Prudent Development of CO_2-EWR: Realizing the Potential of China's CCUS and Energy Security

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Guideline

- Let's retrospect one of the perspectives concluded by Deputy director general of ACCA21 Dr. Sizhen Peng in yesterday's talk.

- ***CCUS should not only aim for mitigation of anthropogenic CO2 but also serve as an important role or tool to solve national energy and resources issues in China.***

Outline

- Background of CO_2-EWR
- Potential of CO_2-EWR in China
- Focus of CO_2-EWR in Western China
- Concluding remarks

Background of CO_2-EWR

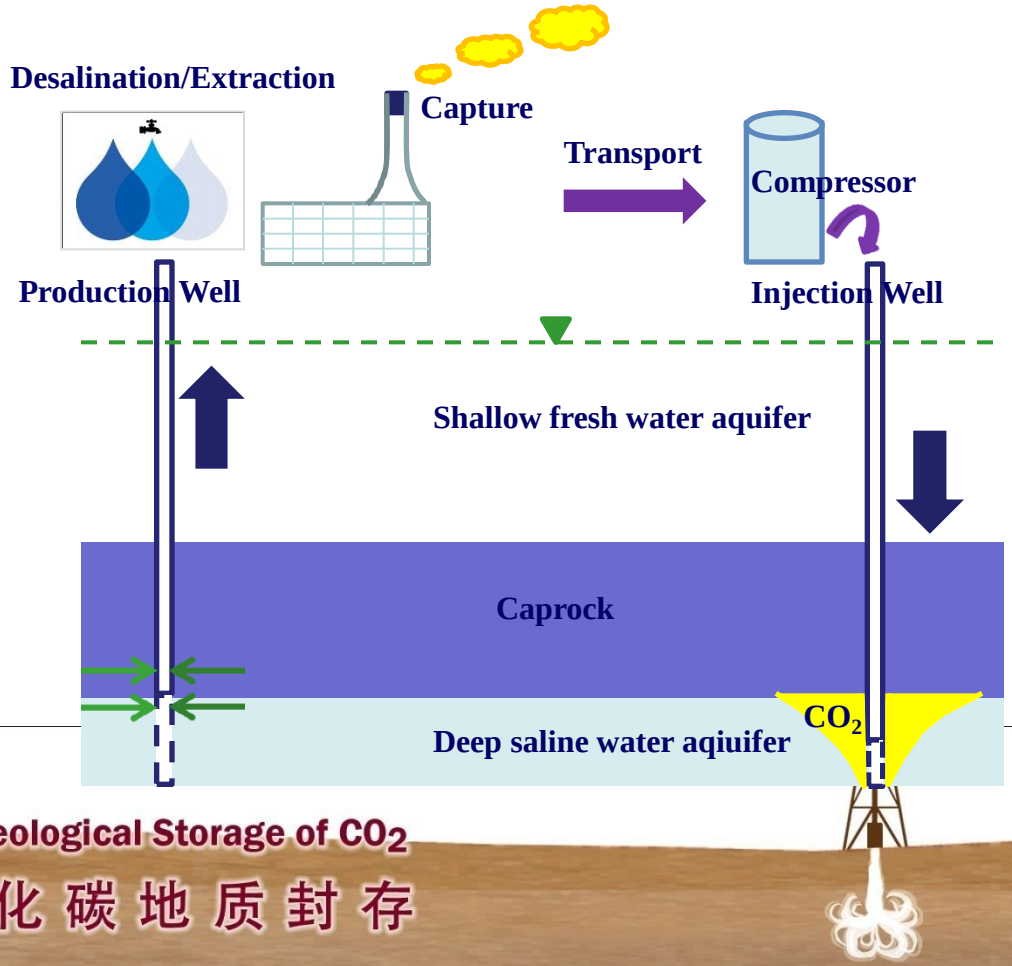
1) What is CO_2-EWR?

- Depending on types of recovered resources from underground *more than 800 m depth*, two subclasses are included in the definition of CO_2-EWR.

I. CO_2 g***E***ological storage ***W***ith liquid mineral ***R***ecovery

II. CO_2 ***E***nhanced deep saline ***W***ater ***R***ecovery

- CO_2-EWR → CCS+U



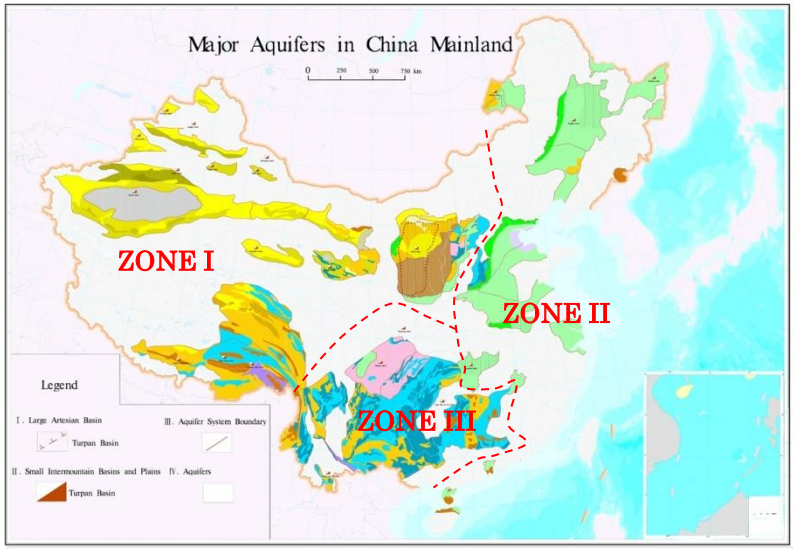
Background of CO_2-EWR

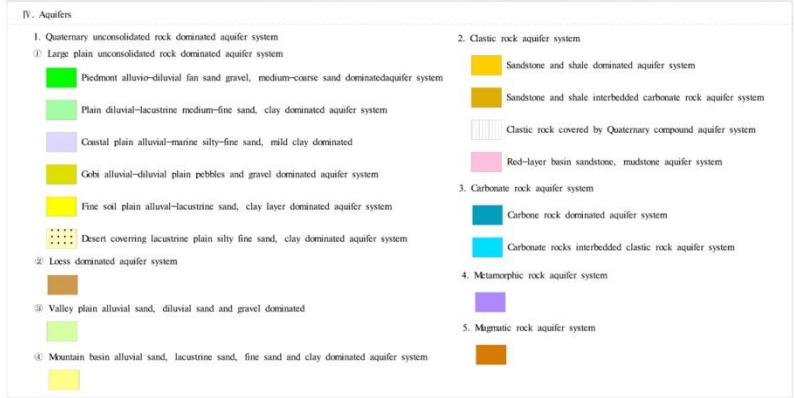
2) Initial

- Traditional CO_2 geological storage (CGS) usually leads to the increase of formation pressure, this affects two main respects: *i) potential intensifying of induced seismicity and ii) injectivity lowering down*. Both of the effects increase possibilities of leakage risk of sequestrated CO_2.
- To mitigate such a pressure buildup of CO_2 plume for pure geological storage aforementioned, the two ways are often adopted in CGS operation learned from long history of subsurface hydrocarbon extraction: *i) to drill pressure management wells and ii) to drill production wells in the same storage formation*.

