Potentials for Power-to-Gas based subsurface energy storage in China

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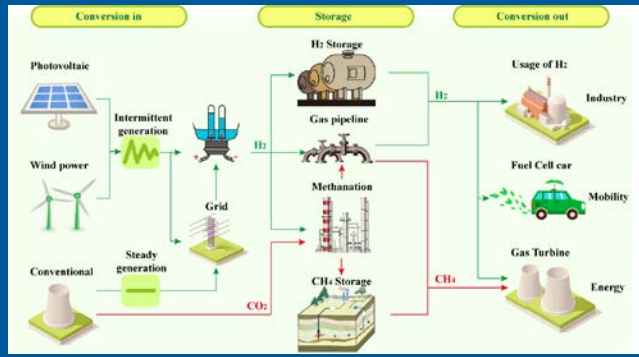

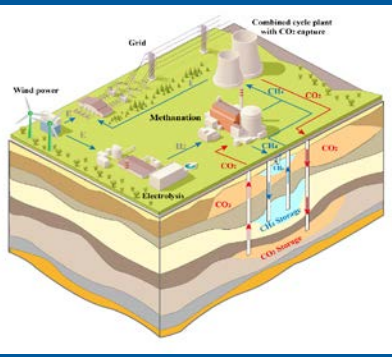

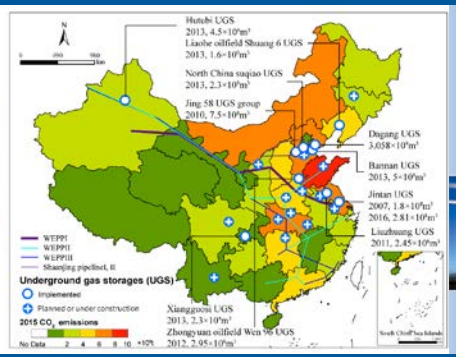

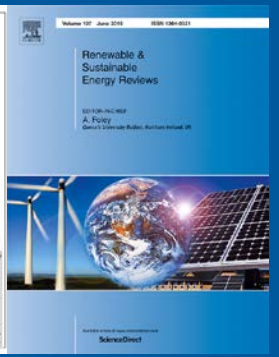

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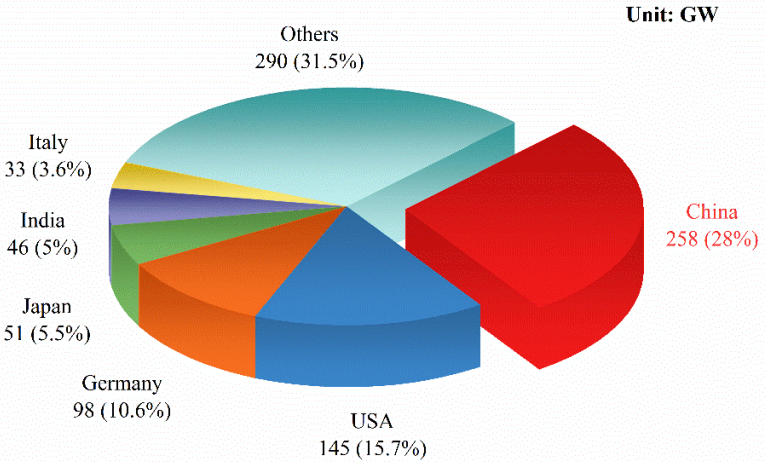
Ma et al. (2018)

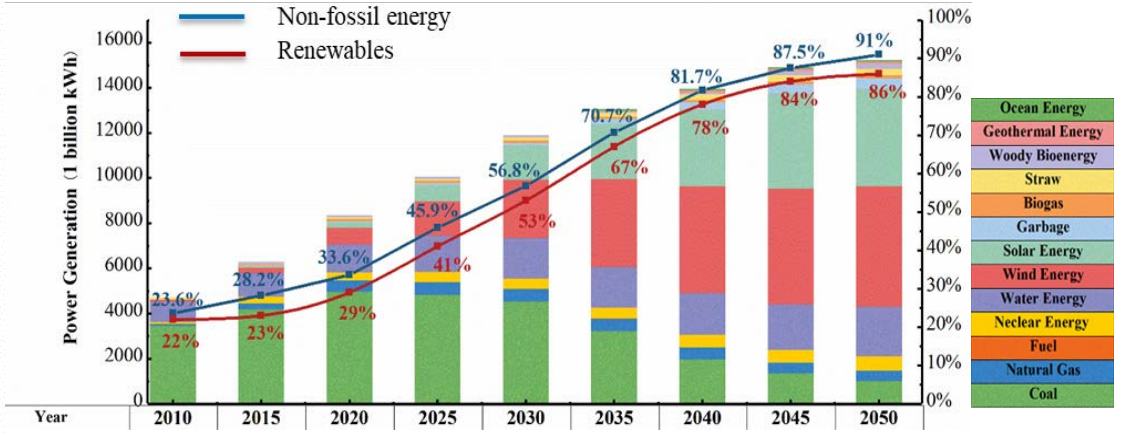
China contributes more than 25% of the installed capacity of renewable energy (RE) in the world

