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carbon capture & storage

Regional Assessment of Carbon Dioxide Storage Potential

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May 2008

Back ground

- NZEC: Near Zero Emissions from Coal

  —Cooperation between China and UK
- Kick-off meeting in Beijing November 2007
- Project Coordinator

  AEA Energy & Environment, UK

  ACCA21, MOST, China
- Work-package 4 – Carbon dioxide storage potential

1. Aims and objectives

Aims

To build capacity in China for evaluating storage potential and performing appropriate first stage site characterisation for site selection.

Objectives

- To deliver clear information on the future potential for CO_2 storage, both as an additional benefit in CO_2 enhanced oil recovery (EOR) and enhanced coal-bed methane (ECBM) recovery by CO_2 sequestration, and as direct storage in saline aquifers in a range of basins.

- **A GIS system based on ARCGIS will be developed to incorporate point emissions data from WP2 and storage data from this work package. Mapping of CO_2 sources and potential sinks will be carried out.**

2. Team members

- **UK lead: Nick Riley, BGS**

  Heriot Watt University, BP, Shell, AEA Energy & Environment

- **Chinese lead: Mingyuan Li, China University of Petroleum (CUP, Beijing)**

  China University of Petroleum (CUP, HuaDong)

  Institute of Geology and Geophysics Chinese Academy of Sciences (CAS)

  Tsinghua University

  China United Coalbed Methane Co., Ltd. (CUCBM)

  PetroChina,

3. Basins selected

Songliao basin
EOR
saline aquifer

Qinshui basin
ECBM

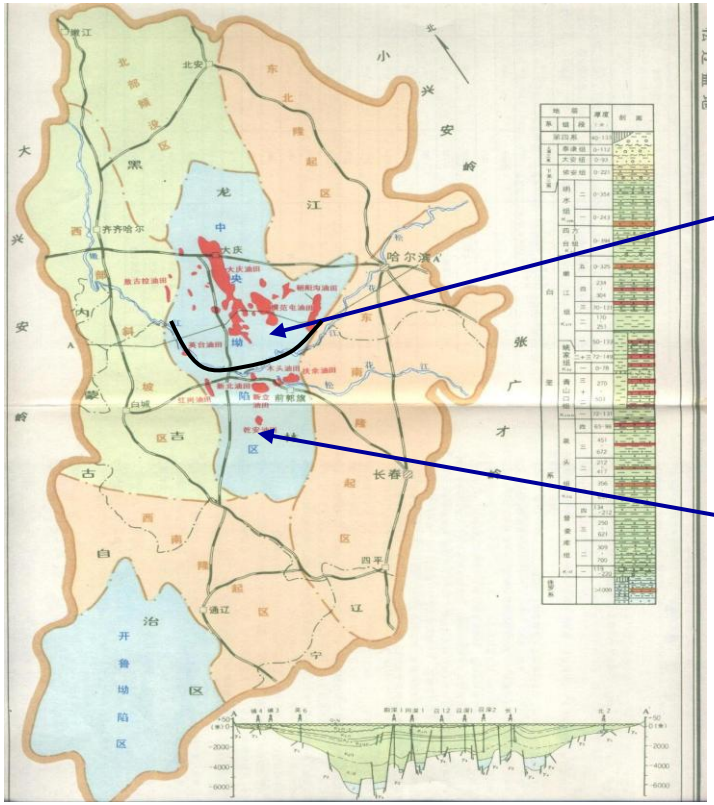
Subai basin
EOR

Task of WP4

	CO_2 storage with EOR		CO_2 storage with ECBM		Saline aquifer CO_2 storage	
Basin	Lead Organisation	UK support	Lead Organisation	UK support	Lead Organisation	UK support
Songliao	CUP (Beijing)	BGS/HW/ BP			CAS	BGS/Shell
Subei	CUP (Huadong)	BGS/HW				
Qinshui			CUCBM	BGS/ Shell		