Potential of CO_2-EWR in China

1) Localization: Three Zones

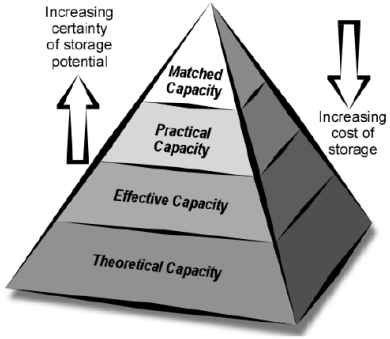




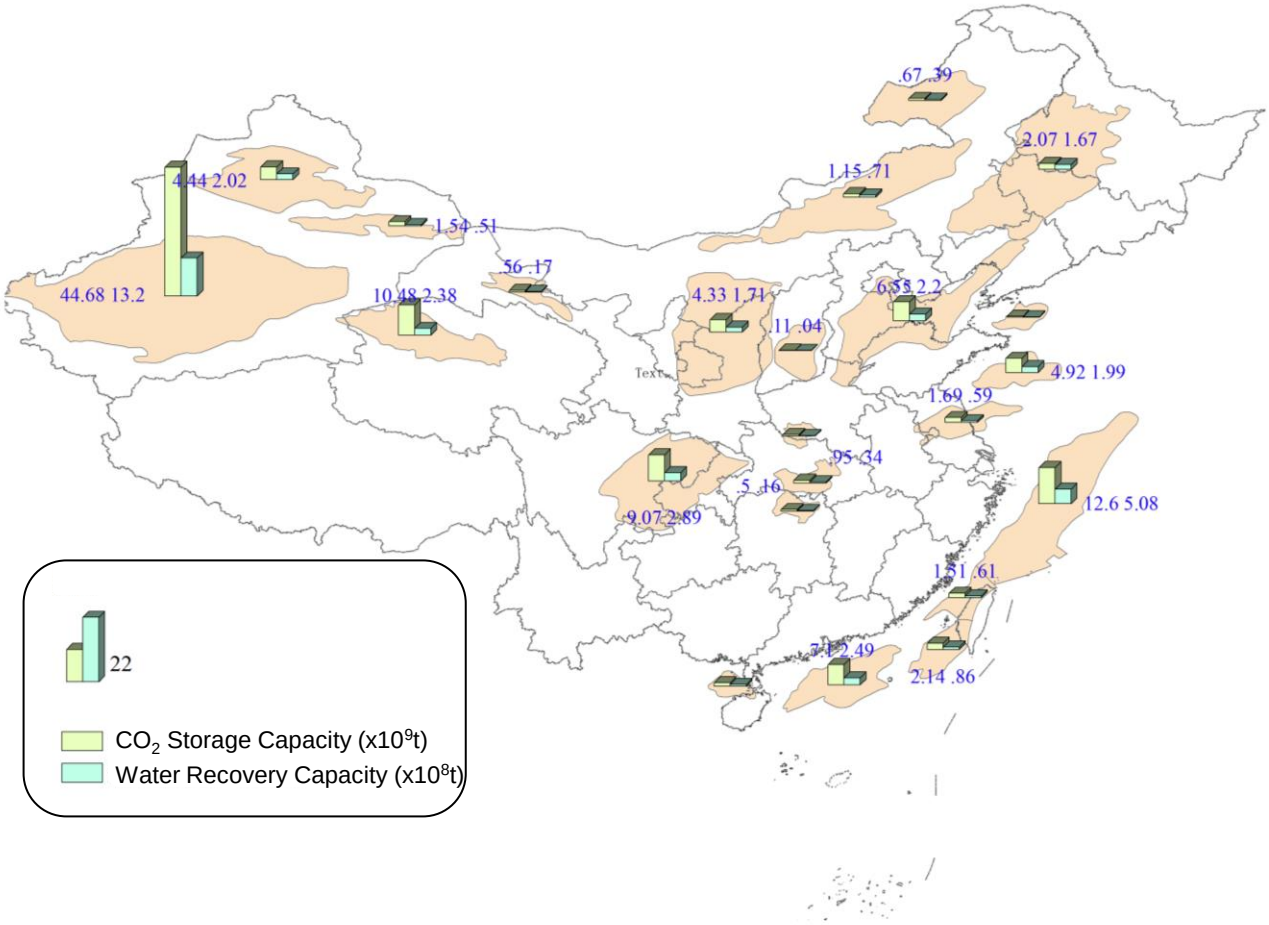
- To utilize CO_2 and its pressure buildup to enhance deep saline water recovery to meet water shortage in *Western CHINA*
- To mitigate subsidence induced by over exploration of groundwater in *North CHINA* and *Changjiang delta*
- To enhance brine and other liquid mineral extraction in *South CHINA*

Potential of CO_2-EWR in China

2) Theoretical Potential of Enhanced Water Recovery

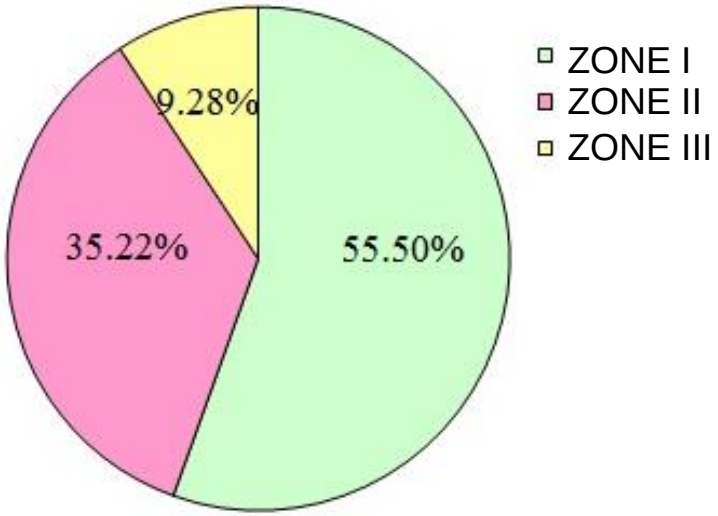


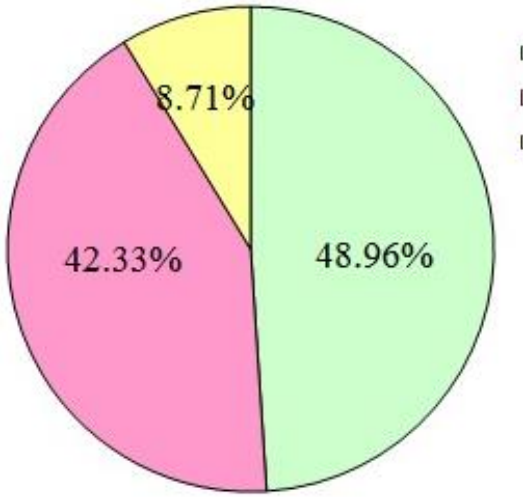
SOURCE: CSLF, 2008.



