Non-Power Opportunities for CCS in China

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Outline

- Industry CO₂ emission in China
- Non-power industry CCS opportunities
  - Iron & steel industry
  - Coal chemical industry
  - Cement industry
- CAS carbon budget project
- Conclusion
Energy consumption & CO\textsubscript{2} emission in China

- Coal provides the mainly power in China

中国能源消费中煤炭占70%左右，工业过程CO\textsubscript{2}排放量巨大

- Fossil fuel consumption in China’s main industries

石化、水泥、冶金等过程煤炭消耗量占40%以上，是CO\textsubscript{2}的主要排放源之一

Energy consumption (China, 2009)

Source: China energy statistical yearbook 2010
CO₂ emission in China’s main industry

冶金、石化、水泥等非能源工业过程CO₂排放量占到工业过程总排放量的40%以上，并在逐渐增加。
CO$_2$ emission sources across China

*Dahowskie and Li, PNNL, 2009*
Characteristics of CO$_2$ emission in non-power industry

- Mainly refers to Iron & steel, petroleum & chemical, cement.
- The amount of CO$_2$ emission accounts for about 40% of the total China’s CO$_2$ emission, which nearly to that of from power industry.
- Discharged gases from non-power industry usually have higher CO$_2$ concentration (20~100%), and more complicated compositions.
- CO$_2$ production does not restrict to fuel combustion like in power generation, the conversion of C to CO$_2$ are flexible, such as gasification, reduction reaction.
- Lower energy penalty and cost can be achieved in some processes with higher CO$_2$ concentration, which regarded as early opportunity for CCS.
CCS in Iron & steel industry
CO₂ emissions from a typical steel mill

- CO₂ emission: 1800~2200kg/ t crude steel
Energy saving technologies in China’s iron & steel sector

- 10~14kg Coal /t crude steel
- 30~40kg CO₂ /t crude steel
- 40~60kWh /t crude steel
- 20~30kg CO₂ /t crude steel

- Energy saving technologies: the potential for minimizing CO₂ emission 20%~30%.
- End-of-pipe CCS on main emitter (BF) brings only 25 to 30% reduction in CO₂ emissions, at high abatement costs.
Opportunity of Integration of waste solid & heat with CO₂ capture in steel industry

- Slag: CO₂ carbonation
- Low temperature heat: heat source for CO₂ absorption process
Top Gas Recycling Blast Furnace with CCS

Overall CO₂ emission reduction:
- TGRBF+CCS: 50%~60%
- TGRBF alone: 5%~10%
IPE-利用钢铁过程废渣固定捕获的CO₂

利用大宗难处理工业固体废弃物为原料，强化碳酸化反应过程，碳酸化效率＞75%，形成碳酸盐固碳产品，年可实现直接减排1000万吨CO₂，间接减排1亿吨。

与工业过程能量集成，充分利用低品位余热，高附加值产品。

反应媒质的完全回收及高效循环，废渣固碳成分回收，有用组分回收，高附加价值产品。

钢铁冶炼过程，钢渣CaCO₃反应媒质多相体系助剂，废渣固碳成分回收，有用组分回收，高附加价值产品。

生铁钢铁

CaCO₃

Fe₂O₃

CO₂

形成碳酸盐固碳产品，年可实现直接减排1000万吨CO₂，间接减排1亿吨。
CCS in coal chemical industry
China needs new coal chemical industry

**New coal chemical**

- **MeOH/DME**
  - 煤制甲醇/二甲醚
  - 2020: 60 Mt/a

- **MeOH**
  - 11 projects in the construction & plan

- **Coke**

- **Amonia**

- **Carbide**

- **Olefins**
  - 煤制烯烃
  - 2020: 8 Mt/a

**MeOH/CTL**

- 伊泰合成油
- 潞安合成油

**MeOH/DME**

- 煤制烯烃
  - 煤制甲醇/二甲醚
  - 2020: 60 Mt/a

**NG/SNG**

- 6 projects in the construction & plan

**Direct liquefaction:**

- 神华煤直接液化

**Indirect liquefaction:**

- 煤制油
  - 2020: 30 Mt/a

**2020:**

- 巨大排放的 CO2 (>2 Gt)

- Scale: $16 \times 10^{12} \text{ m}^3$
Large CO\textsubscript{2} emission of coal chemical industry

