附录 A: 术语表

ANL:美国阿贡国家实验室

BAU: 常规管理

CFM: 中国机动车模型

CAA: 清洁空气法

CARB: 加州空气资源局

CO: 一氧化碳

DPF: 柴油车颗粒物捕集器

EGR:废气再循环系统

EU:欧盟

EUDC:额外城市行驶工况

GDP: 国内生产总值

GHG:温室气体

HC:碳氢化合物

HCHO: 甲醛

HDV/HD: 重型车

HIA: 健康影响评估工具

ICE:内燃机

LDV/LD: 轻型车

MEP: 环境保护部

NEDC: 新的欧洲行驶工况

NMOG: 非甲烷有机化合物

NOx: 氮氧化物

NTE:排放上限

OBD: 车载诊断系统

PEMS: 便携式排放测量系统

PM:颗粒物

RFG: 新配方汽油

SCR: 选择性催化还原装置

SEA: 选择性达标审核

US EPA: 美国国家环境保护局

THC:总碳氢化合物

TWC: 三元催化器

VECC:机动车排污监控中心

VOCs:挥发性有机化合物

Appendix A: List of acronyms

ANL: Argonne National Laboratory

BAU: Business as usual

CFM: China Fleet Model

CAA: Clean Air Act

CARB: California Air Resources Board

CO: Carbon monoxide

DPF: Diesel particle filter

EGR: Exhaust gas recirculation

EU: European Union

EUDC: Extra urban driving cycle

GDP: Gross domestic product

GHG: Greenhouse gases

HC: Hydrocarbon(s)

HCHO: Formaldehyde

HDV/HD: Heavy-duty vehicle

HIA: Health impact assessment tool

ICE: Internal combustion engine

LDV/LD: Light-duty vehicle

MEP: Ministry of Environmental Protection

NEDC: New European driving cycle

NMOG: Non methane organic gases

NOx: Oxides of nitrogen

NTE: Not-to- exceed

OBD: On-board emission diagnostics

PEMS: Portable emissions measurement system

PM: Particulate matter

RFG: Reformulate gasoline

SCR: Selective catalytic reduction

SEA: Selective enforcement audit

US EPA: United States Environmental Protection Agency

THC: Total hydrocarbons

TWC: Three-way catalyst

VECC: Vehicle Emission Control Center

VOCs: Volatile organic compounds

附录 B- 中国机动车模型及健康影响评估方法学，数据来源和相关假设条件

B. 1 中国机动车模型（CFM）

中国机动车模型可以对整个中国机动车车辆群体在过去及将来不同政策情景下的排放量和燃料消耗进行评估。此模型包括所有影响空气质量和气候变化的主要排放污染物，如：一氧化碳，氮氧化物，总碳氢化合物，颗粒物，二氧化碳，氧化亚氮，甲烷以及黑炭。模型用户可以自定义包括新车排放标准，燃料硫含量，车辆燃料限值等政策情景。同样，模型用户可以调节政策的执行实施效果及电动车的推广程度。

车辆组成参照下表的车辆分类标准。

表 AB1: CFM中的车辆类型

名称	缩写	定义
重型卡车	HDT	车长大于等于6米，总质量大于等于12000公斤
中型卡车	MDT	车长大于等于6米，总质量大于等于4500公斤且小于12000公斤
轻型卡车	LDT	车长小于6米，总质量小于4500公斤
微型卡车	MT	车长小于3..5米，总质量小于750公斤
重型巴士	HDB	车长大于6米,乘坐人数大于20人
中型巴士	MDB	车长小于6米，乘坐人数10-19人
轻型巴士	LDB	车长小于6米，乘坐人数小于等于9人
微型巴士	MB	车长小于3.5米
大型轿车	Lcar	车长小于3.5米，发动机排量大于1.6升
小型轿车	Scar	车长小于3.5米，发动机排量小于1.6升
摩托车	MC	城市或者郊区摩托车
低速汽车	RV	三或四轮

CFM模型评价以下种类的排放污染物：氮氧化物 (NO_x)，颗粒物 (PM)，一氧化碳 (CO)，碳氢化合物 (HC)，氧化亚氮 (N_2O)，甲烷(CH_4)，黑炭[131] (BC)以及二氧化碳(CO_2)。燃料方面，模型只针对汽油和柴油燃料，并没有对其他机动车燃料（如：天然气，液化石油气，甲醇以及生物燃料[132]）进行评估。

下面是CFM中关键政策的时间轴以及情景设置：

- 机动车排气污染物标准的实施，如，国IV, V, VI以及延伸
- 汽柴油硫含量水平
- 政策执行实施的广度和严格程度的增强
- 燃料经济性的改善
- 电动汽车的推广

131 黑炭是颗粒物中的具有强吸光性的固体部分，也是一种强效的气候变暖气溶胶。

132 CFM模型将来自电网的电力作为一种未来情景中的燃料囊括进来，但是并没有对这类机动车消耗的总能源(kWh)进行评估。在未来的电动车汽车的相关讨论部分，电动汽车模块评价了上游电力生产中造成的污染物(NOx, PM, CO, HC, 和 CO_2)的排放情况。

Appendix B- China fleet model and health impact assessment methodology, data sources and assumptions

B. 1 China Fleet Model

The CFM can estimate emissions and fuel consumption from the entire Chinese vehicle fleet under a variety of past and future policy scenarios. The model includes all the major emissions of concern for air quality and climate change such as carbon monoxide, oxides of nitrogen, total hydrocarbon, particulate matter, carbon dioxide, nitrous oxide, methane and black carbon. The model user can customize policy scenarios that cover new vehicle emission standard levels, fuel sulfur concentration and vehicle fuel consumption limits. The model user can also adjust the effectiveness of enforcement and compliance programs and the penetration of all electric vehicles.

The vehicle fleet is represented using the following standardized vehicle groupings.

Table AB1: Vehicle categories in the CFM

NAME	ABBREVIATION	DESCRIPTION
Heavy-duty truck	HDT	Longer than 6m and greater than 12,000kg
Medium-duty truck	MDT	Longer than 6m and between 4,500 and 12,000kg
Light-duty truck	LDT	Shorter than 6m and less than 4,500kg
Mini-truck	MT	Shorter than 3.5m and less than 750kg
Heavy-duty bus	HDB	Longer than 6m and holding 20 or more people
Medium-duty bus	MDB	Shorter than 6m and holding 10-19 people
Light-duty bus	LDB	Shorter than 6m and holding 9 or less people
Mini-bus	MB	Shorter than 3.5m
Large car	Lcar	Shorter than 3.5m and engine displacement > 1.6 liter
Small car	Scar	Shorter than 3.5m and engine displacement < 1.6 liter
Motorcycle	MC	Urban or rural motorcycle
Rural vehicles	RV	3 and 4-wheelers

The CFM estimates the following emitted species: oxides of nitrogen (NOx), particulate matter (PM), carbon monoxide (CO), hydrocarbons (HC), nitrous oxide (N_2O), methane (CH_4), black carbon[131] (BC), and carbon dioxide (CO_2). For fuels, the model is limited to gasoline and diesel and does not account for other vehicle fuels such as natural gas, liquid petroleum gas, methanol, and biofuels[132].

- The following are the key policy timelines and scenario features of the CFM:
- Vehicle emission standard adoption, i.e. China IV, V, VI and beyond
- Gasoline and diesel sulfur levels
- Increased breadth and stringency of compliance and enforcement programs
- Fuel economy improvements
- Electric vehicle penetration

131 Black carbon is the solid fraction of PM that strongly absorbs light and is a potent climate warming aerosol.

132 The CFM does include electricity from the grid as a fuel source in future scenarios but does not estimate the total energy (kWh) consumed by these vehicles. As is discussed further in the 'Electricity' section, the electric vehicle module estimates upstream emissions (NO_x, PM, CO, HC, and CO_2) resulting from electricity production.

接下来三部分将会介绍CFM评价以下三方面的方法论：1)标准限定的污染物排放量评估; 2)燃料消耗量以及二氧化碳排放量评估；以及 3)电动汽车相关动力上游的污染物排放量评估。

机动车标准限定的污染物排放量的评估

用来评价非CO_2排放污染物的模块是基于机动车活动排放因子组建的，以下公式可以对其进行介绍：

[机动车保有量] * [机动车排放因子, g/km] * [机动车行驶里程, km] = 排放量 (单位)

(公式 1)

表AB1中的每种机动车种类在CFM模型中都有独有的工作表(Microsoft Excel) 来评价NOx，PM、CO、HC、N_2O、CH_4、BC排放量[133] 。

在模型中用户界面的‘输入’表中，用户可以选择使用"ICCT"或者“VECC-ICCT综合”排放因子。ICCT排放因子主要是由Michael Walsh开发的，同时也包括了由加州空气资源局开发的排放模型(EMFAC2007)中的数据。VECC-ICCT 排放因子由机动车排污监控中心(VECC)开发的NOx，PM，CO以及 HC数据，以及采用与ICCT排放因子设置相同的N_2O, CH_4排放因子共同组成。在ICCT和 VECC-ICCT数据中, BC 排放因子都被确定为颗粒物排放因子的一定百分比。具体BC占PM的百分比是通过咨询加州空气资源局的相关专家来确定的[134]。本次评价的所有结果全部采用的是ICCT排放因子。

克每公里 (g/km)排放因子极好的诠释了ICCT对一辆车全生命周期平均排放率的评价。另一方面，ICCT正在尝试了解车辆排放控制装置的劣化情况对单种污染物排放因子的影响。在表AB1中的每种车型并不是都有相应的排放因子，但是机动车可以按照表AB2中的分组中获得各车型组对应排放因子。

133 由于缺少相关排放因子数据，CFM模型没有进行低速汽车N_2O 以及 CH_4的评价。

134 Alberto Ayalo, CARB, 2008年10月17日。

The next three sections will describe the methodology of the CFM in estimating 1) criteria pollutant emissions, 2) fuel consumption and carbon dioxide emissions, and 3) the upstream emissions associated with powering electric vehicles.

Vehicle Criteria Pollutant Emissions

The modules for estimating non-CO_2 emissions are based on vehicle activity emission factors and are summarized in the following equation:

[vehicle population] * [vehicle specific emission factors, g/km] * [vehicle activity, km] = mass emissions (units)

(Equation 1)

Each vehicle category in Table AB1 has its own worksheet in the CFM workbook (Microsoft Excel) that estimates NOx, PM, CO, HC, N_2O, CH_4, and BC emissions[133].

On the 'Inputs' sheet, which is the user interface for the model, the user can choose between "ICCT" and "VECC-ICCT hybrid" emission factors. The ICCT emission factors were primarily developed by Michael Walsh, but also include values that were derived from the California Air Resources Board's EMission FACtor (EMFAC2007) model. The VECC-ICCT emission factors are comprised of NOx, PM, CO, and HC data that was developed by the Vehicle Emission Control Center (VECC) and N_2O, CH_4 data that is identical to the ICCT emission factor set. For both the ICCT and VECC-ICCT data sets, BC emission factors are a percentage of the PM emission factors. The fraction of PM that is BC is based on communications with California Air Resources Board experts[134]. The ICCT emission factors were used to develop all of the results in the Retrospective Study.

The gram per kilometer (g/km) emission factors represent ICCT's best estimate of an average emission rate over a full vehicle lifetime. In other words, ICCT is attempting to capture the deterioration of the vehicle's emission control system over time in one single emission factor. There are not individual emission factors for every vehicle type in Table AB1; rather, vehicles are binned according to the designations in Table AB2.

133 Due to lack of emission factor data, the CFM does not have N_2O or CH_4 estimates for rural vehicles.

134 Alberto Ayalo, CARB, October 17, 2008.

表AB2: 排放因子模型的机动车分类

排放因子分组	详细车辆分类	
重型柴油车 (HDDV)	HDT (柴油)	重型柴油卡车
	HDB (柴油)	重型柴油巴士
重型汽油车 (HDGV)	HDT (汽油)	重型汽油卡车
	HDB (汽油)	重型汽油巴士
中型柴油车 (MDDV)	MDT (柴油)	中型柴油卡车
	MDB (柴油)	中型柴油巴士
中型汽油车 (MDGV)	MDT (汽油)	中型汽油卡车
	MDB (汽油)	中型汽油巴士
轻型柴油车(LDDV)	LDT (柴油)	轻型柴油卡车
	MT (柴油)	微型柴油卡车
	LDB (柴油)	轻型柴油巴士
	MB (柴油)	微型柴油巴士
	Lcar (柴油)	大型柴油轿车
	Scar (柴油)	小型柴油轿车
轻型汽油车 (LDGV)	LDT (汽油)	轻型汽油卡车
	MT (汽油)	微型汽油卡车
	LDB (汽油)	轻型汽油巴士
	MB (汽油)	微型汽油巴士
	Lcar (汽油)	大型汽油轿车
	Scar (汽油)	小型汽油轿车
摩托车 (MC)	MC (汽油)	汽油摩托车
低速汽车(RV)	RV (柴油)	柴油低速汽车

对于轻型，中型以及重型车，基于逐步提高的欧洲标准共分九种不同的排放水平[135]。表AB3是对轻型汽油车排放因子设置的一个示例。其中，“无管理”类是指没有采用任何排放控制措施的机动车的排放率。“发动机改良（Engine Mods）”类体现了国I 标准之前发动机技术带来的改善。针对轻型车，“超低排放车” 类是按照最理想情况预测的欧7标准。超低排放车中HC，CO和NOx 的数据源自EMFAC2007，代表了加州典型的2010年型乘用车的水平。PM，N_2O，CH_4和 BC的数据是在欧6数据的基础上简单的减半得到的。对中重型车而言，欧VI标准的数值是每种污染物在欧VI的基础上减半得到的。低速汽车只有两种排放分类：分别是三轮和四轮低速汽车的排放水平。评价分析中低速汽车排放因子是基于清华大学环境科学与工程学院贺克斌教授研究团队提供的数据，包括HC，CO， NOx，PM (其中认为颗粒物中90%为BC)。

135 与世界上许多国家类似，中国选择了参照欧盟制定的机动车和燃料标准的路线。从而，中国的机动车排放控制和燃料质量控制都是以欧洲标准作为蓝本的。轻型和重型车的排放阶段分别用阿拉伯数字和罗马数字进行标注。标准严格程度的加深由数值的增加来表示。

Table AB2: Vehicle groupings for emission factor modeling

EMISSION FACTOR GROUP	SPECIFIC VEHICLES INCLUDED	
Heavy-duty diesel vehicle (HDDV)	HDT (diesel)	Heavy-duty diesel truck
	HDB (diesel)	Heavy-duty diesel bus
Heavy-duty gas vehicle (HDGV)	HDT (gas)	Heavy-duty gas truck
	HDB (gas)	Heavy-duty gas bus
Medium-duty diesel vehicle (MDDV)	MDT (diesel)	Medium-duty diesel truck
	MDB (diesel)	Medium-duty diesel bus
Medium-duty gas vehicle (MDGV)	MDT (gas)	Medium-duty gas truck
	MDB (gas)	Medium-duty gas bus
Light-duty diesel vehicle (LDDV)	LDT (diesel)	Light-duty diesel truck
	MT (diesel)	Mini diesel truck
	LDB (diesel)	Light-duty diesel bus
	MB (diesel)	Mini diesel bus
	Lcar (diesel)	Large diesel car
	Scar (diesel)	Small diesel car
Light-duty gas vehicle (LDGV)	LDT (gas)	Light-duty gas truck
	MT (gas)	Mini gas truck
	LDB (gas)	Light-duty gas bus
	MB (gas)	Mini gas bus
	Lcar (gas)	Large gas car
	Scar (gas)	Small gas car
Motorcycle (MC)	MC (gas)	Gas motorcycle
Rural vehicle (RV)	RV (diesel)	Diesel rural vehicle

For light-, medium- and heavy-duty vehicles, there are nine different emission levels based on a progression through the 'Euro'standards[135]. Table AB3 is an example emission factor set for light-duty gasoline vehicles. The "Uncontrolled" level represents emission rates from a vehicle without any emission control systems in place, and "Engine Mods" category characterizes advances in engine technology that preceded the China I standard. For light-duty vehicles, the "SULEV" category is the best guess for ‘Euro 7' levels. For HC, CO, and NOx, the Super Low Emission Vehicle (SULEV) values are derived from EMFAC2007 and represent a typical model year 2010 passenger car in California. Values for PM, N_2O, and CH_4, and BC are simply half of the Euro 6 values. For medium- and heavy-duty vehicles, Euro VII values for every pollutant are estimated as being half of Euro VI values. Rural vehicles only have two emission levels: one each for 3- and 4-wheeled vehicles. The rural vehicle emission factor set used in the Retrospective analysis is based on data from Prof. He Kebin's research group at the Department of Environmental Science and Engineering at Tsinghua University and includes HC, CO, NO_x, PM (and BC is estimate to be 90% of the PM value).

135 Like many countries around the world, China has chosen to mirror its vehicle and fuels programs after those set forth by the European Commission. As such, the ‘Euro' standards are the blueprint for the ‘China' vehicle emission limits and fuel quality guidelines. The Arabic numerals and Roman numerals denote standards for light- and heavy-duty vehicles respectively. Increasing number values imply greater stringency of the standard.

表AB3: 轻型汽油车排放因子(g/km)

	无管理	发动机改良	国 I	国 II	国 III	国IV	国 V	国VI	“超低排放车”
THC	8.373	4.174	1.203	0.620	0.364	0.182	0.182	0.182	0.036
CO	59.533	37.253	13.736	11.124	7.800	3.391	3.391	3.391	0.469
NOx	2.137	2.701	0.975	0.498	0.599	0.159	0.119	0.119	0.029
PM	0.186	0.186	0.025	0.025	0.012	0.001	0.001	0.001	0.000
N2O	0.010	0.010	0.032	0.051	0.029	0.018	0.018	0.018	0.009
CH4	0.135	0.120	0.070	0.030	0.040	0.025	0.025	0.025	0.013
BC	0.112	0.112	0.015	0.015	0.006	0.000	0.000	0.000	0.000

每个机动车排放量工作表在2000-2030年间，以5年为间隔选取目标年，对其排放量进行评估。对每个目标年来说，计算其排放量用到的每个模型年（MY）都会得到“输入”表格赋予一个排放标准的阶段。举例来说，由于2005年全国范围实施国II阶段标准，2007年全国范围实施国III阶段标准，模型会赋予模型年MY2005和MY2006国II的排放因子，赋予模型年MY2007国III的排放因子。

所有的机动车排放量工作表都具有相同的组织架构。图AB1显示了数据和计算的流程。

Table AB3: Emission factors (g/km) for a light-duty gasoline vehicle

	UNCONTROLLED	ENGINE MODS	CHINA I	CHINA II	CHINA III	CHINA IV	CHINA V	CHINA VI	"SULEV"
THC	8.373	4.174	1.203	0.620	0.364	0.182	0.182	0.182	0.036
CO	59.533	37.253	13.736	11.124	7.800	3.391	3.391	3.391	0.469
NOx	2.137	2.701	0.975	0.498	0.599	0.159	0.119	0.119	0.029
PM	0.186	0.186	0.025	0.025	0.012	0.001	0.001	0.001	0.000
N2O	0.010	0.010	0.032	0.051	0.029	0.018	0.018	0.018	0.009
CH4	0.135	0.120	0.070	0.030	0.040	0.025	0.025	0.025	0.013
BC	0.112	0.112	0.015	0.015	0.006	0.000	0.000	0.000	0.000

Each vehicle emissions worksheet estimates emissions at five-year intervals between 2000 and 2030. For each year, every model year (MY) is assigned an emission level based on controls on the 'Inputs' sheet. For example, since China II was adopted nationwide in 2005 and China III in 2007, the model assigns China II emission factors to MY 2005 and MY 2006 vehicles and China III emission factors to MY 2007 vehicles.

All of vehicle emission sheets are structured identically, and the flow of data and calculations is shown below in Figure AB1.

