Lessons Learned from Alternative Fuels Experience
China’s Case Study

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Outline

- Background
- Policies and development status
- Environment impacts
- Future perspectives and challenges
China is currently the fourth ethanol producer in the globe

- Ethanol fuel has several potential advantages.
- In 2019, China produced 3.1% of world’s ethanol, following USA (54.4%), Brazil (29.5%) and EU (5.0%).

Advantages of ethanol fuel

- Better engine performance
- Less hazardous species
- Reduce GHGs emissions
- Increase energy diversity

Global ethanol production, 2019

Source: Renewable Fuels Association (RFA)
Ethanol has a synergy with the trend in improving gasoline quality in China

- Historically, fluid cracking catalyst (FCC) gasoline provided the majority of fuel portion in China. High contents of olefins and aromatics maintain the octane number.
- The ultra-low sulfur (10 ppm) limit and lower limits on olefins and aromatics have spurred an increased reliance on alkylation gasoline.
- Ethanol is a good option of high-octane-number additives than the hazardous MTBE and aromatics.

**Gasoline fuel quality standards in China**

<table>
<thead>
<tr>
<th>Standard stage</th>
<th>Sulfur (mg/kg)</th>
<th>Olefins</th>
<th>Aromatics</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>China 1</td>
<td>800</td>
<td>35%</td>
<td>40%</td>
<td>2003</td>
</tr>
<tr>
<td>China 2</td>
<td>500</td>
<td>35%</td>
<td>40%</td>
<td>2006</td>
</tr>
<tr>
<td>China 3</td>
<td>150</td>
<td>30%</td>
<td>40%</td>
<td>2010</td>
</tr>
<tr>
<td>China 4</td>
<td>50</td>
<td>28%</td>
<td>40%</td>
<td>2014</td>
</tr>
<tr>
<td>China 5</td>
<td>10</td>
<td>24%</td>
<td>40%</td>
<td>2018</td>
</tr>
<tr>
<td>China 6a</td>
<td>10</td>
<td>18%</td>
<td>35%</td>
<td>2020</td>
</tr>
<tr>
<td>China 6b</td>
<td>10</td>
<td>15%</td>
<td>35%</td>
<td>2023</td>
</tr>
</tbody>
</table>

**High-octane-number additives**

- Tetraethyl lead (banned in 2000)
- MMT (banned in 2018)
- MTBE (partially banned now)
- Ethanol
Grain stock and food security often affect bio-ethanol industry

- High stock of aged grain increased financial burdens (e.g., ~2000, ~2016). Production of grain-based ethanol could be a solution to reducing grain storage costs.
- When the grain price increases (e.g., ~2007-2011, ~2018), the concerns regarding food security would arise. The motivation to produce grain-based ethanol then would be argued.

**Fuel or Food** debated in China

![Graph showing corn stocks, fuel ethanol production, and corn prices from 1997 to 2018](image)

Source: USDA, COFCO, IAED
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The governmental policies of ethanol industry in China

- Detail Regulations for Implementing the Pilot Testing Program of Bioethanol Gasoline for Automobiles (2004)

- The 10th Five-Year Plan (2001-2005)
- The 12th Five-Year Plan for Bioenergy Development (2011-2016)
- The 13th Five-Year Plan for Bioenergy Development (2016)
- The 13th Five-Year Plan for Renewable Energy Development (2016)
The development of ethanol fuel in China, 2002-2016

- Early stage (2001-2006): Subsides motivated the beginning of ethanol fuel industry, which was profitable
- 2007-2016: Halted grain ethanol due to food security concern and reduced tax incentives for non-grain ethanol in 2011
- Since 2017: A new round of policies to support the use of E10 fuels in more provinces and to develop cellulosic ethanol capacity
More production capacity has been developed since 2017

- The annual capacity added up to 2.47 million tonnes before 2017.
- Since the announcement of Implementation Plan in 2017, the annual production capacity has increased to 3.22 million tonnes in 2018 and 4.25 million tonnes in 2019