- 新型煤化工行业：
  - 年产100万吨直接煤制油项目将年排放二氧化碳210万吨；
  - 年产60万吨聚烯烃装置将年排放360多万吨二氧化碳；
  - 年产20亿立方米的煤制天然气项目将年排放二氧化碳近600万吨；
Direct coal liquefaction (DCL) vs Indirect coal liquefaction (ICL)

Comparison of various CTL configurations

- CO₂ emission from DCL is 50% less than ICL
- Over 80% of this CO₂ is in concentrated form ready for sequestration
Direct liquefaction process produces little CO₂
CO₂ comes from: hydrogen production (2.9 t/t), fuel combustion (0.7 t/t), total 3.6 t/t
DCL carbon footprint

- **81.8% (CCS)**
  - Coal Preparation
  - Make-up H2 Production
  - Hydrogen
  - Direct Coal Liq.
  - Liquid Products

- **6.6%**
  - Coal

- **2.4% (CCS)**
  - Power Island
  - Fuel Gas Clean-up

- **9.2%**
CCS opportunity for coal chemical industry

- CTL + EOR could be an winning combination for large scale CCS implementation and commercialization
- Large volume, low cost, pure CO\(_2\) supply
- Provides income to offset the cost, and potentially profitable
- Use EOR to build infrastructure that could be utilized for other CCS projects, thus lower the entry hurdle
**CCS opportunity for coal chemical industry**

- CO₂ industrial废气制备化学品（CTP）是煤化工过程CO₂减排的技术重要方向
- 煤化工过程CO₂废气浓度高，现有分离提纯技术成本可以接受
- 据预测，CO₂化工利用量可以达到年1亿吨
三重整反应器
\[ \text{CO}_2 + \text{CH}_4 = 2\text{CO} + 2\text{H}_2 \]
\[ \text{H}_2\text{O} + \text{CH}_4 = \text{CO} + 3\text{H}_2 \]
\[ \frac{1}{2}\text{O}_2 + \text{CH}_4 = \text{CO} + 2\text{H}_2 \]

（Main reactors）

潞安集团在建重整示范平台

● CO₂与甲烷三重整（Tri-reforming）技术可以实现煤化工过程高浓CO₂气体与煤层气原位制备合成气，可以实现CO₂大规模捕获利用
CCS in Cement industry
CO₂ emission in cement production process

- Half of CO₂ emission comes from CaCO₃ calcination, which can not be avoided.
- The potential for CO₂ reduction lies in fuel combustion processes, which has an upper limit to 40% as shown in the figure.

China: 0.89 t CO₂/t cement
Cement exhausted gas CO₂ concentration: 14-33% (W/W)
Oxyfuel cement plant (full capture)

- Oxy-fuel combustion technology is the most promising CCS enabling technology in cement industry.
Construction of “carbon oxidation factor” system suitable for China

Establishment of CO₂ emission data base across China in terms of different energy type, i.e. coal, oil and gas

Establishment of dynamic prediction method to analysis CO₂ emission trend

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<tr>
<th>Industry</th>
<th>Classification</th>
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<tbody>
<tr>
<td>Power</td>
<td>Petroleum refining</td>
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<tr>
<td>Iron&amp;steel</td>
<td>Oil terminal using</td>
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<tr>
<td>Non-Ferrous Metal industry</td>
<td>Bulk chemicals</td>
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<tr>
<td>Building material</td>
<td>Fine chemicals</td>
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<tr>
<td>Traditional coal chemical industry</td>
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<td>New coal chemical industry</td>
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<td>Civil coal</td>
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The overall CO\textsubscript{2} emission from non-power industries, such as Iron & steel, coal chemical and cement, accounts for about 40\% of the total CO\textsubscript{2} emission in China, which should be given enough concern.

Implementation of CCUS in non-power industries is more complex compared to power industry.

The current energy saving technologies in steel industry, such as CDQ and TRT, are limited to reduce CO\textsubscript{2} emission, hence, breakthrough technologies are urgent to greatly reduce CO\textsubscript{2} emission.

New coal chemical technology provides important way of coal utilization in China, however, it also brings huge amount of CO\textsubscript{2} emission. On the other hand, coal chemical process provides high concentration of CO\textsubscript{2} and facilitate the implementation of CCS porject.

It is important to develop the CCUS technology to reduce CO\textsubscript{2} emission in non-power industry.
THANK YOU FOR YOUR ATTENTION