ADVANCED MOTOR FUELS
Technology Collaboration Programme on
Advanced Motor Fuels

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Lessons Learned from Alternative Fuels Experience China's Case Study

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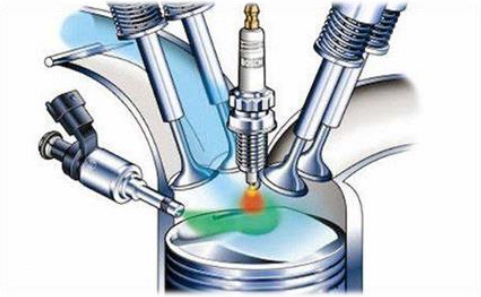
Outline

- **Background**
- **Policies and development status**
- **Environment impacts**
- **Future perspectives and challenges**

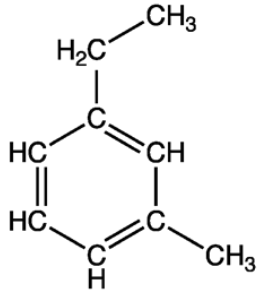
China is currently the fourth ethanol producer in the globe

- 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%).

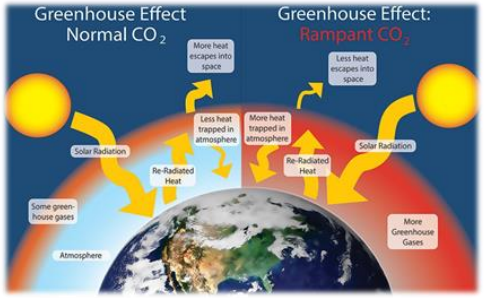
Advantages of ethanol fuel



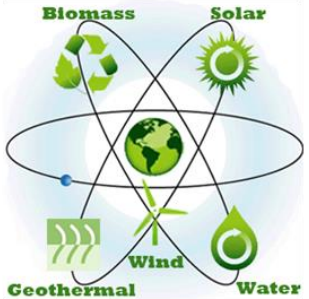
Better engine performance



Less hazardous species

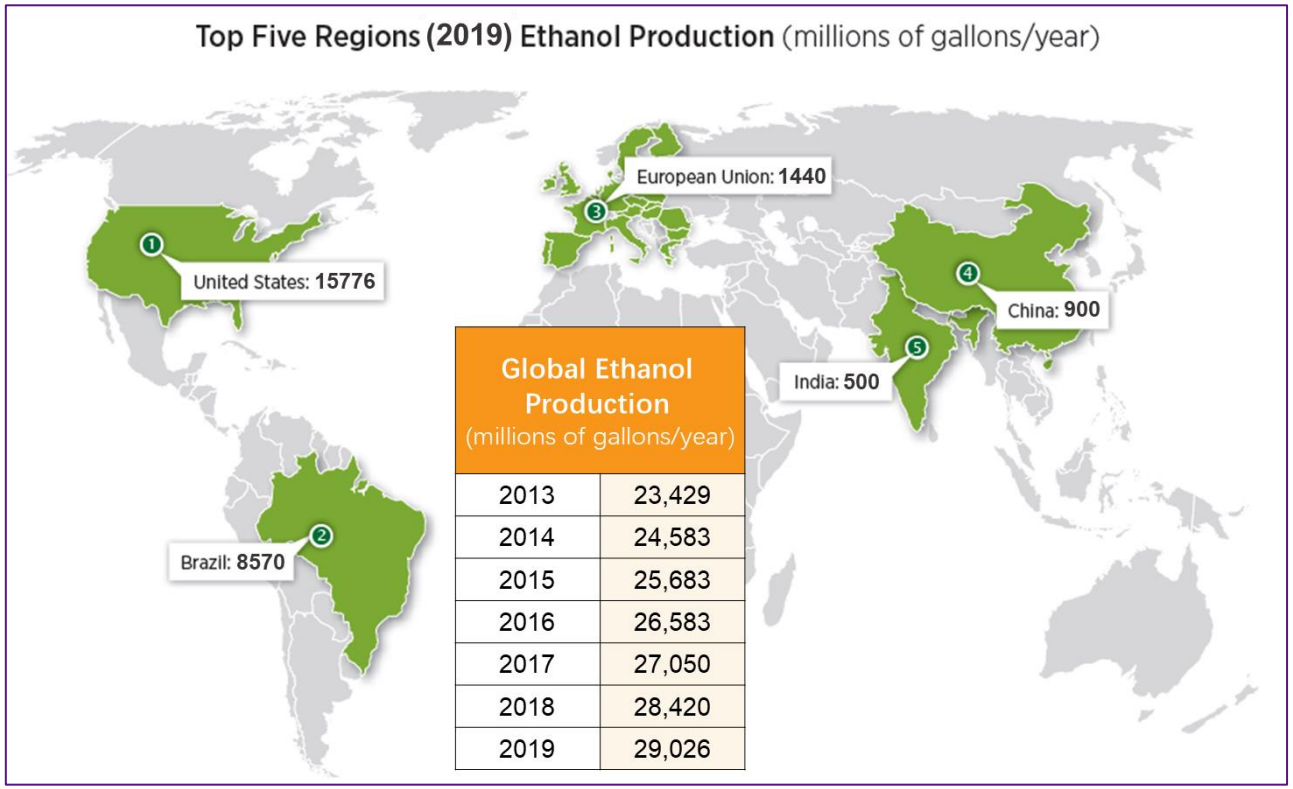


Reduce GHGs emissions



Increase energy diversity

Global ethanol production, 2019



Global Ethanol Production (millions of gallons/year)	
2013	23,429
2014	24,583
2015	25,683
2016	26,583
2017	27,050
2018	28,420
2019	29,026

