industrial production 42%

Current CO₂ Trapping Cost: 40-60 \$/T

Oxygen-rich combustion/Decarbonation after
Combustion/ Decarbonation before Combustion

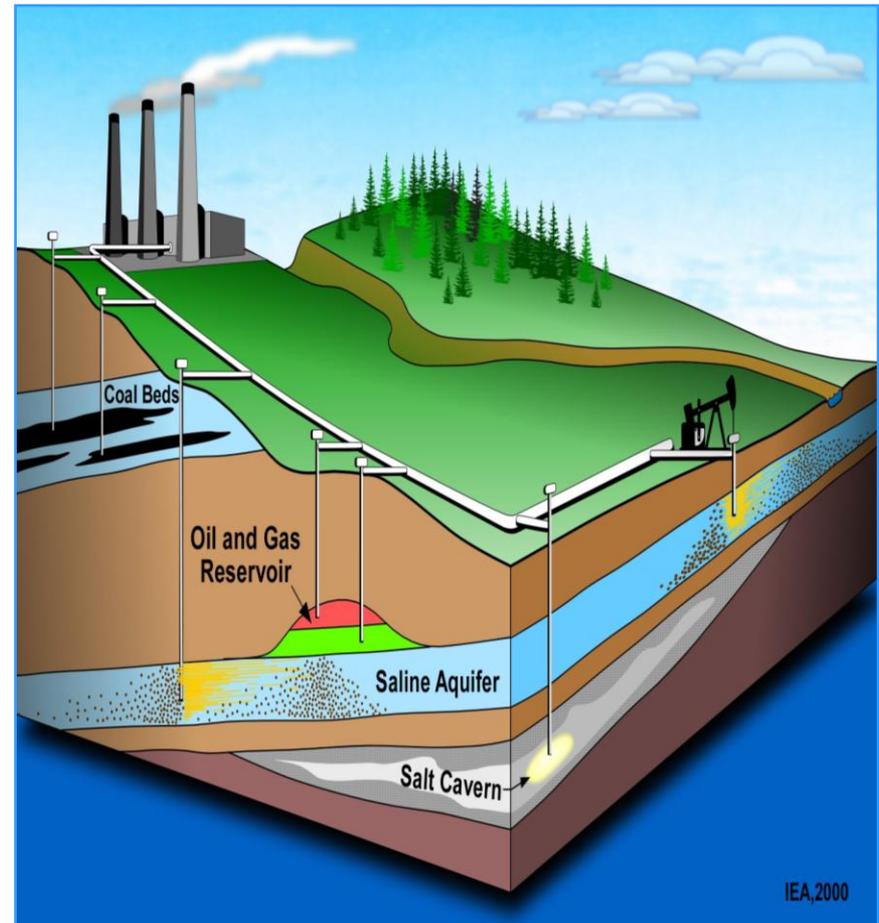
Available Price for industry is 20\$/T.





I .Introduction

● Injecting the captured CO₂ into the reservoir can not only reduce the emission, but also enhance the oil recovery. So, it has perfect economic performance.

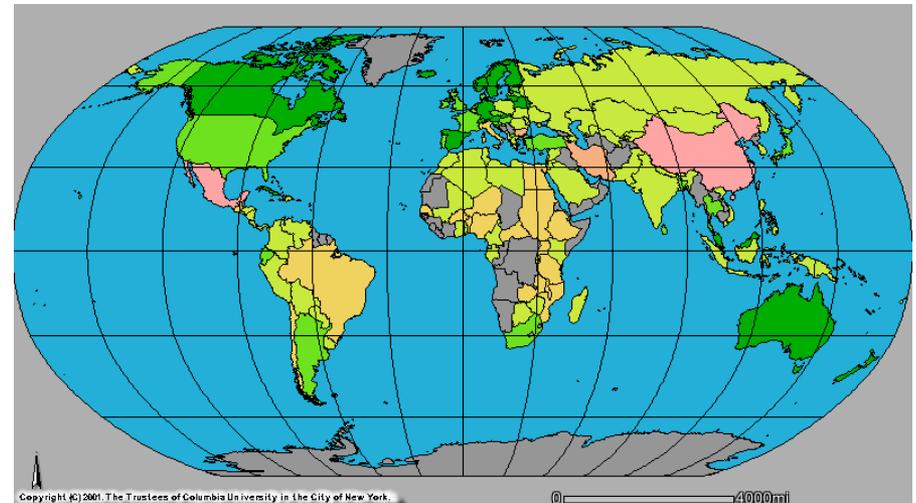
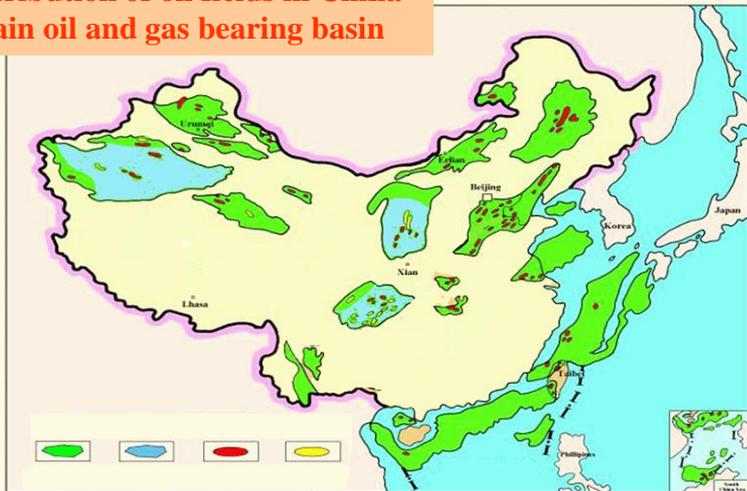