Potential of CO_2-EWR in China

3) Theoretical Potential of Enhanced Water Recovery





- CO_2 Storage

Saline water recovery

Focus of CO_2-EWR in Western China

1) Why we first focus on Western China? Reason One

- Xinjiang and Inner Mongolia have the second and third largest reserves of coal after Shanxi province in China.
- According to China Basic Strategy of National Development, both areas are the focus in the next planning, in particular with respect to energy construction.

Focus of CO_2-EWR in Western China

1) Why we first focus on Western China? Reason Two

- China energy heavily depends on coal.
- China is the largest consumer of coal and major importer of coal though China has the largest reserves of coal in the world.
- As noted by Mr. Sean Hannan, Australia is world's largest net exporter of coal.
- This status cannot change in the near term for both countries.

Focus of CO_2-EWR in Western China

1) Why we first focus on Western China? Reason Three

- According to the special conditions of western region, China central government planned some key areas to implement coal chemical industries (CCI), such as CTL CTG and so on.
- For example, five key areas were planned for CCI in Xinjiang, i.e. *Zhundong, Tuha, Ili, Kubai and Hefeng-Kelamai*

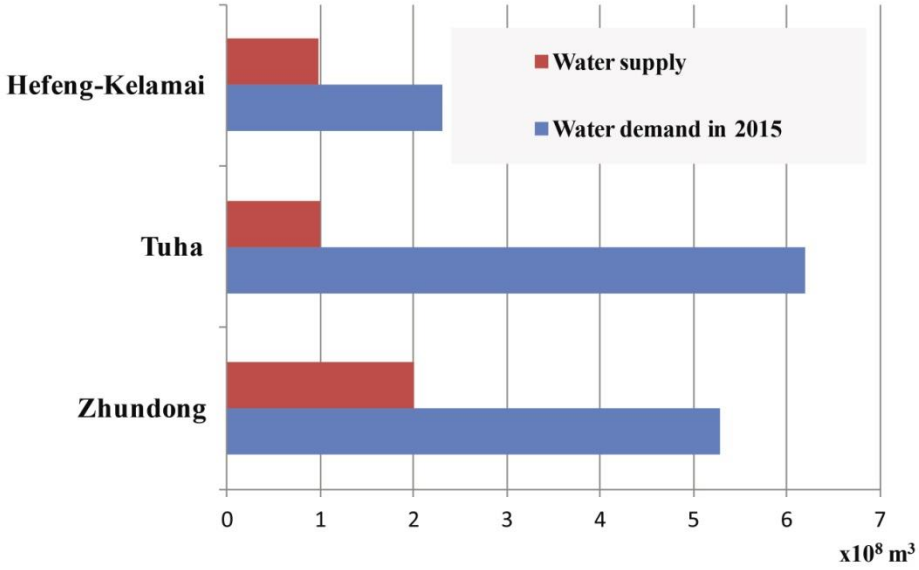
Focus of CO_2-EWR in Western China

2) Dilemma of XinJiang CCI

- CCI is a river demand industry with high concentration CO_2 emissions, e.g. standard large CCI factory may needs water 2,000-3,000 tonnes per hour.

- Among the five key CCI areas in Xinjiang, the gap of water demand till 2015 is very serious for three areas, i.e. *Zhundong, Tuha, and Hefeng-Kelamai*.

Product of CCI	Water demand per unit product (t/t)	CO_2 emission per unit product (t/t)
Synthetic ammonia	21.60	4.04
Methanol	8.50	3.16
DTL	12.00	2.90
ITL	13.00	7.22

