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The Impact on Biofuels on Air Emissions and Toxins for Beijing/Tianjin Region
生物燃料对北京/天津地区大气排放和有毒污染物的影响

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THE UNIVERSITY OF ILLINOIS AT CHICAGO

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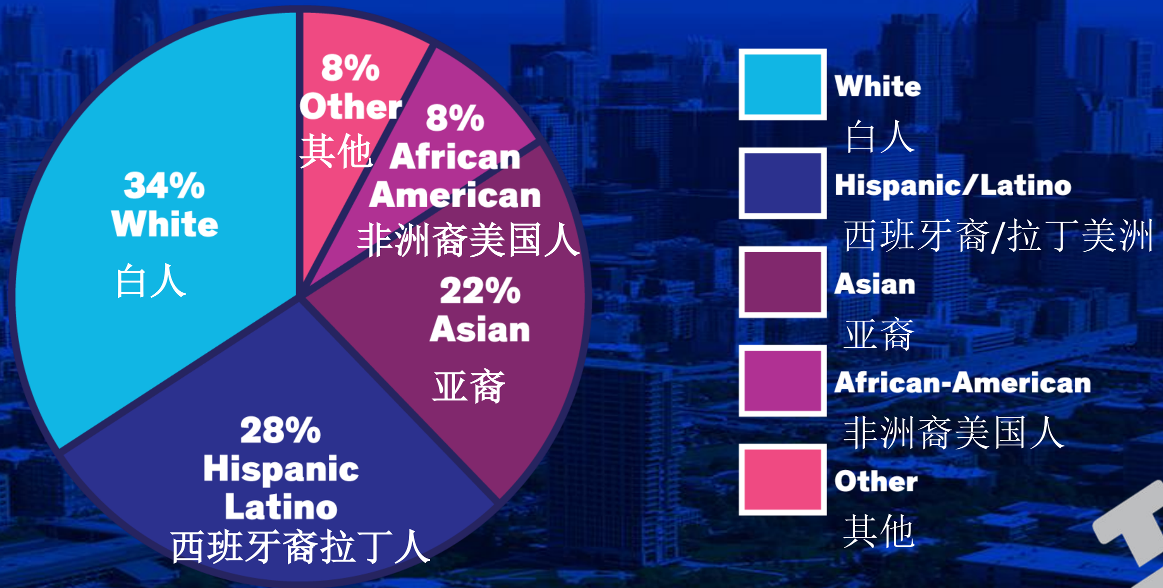
Sino-U.S. Biofuels Forum
中美生物燃料论坛
Washington, DC
华盛顿
November 14, 2017
2017年11月14日

University of Illinois at Chicago Diverse Student Body
伊利诺伊大学芝加哥校区学生组成情况
29,000 students 29,000名学生



*Fall 2015 Undergraduates
2015年秋季本科生

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Biofuels Research
生物燃料研究

- 2 Senior Scientists – 5 Students/Interns – Large Network of Cooperators
  两位资深科学家 — 五名学生/实习生 — 广泛的合作团队网络
- Fuel Ethanol life cycle and combustion emissions modeling
  燃料乙醇生命周期和燃烧排放建模
- New biofuels technology evaluation/commercialization
  新型生物燃料技术评估/商业化
- Land use research using Remote Sensing/Satellite tools
  运用遥感/卫星技术进行的土地利用研究
- Pollinator habitat conservation 授粉昆虫栖息地保护

Presentation Overview and Terms
报告要点和专门用语

Presentation Overview报告要点:

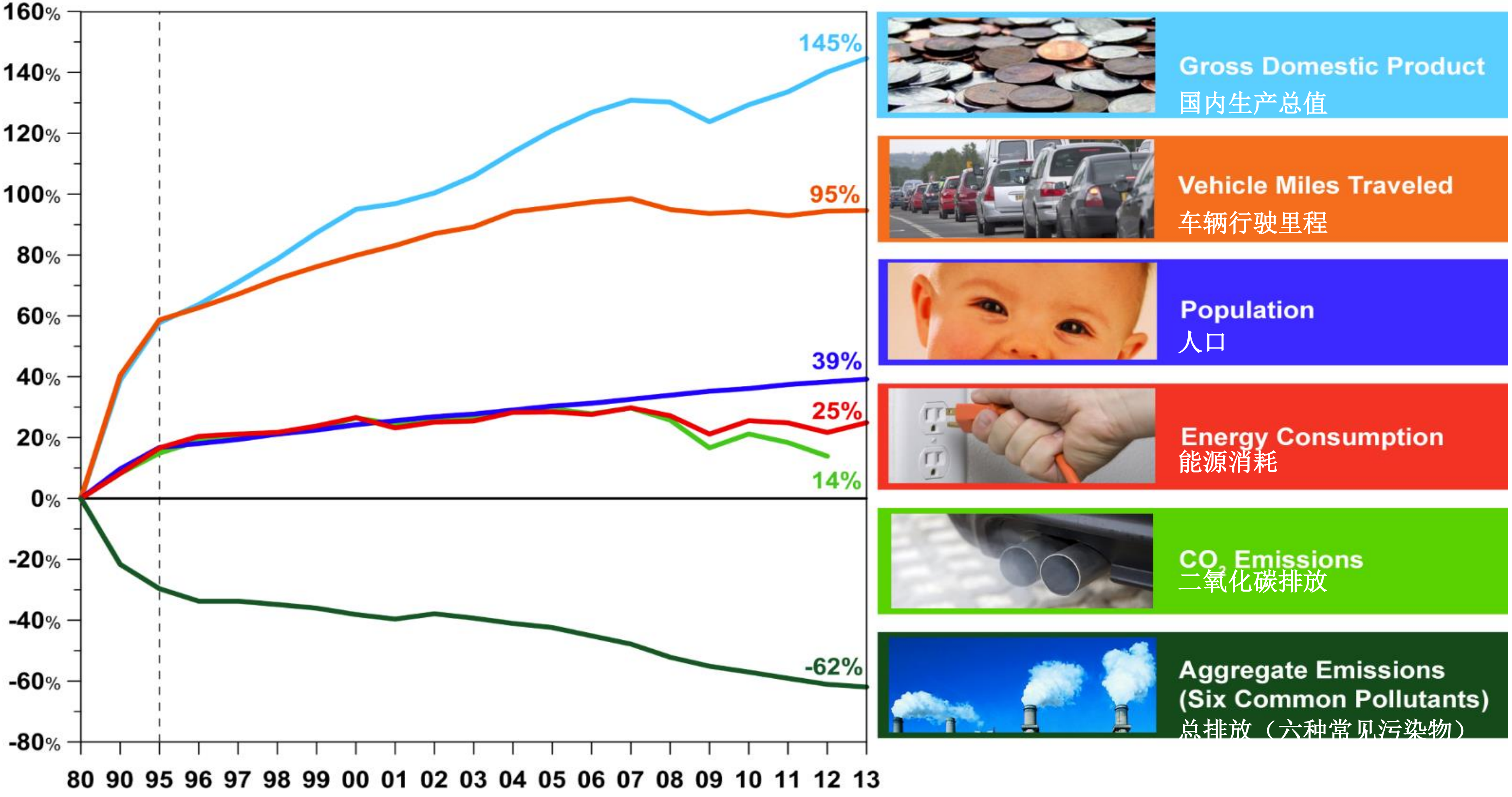
- Emissions Reductions from the US Clean Air Act
  美国清洁空气法案带来的排放减少
- Reductions of Emissions and Air Toxins with Ethanol Blended Gasoline
  乙醇混配汽油带来的排放及有毒污染物减少
- New Emissions Study for Global Cities including Beijing
  最新的包括北京在内的全球城市排放研究