II. Chinese Government Concerns Greatly about Reduction of CO2 Emission and Using It as Resources



- ◆ In 2006, a 973 project (The National Basic Research Program) named ‘Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground ’ was authorized by China Ministry of Science and Technology.
- ◆ In 2007, a key science & technology research project named ‘Utilizing Greenhouse Gas as Resource in EOR and Storage Underground’ was established by PetroChina.
- ◆ In 2007, a key pilot test named ‘Pilot Test of CO2 EOR and Storage in Jilin Oil Field’ was established by PetroChina

Distribution of oil fields in China
main oil and gas bearing basin



III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



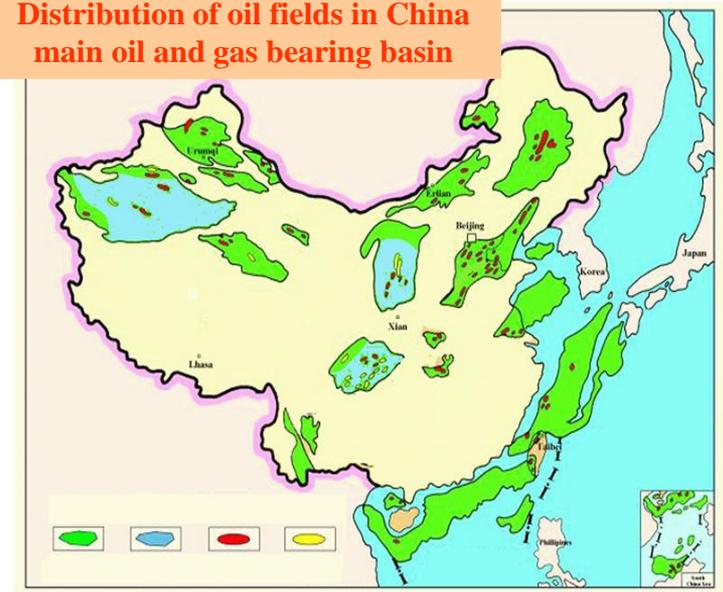
1. Establishing CO₂ storage evaluation system who meets China geologic characteristic

Demand: Potential for long time, safe and economical storage of CO₂

Research:

- Establishing CO₂ storage and EOR evaluation system who meets China geologic characteristic
- Confirming CO₂ storage potential in China
- Confirming oilfields that are suitable for CO₂ storage in China, and the potential for EOR

Distribution of oil fields in China
main oil and gas bearing basin



Project 1 Standard stipulation and potential evaluation for CO₂ storage who meets China geologic characteristic---- PetroChina

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground' -- A National Research Project of China



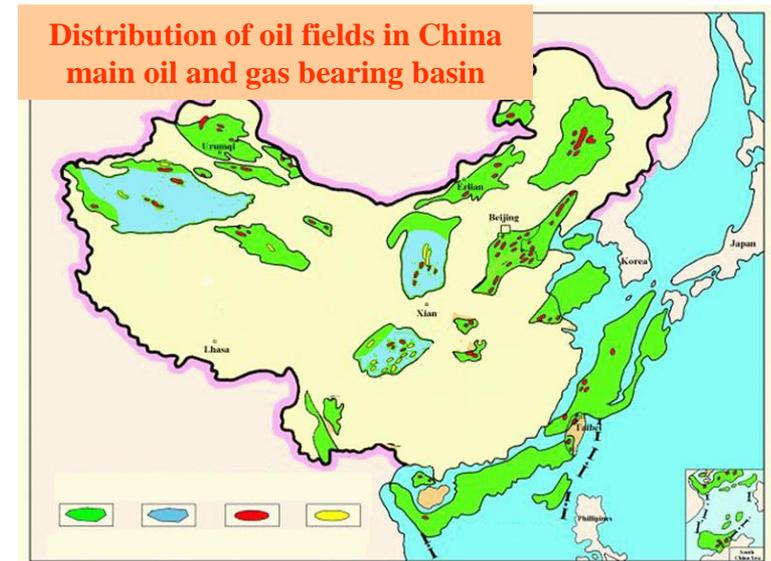
1. Establishing CO₂ storage evaluation system who meets China geologic characteristic

