China’s Efforts to Advance HELE Coal Plants & Coal Conversion Facilities

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April 12, 2018
China Energy Investment Group

Corporate profile

- Formed in 2017 by merger of Shenhua and Guodian
- Over 1.8 Trillion RMB in assets + 330K employees

World’s largest ...

- **500 MM** MT/yr Coal production
- **190 GW** Coal-fired power capacity
- **33 GW** Wind power capacity
- **15 MM** MT/yr Coal-chemicals production
Corporate R&D lab

- **Mission** ... To become a world-class R&D institute supporting China Energy’s transition to a clean and low carbon energy supplier
- Founded in 2009 ... ~500 researchers
- Sites ... Beijing, China; Mountain View, CA; Schwabisch Hall, Germany

Mission-driven Research Platforms

- Catalysis
- Clean coal
- Coal-based materials
- Distributed Energy
- Hydrogen Energy
- Water Treatment
- Advanced technologies
  - ... Emissions/carbon management
  - ... Innovation pipeline
Policy landscape:
13th Five Year Plan
(2016-2020)
Energy landscape

Energy targets for 2020

Total Use

- 141 EJ
- 4.8 BB sce

Non-fossil

- 15% share
  (20% by 2030)

O&G

- 15-30 BB m³
  Shale gas

CO₂

- 18% reduction
  vs 2015

Generation mix by 2020 (capacity, GW)

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Hydro</th>
<th>Wind</th>
<th>Nuclear</th>
<th>Solar-PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 EOY est</td>
<td>960</td>
<td>330</td>
<td>149</td>
<td>34</td>
<td>77</td>
</tr>
<tr>
<td>2020 target</td>
<td>1100</td>
<td>380</td>
<td>210</td>
<td>58</td>
<td>110</td>
</tr>
</tbody>
</table>

300 g sce/kWh ~ 40.9% LHV efficiency
Coal mining

- **Cap total output.**
  - 3.3 BB MT/yr (2016) → 3.9 BB MT/yr (2020)

- **Improve efficiency.**
  - 800 MT/yr (inefficient) → 500 MT/yr (adv)

- **Consolidate industry.**
  - 6000 mines with 80% >1.2 MM MT/yr

Coal usage

- **Power Generation**
  - Efficiency
    - 300 g sce/kWh (new)
    - 310 g sce/kWh (old)
  - CHP integration
  - ULE upgrades

- **Coal-to-Chemicals**
  - Modernize industry
  - Indigenous capabilities
    - classification
    - gasification
    - syngas cleanup
    - wastewater treatment

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Emissions

• State Council Action Plan (2013)
  ... Reduce urban PM$_{2.5}$ by 10% vs 2012 levels
  ... Reduce PM$_{2.5}$ in Jing-Jin-Ji by 25%, Pearl River Delta by 20% and Yangtze River Delta by 15%
  ... Reduce annual PM in Beijing to <60 ug/m$^3$

• CO$_2$ trading markets
  ... Seven regional markets now; national in 2020
  ... Power industry target... 550 g/kWh (2020)

• Ministry of Ecological Environment
  ... announced March 2018
  ... assumes responsibility from MEP and NDRC

Ultra-low emissions power plant
Guohua Zhoushan No. 4 (2014)

<table>
<thead>
<tr>
<th>Source</th>
<th>Particulate Matter, mg/Nm$^3$</th>
<th>SO$_x$, mg/Nm$^3$</th>
<th>NO$_x$, mg/Nm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guohua Zhoushan No. 4 Unit</td>
<td>2.46</td>
<td>2.76</td>
<td>19.8</td>
</tr>
<tr>
<td>Gas power unit emission standards</td>
<td>5</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Coal-fired emission standards (key areas)</td>
<td>20</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Ref: Ling, Cornerstone 2015, 3, 12-14.
R&D focus areas