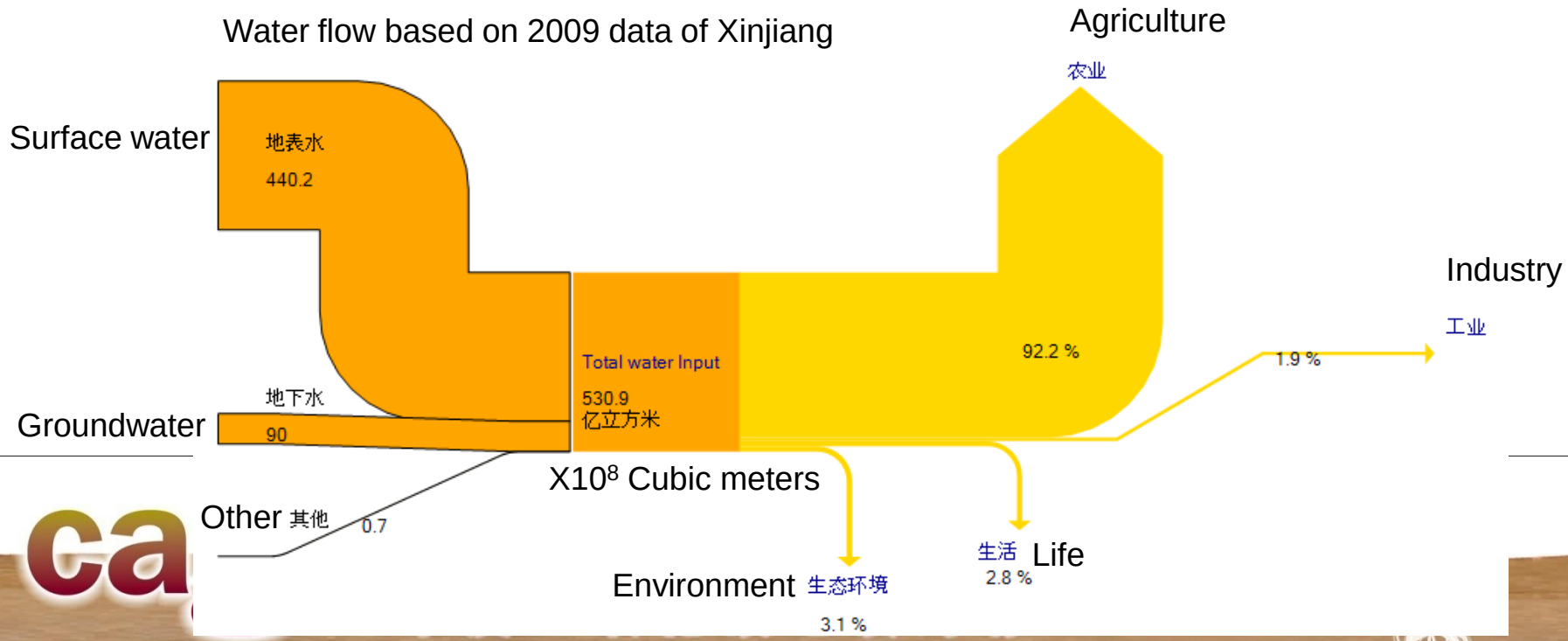


Focus of CO_2-EWR in Western China

3) Possible options to meet water demand in 2015 in XinJiang

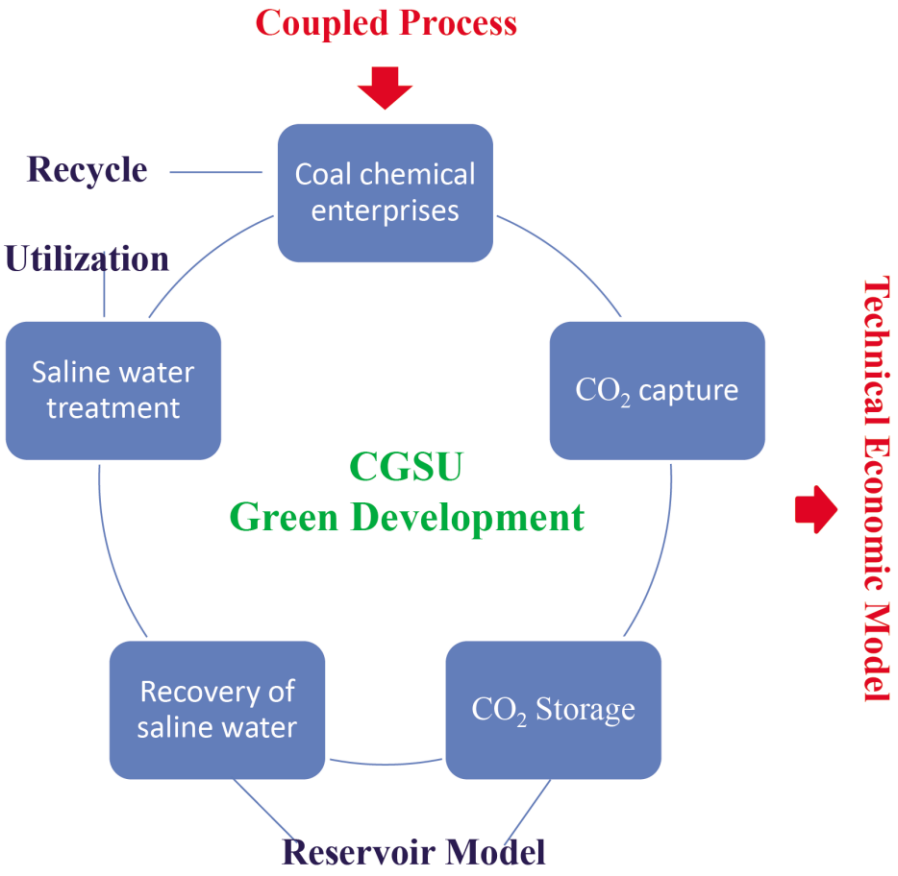
- To cut the quota of other usages
- Long-distance water transfer (LDWT) from water abundant region
- CO_2-EWR

  According to most research, if distance is greater than 40 km, cost of LDWT will be greater than one of seawater desalination.



Focus of CO_2-EWR in Western China

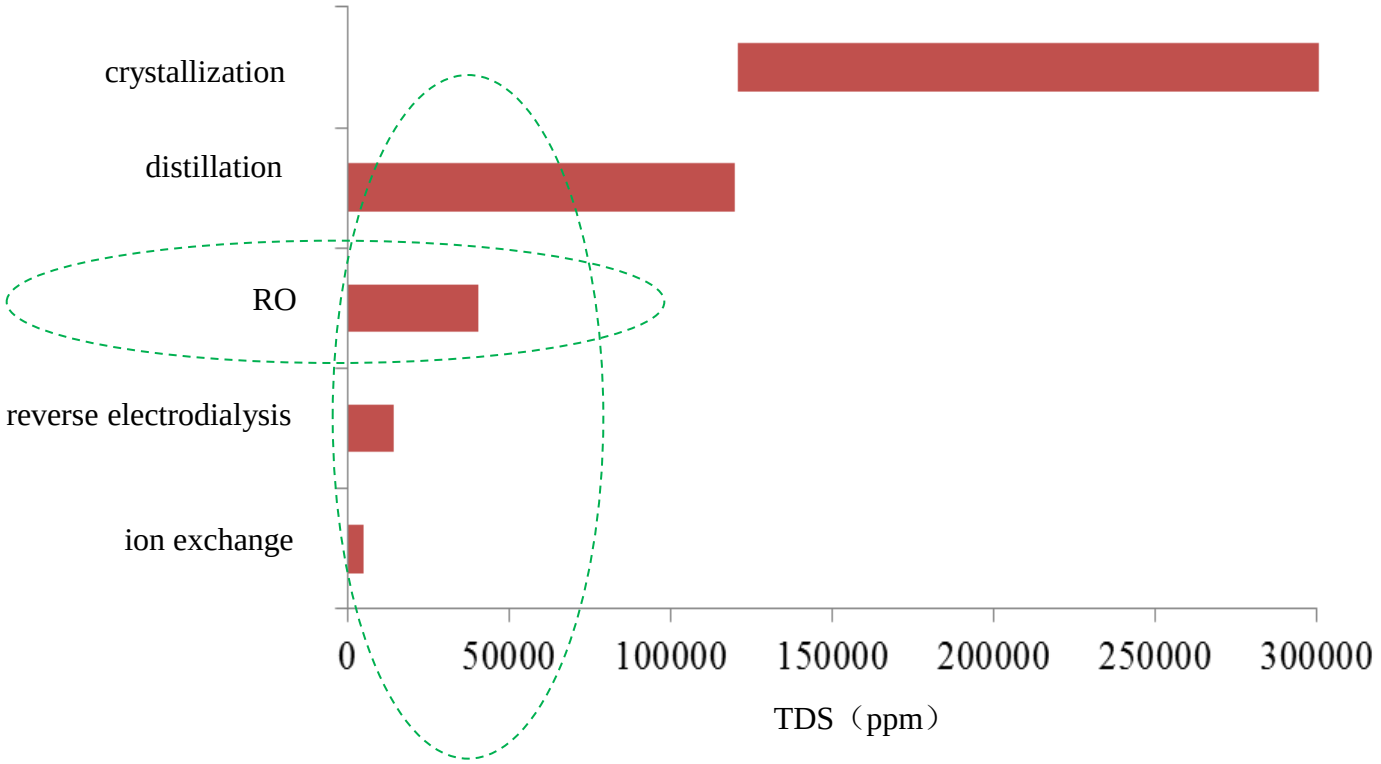
4) Research Module



1. Plant Module
2. CO_2 Capture Module
3. CO_2 Sequestration Module
4. *Extracted Water Module*
5. *Water Reverse Osmosis Module*