Progress:

- Selecting standards for CCS and EOR, which is suitable for China geologic characteristic were preliminarily formulated.
- Calculation methods for theory potential, effective potential and EOR additional potential were determined.
- Data bases for hydrocarbon reserves of every basin in China were set up, which conclude:

Total reserves forecast, total reserves founded

Recoverable oil forecast, recoverable oil founded



III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China

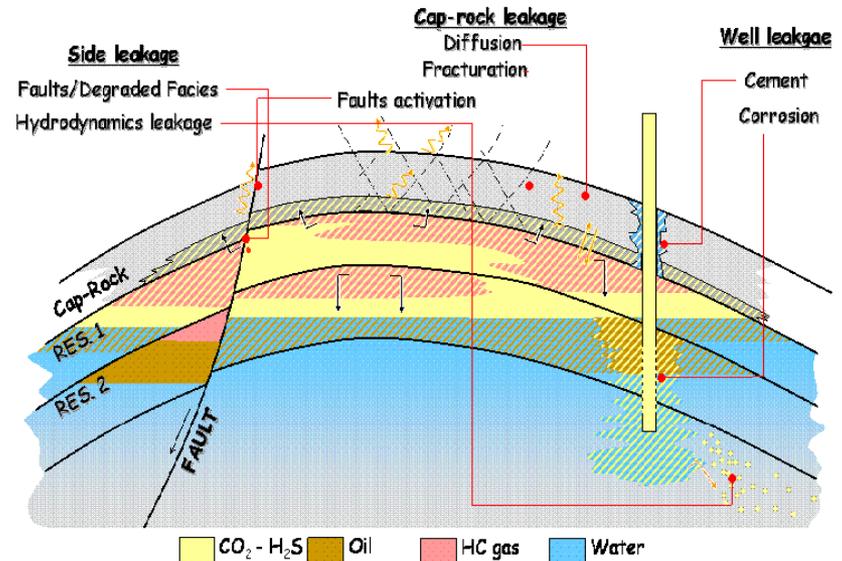


2. Basic problem of CO₂ storage theory who meets China geologic characteristic

Demand : Most oilfields in China are continental deposit ones and have severe heterogeneity

Research:

- Establishing geologic model for CO₂ storage (Emphasis: fracture, Caprock, mineral composition, reservoir description)
- Long time phase change and chemical reactions of CO₂ in the layer
- Front breakthrough mechanism of CO₂. Movement rule of CO₂. Research on movement forecast theory and method
- Risk evaluation of CO₂ storage



Project 2 Geologic theory of CO₂ subsurface storage ---Chinese Academy of Sciences

Project 3 Theory and technology of monitoring and front predicting during CO₂ storage process----Peking University

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



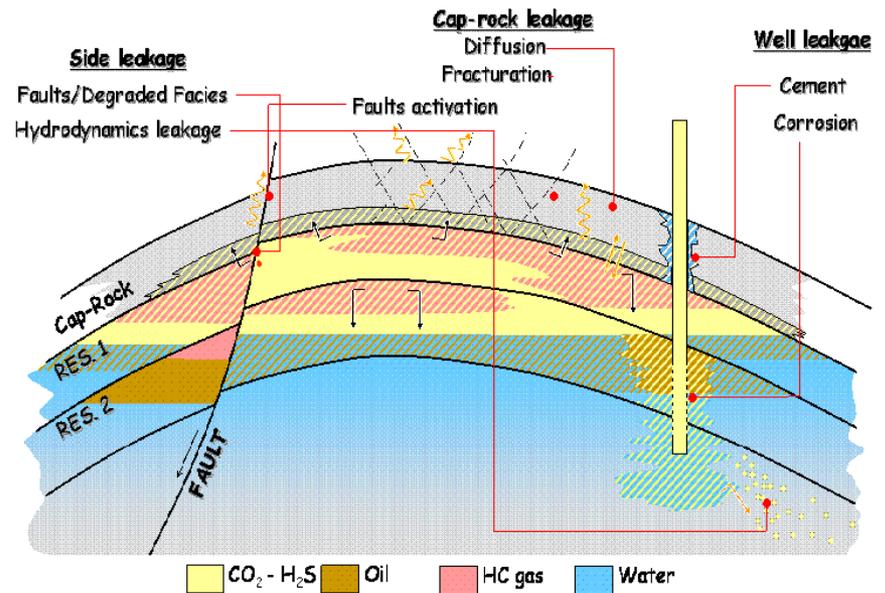
2. Basic problem of CO₂ storage theory who meets China geologic characteristic

Progress of project2:

Oil and gas geologic mode of China was preliminarily established.

Research on reservoir description was implemented, taking Daqingzi region of Jilin Oil field as the case.