CO_2 Emissions control in China

- **Peak of CO_2 emissions** will be reached in **2030**
- **Eight** large-scale **CCS** (Carbon Capture and Storage) projects in development or construction



Total installed capacity of wind and solar energy



High proportion renewables development scenarios and paths for China

Li et al. (2017); REN 21 (2017);
Global carbon capture and storage institute (2017);
Energy research institute national development and reform commission of China (2015)

CCS reduces the process and economic efficiency and could be optimized by integration of CCUS

Instead of CCS only it should be combined with CC**U**S (**Utilization**)

- Pure **CCS** technology is **not cost-effective**
- Integration of the effective **utilization** of **CO_2** is necessary

Excess energy loss due to intermittency and low controllability of renewables

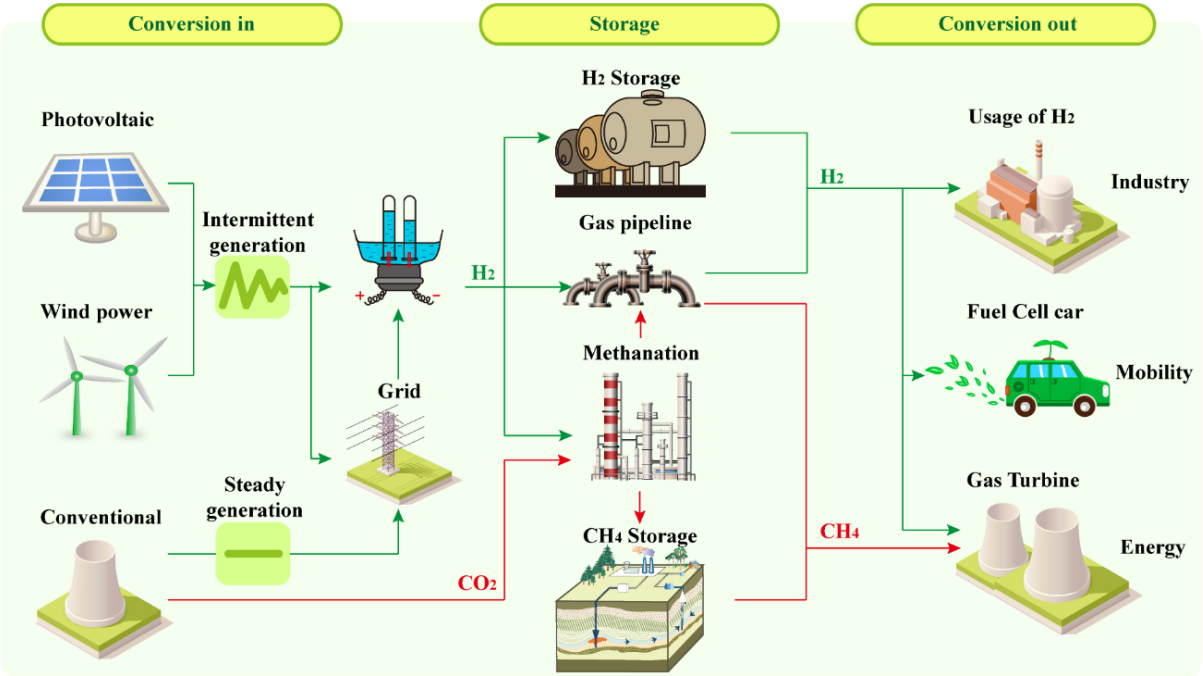
Year	The national average rate of abandoned wind (%)	Abandoned wind power losses (10^8 kWh)	Electricity loss (10^8 RMB)	Raw coal (10^4 t)
2011	16.23	123	66	5665
2012	17.12	208	112	9474
2013	10.74	162	88	7294
2014	8.00	126	68	5662
2015	15.00	339	183	15234
Summation	13.00	959	518	43330