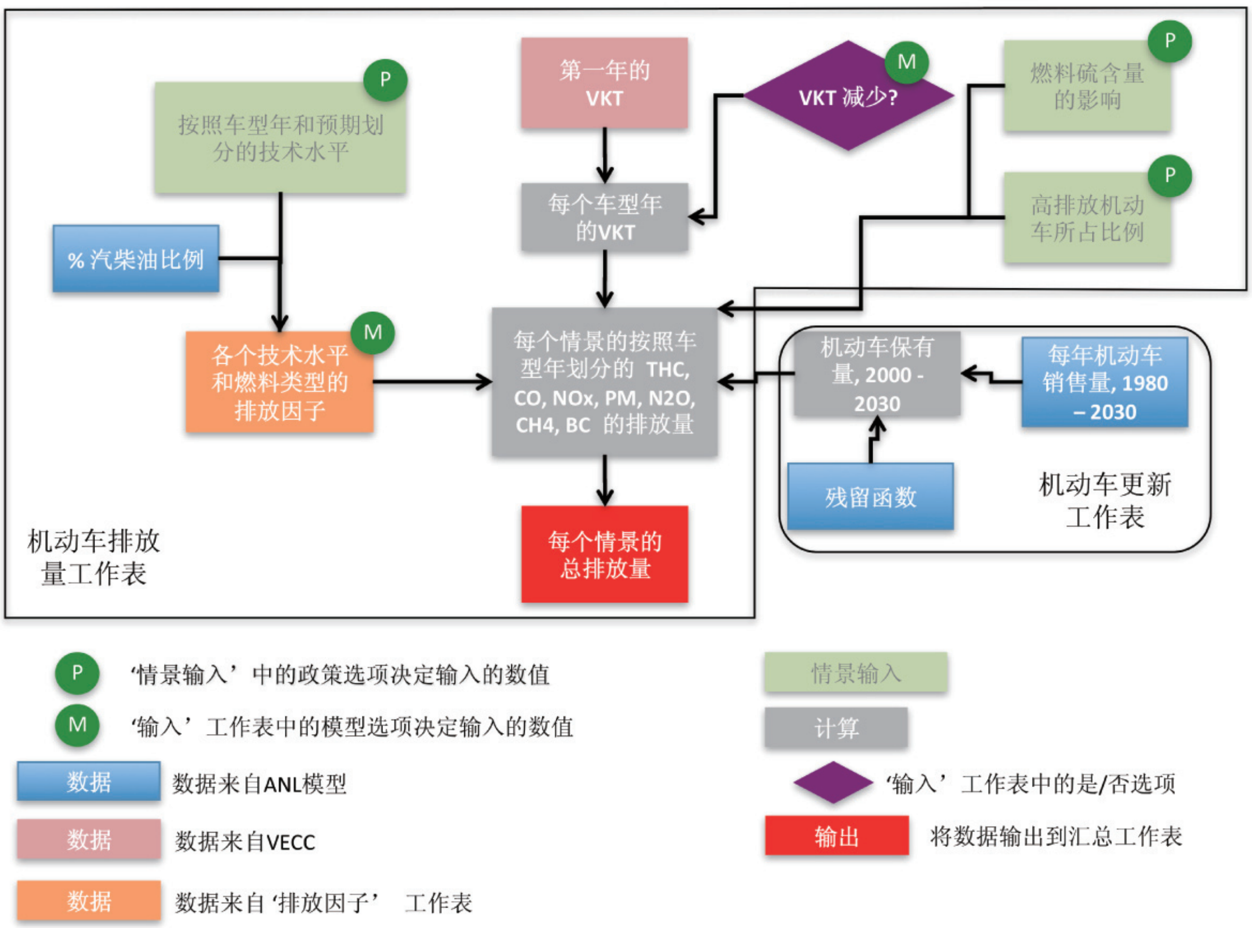


图 AB1: 排放量工作表流程图

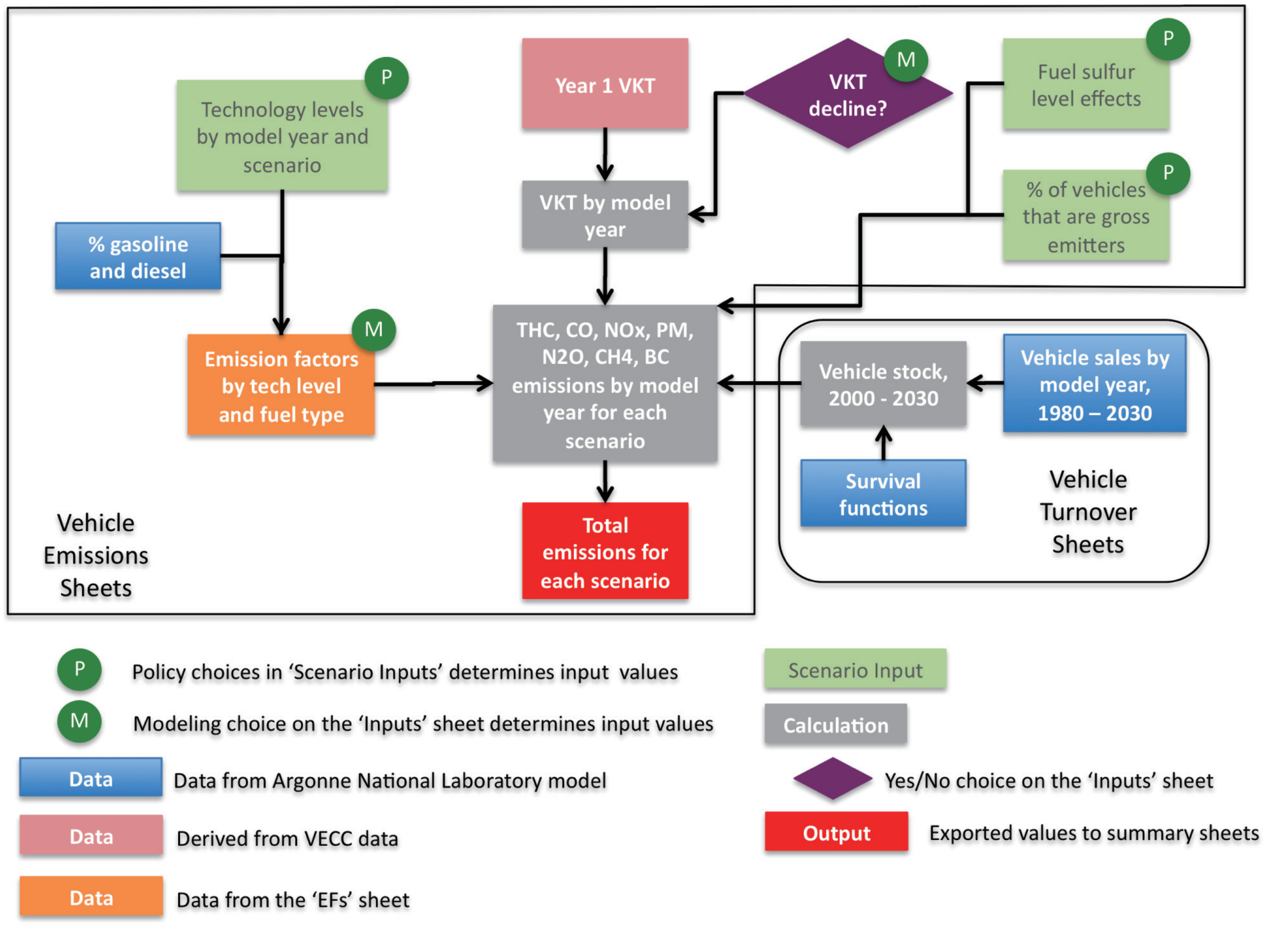


Figure AB1: Flow diagram for vehicle emissions sheets

如上图所示，除排放因子之外，排放量计算还需要另外4个输入项。

1. VKT （车辆行驶里程）– 每个模型年的年行驶里程是基于VECC的2007年行驶里程数值得到的。2007年以外其他模型年的行驶里程采用以2007年为基准，乘以霍红博士模型（即ANL 模型）[136] 中目标年与2007年VKT比例的方法得到。例如：

- VECC 2007 VKT = 10,000 km
- ANL 2007 VKT = 11,000 km
- ANL 2010 VKT = 12,000 km
- CFM 2010 VKT = 10,000 * (12,000/11,000) = 10,909 km

用户可以选择是否使VKT随着车龄的增加而减少。通常来说，一辆车的VKT会随着他的生命周期而减少。目前ICCT团队尚且没有开发出适合中国机动车的VKT的衰减曲线。如果用户选择VKT会衰减（评价研究中选择VKT会衰减），VKT会按照下面所给的2001年EPA的报告[137]的公式进行衰减。

$VKT_t = VKT_1 * (\exp \wedge (\alpha * t))$ （公式 2）

其中 VKTt ＝t年的VKT

VKT1 =第一年的 VKT

α = VKT衰减因子 (用户可以调节这个数值)

t =车龄

2. 硫含量影响–目前燃料中硫含量对于排放水平有着一定影响。为了评价硫含量对于中国汽柴油车排放的影响程度，引用了刘欢等人[138] 2008年发表论文中表 2和表 3。下表是以氮氧化物为例介绍数据是如何组织起来的。

表AB4: 汽油车氮氧化物排放变化的百分比

硫含量	国 I	国II	国III	国 IV	国 V
800 ppm	100.0%	108.4%	129.1%	257.2%	257.2%
500 ppm	98.6%	100.0%	122.5%	207.9%	207.9%
150 ppm	95.0%	89.6%	100.0%	136.4%	136.4%
50 ppm	91.7%	86.0%	93.7%	100.0%	100.0%
10 ppm	86.8%	63.3%	88.6%	88.3%	88.3%

3. 机动车保有量 – 机动车现存量函数直接采用了ANL模型中相应部分。对每种车型（不包括低速汽车）都有三种关于现存量的设置： 1)车型年1997之前, 2) 车型年1997-2020，以及 3)车型年2020以后。

4. 高排放车辆 –研究表明车队中一小部分高排放车贡献了很大部分的排放量[139]。 在“输入”工作表中，用户可以自行定义车队中高排放车（即在任意车型年，其排放因子为“无管理”类的车）的比例。对高排放车辆比例的选择是用来模拟相关政策的管理和实施情况的。政策越有效，车队中高排放车辆的数量越少。

136 报告采用了霍红博士在美国阿贡国家实验室建立的模型，“2050年中国机动车增长，燃料需求量，CO_2排放量的预测（Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO_2 Emissions through 2050）”。

137 Jackson, T. 2001. MOBILE6的车队特征数据: MOBILE6中使用的车龄分类的开发与使用，平均年行驶里程累积速率，以及机动车保有量统计的设计。美国国家环境保护局。

138 刘欢，贺克斌等人2008年发表的"燃料硫含量对中国机动车排放影响分析（Analysis of the impacts of fuel sulfur on vehicle emissions in China）." Fuel。Vol. 87(13-14): 3147-3154。

139 Niemeier, D., K. Shafizadeh, 等. 2004.高排放车辆: 文献综述。加州大学戴维斯分校-加州交通局空气质量计划。城市与环境工程学部, 加州大学戴维斯分校。

Looking at the diagram, in addition to emission factors, there are four inputs that go into the emissions calculations.

1. VKT – For each MY, the VKT in year one is based on the VECC VKT value for 2007. To estimate the year one VKT for all non-2007 MYs, back- and forecasting is done by taking ratios of the year one VKT values from Dr. Hong Huo's model (henceforth referred to as the ANL model)[136]. For example,

- VECC 2007 VKT = 10,000 km
- NL 2007 VKT = 11,000 km
- NL 2010 VKT = 12,000 km
- CFM 2010 VKT = 10,000 * (12,000/11,000) = 10,909 km

The user can decide whether or not VKT diminishes as a vehicle ages. Typically, a vehicle's VKT will decline over its lifetime; however, the ICCT team was unable to find VKT degradation curves for Chinese vehicles. If the user chooses VKT decline (as was done for the Retrospective analysis), VKT is given by the following equation, which is based on the EPA's 2001 report[137].

VKTt = VKT1 * (exp ^ (α * t)) (Equation 2)

where VKTt = VKT in year t

VKT1 = VKT in year 1

α = VKT decline factor (user may control value)

t = vehicle age in years

2. Fuel sulfur effects – The sulfur levels present in fuels have an effect on emission levels. To estimate how sulfur levels in gasoline and diesel affect vehicles in China, Tables 2 and 3 of Liu et al.'s 2008 paper are used[138]. An example of how this data is organized is shown in the table below.

Table AB4: Percent changes in NOx emissions in gasoline vehicles

SULFUR LEVEL	CHINA I	CHINA II	CHINA III	CHINA IV	CHINA V
800 ppm	100.0%	108.4%	129.1%	257.2%	257.2%
500 ppm	98.6%	100.0%	122.5%	207.9%	207.9%
150 ppm	95.0%	89.6%	100.0%	136.4%	136.4%
50 ppm	91.7%	86.0%	93.7%	100.0%	100.0%
10 ppm	86.8%	63.3%	88.6%	88.3%	88.3%

3. Vehicle stock (population) – vehicle survival functions are taken directly from the ANL model. There are three sets of survival assumptions for each vehicle type (excluding rural vehicles): 1) pre MY1997, 2) MY1997-MY2020, and 3) post MY2020.

4. Gross emitters – Studies have shown that a relatively small portion of the fleet contributes to a large percentage of the emissions[139] .On the 'Inputs' sheet, the user can control the percent of the fleet that are gross emitters (assumed to have the emission factors of an 'uncontrolled' vehicle regardless of model year). This gross emitters control is meant to model the effects of a compliance and enforcement program. The more effective the program is, the fewer gross emitters there are in the fleet.

136 Dr. Hong Huo created a model while at Argonne National Laboratory in support of the report, "Projection of Chinese Motor Vehicle Growth, Oil Demand, and CO_2 Emissions through 2050".

137 Jackson, T. 2001. Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates, and Projected Vehicle Counts for Use in MOBILE6, U.S. Environmental Protection Agency.

138 Liu, H., K. He, et al. 2008. "Analysis of the impacts of fuel sulfur on vehicle emissions in China." Fuel . Vol. 87(13-14): 3147-3154.

139 Niemeier, D., K. Shafizadeh, et al. 2004. Gross Emitting Vehicles: A Review of the Literature. UC Davis-Caltrans Air Quality Project. Davis, CA, Department of Civil and Environmental Engineering, Univ. of California Davis.

由于缺少销售量、更新率和详细的排放因子数据，低速汽车的计算方法论与其它的车辆类型不同。每年的保有量数据直接采用ANL模型的数据，然后乘以VKT（同样采用ANL模型的数据）以及由清华大学贺克斌教授研究团队开发的排放因子。

燃料消耗量和二氧化碳排放量

与机动车排放量工作表相比，燃料消耗模块就简单很多，所有的计算都囊括在一个工作表中。

图AB2是相关方法学的流程图。

1. 2010年基准燃料经济性即每升燃料行驶的公里数的数值是直接从ANL模型中选取的。在每一种情景下，用户都可以在燃料经济性“输入表”中输入每年燃料经济性增加的百分比。在评价分析中，基准燃料经济性年改善的百分比(2%)模拟了中国I，II， III阶段燃料经济性法规对轻型车的效果。在改善和强化情景中设定的3%和4%的年改善率是基于混合动力和高能效汽车的市场占有率不断增加的假设上的。重型车的基准值为1%，反应了没有相关的燃料经济性管理措施的假设。美国历史上中重型车的燃料经济性每年的改善比例大概为1%。改善情景中设定了到从2015年到2030的改善率为20%，也就是燃料经济性每年的改善率为1.2%。同样的时间段内，强化情景设定了50%的总体改善率，相当于每年的改善比例为2.7%。ICCT团队认为如果目前正在发展中的重型车燃料消耗限值可以促进重型车采用更先进的空气动力学设计，低滚动阻力的轮胎以及先进的发动机技术，从而推进燃料经济性的改善。

2. 不同燃料类型的各个机动车型的总 VKT采用机动车排放量工作表中的数据。

3. 汽柴油的密度 (kg/L)和燃料CO_2强度因子选自ANL模型。

Due a lack of sales, turnover, and detailed emission factor data, the calculation methodology for rural vehicles differs from the other vehicle types. Population values for each calendar year are taken directly from the ANL model and multiplied by VKT values (also from the ANL model) and emission factors, which were developed by Prof. He Kebin's research group at Tsinghua University.

Fuel Consumption and Carbon Dioxide Emissions

Compared to the vehicle emissions sheets, the fuel consumption module is much simpler, and all of the calculations are contained in one worksheet. Figure AB2 is a flow diagram of the methodology.

1. The baseline kilometer per liter fuel economy (FE) values for 2010 are taken directly from the ANL model. For each scenario, the user may input the annual percentage improvement in FE on the 'Inputs' sheet. For the Retrospective analysis, the baseline FE percent (2%) models the effect that the Phase I, II, and III FE regulations in China have had on the light-duty fleet. The annual percent improvements for the Improved and Strong programs—3% and 4% respectively—assume that there is increased penetration of hybrid and high efficiency vehicles. For heavy-duty vehicles, the baseline value (1%) assumes that there is no FE regulation. In the US, fuel efficiencies of medium- and heavy-duty vehicles have historically shown roughly 1% annual improvements. The 20% improvement by 2030 (starting in 2015) of the Improved Program translates to a 1.2% annual increase in FE. Over this same timeframe, the Strong's Program's 50% improvement is equivalent to a 2.7% annual increase. The ICCT team assumed that increased adoption of advanced aerodynamics, lower rolling resistance tires, and improved engine technologies induced by HDV fuel consumption limits being currently developed would account for FE progress.