Water layer was researched. Reaction between CO₂ and water with different salinity was implemented.



Project 2 Geologic theory of CO₂ subsurface storage ---Chinese Academic of Sciences

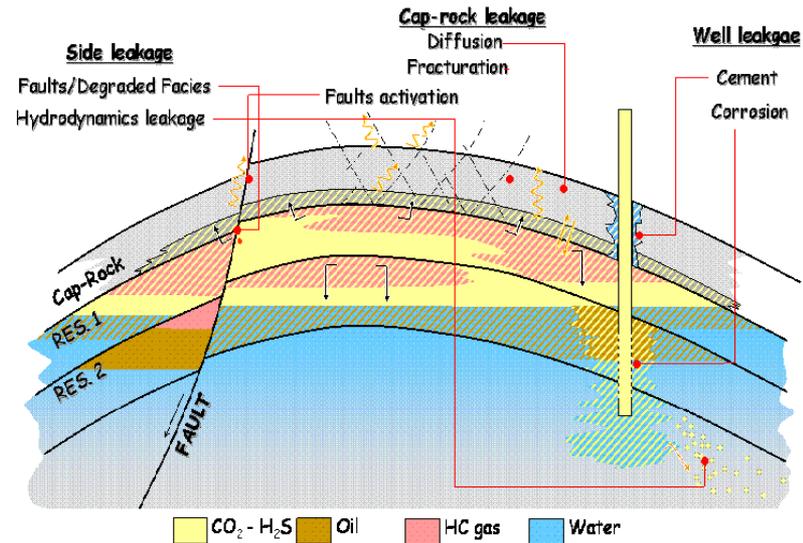
III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



2. Basic problem of CO₂ storage theory who meets China geologic characteristic

Progress of project3:

- ◆ Crosshole seismic research result show that heterogeneity within 3 m thick can be determined.
- ◆ Comprehensive utilization of messages from crosshole seismic, vertical seismic and surface seismic may be used for research of thin layer, low permeability layer, gas injection or front monitored, etc.
- ◆ Four kinds of gas tagged agent were investigated.



Project 3 Theory and technology of monitoring and front predicting during CO₂ storage process----
Peking University

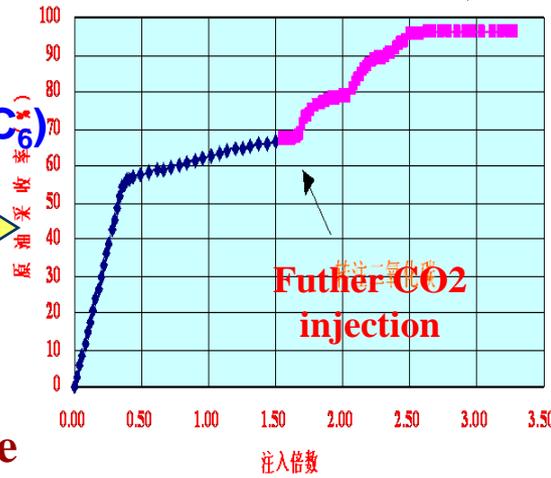
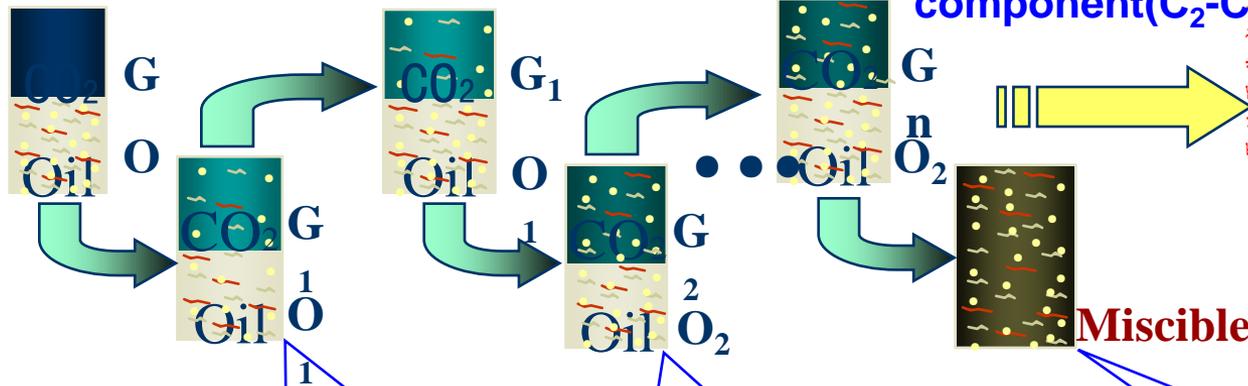
III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground' -- A National Research Project of China



3. Scientific questions about CO₂-EOR

Demand: Recovery=swept volume* displacement efficiency, How to improve it?

Displacement efficiency can reach to 97.6% in miscible displacement



Which component of crude oil could be extracted by CO₂ at specific P and T.