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

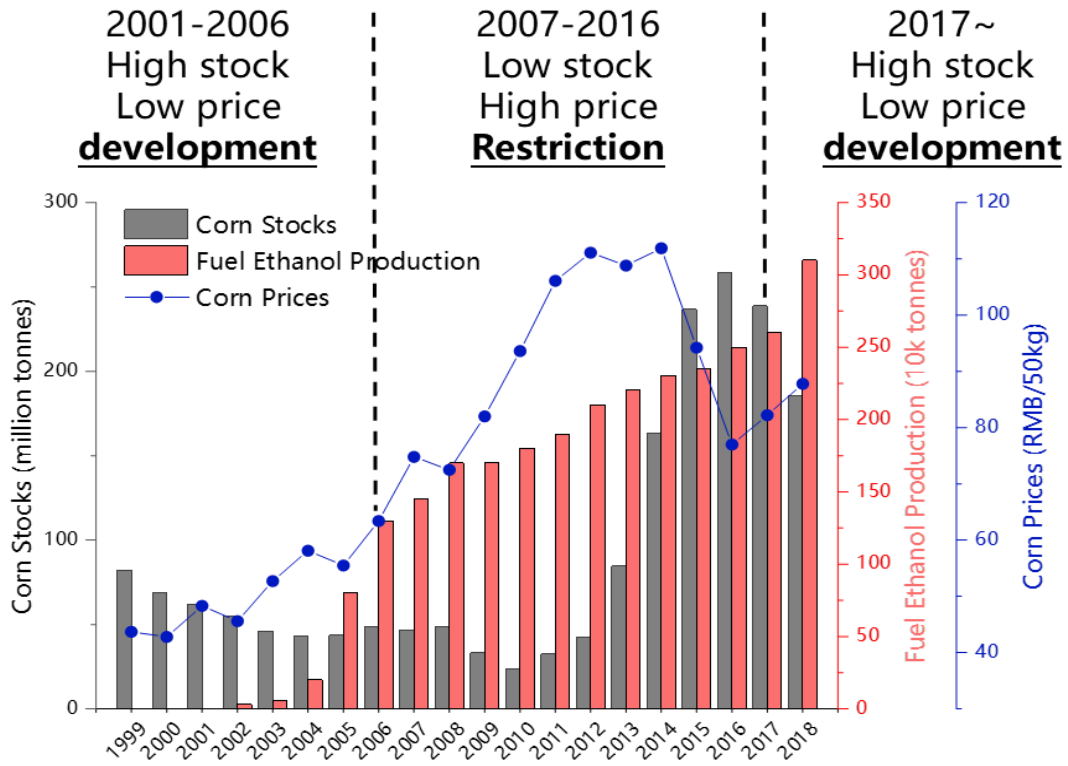
Standard stage	Sulfur (mg/kg)	Olefins	Aromatics	Year
China 1	800	35%	40%	2003
China 2	500	35%	40%	2006
China 3	150	30%	40%	2010
China 4	50	28%	40%	2014
China 5	10	24%	40%	2018
China 6a	10	18%	35%	2020
China 6b	10	15%	35%	2023

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



Source: USDA, COFCO, IAED

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The governmental policies of ethanol industry in China

- The Special Development Plan for Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles (2002)
- the Pilot Testing Program of Bioethanol Gasoline for Automobiles (2004)
- Detail Regulations for Implementing the Pilot Testing Program of Bioethanol Gasoline for Automobiles (2004)

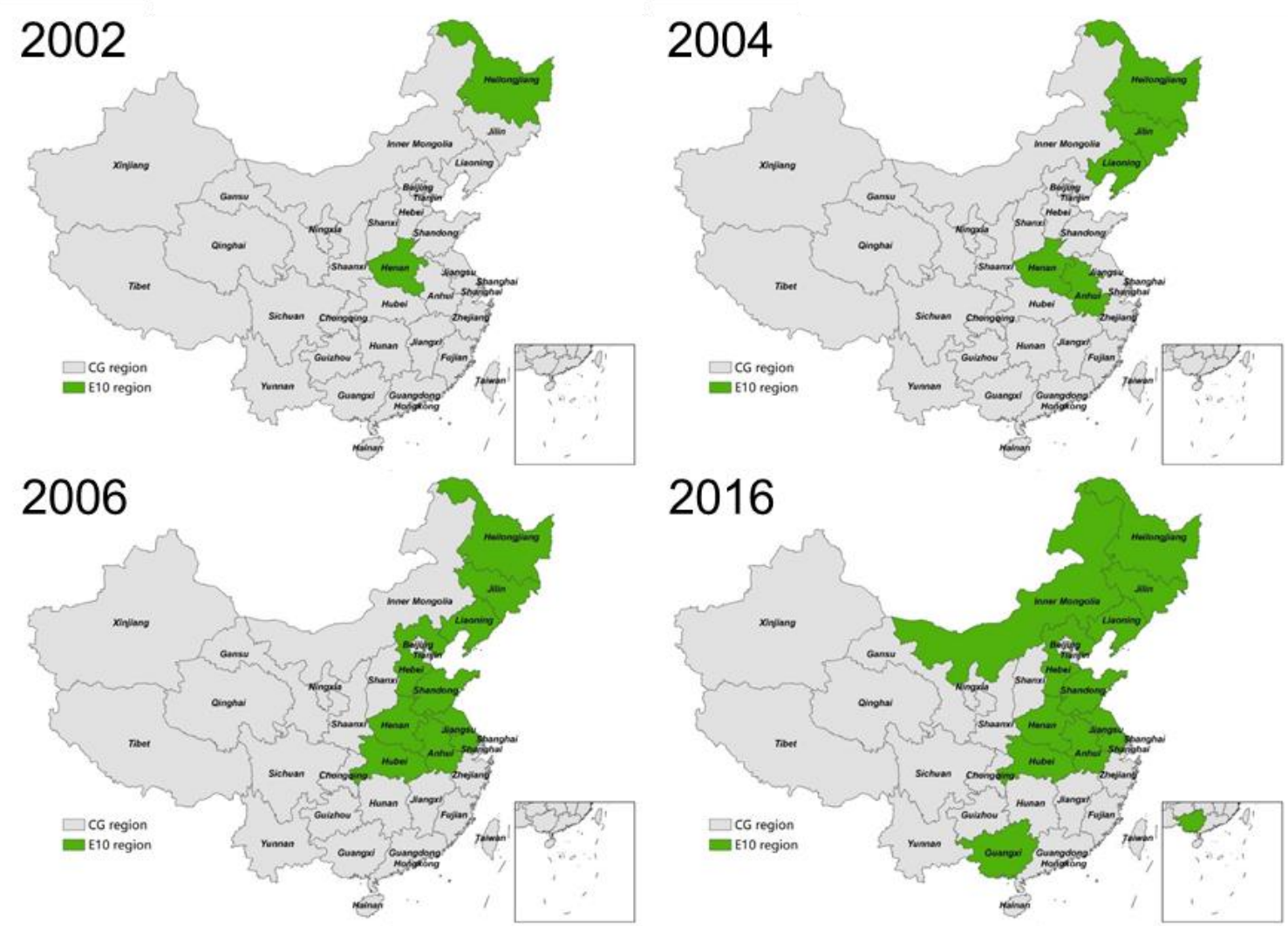
The 10th Five-Year Plan (2001-2005)