2. Total VKT by vehicle category and fuel type comes from the vehicle emissions sheets.

3. The density (kg/liter) values and CO_2 intensity factors for gasoline and diesel come directly from the ANL model.

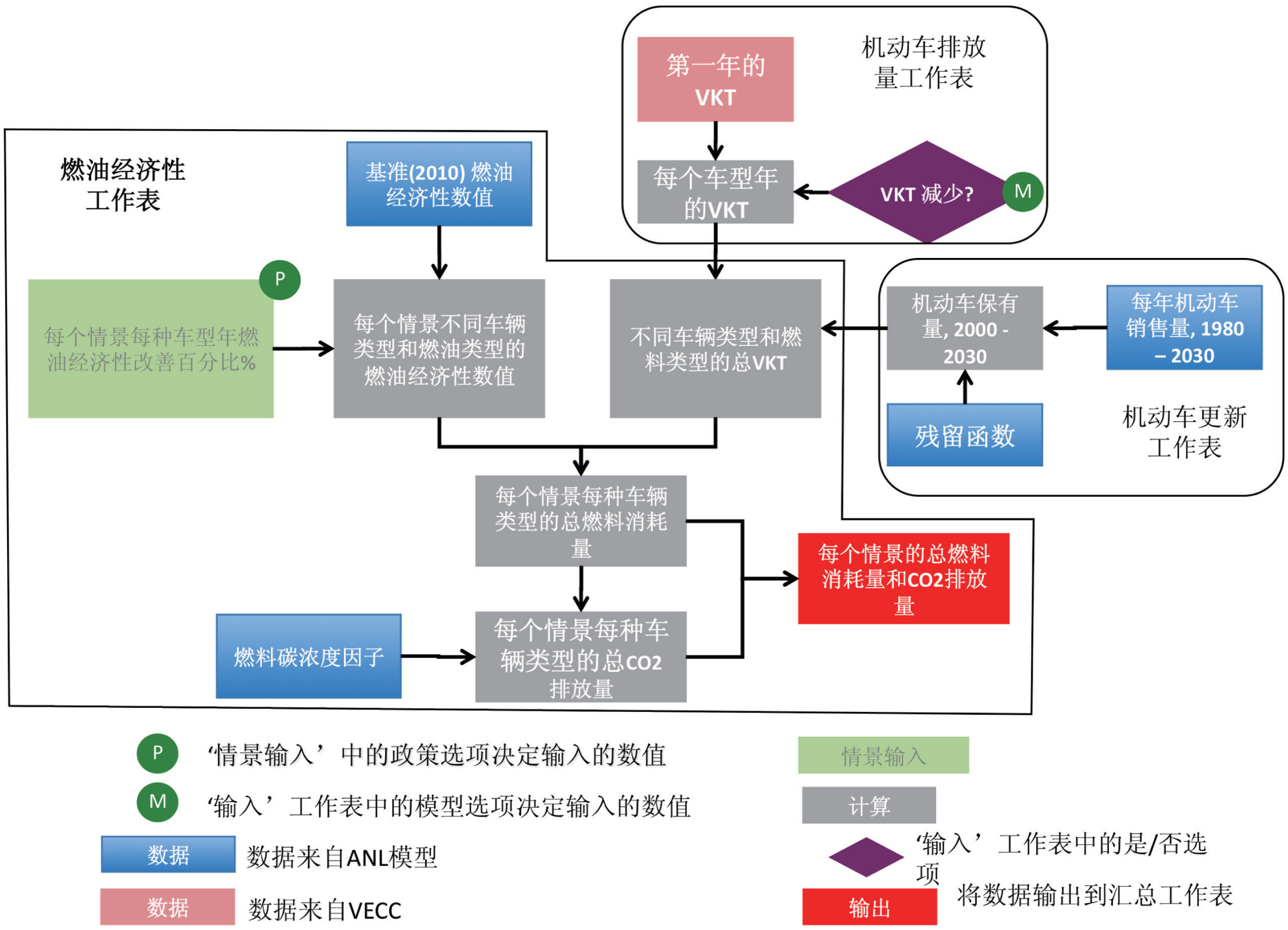


图 AB2: 燃料消耗和CO_2排放量工作表流程图

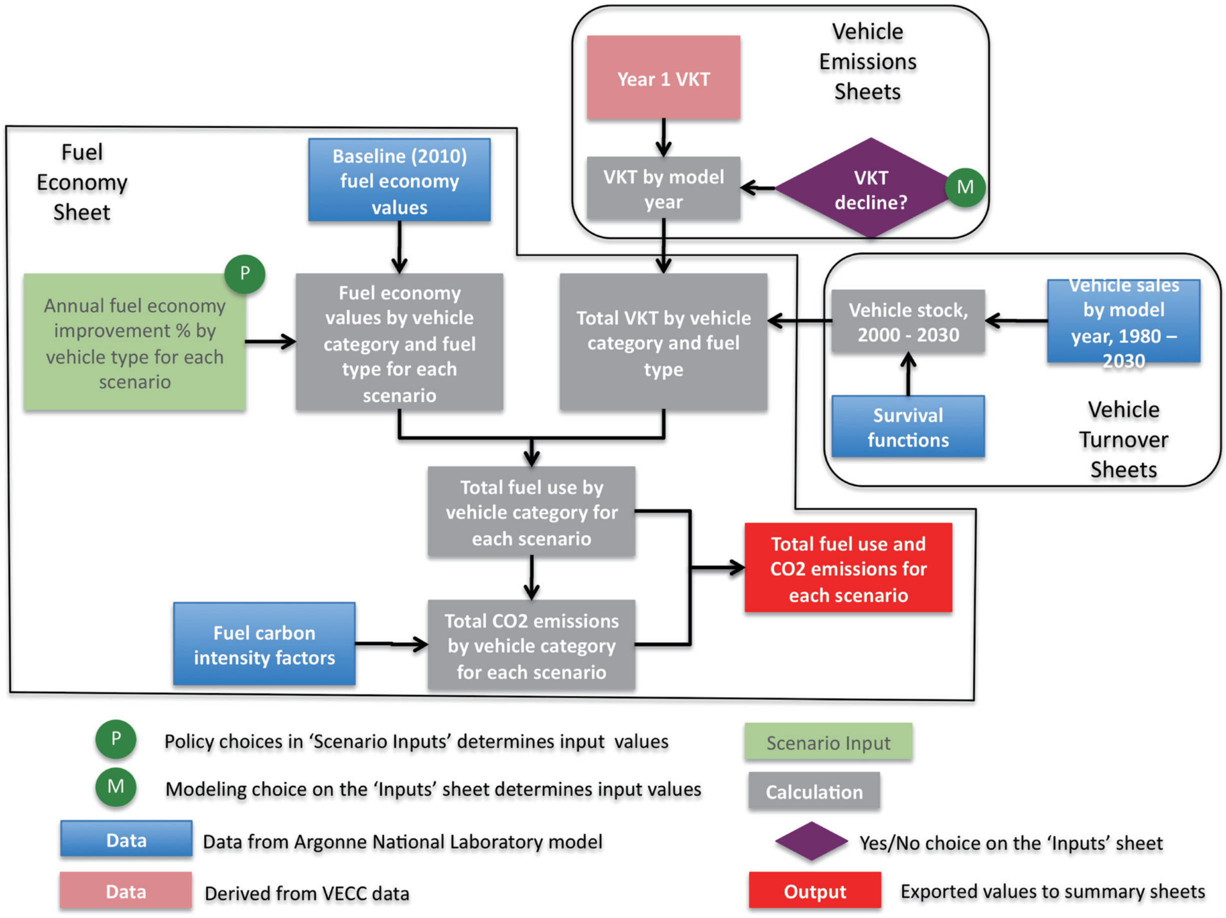


Figure AB2: Flow diagram for the fuel consumption and CO_2 emissions sheet

电动汽车

在CFM模型中，只在轻型车改善和加强情景中会有电动汽车(EV)的市场推广假设，所有情景都没有考虑电动自行车的年销售量增加；但用户可以在“输入”工作表中调整2010年以后电动自行车的增长比例。评价研究中，基于历史数据和ICCT对于未来情况的最佳预测，将电动自行车的增长率设置为4%。轻型车方面，基于ICCT团队的判断和清华大学的欧阳明高教授[140] 的演讲得到了电动车推广比例（见表AB5）。

表 AB5:轻型电动汽车所占的新车销售比例

情景	2010	2015	2020	2025	2030
现行管理	0%	0%	0%	0%	0%
改善方案	0%	0.5%	1%	3%	5%
强化方案	0%	1%	4%	7%	10%

为了计算电动汽车生命周期的上游（如发电厂）排放量，我们评估了各个车型每公里的平均耗能(kWh)，并且使用了Cherry等[141]文中的电厂平均单位能耗排放因子（克/千瓦时）(CO，NOx，PM，HC，CO_2)数据。电动汽车模块的工作流程如图AB3所示。

注:基于电动汽车行驶范围和充电的限制，ICCT团队设置电动汽车的VKT为传统燃料汽车的70%。

140 欧阳明高. 2009.中国电动汽车的发展FISITA 世界机动车高级会议. Falkenstein, 德国。

141 Cherry, C., J. Weinert等人 2009. "中国电动自行车的环境影响." 交通运输研究部分 Part D: 交通与环境.卷. 14(5): 281-290。

Electric Vehicles

In the CFM, all electric vehicle (EV) market penetration is assumed to happen in the Improved and Strong scenarios for the light-duty sector only. Annual sales growth in electric bikes is not included in any scenarios; however, the user may control the percent growth rate beyond 2010 on the 'Inputs' sheets. For the Retrospective analysis, this e-bike growth rate was set to 4% based on historical data and the ICCT's best estimates for the future. For light-duty vehicles, the electric vehicle adoption rates (see Table AB5) are based on the judgment of the ICCT team and a presentation given by Prof. Ouyang Minggao of Tsinghua University[140].

Table AB5: Light-duty electric vehicles – percent of new vehicle sales

SCENARIO	2010	2015	2020	2025	2030
Business as Usual	0%	0%	0%	0%	0%
Improved Program	0%	0.5%	1%	3%	5%
Strong Program	0%	1%	4%	7%	10%

To calculate the upstream (i.e. power plant) emissions associated with electric vehicles, the team estimated the average energy (kWh) use per kilometer for each vehicle type and used average gram/kWh emission factors (CO, NOx, PM, HC, and CO_2) for the power sector, which are taken from Cherry et al[141]. The functionality of the electric vehicle module is shown in Figure AB3.

Note: based on the range and charging limitations of electric vehicles, the ICCT team estimates that an EV has 70% of the VKT of a conventional vehide.

140 Ouyang, M. 2009. Development of Electric Vehicles in China. FISITA World Automotive Summit. Falkenstein, Germany.

141 Cherry, C., J. Weinert, et al. 2009. "Comparative environmental impacts of electric bikes in China". Transportation Research Part D: Transport and Environment. Vol. 14(5): 281-290.

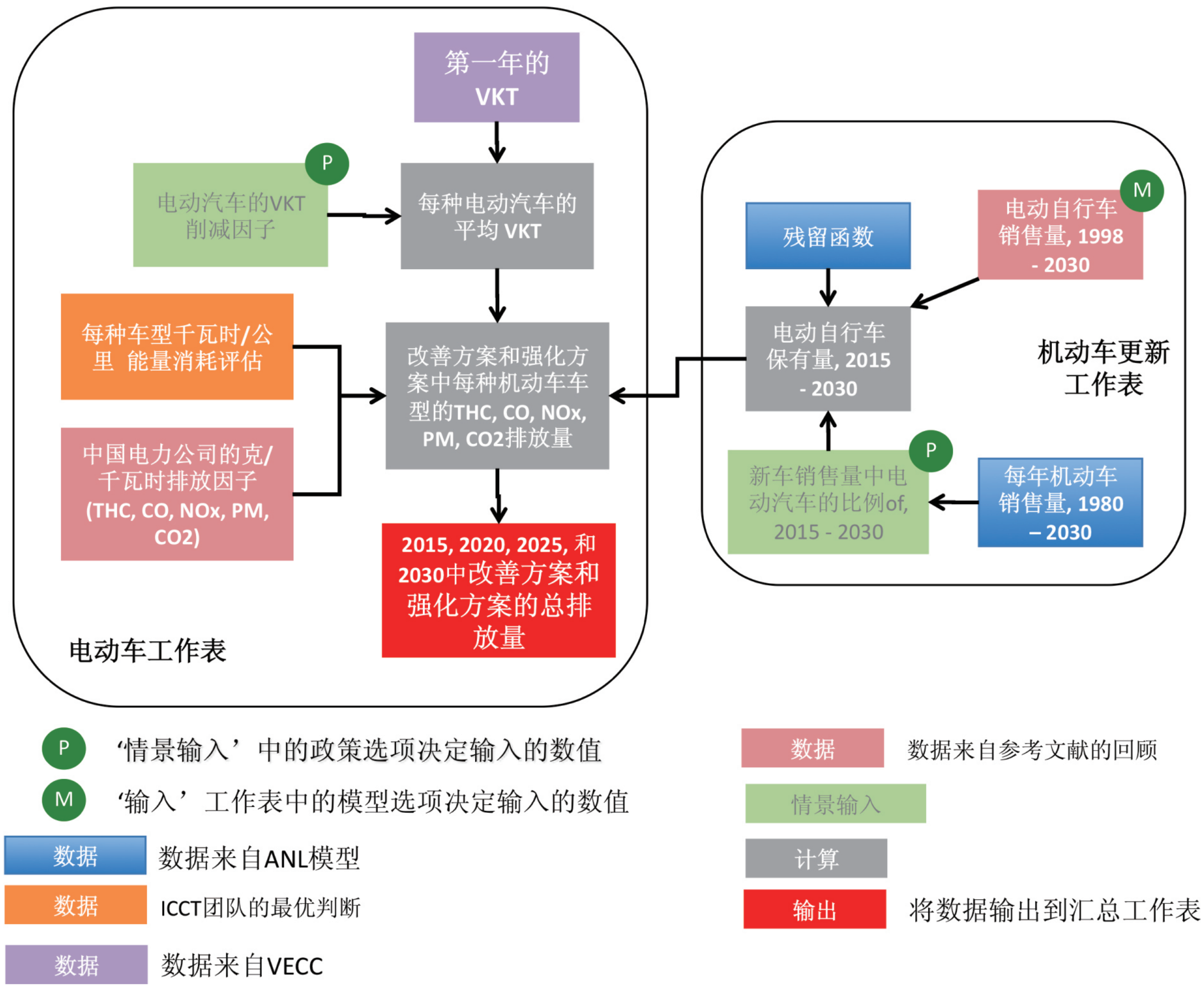


图 AB3: 电动车工作表流程图

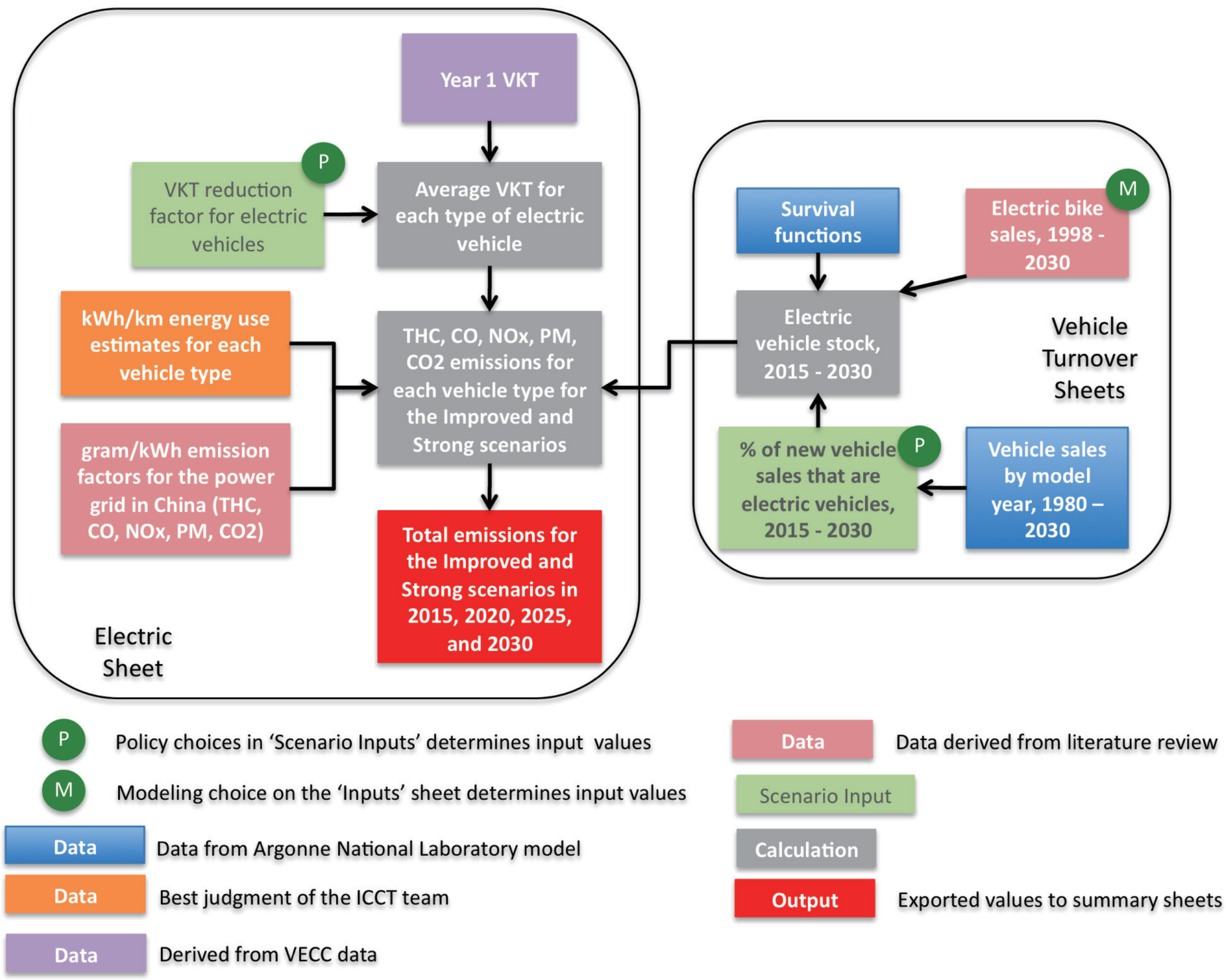


Figure AB3: Flow diagram for the electric vehicle shee

排放控制设备的成本

CFM模型评估了与“无管理”类车辆相比采用排放控制的装置和发动机技术的成本。Michael Walsh开发了成本评估部分，其中包括了基于“欧洲”排放标准的推进的成本的增加(即 Euro 1/I, 2/II,⋯,6/VI)。其中没有考虑通货膨胀的因素，也没有考虑中国市场的特殊的技术和成本。

B.2健康影响评估

为了评估中国燃料硫含量降低的影响，在2005年和2006年首次开发了健康影响评估 (HIA)的工具。ICCT与清华大学联合研究了中国燃料硫含量削减的成本和效益（2006）。通过引入近期研究中的多个变量对该工具进行了升级。此外，为了确保此次研究对中国机动车健康影响的潜力提出一个低端的评估，在此次研究中尽可能的采用了比较保守的数据。大部分的方法论论述都是源自2006年的研究。

此次分析对直接颗粒物排放和由氮氧化物排放造成的大气中二次颗粒物排放（减排）的效益进行了量化分析。但对以下的额外影响没有进行量化分析：

■ 中国臭氧暴露量的减少——很难量化分析，但可能效益相对明显，这是因为中国臭氧排放水平高并还在不断增加；

■ 农业的效益——农业的效益在中国可能比在欧洲和美国更大，一部分是因为死亡率和发病率的影响在中国被赋予的价值较低，以及农业在中国所有经济中的重要地位；

■ 对能见度，旅游业以及环境和实物损失方面损害的削减——这方面的效益可能也比较大，因为旅游业日趋重要，和古建筑工艺品的易损性。

通过最近美国和欧洲的管理评价，包括《欧洲对大气污染的主要策略的影响评价》及美国EPA对燃料和机动车近期出台的三项法规，发现这些附带的效益大概可以增加净效益值的2-3%。

暴露量分析

分析计算了可以在大气中形成颗粒物的颗粒物和氮氧化物排放。分析选取了59个最大的城市 (基于2002 人口数据)。由于城市中污染源和人类受体的高度集中，城市人口通常可以从机动车排放削减中获得更多的效益。由于颗粒物的大气化学性质相对的明确，所以有可能通过使用一个缩放比例——称作吸入因子——来估计每个城市区域中造成人体直接暴露的那部分排放。我们对所研究的城市区域及国内其余的城市进行了颗粒物暴露的评价以及效益的量化。

吸入因子(iF)的方法应用于评价所有移动源的排放在特定城市区域实际被人群吸入的部分。无量纲的吸入因子数值是吸入的污染物与污染物排放总量的比值，又被称为暴露效率。因此，吸入因子揭示了排放量和暴露量的关系，这个关系可以用来将暴露或者浓度反应与各种健康影响进行关联，来对减排的健康效益进行量化。吸入因子的定义如下：

$$\text{吸入因子} = \frac{\text{人群吸入量}}{\text{总排放量}} \quad \text{（公式3）}$$

Costs of Emission Control Equipment

The CFM estimates the costs of emission control devices and engine technology compared to an 'uncontrolled' vehicle. The costs were developed by Michael Walsh, and there are incremental cost deltas based on the 'Euro' emission standard progression (i.e. Euro 1/I, 2/II,…,6/VI). The values do not account for inflation and are not specific to the technologies and costs in the Chinese market.

B.2 Health Impacts Assessment

The Health Impacts Assessment (HIA) tool was first developed in 2005 and 2006 in order to assess the impacts of reduced sulfur fuels in China. The Costs and Benefits of Reduced Sulfur Fuels in China (2006) was collaboration between ICCT and Tsinghua University. The tool was updated with variables drawn from more recent research. In addition, wherever possible, more conservative values were chosen for this analysis, in order to ensure that this study provides a low-end estimate of the potential impacts of vehicles in China. Much of the methodology description below was drawn from the 2006 study.

This analysis quantifies the benefits that would result only from direct particulate matter emissions and secondary particle formation in the atmosphere from NOx emissions. It does not quantify the following additional impacts:

■ Reduced exposure to ozone in China—difficult to quantify but may be relatively significant, due to high and increasing ozone levels;

■ Benefits to agriculture—may be more significant in China than in Europe or the US, partly due to the lower values placed on mortality and morbidity impacts, and to the importance of agriculture to China's overall economy;

■ Reduced impairments in visibility, tourism, and environmental & material damage—may also be significant, due to the growing importance of the tourism industry and the fragility of ancient buildings and artifacts.

Recent regulatory assessments in the United States and Europe, including the European Impact Assessment of the Thematic Strategy on Air Pollution and the three recent U.S. EPA regulations on fuels and vehicles, suggest these added benefits would add approximately 2–3 percent to the net value of benefits.

Exposure analysis

This analysis accounts for emissions of PM and of NOx, which forms PM in the atmosphere. The analysis focuses on the 59 largest cities in China (based upon 2002 population data). Urban populations generally benefit more from vehicle emissions reductions because of the high concentration of both sources and human receptors in cities. Because the atmospheric chemistry of PM is relatively straightforward, it is possible to use a scaling factor—called an intake fraction—to estimate the portion of emissions that would result in direct human exposure within each urban area. PM exposure is estimated and benefits quantified for each of the urban areas studied as well as for the rest of the country.

