Innovating green chemical industry to promote sustainable development in China

Shanying Hu
Center for Industrial Ecology
Department of Chemical Engineering
Institute of Circular Economy
Tsinghua University
Consulting Project of the Chinese Academy of Engineering and ministry of industry and information technology:

Engineering science and technology strategy for green industry development

- Iron and Steel
- Nonferrous metal
- Chemical industry
- PetroChemical industry
- Building materials
- Papermaking industry
1. Research Framework

2. Analysis of Green Chemical Industry development


4. Engineering Science and Technology Strategy in Green Chemical Industry

5. Key Technologies and Innovating Projects in Green Chemical Industry
1. Research Framework

- **Five Processes**
- **Three Developments:**
  - Circular development
  - Green development
  - Low-carbon development

- **Six subindustries**
  - Fertilizer Industry
  - Coal Chemical Industry

- Resource
- Process
- Integration
- Application
- Product

- Full lifecycle
2. Analysis of Green Chemical Industry development

International Development of Green Chemical Industry

- Development Status of Green Chemical Industry
  - Europe—Propose solutions of technology and market
  - America—Law of green chemical action
  - Japan—Develop pollution reducing projects in chemical industry

Experience and Enlightenment

- European Reach Regulations: Environmental protection product oriented regulation, will force the greening development of the chemical production process.
- DuPont Development Model: The market-oriented development model, promote the Green Development in the production process.
- American Presidential Green Chemistry Challenge Award: Green Chemical Industry will be the inevitable choice of Chinese Chemical Industry Development in the future.
2. Analysis of Green Chemical Industry development

Chinese Development of Green Chemical Industry

- General Problems
  - Excess production capacity
- Fertilizer Industry

<table>
<thead>
<tr>
<th>Domestic Production Capability in 2010(%)</th>
<th>Fertilizer in total</th>
<th>Nitrogen Fertilizer (convert into N)</th>
<th>Phosphate Fertilizer (convert into P₂O₅)</th>
<th>Kalium Fertilizer (convert into K₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>106</td>
<td>111</td>
<td>115</td>
<td>56</td>
</tr>
</tbody>
</table>

- The Traditional Coal Chemical Industry: Coke production was 442.32 million tons in 2012, meanwhile the excess production was 120.47 million tons. Calcium Carbide production was 18.69 million tons, meanwhile the excess production was 1.66 million tons.

- Green Chemical Industry Development Activities: mainly focused on the production stage, more techniques of resource utilization, high value-added product development, and system integration, etc. are needed.
Problems and challenges in the New Coal Chemical Industry

- The coal quality and the comprehensive utilization of resources
- Hierarchical qualitative transformation, lignite gasification, other technical problems

The gas base of integrated technology

High ash melting point coal pressurized gasification technology; Carbon dioxide emissions
- Part of the technology has yet to achieve industrialization, there are some technical risk
- Improve product quality, develop new products

The restriction of coal-based gas transportation pipeline
Some important new coal chemical products

<table>
<thead>
<tr>
<th>MTA</th>
<th>MTP</th>
<th>MTO</th>
<th>EG</th>
<th>SNG</th>
<th>Liquid Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Aromatic)</td>
<td>(Propylene)</td>
<td>(Olefine)</td>
<td>(Ethylene glycol)</td>
<td>(Natural gas)</td>
<td>(Gasoline)</td>
</tr>
</tbody>
</table>
MTA: The New Coal Chemical Industry Analysis

The advantage of MTA

- The domestic aromatics price order in recent years
- The main competitor is on the decline
  - Domestic aromatics sources: Coking benzene 20% + petroleum benzene 80%
  - Domestic petroleum base aromatic competitiveness is on the decline
  - Domestic coking benzene competitiveness is on the decline
  - Main competitor is on the decline, it benefits the MTA industrialization.

- Since the economic crisis of 2008, aromatic market prospect was good.
The Risk of MTA

- **FMTA industrial technology conference (2013)**

- Tsinghua University and Huadian Group Share FMTA technical research.