Assessment of CO_2 sources in Jilin province for GIS by Tsinghua University

5. CO_2 storage capacity in oil/gas reservoir of Songliao basin

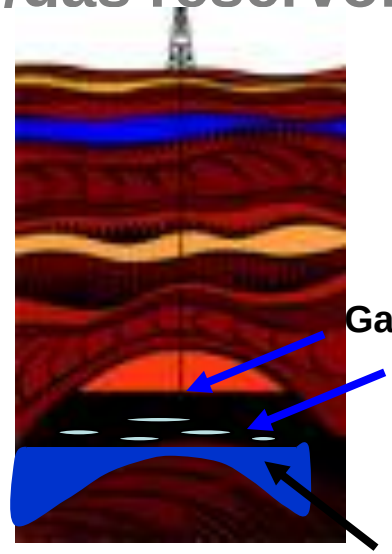


（1）CO_2 storage capacity model for oil/gas reservoir

$$M=M_1+M_2+M_3+M_4$$

$$=E_f\times A\times h\times \varphi\times[S_o\times R_{0(CO2)}+(1-S_0)\times R_{w(CO2)}]$$

$$+h\times A\times \varphi\times R_{w(CO2)}+(M_p\times 4\%/\rho_f)$$



M - Total storage capacity of CO_2

M_1 - storage capacity of CO_2 is soluble in oil and water in oil bearing reservoir

M_2 - storage capacity of CO_2 is soluble in formation water

M_3 - storage capacity of CO_2 in oil bearing reservoir by CO_2 flooding

M_4 - storage capacity of CO_2 reacted with rock

E_f - overall sweep efficiency (fraction), E_f=5%-25%, assume E_f=18%

A - area of oil-bearing reservoir (m^2)

h - formation thickness (m)

Φ- porosity (fraction)

S_o - oil saturation (fraction)

$R_{o(CO2)}$ - CO_2 solubility in oil (fraction)

$R_{w(CO2)}$ - CO_2 solubility in water (fraction)

S_w - CO_2 solubility in formation water (fraction)

M_p - residual oil in reservoir (10^4t)

ρ_f - oil density in reservoir (Kg/m^3)

（2） CO_2 storage capacity in oil/gas reservoir of Daqing oil field

oilfield	M_1 ($\times 10^6 m^3$)	M_1/M (%)	M_2 ($\times 10^6 m^3$)	M_2/M (%)	M_3 ($\times 10^6 m^3$)	M_3/M (%)	Total ($\times 10^6 m^3$)
Lamadian	43.27	17.40	151	60.72	54.43	21.89	248.7
Sa'ertu	80.85	21.42	218	57.76	78.57	20.82	377.42
Xingshugang	25.62	21.49	68.8	57.72	24.78	20.79	119.2
Gaotaizi	0.33	23.24	0.8	56.34	0.29	20.42	1.42
Taipingtun	1.49	23.24	3.6.	56.16	1.32	20.59	6.41
Putaohua	1.53	15.58	6.1.	62.12	2.19	22.30	9.82
Aobaota	0.42	24.14	0.96	55.17	0.36	20.69	1.74
Total	153.51	20.01	449.26	58.75	161.94	21.18	764.71

Table 3 The CO_2 storage capacity with different S_o in Daqing oil field ($\times 10^6 m^3$)

oilfield	S_o=0.75	S_o=0.6	S_o=0.5	S_o=0.4	S_o=0.3	S_o=0.25
Lamadian	43.27	40.04	37.88	35.73	33.57	32.50
Sa'ertu	80.85	72.50	66.94	61.38	55.81	53.03
Xingshugang	25.62	22.97	21.20	19.43	17.66	16.77
Gaotaizi	0.33	0.29	0.27	0.24	0.22	0.21
Taipingtun	1.49	1.32	1.21	1.10	0.99	0.93
Putaohua	1.53	1.44	1.38	1.32	1.26	1.23
Aobaota	0.42	0.36	0.32	0.29	0.26	0.25
Ttotal	764.71	717.75	686.42	655.11	623.81	608.17

（3） CO_2 storage capacity in oil/gas reservoir of Jilin oil field

Oilfield	M_1 ($\times 10^6 m^3$)	M_1/M (%)	M_2 ($\times 10^6 m^3$)	M_2/M (%)	M_3 ($\times 10^6 m^3$)	M_3/M (%)	Total ($\times 10^6 m^3$)
Hongang	1.44	21	4.15	60	1.30	19	6.89
Xinli	2.99		8.64		2.71		14.34
Mutou	0.93		2.69		0.84		4.46
Qian'an	6.47		18.68		5.85		31
Yingtai	5.23		15.10		4.73		25.06
Total	17.06		49.26		15.43		81.75

