KAPSARC

مركـــز الملـــك عبـــدالله للدراســـات والبحوث البتروليـــة
King Abdullah Petroleum Studies and Research Center

Could China meet CO2 emission reduction targets by CO2-EOR?

Sa’d Shannak

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KAPSARC in Brief …

King Abdullah Petroleum Studies and Research Center (KAPSARC)

- Independent, non-profit, research institution
- Focuses on energy economics, policy, technology, and the environment
- Global and local
- Has financial and administrative independence
- Located in Riyadh

KAPSARC Research Programs and Focus Areas

Research Programs (Teams):

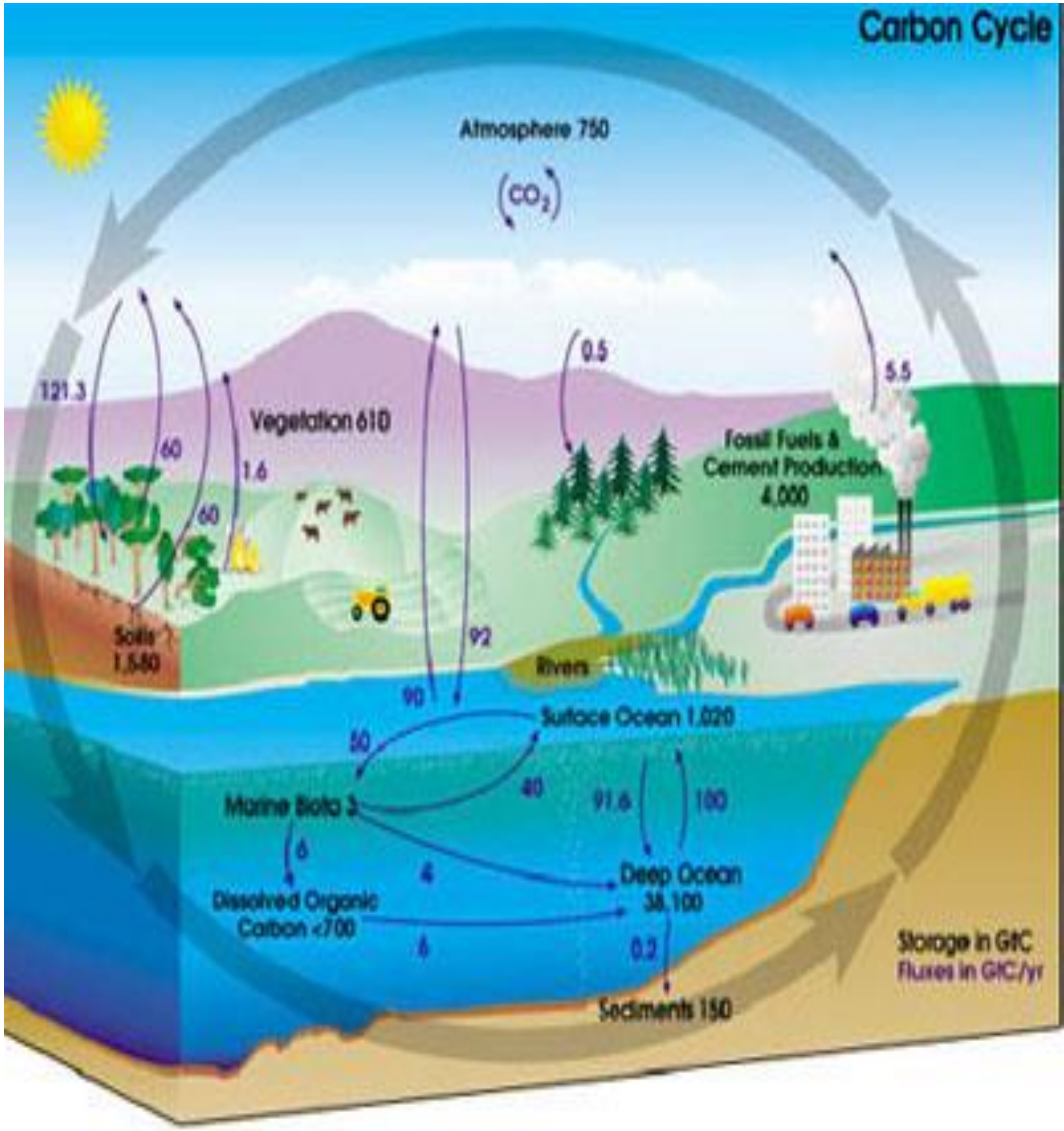
- Energy Systems Modeling and Economics
- Energy Markets, Fuels & Feedstocks
- Energy Transitions, Econometrics & Macro
- Human Geography of Energy