- The prior stage of the MTA - industrial experimental data
  - Liquid products:
    - C6 (Benzene, B) 8%;
    - C7 (Methylbenzene, T) 28%;
    - C8 (Dimethylbenzene, X) 50%;
    - C9 (Trimethylbenzene) =<14%;
    - BTX+Trimethylbenzene=90% in the solution

- The MTA technology was only a pilot scale (10000ton/year). Large-scale industrialization are still building.
MTA: The New Coal Chemical Industry

MTA: Technical Economy Analysis

- MTA: Profits Vary with Coal Prices
  - When the coal prices was equal to 650 Yuan/ton, the average value of BTX was equal or greater than 6776 Yuan/ton, the Projects could be profitable. When the Coal prices was equal to 270 Yuan/ton, the Projects could be profitable anyway.

- MTA: Profits Vary with Methanol Prices
  - Resistance of Raw Material Price Volatility Risk:
    MTA project which did not include the coal to methanol section was less than the MTA project which included the coal to methanol section.
There are two routes downstream of the MTA chemical products development, one is the polyester industry chain under the leader of C8, another is fine chemical industry chain under the leader of C6.

The MTA has a larger advantage and potential in the market, technology, economy and availability.
### Green technology List of Fertilizer Industry

<table>
<thead>
<tr>
<th></th>
<th>Resource</th>
<th>Process</th>
<th>Product</th>
<th>Application</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phosphate Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclic Development</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Development</td>
<td></td>
<td>3</td>
<td>5</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Low-carbon Development</td>
<td></td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nitrogenous Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclic Development</td>
<td>2</td>
<td>11</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Green Development</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-carbon Development</td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Potash Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyclic Development</td>
<td>6</td>
<td></td>
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<td></td>
<td>3</td>
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<tr>
<td>Green Development</td>
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<td>5</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Low-carbon Development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Analysis of Green Chemical Industry development
2. Analysis of Green Chemical Industry development

- Coke
  - Cyclic Development: 
  - Green Development: 1
  - Low-carbon Development: 1

- Calcium Carbide
  - Cyclic Development: 
  - Green Development: 1
  - Low-carbon Development: 2

- New Coal Chemical Industry
  - Cyclic Development: 7
  - Green Development: 2
  - Low-carbon Development: 3

Green technology List of Coal Chemical industry

- Coke
  - Pulverized coal pressurized gasification technology
  - the new type of coal water slurry gasification technology; Coal seam gas in low temperature catalytic gasification technology; Coal base catalyst for ethylene glycol improvement techniques; Catalyst regeneration utilization technology; The use of circulating water and regeneration air; High temperature/low temperature coal indirect liquefaction.
Two “Kuznets curve” model

In the long term, resources consumption, energy consumption, waste and pollutant emissions and environmental impact will be followed as the general two “Kuznets curve“ in turn

- Intensity Curve
- Total Quantity Curve

Different curve peak experience of time could be shortened, and the difference between peak could be reduced.

Resource consumption, energy consumption, waste and pollutant emissions
Green Chemical Industry: Analysis of the present situation and development trend

(1) Total Energy and resource Consumption

Peak point judgment:
Before 2020, it sustains growth. It will reach peak in 2030.

Peak point judgment:
Energy consumption of phosphate rock resources will be reached its peak in 2015.
Peak point judgment: Pollutants inflection point has been emerged.
Analysis of the sustainable development ways: Structural adjustment and greening development

- Optimize the raw material
- Optimize the product structure
- Eliminate backward production capacity, control the total amount
- Develop Green Chemical Technology
- Optimize the industrial structure
- Extend production to application
- Strengthen energy saving and emissions reducing

Goals in the Green Chemical Industry

1. Reverse the process of cleaner production and energy saving and emissions reducing into full lifecycle of greening industry.

2. Reduce waste emission and resource consumption before 2015, and energy consumption before 2030.

3. Strengthen the green technology in the production process, resource exploitation, product design, consumption and industrial chain integration.

**Green Chemical Industry : Strategic Goals**

**Energy consumption intensity target**

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>20%</td>
<td>30%</td>
<td>60%</td>
<td></td>
</tr>
</tbody>
</table>

**Phosphate resources consumption goal**

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>30%</td>
<td>16%</td>
<td>Unchanged</td>
<td></td>
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</table>

**Sulfur dioxide emissions targets**

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>8%</td>
<td>6%</td>
<td>10%</td>
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</table>

**Wastewater emissions targets**

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td></td>
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</tbody>
</table>

**COD emissions targets**

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>10%</td>
<td>8%</td>
<td>15%</td>
<td></td>
</tr>
</tbody>
</table>

**Ammonia nitrogen emissions targets**

<table>
<thead>
<tr>
<th>Year</th>
<th>2011</th>
<th>2016</th>
<th>2021</th>
<th>2026</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>12%</td>
<td>10%</td>
<td>16%</td>
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</table>
The target of new coal chemical industry

- **Upgrade and adjust the industrial structure.** Encourage petrochemical associated with coal or electricity together. Form more than 10 large enterprises as the main body of the electrochemical heat integration coal industry cluster and large-scale coal chemical production base before 2020.