- Middle and Long Term Development Plan of Renewable Energy (2007)

The 12th Five-Year Plan for Bioenergy Development (2011-2016)

- The 13th Five-Year Plan for Bioenergy Development (2016-2020)
- The 13th Five-Year Plan for Renewable Energy Development (2016)
- ***Implementation Plan Regarding the Expansion of Ethanol Production and Promotion for Transportation Fuel (2017)***

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

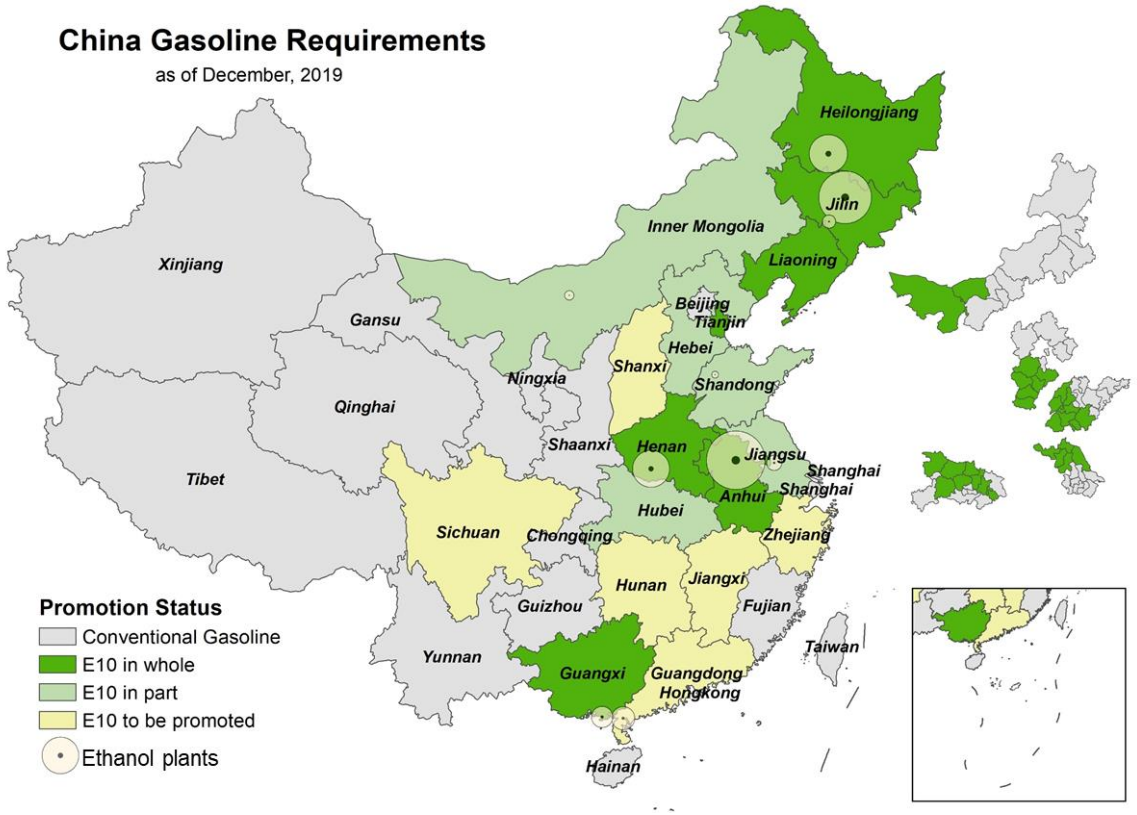
	Company	Location	Production (10^4t)
1	COFCO Biochemical (Zhaodong)	Zhaodong, Heilongjiang	32
2	Jilin Fuel Alcohol	Jilin, Jilin	58
3	COFCO Biochemical (Anhui)	Bengbu, Anhui	55
4	Henan Tianguan Group	Nanyang, Henan	28
5	COFCO Biochemical (Guangxi)	Beihai, Guangxi	14
6	Zonergy	Inner Mongolia	0
7	Longlive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

Major projects proposed after 2017

	Location	Capacity (10^4t)
1	Diaobingshan, Liaoning	30
2	Fujin, Heilongjiang	60
3	Hailun, Heilongjiang	30
4	Huachuan, Heilongjiang	30
5	Nehe, Heilongjiang	30
6	Shuangyashan, Heilongjiang	30
7	Shuangcheng, Heilongjiang	15
8	Siping, Jilin	90
9	Baicheng, Jilin	30
10	Jilin, Jilin	30
	Total (by May, 2019)	**375**