Terms专门用语:

E10	10% Ethanol in Gasoline 汽油中含有10%的乙醇
E20	20% Ethanol in Gasoline 汽油中含有20%的乙醇
EV	Electric Vehicle 电动汽车

Emissions Reductions from the US Clean Air Act
美国清洁空气法案带来的排放减少

Clean Air Act Progress
清洁空气法案的进展



Source: US Environmental Protection Agency 来源：美国环境保护署

Gasoline 汽油

- Finished gasoline typically contains more than 150 separate compounds
  成品汽油一般含有超过150种不同的化合物
  - some blends may have many more compounds
    有些混合汽油可能含有更多种化合物
- Health and Cancer risk of many compounds and pollutants
  很多化合物和污染物有害健康，有致癌风险

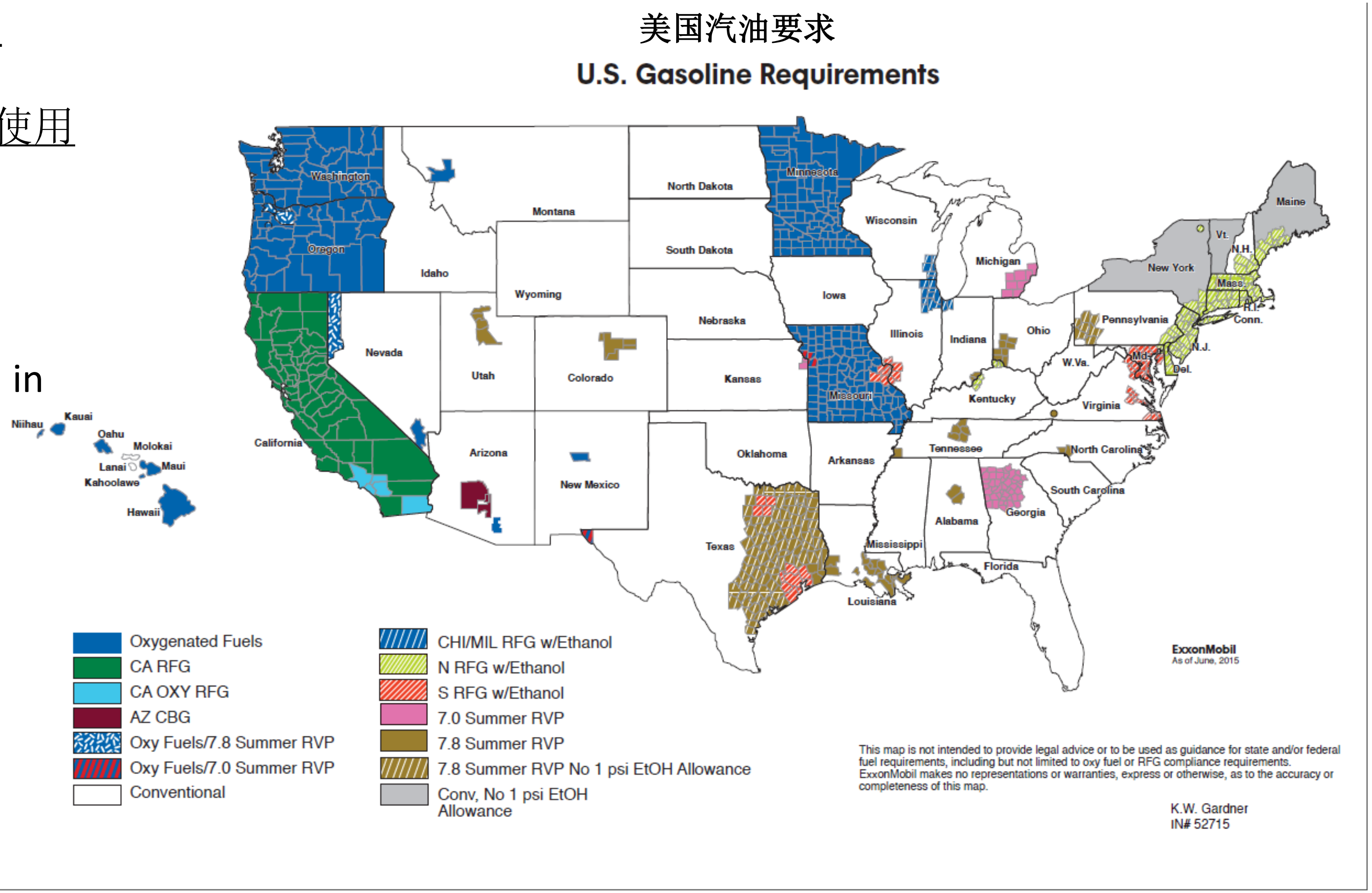
Gasoline-Ethanol Blends
汽油-乙醇混合燃料

<u>E10 is used in almost all fuel in the US, all regions, across all seasons.</u>
<u>E10一年四季在美国几乎所有地区普遍使用</u>

E15 and higher flex fuels are also in use.
E15和更高混合比例的汽油也有所使用

Specially reformulated gasolines are used in high polluted urban areas.
新配方汽油在污染情况严重的城市地区使用尤其普遍