Research Focus Area:

- Allocating Energy Resources in an Economy
- Energy Flows and Market Impacts
- Social and Environmental Spillovers of Energy Policy Choices
- Energy Productivity
- Transportation; Modes, Fuels and Technologies
- Energy Transitions

The Carbon Cycle

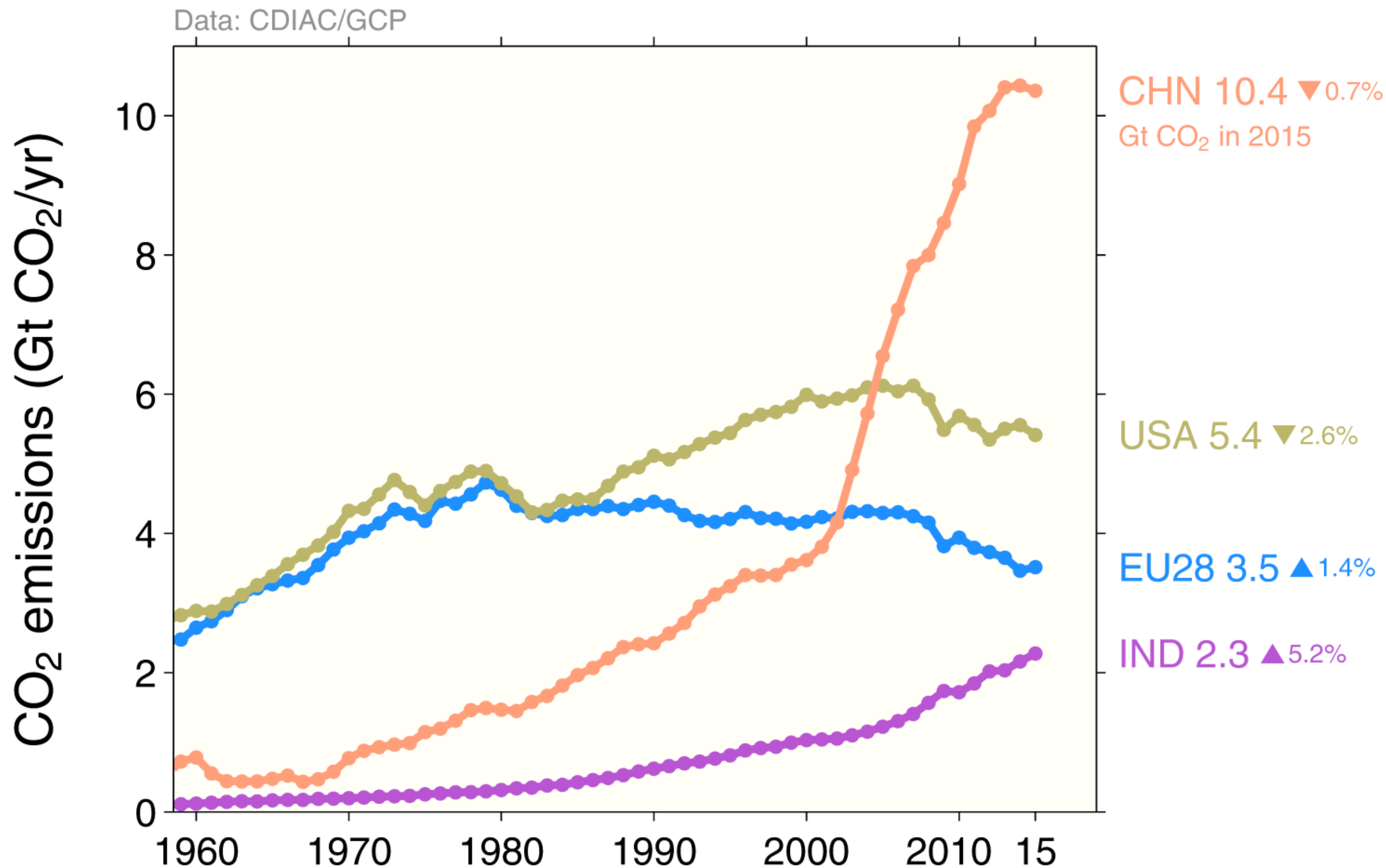
- There is a certain amount of carbon circulating through the environment.
- This amounts has been preserved for hundred of million of years;
- We are adding to the mix and change net amounts can be absorbed