Focus of CO_2-EWR in Western China

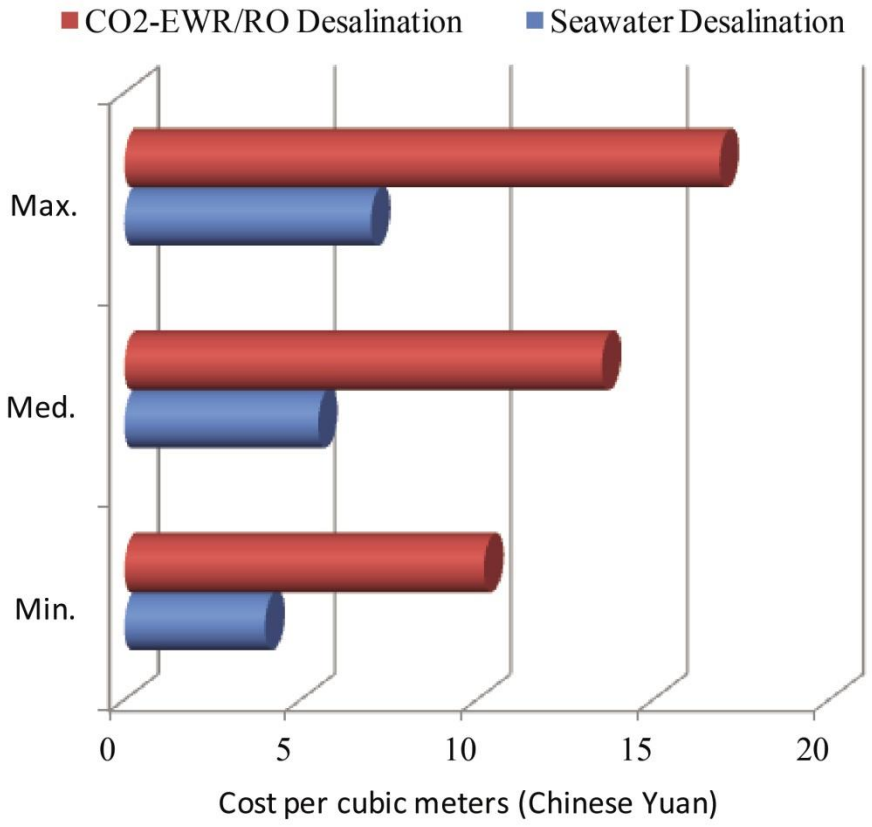
5) Desalination option for recovered deep saline water



Focus of CO_2-EWR in Western China

6) Cost Analysis

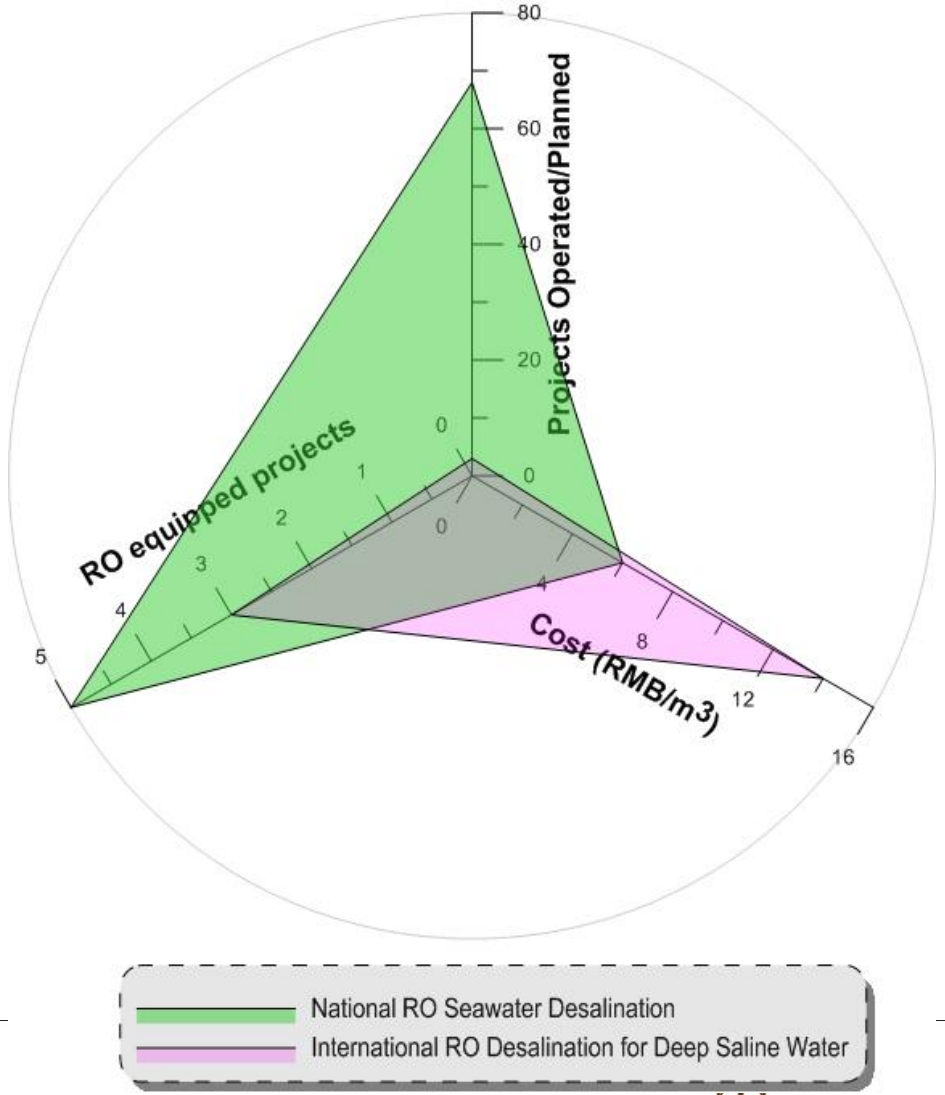
- Cost of RO desalination for recovered deep saline water is double greater than one of seawater desalination.
- If the CO_2-EWR/RO desalination technology can also obtain the same subsidy to seawater desalination from China Central Government, the cost gap will be further narrow.
- Furthermore, such cost gap can not block CCI has motivation to implement CO_2-EWR in very water shortage western region of China.