- **Advance technology.** Breakthrough a number of core technology, key technology and upgrade the coal liquefaction, MTO, FMTP technology and equipment, EG, MTA in the large-scale coal chemical industry.

- **Energy saving and emission reducing.** Raise efficiency in coal chemical industry and encourage the water-saving technology and the CCS technology.
Coal Chemical Industry Circular Economy Industrial Chain

4、Engineering Science and Technology Strategy in Green Chemical Industry

The use of low grade raw materials, the new raw material substitution and development, associated resources recycling technology, etc.

Focus on key technologies in energy conservation and emissions reduction, clean production, circular economy and other aspects of the green chemical process.

Rely on scientific and technological innovation to foster new areas of growth.

Green products, high added-value product, increase resource productivity.

Focus on the key technology in extension of industrial chain, processes coupling, industry park development, etc.

Green products in the process of application technology, strengthen the service.
### Policy Dimensions

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<tbody>
<tr>
<td>Phosphatic Fertilizer</td>
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<td>✓</td>
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</tr>
<tr>
<td>Potash Fertilizer</td>
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<tr>
<td>Nitrogenous Fertilizer</td>
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<tr>
<td>Calcium Carbide</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Coke</td>
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<tr>
<td>New Coal Chemical Industry</td>
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</tr>
</tbody>
</table>

4. Engineering science and technology strategy in green chemical industry
### Innovative Technologies in Green Chemical Industry

<table>
<thead>
<tr>
<th>Technologies to be applied</th>
<th>Technologies to be commercialized in the near future</th>
<th>Technologies to be developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMTO technology; PMTP technology; Technology of comprehensive utilization of phosphogypsum; Technology for purification of wet phosphoric acid; Gasification technology with fixed-bed gasifier; Clean production technology of nitrogen fertilizer; Technology for production of energy-saving and water-saving; Technology of methane production by coke oven gas</td>
<td>MTA technology; Coal-water slurry gasification with opposed multiburners; Technology for Pulverized Coal Gasification under Pressure in Aerospace Gasifier; Utilization technology of water-insoluble potassium ore resource; Utilization technology of slow controlled release fertilizer; New technology of polysilicon production with fluidized bed;</td>
<td>Recycling technology of associated resources of phosphate ore; Production technology of high value-added material in new coal chemical industry; Technology that coke oven gas directly reduced reduced iron;</td>
</tr>
</tbody>
</table>
Innovating project for chemical fertilizer industry served modern circular agriculture

Innovating project for energy chemical industry to solve vehicle fuel and pollution problem

New technology for thermo-chemical comprehensive utilization of coal

Innovating project for new coal chemical products
Transformation Strategy of Green Chemical Industry

Green Chemical Industry

Society Sustainable development

Agriculture  Environment  Energy  Material
Green Agriculture

Food supply and land scarcity are the key factors limiting economic development in China.

<table>
<thead>
<tr>
<th></th>
<th>Population Density person/km²</th>
<th>Arable land Ha/person</th>
<th>water m³/person</th>
<th>Mine dollar/person</th>
<th>Energy ton/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>131</td>
<td>0.1</td>
<td>2220</td>
<td>546</td>
<td>49.4</td>
</tr>
<tr>
<td>World's Average</td>
<td>44</td>
<td>0.23</td>
<td>6956</td>
<td>1163</td>
<td>128</td>
</tr>
<tr>
<td>Percentage%</td>
<td>297%</td>
<td>43%</td>
<td>32%</td>
<td>47%</td>
<td>39%</td>
</tr>
</tbody>
</table>

Modern agricultural production based on drip irrigation, mechanization and informationization is a fundamental way in the future.
Green Agriculture

New Planting Pattern

Reducing water, land, fertilizer, manpower and reducing usage of pesticide. Increasing food output, as well as raising land and resource productivity.

