Supporting early CCS development in non-power industrial sectors

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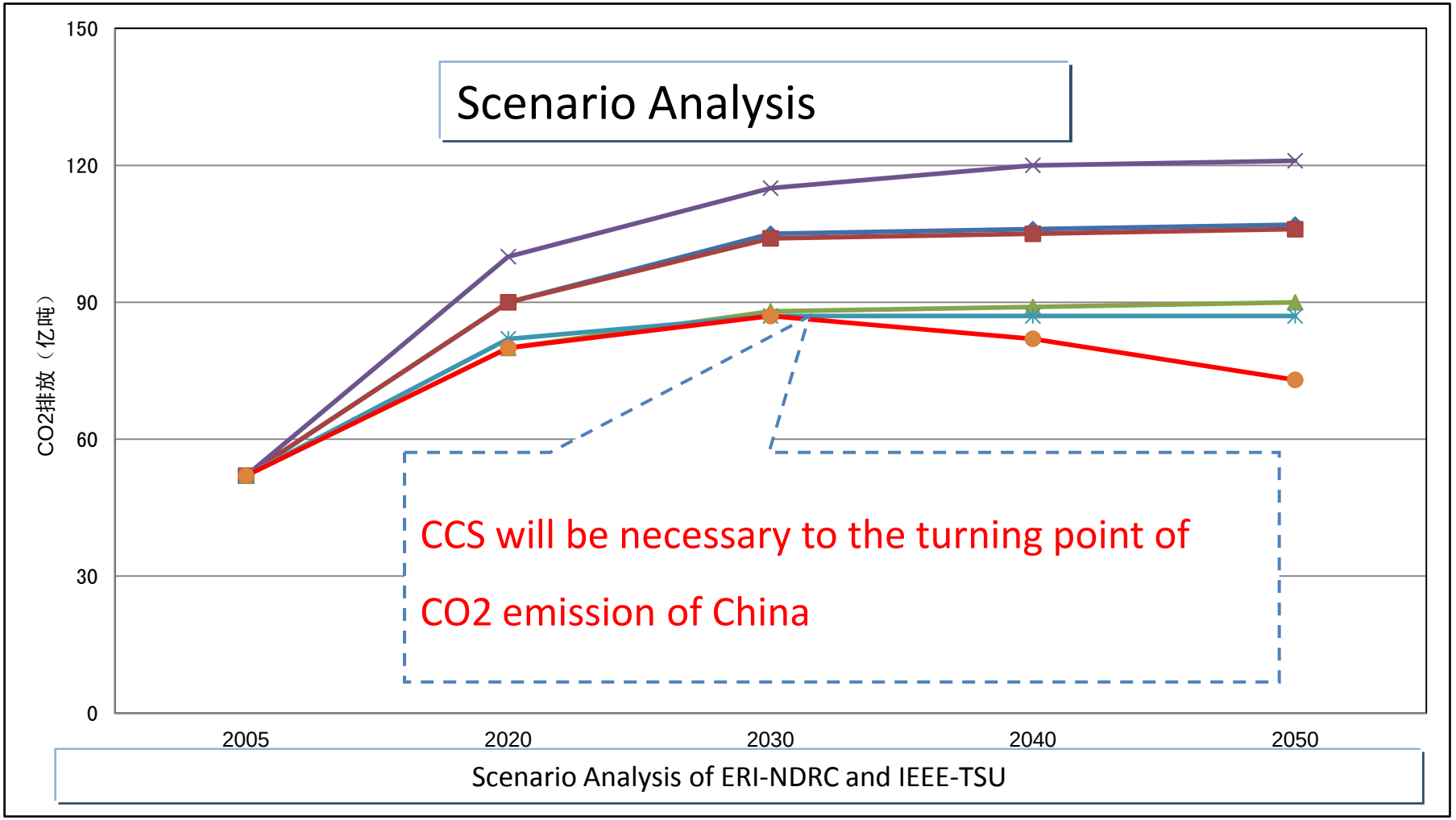
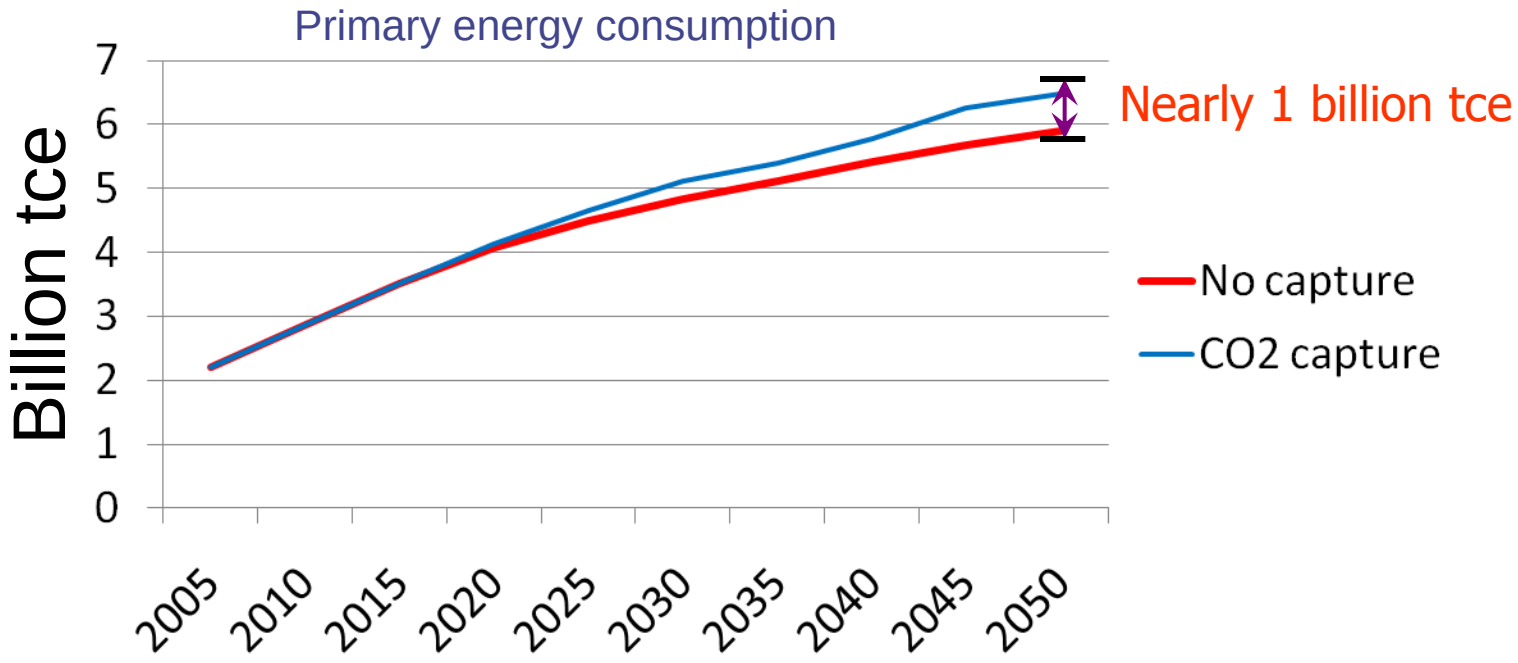
Role of CCS in China