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



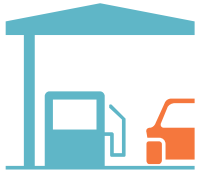
Production approval

- 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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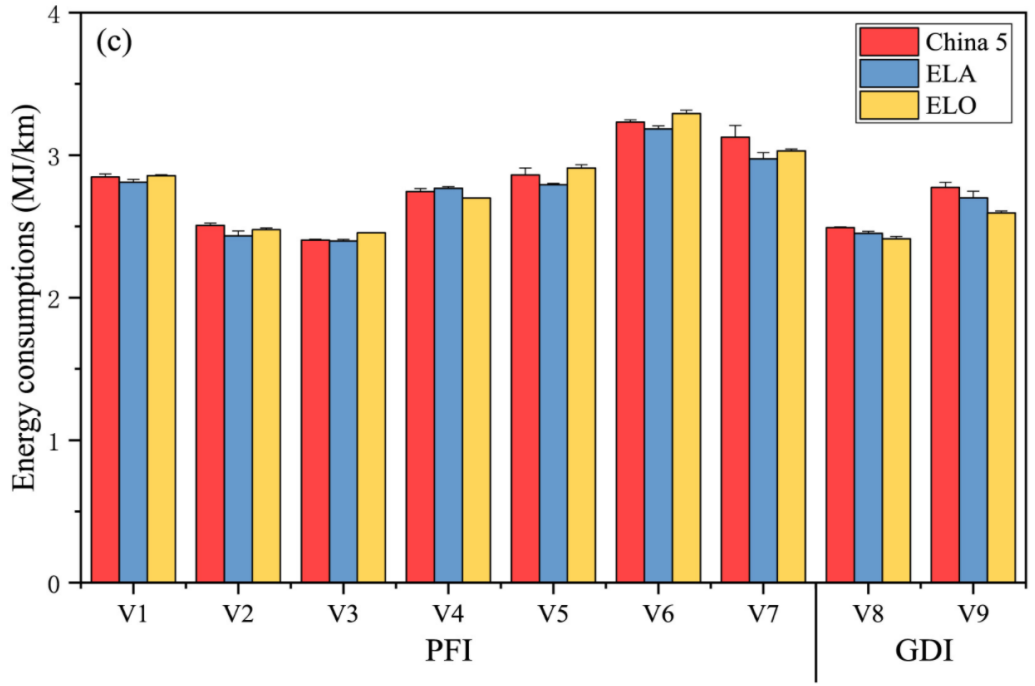
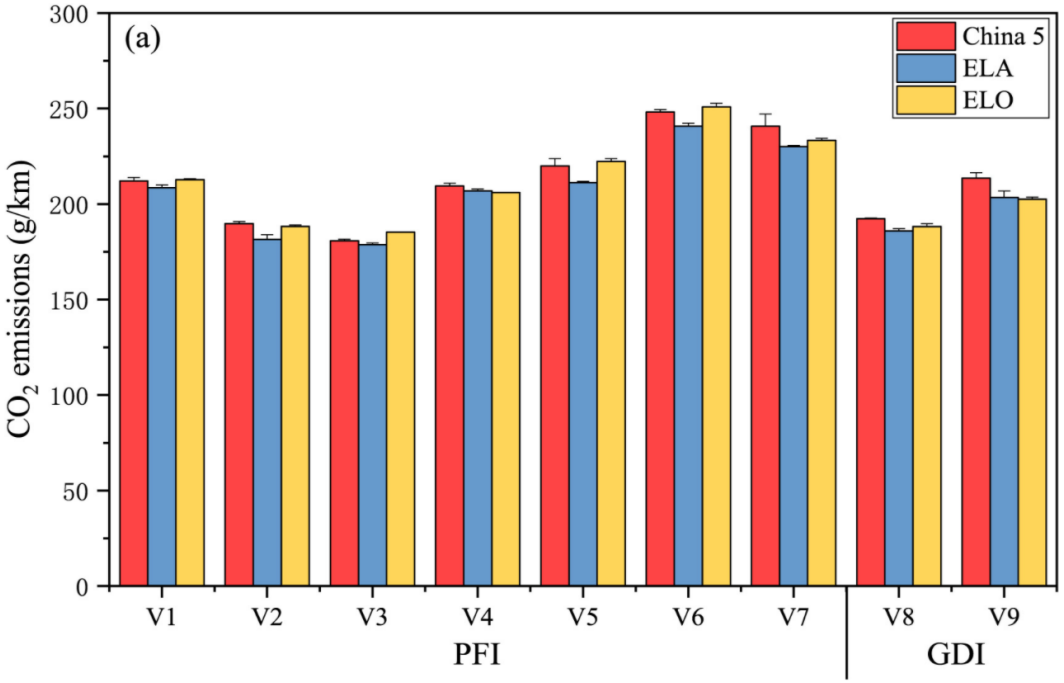
E10 could reduce tailpipe CO_2 emissions and energy consumption for GDI vehicles

- E10 with lower aromatics (ELA) and E10 with lower olefins (ELO) were tested
- ELA could reduces 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.