An intake fraction (iF) approach is used to estimate the portion of overall mobile source emissions actually inhaled by people within a given urban area. Also known as exposure efficiency, the dimensionless iF number is a ratio of the amount of pollutant inhaled to the amount of pollutant emitted. As such, it describes an emissions-to-exposure relationship that can be used in conjunction with exposure- or concentration-response relationships for various health endpoints to quantify the health benefits of reducing emissions. Specifically, the intake fraction is defined as:

$$iF = \frac{Population\ Intake}{Total\ Emissions} \quad \text{(Equation 3)}$$

吸入因子的估计方法既可以简单也可以复杂。Evans 等人 (2002) 所描述的暴露效率，或称吸入因子，是设置完善的环境健康政策的重要工具[142]。

此次分析中，59个城市中每个城市的吸入因子的评价是通过一个简单的单格箱模型得到的。计算吸入因子所需的城市人口和区域如表AB6所示。由于收集和核实有详细人口的区域面积的数据需要一个长时间的过程，所以ICCT在此再次使用了2006年研究中的数据。为了确保这一假设不会有太大偏差，对几个城市的人口清单进行核实，确认了变化很小，并且不会对分析结果造成重要影响。遗憾的是城市区域边界的界定是一个难以确定的部分 (可以通过差别很大的人口密度看出)，但是ICCT发现吸入因子的结果跟其它类似的比较分析比很接近或者更趋于保守，如下表所示。

142 Evans, J. S. 等 2002. 暴露效率： 一个时机成熟的想法?"Exposure efficiency: an idea whose time has come?" Chemosphere 49:1075-1091. 这篇文章对已发表的吸入因子进行了综述，本研究中对农业和二次颗粒物吸入因子的部分很大程度上借鉴了该文献综述的信息。

Estimations of intake fractions can range from simple to complex. Evans et al. (2002) described exposure efficiency, or intake fraction, as an important tool in setting sound environmental health policy[142].

In this analysis, a simple one-compartment box model is used to derive estimated intake fractions for each of the 59 cities. City populations and areas needed to derive the intake fraction are included in Table AB6. Because collecting and verifying the district area data that could be assigned to a particular population was a time-intensive process, ICCT used the data collected for the 2006 study again. In order to verify that this is not a highly flawed assumption, several urban population lists were checked and it was determined that the changes were minor and unlikely to impact the outcome of the analysis significantly. Unfortunately the definition of the limits of urban areas is an area of uncertainty (as can be seen by the highly variable population density), but ICCT found that the resulting intake fractions were similar or more conservative than other comparable analysis, as described below.

142 Evans, J. S. et al. 2002. Exposure efficiency: an idea whose time has come? Chemosphere 49:1075-1091. This article provides a literature review of published intake fractions that were drawn upon heavily for the rural and secondary particle intake fractions in this analysis.

AB6. 本研究中使用的城市、人口和城区[143]

城市名称		人口	区域面积	人口密度
中文	英文		(km^2)	(人/km^2)
鞍山	Anshan	1,454,772	624	2,331
包头	Baotou	1,419,017	2,696	526
北京	Beijing	10,177,849	12,484	815
长春	Changchun	3,100,132	3,603	860
长沙	Changsha	1,962,561	556	3,530
常州	Changzhou[144]	2,134,121	1,650	1,293
成都	Chengdu	4,525,719	2,176	2,080
赤峰	Chifeng	1,131,095	7,012	161
重庆	Chongqing	10,101,208	16,291	620
大连	Dalian	2,747,783	2,415	1,138
佛山	Foshan[145]	3,442,440	3,813	903
抚顺	Fushun	1,415,138	714	1,982
福州	Fuzhou, Fujian	1,662,411	1,043	1,594
广州	Guangzhou	5,882,553	3,179	1,850
海口	Guiyang	2,401,839	8,034	299
邯郸	Handan	1,382,100	434	3,185
杭州	Hangzhou	3,931,864	3,068	1,282
哈尔滨	Harbin	3,151,917	1,660	1,899
合肥	Hefei	1,558,671	596	2,615
淮安	Huaian	2,681,688	3,171	846
淮南	Huainan	1,420,155	1,091	1,302
呼和浩特	Huhehaote/Hohhot[146]	1,096,955	2,054	534
湖州	Huzhou	1,077,227	1,567	687
吉林	Jilin	1,795,531	3,636	494
济南	Jinan	3,348,025	3,257	1,028
昆明	Kunming	2,242,199	4,033	556
兰州	Lanzhou	1,949,146	1,632	1,194
洛阳	Luoyang	1,489,328	544	2,738
南昌	Nanchang	1,794,988	563	3,188
南京	Nanjing	4,897,571	4,729	1,036
南宁	Nanning	1,457,726	1,834	795
宁波	Ningbo	2,069,098	1,033	2,003
莆田	Putian	2,016,336	2,012	1,002
青岛	Qingdao	2,467,702	1,349	1,829

143 所有数据来自于2005. www.bjinfobank.com/irisweb/infobank.htm; Brinkhoff, T. 城市人口www.citypopulation.de; 福建大学http://www.fzu.edu.cn; 海口政府www.haikou.gov.cn/haikougov.asp。

144 常州总商会. www.czsh.org.cn/english/shdh/index.asp。

145 佛山市政府. www.foshan.gov.cn/english。

146 清洁能源行动. 呼和浩特 www.cct.org.cn/cea_asptest/eng/city/huhehaote.htm。

Table AB6. Cities, populations, and urban areas used in the analysis[143]

CITY NAME		GIVEN POPULATION	DISTRICT AREA	POPULATION DENSITY
CHINESE	ENGLISH		(km^2)	($people/km^2$)
鞍山	Anshan	1,454,772	624	2,331
包头	Baotou	1,419,017	2,696	526
北京	Beijing	10,177,849	12,484	815
长春	Changchun	3,100,132	3,603	860
长沙	Changsha	1,962,561	556	3,530
常州	Changzhou[144]	2,134,121	1,650	1,293
成都	Chengdu	4,525,719	2,176	2,080
赤峰	Chifeng	1,131,095	7,012	161
重庆	Chongqing	10,101,208	16,291	620
大连	Dalian	2,747,783	2,415	1,138
佛山	Foshan[145]	3,442,440	3,813	903
抚顺	Fushun	1,415,138	714	1,982
福州	Fuzhou, Fujian	1,662,411	1,043	1,594
广州	Guangzhou	5,882,553	3,179	1,850
海口	Guiyang	2,401,839	8,034	299
邯郸	Handan	1,382,100	434	3,185
杭州	Hangzhou	3,931,864	3,068	1,282
哈尔滨	Harbin	3,151,917	1,660	1,899
合肥	Hefei	1,558,671	596	2,615
淮安	Huaian	2,681,688	3,171	846
淮南	Huainan	1,420,155	1,091	1,302
呼和浩特	Huhehaote/Hohhot[146]	1,096,955	2,054	534
湖州	Huzhou	1,077,227	1,567	687
吉林	Jilin	1,795,531	3,636	494
济南	Jinan	3,348,025	3,257	1,028
昆明	Kunming	2,242,199	4,033	556
兰州	Lanzhou	1,949,146	1,632	1,194
洛阳	Luoyang	1,489,328	544	2,738
南昌	Nanchang	1,794,988	563	3,188
南京	Nanjing	4,897,571	4,729	1,036
南宁	Nanning	1,457,726	1,834	795
宁波	Ningbo	2,069,098	1,033	2,003
莆田	Putian	2,016,336	2,012	1,002
青岛	Qingdao	2,467,702	1,349	1,829

143 All sources accessed via the internet in 2005. www.bjinfobank.com/irisweb/infobank.htm; Brinkhoff, T. City Population. www.citypopulation.de; Fujian University. http://www.fzu.edu.cn; Haikou Government. www.haikou.gov.cn/haikougov.asp.

144 Changzhou General Chamber of Commerce. www.czsh.org.cn/english/shdh/index.asp.

145 Foshan City government. www.foshan.gov.cn/english.

146 Clean Energy Action. Hohehot. www.cct.org.cn/cea_asptest/eng/city/huhehaote.htm.

齐齐哈尔	Qiqihar	1,426,710	4,365	327
上海	Shanghai	12,293,700	5,299	2,320
汕头	Shantou	1,280,625	294	4,356
沈阳	Shenyang	4,884,076	3,459	1,412
深圳	Shenzhen	1,512,073	1,949	776
石家庄	Shijiazhuang	2,110,894	456	4,629
苏州	Suzhou, Jiangsu	2,168,663	1,964	1,104
太原	Taiyuan	2,502,727	1,460	1,714
台州	Taizhou[147]	1,460,452	1,536	951
唐山	Tangshan	2,949,101	1,182	2,495
天津	Tianjin	7,636,137	7,418	1,029
乌鲁木齐	Urumqi	1,732,947	10,800	160
潍坊	Weifang	1,423,294	1,472	967
温州	Wenzhou	1,346,505	1,187	1,134
武汉	Wuhan	7,811,855	8,494	920
无锡	Wuxi	2,195,973	1,623	1,353
厦门	Xiamen[148]	1,417,579	1,565	906
西安	Xian	5,102,553	3,502	1,457
徐州	Xuzhou	1,673,296	1,038	1,612
烟台	Yantai	1,708,328	2,722	628
扬州	Yangzhou	1,125,165	980	1,148
宜昌	Yichang	1,209,741	527	2,296
湛江	Zhanjiang	1,442,522	1,460	988
郑州	Zhengzhou	2,398,460	1,010	2,375
淄博	Zibo	2,733,691	2,960	924

模型将每个空气品质区作为一个箱子，污染物通过长时间空气流动传输出这个箱子。对于长时间不反应或反应缓慢的广泛分布于地面源（如来自轻重型车)的污染物，事实证明单格箱模型能对其在城市区域内空间平均浓度提供比较准确的评估[149]。 由于细颗粒(PM2.5) 的生命周期明显比在城市区域中的滞留时间长，所以假设这些颗粒物是不发生变化的。

单格箱吸入因子的公式如下：

$$iF_{compartment} = \frac{QP}{uH\sqrt{A}} \quad \text{(公式 4)}$$

147 www.zhejiang.gov.cn/gb/node2/node1619/node1622/node1810/userobject13ai707.html。

148 美国驻北京大使馆. 1999. Greener that green: 厦门, 一个环境达标模型 www.usembassy-china.org.cn/sandt/Xiamweb.htm。

149 Marshall J. D., Teoh, S. K.,和 Nazaroff, W. W. 2005.美国城市区域不反应的机动车排放的吸入因子.大气环境 .Vol. 39(7), pp. 1363-1371。

齐齐哈尔	Qiqihar	1,426,710	4,365	327
上海	Shanghai	12,293,700	5,299	2,320
汕头	Shantou	1,280,625	294	4,356
沈阳	Shenyang	4,884,076	3,459	1,412
深圳	Shenzhen	1,512,073	1,949	776
石家庄	Shijiazhuang	2,110,894	456	4,629
苏州	Suzhou, Jiangsu	2,168,663	1,964	1,104
太原	Taiyuan	2,502,727	1,460	1,714
台州	Taizhou[147]	1,460,452	1,536	951
唐山	Tangshan	2,949,101	1,182	2,495
天津	Tianjin	7,636,137	7,418	1,029
乌鲁木齐	Urumqi	1,732,947	10,800	160
潍坊	Weifang	1,423,294	1,472	967
温州	Wenzhou	1,346,505	1,187	1,134
武汉	Wuhan	7,811,855	8,494	920
无锡	Wuxi	2,195,973	1,623	1,353
厦门	Xiamen[148]	1,417,579	1,565	906
西安	Xian	5,102,553	3,502	1,457
徐州	Xuzhou	1,673,296	1,038	1,612
烟台	Yantai	1,708,328	2,722	628
扬州	Yangzhou	1,125,165	980	1,148
宜昌	Yichang	1,209,741	527	2,296
湛江	Zhanjiang	1,442,522	1,460	988
郑州	Zhengzhou	2,398,460	1,010	2,375
淄博	Zibo	2,733,691	2,960	924

The model describes each air basin as a box, with emissions transported out of the box through the flow of air over time. For conserved or slowly reacting emissions from broadly distributed ground-level sources, such as light- and heavy-duty vehicles, the one-compartment model has been found to offer a reasonably accurate estimate of spatially averaged concentrations in urban areas.[149] Because the lifetime of fine particles (PM2.5) is significantly longer than their residence time in urban areas, these particles can be assumed to be conserved.

The equation for a one-compartment intake fraction is as follows:

$$iF_{compartment} = \frac{QP}{uH\sqrt{A}} \quad \text{(Equation 4)}$$

147 www.zhejiang.gov.cn/gb/node2/node1619/node1622/node1810/userobject13ai707.html.

148 U.S. Embassy Beijing. 1999. Greener that green: Xiamen, a model of environmental achievement. www.usembassy-china.org.cn/sandt/Xiamweb.htm.

149 Marshall J. D., Teoh, S. K., and Nazaroff, W. W. 2005. Intake fraction of nonreactive vehicle emissions in US urban areas. Atmospheric Environment. Vol. 39(7), pp. 1363-1371.

公式中, Q 表示人口平均的呼吸速率(立方米每人每秒)。 P代表人口。U代表大气混合层高度的平均风速(米每秒) 。H (米)。A代表城市区域面积 (平方米)。由于ICCT没有每个城市风速和混合层高度的详细数据，所以标准化稀释速率中值uH采用美国使用的数据[150] 。

分析中同样包括了城市区域外的PM2.5排放以及城市及郊区NOx转化为硝酸盐的二次颗粒物的健康影响。虽然接下来要提及的一些研究中对吸入因子的估计值都较高，ICCT比较保守地选择了同行评审文献中的平均吸入因子。

为了对模型进行测试，ICCT将其与一个更加复杂的吸入因子模型进行比较。王书肖等人通过使用一个基于75个典型路段的交通流的模型，完成了中国北京、济南和大连三个城市机动车排放吸入因子分析。结果三个城市PM10的排放加权的平均吸入因子为7.72±0.60x10-5，与本次分析使用的平均值相比高很多[151]。 王书肖的研究发现机动车排放的一次颗粒物排放的吸入因子与工业源相比高一个数量级，机动车排放的SO_2的吸入因子几乎要（比工业源）高两个数量级，比PM10的吸入因子高两倍。由于大多数机动车颗粒物的排放是细颗粒和超细颗粒，这种颗粒物可以在大气中滞留相对较长的时间(类似于 SO_2)。王书肖的结果可能低估了预测的机动车PM2.5的排放吸入因子。

表AB7a提供了本次研究中采用的所有的吸入因子，表 AB7b 展示了王书肖等人的结果与其进行比较。正如所看到的，简易的箱式模型可能低估了现实城区的暴露水平，在这些区域中颗粒物被近距离排放于人群，并且这些排放也达不到平均稀释速率。本次研究中最大的不确定因素是每个城市的人口区域和稀释速率。预计每个因素都导致了对iF的估计过低。

表AB7a.本次研究采用的吸入因子

污染物	范围	平均iF	最大 iF	最小 iF	区域	方法学	来源
$PM_{2.5}$	城区	1.7E-05	5.0E-05	4.0E-06	59 个城市	单格箱模型	HIA 的工具
	郊区	4.7E-06	—	—	中国其余地区 (按照人口进行衡量)	大气扩散	采用Evans.等人数据 2002年
二次颗粒物 (来源于 NO_x)	城区	2.3E-07	—	—	城区	大气扩散	Greco等 2007年
	郊区	1.0E-07	—	—	中国其余地区	大气扩散	Greco 等2007年

150 同前。

151 王书肖，郝吉明等2005第五章草案—地方人口对主要工业部门和交通污染物的暴露量。选自麻省理工大学出版的一本书。

In this equation, Q represents the population average breathing rate (m3 person-1 s-1), P is the population, u is the wind speed (m s-1) averaged over the mixing height, H (m), and A is the urban land area (m^2). Because ICCT did not have detailed information on wind speed and mixing height for each city, the median normalized dilution rate uH derived for the United States was used[150].

The analysis also includes health impacts of $PM_{2.5}$ emissions outside of these urban areas and impacts of secondary particle formation of NO_x into nitrates in both urban and rural areas. While higher values were estimated in the study described below, ICCT chose to be conservative by using average intake fractions described in peer-reviewed literature for all these values.

In order to test the model, ICCT compared it to a more complicated model for intake fractions. Wang et al. completed an analysis of the intake fractions for vehicle emissions in three Chinese cities—Beijing, Jinan and Dalian—using a model based on traffic flows on 75 modeled road segments. The resulting emission-weighted average intake fraction for PM_{10} was 7.72±0.60x10-5 for the three cities, much higher than the average value used in this analysis[151]. Wang's analysis found intake fractions for primary particle emissions to be an order of magnitude higher for vehicle emissions than for industrial sources. Vehicle intake fractions for SO_2 were almost two orders of magnitude higher and were two times higher than the PM_{10} intake fraction, according to the analysis by Wang et al. Because the majority of the particles emitted from vehicles are in the fine and ultrafine size range, which remain in the atmosphere longer (similar to SO_2), Wang's results may underestimate intake fractions intended to represent the $PM_{2.5}$ emissions from vehicles.

Table AB7a provides all the intake fractions used in this analysis and Table AB7b shows the Wang et al results described above for comparison. As can be seen, this simple box model is likely to underestimate real exposure levels in these urban areas, where particles are emitted in close proximity to exposed populations and where emissions may not be diluted as quickly as averaged rates would suggest. The largest sources of uncertainty in the approach used for this study are the population areas being considered and the dilution rate for each city. It is expected that each factor will contribute generally to an underestimation of the iF.

Table AB7a. Intake Fractions used in this analysis

POLLUTANT	SCALE	MEAN iF	MAX iF	MIN iF	LOCATION	METHODOLOGY	SOURCE
$PM_{2.5}$	Urban	1.7E-05	5.0E-05	4.0E-06	59 cities	One-compartment model	HIA tool
	Rural	4.7E-06	—	—	Rest of China (population -scaled)	Atmospheric dispersion	Adopted from Evans et al. 2002
Secondary PM (from NO_x)	Urban	2.3E-07	—	—	Urban	Atmospheric dispersion	Greco et al. 2007
	Rural	1.0E-07	—	—	Rest of China	Atmospheric dispersion	Greco et al. 2007

150 Ibid.

151 Wang, S., J. Hao, Y. Lu, J. Li. 2005 draft. Chapter 5—Local population exposure to pollutants from major industrial sectors and transportation. From a book by MIT Press.

表 AB7b 本次研究未采用的吸入因子

污染物	范围	平均iF	最大 iF	最小 iF	区域	方法学	来源
$PM_{2.5}$		7.72E-05	1.54E-04	1.84E-05	北京，济南，大连	75个典型路段	王书肖等. 2005年
二次颗粒物 (来源于 NO_x)		3.10E-06	6.25E-06	4.42E-05	无详细信息		王书肖等2005年

健康影响

健康影响由吸入因子、平均吸入速率与浓度反应 (CR)方程共同计算得出。公式如下所示:

$$cases_{i,j} = \frac{iF_j \quad E_j \quad CR_i \quad I_i}{BR} \text{(公式5)}$$

其中 iFj代表区域j的吸入因子， Ej代表区域j的颗粒物排放变化， CRi代表健康影响i的浓度反应系数， Ii代表i的每年基准值，BR代表平均呼吸率。

CR 系数如表AB8中所示。以下数据表明了颗粒物浓度每微克每立方米(mg/m^3)的变化造成的死亡率和发病率比例的变化。误工时间，误学时间，额外的呼吸症状（感冒等），急诊次数的 CR系数在此次研究中没有考虑。

Table AB7b. Intake Fractions not used in this analysis

POLLUTANT	SCALE	MEAN iF	MAX iF	MIN iF	LOCATION	METHODOLOGY	SOURCE
$PM_{2.5}$		7.72E-05	1.54E-04	1.84E-05	Beijing, Jinan & Dalian	75 modeled road segments	Wang et al. 2005
Secondary PM (from NO_x)		3.10E-06	6.25E-06	4.42E-05	Not specified		Wang et al. 2005

Health impacts

To determine the health impacts, intake fractions are used with concentration-response (CR) functions, in combination with the average population inhalation rate. The general equation is as follows:

$$cases_{i,j} = \frac{iF_j \quad E_j \quad CR_i \quad I_i}{BR} \text{ (Equation 5)}$$

where iFj represents the intake fraction for area j, Ej is the change in PM emissions for area j, CRi is the concentration response coefficient for health impact i, Ii is the annual baseline rate for i, and BR is the average breathing rate.

CR coefficients are listed below, in Table AB8. These values represent the percent change in morbidity and mortality expected in response to a 1 microgram per cubic meter (mg/m^3) change in PM concentration. CR functions for work-loss days, missed school days, additional respiratory symptoms (colds, etc.), or emergency rooms visits are not included in this analysis.