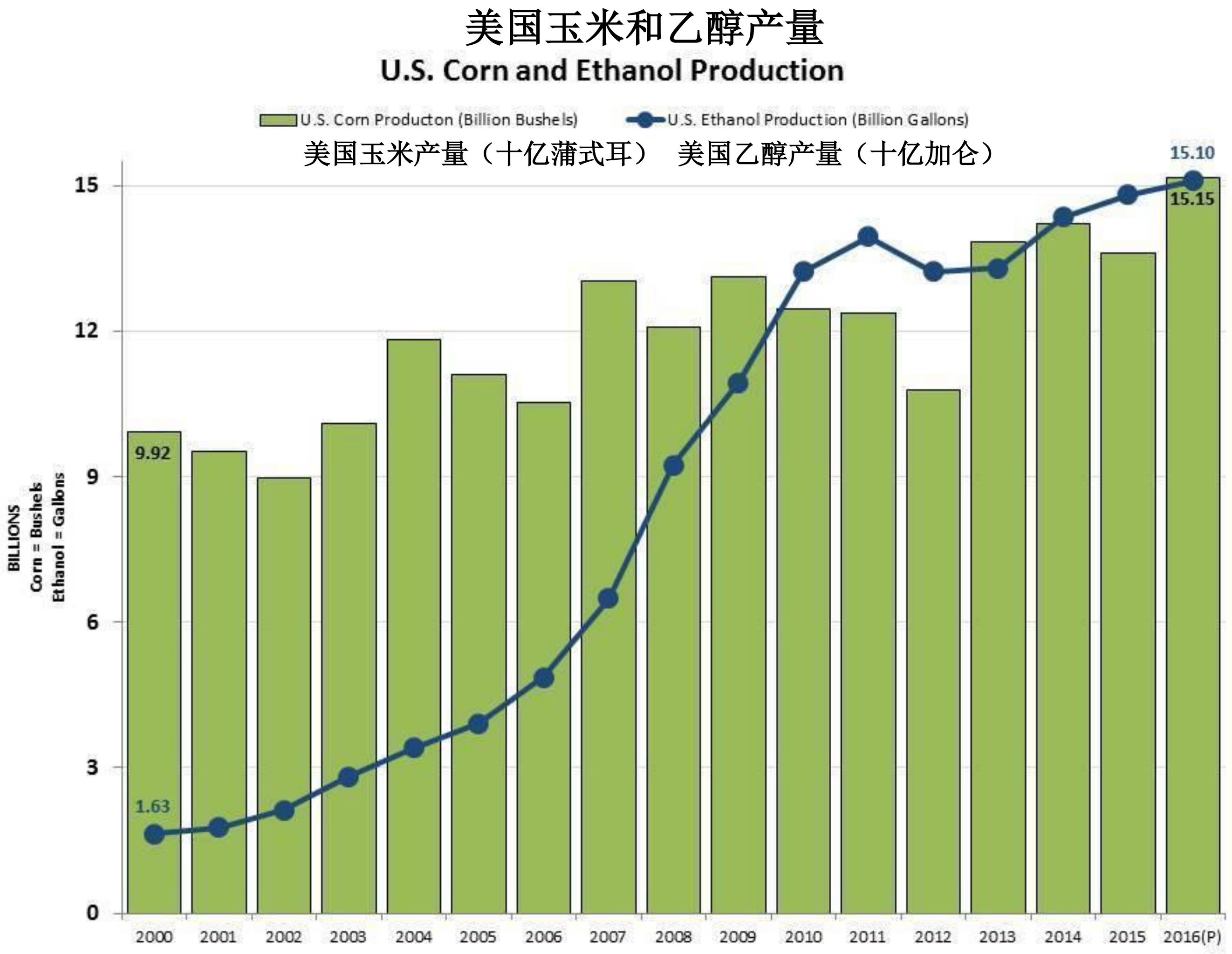
Reformulated gasolines contain ethanol
新配方汽油含有乙醇



Benefits of Ethanol Blended into Gasoline
在汽油中混调乙醇的好处

- Increased ethanol results in lower burned gas and exhaust temperatures.
  添加乙醇会使燃烧废气减少和尾气温度降低
- High Octane Rating (wanted by car manufacturers for higher knock resistance in engines)
  高辛烷值（受到汽车制造业欢迎，因其能够提高发动机抗爆震性能）
  - In fuel formulations ethanol substitutes for and dilutes other octane enhancers such as benzene, toluene, and xylene.
    乙醇在燃料配方中能替代和减少其他辛烷值增强剂的使用，如苯、甲苯和二甲苯
- Oxygenate in Fuel (reduces certain emissions)
  燃料增氧剂 （减少某些排放）
- Reduction in Key Toxins from Combustion Process
  在燃烧过程中减少主要有毒污染物

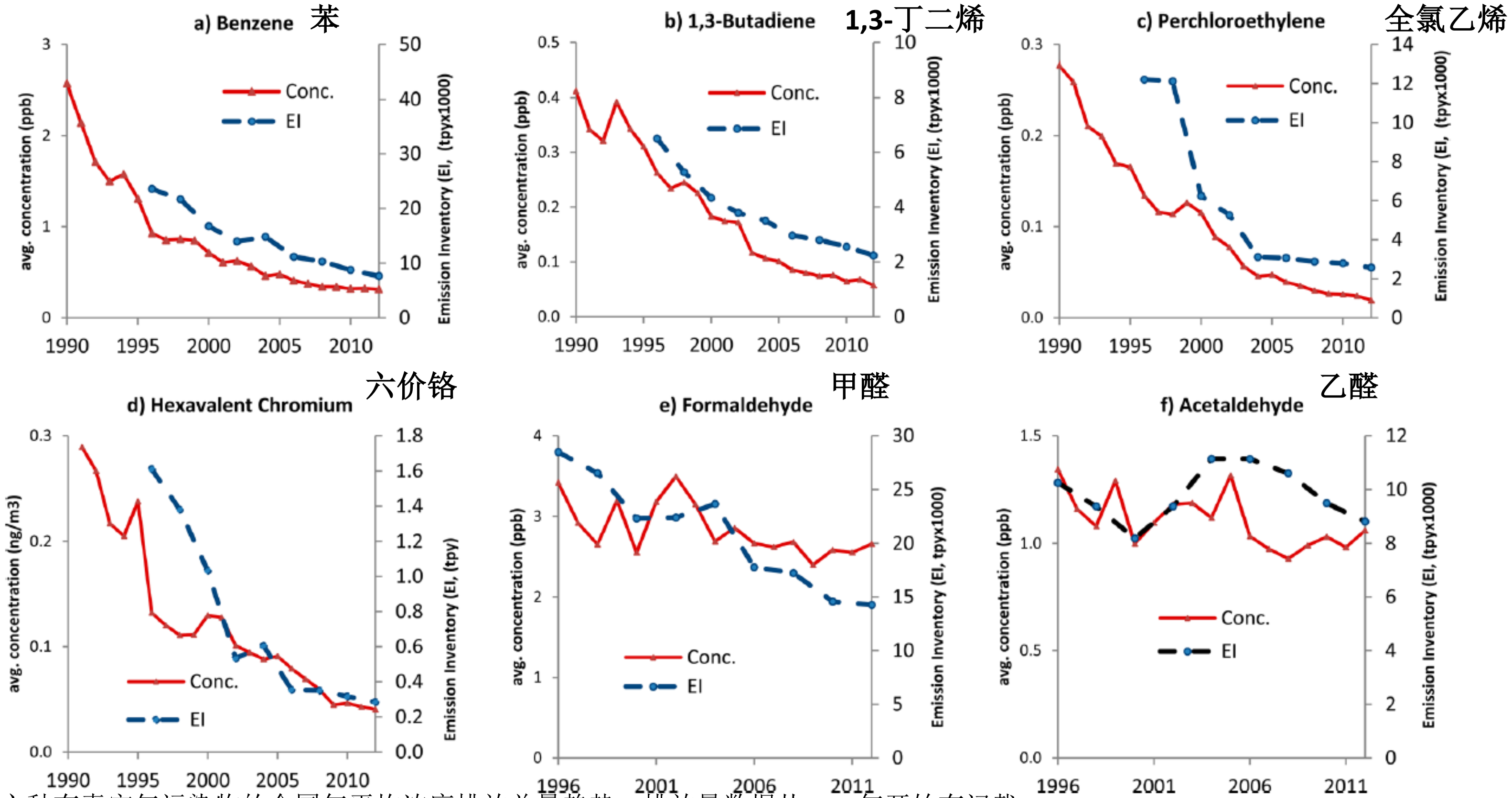
Increase in Corn Ethanol Use
玉米乙醇使用量的增加



Decrease in Air Toxins
空气中有毒物质减少

Ambient and Emission Trends of Toxic Air Contaminants in California
加利福尼亚州有毒空气污染物排放趋势