Fossil Fuel CO2 emissions : Top emitters

- The top four emitters in 2015 covered 59% of global emissions

China (29%), United States (15%), EU28 (10%), India (6%)



Source: CDIAC; Le Quéré et al 2016; Global Carbon Budget 2016

Overview of Goal and Plans

- China at COP 21 has promised to:
  - Cut emissions from its coal power plants by 60% by 2020
  - Lower total carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level by 2030
  - Start in 2017 its national emission trading system, covering key industry sectors

CCUS in China

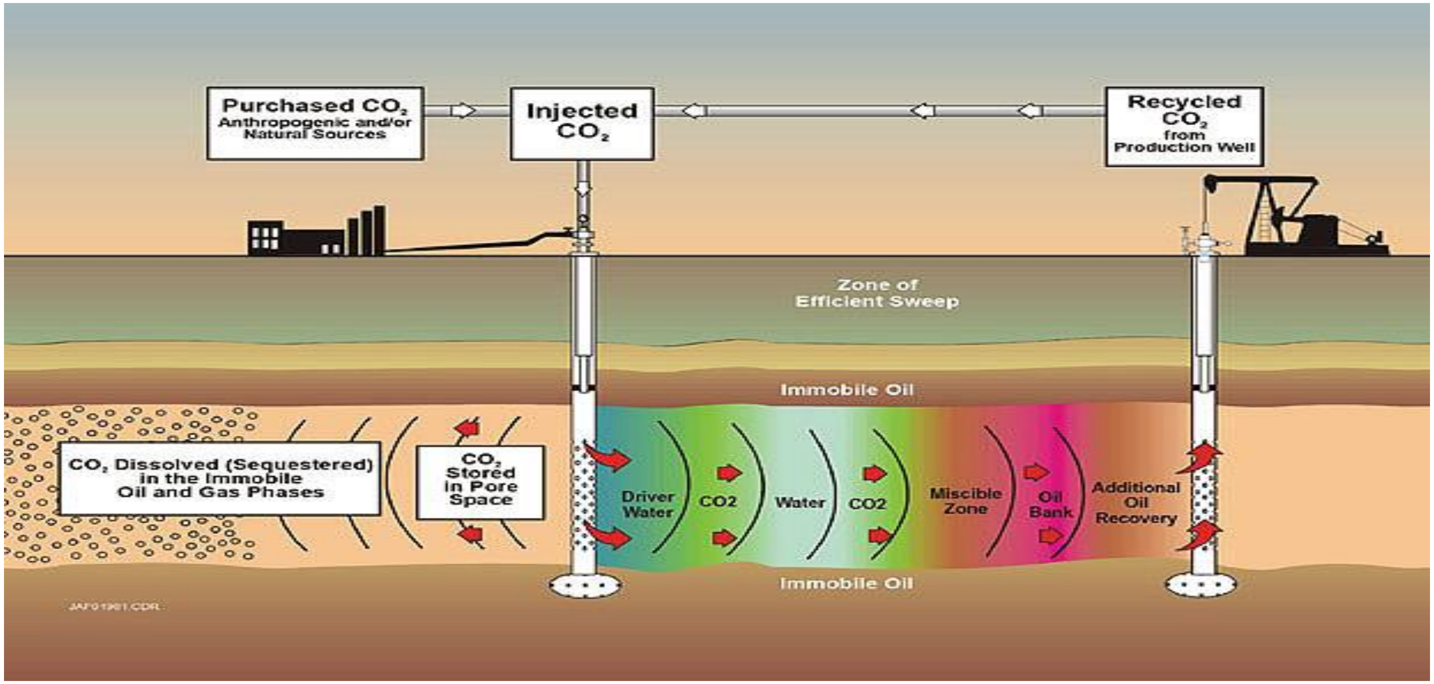
- China current 13th Five-year plan (2016–2020) focuses on technology development for CCS R&D with an industry matching fund of around two billion