China wind energy abandoned from 2011 to 2015

Three Gorges hydropower station

Meinshausen et al. (2009); Rahman et al. (2017); Niu et al. (2017); Yue et al. (2016)

Power-to-Gas (PtG): potential future energy system to even out fluctuation of RE and to consume CO_2



Flow chart of PtG energy system

- **Electrolysis**

$$2H_2O \longrightarrow 2H_2 + O_2$$

- **Methanation**

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

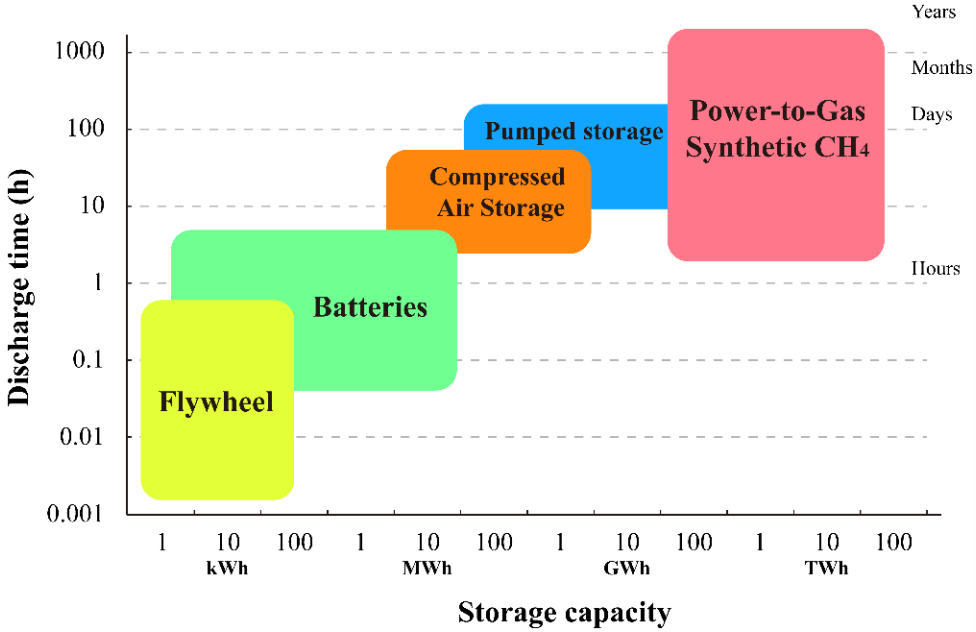
- **Storage**

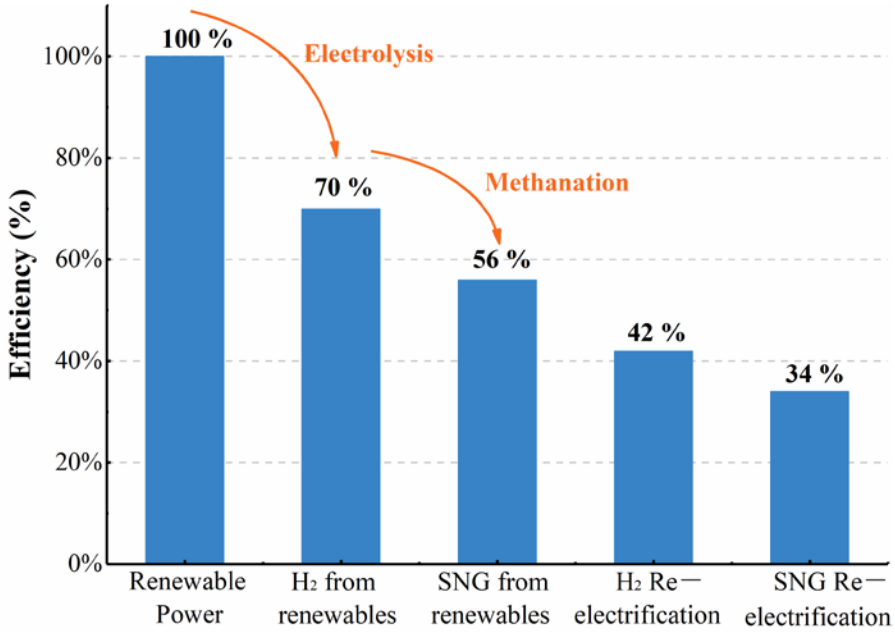
  Surface and subsurface

- **Regeneration**

EASE (2013); Kühn et al. (2014)

Long-term storage of large amounts of RE is only possible via the PtG technology and synthetic methane