Environmental Science & Technology
Article



六种有毒空气污染物的全国年平均浓度排放总量趋势，排放量数据从1996年开始有记载。

Figure 3. Statewide annual average concentrations and emissions inventory (EI) trends for six toxic air contaminants. EI data were available starting in 1996. (a) Benzene (1990–2012), (b) 1,3-Butadiene (1990–2012), (c) Perchloroethylene (1990–2012), (d) Hexavalent Chromium (1991–2012), (e) Formaldehyde (1996–2012), (f) Acetaldehyde (1996–2012).

Toxic Air Contaminants 有毒空气污染物
(California Air Resources Board)
（加利福尼亚州空气资源委员会）

- "Toxic air contaminant" means benzene, 1,3-butadiene, formaldehyde, or acetaldehyde.
  "有毒空气污染物"指的是苯、1,3－丁二烯，全氯乙烯或乙醛。
- "In each test, the emission rate of each toxic pollutant shall be multiplied by its relative potency, as shown in the following table, and the four products shall be summed."
  "在每次测试中，各有毒污染物的排放速率应与其相对效力相乘，如下表所示，且应取四种物质之和。"

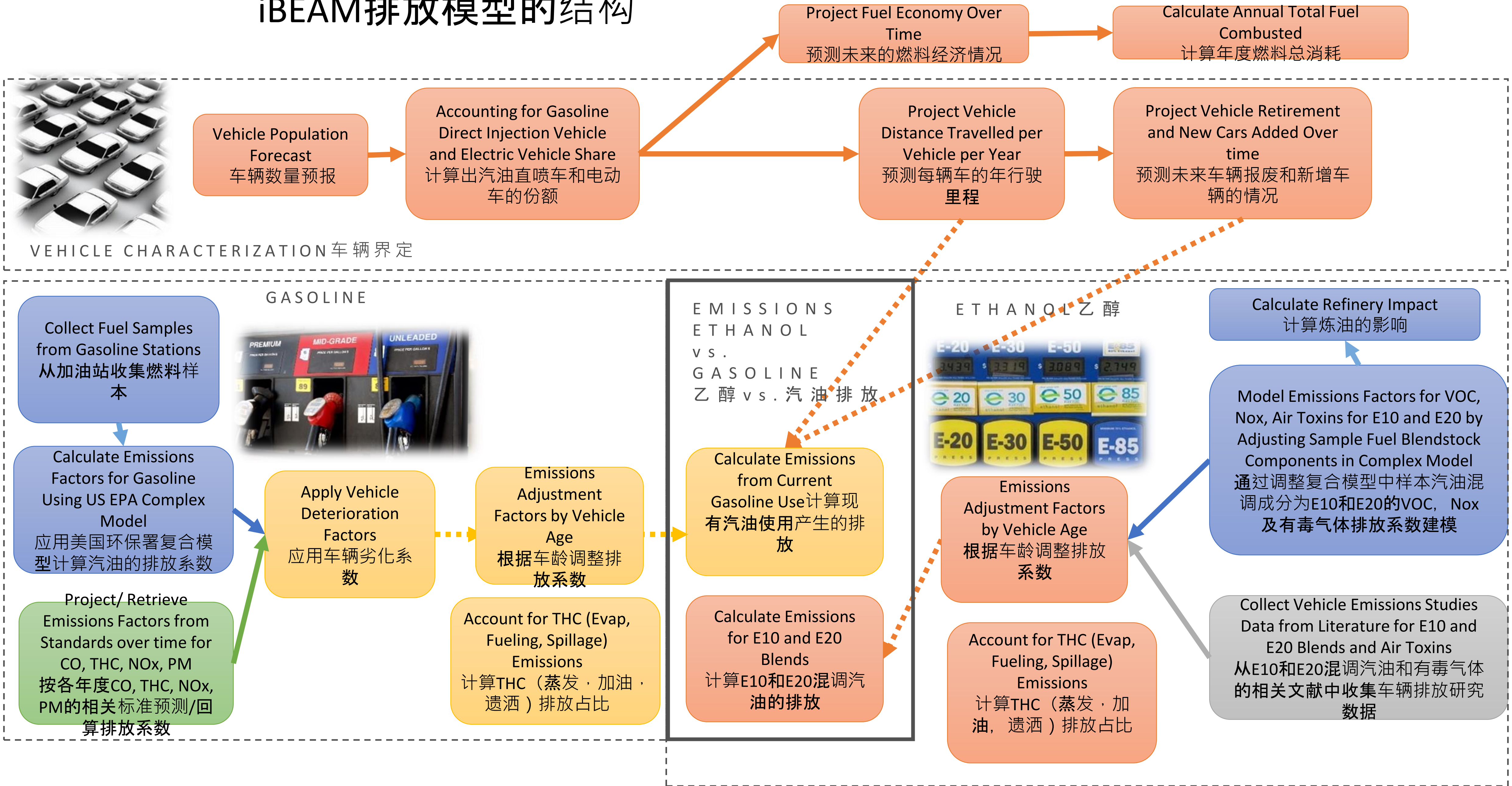
	相对效力*Relative Potency*
1,3-butadiene 1,3－丁二烯	1.0
benzene 苯	0.17
formaldehyde 全氯乙烯	0.035
acetaldehyde 乙醛	0.016

ATTACHMENT A-13; State of California; California Environmental Protection Agency; AIR RESOURCES BOARD; Stationary Source Division CALIFORNIA TEST PROCEDURES FOR EVALUATING SUBSTITUTE FUELS AND NEW CLEAN FUELS IN 2015 AND SUBSEQUENT YEARS; Adopted: March 22, 2012

New Emissions Study for 5 Major Global Cities including Beijing/Tianjin
包括北京/天津在内的全球五大城市最新排放研究

The University of Illinois at Chicago International Biofuels and Emissions Analysis Model (iBEAM)
伊利诺伊大学芝加哥校区国际生物能源和排放分析模型（iBEAM）

Structure of The iBEAM Emissions Model
iBEAM排放模型的结构



iBEAM Study for Beijing
北京的iBEAM研究

Key Features要点:

- Based on actual fuel samples taken in the Beijing/Tianjin Region
  研究是基于在北京/天津地区采集的燃料样本
- Integrates US Environmental Protection Agency's Complex Model (used by refiners) with UIC iBEAM Model
  结合美国环保署的复合模型（炼油厂商所采用的）与UIC的iBEAM模型
- Considers city specific fuel consumption, emissions standards, and vehicle control technologies
  将城市特有的燃料消费、排放标准和车辆控制技术考虑在内
- Incorporates the latest scientific literature on E10 and E20 ethanol-gasoline blends
  包含了E10和E20乙醇混调汽油方面的最新科学文献
- Includes an assessment of air toxins, polycyclics, total hydrocarbons (THC), oxides of nitrogen (NOx), carbon monoxide (CO), and Particulate Matter (PM).
  包括对有毒气体、多环芳烃、总碳氢化合物（THC）、氮氧化物（Nox）、一氧化碳（CO）和颗粒物（PM）的评估
- Assesses Impact on Revenues to Local Refineries from Switching to Ethanol Blends
  评估改用乙醇调和汽油对当地炼油企业收入的影响

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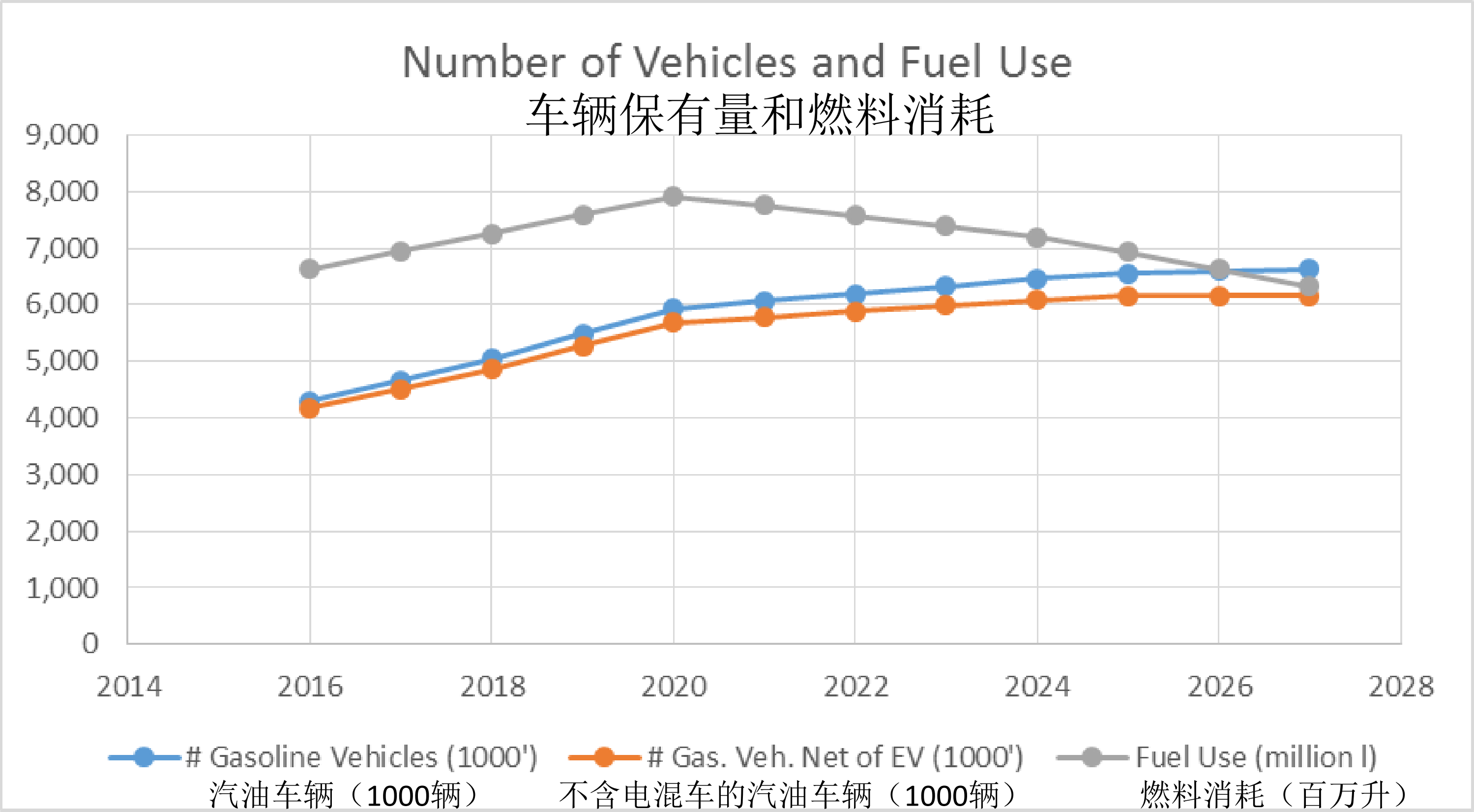
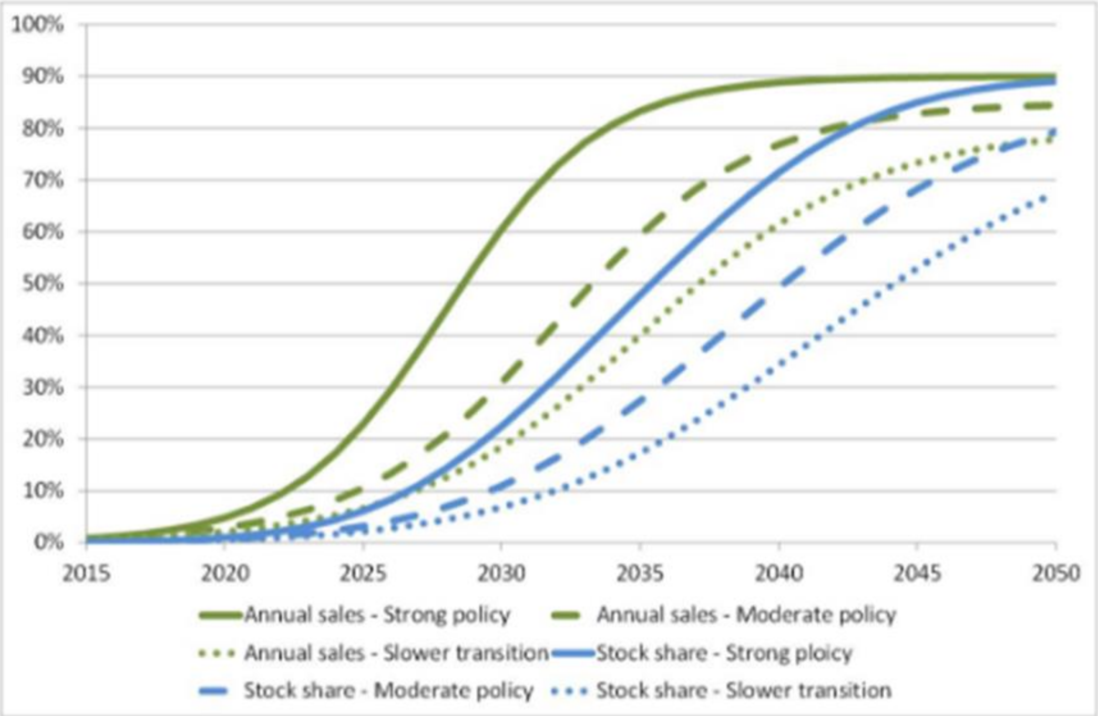
Beijing/Tianjin 北京/天津