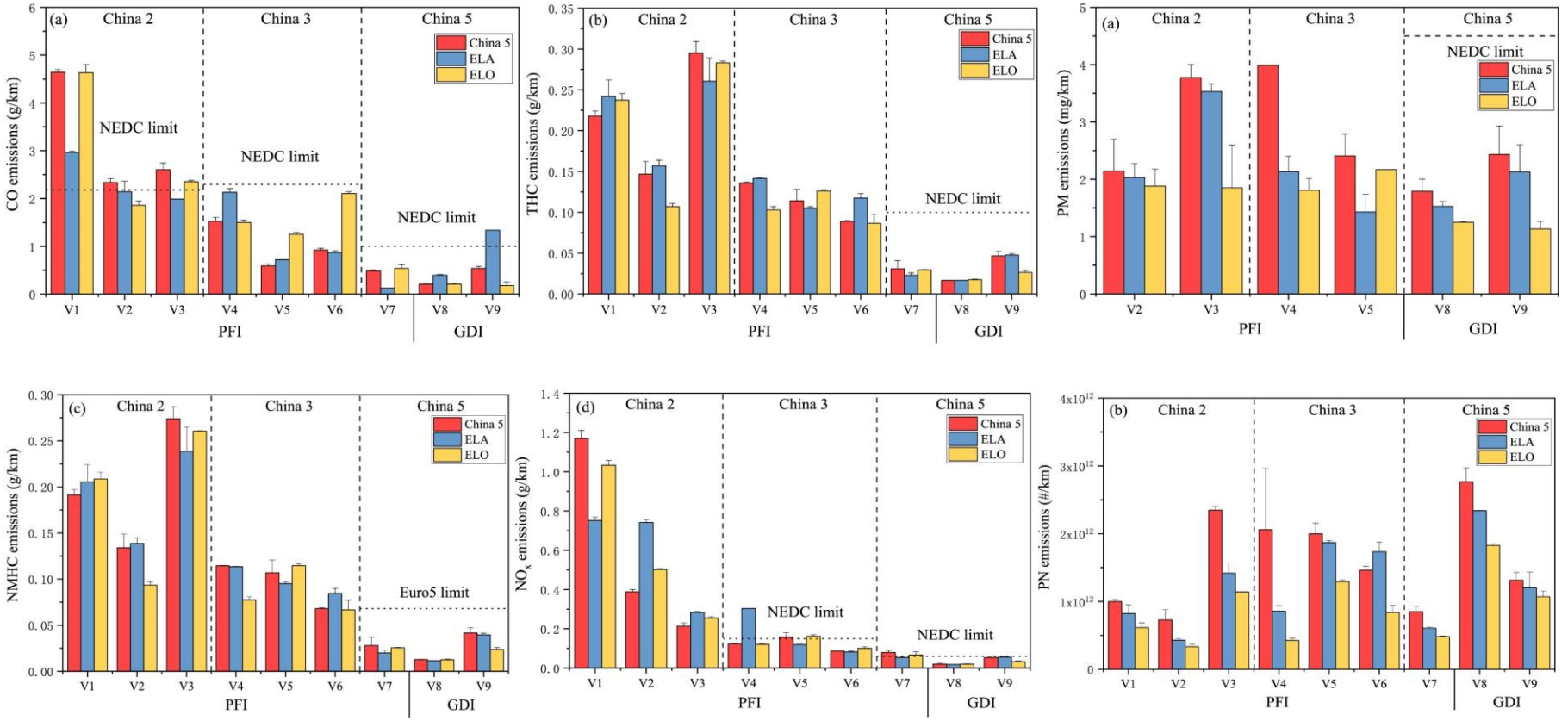




(Wu et al., Environ. Pollu., 2019)

E10 can significantly reduce PM emissions

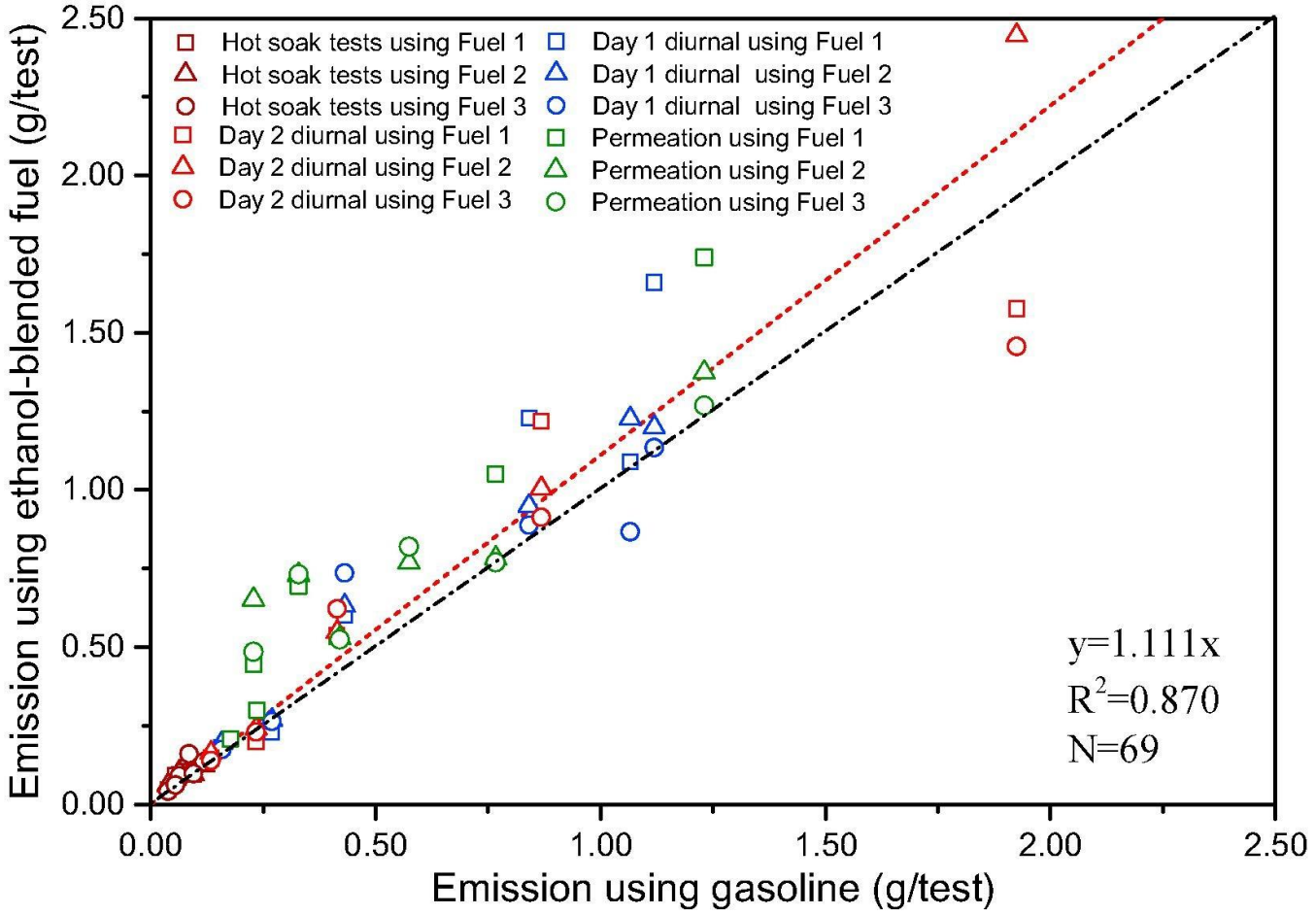
- No statistically differences in CO, THC and NO_X emissions between E0 and E10 (ELO and ELA) fuels.
- Both ELA and ELO fuels showed reductions for PM (reduced by 21%~35%) and PN (reduced by 22%~44%) emissions compared with conventional E0 fuel.