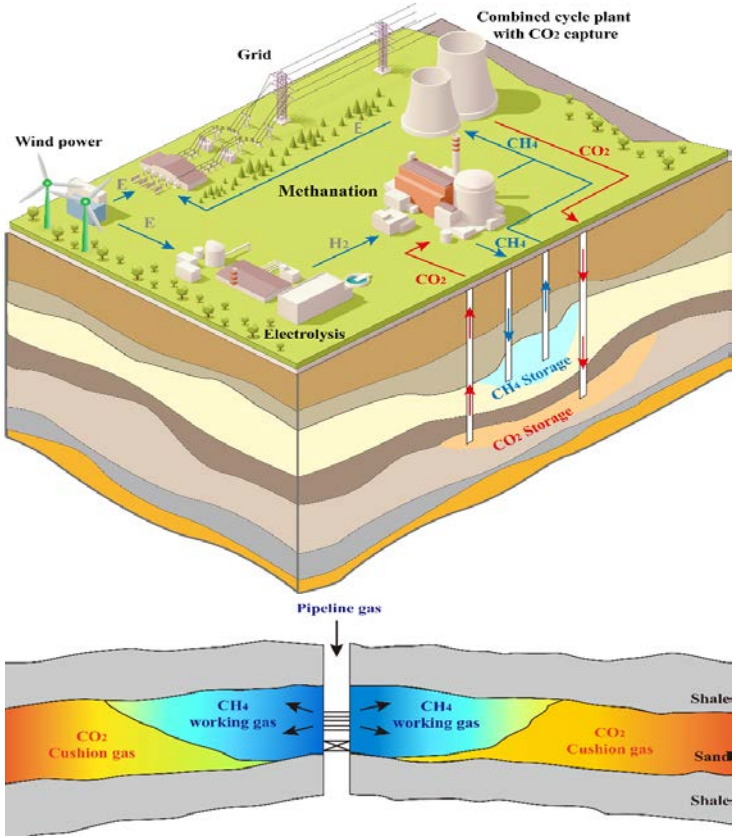




Energy efficiency of whole process can go down to **30-40%**, a level is also typical for conventional coal fired steam power plants. Development is expected to reach **40-50%** by 2030.

Kühn et al. (2014); EASE (2013); Sauer et al. (2012)

Different subsurface storage schemes available



Subsurface energy storage

- **Superior economy** and **large storage capacity** compared to surface gas tanks

Storage in different formations

- **No mixing** of CO_2 and CH_4
- **Specific geological conditions** required
- **Energy waste** without cushion gas

Storage in the same formation

- **Economic benefits** using **cushion gas**
- **Mixing problem** can not be avoided

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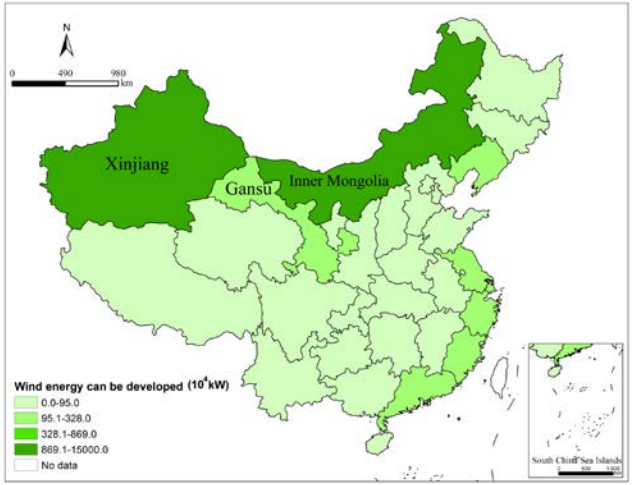
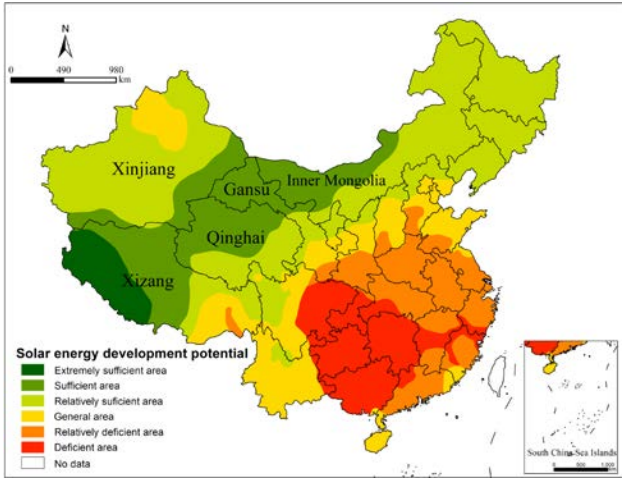
Ma et al. (2018); Oldenburg (2003); Tek et al.(1989)