Clean coal utilization

• Automation for mining & Deep mine safety
• Unconventional oil and gas development
• Low- and medium-temperature pyrolysis for upgrading of low-rank coal
• Advanced ultrasupercritical (700°C) coal-fired power generation
• Design and manufacturing of high energy-efficient boilers and electric motors
Ultra-low emissions (ULE) technology deployment and impacts

Acknowledgments: X Liu, X Gao, X Wu, J Lin
## ULE targets

### Primary emissions limits (mg/m$^3$)

<table>
<thead>
<tr>
<th></th>
<th>Existing units</th>
<th>New builds</th>
<th>Special areas</th>
<th>ULE limits</th>
<th>NGCC emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>200</td>
<td>100</td>
<td>50</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

### Installation ... all power plants by 2020

<table>
<thead>
<tr>
<th>Company</th>
<th>Huaneng</th>
<th>Datang</th>
<th>Huadian</th>
<th>Guodian</th>
<th>Zhongdiantou</th>
<th>Shenhua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation ratio (end of 2016)</td>
<td>59%</td>
<td>68%</td>
<td>51%</td>
<td>53%</td>
<td>52%</td>
<td>63%</td>
</tr>
</tbody>
</table>
Case study

Objective

Estimate benefits of ULE retrofitting on NO\textsubscript{x}, SO\textsubscript{2} and PM emissions factors and air quality in urban areas

Data set

• 42 units at 18 power plants
  ... 215 to 1050 MW capacity
  ... 6 geographic regions

  ... 22 units – electricity only
  ... 20 units – cogeneration

• Data from Jan 2015 to Oct 2017
  ... pre-and post ULE retrofit

Ref: Liu, 2018
8 unique configurations used in the 42 units examined
Individual power plant data

Raw data ... hourly emissions profiles from a single plant

Emissions factors ... corrected for power plant load

Ref: Liu, 2018
Fleet level performance

ULE performance across the sampled fleet

PM (pre-ULE retrofit)  PM (post-ULE retrofit)

Ref: Liu, 2018
Updated emissions factors

Comparison of EF from different inventories

Fleet-average EF’s for ULE retrofitted plants are up to order of magnitude lower than from inventories before ULE retrofitting.

Refs: Zhang, 2009; Liu, 2011; Liu, 2018
Power industry contributions to haze

Haze formation mechanism

Emissions ≠ Impacts

Secondary reactions

Atmospheric models

Meteorology

Photochemistry

SO₂ + (OH, H₂O₂, O₃, NO₂) => SO₄²⁻


Emissions ≠ Impacts

Primary emissions

Coal power

Industrial

Residential

Transport

Emission factors

P2.5 SO₄²⁻
ULE Impacts on air quality

Modeling the effectiveness of different mitigation options (work in progress)

Atmospheric modeling of PM$_{2.5}$ haze in Jing-Jin-Ji region (MEIC inventory data, Time averaged 2012)

- 100% ULE
- No ULE
- Difference

4.5% avg reduction

Ref: Liu, 2017
Coal conversion

Acknowledgments: Y Tian, X Wu, M Xu
Coal conversion

Large scale projects

Ordos (DCL)
- 6000 tpd coal
- 1 MM tpa liquids (naphtha, diesel, etc)

Baotou (MTO)
- 4.4 MM tpa coal
- 1.8 MM tpa MeOH
- 600 k tpa olefins (PE, PP)

Ref: T Yajun, 2012
Key technology features:
1. Mild operating conditions (18MPa, 445-455°C)
2. New and high-efficiency coal liquefaction catalyst
3. Robust engineering design

Ref: Y Zhang, 2010
Baotou MTO plant

Coal-to-methanol
Methanol-to-olefins

Commercial operation since 2010

Production in 2017
350k tpy PE
400k tpy PP

Ref: Zhang and Lu, 2011
Outlook

• Coal will continue to be an important part of China’s energy mix.

• ULE technology is rapidly being deployed across the power sector.

• Large scale coal-to-chemicals operations are approaching their second decade of operation and remain an area of strategic interest.

• Sustained R&D will continue to clarify impacts of policies to date and move capabilities forward.