What is the characteristic for phase change of extracted components?

What is the optimum composition of oil for EOR?

Multicontact miscible mechanism —→ phase theory during equilibrium process

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



3. Scientific questions about CO₂-EOR

Research:

- Phase theory during equilibrium and dynamics process
- Phase theory in porous media
- physical simulation at HTHP (microscope or macroscopic)
- Developing and completing multiphase and multicomponent state equation and numerical simulation



Project 4 Research on phase theory of multiphase and multicomponent during CO₂ flooding process-----PetroChina

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground' -- A National Research Project of China



3. Scientific questions about CO₂-EOR

Progress:

- HTHP microscopic physical simulation.
- The main influencing components for oil miscible of Jilin oil field are C2-C5.
- The phase state in the core is different from that in PVT test.
- Multiple-contact of CO₂ reflect that it is an evaporation-condensation displacement.



**Project 4 Research on phase theory of multiphase and multicomponent during CO₂ flooding process
-----PetroChina**

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China

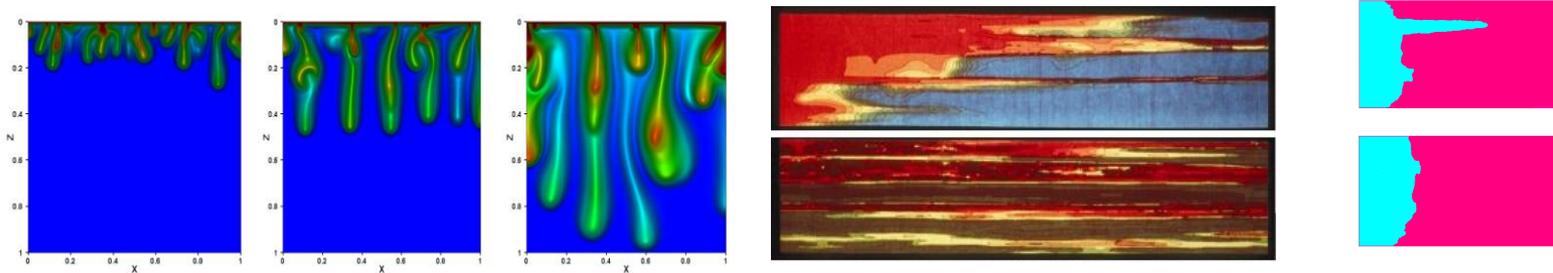


3. Scientific questions about CO₂-EOR

Demand: Improving swept efficiency

Research:

- Theory for dispersion, fingering and diffusion during CO₂ flooding
- Theory and method for discerning crossflow channel and countermeasures for preventing gas breakthrough during CO₂ flooding
- Complex flow of multiphase and multicomponent mixture of CO₂, oil and water



Project 5 Nonlinearity flow mechanism and law of multiphase and multicomponent during CO₂ flooding process----China University of Petroleum

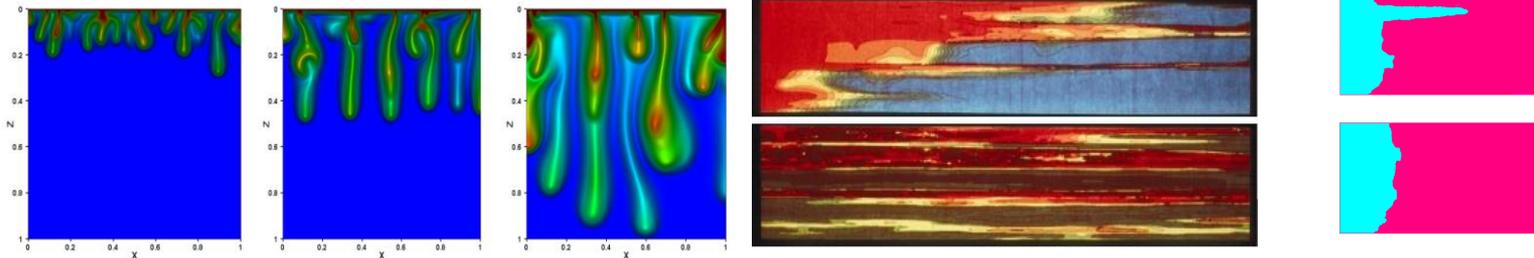
III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



3. Scientific questions about CO₂-EOR

Progress:

- HTHP CO₂ flooding physical simulation equipment, which is 30m long, was invented.
- One-dimensional flow of CO₂ in porous media was studied.
- Cross flow channeling identification was development. A kind of CO₂-sodium silicate deep plugging material was invented.



Project 5 Nonlinearity flow mechanism and law of multiphase and multicomponent during CO₂ flooding process----China University of Petroleum

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground' -- A National Research Project of China



4. Scientific questions about effective and cheap CO₂ trapping

Demand: Cheap CO₂ with purity of 95%

Research:

- **Combustion Kinetics** of coal in O₂/CO₂ circulating combustion
- **Reaction removal mechanism** and **synergetic control** of various pollutant

Progress:

- O₂/CO₂ Combustion Kinetics of typical coal, and the property of associated pollutant were researched
- Gantry pilot test plant was built.