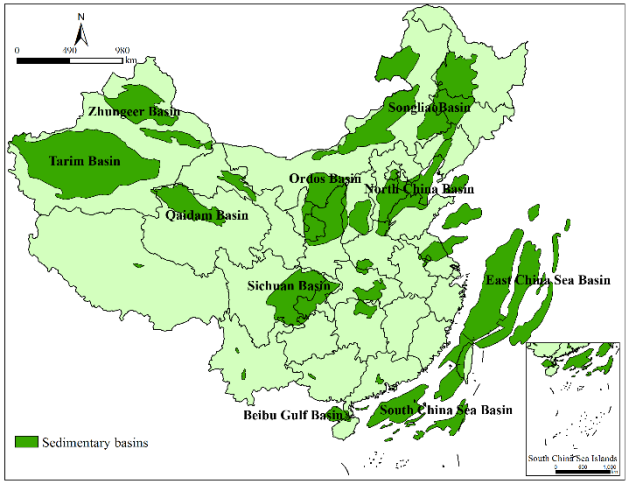
Occurrence of excess wind and solar energy needs superposition with reservoirs in sedimentary basins



Wind energy



Solar energy



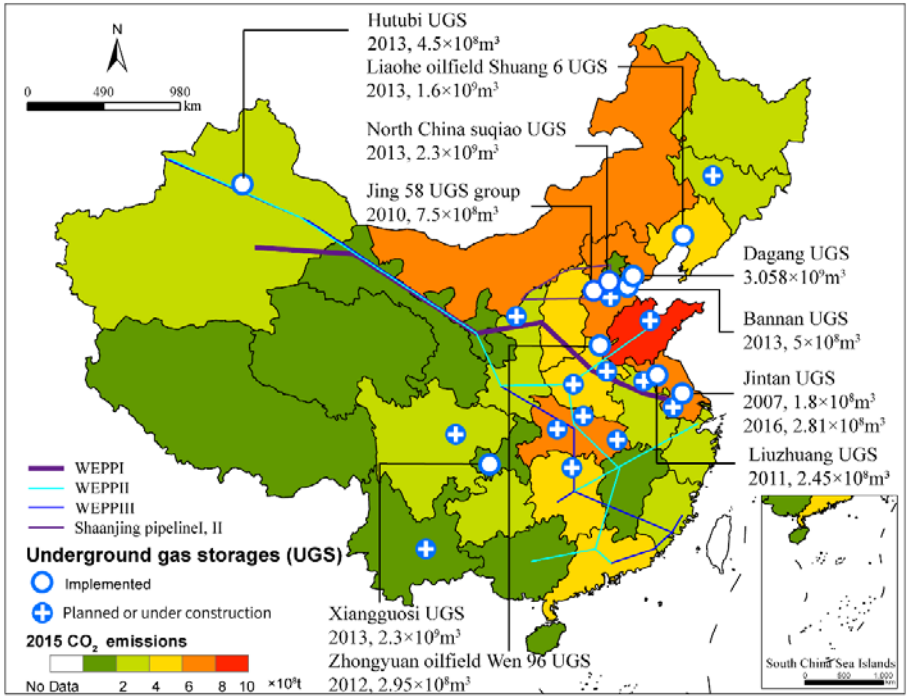
Sedimentary basins

- Abundant resources of wind and solar energy that provide excess energy are mainly located in **West and North of China**, especially in Xinjiang, Inner Mongolia, Gansu, Qinghai and Xizang
- Based on the distribution of RE, suitable potential reservoirs are in **Zhungeer, Tarim, Qaidam, Ordos,** and **Songliao Basin**

Lan (2015); Li et al. (2010)

Northwest of China along the WEPP seems to be the best choice for PtG based subsurface energy storage