- CCUS roadmap targets during the Five-Year plan:
    - identify unique low-cost opportunities for CCS demonstration
    - launch at least two large-scale CCS demonstration projects, with an installed capacity to capture at least 2 million tons of CO_2 per year.

- Two main challenges :
    - public funding and
    - knowledge about potential CO_2 storage sites.

Opportunity

- CO_2 is injected into reservoirs to boost oil recovery and slow declining oil production
- Regulations pertaining EOR are generally clear
- Operators especially in the states have 30-years commercial experience
- CO2 storage can be attained along oil production



Research Question

- What is the potential of CO2-EOR projects in China and its impact on electricity market ?

Objectives

- Analyze the consequence of using CO2 capture for CO2-EOR on the Chinese electricity market.
- Develop an economic model to understand the supply side economics associated with CO2-EOR

Motivations

- China ambition to reduce CO2 emissions
- Existing opportunities to use CO2-EOR for climate change purposes

A framework for analyzing the CO_2-EOR suitability

Sources

- Power
- Refinery
- Biomass
- Chemical Plants
- Cement
- Steel

screening methodology

Sinks

- Oil fields

Optimize the cost of supplying CO_2 to sinks by applying a GAMS-based model:

Maximize potential CO_2 storage through CO_2-EOR
Minimize CO_2 capture, and transport costs
Minimize additional power requirements and upstream upgrade
Maximize additional recovery through CO_2-EOR

Policy Instruments:
Carbon price
Carbon cap
Carbon trading scheme

Screening Criteria (sources)

- Considered so far screening criteria
  - Age of facility: Younger than 20 years for power plant
  - Status (operating and constructed)
  - Coal and natural gas
  - Total capacity >100 MW (Power Plant)
  - Distance to sink (max 500 KM)

Sources

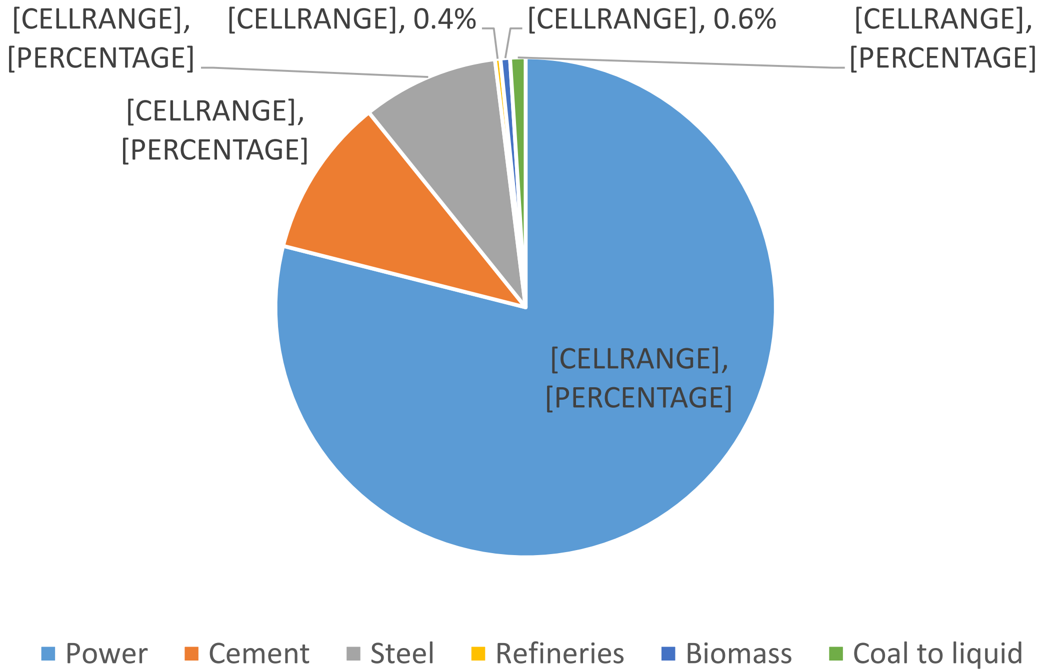
- Potential CO_2 emission from each source was calculated by multiplying the fuel consumption by corresponding emission factor