It is hard to reverse the ascend of CO_2 emission of China just relying on energy saving and renewable energy utilization

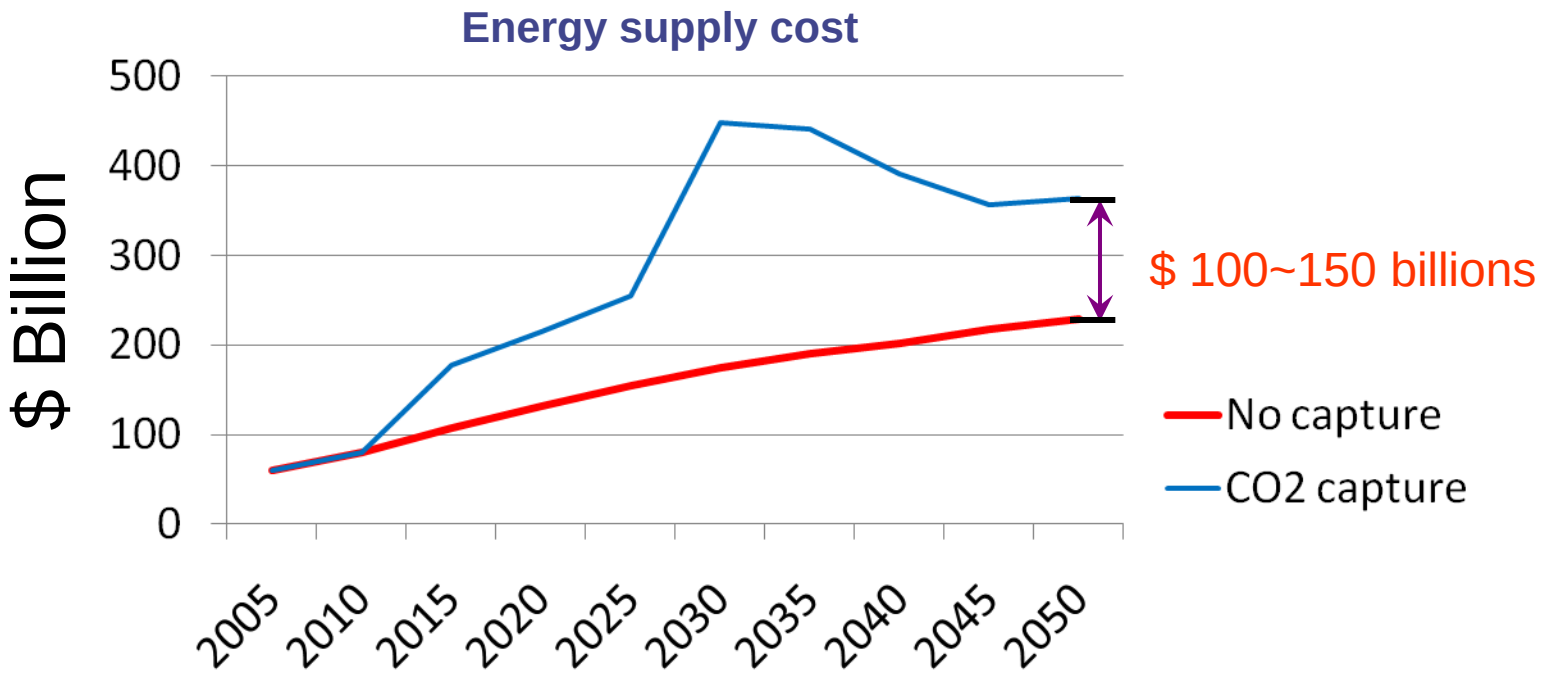
Background
— Special Issues for CCS in China