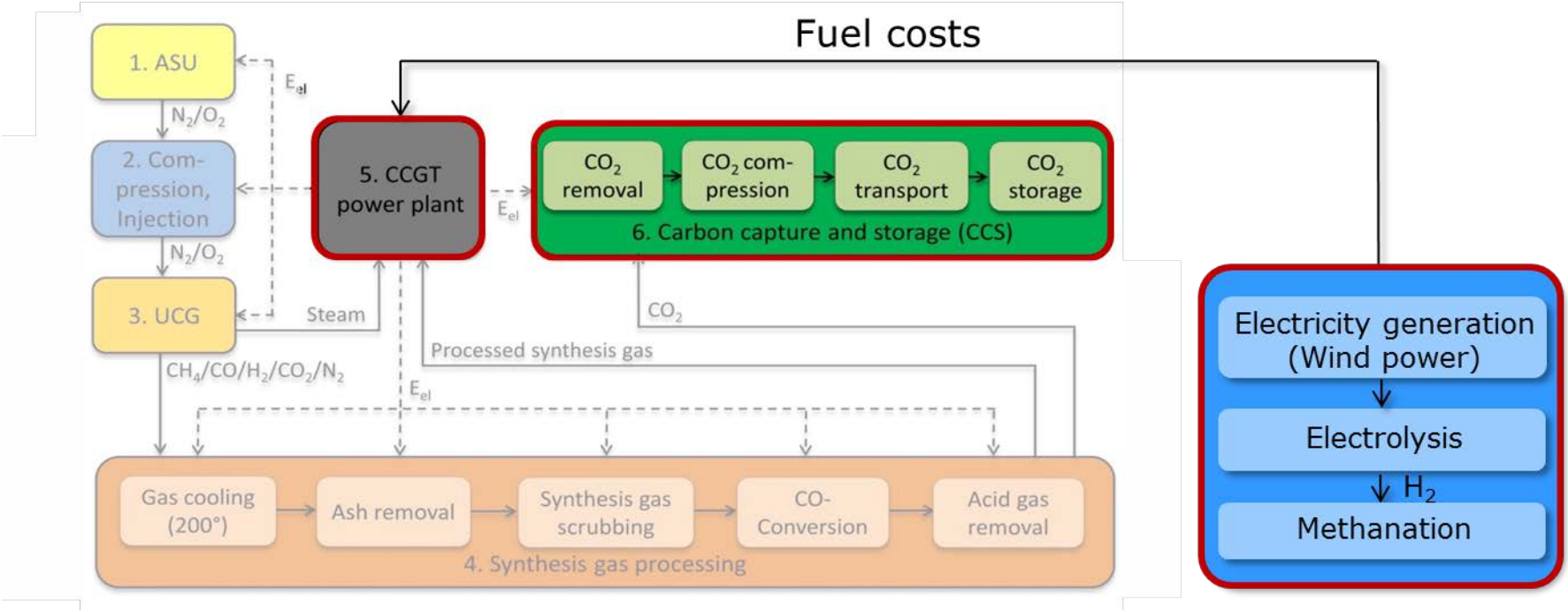
- **25** conventional underground gas storage facilities are mostly located close to the **large CO_2 emission sources**
- **Large demand** of energy storage
- **Fragmented structures** and **insufficient RE** in the East of China may restrict scale and efficiency of the PtG
- **WEPP** (West East Pipeline Project) **connects** energy production and consumption areas **improving** the **feasibility** of PtG



Gas storage facilities and CO_2 emissions in China

Liu et al. (2017); Ma et al. (2018)