	Pounds of CO2 per million Btu	Heat rate (Btu per kWh)	Pounds of CO2 per kWh	Grams of CO2 per kWh
Coal				
Bituminous	205.691	10,080	2.07	938.9
Subbituminous	214.289	10,080	2.16	979.7
Lignite	215.392	10,080	2.17	984
Natural gas	116.999	10,408	1.22	553
Distillate oil (No. 2)	161.29	10,156	1.64	743
Residual oil (No. 6)	173.702	10,156	1.76	798

Sources

- In total the combined database comprises 3275 sources (2361 power plants, 674 cement plants, 16 steel plants, 114 oil refinery plants, 60 biomass plants, and 23 coal to liquid plants)

- The total emission amounts estimated to be 5730 MtonCO_2/year (almost 6 Gt/year) and the emission share as follows: 79%, 10%, 9%, 0.4%, 1%, and 1% for power, cement, steel, refinery, biomass and coal to liquid respectively



Screening methodology of Sinks (oil fields)

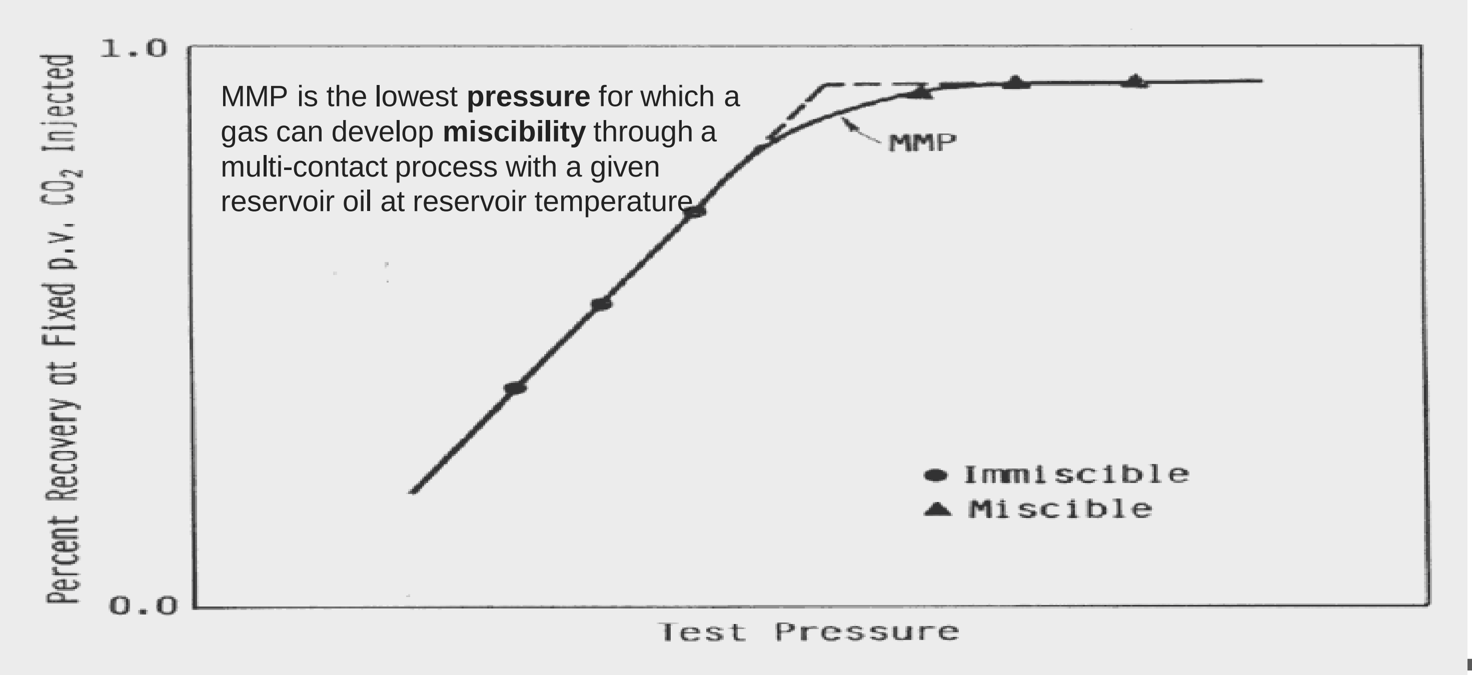
Scoring criteria	Miscible flood	Immiscible flood	Score
Remaining oil saturation	The intention of this criteria is to exclude fields that has come too far in its production life cycle. However, the criteria is redundant since this is captured by the recovery phase criteria		0 or 2
Effective mobility	Reservoirs are assumed to require an effective mobility higher than 5	N/A	0, 1 or 2
Viscosity	N/A	Minimum viscosity for Immiscible flood is set at 10 cP, i.e. viscosity must be greater than 10 cP	0, 1 or 2
Pure oil field	Gas/oil ratio (GOR) must be less than 25%		0, 1 or 2
Drive mechanism	Fields with gas injection are unfit for CO2 EOR and receive a zero if known to have gas injection. Similarly, water or WAG injection has high potential and receive score 2		0, 1 or 2
Recovery phase score	Remaining oil in place must be higher than 30% of OOIP in order to make EOR economically viable, i.e. current recovery factor must be less than 70% (this was set at 80% in the report which was a typo)		0 or 2
Total	The total score is calculated as the product of all the above		0, 8, 16 or 64

