Practice and Development for CCUS in Shaanxi Yanchang Petroleum (Group) Co. Ltd., China

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Shaanxi Yanchang Petroleum (Group) Co. Ltd.
Outline

1. Introduction of Energy & Resources in Northern Shaanxi
2. Main Challenges of Energy & Chemical industry in Northern Shaanxi
3. Innovations in Coal Chemical Development
4. Why CCUS in Yanchang Petroleum?
5. Current Development of Yanchang CCUS Project
6. Main Challenges in implementing CCUS
Where is Yanchang Co. in China?

- Xian, Shaanxi -- Head office, NW China
- Yanan, Shaanxi -- Most Oil Field, Pagoda Hill
- GDP, ~ US $26 Billion in 2012, 4th Oil Co. in China

Have you heard about the Terracotta Warriors?
1. Introduction of Energy & Resources in Northern Shaanxi

- A large area with rich oil, gas, coal, salt resources
- Quick development of Energy & Chemical Industry: provide a solid foundation
(1) Total resources overview in Northern Shaanxi

- **Coal, gas and Coal Bed Methane (CBM):**
  - Have the richest reserves among China basins
- **Total amount of coal:** 3.98 trillion tons (over 1/3 of total amount in China)
  - **Explored amount:** 366.708 billion tons
- **Total amount of Natural Gas:** 10.95 trillion cubic meters
(2) Oil & gas resource in Ordos Basin

Amount: The third one among China basins

- Oil: \(12.8 \times 10^9\) tons
- Natural Gas: \(10.95 \times 10^{12}\) m³
(3) Spatial distribution of resources

- Resources orderly superimposed on the space combination
- From bottom to top:
  - Natural Gas → Salt → Coal → CBM → Oil → Coal → Uranium → Water
- Provide favorable conditions for the comprehensive exploration, exploitation and conversion of multi resources
2. Main Challenges of Energy & Chemical industry in Northern Shaanxi

(1) The development of Energy & Chemical Industry in Northern Shaanxi

- The exploitation of oil and gas
  - **Source:** Ordos Basin — typical ultra-low permeability stratum
  - **Two oil reservoir:** PCOC (CNPC), Yanchang Petroleum
  - **Production in 2012:** Oil—34,500,000 tons; Natural Gas—30 billion cubic meters

- Environment effect: caused by injection water (over 70 million tons/year)
  - Intense the drought degree
  - Large amount of sewage
Challenges of Energy & Chemical industry

(1) The development of Energy & Chemical Industry in Northern Shaanxi

◆ The development of Coal-Chemical Industry
  ➢ Crude oil processing: 18 million tons/year;
  ➢ Methanol synthesis: 24.04 million tons/year;
  ➢ Semi coke: 10.60 million tons/year;
  ➢ Ammonia synthesis: 900,000 tons/year;
  ➢ Urea plant: 820,000 tons/year;
  ➢ Coal-to-liquid: 1.25,00 million tons/year;
  ➢ Polyolefin: 2.9 million tons/year;
  ➢ PVC: 1.5 million tons/year
  ➢ Other approval project: calcium carbide, arene and tar process
Challenges of Energy & Chemical industry

(2) Prominent contradictions

- Large amount of injection water intense the drought degree area
- Output sewage pollute the environment, and its purification cost
- Not performed industrial chain: all productive process are isolated and not integrated with each other. (coal, and NG)
- The contradiction between industrial development and energy conservation & emission reduction

The biggest challenge: How to solve them?
3. Innovations in developing Coal-Chemical Industry of Yanchang

(1) Implementation of C/H complementation and comprehensive utilization of energy to reduce CO₂ emissions

◆ Method:
  ➢ Synthesis gas (CO + H₂):
    Foundation of organic synthesis
  ➢ Natural gas and oil: many C, few H
  ➢ Coal: many H, few C

◆ Advantages:
  ➢ Enhance C utilization
  ➢ Reduce energy consumption
  ➢ Reduce the emission of exhaust gas, water and residues
3. Innovations in Coal Chemical Industry in Yanchang Petroleum

(1) Implementation of C/H complementation and comprehensive utilization of energy to reduce CO₂ emissions

◆ Project:

➢ Jingbian chemical industrial park project
➢ Utilization the comprehensive oil, gas, coal and salt resources
➢ CO₂ emissions reduced: 4.7 M tons/year

◆ Meanings:

➢ Realize fully efficient utilization of resources
➢ A benchmark of carbon emissions, and play an important leading and exemplary role
3. Innovations in Coal Chemical Industry in Yanchang Petroleum

Energy conservation & emissions reduction of Jingbian project in Yanchang Petroleum Co. Ltd.