(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)

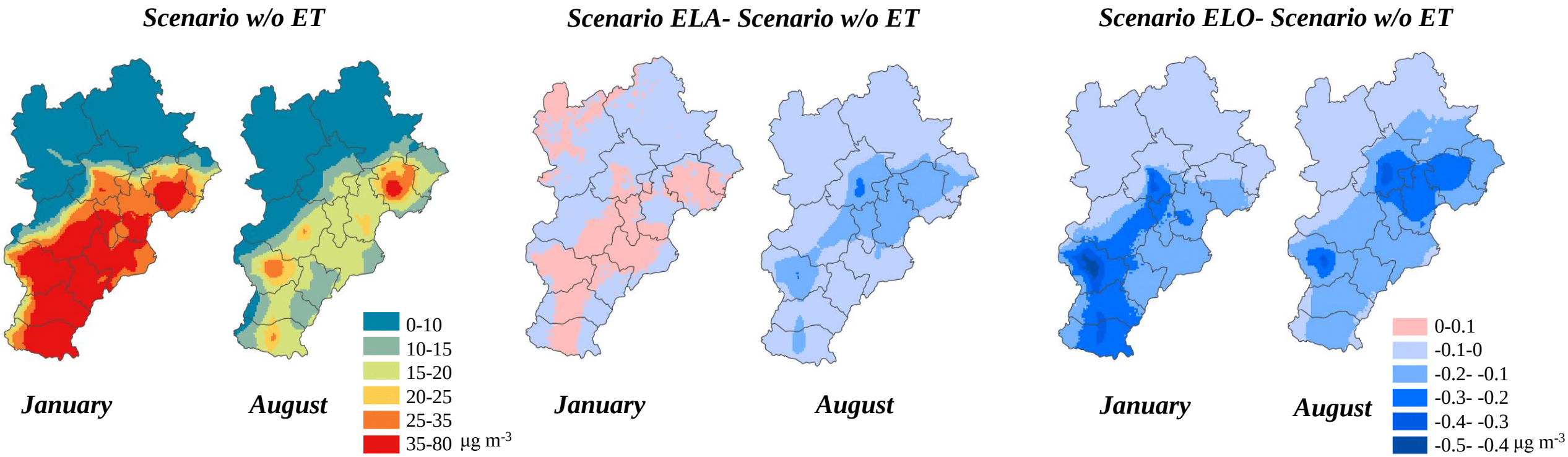


(Man et al., 2018, Appl. Energy)

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.

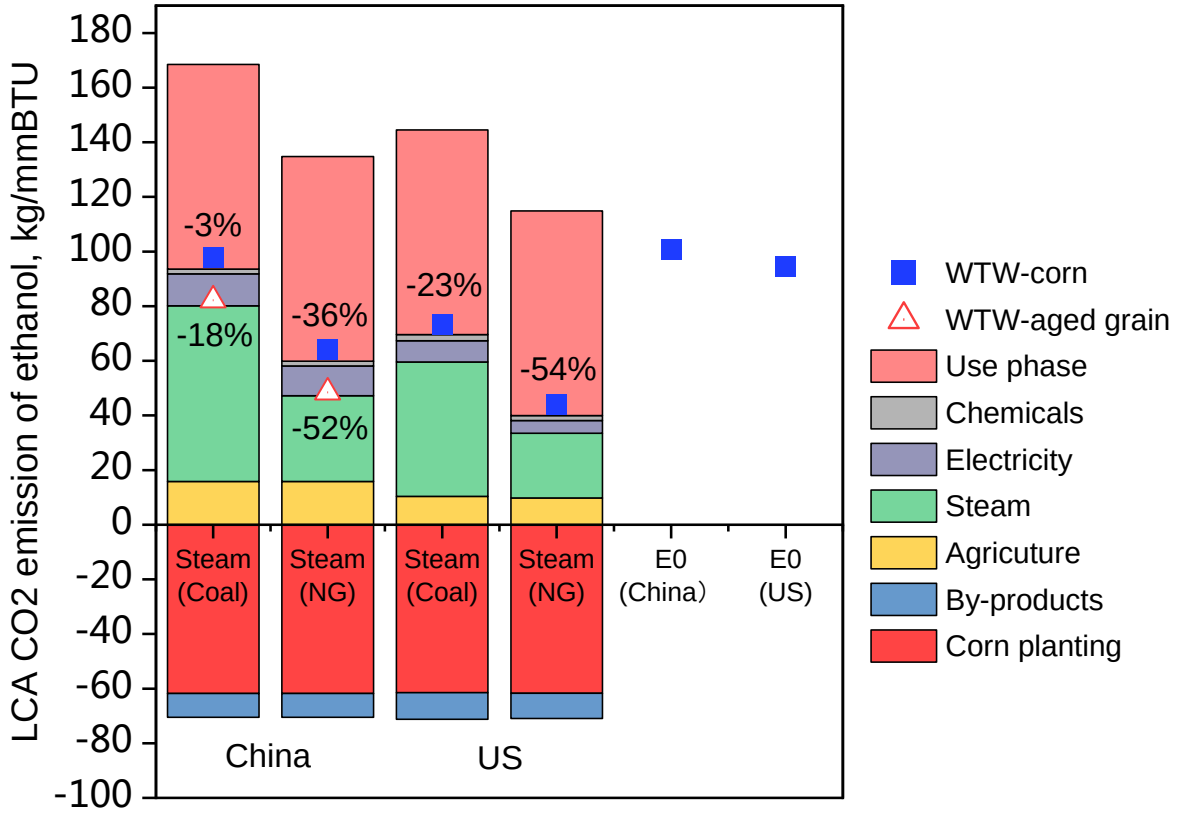
Chemical transport modeling (WRF/CMAQ) of ethanol fuel-related $PM_{2.5}$ concentrations