Focus of CO_2-EWR in Western China

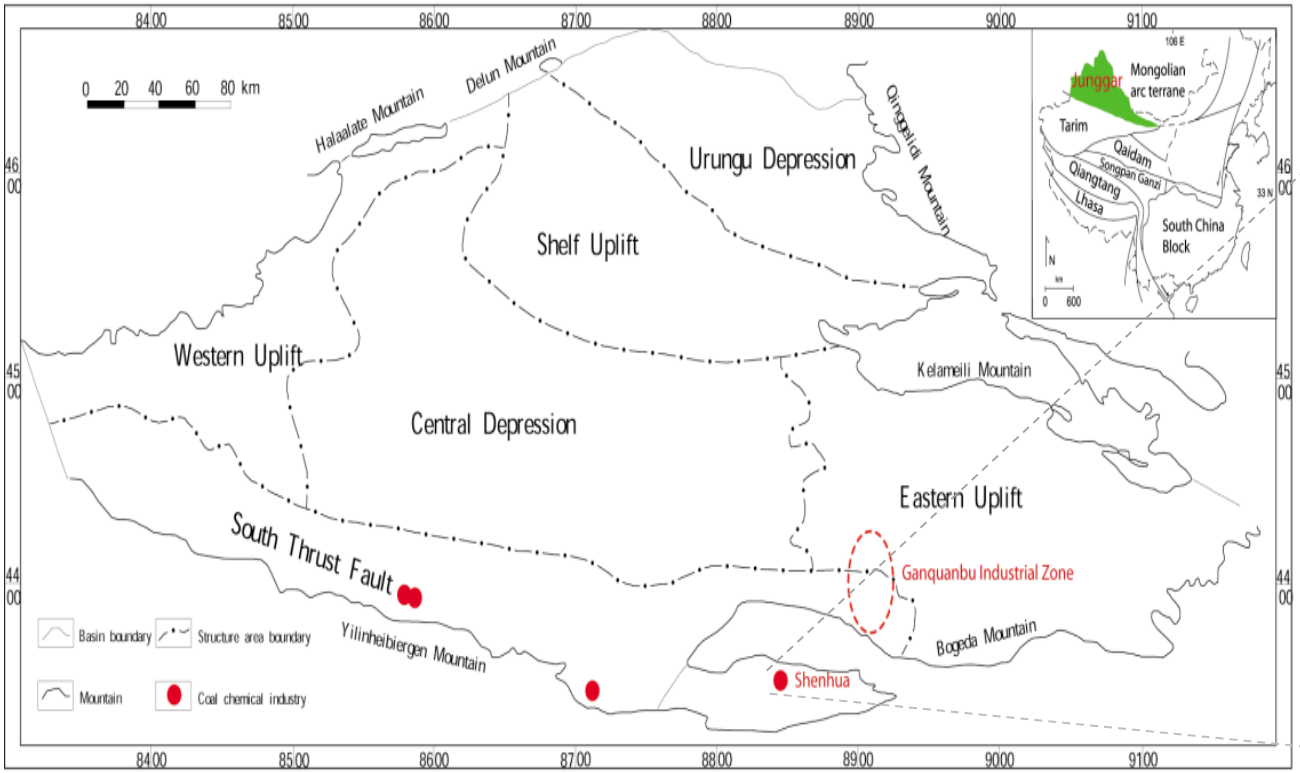
6) Comparative Analysis

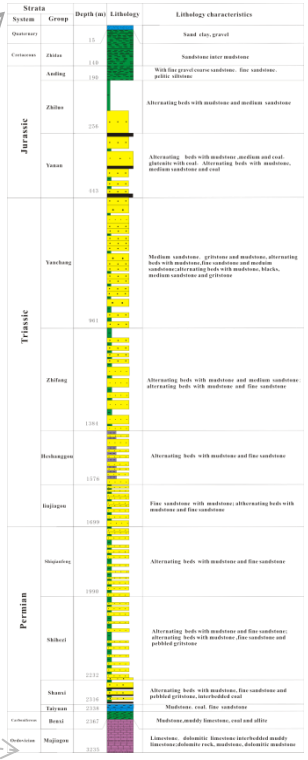
- Five seawater desalination factories over 10,000 tonnes per day operated by RO technologies in China East.
- Gorgon project may be the first CCS project with EWR and RO in the world.



Focus of CO_2-EWR in Western China

7) Geological Setting for a practical case study

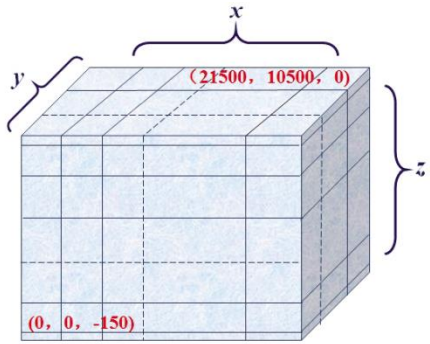


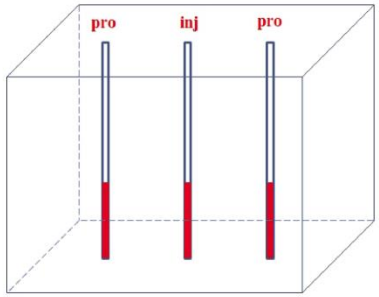


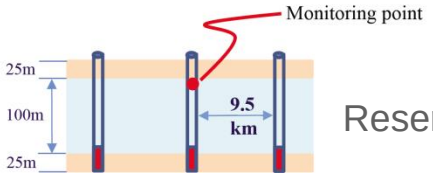
Focus of CO_2-EWR in Western China

8) Model Setup and Validation Analysis

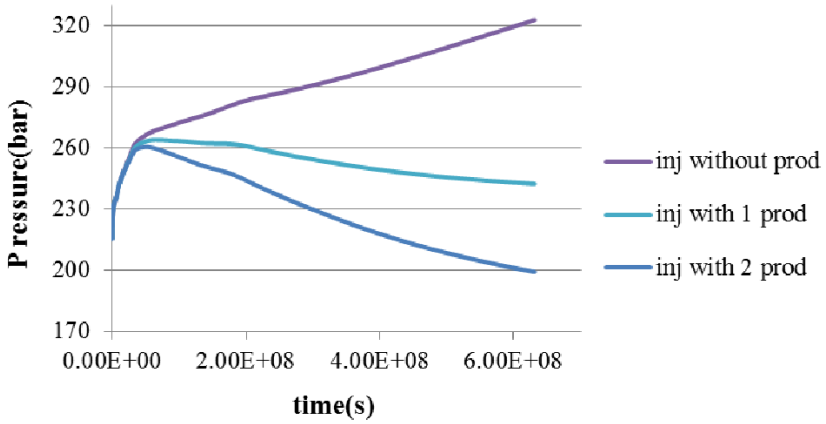
- Numerical model validated with comparison to LLNL NUFT code.