<table>
<thead>
<tr>
<th>Number</th>
<th>Whole Project</th>
<th>This project</th>
<th>International level</th>
<th>Domestic level</th>
<th>Comparison with international level</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Methanol production (10kt/a)</td>
<td>180</td>
<td>165.35</td>
<td>153.12</td>
<td>+8.86%</td>
<td>Same raw material</td>
</tr>
<tr>
<td>2</td>
<td>Relative coal saving</td>
<td>67.3</td>
<td>79.6</td>
<td></td>
<td></td>
<td>Standard coal</td>
</tr>
<tr>
<td>3</td>
<td>Energy consumption (GJ/t methanol)</td>
<td>37</td>
<td>48</td>
<td>50</td>
<td>-23.8%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Water consumption (m³/t methanol)</td>
<td>4.1</td>
<td>10</td>
<td>15</td>
<td>-59.00%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Olefin water consumption (m³/t olefin)</td>
<td>19.8</td>
<td>27</td>
<td>27</td>
<td>-26.67%</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>CO₂ emission (10kt/a)</td>
<td>285</td>
<td>720</td>
<td>720</td>
<td>-60.42%</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SO₂ emission (t/a)</td>
<td>634</td>
<td>1389</td>
<td>1389</td>
<td>-54.36%</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Wastewater discharge (m³/H)</td>
<td>83.4</td>
<td>252.9</td>
<td>252.9</td>
<td>-67.02%</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Solid waste discharge (10kt/a)</td>
<td>12.82</td>
<td>39.82</td>
<td>39.82</td>
<td>-67.81%</td>
<td>Slag field landfill</td>
</tr>
</tbody>
</table>

Remark:本表中项目均按180万吨甲醇规模计算。
In November 11th, 2009-China Coal Conversion High-tech International BBS, the technology of oil, gas, coal and salt conversion in Yanchang Petroleum Co. is highly appreciate by domestic and international experts.

In the 3rd round table conference of international enterprise CEO, This conversion mode was regarded as “clean coal technology demonstration & extending program of United Nation”, Yanchang Petroleum Co. was regarded as demonstration & extending enterprise.
3. Innovations in Coal Chemical Industry in Yanchang Petroleum

(2) Carrying out CO₂ capture technology in coal chemical industry with lower cost

◆ Low temperature methanol washing technology:
  ➢ Extracting highly purified CO₂ from methanol solvent directly
  ➢ The cost: ~￥100 ($17) per ton CO₂

◆ Novel chemical absorption method
  ➢ Reducing a large amount of energy consumption
  ➢ Minimizing capture cost, working with iCCS Hunan University
3. Innovations in Coal Chemical Industry in Yanchang Petroleum

(3) CO₂ enhanced oil recovery

◆ CO₂-EOR technology
  - Suitable reservoir: low permeability reservoir
  - Advantages: expanding swept volume, enhance oil recovery rate, save water consumption, and reduce the cost of sewage treatment

◆ CO₂ fracturing technology
  - Low filtration of CO₂ fracturing fluid: reduce the pollution to formation
  - High flow-back, plug removal and clay swelling inhibiting ability
  - High dissolubility, can reduce oil viscosity
  - An alternative to water-based fracturing liquid
3. Innovations in Coal Chemical Industry in Yanchang Petroleum

(4) CO$_2$ geological storage

Advantages:
- Large area, stabled stratum structure without large fault zone
- Buried depth: 800~3500m
- Beneficial to realize and keep supercritical state of CO$_2$ in natural conditions
- Combine CO$_2$ EOR with geological storage: reducing cost of geological storage
4. Why CCUS in Yanchang Petroleum Co.?

(1) Significance

◆ An positive response to the “United Nations framework convention on climate change”

◆ A main tool for the exploitation of ultra-low permeability reservoir and enhance oil recovery

◆ The needs of saving oil field water and efficient development

◆ An useful exploration to address the issue of coal chemical industry of CO₂ storage, and the development of circular economy between coal chemical industry and petroleum exploitation.
4. Why in Yanchang?

(2) Advantages

- lower cost and higher purity CO2;
- Integration of CO₂ Capture, Storage and Utilization in one area, to further reduce CCUS cost;
- CO₂-EOR flooding can be applied in many oil reservoirs
- Beneficial for CO₂ geological storage:
  - Stabled stratum structure without large fault zone
  - Have enough storage space in abandoned reservoir
- Accumulating advanced experience by pilot test of CO₂ flooding, storage and monitoring
4. Why in Yanchang?

