Cost-Benefit Analysis of China 6/VI Standards

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Main themes

- China's air pollution is at crisis levels.
- Motor vehicles are a large and growing contributor to this air pollution, especially in cities.
- China has made tremendous progress in developing and implementing comprehensive motor vehicle emission control programs.
- But more must be done!
- *In addition to strengthened compliance programs*, world-class "China 6/VI" standards are necessary for long-term pollution control.
- These standards are extremely cost-effective.

Outline

1. Introduction to the ICCT
2. Air pollution in China
3. Status of clean vehicles and fuels in China
4. China clean fuels and vehicles cost-benefit model overview
5. Future policies and scenarios
6. Results
7. Summary and conclusions

1 Introduction to the ICCT

ICCT's mission and activities

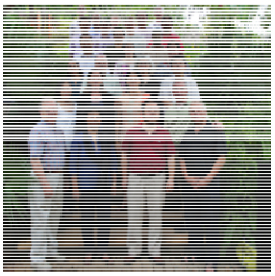
The mission of ICCT is to dramatically improve the environmental performance and efficiency of cars, trucks, buses, and transportation systems in order to protect and improve public health, the environment, and quality of life.

- Non-profit research organization
- Air Pollution and Climate Impacts
- Focus on regulatory policies and fiscal incentives
- Activity across modes including aviation and marine
- Global outreach, with special focus on largest markets
- 10+ years experience in China
- ICCT's founding Chair, Michael Walsh, received State Council Friendship Award in 2010

ICCT's council

The Council is made up of regulators and experts from leading auto markets around the world, including China.

Current Chinese participants include Tang Dagang (VECC-MEP), He Kebin (Tsinghua), Jin Yuefu (CATARC), Li Kunsheng (Beijing EPB).



ICCT Council of Participants – Kerala 2012

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Background – Air Pollution in China

Air pollution in China is at crisis levels

- In 2013, only 3 of 74 key cities in China met ambient air quality standards
- 2013 average $PM_{2.5}$ level in 74 cities: 72 μg/m³
  - Jing-Jin-Ji region: 106 μg/m³
- China's annual PM2.5 standard: 35 μg/m³
- WHO annual standard: 10 μg/m³

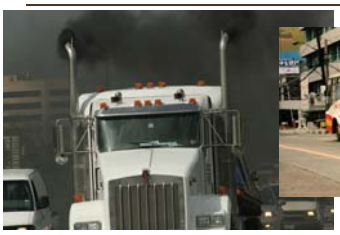
http://www.mep.gov.cn/gkml/hbb/qt/201403/t20140325_269848.htm
http://www.theatlantic.com/infocus/2013/01/chinas-toxic-sky/100449/

Motor vehicles are a large and growing source of air pollution

- Vehicle contribution to ambient $PM_{2.5}$ in major cities:
  - Beijing: 31%
  - Shanghai: 26%
  - Guangzhou: 23%
- Even higher fractions of NOx and VOCs


http://bjepb.gov.cn/bjepb/323265/340674/396253/index.html
http://news.ifeng.com/a/20140417/35834516_0.shtml
http://news.sina.com.cn/c/2014-02-14/151029471760.shtml

Diesel is a key problem…




World Health Organization

Diesel engine exhaust carcinogenic

12 June 2012 – After a week-long meeting of international experts, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization, today classified diesel engine exhaust as carcinogenic to humans (Group 1), based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Read the press release from IARC on diesel engine exhaust

…especially diesel trucks

Diesel trucks are just 5% of China's vehicle fleet → But they emit 61% of all vehicular particulate matter

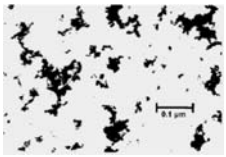
图3 按车型划分的汽车保有量构成

图15 各类型汽车的颗粒物（PM）排放量分担率

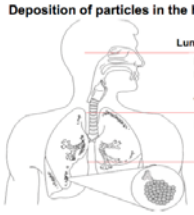
Source: MEP

Characteristics of diesel soot (a k a particulate matter (PM))