Table 6 The CO_2 storage capacity with different S_o in Jilin oil field ($\times 10^6 m^3$)

	S_o=65%	S_o=50%	S_o=40%	S_o=30%	S_o=25%
Hongang	6.89	6.43	6.12	5.82	5.66
Xinli	14.34	13.39	12.75	12.1	11.78
Mutou	4.46	4.17	3.97	3.77	3.68
Qian'an	31	28.93	27.55	26.18	25.49
Yingtai	25.06	23.39	22.27	21.16	20.61
Total	81.75	76.31	72.66	69.03	67.22

（4）Potential of oil recovered by CO_2 EOR

Table8 Potential of oil recovered by CO_2 EOR in Daqing oil field ($\times 10^4$t)

Oil field	Mp（$\times 10^4$t）	EOR2%	EOR4%	EOR6%	EOR8%	EOR10%
Lamadian	57000	1140	2280	3420	4560	5700
Sa'ertu	93000	1860	3720	5580	7440	9300
Xingshugang	25000	500	1000	1500	2000	2500
Gaotaizi	290	5.8	11.6	17.4	23.2	29
Taipingtun	1300	26	52	78	104	130
Putaohua	2200	44	88	132	176	220
Aobaota	330	6.6	13.2	19.8	26.4	33
Total	179120	3582.4	7164.8	10747.2	14329.6	17912

Table9 Potential of oil recovered by CO_2 EOR in Jilin oil field ($\times 10^4$t)

Oil field	Mp/($\times 10^4$t)	EOR2%	EOR4%	EOR6%	EOR8%	EOR10%
Hongang	1753.74	35.1	70.1	105.2	140.3	175.4
Xinli	4935.83	98.7	197.4	296.1	394.9	493.6
Mutou	1821.28	36.4	72.9	109.3	145.7	182.1
Qian'an	12138.87	242.8	485.6	728.3	971.1	1213.8
Yingtai	10017.4	200.3	400.6	601	801.4	1001.7
Total	30667.12	613.3	1226.6	1839.9	2453.4	3066.6

6. CO_2 storage capacity in oil/gas reservoir of Subei basin

(1) For EOR oil reservoirs,

$$EOR_{index} = ER_{index} \times OOIP \times C = ER_{index} \times \left[\frac{URR}{(API_{gravity} + 5)/100} \right]_{OOIP} \times C$$

$$(M_{CO2})_{index} = EOR_{index} \times (R_{CO2})_{index}$$

(2)For depleted oil reservoirs,

$$(M_{CO2})_{index} = V_{total} \times BO \times \rho_{CO2} \times S_{index}$$

(Stevens, 1999)

With:

EOR-incremental oil production, BO;

ER- incremental recovery;

OOIP- original oil in place, BO ;

C-contact factor;

URR- Ultimate Recoverable Resources, BO;

R_{CO2}-ratio for net CO_2 injection versus oil production, t/BO;

M_{CO2}-mass of stored CO_2 potentially;

V_{total}-total oil produced in the past,

BO-0.159m^3; ρ_{CO2} -density of CO_2 at reservoir condition;

S - "space factor", % of the original space that can be used for CO_2 storage;

index-representing max, min, optimized value

Screening Results of CO_2 EOR and Storage

In 108 reservoirs which have been assessed, there are

75 reservoirs are suitable for CO_2 EOR.

33 reservoirs are unsuitable for CO_2 EOR.