Screening methodology of Sinks (oilfields)

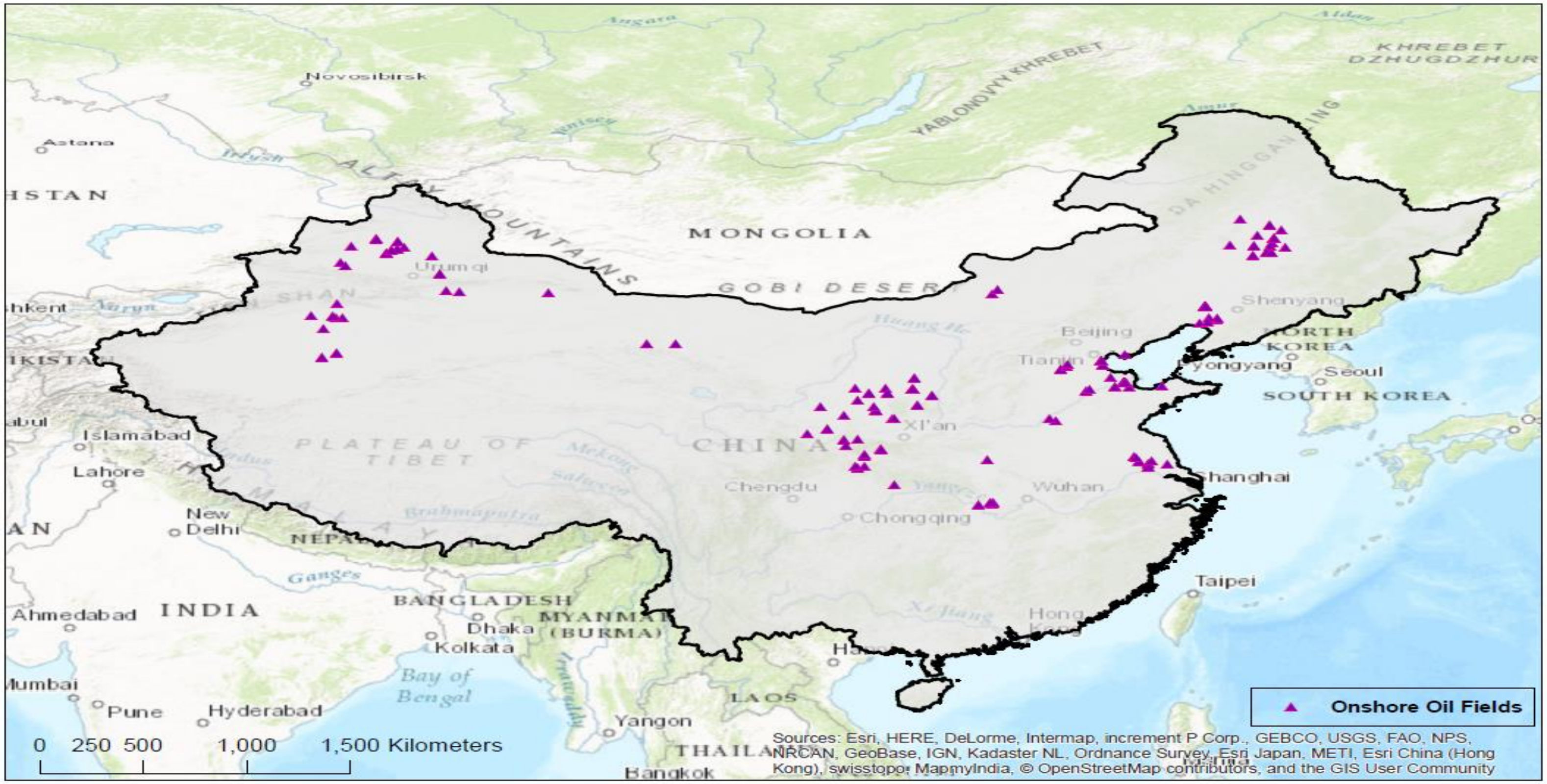
$$MMP = -329.558 + (7.727 * \mathrm{MW} * 1.005\,\mathrm{Temp}) - (4.377 * \mathrm{MW})$$