- Diesel PM is
  - Tiny
  - Dangerous
  - Mostly black carbon



Deposition of particles in the human lung



Lung structures	Particle size
Nose-pharynx	5-10 μm
Trachea	3-5 μm
Bronchi	2-3 μm
Bronchioli	1-2 μm
Alveoli	0.1-1 μm

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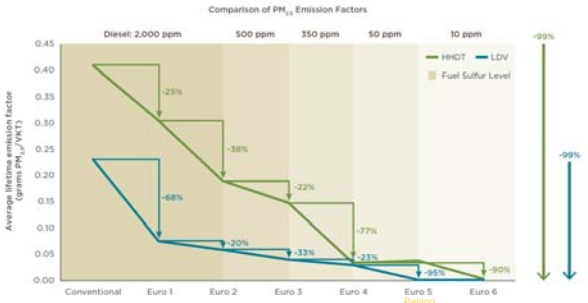
Status of Clean Vehicles and Fuels in China

Progressively stringent tailpipe emission standards are extremely effective at reducing emissions to near-zero levels



China 1999

China 2013

Beijing 2013 Shanghai 2014 Guangdong 2015

China ???

Vehicle standards

- Beginning in 2000, very rapid progress in China moving from China 0 → China 4 for light-duty gasoline vehicles and China 0 → China III for heavy-duty diesel vehicles.
- But nationwide progress has slowed recently, in part due to fuel quality concerns.
  - China IV HDDV standard delayed 2.5 years, finally implemented 7/1/13
  - China 4 LDDV standard delayed 3.5 years, expected implementation 1/1/15
  - China 5/V standards not expected until 2018
  - No timeline yet for nationwide China 6/VI
- Key regions moving forward with early local implementation of more stringent standards.

LDGV

Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	China 1				China 2				China 3			China 4				China 5					
Beijing	China 1		China 2			CN 3	China 4								China 5		Beijing 6				
Shanghai	China 1		China 2						China 3		China 4					China 5					
Guangzhou	China 1					China 2			China 3		China 4						China 5				
EU-27	Euro 3					Euro 4						Euro 5a			Euro 5b			Euro 6			
USA	NLEV					Tier 2 (phase-in)					Tier 2								Tier 3 (phase-in)		

HDDV

Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	China I				China II				China III					China IV					China V		
Beijing	China I			China II			China III			China IV				China V			Beijing VI				
Shanghai	China I			China II			China III			China IV				China V							
Guangzhou	China I					China II	China III				China IV					China V					
EU-27	Euro III						Euro IV				Euro V					Euro VI					
USA	US 1998				US 2004				US 2007			US 2010									

Dates shown are implementation dates for all vehicle sales and registrations; in some cases type approval implementation dates are earlier.

Fuel standards

- In 2013, breakthrough timeline for ULSF supply announced in China.
  - Nationwide:
    - 50ppm gasoline by end of 2013; 50ppm diesel by end of 2014
    - 10ppm gasoline/diesel by end of 2017
  - Three key regions:
    - 10ppm gasoline/diesel by end of 2015
- In October 2013, NDRC issued price revisions – higher prices for higher quality fuel. A critical step towards ensuring timeline is met.
- Major progress: fuel quality basically removed as a long-term bottleneck to more stringent vehicle standards.

Gasoline sulfur levels

Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	500										150				50				10		
Beijing	500					150		50				10									
Shanghai	500					150				50				10							
Guangzhou	500						150				50					10					
EU-27	150				50					10											
USA	30/300										30 (avg) / 80 (cap)								10		

Diesel sulfur levels

Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	2000						500 (voluntary)						350			50			10		
Beijing	2000					350		50				10									
Shanghai	2000					500		350			50				10						
Guangzhou	2000					500		350			50					10					
EU-27	350				50					10											
USA	500						15														

China V vs. China VI

- Compared to China V, China VI emission limits for heavy-duty diesel vehicles:
  - NOx limit reduced 80% from 2.0 to 0.4 g/kWh
  - PM limit reduced 50% from 0.02 to 0.01 g/kWh
- Most importantly, to meet this PM limit, diesel vehicles must install wall-flow diesel particulate filters (DPFs), which trap 99% of particles including black carbon.
- China VI is the key to virtually eliminating pollution emissions from heavy-duty diesel vehicles.