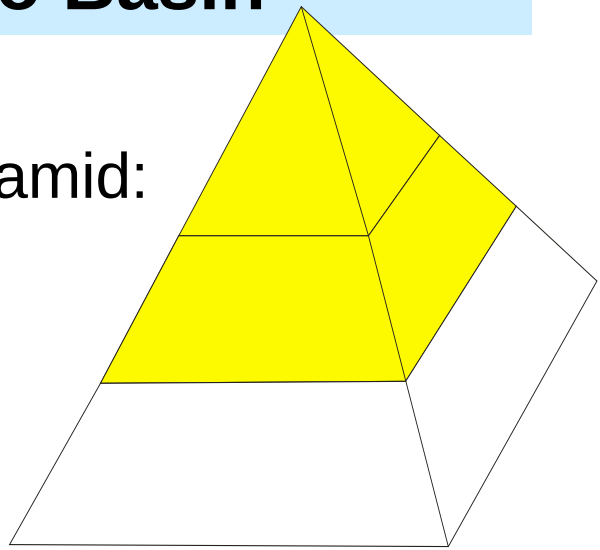
- **For all the 108 reservoirs in Jiang Su oilfield, the total CO2 storage potential is 20.4614 M t .**

- **For the 75 reservoirs suitable for CO2 EOR, the CO2 storage potential during EOR process is 15.76 M t. the incremental oil production is 4.67 M t, and the incremental recovery factor is 5.71%. That is equivalent to 0.3 t oil due by 1 t CO2 injection .**

- **For the 33 reservoirs unsuitable for CO2 EOR, the CO2 storage potential in depleted reservoirs is 4.70 M t.**

7. CO_2 Storage Potential in Saline Aquifers of Songliao Basin

Deep saline aquifers



Regional estimates in the middle of the pyramid:

$$M_{CO2e} = A \times h \times \varphi \times \rho_{CO2r} \times S_{cff}$$

- M_{CO2e} : effective storage capacity
- A : area of regional aquifer
- h : average height of aquifer × average net to gross ratio
- φ : average reservoir porosity
- ρ_{CO2r} : CO_2 density at reservoir conditions
- S_{cff} : storage coefficient (possibly estimated)

Typical S_{cff} ranges depending on methodology: 1 – 2 – 10 %

Songliao Basin

Songliao Basin (260,000 sq km)

- **About 380m saline aquifer**
- **Total regional theoretical storage capacity:**

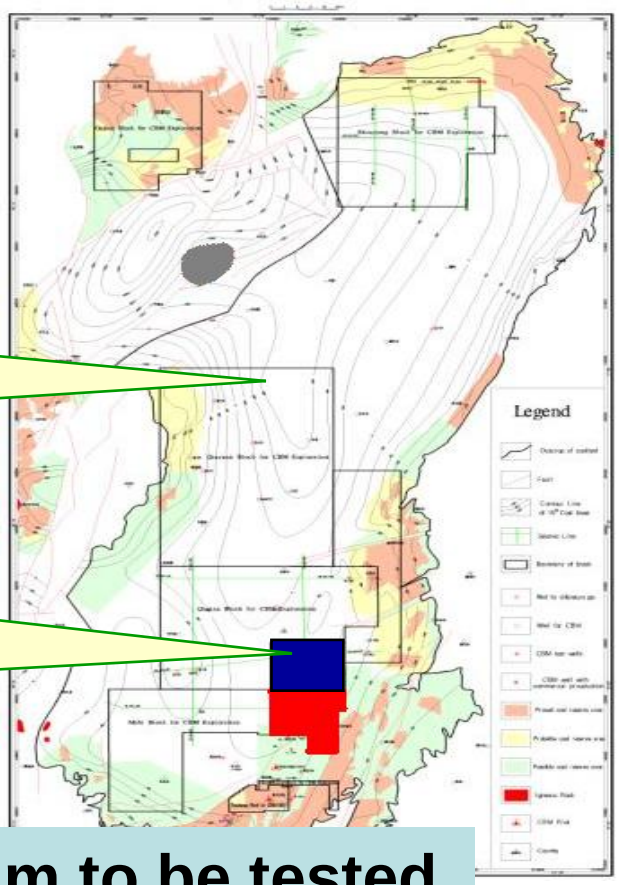
83 Gt CO_2

(Storage coefficient of 2% applied)

8. CO_2 Storage Potential in Coal Seams of Qinshui Basin

1500-2000m
No CBM activity,
inject CO_2 directly

1000-1500m
CBM activity,
inject CO_2 with cbm production



The adsorption of CO_2 on coal seam to be tested.


Thanks