Where MW is the mole weight of the C5+ component of the reservoir oil estimated as follows:

$$MW = (7864.9 \div API)^{\left(\frac{1}{10386}\right)}$$



Oil field candidates suitable for CO2-EOR application



- 151 onshore oilfields for CO2-EOR flooding were selected and used in this study. It is worth noting that all offshore fields were excluded from initial screening as the CO2-EOR application can be exceptionally costly.

Optimization model to analyze tradeoffs in developing CO2-EOR projects

- The objective function maximizes the revenues as follows:

$$\max = \sum (Q \times O_p) + (Q_c \times C_p)$$

Q is the additional oil recovery due to CO2-EOR in barrels
OP is the price of oil barrel in U.S dollars
Qc is the quantity of CO2 stored in the formation
Cp is the CO2 price

- Constraints:

CO2 demand for each CO2-EOR operation has been met and additional power requirements to capture CO2 is also met

Optimization model to analyze tradeoffs in developing CO2-EOR projects

The model eventually works on maximizing the profit of oil revenues from total costs as shown below:

P=

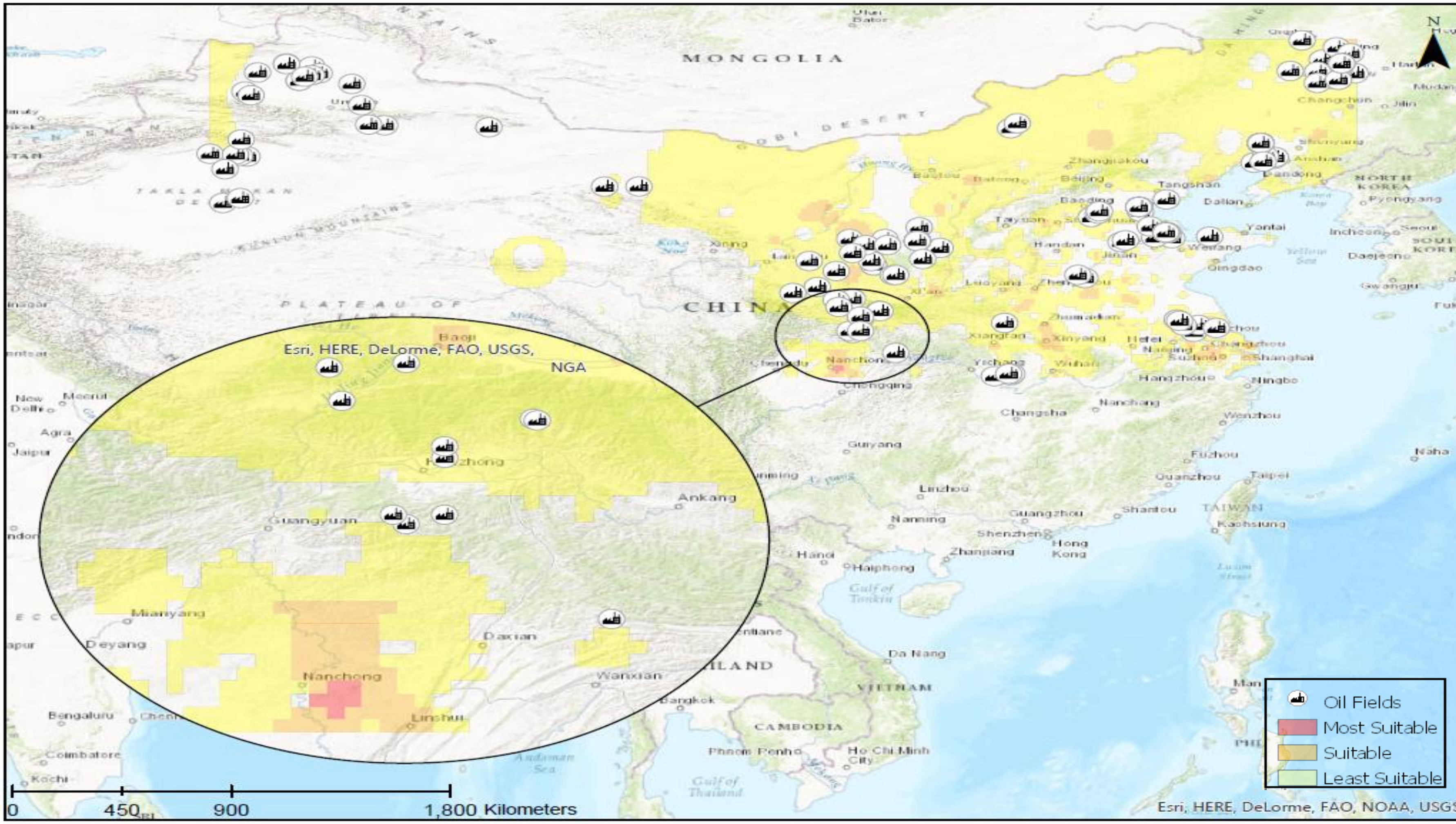
$$(Q \times O_p) + (Q_c \times C_p) - \{(D_{OS} \times S_s \times T) + (S_s \times C_C) + (U_c \times Q) + (S_S \times E_r \times A_{cc}) + (Q \times TX)\}$$

- DOS is the distance between oil filed and CO2 supply source,
- T is the transport rate,
- CC is the capture cost for different CO2 sources,
- Uc : is the upstream facility upgrade cost, and
- TX is the tax rate payable for the government

CO2-EOR: Storage and Recovery (IEA Scenarios)

Scenario Name	Description	Incremental Recovery, % OOIP	Utilisation, tCO_2/bbl
Conventional	Miscible WAG flood with vertical injector and producer wells in a "five spot" or similar pattern. Operational practices that seek to minimize CO_2 utilization.	6.5	0.3
EOR+	Miscible flooding following current best practices optimized for oil recovery. May also involve some "next" and "second generation" approaches that drive increased recovery and utilization.	13	0.6
Maximum Storage	Miscible flooding where injection is designed and operated with the explicit goal of increasing storage. Could include approached where water is removed from reservoir to increase available pore volume.	13	0.9

Sources to sinks: KAPSARC as a matchmaker



Conclusions

Substantial opportunity for storage & oil recovery through CO2-EOR

31% emission reduction through CO2-EOR can be attained

Additional sources of emission besides power plants could provide an economic opportunity

Need for pilot projects to demonstrate the dual CO2-EOR objectives.

Design of proper policy instruments and incentives need to be in place

Thank You

Sad.Shannak@kapsarc.org