large energy consumption plus *high energy penalty* (7~15%), with the existing CCS technologies



Nearly *0.7~1.0 billions* tce/y of *extra* energy consumption for CCS in China by 2050 (keep 2005 emission level)

high cost (30~50$/t) and *large amount* of CO2 to capture
Based on the existing CCS technologies



More than One hundred billions $ per year for CO_2 capture

Reducing the *penalty* of CCS technologies are *necessary* for Chinese sustainable development!

Great Passion but Fatal Defects

序号	项目名称	地点	规模	示范内容	现状
1	中国石油吉林油田 CO_2EOR 研究与示范	吉林油田	封存量：约 10 万吨/年	CCS-EOR	2007 年投运
2	中科金龙 CO_2 化工利用项目	江苏泰兴	利用量：约 10000 吨/年	酒精厂 CO_2 化工利用	2007 年投运
3	华能集团北京热电厂捕集试验项目	北京高碑店	捕集量：3000 吨/年	燃烧后捕集	2008 年投运
4	中海油 CO_2 制可降解塑料项目	海南东方市	利用量：2100 吨/年	天然气分离 CO_2 化工利用	2009 年投运
5	华能集团上海石洞口捕集示范项目	上海石洞口	捕集量：12 万吨/年	燃烧后捕集	2009 年投运
6	中电投重庆双槐电厂碳捕集示范项目	重庆合川	捕集量：1 万吨/年	燃烧后捕集	2010 年投运
7	中石化胜利油田 CO_2 捕集和驱油示范	胜利油田	捕集和利用量 4 万吨/年	燃烧后捕集 CCS-EOR	2010 年投运
8	连云港清洁煤能源动力系统研究设施	江苏连云港	捕集量：3 万吨/年	燃烧前捕集	2011 年投运
9	神华集团煤制油 CO_2 捕集和封存示范	内蒙古鄂尔多斯	捕集量：10 万吨/年 封存量：约 10 万吨/年	煤液化厂捕集+咸水层	2011 年投运
10	新奥集团微藻固碳生物能源示范项目	内蒙古达拉特旗	拟利用量：约 2 万吨/年	煤化工烟气生物利用	一期投产；二期在建；三期筹备
11	华能绿色煤电 IGCC 电厂捕集利用和封存示范	天津滨海新区	捕集量：6-10 万吨/年	燃烧前捕集 CCS-EOR	2011 年启动
12	华中科技大学 35MWt 富氧燃烧技术研究与示范	湖北应城市	捕集量：5 万吨/年	富氧燃烧捕集	2011 年启动
13	国电集团 CO_2 捕集和利用示范工程	天津塘沽区	捕集量：2 万吨/年	燃烧后捕集	前期筹备
14	中石化煤制气 CO_2 捕集和驱油封存示范工程	胜利油田	捕集利用量：70 万吨/年	煤制气捕集 CCS-EOR	前期筹备
15	中石化胜利油田 CO_2 捕集和封存驱油示范工程	胜利油田	捕集利用量：50-100 万吨/年	燃烧后捕集 CCS-EOR	前期筹备
16	内蒙古 CO_2 地质储藏项目	内蒙古准格尔旗	拟封存量：100 万吨/年	煤化工烟气捕集+咸水层	前期筹备