Efficacy of DPF

Current status and future prospects

- China has made impressive progress:
  - China 4/IV vehicle standards in place nationwide now
  - China 5/V vehicle standards coming nationwide in 2018
  - Nationwide 10ppm sulfur fuel by end of 2017
  - More aggressive action in key regions
- However, more must be done to reduce air pollution and improve public health.

4 **China clean fuels and vehicles cost-benefit model overview**

Overview

- ICCT's China model is a customized version of our global Roadmap Model
  - Global Roadmap Model is peer-reviewed, and publicly available with documentation at http://theicct.org/global-transportation-roadmap-model
- Three modules:
  - **Emissions:** GHG and local air pollutant emissions
  - **Health and climate impacts:** premature mortality, and CO_{2e}
  - **Technology costs:** of vehicles and fuels
- Multiple scenarios are run assuming different policy implementation dates
- Modules are combined to estimate overall benefit/cost ratios

Scope – modes, fuels, pollutants

	Current	Future
Modes	On-road: cars, trucks, buses, motorcycles	Marine, locomotives, aviation Nonroad equipment
Fuels	Gasoline, diesel, natural gas	Electricity as transportation fuel
Pollutants	**Air:** PM2.5, NOx, HC, CO, N2O, SO4 **Climate:** CO2, BC, OC, CH4	

Scope – regions

- Multiple regions modeled separately; national results are sum of individual regions
- Regions were chosen anticipating where sub-national aggressive action is likely in the coming years
- Regions:
  1. Beijing
  2. Hebei-Tianjin (greater Beijing region)
  3. Shanghai
  4. Jiangsu-Zhejiang (Yangtze River Delta region)
  5. Guangzhou
  6. Shenzhen
  7. Rest of Pearl River Delta region
  8. Rest of Guangdong
  9. Rest of China
- Each region has unique data inputs for vehicle population, VKT, implementation dates for vehicle emissions and fuel quality standards, and scrappage scenarios

Data sources

- Base national-level data sources for Global Roadmap:
  - China Automotive Technology and Research Center (CATARC)
  - Tsinghua University FEEI model
  - International Energy Agency MoMo model
- Global Roadmap goes through regular, rigorous data validation
- China model includes new, local-level vehicle population and VKT data from Vehicle Emission Control Center, Ministry of Environmental Protection, China (VECC-MEP)
- Emission factors are ICCT-derived based on COPERT
- Goal is for results to be independent, but validated by local partners
  - Extensive data validation conducted with VECC-MEP in fall 2013
- Validated results mean implications and recommendations are more likely to be accepted in China

Scope – policies

- Stringent new vehicle emission standards
- Fuel quality standards
- Scrappage/replacement programs
- Fuel consumption standards

Cost-benefit evaluation

- Cost-benefit analysis is a widespread and mature framework for evaluating public policies over a long-term time scale
- Costs: What government pays to implement a new regulation and what society pays to comply with this new regulation
- Benefits: Potential economic, environmental, public health, safety, and or other advantages
- Examples of international cost benefit analysis of stringent vehicle and fuel policies:

Region	Policy	Costs	Benefits	Ratio (Benefits: Costs)	Source
USA	Tier 2	$5,3 billion	$25,2 billion	5:1	EPA, 1999
USA	Tier 3	$1,5 billion	$6,7-$19 billion	4:1 to 13:1	EPA, 2014
Mexico	Tier 2-equivalent	<$1 billion	$7 billion	8:1	INE, 2006
Sub-Saharan Africa	Low sulfur fuel supply	$2.7 billion	$25 billion	9:1	UNEP, 2009
India	Ultralow sulfur fuel supply and world class emission standards	$14.2 billion	$107 billion	8:1	Bansal and Bandivadekar, 2013