(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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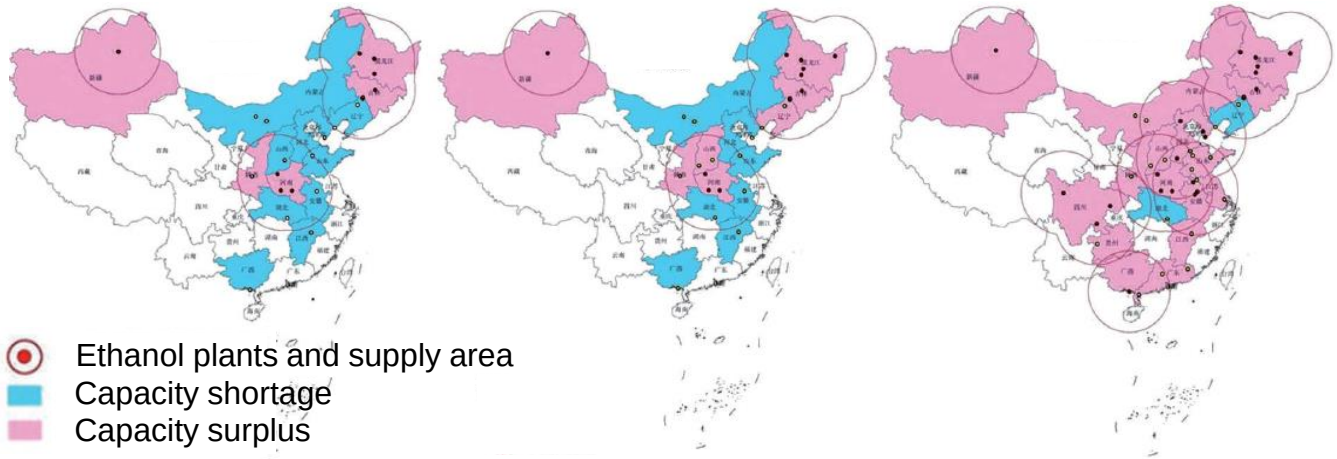
Future perspectives and challenges

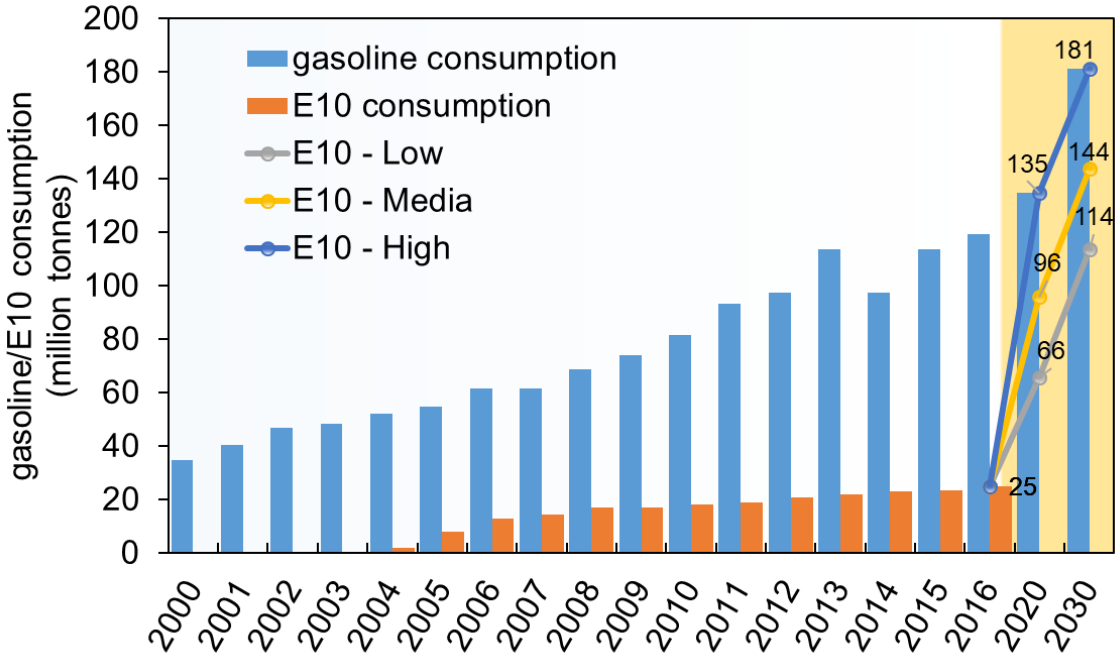
- Compared with the projected demand of ethanol fuels, the current production capability is relatively low. This implies the concern regarding policy uncertainty in the future.
- The possible variabilities in grain stock and concerns about food security could be barriers for central and local governments 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_X emissions, which lead to a concern on ozone and SOA (secondary organic areasols) 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.