(3) CCUS integrated mode

- Coal
- Oil
- Natural gas
- Salt

Integrated utilization of various resources

Comprehensive transformation

C/H complementation

Oil product
Chemical product
Electricity

CO₂ emission

CO₂ Capture

In situ transmission

CO₂ geologic storage

Further processing and utilization

Further processing and utilization
5. Development of Yanchang CCUS Projects

(1) Undertaking CCUS projects

- 2010: “A set of CO₂-EOR techniques research in Yanchang reservoir”
- 2012: National MOST Sci-Tech support plan project—“CO₂ capture, storage and EOR demonstration technology for coal chemical industry in Northern Shaanxi” (with Universities…)
- 2012: National MOST 863 plan project—“Flue gas CCUS key techniques in coal-fired power plant-topic 3: CO₂ geological storage key techniques”
- 2013: “China-Australia international cooperation demonstration project for integrated CCUS”—Global CCS
5. Development of Yanchang CCUS Projects

(2) CO$_2$ capture Projects

- Shaanxi Xinghua Xin Ke Qi Ti Business CO.LTD: Capturing and purifying flue gas to produce food grade liquid CO$_2$ for 80,000 tons/year

- Shaanxi Yanchang Petroleum Yulin Coal Chemical Company: 2012-11, CO$_2$ capture plant for 50,000 tons/year;

- Shaanxi Yanchang China Coal Yulin energy & chemical industry company: CO$_2$ capture device for 360,000 tons/year, plan to finish at the end of 2013, and put into production in July, 2014.

Note: Last two capture device adopt CERI technology extracting highly purified CO$_2$ from methanol solvent directly
5. Development of Yanchang CCUS Projects

(2) CO$_2$ capture projects

Yulin coal chemical CO$_2$ capture plant for 50,000 tons/year
5. Development of Yanchang CCUS Projects

(2) CO$_2$ capture projects

Yulin coal chemical CO$_2$ capture construction
5. Development of Yanchang CCUS Projects

(3) \( \text{CO}_2 \) flooding pilot test

Test area: 9.88\( \text{km}^2 \), reserves: 4.35 M tons,
Average reserve abundance: 0.44M tons/km\(^2\).
Have finished: indoor evaluation, reservoir engineering proposal,
build geologic model and numerical reservoir simulation.

The well pattern of \( \text{CO}_2 \) flooding pilot test in Jingbian reservoir.
5. Development of Yanchang CCUS Projects

(3) CO₂ flooding pilot test

Production beginning at September, 2012;
Designed single well injection rate (liquid CO₂): 10 ~ 20t;
Injection pressure: 5MPa;
Have Injected CO₂: 2250 tons.

CO₂ flooding pilot test area in Jingbian reservoir
5. Development of Yanchang CCUS Projects

(3) CO$_2$ flooding pilot test
5. Development of Yanchang CCUS Projects

(4) Research on safety monitoring technology for CO$_2$ geological sequestration

- Monitoring feasibility research and method optimization of CO$_2$ displacement front;
- 4-dimensional seismic surveillance design for 5km$^2$ area;
- Monitoring of CO$_2$ injection rate, injection pressure and reservoir pressure;
- Wellhole integrity monitoring and method optimization;
- Monitoring of reservoir well output liquid;
- Monitoring of shallow aquifers and surface;
- Test area CO$_2$ storage capacity calculation;
- Safety evaluation of CO$_2$ storage.
5. Development of Yanchang CCUS Projects

5. CO₂ fracturing technology research and application
5. Development of Yanchang CCUS Projects

(5). CO₂ fracturing technology research and application

◆ Test 3 well:
  ➢ Before fracturing: open-flow-capacity: 21533m³/d
  ➢ After fracturing: open-flow-capacity: 99293m³/d, increase 360% ;

◆ Yan 293 well:
  ➢ Before fracturing: open-flow-capacity: 3249m³/d
  ➢ After fracturing: open-flow-capacity: 5224m³/d, increase 60.8% ;

◆ Yan 287 well:
  ➢ Before fracturing: open-flow-capacity: 14243m³/d
  ➢ After fracturing: open-flow-capacity: 16891m³/d, increase 18.6%.
6. Main Challenges and Cognitions in implementing CCUS

(1) Challenges

- CCUS project has a relatively high investment cost.
- Further research needs of CO₂-EOR technologies for various reservoir conditions.
- Unsystematic and lack of scientific basis of the safety assessment for CO₂ storage.
6. Challenges and cognitions by the implementation of CCUS

(2) Cognitions

◆ Key points: low-cost capture & storage and effective EOR technology
◆ Explore to establish relevant policy incentive mechanism in order to encourage enterprises to carry out CCUS
◆ CO₂ capturing, utilization and storage strategic research plans should be strengthened in advance.
◆ Relevant standard specification about carbon capture, utilization and storage should be formulated.
◆ Development and perfection of risk assessment and management system should be established.
◆ Reinforce international cooperation and share technologies of CCUS
Thank you for your attention!