Account for Electric Vehicle Share: Annual Sales vs. Stock Change
电车份额占比：年销量vs.汽车保有量变化

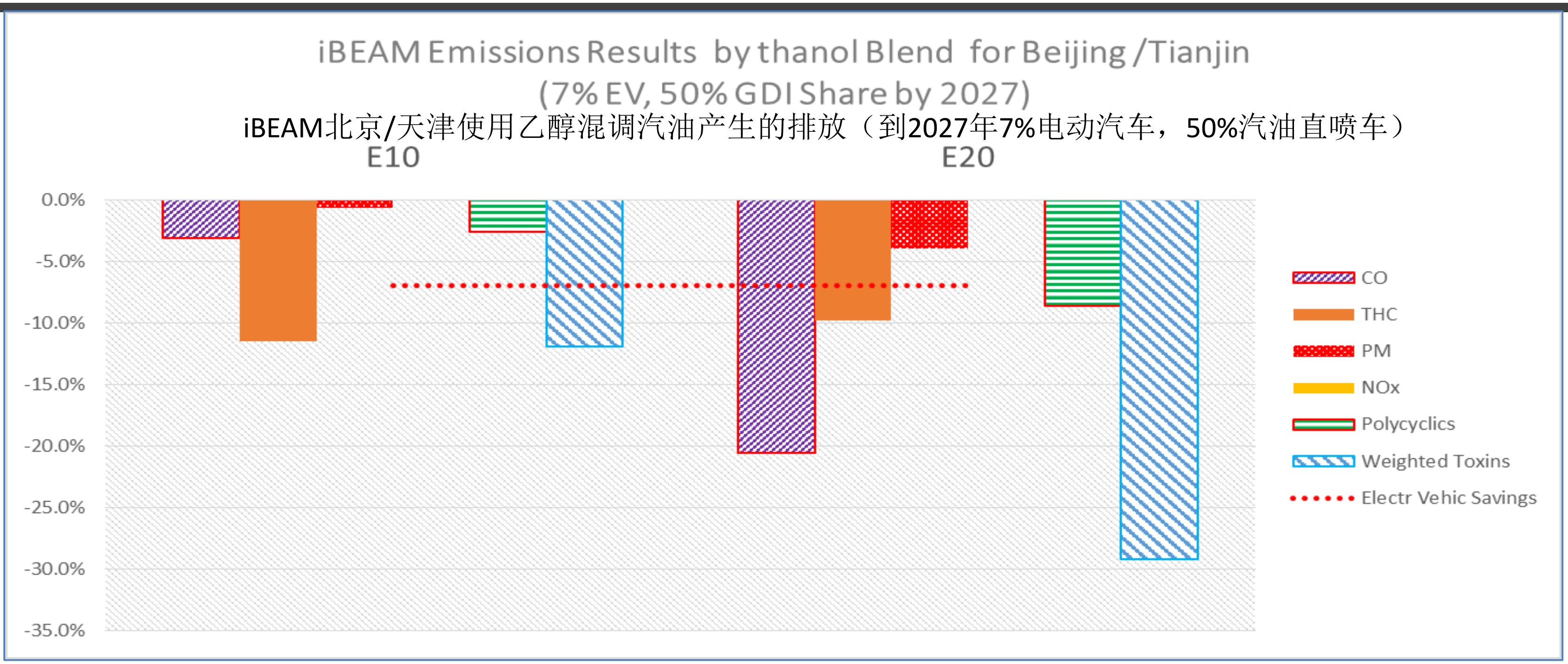
- Whitmore global EV adoption model: Annual EV vehicle sales will account for between 20% to 60% by the year 2030 converting to 7% and 22% of total vehicle stock depending on the policy scenario.
  惠特莫尔全球电动车采用模型：电动车辆年销售量占比到2030年前将达到20%到60%，在不同的政策情景下可转换为7%和22%的车辆保有量
- Roland Berger report cites annual new vehicle sales of EVs by 2030 of 19% (3% Battery Hybrid plus 3% Plug-in Electric Vehicle plus 1% Full Hybrid and 11% Mild Hybrid) which would correspond more closely with the slower adoption scenario by Whitmore
  罗兰贝格报告引用的电动车新车年销量占比到2030年前达到19%（3%电池混动加3%增程式加1%全混动加11%轻混动），与惠特莫尔模型中的慢速采用情景更接近。
- China recently introduced a new vehicle energy score with aggressive targets of 10 percent of low or zero emissions vehicle sales per auto manufacturer starting in 2019, rising to 12 percent in 2020.
  中国近年来引入了新能源汽车积分，设定了激进的目标：从2019年开始，每家汽车生产企业销售的低排放或零排放汽车须占总销售量的10%，到2020年提高到12%。



Source: Whitmore, Adam: How fast could the market for electric vehicles grow?
来源：惠特莫尔，亚当：电动汽车市场增长有多迅速？

Beijing/Tianjin Emissions Reductions with Ethanol
乙醇对北京/天津的减排贡献

Ethanol would Likely Result in Higher Emissions Reductions than EV Vehicles Through 2027
到2027年，乙醇可能比电动车辆带来更多排放减少



减排百分比

Percent Reductions	E10	E20
CO	-3.1%	-20.6%
THC	-11.5%	-9.8%
PM	-0.7%	-4.0%
NOx	0.0%	0.0%
Polycyclics 多环芳烃	-2.7%	-8.6%
Weighted Toxins 毒性污染物加权	-12.0%	-29.2%
Electr Vehic Savings 电动车辆节能	-7%	-7%

减排量（吨）

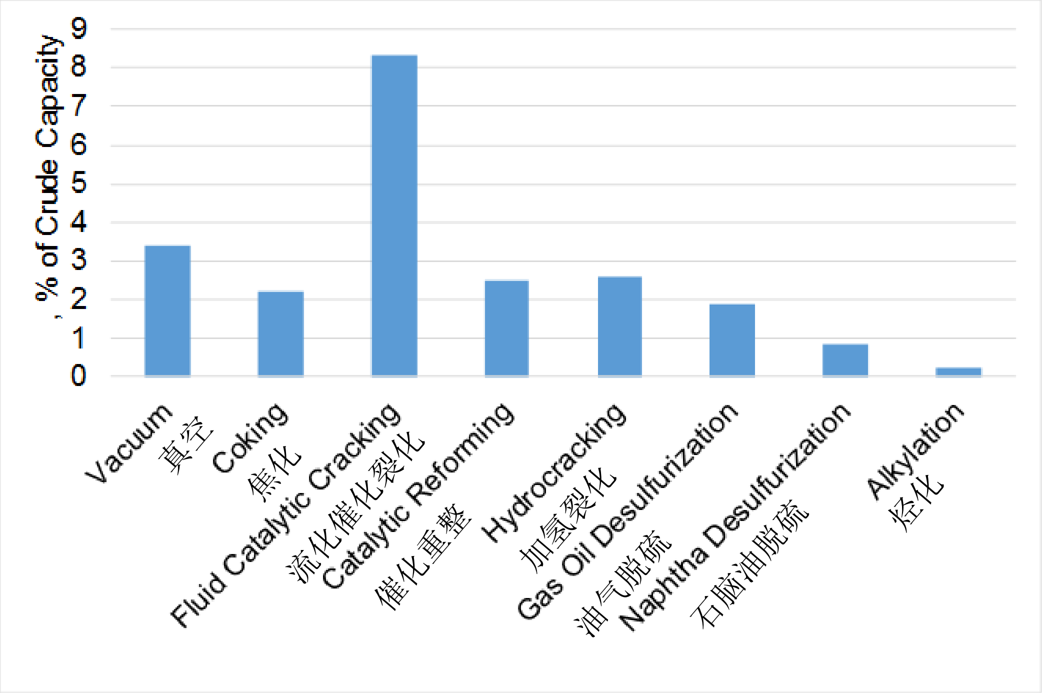
Tonnes Reductions 2016-2027	E10	E20
CO	-69,613	-462,832
THC	-29,238	-24,866
PM	-10	-58
NOx	0	0