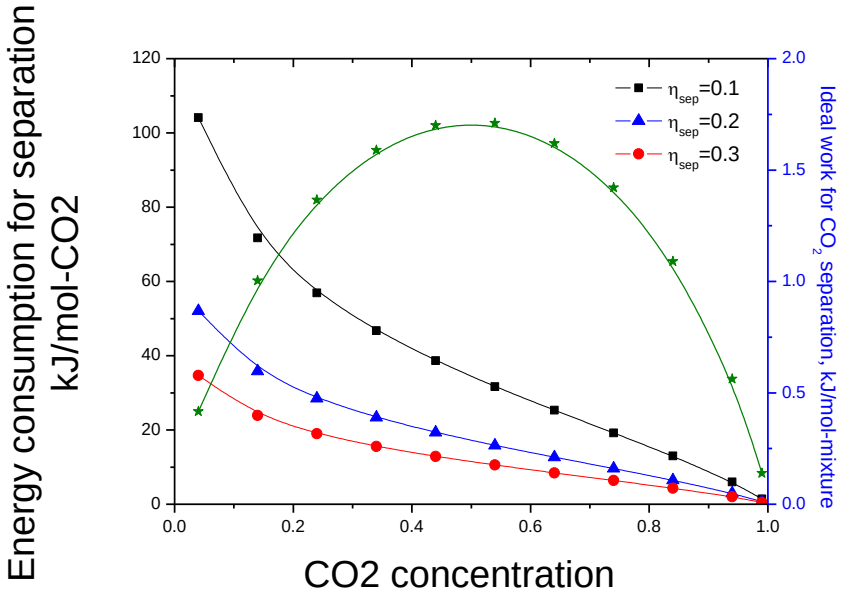
Demo to Death

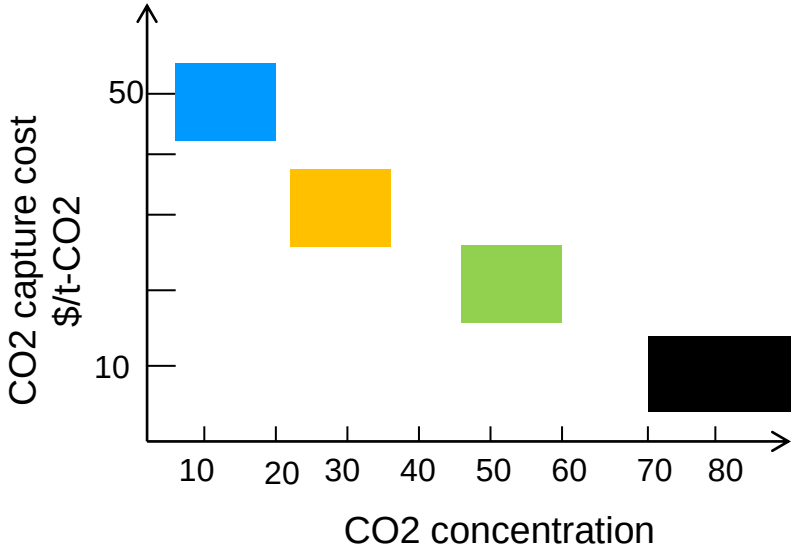
The initial phase is very important to technologies

The future of technology maybe terminated by rash demos without solving the problem

Finding the breakpoint for new technology deployment is the key

Background for this project —Applying CCS in non-power sector





Higher CO_2 concentration

Lower energy consumption &Lower cost

Non-Power sector: usually high purity CO_2 sources

Low energy consumption & cost to promote demo project

High-purity CO_2 sources in non-power sectors

	Plant type of CO_2 source	CO_2 purity	Purity class	Emission scale, Mt/y	Desulphurization or not	Dehydration or not	Difficulty level of pre-treatment
Refining chemical plant	Refinery plant	8%	Low	0.1~0.6	Yes	Yes	Hard
	Ethylene plant	12%	Low	0.25~2.5	No	No	Hard
	Ethylene oxide plant	99%	High	0.2~1	Yes	No	Easy
	Hydrogen plant	99%	High	0.2~0.6	No	No	Easy

High-purity CO_2 sources in non-power sectors

Chemical Fertilizer Plant	**Ammonia plant**	**99.5%**	**High**	**0.38~3.8**	**No**	**No**	**Easy**
	Methanol/DME plant	99%	High	0.25~2.5	No	No	Easy
Iron and Steel Plant		15%-25%	Low-medium	2 ~10	Yes	Yes	Hard
Cement factory	Cement plant	20%-25%	Low	0.1~2	Yes	Yes	Hard
Iron and Steel Plant		15%-25%	Low-medium	2 ~10	Yes	Yes	Hard

Criteria for CO_2 sources selection

1)Technical feasibility and maturity principle

It means that the capture technology is engineering available, and the mature technology should be given priority to reduce the risk and uncertainty of the project.