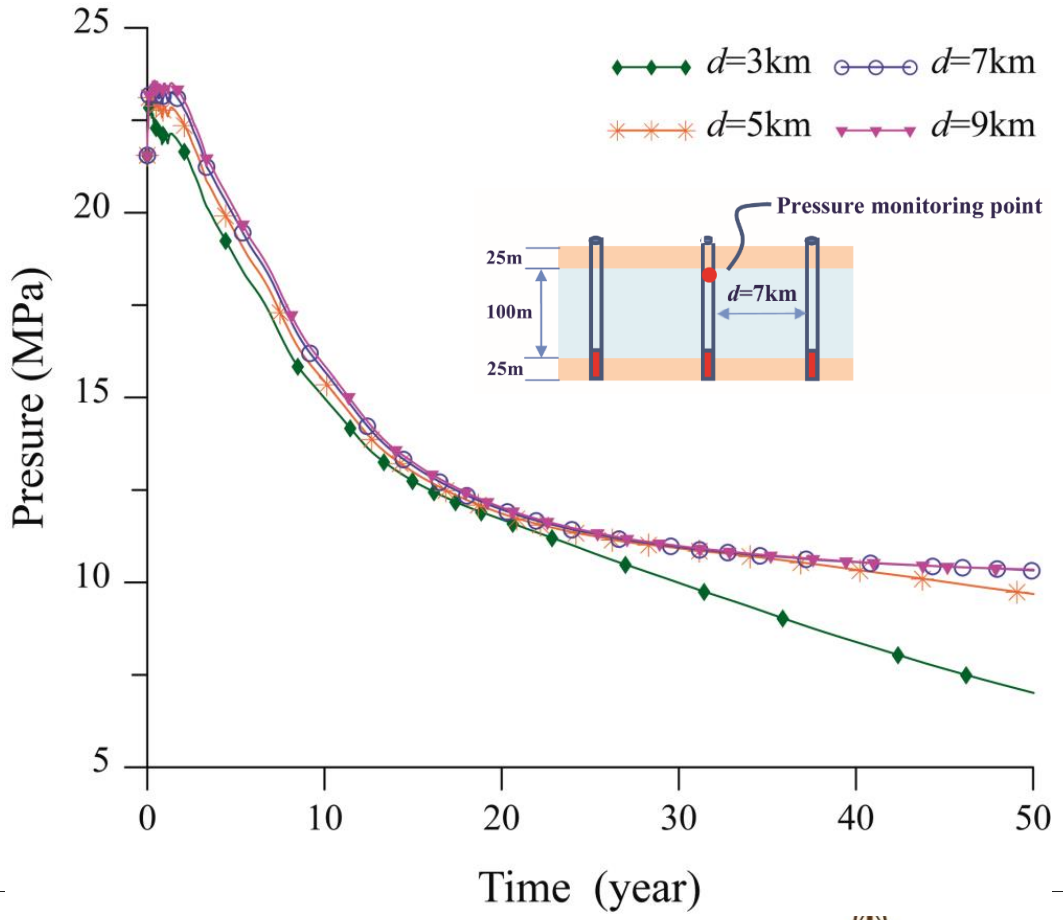
Reservoir



Focus of CO_2-EWR in Western China

9) Parameter Analysis: Different distance arrangements of pumping wells

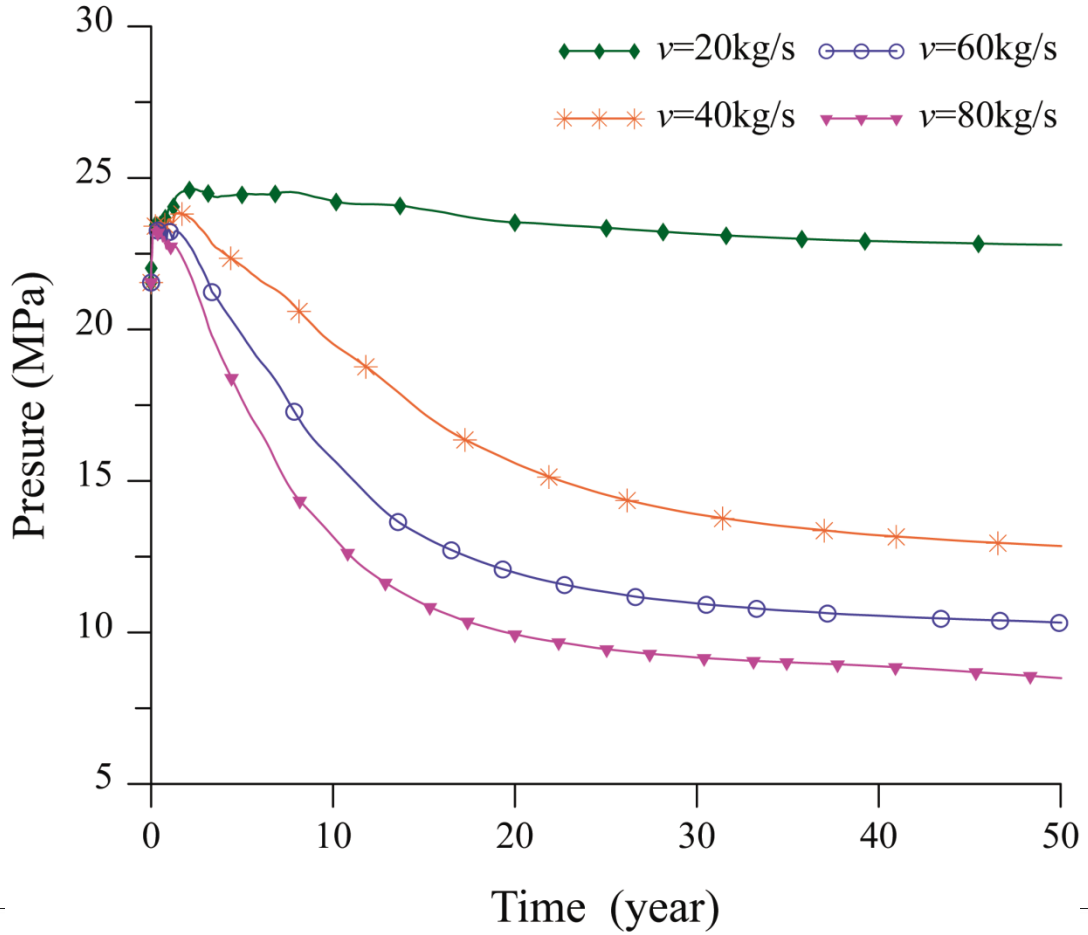
- Figure shows the pressure of monitoring point versus time under different distance arrangements of pumping wells.
- The shorter distance away from the injection well, the smaller the pressure value is monitored.
- In the same variation range (Δd = 2km), the larger the distance results the smaller pressure difference.



Focus of CO_2-EWR in Western China

9) Parameter Analysis: Different pumping rates

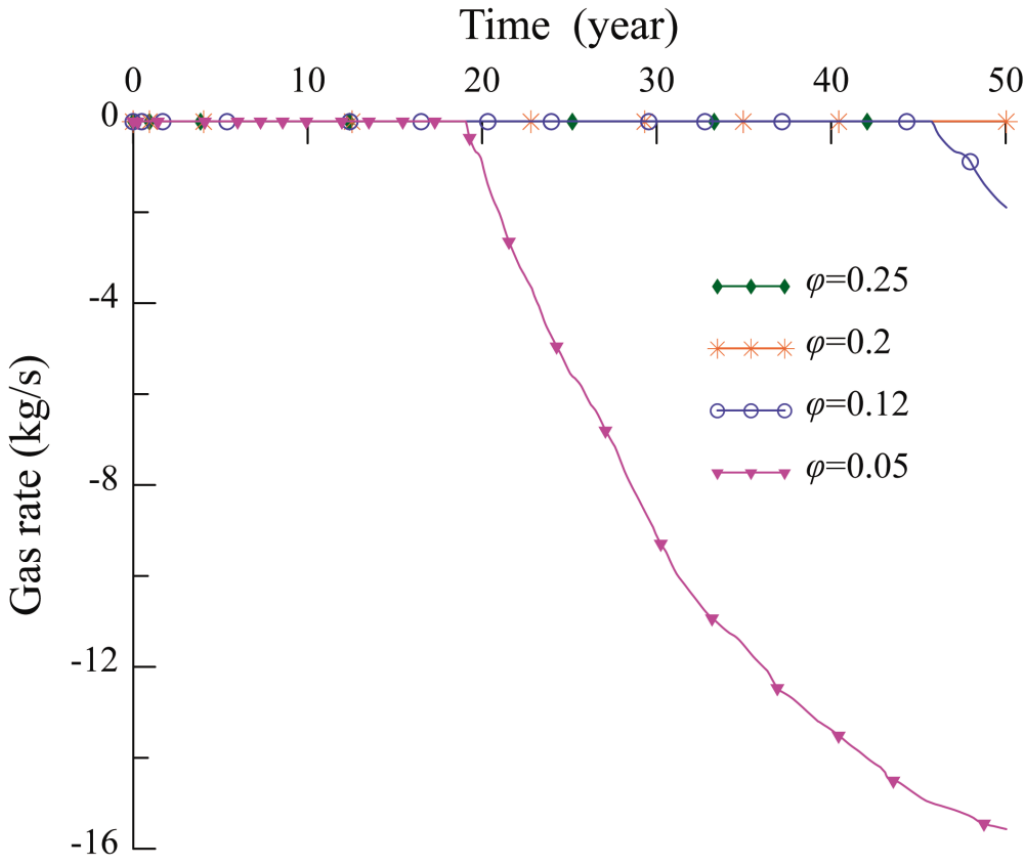
- Under different pumping rate conditions the pressure curves display a downward trend after a slight increase in the initial short period of time.
- Large pumping rate decrease the pressure buildup quickly.