Country-Specific Refinery Profitability Considerations
符合具体国情的炼油业利润率考量

We established a Refinery Profile for each of Our Countries
我们为每个国家建立了一个炼油业档案

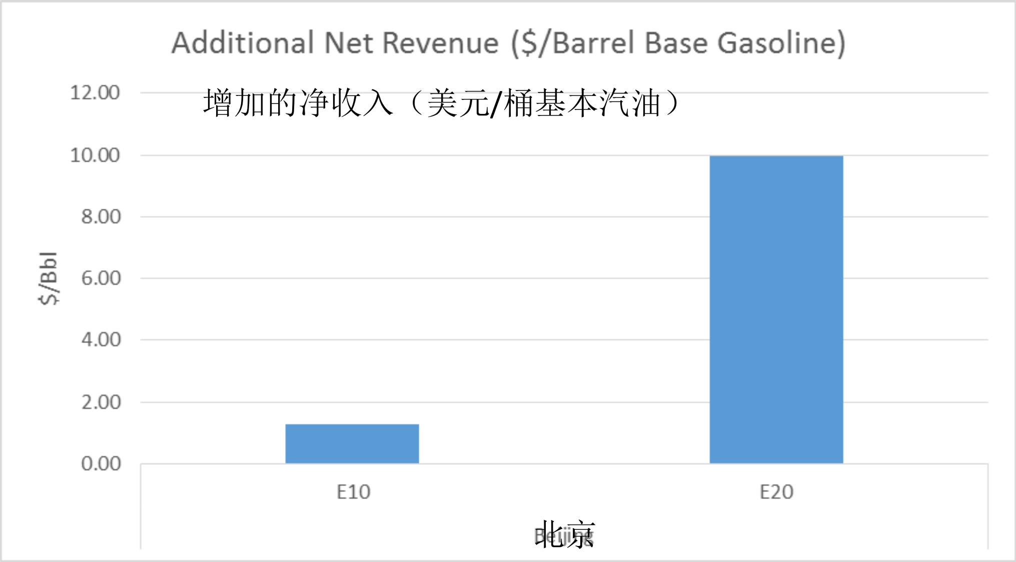
- China has steadily expanded its oil refining capacity to meet its strong demand growth and to process a wider range of crude oil types.
  为满足强劲的需求增长和加工更多类型的原油，中国稳步扩大其炼油产能。
- The country now ranks behind only the United States and the European Union in the amount of refining capacity.
  中国在炼油产能方面仅次于美国和欧盟。
- China‘s installed crude refining capacity reached nearly 14.2 million barrels per day (BPD) by 2015, about 680,000 BPD higher than in 2013.
  2015年中国原油炼制的装机产能已接近日产1420万桶，比2013年的日产量高68万桶。
- Some of the new refineries are designed to accept all grades of crude oil, making Chinese refineries a strong regional competitor.
  有些新炼油厂的设计能够处理各种等级的原油，使中国炼油企业成了强有力的区域竞争者。

The breakdown of Chinese refining capacity by major processing units as percent of crude oil
中国炼油产能在各加工工艺流程中的分配情况，以原油百分比表示



Net Revenue Impact for Refiners in Each Country From Ethanol Use
使用乙醇对各国炼油企业净收入的影响

- When oxygenates (like ethanol in E10 or E20) are added in gasoline blending, there is less need for octane from the catalytic reforming unit within a refinery and more hydrotreated naphtha feed to the catalytic reforming unit can be bypassed and blended directly to gasoline.
当增氧剂（如E10或E20中的乙醇）添加到混调型汽油中，炼油厂的催化重整单元对辛烷的需求减少，加氢石脑油无需加入催化重整单元，可直接与汽油混合。
- The result is more gasoline production. However, as a result of operating at lower severity and processing less feed, there is less hydrogen produced from this unit for use in other plant processes.
结果是会出产更多汽油。而由于操作的严谨性要求降低，需要加工的进料减少，此单元产生的氢气也减少，这些氢气用于其他生产过程。
- Based on our assessment of each country's refinery profile we determined the incremental hydrogen and incremental gasoline production and net revenue impact resulting from accommodating E10 and E20 in the blends.
根据对各国炼油企业情况的评估，我们确定出氢和汽油产量的增加情况，以及按E10和E20标准生产混调汽油带来的净收入影响。
- The net revenue was calculated on the basis of dollar per barrels of base case gasoline for each city.
净收入的计算是基于各城市每桶基本汽油的美元价格。



The results show that ethanol blended fuels for China would likely increase revenue for local refiners.
结果显示中国的乙醇混调汽油会是当地炼油企业收入增加。

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Summary 小结

- E10 (and regionally E15) is standard in the US fuel supply. Dramatic emissions reductions for pollutants/toxins under the Clean Air Act
  E10（在某些地区的E15）是美国燃料供应的标准。清洁空气法案使污染物/有毒气体大幅减少。
  - For example ethanol reduces toxicity and cancer risk by diluting **and substituting** for 1,3 Butadiene and Benzene.
    比如，乙醇通过稀释及替代1,3丁二烯和苯减少了毒性物质和致癌风险。
- Adding E10 or E20 to the Fuel Supply for BeijingTianjin results in significant immediate emissions reductions
  在北京和天津的燃料供应中加入E10和E20带来了直接的明显减排效果。
  - Significant Total Hydrocarbon Reductions, Volatile organic compound (THC, VOC) resulting in Significant Risk Reductions of Ozone for the Area
    总碳氢化合物,挥发性有机化合物(THC, VOC) 排放明显减少，从而使区域臭氧风险明显降低。
  - Significant Polycyclics and Weighted Toxins Reductions Reducing Cancer Risk for the Area
    多环芳烃和加权有毒气体明显减少，降低了该地区的患癌风险。
  - No effect on NOx 对氮氧化合物无影响
  - Reduced CO Emissions reduces heart disease and other health effects
    一氧化碳排放的减少降低了心脏疾病发病率和其他健康影响
- Even high annual sales will only slowly change electric vehicle stock: Ethanol for the current vehicle stock and electrification of future vehicle sales provide a combined solution to the pollution problem
  即使较高的年销售量只会带来电动车辆存量的缓慢变化：将在现有存量车辆中使用乙醇与在未来汽车销售中提高电动车辆比例相结合，是解决污染问题的办法。
- Linear Refinery Programming Showed that these Ethanol Blends Given Each China's Refinery Structure can be Produced with Additional Profits to the Refining Sector.
  炼油厂线性规划显示如果在中国的炼油结构中采用乙醇混配，将为炼油业带来额外利润。