For example (drip irrigation for rice planting in Tianye Enterprise, Xinjiang)

- Saving more than 50% water
- Reducing fertilizer use by 30%
- Increasing effective land utilization
- Saving manpower and cost
- Raising rice yield by 30%
- Improving rice product quality
- Reducing plant diseases and insect pests
- Reducing methane emission
ianye provided drip irrigation equipment (PVC pipe etc)

- PVC pipes underground for drip irrigation can be used for 20 to 30 years, the investment of per acre is 700 Yuan.
- PVC pipes on the ground and PE drip irrigation belts are replaced every five years and a year respectively. The cost each year is more than 100 Yuan per mu.
- At first it was used for commercial crop and the economic benefit was very good. Then it has been popularized for a variety of crops all over the country.
- The huge demand of facility agriculture for products based on PVC and other raw materials can solve overcapacity problem of the related industries.

Planting Pattern

Green Agriculture
The fertilizer industry needs to innovate, and extend industrial production to agrochemical service.

- **Product**: According to the land, crops and their growth cycle, modern agricultural production requires fine, efficient intelligent fertilizer with a variety of nutrition balanced, to meet the different needs.

- **Service**: Based on data of crop growth and fertility data of soil and water, scientific service of fertilization will be provided.
Increase utilization rate of fertilizers. From the current 30% to above 80%.

Reduce fertilizer usage, save resources and improve resource productivity. If drip irrigation reaches 50% in China, the use of nitrogen and phosphate fertilizer will be reduced by 15.63 million tons and 5.42 million tons respectively. It equals saving coal 3.44 million tons, phosphate rock 13.7 million and improving resource productivity more than 100%.

Reduce pollution. Reduce pollution emissions in fertilizer production; greatly reduce water eutrophication caused by the unabsorbed fertilizers and air pollution caused by ammonia.

Save water. Save agricultural water 180 million tons.

Save land resources. Increasing the yield of Grain is equivalent to save25% land and release more than 200 million mu land.

Improve enterprise benifit. Benefit of fertilizer enterprises will be from high quality service and value-added products.
Green Agriculture

Besides drip irrigation and fertilizer, the chemical industry also can provide green pesticide products and animal feeds, as well as provide technology and service in waste recycling such as straw, waste chine films, drip irrigation, livestock manure.

While promoting the development of green agriculture, chemical fertilizer and related chemical industry will be simultaneously sformed and upgraded, achieving comprehensively green and ainable development.
Vehicle Fuel and the Environmental Problems

Problem

Air pollution seriously
Automotive Exhaust Emission: Organic hydrocarbon, NO$_x$, SO$_2$
What can Chemical Industry do?
Improving oil quality by hydrorefining

Heavy oil hydrocracking

Vehicle Fuel and the Environmental Problems

Hydrogen Production:
- Reforming of Steam and Methane
- Coal Gasification + Conversion
- Coke Oven Gas
Develop alcohol ether alternative fuel, replace gasoline and diesel by methanol, dimethyl ether, DMMI etc.

- Its energy efficiency is significantly higher than that of coal-to-liquid fuels.

- Exhaust pollutant emissions is reduced. Adding 5-30% DMMI into diesel will lead the $\text{NO}_x$ in the exhaust gas reduced by 7-10%, particulate matter by 5% - 35%.

- The reform of petrochemical industry brings opportunity for development of alcohol ether fuel.
Develop electric vehicles and utilize solar photovoltaic. Cost of polysilicon is the bottleneck. New polysilicon production with fluidized bed can greatly lower energy and cost.

Silicon particles instead of silicon rods

Deposition efficiency increases by 1000 times

Close to the equilibrium conversion rate

Energy consumption lows by More than 60%

Use SiCl₄ directly

Realize no SiCl₄ exist

Solution

High energy consumption and, a large number of by-product SiCl₄ are the two
Conclusions

Green transformation of chemical industry is not only its own need, but also the demand of whole society sustainable development.

During the third industrial revolution, green transformation needs to change the traditional thinking, and design new products and service for users’ demands directly, which need innovating industry pattern, product and technology.

For overcapacity problem, solution firstly comes from strict environmental monitoring and market competition, and also from innovating to push more new products for users in the future.
THANK YOU!

“化学工业绿色发展工程科技战略与对策”课题组
2014年3月14日