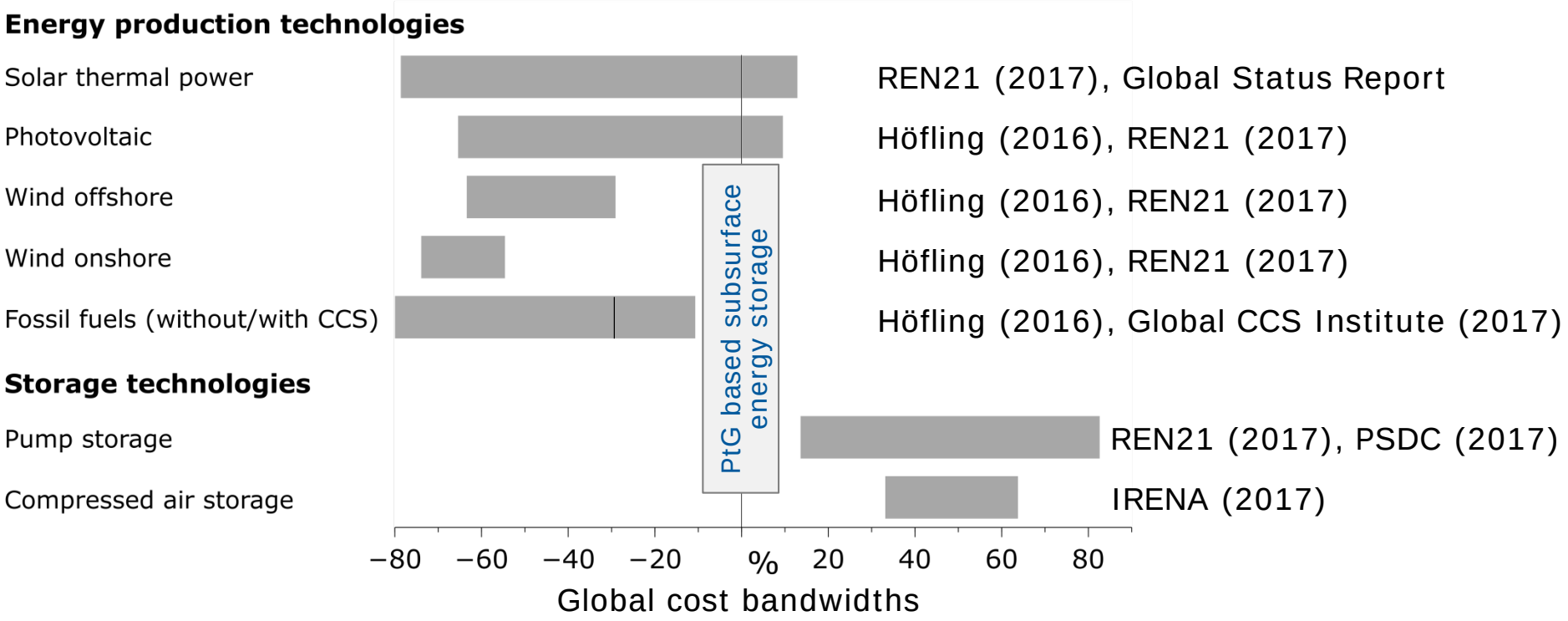
Application of a techno-economic model to determine overall costs of PtG based subsurface energy storage



Costs of electricity (COE) is **204 € / MWh**

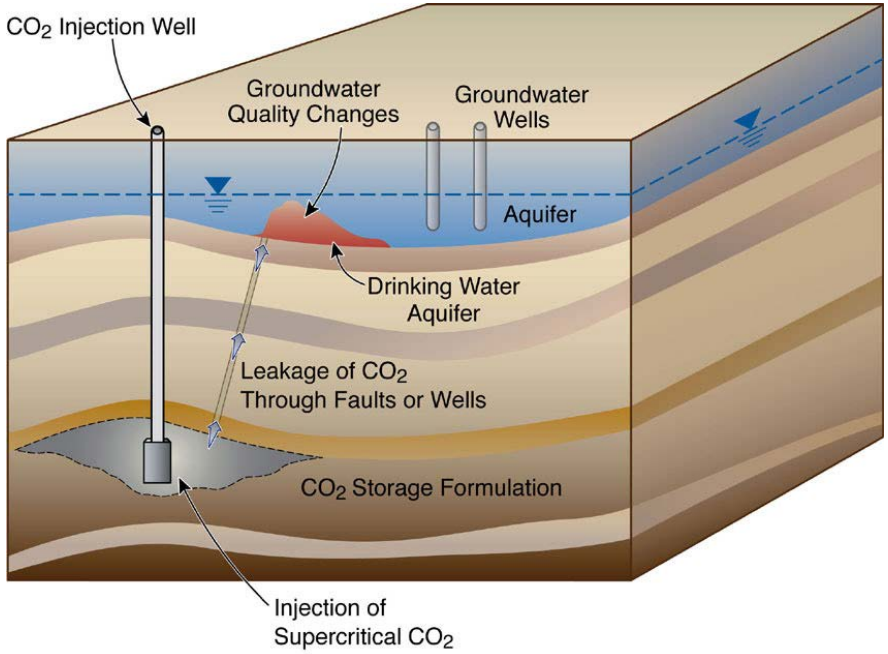
Nakaten et al. (2014)