2) The energy penalty and cost minimization principle

high purity CO_2 sources to reduce capture cost and energy penalty.

Target Region: Shaanxi province

- Coal reserve and production are both large
  168.5 Gt, 16% of the total reserve

- CO_2 emissions in Shaanxi are huge
  around 75Mt/a(2006 data)

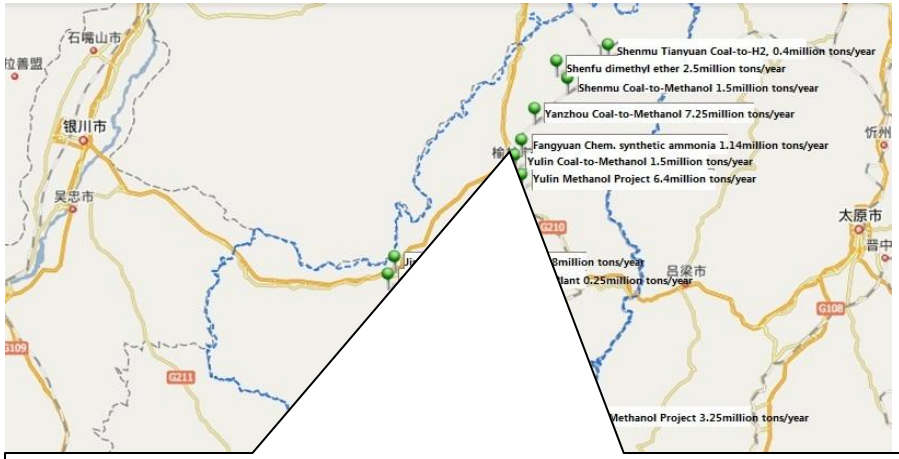
- Many sources with high CO_2 purity
  Coal chemical industry is developed
  (E.g., methanol plant, DME plant, NH_3 plant)

- With local government owned oil fields suitable for CO_2 EOR
  Yanchang oil field
  Changqing oil field

- With coal fields suitable for ECBM
  Shenfu coal fields: biggest in China

- Under reduction pressure, local government wishes to CCS demo

High-purity CO_2 sources in Shaanxi



- Total CO_2 emission scale: 61.1Mt/y
- Most sources are located in **Yulin** city
- **10 methanol** plants with over **99%** purity CO_2 and **42.5Mt/y** emissions
- **7 ammonia** plants with over 99% purity

Examples:

Methanol production projects in Yulin

Capacity: 0.6 Mt per year

Coal consumption: 1.8 Mt per year

CO2 emissions: 4.0 Mt per year

Water consumption: 6.0 Mt per year

CO_2 transportation options in Shaanxi

- Road – flexible, using existing road infrastructure
- Rail – flexible, using existing road infrastructure
- Pipeline – more cost-effective, suitable for larger volumes (>2MT/yr), full-scale demonstration projects
- Road and rail most suitable in early stages of CCUS development
- Pipelines most suitable when CCUS reaches larger scale

Recommendations for CO_2 transportation

Transportation method	Preferable scale	transportation cost
Pipeline	**Large** scale, >2Mt/year	~1$/t/100km
Railway/Road tanks	**Small scale**	6~17$/ t /100km
Ship	Median-large	0.6~5$/ t /100km

EOR potential in Shaanxi — Yanchang oil field

- Yanchang oil field
  - 2010 production **12 million ton** oil
  - Ownership: Shaanxi provincial government
  - Estimated indicative storage capacity: **45~88Mt CO_2**
  - EOR plans: promote and apply water flood recovery, **actively** research and develop **CO_2-EOR**

Oil exploration spots in Yanchang oil filed (23 spots)