表AB8. 浓度反应(CR)系数和死亡率和发病率的基准值

健康结果	污染物	受影响年龄	CR 系数 每 Δ 1 mg/m³颗粒物 (95%置信度)	I –基准值 (每人比例)	参考文献
成年人全原因死亡率 *	$PM_{2.5}$	30岁及以上	0.41% (0.1%-1.1%)	0.0068–0.0097 (随年龄增加而增加)	Pope 等 2002年; Wang 和 Mauzerall 2005年
婴幼儿死亡率 **	PM_{10}	27 天至1年	0.39% (0.2%-0.7%)	0.02696–0.00441	Woodruff 等. 1997年; CIA 2000-2006年
慢性支气管炎	PM_{10}	全年龄段	0.45% (0.15%-0.77%)	0.0139	Chen 等. 2005年; Chen等. 2002年
急性支气管炎	PM_{10}	全年龄段	0.46% (0.0%-0.92%)	0.0372	Wang等. 1994年
心血管疾病入院	PM_{10}	65岁及以上	0.1% (0.067%-0.15%)	0.01	Kan 和 Chen 2004年; Samet 等. 2000年; CMH 2005年
呼吸疾病入院	PM_{10}	全年龄段	0.036% (0.012%-0.06%)	0.0042	Kan 和Chen 2004年; CMH 2005年
哮喘发病	PM_{10}	15 岁以下	0.44% (0.27%-0.62%)	0.0693	Kan和 Chen 2004年
哮喘发病	PM_{10}	15 岁及以上	0.39% (0.19%-0.59%)	0.0561	Kan 和 Chen 2004年
活动受限天数	$PM_{2.5}$	18 至 65岁	0.94% (0.79%-1.09%)	3.0	Ostro 1990年; Kan和Chen 2004年

* 随着人口年龄增加而增加。

** 每1,000出生婴幼儿的死亡率，这里假设现有按照指数递减的婴幼儿的死亡率的趋势延续。考虑到收入的增加和更佳的医疗服务，将城市的平均比例调整为0.4。

中国几个关于空气污染影响的急性死亡率影响的研究已经完成，但是即使世界范围内也很少有对长期、综合的研究来探究空气污染对慢性死亡率的影响。因此我们使用了美国的流行病学相关研究中的相对风险因子（特别是借鉴了由Pope等人和美国癌症协会通过追踪120万人超过16年时间的研究中分析得出风险因子)[152] 。 EPA提供给科学顾问委员会用来评估颗粒物污染造成的死亡率的建议也是根据这些研究结果[153]。另一方面，英国也确定了采用0.6%的CR系数来评估提前死亡率的相对风险为最佳的评估[154]。因此我们采用了CR 系数0.41%作为对死亡率影响的相对保守的假设。为了避免重复计算，本研究没有对空气质量对短期死亡率的影响进行分析。

152 Pope, C. A., 等。2002年. 肺癌，心肺疾病死亡率和长时间暴露在空气污染的细颗粒。美国医学联合会的期刊 287(9)1132-1141。

153 美国国家环境保护局科学顾问委员会2004年. EPA第二次预测分析—清洁空气法的成本收益分析1990-2020年中对健康影响分析计划的建议。顾问委员会健康影响分会对清洁空气达标分析的建议。华盛顿，美国国家环境保护局科学顾问委员会办公室 (1400A). EPA-SAB-COUNCIL-ADV-04-002。

154 大气污染医学影响委员会。2001年 颗粒物对发病率的长期影响的综述。健康处，英国，伦敦。

Table AB8. Concentration response coefficients and baseline incidence rates for mortality and morbidity

HEALTH ENDPOINT	POLLUTANT	AGES AFFECTED	CR COEFFICIENT per Δ 1 mg/m³ PM (95% confidence)	I – BASELINE INCIDENCE (RATE PER PERSON)	REFERENCES
Adult all-cause mortality*	$PM_{2.5}$	Age 30 & over	0.41% (0.1%-1.1%)	0.0068–0.0097 (increases over time with aging population)	Pope et al. 2002; Wang and Mauzerall 2005
Infant Mortality*	PM_{10}	27 days to 1 year	0.39% (0.2%-0.7%)	0.02696–0.00441	Woodruff et al. 1997; CIA 2000-2006
Chronic bronchitis	PM_{10}	All ages	0.45% (0.15%-0.77%)	0.0139	Chen et al. 2005; Chen et al. 2002
Acute bronchitis	PM_{10}	All ages	0.46% (0.0%-0.92%)	0.0372	Wang et al. 1994
Cardiovascular hospital admission	PM_{10}	Age 65 & over	0.1% (0.067%-0.15%)	0.01	Kan and Chen 2004; Samet et al. 2000; CMH 2005
Respiratory hospital admission	PM_{10}	All ages	0.036% (0.012%-0.06%)	0.0042	Kan and Chen 2004; CMH 2005
Asthma attack	PM_{10}	Under 15	0.44% (0.27%-0.62%)	0.0693	Kan and Chen 2004
Asthma attack	PM_{10}	Age 15 & over	0.39% (0.19%-0.59%)	0.0561	Kan and Chen 2004
Restricted activity day	$PM_{2.5}$	Age 18 to 65	0.94% (0.79%-1.09%)	3.0	Ostro 1990; Kan and Chen 2004

* Increases over time as the population ages.

** Per 1,000 live births, with the current trend of exponential decrease assumed to continue. The average rate was adjusted by 0.4 for cities, to account for higher income and better health care.

Several studies on the acute mortality impacts of air pollution have been conducted in China, but very few long-term, cohort studies have been done anywhere in the world to investigate the chronic mortality impacts of air pollution. Accordingly, relative risk factors from epidemiological studies conducted in the United States—specifically, risk factors developed by Pope at al. in their reanalysis and extension of the American Cancer Society study, which followed 1.2 million adults for over 16 years—are used for this analysis[152]. EPA used the same study on the recommendation of the Health Effects Subgroup of the Science Advisory Board to estimate mortality from particulate matter pollution[153]. On the other hand, the United Kingdom determined that a CR coefficient of 0.6% for the relative risk of premature mortality was the best central estimate[154]. With a CR coefficient of 0.41%, this analysis may, therefore, be considered a relatively conservative assessment of the likely mortality impacts. To avoid double counting, no attempt was made in this analysis to determine short-term air quality impacts on mortality.

152 Pope, C. A., et al. 2002. Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. Journal of the American Medical Association 287(9)1132-1141.

153 U.S. Environmental Protection Agency Science Advisory Board. 2004. Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act, 1990-2020. Advisory by the Health Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis. Washington, D.C.: U.S. Environmental Protection Agency Science Advisory Board Staff Office (1400A). EPA-SAB-COUNCIL-ADV-04-002.

154 Committee on the Medical Effects of Air Pollutants. 2001. Statement on long-term effects of particles on mortality. Department of Health. London, UK.

效益评估

要全面分析收益，将每一种健康结果进行货币化是很必要的，由于每个生命都是宝贵并有价值的，个体之间不存在价值差异，所以这部分是很困难的。在健康影响评估中，ICCT参照了经济学家提出的通用做法，根据支付意愿额度（如同条件价值评估法中所衡量的）和疾病的开销来评定的健康结果的货币价值[155]。这个方法不用来也不能用来计算一个人的实质价值、患病或者生活质量下降的价值。

为了让评估方法可以被中国的政策制定者采纳，此次分析依托于中国大陆最近完成的支付意愿（即愿意为避免疾病（发病率）和提前死亡（发病率）支付的费用）研究。尽管这些研究中的数值明显比美国、欧洲及许多其他地区的报告中的数值低，本报告采用了中国的研究数据来确保在中国国情下空气质量改善的效益不被过高地估计。虽然我们采用了这些研究数据，但我们并不鼓吹它们就一定是最适合的数据来源，更不表示中国人的生命价值比美国和欧洲低。其他政府和地区的范例证明此处使用的数值是保守的，减少未过早死亡率的实际年效益很可能要高很多。

中国大陆近期研究中得出的为减少发病率和过早死亡的WTP数值明显低于世界其他地区研究的数值。北京以及安庆城区郊区的研究表明平均统计学生命价值(VSL)在124,000元人民币到1,470,000 元人民币之间（美国（1999年）15,000-178,000美元）[156]。 该研究的作者们认为，如果这些研究中的问题采取不同的设计，结果（WTP）可能会高出10倍。因此，Zhou和Hammitt指出他们的估计值应该被“谨慎地解释，也许仅仅是评价的下限”。

Wang和 Mullahy (2006年)的早期研究提出了重庆的平均统计学生命价值为 287,660元人民币。这个研究指出随着年收入每增长1207元人民币（145.8美元），VSL会增加120,450元人民币（14,550美元），即弹性系数为1.42[157]。弹性系数是指年收入每增加一美元所引起的VSL的变化率。将上面的结果应用于到2005年中国的平均收入增长，VSL将会是1,110,930元人民币 (US美元(2010年)162,760)[158]。另外一项1999年进行的北京的研究表明中国城市的VSL处于500,000—1,600,000元人民币之间(1999年美元60,000-200,000)[159]。

155 支付意愿额度描述了个人认为减少健康风险等价的货币量。条件价值评估法用多种与研究主题相关的不同假设情景来询问问卷调查受访者在不同风险和财政结果中如何选择。疾病费用研究只考虑了患病的实际医疗费用，并没有包括个人的选择和其他患病的替代方案。

156 统计学的的生命价值是统计学上避免提前死亡的平均支付意愿的货币量。它不具有描述个人生命价值的含义。Zhou, Y和 J. K. Hammitt. 2005年草案，第八章—中国大气污染相关的健康风险的经济价值：一项条件价值评估。源自麻省理工大学即将出版的一本书籍。

157 Wang, H.和J. Mullahy. 2006. 通过改善空气质量减少死亡风险的支付意愿：中国重庆的一项条件价值评估。环境科学，正在出版中。

158 人口评价源自：联合国, 2006年. 国民经济核算主数据库。联合国统计处，纽约市，纽约州。

159 Zhang, X.和Y. Zheng. 2001年. 中国的气候变化，健康风险和经济分析。 在第四届中韩美经济环境模型研讨会上发表，北京，5月23-25日。

Valuation of benefits

To complete the benefits analysis, it is necessary to monetize each health endpoint, which is difficult because every life is valuable and precious and no individual life is worth more or less than any other. In the HIA, ICCT follows the standard practice developed by economists to assign monetary values for health endpoints based upon willingness-to-pay (WTP), as measured in contingent valuation (CV) studies, and the cost of illnesses[155]. This approach does not and cannot account for the essential worth of a person, nor for suffering or reduction in quality of life.

In order for it to be acceptable to local policy-makers, the analysis relies heavily on recent studies that have been conducted in mainland China to estimate WTP to avoid illness (morbidity) or premature death (mortality). Even though the values reported in these studies are much lower than the values reported in the United States, Europe and many other regions, they are used here in order to make certain that the benefits of improved air quality were not overestimated in the Chinese context. These studies are not advocated as necessarily the most appropriate and their use here is not intended to suggest that Chinese lives have a lower value than U.S. or European lives. Examples from other governments and regions are provided to demonstrate that the values used here are very conservative and the actual benefits of reducing premature mortality are likely to be substantially higher.

Recent studies of WTP for avoided morbidity or premature mortality in mainland China have typically found much lower values than studies elsewhere in the world. A study conducted in Beijing and in rural and urban areas of Anqing, found the mean value of a statistical life (VSL) to range from ¥124,000 to ¥1,470,000 (US$(1999)15,000-$178,000)[156]. The authors of this study suggest that, had they designed the questions differently, the resulting value could have been as much as 10 times higher. Accordingly, Zhou and Hammitt recommend that their estimates be “interpreted cautiously, perhaps as lower bound estimates.”

An earlier study by Wang and Mullahy (2006) reported an average VSL of ¥287,660 (US$(1998)34,750) for Chongqing. That study reported a marginal increase in VSL of ¥120,450 (US$14,550) with an annual income increase of ¥1,207 (US$145.8), implying an elasticity of 1.42[157]. This elasticity represents the ratio of change in VSL for every dollar of change in annual income. By applying these results to the growth in average income in China to 2005, the VSL would be ¥ 1,110,930 (US$(2010)162,760)[158]. One additional study conducted in Beijing in 1999 found that urban VSL in China ranged from ¥500,000 to ¥1,600,000 (US$(1999)60,000-$200,000)[159].

155 Willingness to pay describes the amount of money that an individual finds equally valuable to the reduction in health risk. Contingent valuation studies ask survey respondents how they would choose between alternatives that differ in risk and financial consequences, using a variety hypothetical settings that relate to the situation being studied. Cost of illness studies consider only the actual medical costs of illnesses and do not include any personal preferences or other surrogate for suffering.

156 Value of a Statistical Life is the amount of money attributed to a statistically averaged willingness to pay to avoid the risk of premature death. It is not intended to represent the value of any individual person's life. Zhou, Y. and J. K. Hammitt. 2005 draft. Chapter 8—The economic value of air-pollution-related health risks in China: A contingent valuation study. From a forthcoming book for MIT Press.

157 Wang, H. and J. Mullahy. 2006. Willingness to pay for reducing fatal risk by improving air quality: A contingent valuation study in Chongqing, China. Science of the Total Environment. In press.

158 Population estimates from: UN, 2006. National Accounts Main Aggregates Database. United Nations Statistics Division. New York, New York.

159 Zhang, X. and Y. Zheng. 2001. Climate Change, Health Risk and Economic Analysis in China. Presented at the 4th Sino-Korean-U.S. Economic Environmental Modeling Workshop. Beijing. May 23-25.

台湾的研究表明VSL的差异可能部分是由于文化的差异造成的，但它也可能随着收入的增加而迅速变化。一项近期的研究表明避免空气污染引起的发病率的WTP，台湾人比居住在台湾的大陆人明显更高[160]。此外一项早期研究表明台湾的VSL在最近十年中快速增长。这项研究得出的弹性系数在2-3之间，明显比重庆的研究要高[161]。Bowland和Beghin同样也发现了VSL介于1.7–2.3, 中值为1.95[162]。这些研究有力地证明了VSL增加比收入增加更快，并且在中国随着近年收入的增长，VSL可能已经提高很多了。遗憾的是，中国没有更近期的研究。

表AB9展示了中国大陆，台北，美国，欧洲和泰国VSL研究的结果。

160 Hammitt, J. K.和 J. T. Liu. 2002年. 基于发病率风险价值的疾病类型和潜伏期的影响 Effects of disease type and latency on the value of mortality risk.《Risk and Uncertainty》期刊 Journal of Risk and Uncertainty 28(1)73-95。

161 Hammitt, J. K., J. L. Liu, 和J. L. Liu. 2000年. 生存是一种奢侈品。Survival is a luxury good. 为国家经济研究局 (NBER) 夏季学会公共政策和环境研讨会而著。坎布里奇, 马萨诸塞州。

162 Bowland, B. J.,和J. C. Beghin. 1998年. 发展中国家统计学生命价值的评估：对圣地亚哥地区污染和死亡率的应用。Robust estimated of value of a statistical life for developing economies: An application to pollution and mortality in Santiago. 农业和郊区发展中心，爱荷华州立大学，埃文斯市，爱荷华州. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa. 工作论文 Working Paper 99-WP 214。

Studies conducted on the island of Taiwan suggest that the divergence in VSL could be partly due to cultural differences but might change rapidly with rising income. A recent study found that WTP to avoid morbidity impacts of air pollution was significantly higher for Taiwanese natives than for people from mainland China living on the island of Taiwan[160].And an earlier study found that the VSL in the island of Taiwan has risen rapidly in recent decades, significantly more so than the growth of income. This study found an elasticity of 2–3, significantly higher than the Chongqing study[161]. Bowland and Beghin also found elasticity for VSL to be within the range of 1.7–2.3, with a median estimate of 1.95[162].These studies provide strong confirmation that VSL rises more quickly than income and that, with recent income growth in China, VSL's may have grown substantially higher. Unfortunately, more recent studies in the region were not available.

Table AB9 shows the results of available studies of VSL in mainland China, Taipei, the United States, Europe, and Thailand.

160 Hammitt, J. K., and J. T. Liu. 2002. Effects of disease type and latency on the value of mortality risk. Journal of Risk and Uncertainty 28(1)73-95.

161 Hammitt, J. K., J. L. Liu, and J. L. Liu. 2000. Survival is a luxury good. Prepared for the NBER Summer Institute Workshop on Public Policy and the Environment. Cambridge, Massachusetts.

162 Bowland, B. J., and J. C. Beghin. 1998. Robust estimated of value of a statistical life for developing economies: An application to pollution and mortality in Santiago. Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa. Working Paper 99-WP 214.

表AB9. 统计学生命价值研究结果汇总

VSL 范围 美元	区域	研究类型	参考文献
15,000–178,000	北京和安庆 (1999年)	条件价值– 空气污染	Zhou 和Hammitt 2005年
34,600	重庆 (1998年)	条件价值 – 空气污染	Wang 和 Mullahy 2006年
60,000–200,000	北京 (1999年)	条件价值 – 空气污染	Zhang 和 Zheng 2001年
5,000,000	台北 (1997年)	补偿工资差异-风险	Hammitt 等人2000年
5,500,000	美国 (1999年)	使用Meta-analysis方法*对工资风险的研究	EPA 2004年
1,180,000–2,400,000	欧盟 (2005年)	空气污染	DG 环境 2005年
959,700–1,523,000	泰国 (2003年)	条件价值 – 空气污染	Vassanadumrongdee 2003年

* Meta-analysis 目前没有权威的翻译方法，台湾一些学者称之为“整合分析”。

本研究使用了从111个中国城市的近期评价的平均值，并按照上面提到的Wang 和Mullahy的研究进行调整得到的，来反映出本研究评估的健康影响主要作用于中国财富相对集中地区的城区和城区居民[163]。如前所述，即使用了Wang和Mullahy提出的1.42的弹性系数来修正收入差异的，这个数据也要比世界上其他的国家的数据要更加的保守。

表AB10是本研究中使用的2004年度发病率和死亡率的价值，基本是采用了Zhang近期的分析。当疾病费用不能作为适当的估算方法时，我们使用了经调整的EPA的WTP, 调整因子为中美避免感冒的WTP的比值。Zhou和Hammitt发现中国参与调查的人愿意支付24–48元人民币 (3–6美元)来避免他们近期患感冒[164]。美国避免一天感冒症状的WTP处于130–1600元人民币 (2005年美元16–200美元)，我们用平均值，即1000 人民币(120美元) 来计算两国WTP比值。ICCT尽可能地在所有的部分都对发病率采用了更加保守的数据。例如，ICCT对轻微症状(急性支气管炎，哮喘发作，和活动受限天数)采用了调整因子（即如上面例子里的缩放比例）因为它们更加保守，但对慢性支气管炎则使用了Zhang研究的数值，因为如果还用调整因子得到的数值可能更高。

163 Zhang, M.等人2008年. 通过使用疾病经济负担分析法对中国111个城市与颗粒物相关的健康影响的经济评估。环境管理期刊88:947-954。

164 Zhou, Y. 和J. K. Hammitt. 2005年 草案. 第八章—中国大气污染相关的健康风险的经济价值：一种条件价值评估分析。源自麻省理工大学即将出版的一本书籍。

Table AB9. Value of a Statistical Life study results

VSL RANGE ORIGINAL US$	ORIGINAL LOCATION	TYPE OF STUDY	REFERENCE
15,000–178,000	Beijing and Anqing (1999)	CV – air pollution	Zhou & Hammitt 2005
34,600	Chongqing (1998)	CV – air pollution	Wang and Mullahy 2006
60,000–200,000	Beijing (1999)	CV – air pollution	Zhang & Zheng 2001
5,000,000	Taipei (1997)	Compensating wage differential – risk	Hammitt et al. 2000
5,500,000	US (1999)	Meta-analysis of wage-risk studies	EPA 2004
1,180,000–2,400,000	EU (2005)	Air pollution	DG Environment 2005
959,700–1,523,000	Thailand (2003)	CV – air pollution	Vassanadumrongdee 2003

To account for the fact that health impacts measured in this analysis occur primarily in or to resident in urban areas, where wealth in China is concentrated, this study uses an average value taken from a recent health assessment for 111 Chinese cities adjusted from the Wang and Mullahy study referenced above[163]. As mentioned earlier, this is also a much more conservative value than is used by other governments around the world, even when corrected for difference in income and with the elasticity of 1.42 reported by Wang and Mullahy.