The first pilot test plant in China

Project 6 Principle of O₂/CO₂ circulating combustion for coal and mechanism of synergetic removal pollutant---Huazhong University of Science and technology

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



4. Scientific questions about effective and cheap CO₂ trapping

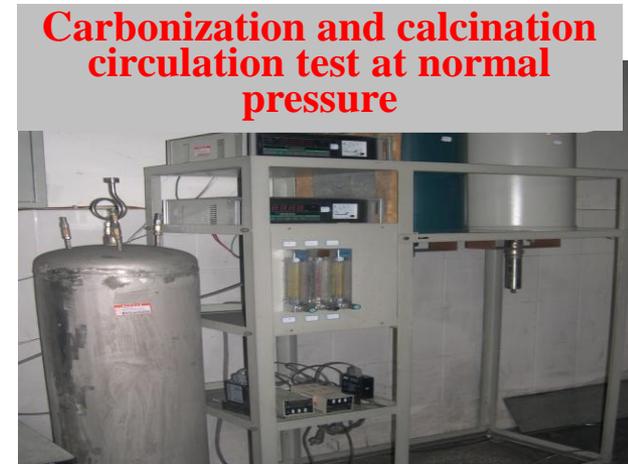
Demand: Cheap purified CO₂ from power station and industrial gas

Research:

- Research on effective separation theory of CO₂ such as adsorption agents, membrane separation, etc.
- Chemical principle of CO₂ absorption and separation based on calcium absorption agents
- Theory of Coal reacting with supercritical water to get hydrogen and CO₂ concentration

Progress:

- Influencing factor of CaO in fluidized bed.
- Research on supercritical water in coal gasification for producing hydrogen, and CO₂ anchoring integrated adsorption.
- MDEA+PE
- The action between fixed supporter membrane (containing RNH₂, R₂NH) and CO₂ was thoroughly investigated and studied.



Project 7 Theory and technology of CO₂ separation and concentration in industrial gas----Tinghua University

III. 'Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground'-- A National Research Project of China



5. Scientific questions about CO₂ storage , transportation and corrosion

Demand: Decreasing of related engineering cost during CO₂ storage process

Research:

- Safe and efficient technology of storage and transportation
- Research on the mechanism of CO₂ corrosion and scaling. Looking for the cheap and effective method for corrosion and scaling prevention
- Technology and method of engineering during CO₂ storage process

Development:

Research of Preservation: A series of methods for preventing corrosion and scaling such as that in gas injecting well, have been developed.

Transport program of CO₂ 2 kinds of inhibitor and 3 kinds of CO₂ transport program were studied.

Separation technology for gas, which contains CO₂ was established.

Producing process: Monitor method for CO₂ flooding in pilot test was proposed.



Project 8 Theory and method of engineering for CO₂ corrosion prevention and antiscale---Jilin Oil field



IV.Key Science & Technology Research Project and Key Pilot Test were established by PetroChina

1.Pilot test of injecting CO2 for EOR and storageing it underground was implemented

Pilot Test for Liquid CO₂ Injection --- Xin 228 Block of Xinli Oilfield

● Xin 228 block is a part of Xinli structure and is located in the north of it. The angle of structure dip is 1.06 degree. The average effective thickness of reservoir is 8.93 m, average permeability of reservoir is 0.35 mD, porosity is 12.38%, temperature is 66 °C

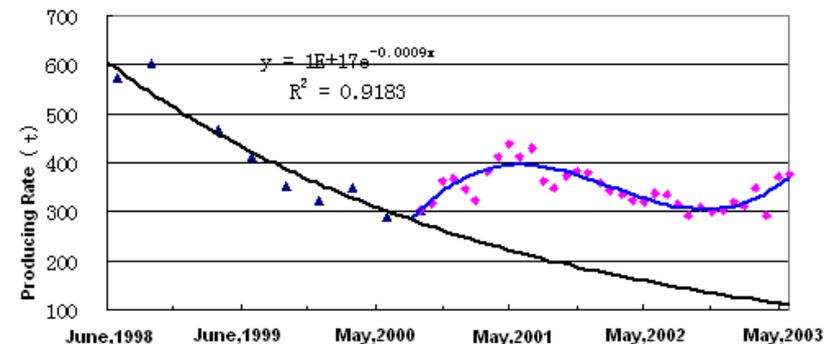
Test Result

● By the end of June, 2003, **5121 tons** of crude oil was cumulatively increased, injection/production ratio is 1:4.28, 3.2 tons of crude oil could be increased by each ton of CO₂. Preferable effect can be seen.