Plant name	Plant type	Location	Scale
Attatched to Yanchang Petroleum			
Yanchang Petroleum Zichang oil exploitation plant	Oil exploitation	Yanan Zichang country	Oil production ~400,000t/year in 2006
Yanchang Petroleum Dingbian oil exploitation plant	Oil exploitation	Yulin Dingbian Country	Oil production ~900,000t/year in 2007
Yanchang Petroleum Jingbian oil exploitation plant	Oil exploitation	Yulin Jingbian Country	Oil production ~780,000t/year in 2009
Yanchang Petroleum Wuqi oil exploitation plant	Oil exploitation	Yanan Baotao district	Oil production ~1400,000t/year
Yanchang Petroleum Wangjiachuan oil exploitation plant	Oil exploitation	Yanan Yanchang country	Oil production ~460,000t/year in 2008
Yanchang Petroleum Ganguyi oil exploitation plant	Oil exploitation	Yanan Baotao district	Oil production ~260,000t/year in 2008
Yanchang Petroleum Yongning oil exploitation plant	Oil exploitation	Yanan Zhidan country	Oil production ~1260,000t/year in 2008
Yanchang Petroleum Xiqu oil exploitation plant	Oil exploitation	Yanan Zhidan country	Oil production ~1000,000t/year

Oil exploration spots in Yanchang oil filed (23 spots)

Yanchang Petroleum Xingxichuan oil exploitation plant	**Oil exploitation**	**Yanan Ansai country**	**Oil production ~650,000t/year**
Yanchang Petroleum Nanniwan oil exploitation plant	**Oil exploitation**	**Yanan Baotao district**	**Oil production ~500,000t/year**
Yanchang Petroleum Chuankou oil exploitation plant	**Oil exploitation**	**Yanan Baotao district**	**Oil production ~500,000t/year**
Yanchang Petroleum Xiasiwan oil exploitation plant	**Oil exploitation**	**Yanan Ganquan country**	**Oil production ~420,000t/year**
Yanchang Petroleum Wayaobao oil exploitation plant	**Oil exploitation**	**Yanan Zichang country**	**Oil production ~350,000t/year**
Yanchang Petroleum Qilicun oil exploitation plant	**Oil exploitation**	**Yanan Yanchang country**	**Oil production ~300,000t/year**
Yanchang Petroleum Zibei oil exploitation plant	**Oil exploitation**	**Yanan Zichang country**	**Oil production -**
Yanchang Petroleum Hengshan oil exploitation plant	**Oil exploitation**	**Yanan Hengshan country**	**Oil production ~140,000t/year**
Yanchang Petroleum Qingpingchuan oil exploitation plant	**Oil exploitation**	**Yanan Yanchuan country**	**Oil production ~100,000t/year**
Yanchang Petroleum Panlong oil exploitation plant	**Oil exploitation**	**Yanan Baota district**	**Oil production ~140,000t/year**
Yanchang Petroleum Zhiluo oil exploitation plant	**Oil exploitation**	**Yanan Fu country**	**Oil production ~70,000t/year**
Yanchang Petroleum Nanqu oil exploitation plant	**Oil exploitation**	**-**	**Oil production ~120,000t/year**
Yanchang Petroleum Zizhou oil exploitation plant	**Oil exploitation**	**Yulin Zizhou country**	**Oil production ~40,000t/year**
Yanchang Petroleum Yingwang oil exploitation plant	**Oil exploitation**	**Yanan Yichuan country**	**-**

EOR potential in Shaanxi — Changqing oil field

- Changqing oil field
  - Part of Shaanxi-Gansu-Ningxia basin
  - Proven geological oil reserves of about 336 million tons, controlled reserves of about 394 million tons and prognostic reserves of about 533 million tons since 1999.
  - Ownership: PetroChina
  - Indicative storage capacity: **41~80Mt CO_2**
  - EOR plans: currently promote and apply water flood recovery, **actively** research and develop **CO_2-EOR**

Oil exploration spots in Changqing oil filed (3 spots)

Plant name	Plant type	Location	Scale
Attatched to Changqing Petroleum			
Changqing Petroleum 3th oil exploitation plant	**Oil exploitation**	**Yanan Wuqi country**	-
Changqing Petroleum 4th oil exploitation plant	**Oil exploitation**	**Yulin Changqing industry base**	-
Changqing Petroleum 6th oil exploitation plant	**Oil exploitation**	**Yulin Dingbian country**	-

Criteria for CCUS project selection

Selection Criteria	Evaluation Aspects
1 Technical feasibility (necessary)	Technical maturity capture/transportation/storage technology
2 Match of source and sink(necessary)	CO2 emission scale of sources Sequestration method and volume
3 Economic factor	Capture, transportation and sequestration cost Utilization value
4 Energy penalty	Capture, transportation and sequestration energy penalty
5 Environmental factor	Contribution of carbon emission reduction Impact on local water resources Impact on the emission amount of particles Other impact on environment
6 Transportation factor	Transportation infrastructure/Terrain/Distance
7 Policy factor(necessary)	Local policy support for CCS
8 Social factor	Public acceptance
9 Security factor(necessary)	CO2 transportation security CO2 leakage
10 Demonstration effect	Demonstration site/Demonstration scale
11 Complexity of project organization	Enterprise properties of the CO2 source Properties of the Enterprise in charge of CO2 transportation Properties of the Enterprise in charge of CO2 sequestration