Cost calculations

- Costs include additional technology costs for motor vehicle emission controls as well as costs for refining higher quality fuel (capital and operating costs)
- Costs are based on published research and are localized to China
- Example incremental vehicle technology costs:

	Large Buses	Taxis	Private Cars	Motor-cycles	Light Trucks	Heavy Trucks
Fuel	Diesel	Gasoline	Gasoline	Gasoline	Diesel	Diesel
Euro 1/I	$158	$142	$142	$29	$150	$174
Euro 2/II	$210	$204	$204	$35	$200	$232
Euro 3/III	$683	$326	$326	$51	$650	$752
Euro 4/IV	$2,727	$351	$351	$51	$2,414	$4,991
Euro 5/V	$2,958	$361	$361	$54	$2,632	$5,384
Euro 6/VI	$4,700	$361	$361	$100	$4,190	$9,075

*Costs are summarized as European Standards equivalent.

- Average costs to upgrade refineries and produce 10ppm sulfur fuel in China:
  - Gasoline: 0.7 U.S cents (0.04 RMB) per liter
  - Diesel: 1.7 U.S cents (0.11 RMB) per liter

Health impacts calculations

- Calculates exposure to primary $PM_{2.5}$ in urban areas and resulting health impacts
  - Estimates the share of emissions in **urban areas**
  - Translates urban emissions to **urban concentrations**
  - Simplified approach uses intake fraction as opposed to dispersion/chemical transport modeling
  - Changes in urban concentrations used to estimate subsequent changes in premature mortalities based on population, baseline mortality rates, and dose-response functions
  - Economic costs of premature mortalities estimated using China-specific Value of Statistical Life (VSL) methodology
  - Health impacts estimates are highly conservative, because only estimating impacts from primary PM emissions

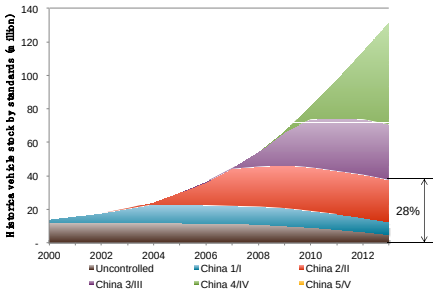
5 Future policies and Scenarios

Future scenarios (overview)

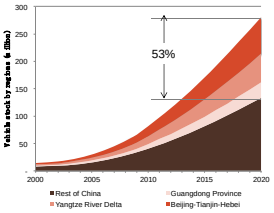
1. Current
   - No additional progress beyond what has already been implemented (including China IV in July 2013)
2. Baseline
   - All announced or expected policies go into effect, including China 5/V starting from 2018
   - Limited early regional action
   - Some limited vehicle scrappage programs
3. Improved
   - China 6/VI is introduced nationwide in 2021, key regions in 2018
   - More aggressive scrappage programs
4. World Class
   - China 5/VI implemented early (2015 nationwide)
   - China 6/VI implemented early (2018 nationwide, 2016 in key regions)

6 | Results

Vehicle Stock (historical by emission standards)

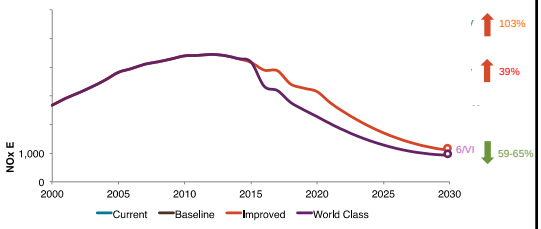


Vehicle market development trend



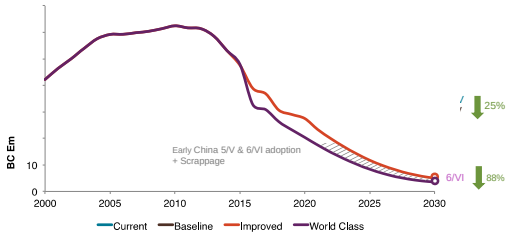
- We project ~275 million vehicles in China by 2020
- Regional focus: early, aggressive action in three main regions can affect at least half of the vehicle market in China