### Annual production before 2017

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Production (10^4t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1    COFCO Biochemical (Zhaodong)</td>
<td>Zhaodong, Heilongjiang</td>
<td>32</td>
</tr>
<tr>
<td>2    Jilin Fuel Alcohol</td>
<td>Jilin, Jilin</td>
<td>58</td>
</tr>
<tr>
<td>3    COFCO Biochemical (Anhui)</td>
<td>Bengbu, Anhui</td>
<td>55</td>
</tr>
<tr>
<td>4    Henan Tianguan Group</td>
<td>Nanyang, Henan</td>
<td>28</td>
</tr>
<tr>
<td>5    COFCO Biochemical (Guangxi)</td>
<td>Beihai, Guangxi</td>
<td>14</td>
</tr>
<tr>
<td>6    Zonergy</td>
<td>Inner Mongolia</td>
<td>0</td>
</tr>
<tr>
<td>7    Longlive</td>
<td>Yucheng, Shandong</td>
<td>0</td>
</tr>
<tr>
<td>8    SDIC(^b) Biotech Investment (Guangdong)</td>
<td>Zhanjiang, Guangdong</td>
<td>8</td>
</tr>
<tr>
<td>9    SDIC BiotechInvestment (Tieling)</td>
<td>Tieling, Liaoning</td>
<td>0</td>
</tr>
<tr>
<td>10   Jiangsu Lianhai Biological Technology</td>
<td>Nantong, Jiangsu</td>
<td>5</td>
</tr>
<tr>
<td>11   Liaoyuan Jufeng Biochemical</td>
<td>Liaoyuan, Jilin</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>205</td>
</tr>
</tbody>
</table>

### Major projects proposed after 2017

<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity (10^4t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Diaobingshan, Liaoning</td>
<td>30</td>
</tr>
<tr>
<td>2 Fujin, Heilongjiang</td>
<td>60</td>
</tr>
<tr>
<td>3 Hailun, Heilongjiang</td>
<td>30</td>
</tr>
<tr>
<td>4 Huachuan, Heilongjiang</td>
<td>30</td>
</tr>
<tr>
<td>5 Nehe, Heilongjiang</td>
<td>30</td>
</tr>
<tr>
<td>6 Shuangyashan, Heilongjiang</td>
<td>30</td>
</tr>
<tr>
<td>7 Shuangcheng, Heilongjiang</td>
<td>15</td>
</tr>
<tr>
<td>8 Siping, Jilin</td>
<td>90</td>
</tr>
<tr>
<td>9 Baicheng, Jilin</td>
<td>30</td>
</tr>
<tr>
<td>10 Jilin, Jilin</td>
<td>30</td>
</tr>
<tr>
<td>Total (by May, 2019)</td>
<td>375</td>
</tr>
</tbody>
</table>
More provinces and cities have launched E10 fuels

- The promotion of E10 fuels needs three steps in each region: production approval, targeted distribution, and closed full-scale promotion.
- Twelve provinces have switched to E10 fuels.

**Production approval**
- Only plants approved by National Development and Reform Commission (NDRC) are eligible to produce fuel ethanol.

**Targeted distribution**
- Produced ethanol by a specific factory is limited to be sold in designated provinces/regions.

**Closed full-scale promotion**
- Conventional gasoline is banned in the regions promoting E10 fuels.
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E10 could reduce tailpipe CO$_2$ emissions and energy consumption for GDI vehicles

- E10 with lower aromatics (ELA) and E10 with lower olefins (ELO) were tested
- ELA could reduce 3.1% of CO$_2$ emissions and 1.9% of energy consumption compared with E0
- ELO could reduce CO$_2$ emissions and energy consumption for GDI vehicles, but the impacts on PFI vehicles are less statistically significant.