The values for morbidity and mortality that are used in this analysis are included in Table AB10 for the year of 2004 and were mostly drawn from Zhang's recent analysis. Where cost of illness does not necessarily provide an appropriate measure, EPA's WTP values are scaled using the ratio of Chinese to U.S. WTP to avoid a cold. Zhou and Hammitt found Chinese respondents are willing to pay ¥24–¥48 ($3–$6) to avoid their most recent cold episode[164]. WTP to avoid one day's cold symptoms in the United States ranges from ¥130–¥1600 (US$ (2005)16–200); the estimated mean of ¥1000 ($120) is used to derive the ratio. In all cases ICCT uses more conservative values for morbidity when possible. For example, ICCT uses the scaled values for minor symptoms (acute bronchitis, asthma attacks, and restricted activity days) because they are more conservative but uses Zhang's value for chronic bronchitis because the value that was arrived at through this same method is much higher.

163 Zhang, M., et al. 2008. Economic assessment of the health effects related to particulate matter pollution in 111 Chinese cities by using economic burden of disease analysis. Journal of Environmental Management 88:947-954.

164 Zhou, Y. and J. K. Hammitt. 2005 draft. Chapter 8—The economic value of air-pollution-related health risks in China: A contingent valuation study. From a forthcoming book for MIT Press.

表AB10. 发病率和死亡率价值

健康影响	基础	货币价值	
		人民币 (2004)	美元(2004)
提前死亡率 (VSL)	WTP (Zhang等人. 2008年)	570,480	83,575
婴幼儿死亡率 (VSL)	与成年人相同	570,480	83,575
慢性支气管炎 ($/每避免一例)	WTP (Zhang等人. 2008年)	29,050	4,256
呼吸疾病入院 ($/每避免一例)	COI (Zhang等人. 2008年)	3,430	503
心血管疾病入院 ($/每避免一例)	COI (Zhang等人. 2008年)	7,004	1,026
急性支气管炎 ($/每避免一例)	由中美避免感冒的WTP的比值得到	89	15
哮喘发作 ($/每避免一例)	由中美避免感冒的WTP的比值得到	14	2
活动受限天数 ($/每避免一例)	由中美避免感冒的WTP的比值得到	14	2

中国2000－2008年的统计数据源于世界银行组织[165]。收录的数据包括总人口，以当前美元计算的国内生产总值（GDP），以购买力评价法得到人均国民总收入（GNI）。表AB11包括基于人口和GDP增加预测的2030年人口和经济指标增长的评价和预测[166]。这里默认中国经济会在接下来的20年中继续保持相对高速增长，缩小对发达国家经济的差距。

表AB11. 中国经济与人口增长的预测

	国务院发展研究中心	中国社会科学院数量经济与技术经济研究所		美国
时期	平均经济增长率 (%)	平均经济增长率 (%)	最终年的人口预测 (亿)	最终年的人口预测 (亿)
2001-2010	7-7.9	8.1	14.23	13.65
2011-2020	5.5-6.6	6.4	15.18	14.29
2021-2030	5.4	5.4	15.72	14.50
2031-2040	4.5	4.9	15.85	--
2041-2050	3.4	4.3	15.52	--

中国收入的增长迅速。本研究中参照Wang和Mullahy对重庆的研究对所有发病率价值使用弹性系数为1，对死亡率采用保守的弹性系数1.42。这意味着发病率价值的增长与收入增长同步，死亡率价值（VSL）比收入增长快，如图AB4所示。

165 世界银行组织。 2009年。世界经济发展指标。 http://go.worldbank.org/U0FSM7AQ40。

166 2009年度， GDP增长采用了Chinability网站的评价 (www.chinability.com/GDP.htm) ，2010年及以后采用了国务院发展中心(DRC)和中国社会科学院(CASS)数量经济与技术经济研究所的研究。人口预测采用了中国社会科学院和美国的数据。美国的预测源自： 联合国. 2004年世界城市化前景：2003年修订，联合国出版社 ，纽约。

Table AB10. Mortality and morbidity values

HEALTH IMPACT	BASIS	MONETARY VALUE	
		RMB (2004)	US$(2004)
Premature mortality (VSL)	WTP (Zhang et al. 2008)	570,480	83,575
Infant mortality (VSL)	Same as adult	570,480	83,575
Chronic bronchitis ($/case avoided)	WTP (Zhang et al. 2008)	29,050	4,256
Respiratory hospital admissions ($/case avoided)	COI (Zhang et al. 2008)	3,430	503
Cardiovascular hospital admissions ($/case avoided)	COI (Zhang et al. 2008)	7,004	1,026
Acute bronchitis ($/case avoided)	China to US ratio of WTP to avoid a cold	89	15
Asthma attack ($/case avoided)	China to US ratio of WTP to avoid a cold	14	2
Restricted activity day ($/case avoided)	China to US ratio of WTP to avoid a cold	14	2

China statistics for the years 2000 to 2008 come from the World Bank Group[165]. Data collected include total population, gross domestic product (GDP) in current US$, gross national income (GNI) per capita on a purchasing power parity (PPP) basis. Population and economic indicators are extended out to 2030 based on population and GDP growth estimates and forecasts included in Table AB11. [166] There is general agreement that China's economy will continue to maintain relatively robust growth over the next twenty years, narrowing the gap that currently separates the China from the economies of the developed world.

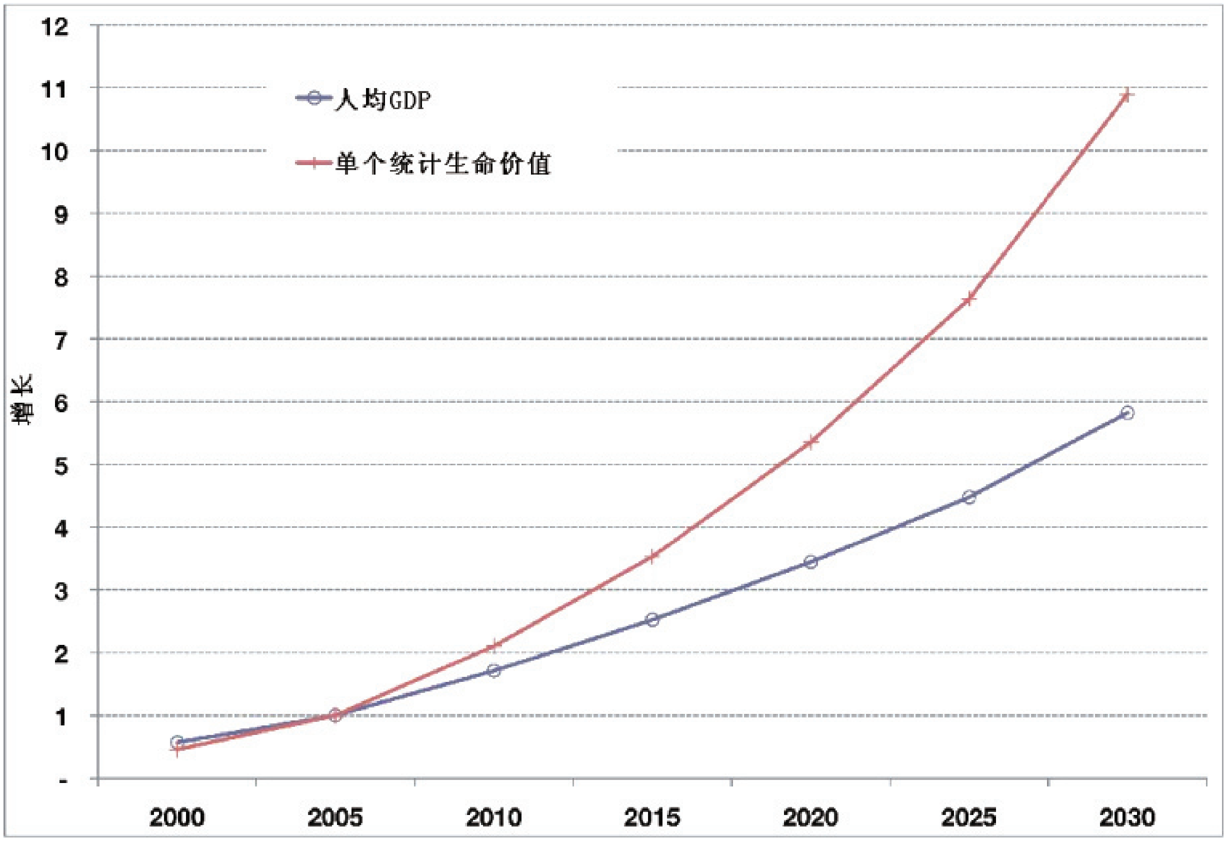
Table AB11. Forecasts for economic and population growth in china

	DRC, STATE COUNCIL	CASS INSTITUTE OF QUANTATIVE AND TECHNICAL ECONOMICS		UNITED NATIONS
PERIOD	AVG. ECONOMIC GROWTH RATE (%)	AVG. ECONOMIC GROWTH RATE (%)	POPULATION FORECAST FOR FINAL YEAR (BILLION)	POPULATION FORECAST FOR FINAL YEAR
2001-2010	7-7.9	8.1	1.423	1.365
2011-2020	5.5-6.6	6.4	1.518	1.429
2021-2030	5.4	5.4	1.572	1.450
2031-2040	4.5	4.9	1.585	--
2041-2050	3.4	4.3	1.552	--

Income is increasing very rapidly in China. For this analysis an elasticity of 1 is used for all morbidity values and a conservative elasticity of 1.42 is used for mortality, as reported by Wang and Mullahy for Chongqing. This means that morbidity values rise at the same rate as income while mortality values (VSL) rise more rapidly, as demonstrated in Figure AB4.

165 World Bank Group. 2009. World development indicators. http://go.worldbank.org/U0FSM7AQ40.

166 For the year 2009, the GDP growth estimate from Chinability was used (www.chinability.com/GDP.htm) and for 2010 and beyond the estimates from Development Research Center (DRC) of the State Council and the Chinese Academy of Social Sciences (CASS) Institute of Quantitative and Technical Economics were used. Population forecasts came from CASS and the United Nations. The United Nations forecasts are available in: United Nations. 2004. World urbanization prospects: The 2003 revisions. United Nations Publication, New York.



图AB4. 随着时间的推移人均GDP (PPP) 和VSL 增长

在本研究涉及的30年时间跨度内，即使采用调整过的弹性系数，中国减少提前死亡的货币价值也远远赶不上其他国家所使用的价值。美国EPA使用的数据按照中国GDP增长进行调整后，仍然将近高出本研究中使用的2030年数据的六倍。这表明本研究中使用的VSL或者弹性系数（或者两者都有）可能要比现实情况低。本研究对健康效益货币化的保守假设可能导致其比预期净效益低。

结论

正如本文所指出的，健康影响分析的结论应该是保守的下限评价。通过与近期Zhang等人的分析相比较，本分析指出机动车排放仅占健康影响的10%[167]。鉴于移动源排放在工业化国家主要城市的大气污染中占到50%甚至80%[168]，非常接近人群的呼吸范围（高度），并且是中国快速增长的污染源，所以估计目前中国的移动源污染会占健康影响的至少20-30%或有可能更大，并会不断增加[169]。本研究与其他近期研究比较表明这些结论应该被作为一个保守的下限评价的影响。

167 Zhang, M等人 2008年。 通过使用疾病经济负担分析法对中国111个城市与颗粒物相关的健康影响的经济评估。环境管理期刊88:947-954。

168 Han, X.,和Naeher, L.P. 2006年. 发展中国家交通相关的大气污染评价研究的回顾。 国际环境32:106-120。

169 北京近期PM2.5的研究表明机动车是城市颗粒物的主要来源 (Chan, C.T.等人 2005年, 北京PM2.5, PM10以及含碳物质垂直分布特征和来源。大气环境39:5113-5124; Dan 等人. 2004年.北京PM2.5的来源和其中碳的种类的特征. 大气环境38:3443-3452.). 2001-2002年间 Dan 等人的研究，冬季PM2.5 浓度会上升50—100 %，表明家庭取暖是一个主要排放源，尽管由于使用更清洁的燃料来代替燃煤家庭取暖排放已经比从前降低。

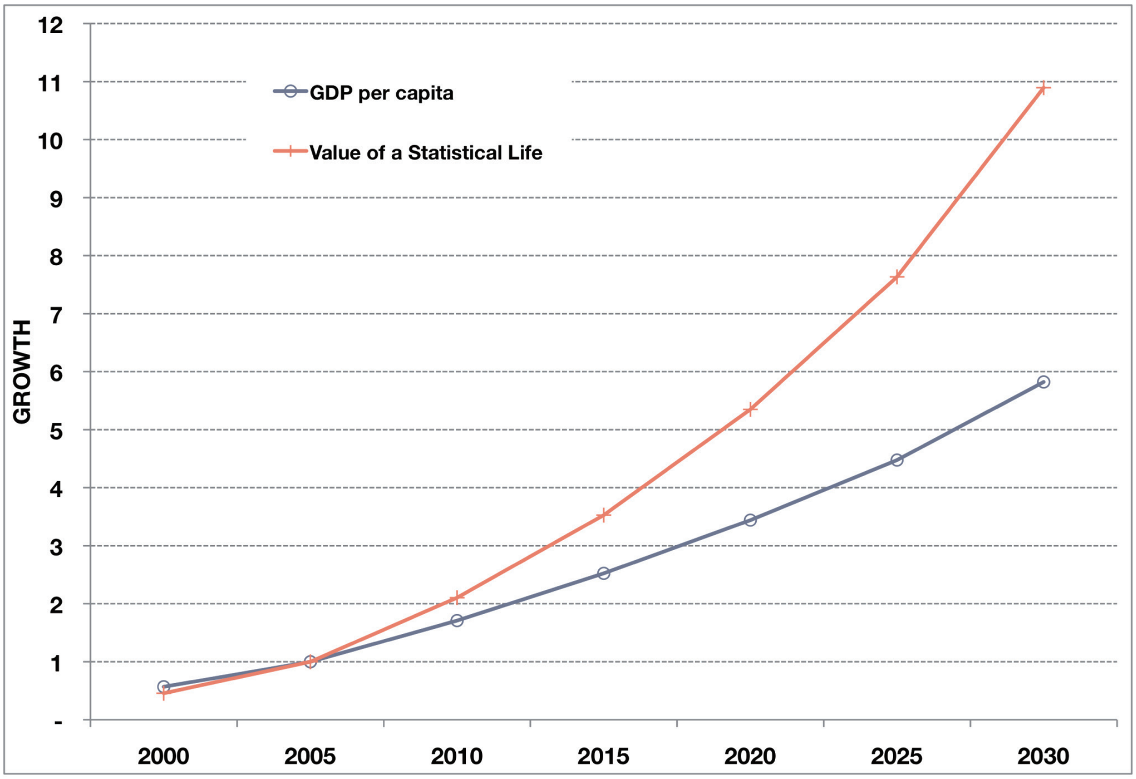


Figure AB4. GDP (PPP) per capita and VSL growth over time

Within the 30-year timeframe of this study, the value assigned to reducing premature mortality in China does not come close to catching up with values used in other countries, even with the elasticity adjustment. The value used by U.S. EPA, when adjusted for the forecasted growth in Chinese GDP, is still almost six times higher than the 2030 value used in this analysis. This suggests that VSL and/or elasticity used in this analysis may be lower than is realistic. The conservative assumptions used in this study to monetize health benefits may lead to lower than expected net benefits.

Findings in context

As stated previously in this document, the findings of the HIA should be taken as conservative, low-end estimates. As compared to a recent analysis by Zhang et al., this analysis would suggest that vehicle emissions account for only 10 percent of health impacts[167]. As mobile sources tend to be responsible for 50 to more than 80 percent of air pollution in major cities in industrialized countries[168], are in close proximity to people breathing, and are a rapidly growing source in China, mobile sources would be expected to be responsible for at least 20 to 30 percent, if not a significantly larger portion, of the health impacts currently and growing over time. Comparison of this analysis with other recent studies suggests that these findings should be viewed as conservative, low-end estimates of impacts[169].

167 Zhang, M., et al. 2008. Economic assessment of the health effects related to particulate matter pollution in 111 Chinese cities by using economic burden of disease analysis. Journal of Environmental Management 88:947-954.

168 Han, X., and Naeher, L.P. 2006. A review of traffic-related air pollution assessment studies in the developing world. Environment International 32:106-120.

169 Recent studies of PM2.5 sources in Beijing found vehicles to be one of the major sources of particles in the city (Chan, C.T. et al. 2005, Characteristics of vertical profiles and sources of PM2.5, PM10, and carbonaceous species in Beijing. Atmospheric Environment 39:5113-5124; Dan et al. 2004. The characteristics of carbonaceous species and their sources in PM2.5 in Beijing. Atmospheric Environment 38:3443-3452.). In the 2001-2002 study by Dan et al., however, PM2.5 concentrations rose by 50 to 100 percent in winter months, suggesting that home heating has been a significant source of emissions, although this source is declining as other, cleaner fuels are replacing coal.

将此研究放入相关背景来看，英国政府近期公布了欧盟环境总署的英国过早死亡可以达到50,000 每年或者占到总死亡率的10%的结论[170]。中国有着更高的人均排放量，大气污染造成死亡会占到更大比例。本研究中，机动车造成的大气污染造成的死亡的百分比在0.2%和最高3%之间(3%对应的是假设不进行额外污染控制情况下2030年的排放情况)。

本研究分析得出的排放引起的健康影响在2010GDP的0.5％（由现行方案带来的收益）到2030年GDP的2.6%（假设采取强化方案带来的收益）之间。世界银行评价显示2003年大气污染带来的经济损失（提现在发病率和死亡率）占到GDP的1.16%[171]。基于2005年的结果，本研究表明道路机动车会占到大气污染相关费用的15—20%。

本研究中的保守因素意味着本研究提供了下列影响的下限估计：

- 城市吸入因子的评价可能比实际值偏低，特别是这些城市持续扩大，人口越来越密集。从2010年到2030年间，中国城市化水平预计会由40%增长到60%[172]。
- 二次颗粒物吸入因子的评价中使用了相对保守的数据。虽然一些研究发现NOx 排放的影响(更高的排放，更低的吸入因子) 与一次颗粒物的影响相约，本研究发现NOx 排放的影响不足一次颗粒物排放的影响的十分之一。
- 虽然中国的收入与美国和欧洲比较只低一个数量级，但是健康影响的价值尤其是死亡率比美国和欧洲使用的价值低两个数量级。
- 随着时间推移死亡率价值的增长可能被低估了。

如果研究中使用其他研究开发的更高的吸入因子来计算，影响会变为现在两倍以上，将占到死亡率比例的5%和2030年GDP的5.5%。

170 下议院，环境审计委员会，空气质量，第五次会议报告2009年10月22日， 2010年3月22日。

171 世界银行. 2007年. 中国污染费用。

172 联合国. 2004年. 世界城市化前景: 2003修订版。

To put this study in context, the UK government recently publicized findings by the European Environment Agency that premature deaths in that country could be as high as 50,000 per year, or 10 percent of all deaths[170]. China has much higher emissions per capita, which could result in an even larger portion mortality impacted by air pollution. In this analysis, the percentage of deaths due to air pollution from vehicles varied between 0.2 percent and three percent at the extreme (2030 emissions with no additional controls in place).

Health impacts of the emissions estimated in this analysis were equal to between 0.5 percent of GDP in 2010 for the impacts avoided due to the current program to 2.6 percent of the GDP in 2030 for the Strong program. The World Bank estimates that the economic cost of air pollution in 2003, in terms of mortality and morbidity, was 1.16 percent of GDP[171]. Based on the 2005 results, this analysis suggests on-road vehicles would be responsible for 15-20 percent of air pollution related costs.

The conservative factors in this analysis suggest that the analysis provides a low-end estimate of impacts include:

• Intake fraction estimates for cities are likely to be lower than justified, especially as cities continue to grow and become more densely populated. China is expected to move from 40 to almost 60 percent urban in between 2010 and 2030[172].

• Conservative values are used for the secondary particle intake fraction estimates. Some studies have found impacts from NOx emissions (higher emissions but lower intake fraction) to be roughly on par with primary PM, while this study found them to be more than an order of magnitude lower.

• Values of health impacts, especially mortality, were two orders of magnitude lower than those used in the United States and Europe, while income differs by only one order of magnitude.

• The growth of mortality values over time was likely to be underestimated.

Were this study to have used the higher intake fractions values, which were developed in other studies, impacts more than twice as high would have been found, accounting for up to five percent of deaths and 5.5 percent of GDP in 2030.