The Effect of Well Group 54-4

Well	Date for action	Effect time (day)	Oil increased per day	Oil increased accumulative	Ratio for production enhancement	Remark
54-6	Oct.,2000	730	1.02	743.70	48.5	Work
56-4	Sep.,2000	560	0.34	190.00	24.2	Work
56-2	Oct.,2000	540	0.32	170.60	28.7	Work
52-4	Dec.,2000	323	0.11	34.00	11.7	Work
54-2	Nov.,2000	360	0.26	93.30	32.4	Watercut decline at first
52-6						Watercut decline at first
56-6	Feb.,2001	400	0.86	343.60	24.5	delay
52-2	Nov.,2001			77.80		
Total				1653.00		

Curve for decreasing of producing rate





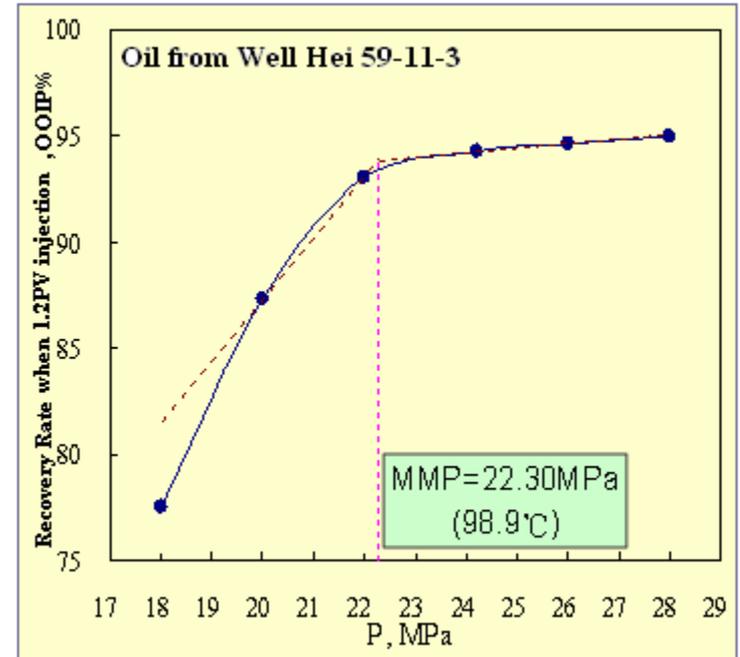
IV. Key Science & Technology Research Project and Key Pilot Test were established by PetroChina

3. The condition of reservoir for miscible and immiscible flooding in Jilin Oil Field

The condition for miscible flooding of typical reservoir in Jilin Oil Field was obtained.

(Recovery rate can be enhanced by 10%~20%)

Miscible flooding condition test result:
Miscible flooding can be achieved in block Hei-59 and Hei-79.



Source for oil sample	Hong8 7-2	Qian'an	Hei-59	Hei-79
Pressure MPa	21.20	18.50	24.20	23.10
Temperature , $^{\circ}$ C	101.6	76.0	98.9	97.3
MMP(Slim-tube test)MPa	27.45	20.20	22.30	22.10
Conclusion	immiscible	immiscible	miscible	miscible

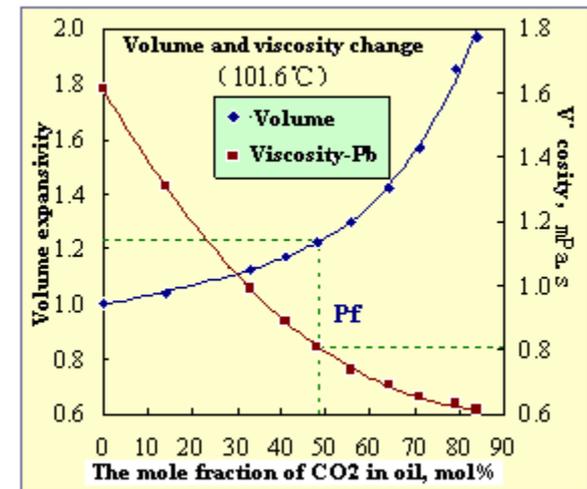


IV.Key Science & Technology Research Project and Key Pilot Test were established by PetroChina

3.The condition of reservoir for miscible and immiscible flooding in Jilin Oil Field

- The condition for immiscible flooding of reservoir in Jilin Oil Field was obtained.(Recovery rate can be enhanced by 5%~10%)
- On the condition of reservoir, CO₂ have strong effect of volume expansion and viscosity reduction for oil from Hei59, Hei79, Hong87-2 and Qian'an formation.
- The CO₂ immiscible flooding is also beneficial for EOR.