Emissions trends (national NO_x)



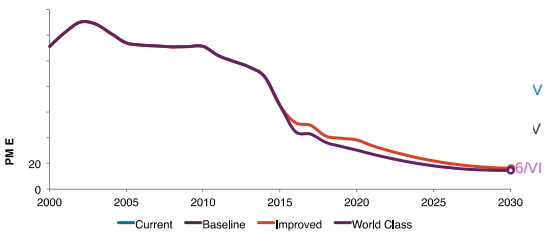
- China 5/V standards (Baseline) are effective at preventing long-term emissions increases.
- However, China 6/VI standards are required for medium and long-term emissions reductions.
- Early adoption shows impacts that last through 2030

Emissions trends (national BC)



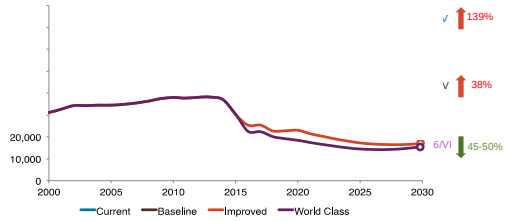
- China existing policies help present Black Carbon increase only in short-term.
- By implementing China 6/VI, BC in 2030 can be reduced by nearly 90% compared to 2000.
- With scrappage and early adoption, reduction impacts are more significant especially in short-term.

Emissions trends (national $PM_{2.5}$)



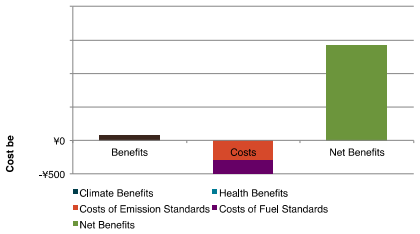
- China's existing policies, especially early desulfurization, have resulted in steadily decreasing total $PM_{2.5}$ emissions from vehicles in short-term
- However, only China 6/VI scenarios result in long-term emissions reductions.

National health impacts



- Compared with 2000, there will be double premature mortalities from on-road transportation in 2030 if no further policies are implemented
- By implementing advanced vehicle regulations (China 6/VI), premature mortalities could be reduced 45-50% compared with 2000
- Premature mortalities increase in Baseline scenario because as urban populations grow, more are exposed to the high urban pollution levels
- Note: these are conservative estimates based on primary $PM_{2.5}$ emissions in urban areas only.

Benefit-cost ratio in World Class scenario



- In the world-class scenario, the benefits are over 4 times greater than the costs in 2040, with most of the benefits coming from reduced health impacts, and this ratio will increase to 7 in 2050.
- This result is parallel to US and EU experience: the overall societal benefits of motor vehicle emission control policies are generally many times greater than the overall costs.

7 **Summary and Conclusions**

Summary and Conclusions

- The ICCT has built a validated model to estimate emissions, costs, and benefits of Chinese motor vehicle emission control policies.
- The purpose of the model is to support policy makers to understand the impacts of stringent motor vehicle control programs and scenarios.
- China 5/V standards are effective at stopping long-term emissions *growth* from China's motor vehicles.
- However, due to continued vehicle population increases, China 6/VI standards are required to achieve long-term emissions *reductions*.
- Aggressive scrappage and early regional adoption can achieve short-term rapid emissions reductions, but nationwide China 6/VI standards are required for long-term control.
- Conservatively, the long-term benefits of the China 6/VI standards far outweigh the costs by a factor of 7 to 1.

Final Thought

- ULSF enables the use of filters, required by China 6/VI standards, which trap 99% of diesel particles.
- Filters belong on tailpipes, not people!