170 House of Commons, Environmental Audit Committee, Air Quality. Fifth Report of Session 2009-10. March 22, 2010.

171 World Bank. 2007. Cost of Pollution in China.

172 United Nations. 2004. World Urbanization Prospects: The 2003 Revision.

附录 C: 美国、欧盟、中国和日本的排放标准

美国: 轻型车排放标准 (FTP-75 底盘测功机测试)*

TIER 2 标准							
标准	车型年	车型	全使用寿命中的排放限值(100 – 120,000 英里) 规定的每英里排放上限(G/MI)				
			NO_X	NMOG	CO	PM	HCHO
Bin 1	2004+	LDV, LLDT, HLDT, MDPV	0.00	0.00	0.0	0.00	0.000
Bin 2	2004+	LDV, LLDT, HLDT, MDPV	0.02	0.01	2.1	0.01	0.004
Bin 3	2004+	LDV, LLDT, HLDT, MDPV	0.03	0.055	2.1	0.01	0.011
Bin 4	2004+	LDV, LLDT, HLDT, MDPV	0.04	0.070	2.1	0.01	0.011
Bin 5	2004+	LDV, LLDT, HLDT, MDPV	0.07	0.090	4.2	0.01	0.018
Bin 6	2004+	LDV, LLDT, HLDT, MDPV	0.10	0.090	4.2	0.01	0.018
Bin 7	2004+	LDV, LLDT, HLDT, MDPV	0.15	0.090	4.2	0.02	0.018
Bin 8a	2004+	LDV, LLDT, HLDT, MDPV	0.20	0.125	4.2	0.02	0.018
Bin 8b	2004-2008	HLDT, MDPV	0.20	0.156	4.2	0.02	0.018
Bin 9a	2004-2006	LDV, LLDT	0.30	0.090	4.2	0.06	0.018
Bin 9b	2004-2006	LDT2	0.30	0.130	4.2	0.06	0.018
Bin 9c	2004-2008	HLDT, MDPV	0.30	0.180	4.2	0.06	0.018
Bin 10a	2004-2006	LDV, LLDT	0.60	0.156	4.2	0.08	0.018
Bin 10b	2004-2008	HLDT, MDPV	0.60	0.230	6.4	0.08	0.027
Bin 10c	2004-2008	LDT4, MDPV	0.60	0.280	6.4	0.08	0.027
Bin 11	2004-2008	MDPV	0.90	0.280	7.3	0.12	0.032
TIER 1 标准							
LDV	1994-2003	LDV	0.60	0.31	4.2	0.10	-
LDT1	1994-2003	LDT1	0.60	0.31	4.2	0.10	0.800
LDV 柴油	1994-2003	LDV柴油	1.25	0.31	4.2	0.10	-
LDT1 柴油	1994-2003	LDT1柴油	1.25	0.31	4.2	0.10	0.800
LDT2	1994-2003	LDT2	0.97	0.40	5.5	0.10	0.800
LDT3	1994-2003	LDT3	0.98	0.46	6.4	0.10	0.800
LDT4	1994-2003	LDT4	1.53	0.56	7.3	0.12	0.800

*从车型年2000开始，机动车必须额外进行US06工况(极速加速和高速行驶)和SC03工况(使用空调)的测试。

Appendix C- Emission Standards in the United States, European Union, China, and Japan

United States: Light-duty Vehicle Emission Standards (FTP-75 chassis dynamometer test)*

TIER 2 PROGRAM							
STANDARD	MODEL YEAR	VEHICLES	EMISSION LIMITS AT FULL USEFUL LIFE (100 – 120,000 MILES) MAXIMUM ALLOWED GRAMS PER MILE (G/MI)				
			NO_x	NMOG	CO	PM	HCHO
Bin 1	2004+	LDV, LLDT, HLDT, MDPV	0.00	0.00	0.0	0.00	0.000
Bin 2	2004+	LDV, LLDT, HLDT, MDPV	0.02	0.01	2.1	0.01	0.004
Bin 3	2004+	LDV, LLDT, HLDT, MDPV	0.03	0.055	2.1	0.01	0.011
Bin 4	2004+	LDV, LLDT, HLDT, MDPV	0.04	0.070	2.1	0.01	0.011
Bin 5	2004+	LDV, LLDT, HLDT, MDPV	0.07	0.090	4.2	0.01	0.018
Bin 6	2004+	LDV, LLDT, HLDT, MDPV	0.10	0.090	4.2	0.01	0.018
Bin 7	2004+	LDV, LLDT, HLDT, MDPV	0.15	0.090	4.2	0.02	0.018
Bin 8a	2004+	LDV, LLDT, HLDT, MDPV	0.20	0.125	4.2	0.02	0.018
Bin 8b	2004-2008	HLDT, MDPV	0.20	0.156	4.2	0.02	0.018
Bin 9a	2004-2006	LDV, LLDT	0.30	0.090	4.2	0.06	0.018
Bin 9b	2004-2006	LDT2	0.30	0.130	4.2	0.06	0.018
Bin 9c	2004-2008	HLDT, MDPV	0.30	0.180	4.2	0.06	0.018
Bin 10a	2004-2006	LDV, LLDT	0.60	0.156	4.2	0.08	0.018
Bin 10b	2004-2008	HLDT, MDPV	0.60	0.230	6.4	0.08	0.027
Bin 10c	2004-2008	LDT4, MDPV	0.60	0.280	6.4	0.08	0.027
Bin 11	2004-2008	MDPV	0.90	0.280	7.3	0.12	0.032
TIER 1 PROGRAM							
LDV	1994-2003	LDV	0.60	0.31	4.2	0.10	-
LDT1	1994-2003	LDT1	0.60	0.31	4.2	0.10	0.800
LDV diesel	1994-2003	LDV diesel	1.25	0.31	4.2	0.10	-
LDT1 diesel	1994-2003	LDT1 diesel	1.25	0.31	4.2	0.10	0.800
LDT2	1994-2003	LDT2	0.97	0.40	5.5	0.10	0.800
LDT3	1994-2003	LDT3	0.98	0.46	6.4	0.10	0.800
LDT4	1994-2003	LDT4	1.53	0.56	7.3	0.12	0.800

* Effective for model year 2000, vehicles had to be additionally tested on the US06 cycle (aggressive, high speed driving) and the SC03 cycle (use of air conditioning).

美国:重型柴油卡车发动机排放标准 (FTP瞬态和SET 测试工况)

	克每制动马力小时(G/BHP-HR)			
	HC	CO	NO_x	PM
1988	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1994	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10
2004	0.5	-	2.0	0.10
2010	0.14	-	0.2	0.01

耐久性要求：

- 重型柴油发动机（轻型） (8,500 – 19,500 磅最大总质量): 8年/110,000 英里 (以先达到的为准)
- 重型柴油发动机（中型） (19,500 – 33,000磅最大总质量): 8年/185,000英里
- 重型柴油发动机（重型） (> 33,000磅最大总质量): 8年/290,000英里

United States: Heavy-duty Diesel Truck Engine Emission Standards (FTP Transient and SET test cycles)

	GRAMS PER BRAKE HORSEPOWER-HOUR (G/BHP-HR)			
	HC	CO	NO_X	PM
1988	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1994	1.3	15.5	5.0	0.10
1998	1.3	15.5	4.0	0.10
2004	0.5	-	2.0	0.10
2010	0.14	-	0.2	0.01

Useful Life Requirements：

- Light heavy-duty diesel engines (8,500 – 19,500 lbs GVWR): 8 years/110,000 miles (whichever occurs first)
- Medium heavy-duty diesel engines (19,500 – 33,000 lbs GVWR): 8 years/185,000 miles
- Heavy heavy-duty diesel engines (> 33,000 lbs GVWR): 8 years/290,000 miles

欧盟: 乘用车排放标准 (ECE15 + EUDC 底盘测功机测试)*

		克每公里 (G/KM)				
柴油	实施日期	CO	HC	HC+ NO_X	NO_X	PM
欧 1[f]	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.140 (0.180)
欧2, IDI	1996.01	1.00	-	0.70	-	0.080
欧2, DI	1996.01[a]	1.00	-	0.90	-	0.100
欧3	2000.01	0.64	-	0.56	0.50	0.050
欧4	2005.01	0.50	-	0.30	0.25	0.025
欧5	2009.09[b]	0.50	-	0.23	0.18	0.005[e]
欧6	2014.09	0.50	-	0.17	0.08	0.005[e]
汽油						
欧1[f]	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-
欧2	1996.01	2.20	-	0.50	-	-
欧3	2000.01	2.30	0.2	-	0.15	-
欧4	2005.01	1.00	0.1	-	0.08	-
欧5	2009.09[b]	1.00	0.1[c]	-	0.06	0.005[d,e]
欧6	2014.09	1.00	0.1[c]	-	0.06	0.005[d,e]

* M1类车。欧 1 到欧 4阶段, 车重超过 2,500 kg 被作为 N1类车进行型式认证

a –1999年9月30日之后，装有直喷发动机的车要求达到非直喷限值

b – 2011年1月起对所有车型进行要求

c – 非甲烷碳氢化合物限值= 0.068 g/km

d – 仅适用于装有直喷发动机的机动车

e – 0.0045 g/km 使用颗粒物测量规程时

f – 欧 1 括号里的数值为生产一致性限值

耐久性要求

■ 欧 3: 80,000 公里或者5 年(以先达到的为准); 生产制造商可以使用下面的劣化因子替代实际的劣化试验：

o 点燃式发动机 (汽油): CO, HC和NOx为1.2

o 压燃式发动机(柴油): CO, NOx, HC+NOx,为1.1， PM为1.2

■ 欧4: 100,000公里或者5 年 (以先达到的为准)。

■ 欧5/6: 使用一致性要求为100,000公里或者5年;型式核准的污染物控制装置的耐久性要求 160,000公里或者5年(以先达到的为准); 生产制造商可以使用下面的劣化因子替代实际的劣化试验(欧 6的劣化因子尚未确定):

o 点燃式发动机: CO为1.5, HC为1.3, NOx为1.6, PM为1.0

o 压燃式发动机: CO为1.5, NOx和HC+NOx, PM为1.0

European Union: Emission Standards for Passenger Cars (ECE15 + EUDC chassis dynamometer test)*

		GRAMS PER KILOMETER (G/KM)				
DIESELS	DATE	CO	HC	HC+ NO_X	NO_X	PM
Euro 1[f]	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.140 (0.180)
Euro 2, IDI	1996.01	1.00	-	0.70	-	0.080
Euro 2, DI	1996.01[a]	1.00	-	0.90	-	0.100
Euro 3	2000.01	0.64	-	0.56	0.50	0.050
Euro 4	2005.01	0.50	-	0.30	0.25	0.025
Euro 5	2009.09[b]	0.50	-	0.23	0.18	0.005[e]
Euro 6	2014.09	0.50	-	0.17	0.08	0.005[e]
GASOLINE						
Euro 1[f]	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-
Euro 2	1996.01	2.20	-	0.50	-	-
Euro 3	2000.01	2.30	0.2	-	0.15	-
Euro 4	2005.01	1.00	0.1	-	0.08	-
Euro 5	2009.09[b]	1.00	0.1[c]	-	0.06	0.005[d,e]
Euro 6	2014.09	1.00	0.1[c]	-	0.06	0.005[d,e]

* Category M1 vehicles. For Euro 1 through 4, vehicles greater than 2,500 kg were type approved as Category N1 vehicles

a – After Sept 30, 1999, vehicles with DI engines had to meet the IDI limits

b – Jan 2011 for all models

c – NMHC limit = 0.068 g/km

d – applicable only to vehicles with DI engines

e – 0.0045 g/km using the PMP measurement procedure

f – Euro 1 values in brackets are conformity of production limits

Useful Life Requirements

■ Euro 3: 80,000 km or 5 years (whichever occurs first); in lieu of an actual deterioration run, manufacturers may use the following deterioration factors:

o Spark ignition (gasoline): 1.2 for CO, HC, and NO_x

o Compression ignition (diesel): 1.1 for CO, NOx, HC+NOx, and 1.2 for PM

■ Euro 4: 100,000 km or 5 years (whichever occurs first).

■ Euro 5/6: in-service conformity of 100,000 km or 5 years; durability testing of pollution control devices for type approval is 160,000 km or 5 years (whichever occurs first); in lieu of a durability test, manufacturers may use the following deterioration factors (Euro 6 deterioration factors to be determined):

o Spark ignition: 1.5 for CO, 1.3 for HC, 1.6 for NOx, and 1.0 for PM

o Compression ignition: 1.5 for CO, 1.1 for NOx and HC+NOx, and 1.0 for PM

欧盟:重型柴油发动机的排放标准

			克每千瓦时 (G/KWH)			
	实施日期	测试工况	CO	HC	NO_X	PM
欧 I	1992, < 85 kW	ECE R-49	4.5	1.1	8.0	0.612
	1992, > 85 kW		4.5	1.1	8.0	0.36
欧II	1996.10		4.0	1.1	7.0	0.25
	1998.10		4.0	1.1	7.0	0.15
欧 III	1999.10, 仅适用于环境友好汽车*	ESC & ELR	1.5	0.25	2.0	0.02
	2000.10		2.1	0.66	5.0	0.10 0.13[a]
欧 IV	2005.10		1.5	0.46	3.5	0.02
欧 V	2008.10		1.5	0.46	2.0	0.02
欧 VI	2013.01		1.5	0.13	0.4	0.01

a –适用于每个汽缸工作排量小于0.75立方分米并且额定功率转速大于3000转/分钟的发动机

			克每千瓦时 (G/KWH)				
	实施日期	测试工况	CO	NMHC	CH_4[A]	NO_X	PM[B]
欧III	1999.10, 仅适用于环境友好汽车	ETC	3.0	0.40	0.65	2.0	0.02
	2000.10		5.45	0.78	1.6	5.0	0.16 0.21[c]
欧IV	2005.10		4.0	0.55	1.1	3.5	0.03
欧V	2008.10		4.0	0.55	1.1	2.0	0.03
欧VI	2013.01		4.0	0.16[d]	0.5	0.4	0.01

a – 仅适用于点燃式发动机：欧III 至欧 V：仅适用于天然气发动机；欧VI：天然气和液化石油气

b – 对欧III 和欧 V汽油发动机不适用

c –适用于每个汽缸工作排量小于0.75立方分米并且额定功率转速大于3000转/分钟的发动机

d –对柴油发动机是总碳氢化合物

European Union: Emission Standards for Heavy-duty Diesel Engines

			GRAMS PER KILOWATT-HOUR (G/KWH)			
	DATE	TEST CYCLE	CO	HC	NO_X	PM
Euro I	1992, < 85 kW	ECE R-49	4.5	1.1	8.0	0.612
	1992, > 85 kW		4.5	1.1	8.0	0.36
Euro II	1996.10		4.0	1.1	7.0	0.25
	1998.10		4.0	1.1	7.0	0.15
Euro III	1999.10, EEVs* only	ESC & ELR	1.5	0.25	2.0	0.02
	2000.10		2.1	0.66	5.0	0.10 0.13[a]
Euro IV	2005.10		1.5	0.46	3.5	0.02
Euro V	2008.10		1.5	0.46	2.0	0.02
Euro VI	2013.01		1.5	0.13	0.4	0.01

a – for engines with swept volume per cylinder less than 0.75 dm^3 and rated power speed greater than 3000min^{-1}

			GRAMS PER KILOWATT-HOUR (G/KWH)				
	DATE	TEST CYCLE	CO	NMHC	CH_4[A]	NO_X	PM[B]
Euro III	1999.10, EEVs only	ETC	3.0	0.40	0.65	2.0	0.02
	2000.10		5.45	0.78	1.6	5.0	0.16 0.21[c]
Euro IV	2005.10		4.0	0.55	1.1	3.5	0.03
Euro V	2008.10		4.0	0.55	1.1	2.0	0.03
Euro VI	2013.01		4.0	0.16[d]	0.5	0.4	0.01

a – for spark ignition engines only; Euro III through V: natural gas only; Euro VI: natural gas and liquid petroleum gas

b – not applicable for Euro III and IV gasoline engines

c – for engines with swept volume per cylinder less than 0.75 dm^3 and rated power speed greater than 3000min^{-1}

d – total hydrocarbon for diesel engines

耐久性要求

2005年10月对新车型进行型式核准，2006年10月对全部车型进行型式核准：生产制造商必须保证在下列耐久性周期内达到排放限值：

车辆类型	耐久性要求 (以先达到的为准)	
	欧 IV, V	欧 VI
N1 和 M2	100,000 公里/5年	160,000公里/5年
N2	200,000公里/6年	300,000公里/6年
N3 < 16 吨		
M3 I级, A类, 以及B类< 7.5 吨		
N3 > 16吨	500,000公里/7年	700,000公里/7年
M3 III级, 以及B类> 7.5 吨		

Useful Life Requirements

Effective October 2005 for new type approvals and October 2006 for all type approvals, manufacturers must adhere to emission limits over the following useful life periods:

VEHICLE CATEGORY	PERIOD (WHICHEVER EVENT OCCURS FIRST)	
	EURO IV, V	EURO VI
N1 and M2	100,000 km/5 years	160,000 km/5 years
N2	200,000 km/6 years	300,000 km/6 years
N3 < 16 tonnes		
M3 Class I, Class A, and Class B < 7.5 tonnes		
N3 > 16 tonnes	500,000 km/7 years	700,000 km/7 years
M3 Class III, and Class B > 7.5 tonnes		

中国: 轻型车新车†型式核准排放标准(ECE15 + EUDC 底盘测功机测试)*

柴油	全国	北京	上海	广州	生产一致性	在用符合性	耐久性	OBD 要求
国 I	2000.01 (T1) 2001.01 (T2)[a]	1999	/	/	抽一辆样车	不要求	80,000 公里	不要求
国 II	2004.07 (T1) 2005.07 (T2)	2002	2003.03	2005.07	抽一辆样车	不要求	80,000公里	不要求
国 III[b]	2007.07	2007.01	2007.12.31	2006.09	抽三辆样车	要求	5 年或80,000公里	2008.07 (< 6座, GVWR < 2.5吨); 2010.07 起对其他车型进行要求
国 IV	2010.07	/	/	/	抽三辆样车	要求	5年或 80,000公里	2010.07
汽油								
国 I	2000.01 (T1) 2001.01 (T2)[a]	1999	/	/	抽一辆样车	不要求	80,000 公里	不要求
国 II	2004.07 (T1) 2005.07 (T2)	2002	/	/	抽一辆样车	不要求	80,000公里	不要求
国 III[b]	2007.07	2005.12.31	/	/	抽三辆样车	要求	5 年或80,000公里	2008.07 (< 6座, GVWR < 2.5吨); 2010.07 起对其他车型进行要求
国 IV	2010.07	2008.03	2009.11	/	抽三辆样车	要求	5年或 80,000公里	2010.07

† 自型式核准执行日期之后一年起，不达标的新车和新发动机不得销售、注册或使用。标准不适用于在型式核准执行日期之前已登记注册的车型

* 速度点与ECE15和EUDC工况基本相同，除了有部分瞬态速度点

a – T1 M1类轻型车要求不多于 6 座，并且质量不超过25吨；T2是其他非T1类的轻型车

b –国III 标准原定在2007年对所有新车型实施，但是允许有一年的过渡期，所以所有车型在2008年之前都可以销售（重型车截止1月，轻型车截止7月）

China: Emission Standards for New† Light-duty Vehicle Type Approval (ECE15 + EUDC chassis dynamometer test)*

DIESELS	CHINA	BEIJING	SHANGHAI	GUANGZHOU	PRODUCTION CONFORMITY	IN-USE SURVEILLANCE	DURABILITY	OBD REQUIREMENT
China I	2000.01 (T1) 2001.01 (T2)[a]	1999	/	/	Sample of one	No	80,000 km	No
China II	2004.07 (T1) 2005.07 (T2)	2002	2003.03	2005.07	Sample of one	No	80,000 km	No
China III[b]	2007.07	2007.01	2007.12.31	2006.09	Sample of three	Yes	5 years or 80,000 km	2008.07 (< 6 seats, GVWR < 2.5t); 2010.07 for other vehicles
China IV	2010.07	/	/	/	Sample of three	Yes	5 years or 80,000 km	2010.07
GASOLINE								
China I	2000.01 (T1) 2001.01 (T2)[a]	1999	/	/	Sample of one	No	80,000 km	No
China II	2004.07 (T1) 2005.07 (T2)	2002	/	/	Sample of one	No	80,000 km	No
China III[b]	2007.07	2005.12.31	/	/	Sample of three	Yes	5 years or 80,000 km	2008.07 (< 6 seats, GVWR < 2.5t); 2010.07 for other vehicles
China IV	2010.07	2008.03	2009.11	/	Sample of three	Yes	5 years or 80,000 km	2010.07