E10 - Low E10 - Median E10 - High

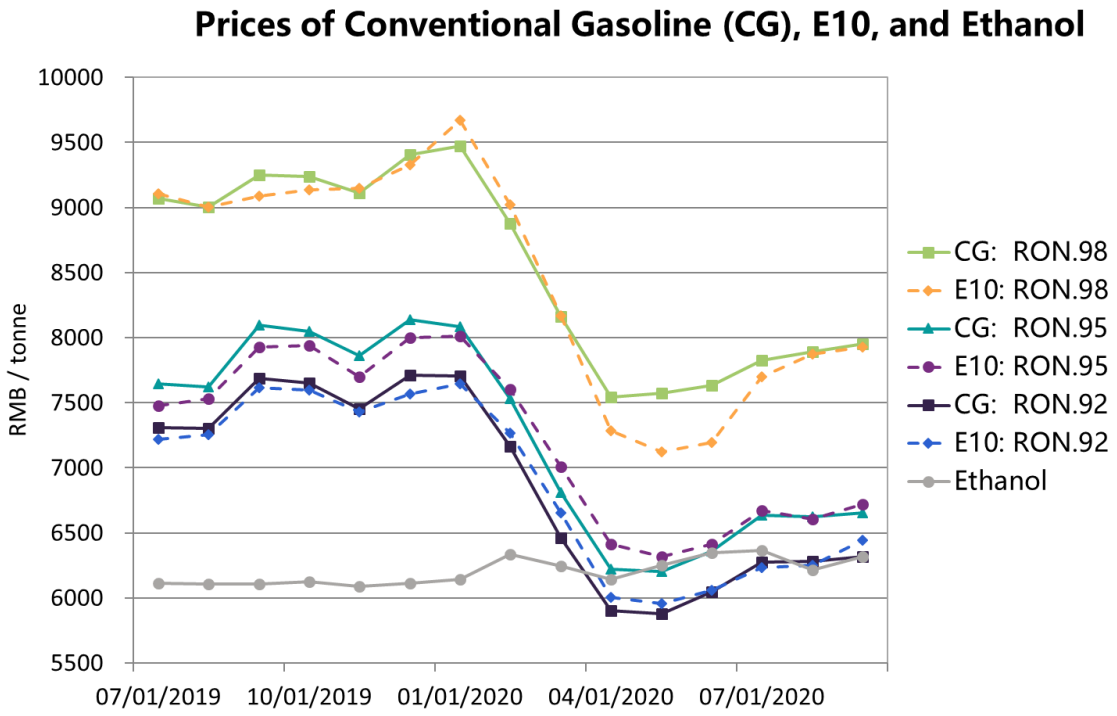


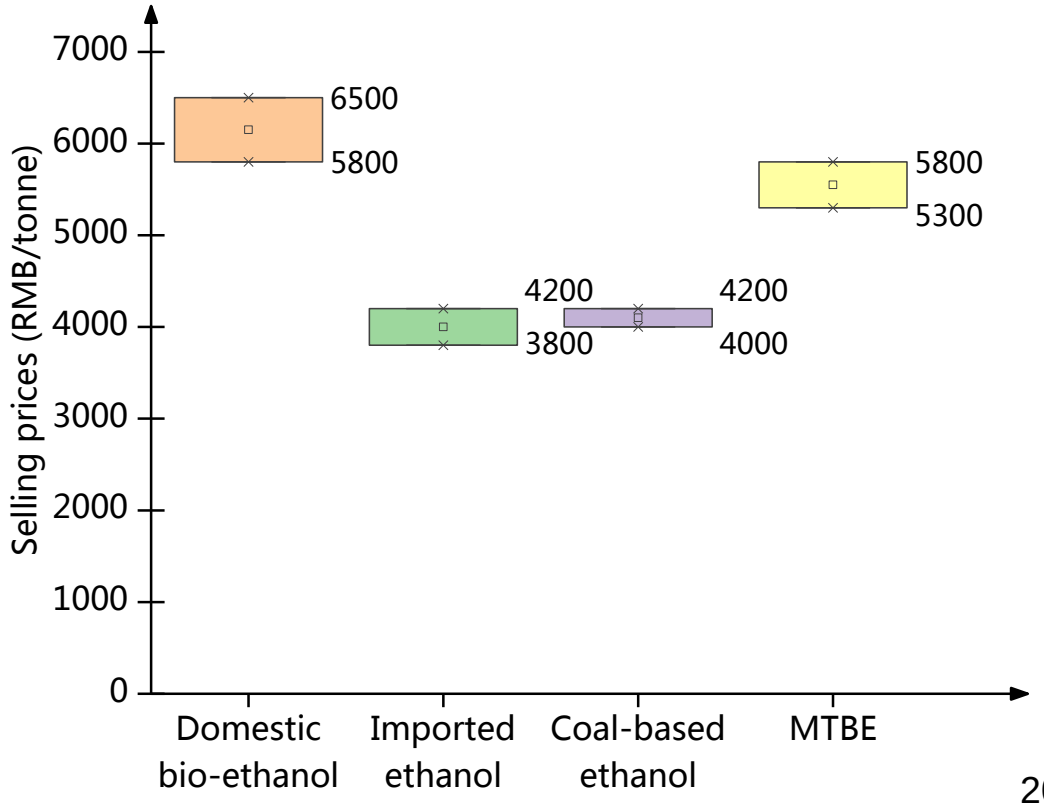
Low: *plants under construction put into operation*
Median: *plants proposed put into operation*
High: *multi ethanol pathway (corn, cellulosic, coal-based)*

Pan et al., Shanghai Energy Conservation, 2019 (in Chinese).

Biofuel ethanol is weak on price competitiveness currently

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