(Wu et al., Environ. Pollu., 2019)
E10 can significantly reduce PM emissions

- No statistically differences in CO, THC and NO\textsubscript{X} emissions between E0 and E10 (ELO and ELA) fuels.
- Both ELA and ELO fuels showed reductions for PM (reduced by 21%~35%) and PN (reduced by 22%~44%) emissions compared with conventional E0 fuel.

(Wu et al., Environ. Pollu., 2019)
The evaporative emission of E10 fuels increases

- The evaporative emissions of E10 fuels are tested to be increased by 11% than E0 fuels.
  - ELA (F2) increased evaporative emissions by 16% (higher permeation of aromatics)
  - ELO (F3) seems to be friendly in evaporative emissions (no change)

![Graph showing emission comparison](image)
E10 fuels favors the improvement in PM$_{2.5}$ concentrations

- **ELO**: Greater reduction occurs in populated megacities (e.g., ~0.3 µg/m$^3$ in Beijing and ~0.3 µg/m$^3$ in southern Hebei).
- **ELA**: The benefit in reducing PM$_{2.5}$ concentrations is lower than that of using ELO.
- The higher benefit from ELO is due to the greater reduction in primary particle emissions.

Chemical transport modeling (WRF/CMAQ) of ethanol fuel-related PM$_{2.5}$ concentrations

(Liang et al., Atmos. Environ., 2020)
Bio-ethanol can reduce WTW CO$_2$ emissions compared with E0 despite the variabilities due to feedstock and processing fuels.

- LCA results (using GREET model and local input data) indicate that using natural gas as fuel of steam production can significant reduce WTW CO$_2$ emissions of bio-ethanol (i.e., E100).

- Ethanol produced from aged grain will further reduce WTW CO$_2$ emissions in China.

Note: the percentages show the relative reductions of WTW CO$_2$ emissions for bio-ethanol (E100) compared with conventional fossil gasoline (E0) fuels in China and US, respectively.
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Future perspectives and challenges

- Compared with the projected demand of ethanol fuels, the current production capability is relatively low. This implies the concern regarding policy uncertainty in the future.

- The possible variabilities in grain stock and concerns about food security could be barriers for central and local governments to implement further policies and supplementary actions to promote ethanol fuels.

- The current price of bio-ethanol is not favorable. Supervision mechanisms should be developed to prohibit coal-based ethanol from the market.

- Acceptances by gasoline producers and consumers need to be improved.

- Specifically, governmental officers in environmental authorities have their concerns about the increase of evaporative emissions and uncertainty in NO\textsubscript{X} emissions, which lead to a concern on ozone and SOA (secondary organic aerosols) issues.
Current capability is still lower than the projected consumption

- Gasoline consumption is estimated 181 million tonnes in 2030, which further relate to 114~181 million tonnes of E10 fuels (varying by scenarios).
- The current capacity (4.25 million tonnes of ethanol, equivalent to ~40 million tonnes of E10) is much smaller compared with the future demand.

Biofuel ethanol is weak on price competitiveness currently

- Fuel ethanol follows Government price but not market-regulated price
  \[ \text{Price}_{\text{biofuel ethanol}} = 0.9111 \times \text{Price}_{\text{RON.93 gasoline}} \]

- Current price of bio-ethanol has no advantages compared with imported ethanol and coal-based ethanol.

- Supervision mechanisms should be in place to prohibit coal-based ethanol entering the market.
To improve the acceptances of gasoline producers and consumers

- For producers (including gas stations): more requirements are increased during the loading, unloading, storage, blending and transportation processes.
- For consumers (including gas stations): concerns regarding the impacts on fuel economy, cold-start performance, and engine power performance.
- Despite no evidences of significantly negative impacts from E10 fuels, more education work is necessary to improve the acceptance of gasoline producers and consumers.

Production & Transportation  Refueling station  Vehicle use

*RON 95 fuels with 10% ethanol blending*
Thanks