Criteria for CCUS project selection -Scoring mechanism for unnecessary factors

	0	1	2	3	4	5
Capture cost						
Transportation cost						
Sequestration cost						
Capture energy consumption						
Transportation energy consumption						
Sequestration energy consumption						
Traffic conditions						
Contribution to CO_2 emission reduction						
Impact to local water resources						
Difficulty level in deploying the projects						

Notice: mark an ‘X’ in the box. 0-very low, 1-low, 2-middle, 3-high, 4-very high,5-extremely high

Recommended non-power CCUS projects in Shaanxi province

Cas		illion year
Cas		illion year
Cas		million year
Cas		illion year

Case 1 Yanchang oil field methanol plant – Yanchang oil field

- Capture and compression characteristics and cost: ~12Mpa 99.9% CO_2 15~25$/t
- Emission volume 1.14 Mt/yr
- Distance from injection site: 160 km
- Transportation options and characteristics: pipeline
- Utilization characteristics and cost: EOR, injection cost ~6$/t, net cost -16~-80$/t
- Key aspects from applying selection criteria: short distance to the oil exploitation field, high purity CO_2, owned by Yanchang oil petroleum

Case 2 Yanan Fuxian methanol plant – Yanchang oil field

- Capture and compression characteristics and cost: ~15MPa 99.9% CO_2 15~25$/t
- Emission volume 6.8 Mt/yr
- Distance from injection site: 170 km
- Transportation options and characteristics: pipeline
- Utilization characteristics and cost: EOR, injection cost ~6$/t, net cost -16~-80$/t
- Key aspects from applying selection criteria: high purity CO_2, near to oil exploitation field, owned by Yanchang oil petroleum

Case 3 Changqing oil field methanol plant – Changqing oil field

- Capture and compression characteristics and cost: 2~4Mpa 99.9% CO_2 15~25$/t
- Emission volume 0.25 Mt/yr
- Distance from injection site: 40 km
- Transportation options and characteristics: road
- Utilization characteristics and cost: EOR, injection cost ~6$/t, net cost -16~-80$/t
- Key aspects from applying selection criteria: short distance, high purity CO_2, owned by Changqing oil petroleum

Case 4 Jingbian methanol plant – Changqing oil field

- Capture and compression characteristics and cost: ~15MPa 99.9% CO_2 15~25$/t
- Emission volume 6.8 Mt/yr
- Distance from injection site: 40 km
- Transportation options and characteristics: pipeline
- Utilization characteristics and cost: EOR, injection cost ~6$/t, net cost -16~-80$/t
- Key aspects from applying selection criteria: short distance, high purity CO_2

Cost-Benefit Analysis assumptions

1. Pipeline transportation, 160km
2. Pipeline transportation, 170km
3. Highway tanks transportation, 40km.
4. Pipeline transportation, 40km.
5. Excluding EOR benefit : data from IPCC special report on carbon capture and storage.
6. Excluding EOR benefit.
7. Including the benefit from oil production. Based on IPCC report, the net EOR cost is around -16$/t assuming the oil price is 20$/t. In this report, the oil price is assumed to range from 20$/t to 100$/t.
8. CO_2 is captured from traditional coal-fired power plant.
9. Pipeline transportation, 300km.

Cost-Benefit Analysis Shaanxi CCUS projects

	CO_2 capture cost	Transportation cost	Injection cost[5]	Total CCS cost[6]	Total CCS cost after considering the oil benefit[7]
Case 1	15~20$/t	1.5$/t[1]	6$/t	22.5~27.5$/t	-50.5~5.5$/t
Case 2	15~20$/t	1.7$/t[2]	6$/t	24~29$/t	-46~7$/t
Case 3	15~20$/t	3.2$/t[3]	6$/t	29~34$/t	-41~12$/t
Case 4	15~20$/t	0.7$/t[4]	6$/t	24~29$/t	-46~7$/t
Capture from power plant	35~50$/t[8]	3$/t[9]	6$/t	44~59$/t	-20~37$/t

Cost effective for the four cases

National Support on CCUS in Yanchang Petroleum

1. " Research for the supporting technologies of CO_2-EOR in Yanchang Oil field" in 2010;
2. "Demonstration of CCS and EOR technologies: started in 2012;

Target: 50,000 tons per year of CO_2 capture facility, build 10-15 wells for CO2-EOR demonstration, over 40,000 tons of CO2 per year will be stored

3. " key CCUS technologies in coal fired power plants—CO_2 storage key technologies" —863 project stared in 2012