Source	Pressure(MPa)	Temperature (°C)	Solubility of CO ₂ (mol/%)	Volume expansion	Viscosity Reduction(%)
Hong87-2	21.20	101.6	48.30	1.23	56.70
Qian'an	18.50	76.0	45.90	1.27	58.40
Hei59	24.20	98.9	63.96	1.47	63.20
Hei79	23.11	97.3	63.58	1.41	59.62





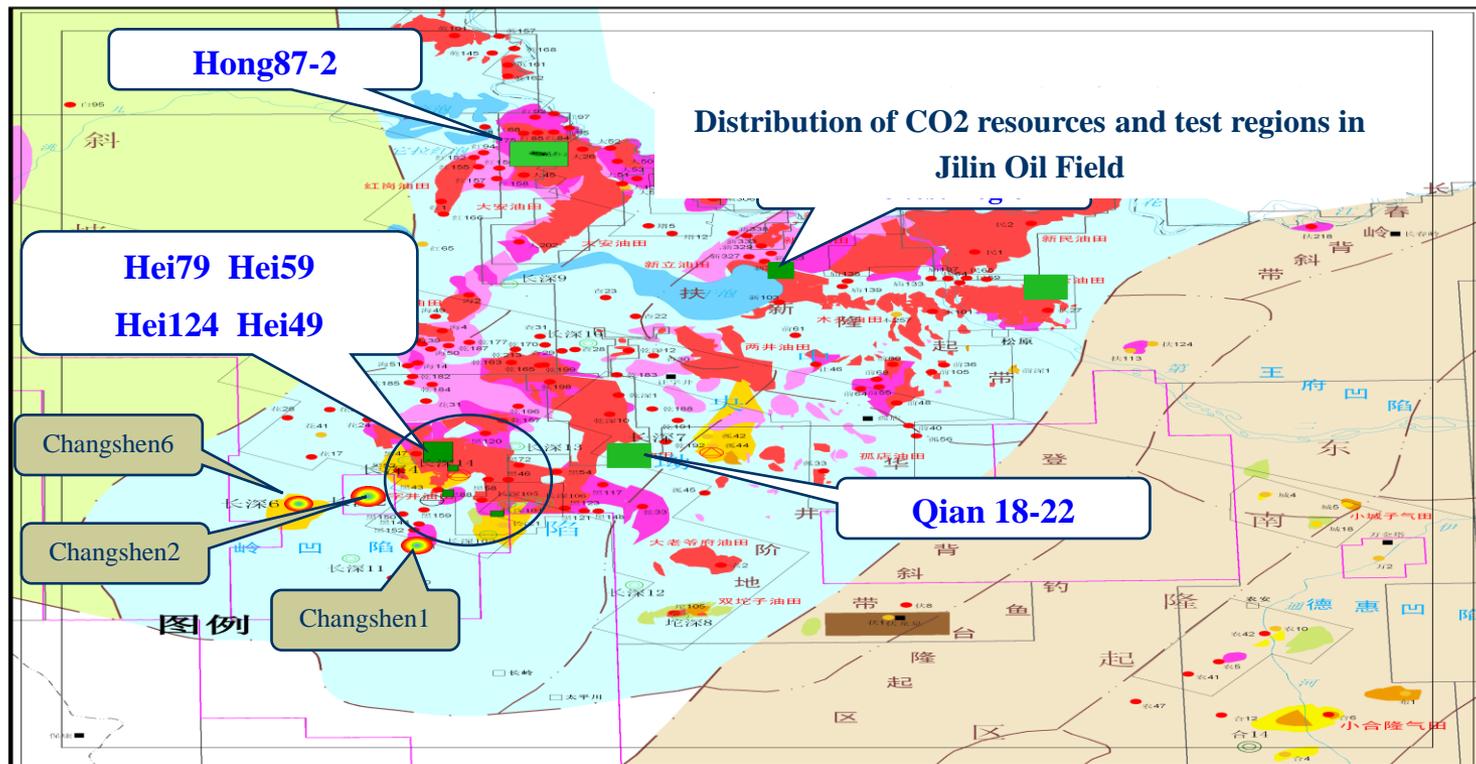
IV.Key Science & Technology Research Project and Key Pilot Test were established by PetroChina

4.Pilot test program of block Hei79, Hei59, Hong87-2, Qian'an were formulated.

Pilot test program of miscible flooding in Hei79 and Hei59

Immiscible flooding pilot test program in Hong87-2

Pilot test program in Qian'an



V. Conclusions



- 1.Reduction of green house gas emission is an important issue concerned by international community.**
- 2.China is a developing country, which has the sense of responsibility, has taken a series measures, such as authorizing the 973 project (The National Basic Research Program) named ‘Research for Utilizing Greenhouse Gas as Resource in EOR and Storing It Underground’.**
- 3. In 2007, a key science & technology research project named ‘CO₂ EOR and Storage Underground’ and a key pilot test named ‘CO₂ EOR and Storage Pilot Test in Jilin Oil Field’ were established by PetroChina.**
- 4.Chinese government is active to join international cooperation, and is aiming for the combination of CO₂ storage and EOR together, which will contribute a lot for efficient & sustainable development of global resources and environment.**





Thank you !