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Citations and Supporting Material
引证和参考资料

Tail Pipe Emissions Citations
尾气排放引证

THC/NMHC

	Pollutant	E10	E20	
Hilton and Duddy	THC		-13.70%	
Karavalakis	THC	-12.80%	-22.90%	
Suarez- Bertoa	THC	-65.00%	-59%	vs E5
ExxonMobile	THC	-4.90%		
NREL	NMHC	-12.00%	-15.10%	
Storey	NMHC	-20.00%		
Bertoa	NMHC	-68.00%		vs E5
ExxonMobile	NMHC	-5.90%		
ORNL 2012	NMHC	-7.02%	-17.10%	
ORNL 2012		-1.36%	-0.90%	
Average	THC/NMC	-26.94%	-21.44%	

CO

	Pollutant	E10	E20	
Hilton and Duddy	CO		-23.20%	
Karavalakis	CO		-47.10%	
NREL	CO	-15.00%	-12.30%	
Storey	CO	3.00%	-14.00%	
Suarez- Bertoa	CO	13%		vs E5
ExxonMobile	CO	-13.40%		
ORNL 2012		-2.36%	-20.40%	
Average	CO	-3.10%	-24.20%	

Nox

	Pollutant	E10	E20	
Hilton and Duddy	NOx		-2.40%	
Karavalakis	NOx	13.60%	22.10%	
Storey	Nox	-42.00%	-71.00%	
Suarez- Bertoa	NOx	-24%		vs E5
ExxonMobile	NOx	5.10%		
ORNL 2012		34.30%	12.30%	
Average	NOx	-11.80%	-17.10%	

Benzene

	Pollutant	E10	E20	
Storey	PM	-6.00%	-36.00%	
ExxonMobile	Benzene	-11.50%		
Suarez- Bertoa	Benzene	-56.00%		vs E5
Karavalakis	Benzene	-29%	-36%	
Average	Benzene	-32.00%	-36.00%	

1,3 Butadiene

	Pollutant	E10	E20	
Karavalakis	1,3 –butadiene	-30%	-56%	
ExxonMobile	1,3 –butadiene	-5.80%		
Average	1,3 –butadiene	-18%	-56%	

Formaldehyde

	Pollutant	E10	E20	
ExxonMobile	Formaldehyde	19.30%		
Suarez- Bertoa	Formaldehyde	-50%		vs E5
Karavalakis	Formaldehyde	-44%	-36%	
Average	Formaldehyde	-24.90%	-36.00%	

Acetaldehyde

	Pollutant	E10	E20	
ExxonMobile	Acetaldehyde	159.00%		
Suarez- Bertoa	Acetaldehyde	75%		vs E5
Karavalakis	Acetaldehyde	16%	101%	
Average	Acetaldehyde	83.30%	101.00%	

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Cancer Risk Citations
致癌风险引证

- Ethanol generally decreases 1,3 Butadiene and Benzene, increases aldehydes but the weighted sum results in reduced cancer risk
  乙醇一般来说能够减少1,3丁二烯和苯，增加乙醛，但加权总和能够降低致癌风险
- Stein et al./SAE In. J. Engines / Volume 6, Issue 1 (May 2013):
  斯特恩等/SAE国际发动机期刊/第六卷，第一期（2013年5月）：
  - "Increased ethanol in gasoline should decrease emission of 1,3 butadiene and benzene and increase emissions of acetaldehyde and formaldehyde (later two due to incomplete combustion of ethanol). Due to much higher toxicity weighting factors, 1,3-butadiene and benzene dominate the weighted sum of these four toxics even in high ethanol content"
    "汽油中增加乙醇会减少1,3丁二烯和苯，而增加乙醛和甲醛的排放（后两种排放增加是乙醇不完全燃烧导致的）。由于1,3丁二烯和苯的毒性权重高得多，即使使用乙醇含量很高的汽油， 1,3丁二烯和苯的加权总和在四种毒性物质中也占大部分。"
- "Unnasch and Henderson (2014) "Change in Air Quality Impacts Associated with the Use of E15 Blends Instead of E10".
  乌纳什和赫德森（2014） " 用E15替代E10汽油引起的空气质量影响的变化"
- Analysis of CRC Study E80 showed that "a change from E10 to E15 results in a 6.6% reduction in toxic risk. Furthermore, a "reduction in 1,3 butadiene and benzene produces a decrease in impacts that is greater than their relative decrease in mass emissions"
  CRC对E80的分析研究显示"由E10变为E15会减少6.6%的有毒污染风险。此外， 1,3丁二烯和苯的减排与总排放减少相比能降低更多环境影响。

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Air Toxins Citations
空气中有毒物质引证

- Air Toxics Hot Spots Program Risk Assessment Guidelines; Part II; Technical Support; Document for Describing Available Cancer Potency Factors; May 2005; Secretary for Environmental Protection; California Environmental Protection Agency; Alan C. Lloyd, Ph.D.; Director Office of Environmental Health Hazard Assessment; Joan E. Denton, Ph.D.
  空气中有毒物质的热点项目风险评估指南；第二部分；技术支持；描述 现存致癌风险因素的文件；阿兰C.洛伊德博士；环境健康风险评估主管办公室；琼安 E.登顿博士
  - Describes all underlying cancer studies for unit risk factors
    介绍单位风险因素的所有基础致癌性研究
- Air Toxic Emissions from On-road Vehicles in MOVES2014; Assessment and Standards Division; Office of Transportation and Air Quality; U.S. Environmental Protection Agency; EPA-420-R-16-016; November 2016
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  - Describes that MOVES 2014 Air Toxic Analysis is based on Complex Model
    说明MOVES 2014空气中有毒物质分析是基于复合模型做出的
- Unnasch at al. Refinement of Selected Fuel-Cycle Emissions Analyses; Final Report; Prepared for California Air Resources Board; April 20, 2001
  乌纳什等“燃料周期排放分析精选”；报告最终版；提交给加利福尼亚州空气资源委员会；2001年4月20日
- Ambient and Emission Trends of Toxic Air Contaminants in California; Ralph Propper,* Patrick Wong, Son Bui, Jeff Austin, William Vance, Álvaro Alvarado, Bart Croes, and Dongmin Luo*; California Air Resources Board, Environ Sci Technol, 2015.
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  - Shows decreases of toxins over time in California
    显示加利福尼亚州的有毒污染物逐年降低

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