Target: build the safety monitoring system, indentify the leakage risks and paths, build the CO_2-EOR demonstration basis

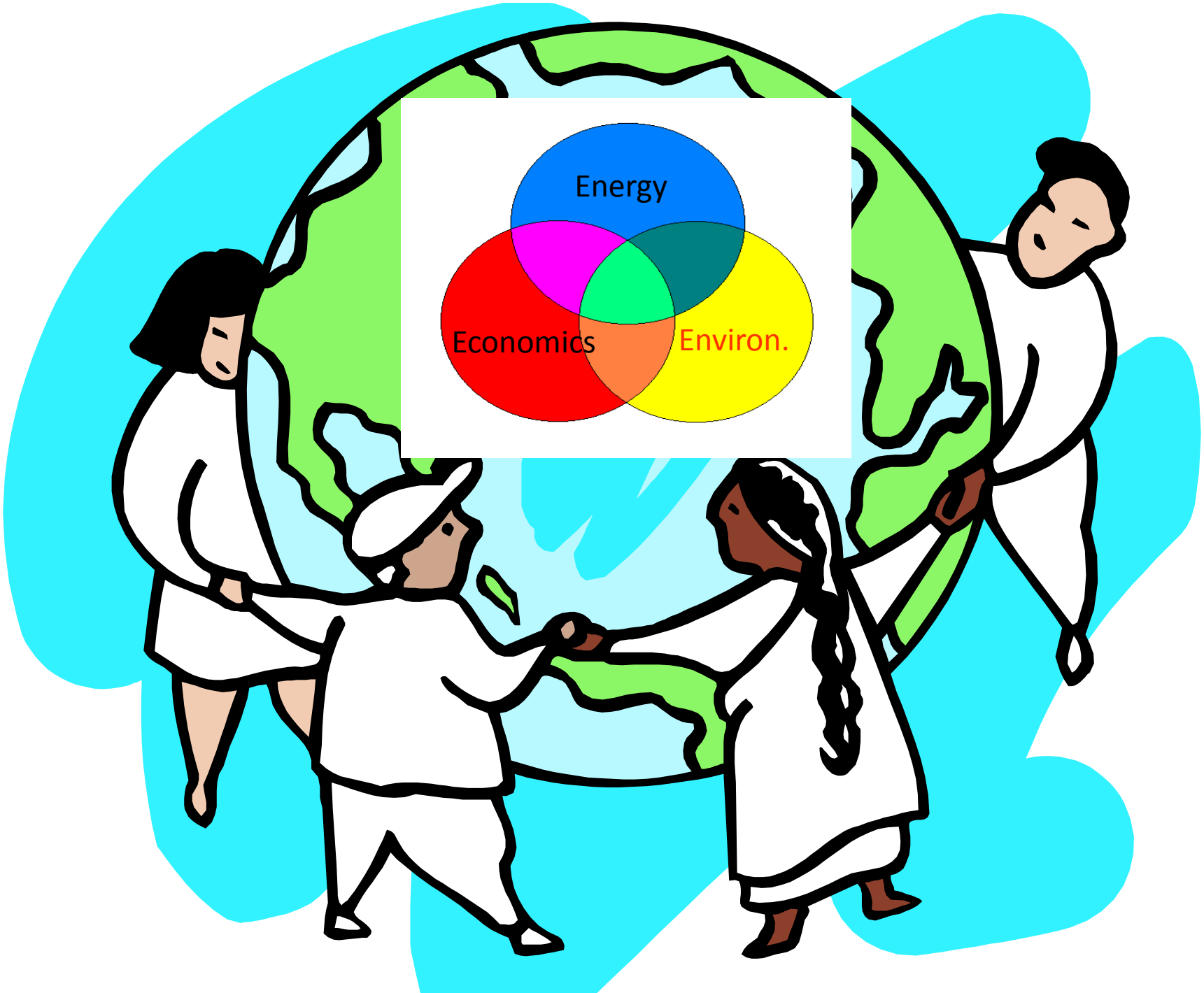
Development of CCUS in Yanchang Petroleum — 50,000 tons per year of CO_2 liquefaction and purification facility in Yulin

CO2 liquification and purification project

Yunlin Coal Chemical Industry of Yanchang Petrolemum group has built 50000 tons per year CO2 separation and purification facility (**Rectisol** process, food class purity: **98.5%)**

Conclusions

- The energy penalty and cost for capturing CO_2 from non-power sector is much lower than that of power plant, and even can gain profit in some cases combined with EoR ;
- Shaanxi Province may become the focused region for deploying early CCS demonstration projects in China due to it’s resources characteristics;
- Detailed feasibility study will promote the progress of CCS demonstration in Shaanxi Province.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