Focus of CO_2-EWR in Western China

4) Parameter Analysis: Different porosity of reservoir

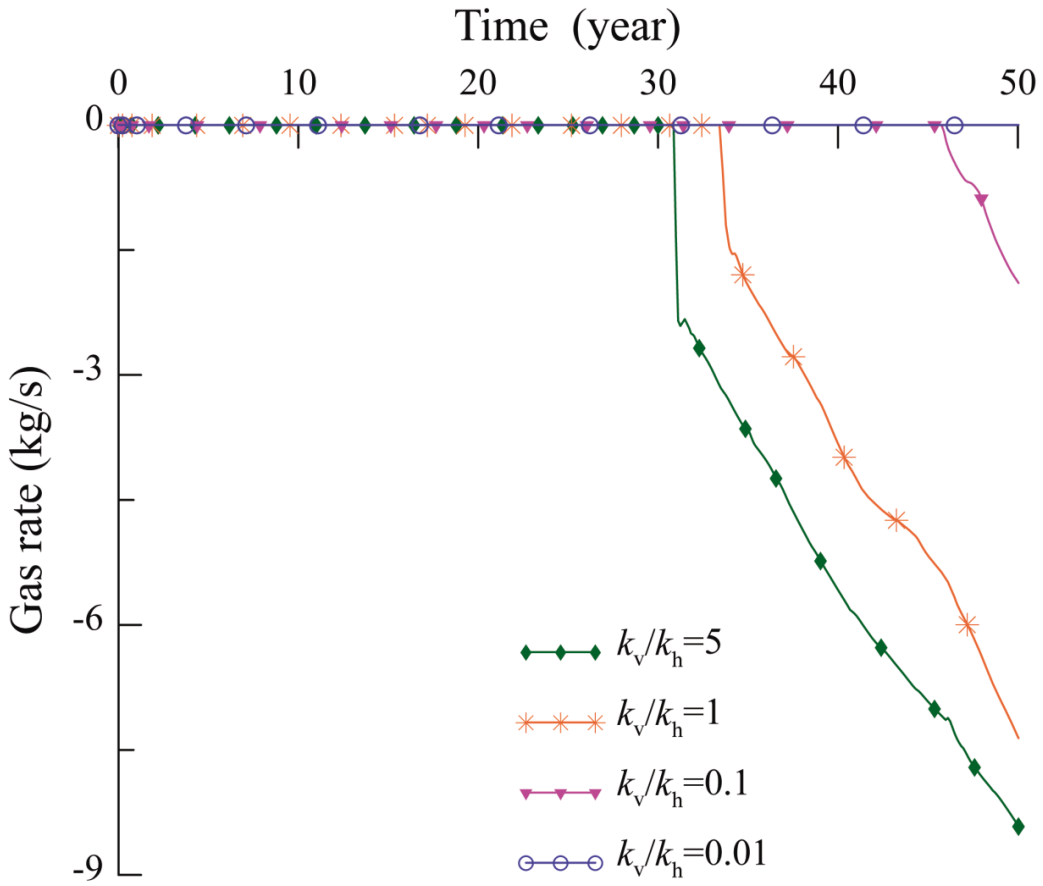
- The impact of porosity is mainly reflected in the residual trapping, as porosity increase, a large CO_2 mass is trapped within the pores, which cause the decrease of free CO_2.
- When porosity reach to 0.2 and 0.25, the gas rate in pumping wells become 0 after 50 years, this indicates that more CO_2 is trapped in the form of residual trapping.



Focus of CO_2-EWR in Western China

4) Parameter Analysis: Different permeability of reservoir

- Under Buoyancy effect, the supercritical CO_2 will migrate under the bottom of caprock gradually once it is injected into the saline aquifer.
- The vertical permeability k_v controls the vertical migration of CO_2 plume, and decides its shape characteristic in space. As k_v increase, less time will be allowed for saline water production, and CO_2 is more prone to leak.



Concluding Remarks

- CO_2-EWR is region dependent CCUS project.
- Coal chemical industry (CCI) in Western China has early opportunities to implement CCUS.
- CO_2-EWR has little secondary effect on environment because of all liquid waste after saline water processed can be re-injected into the same reservoir.
- If national subsidy is applied to CO_2-EWR, cost will be further lowered down and also national carbon market becomes clear before 2015, both factors would enhance enterprise's confidence to speed up its implementation in Western China.

Acknowledgements

- Chinese Academy of Sciences, One-Hundred Talent Program
- ACCA 21

- *Collaborated: Ya-Ni Wei, Guizhen Liu and Miao Jing*

Questions and Comments

- *Related articles*:

*1) Q. Li, Y.-N. Wei, G. Liu, M. Jing, M. Zhang, W. Fei, X.Y. Li, and X. Li, Feasibility of the combination of CO2 geological storage and saline water development in sedimentary basins of China, **Energy Procedia**, 2012.*

*2) Q. Li, Y.-N. Wei, G. Liu, Assessment of CO2 Storage Capacity and Saline Water Development in Sedimentary Basins of China, **South to North Water Transfers and Water Science & Technology**, 2013. (in Chinese)*

*3) Q. Li, Y.-N. Wei, G. Liu, CO2 geological storage combined with deep saline water recovery (CO2-EWR), **China Science Report**, 2013. (in Chinese)*

*4) Q. Li, Y.-N. Wei, G. Liu, Numerical assessment of key parameters on CO2 geological storage combined with deep saline recovery, **Advanced Water Research**, 2014.*

*5) Q. Li and Y.-N. Wei, Attractive option for water shortage mitigation for coal chemical industry in Western China, **Energy Policy**, to be prepared.*

- *Further contact*: qli@whrsm.ac.cn
- *Thanks for your attention!*