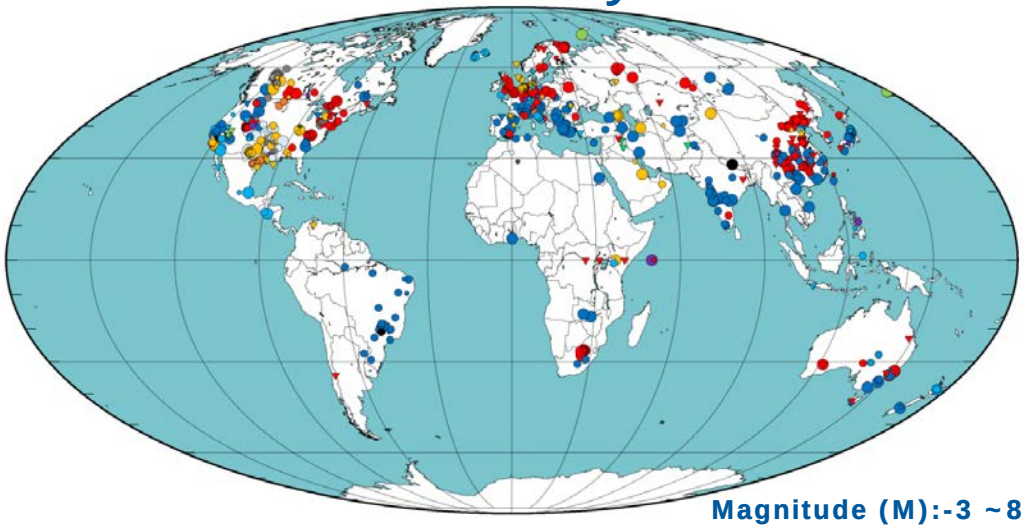
PtG based subsurface energy storage is economically viable compared to other energy storage technologies



REN21 = Renewable Energy Policy Network for the 21st Century
PSDC = Pumped Storage Development Council

Potential for undesired negative consequences: gas leakage and induced seismicity





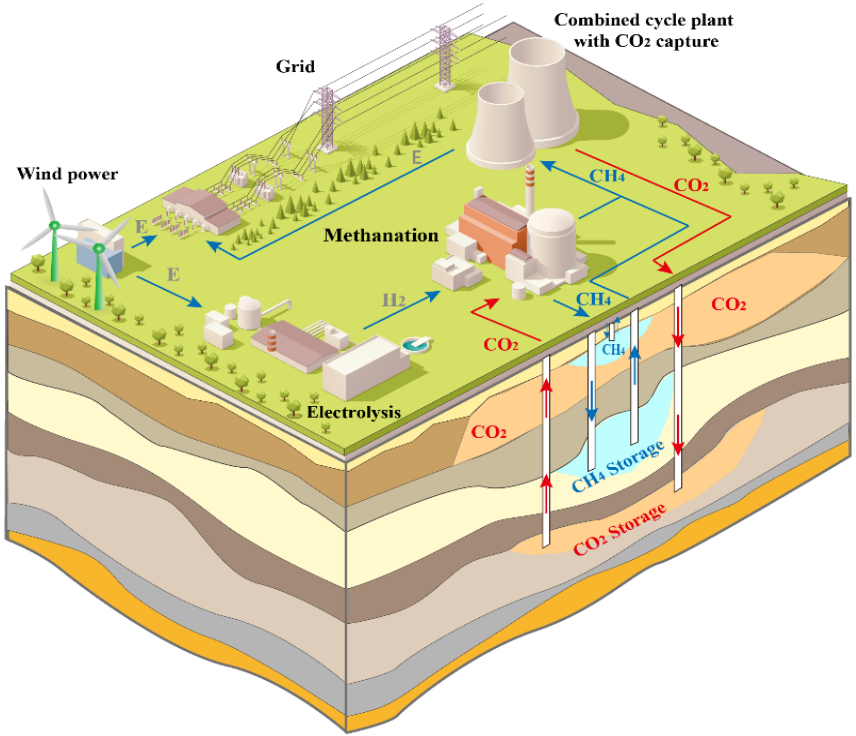
Magnitude (M):-3 ~8

Total projects induced seismicity 728

- CCS 2
- Construction 2
- Deep Penetrating Bombs 4
- Geothermal 57
- Groundwater extraction 5
- Mining 271
- Nuclear Explosions 22
- Oil & gas relatives 12
- Research experiments 14
- Waste fluid deposal 36
- Water impoundment 167

Power-to-Gas based on subsurface energy storage has huge potential for application in China

- Ambitious **emission reduction targets**
- Worldwide **28 %** of **installed capacity** of **RE**
- **Sedimentary basins** offer the **Long-term** and **large-scale** storage of energy
- **Competitive** energy **efficiency** and expected to be **improved**
- **Northwest of China** along the **WEPP** seems to be the best choice for **site selection**
- **Economically viable** compared to other energy storage technologies
- Potential for **undesired negative consequences**
- **Pilot project needs to be built** in the near future



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Thank you very much for your attention!