† Standards for existing models typically implemented one year later than standards for new models prior to the implementation of China IV. Starting from China IV, standards will apply on both new and existing models at the same time

* Speed points are mostly the same as in ECE15 and EUDC cycles, except for some transient speed points

a – Type 1 M1 LDVs carry no more than 6 seats and weigh no more than 25 tonnes; T2-other non-type 1 LDVs

b – The China III standard was supposed to be effective in 2007 for all new vehicle type approval, but a transition period of one year was allowed, so all approved vehicles could still be sold until 2008 (Jan for HDV and July for LDV)

*中国:重型车新车†型式核准排放标准 **

柴油	全国	北京	上海	广州	生产一致性	在用符合性	耐久性	OBD 要求
国 I	2000.09	1999	1999	/	抽一辆样车	不要求	-	不要求
国 II	2003.09	2002	2003.03	2005.07	抽一辆样车	不要求	5 年或80,000公里[e]; 5年或100,000公里[f]; 6年或250,000公里[g]	不要求
国 III[b]	2007.01	2005.12.31	2007.12.31	2006.09	抽三辆样车	不要求	同欧II	不要求
国 IV	2010.01	2008.07[a,c]	2009.11[c]		抽三辆样车	要求	同欧II	要求
汽油								
国 I	2002.07	1999	/	/	抽一辆样车	不要求	5年或80,000公里	不要求
国 II	2003.09	/	/	/	抽一辆样车	不要求	5年或80,000公里[d]	不要求
国 III[b]	2009.07	2005.12.31	/	/	抽三辆样车	不要求	5年或 80,000公里[d]	2009.07
国 IV	2012.07	2008.07[a]	/	/	抽三辆样车	要求	5年或80,000公里	2012.07

† 自型式核准执行日期之后一年起，不达标的新车和新发动机不得销售、注册或使用。标准不适用于在型式核准执行日期之前已登记注册的车型

* 中国沿用欧盟的重型柴油车的测试循环，但是在国III 及以后的耐久性测试中采用了日本05试验

a – 对NOx 进行OBD要求

b –国III 标准原定在2007年对所有新车型实施，但是允许有一年的过渡期，所以所有车型在2008年之前都可以销售（重型车截止1月，轻型车截止7月）

c – 在北京，国IV 标准在柴油公交车和邮政、环卫（垃圾收集）用柴油车中实施；在上海，除在北京实施的车型外还对建筑用卡车进行了要求

d –2007年10月1日实施

e –对质量大于3.5吨的M1类车，和M2类车的耐久性要求

f –对质量小于7.5吨的 M3 类车，和质量小于16吨的N2类车的耐久性要求

g –对质量大于7.5吨的M3 类车，和质量大于16吨的N2类车的耐久性要求

*China: Emission Standards for New† Heavy-duty Vehicle Type Approval**

DIESELS	CHINA	BEIJING	SHANGHAI	GUANGZHOU	PRODUCTION CONFORMITY	IN-USE SURVEILLANCE	DURABILITY	OBD REQUIREMENT
China I	2000.09	1999	1999		Sample of one	No	-	No
China II	2003.09	2002	2003.03	2005.07	Sample of one	No	5 years or 80,000 km[e]; 5 years or 100,000 km[f]; 6 years or 250,000 km[g]	No
China III[b]	2007.01	2005.12.31	2007.12.31	2006.09	Sample of three	No	Same as Euro II	No
China IV	2010.01	2008.07[a,c]	2009.11[c]		Sample of three	Yes	Same as Euro II	Yes
GASOLINE								
China I	2002.07	1999			Sample of one	No	5 years or 80,000 km	No
China II	2003.09				Sample of one	No	5 years or 80,000 km[d]	No
China III[b]	2009.07	2005.12.31			Sample of three	No	5 years or 80,000 km[d]	2009.07
China IV	2012.07	2008.07[a]			Sample of three	Yes	5 years or 80,000 km	2012.07

† Standards for existing models typically implemented one year later than standards for new models prior to the implementation of China IV. Starting from China IV, standards will apply on both new and existing models at the same time

* China follows the same test cycle schedule as the EU but uses the Japan05 test for durability in Euro III and later models

a – Requires OBD for NOx

b – The China III standard was supposed to be effective in 2007 for all new vehicle type approval, but a transition period of one year was allowed, so all approved vehicles could still be sold until 2008 (Jan for HDV and July for LDV)

c – In Beijing, China IV covers diesel public buses and diesel trucks used for postal and public sanitary (garbage collection) services; in Shanghai, it covers those categories regulated under China IV in Beijing plus construction trucks

d – Took effect on October 1, 2007

e – Durability requirement for M1 vehicles with gross vehicle weight greater than 3.5 tons and M2 vehicles

f – Durability requirement for M3 vehicles less than 7.5 tons; N2 and N3 vehicles less than 16 tons

g – Durability requirement for M3 vehicles over 7.5 tons and N3 vehicles over 16 tons

中国:摩托车新车†型式核准排放标准 *

实施年	发动机排量 (cc)	CO (g/km)	HC (g/km)	NO_x (g/km)	HC+ NO_x (g/km)	PM (g/km)	工况	冷启动	耐久性 (km)
两轮车二冲程发动机									
2003	<50 cc (轻便式)	6			3		ECE R47	否	6,000 [1]
	≥50 cc	8	4	0.1			ECE R40	否	6,000 [1]
2004	≥50 cc	5.5	1.2	0.3			ECE R40	否	10,000 [1]
2005	<50 cc (轻便式)	1			1.2		ECE R47	否	10,000 [1]
两轮车四冲程发动机									
2003	<50 cc (轻便式)	6			3		ECE R47	否	6,000 [1]
	≥50 cc	13	3	0.3			ECE R40	否	6,000 [1]
2004	≥50 cc	5.5	1.2	0.3			ECE R40	否	10,000 [1]
2005	<50 cc (轻便式)	1			1.2		ECE R47	否	10,000 [1]
2008	< 50 cc	1			1.2		ECE R47	是	10,000
	50-150 cc	2	0.8	0.15			ECE R40	是	18,000 [2] 30,000 [3]
	≥ 150 cc	2	0.3	0.15			ECE R40 +EUDC	是	18,000 [2] 30,000 [3]
三轮车二冲程发动机									
2003	< 50 cc (轻便式)	12			6		ECE R47	否	6,000 [1]
2003	≥50cc	12	6	0.15			ECE R40	否	6,000 [1]
2004	≥50cc	7	1.5	0.4			ECE R40	否	10,000 [1]
2005	< 50 cc (轻便式)	3.5			1.2		ECE R47	否	10,000 [1]
2008	< 50 cc (轻便式)	3.5			1.2		ECE R47	是	10,000
	≥ 50cc	4	1	0.25			ECE R40	是	12,000 [4] 18,000 [2] 30,000 [3]
三轮车四冲程发动机									
2003	< 50 cc (轻便式)	12			6		ECE R47	否	6,000 [1]
2003	≥50cc	19.5	4.5	0.45			ECE R40	否	6,000 [1]
2005	< 50 cc (轻便式)	3.5			1.2		ECE R47	否	10,000 [1]
2005	≥50cc	7	1.5	0.4			ECE R40	否	10,000 [1]
2008	< 50 cc (轻便式)	3.5			1.2		ECE R47	是	
	≥50cc	4	1	0.25			ECE R40	是	12,000 [4] 18,000 [2] 30,000 [3]

注: 1 是否装有尾气空气装置; 2 最高时速在130 km/h以下并且发动机排量高于 150cc; 3 最高时速在130 km/h或以上并且发动机排量高于150cc; 4 发动机排量在50 和150 cc之间; 轻便式摩托车: 最高时速小于等于50 km/h 并且发动机排量晓于等于50 cc

China: Emission Standards for New Motorcycle Type Approval

Year Began	Engine Size (cc)	CO (g/km)	HC (g/km)	NO_x (g/km)	HC+ NO_x (g/km)	PM (g/km)	Driving Cycle	Cold Start	Durability (km)
Two-Wheeler with Two-Stroke Engine									
2003	<50 cc (moped)	6			3		ECE R47	No	6,000 [1]
	≥50 cc	8	4	0.1			ECE R40	No	6,000 [1]
2004	≥50 cc	5.5	1.2	0.3			ECE R40	No	10,000 [1]
2005	<50 cc (moped)	1			1.2		ECE R47	No	10,000 [1]
Two-Wheeler with Four-Stroke Engine									
2003	<50 cc (moped)	6			3		ECE R47	No	6,000 [1]
	≥50 cc	13	3	0.3			ECE R40	No	6,000 [1]
2004	≥50 cc	5.5	1.2	0.3			ECE R40	No	10,000 [1]
2005	<50 cc (moped)	1			1.2		ECE R47	No	10,000 [1]
2008	< 50 cc	1			1.2		ECE R47	Yes	10,000
	50-150 cc	2	0.8	0.15			ECE R40	Yes	18,000 [2] 30,000 [3]
	≥ 150 cc	2	0.3	0.15			ECE R40 +EUDC	Yes	18,000 [2] 30,000 [3]
Three-Wheeler with Two-Stroke Engine									
2003	< 50 cc (moped)	12			6		ECE R47	No	6,000 [1]
2003	≥50cc	12	6	0.15			ECE R40	No	6,000 [1]
2004	≥50cc	7	1.5	0.4			ECE R40	No	10,000 [1]
2005	< 50 cc (moped)	3.5			1.2		ECE R47	No	10,000 [1]
2008	< 50 cc (moped	3.5			1.2		ECE R47	Yes	10,000
	≥ 50cc	4	1	0.25			ECE R40	Yes	12,000 [4] 18,000 [2] 30,000 [3]
Three-Wheeler with Four-Stroke Engine									
2003	< 50 cc (moped)	12			6		ECE R47	No	6,000 [1]
2003	≥50cc	19.5	4.5	0.45			ECE R40	No	6,000 [1]
2005	< 50 cc (moped)	3.5			1.2		ECE R47	No	10,000 [1]
2005	≥50cc	7	1.5	0.4			ECE R40	No	10,000 [1]
2008	< 50 cc (moped)	3.5			1.2		ECE R47	Yes	
	≥50cc	4	1	0.25			ECE R40	Yes	12,000 [4] 18,000 [2] 30,000 [3]

Notes: 1 If installed with emission control device; 2 Maximum speed under 130 km/h and displacement above 150cc; 3 Maximum speed equal to or above 130 km/h and displacement above 150cc;

4 Displacement between 50 and 150 cc; Moped: Maximum speed under or equal to 50 km/h and displacement under or equal to 50 cc

日本: 汽油和LPG燃料汽车排放标准

	新车型	所有车型/ 进口车型	测试工况	单位	CO	HC[a]	NOx	PM
新短期 (平均值/最大值[b])								
乘用车	2000.10	2002.09	10-15 工况	克/公里	0.67/1.27	0.08/0.17	0.08/0.17	-
			11工况	克/次	19.0/31.1	2.20/4.42	1.40/2.50	-
微型商用车	2002.10	2003.09	10-15工况	克/公里	3.30/5.11	0.13/0.25	0.13/0.25	-
			11工况	克/次	38.0/58.9	3.50/6.40	2.20/3.63	-
轻型商用车	2000.10	2002.09	10-15工况	克/公里	0.67/1.27	0.08/0.17	0.08/0.17	-
			11工况	克/次	19.0/31.1	2.20/4.42	1.40/2.50	-
中型商用车	2001.10	2003.09	10-15工况	克/公里	2.10/3.36	0.08/0.17	0.13/0.25	-
			11工况	克/次	24.0/38.5	2.20/4.42	1.60/2.78	-
新长期 (平均值/最大值)								
乘用车	2005.10	2007.09	10-15工况+ 11工况	克/公里	1.15/1.92	0.05/0.08	0.05/0.08	-
微型商用车	2007.10	2008.09/ 2007.09			4.02/6.67	0.05/0.08	0.05/0.08	-
轻型商用车(轻型)	2005.10	2007.09			1.15/1.92	0.05/0.08	0.05/0.08	-
轻型商用车(中型)					2.55/4.08	0.05/0.08	0.07/0.10	-
后新长期[c]								
乘用车	2009.10	2009.10/ 2010.09	JC08H + JC08C	克/公里	1.15/1.92	0.05/0.08	0.05/0.08	0.005/0.007
轻型商用车(轻型)					1.15/1.92	0.05/0.08	0.05/0.08	0.005/0.007
轻型商用车(中型)					2.55/4.08	0.05/0.08	0.07/0.10	0.007/0.009

a –2005年以后HC按照非甲烷碳氢化合物测试

b – 平均值: 作为产品平均水平的型式核准要求来达标；最大值：如果每年每车型销售少于2000辆，可以作为型式核准的限制，通常是要求一系列产品中所有单个车型都达标

c – 新颗粒物测试方法；采取了技术改进的方法对CO和其他气体进行测试

耐久性要求

- 最大总质量小于3.5吨的乘用车，卡车和巴士：80,000公里
- 最大总质量大于3.5吨的乘用车，卡车和巴士：250,000公里

Japan: Emission Standards for Gasoline and LPG fuelled Vehicles

	NEW MODEL	ALL MODELS/ IMPORTS	TEST CYCLE	UNIT	CO	HC[a]	NOX	PM
NEW SHORT TERM (MEAN/MAX[b])								
PC	2000.10	2002.09	10-15 mode	g/km	0.67/1.27	0.08/0.17	0.08/0.17	-
			11 mode	g/test	19.0/31.1	2.20/4.42	1.40/2.50	-
Mini CV	2002.10	2003.09	10-15 mode	g/km	3.30/5.11	0.13/0.25	0.13/0.25	-
			11 mode	g/test	38.0/58.9	3.50/6.40	2.20/3.63	-
Light CV	2000.10	2002.09	10-15 mode	g/km	0.67/1.27	0.08/0.17	0.08/0.17	-
			11 mode	g/test	19.0/31.1	2.20/4.42	1.40/2.50	-
Medium CV	2001.10	2003.09	10-15 mode	g/km	2.10/3.36	0.08/0.17	0.13/0.25	-
			11 mode	g/test	24.0/38.5	2.20/4.42	1.60/2.78	-
NEW LONG TERM (MEAN/MAX)								
PC	2005.10	2007.09	10-15 mode + 11 mode	g/km	1.15/1.92	0.05/0.08	0.05/0.08	-
Mini CV	2007.10	2008.09/ 2007.09			4.02/6.67	0.05/0.08	0.05/0.08	-
Light CV	2005.10	2007.09			1.15/1.92	0.05/0.08	0.05/0.08	-
Medium LCV					2.55/4.08	0.05/0.08	0.07/0.10	-
POST NEW LONG TERM[C]								
PC	2009.10	2009.10/ 2010.09	JC08H + JC08C	g/km	1.15/1.92	0.05/0.08	0.05/0.08	0.005/0.007
Light LCV					1.15/1.92	0.05/0.08	0.05/0.08	0.005/0.007
Medium LCV					2.55/4.08	0.05/0.08	0.07/0.10	0.007/0.009

a – From 2005, HC is measured as NMHC

b – Mean: to be met as a type approval limit and as a production average; max: to be met as type approval limit if sales are less than 2,000 per vehicle model per year and generally as an individual limit in series production

c – New PM measurement method; technically modified methods for CO and other gases

Useful Life Requirements

■PC, trucks, and buses with GVWR less than 3.5tonnes: 80,000 km

■PC, trucks, and buses with GVWR greater than 3.5tonnes: 250,000 km

OBD – 柴油，汽油，液化石油气

- J-OBDII: 对最大总质量小于3.5吨的乘用车和商用车自2008年10月加强OBD要求
- 同样接纳欧盟/美国 OBD 标准作为等价标准

日本: 柴油车排放标准

	新车型	所有车型/ 进口车型	测试工况	单位	CO	HC[a]	NOx	PM
新短期 (平均值/最大值[b])								
乘用车< 1,265 千克	2002.10	2004.09	10-15 工况	克/公里	0.63/0.98	0.12/0.24	0.28/0.43	0.052/0.11
乘用车> 1,265 千克					0.63/0.98	0.12/0.24	0.30/0.45	0.056/0.11
轻型商用车					0.63/0.98	0.12/0.24	0.28/0.43	0.052/0.11
中型商用车	2003.10				0.63/0.98	0.12/0.24	0.49/0.68	0.06/0.12
新长期 (平均值/最大值)								
乘用车< 1,265 千克	2005.10	2007.09	10-15 工况 + 11 工况	克/公里	0.63/0.84	0.024/0.032	0.14/0.19	0.013/0.017
乘用车> 1,265 千克					0.63/0.84	0.024/0.032	0.15/0.20	0.014/0.019
轻型商用车					0.63/0.84	0.024/0.032	0.14/0.19	0.013/0.017
中型商用车					0.63/0.84	0.024/0.032	0.25/0.33	0.015/0.020
后新长期[c]								
乘用车	2009.10	2009.10/ 2010.09	JC08H + JC08C	克/公里	0.63/0.84	0.024/0.032	0.08/0.11[e]	0.005/0.007
轻型商用车(轻型)					0.63/0.84	0.024/0.032	0.08/0.11	0.005/0.007
轻型商用车(中型)	2010.10[d]				0.63/0.84	0.024/0.032	0.15/0.20	0.007/0.009

a –2005年以后HC按照非甲烷碳氢化合物测试

b – 平均值: 作为产品平均水平的型式核准要求来达标；最大值：如果每年每车型销售少于2000辆，可以作为型式核准的限制，通常是要求一系列产品中所有单个车型都达标

c – 新颗粒物测试方法：采取了技术改进的方法对CO和其他气体进行测试

d –2010年10月对最大总质量处于1,700 —3,500 千克的中型商用车实施，2009年10月对最大总质量处于2,500—3,500千克的中型商用车实施

e –对于最大总质量不超过1,265千克的机动车及最大总质量大于1,265千克的机动车，限值为 0.15/0.20

OBD – Diesel, Gasoline, and LPG

- J-OBDII: enhanced OBD requirement for PCs and CVs with GVWR less than 3.5 tonnes from Oct 2008
- EU/US OBD standards accepted as equivalent

Japan: Emission Standards for Diesel Vehicles

	NEW MODEL	ALL MODELS/ IMPORTS	TEST CYCLE	UNIT	CO	HC[a]	NOX	PM
NEW SHORT TERM (MEAN/MAX[b])								
PC < 1,265 kg	2002.10	2004.09	10-15 mode	g/km	0.63/0.98	0.12/0.24	0.28/0.43	0.052/0.11
PC > 1,265 kg					0.63/0.98	0.12/0.24	0.30/0.45	0.056/0.11
Light CV					0.63/0.98	0.12/0.24	0.28/0.43	0.052/0.11
Medium CV	2003.10				0.63/0.98	0.12/0.24	0.49/0.68	0.06/0.12
NEW LONG TERM (MEAN/MAX)								
PC < 1,265 kg	2005.10	2007.09	10-15 mode + 11 mode	g/km	0.63/0.84	0.024/0.032	0.14/0.19	0.013/0.017
PC > 1,265 kg					0.63/0.84	0.024/0.032	0.15/0.20	0.014/0.019
Light CV					0.63/0.84	0.024/0.032	0.14/0.19	0.013/0.017
Medium CV					0.63/0.84	0.024/0.032	0.25/0.33	0.015/0.020
POST NEW LONG TERM[c]								
PC	2009.10	2009.10/ 2010.09	JC08H + JC08C	g/km	0.63/0.84	0.024/0.032	0.08/0.11[e]	0.005/0.007
Light LCV					0.63/0.84	0.024/0.032	0.08/0.11	0.005/0.007
Medium LCV	2010.10[d]				0.63/0.84	0.024/0.032	0.15/0.20	0.007/0.009

a – From 2005, HC is measured as NMHC

b – Mean: to be met as a type approval limit and as a production average; max: to be met as type approval limit if sales are less than 2,000 per vehicle model per year and generally as an individual limit in series production

c – New PM measurement method; technically modified methods for CO and other gases

d – Oct 2010 for Medium CV with 1,700 kg < GVWR < 3,500 kg; Oct 2009 for Medium CV with 2,500 kg < GVWR < 3,500 kg

e – For vehicles not exceeding 1,265 kg; for vehicles greater than 1,265 kg, the values are 0.15/0.20

术语：

10-15 工况 – 日本适用于轻型车的排放浓度和燃料经济性测试的工况；在10-工况基础上加上另一个最高速度为70公里/小时

15-工况段组成

11-工况 – 日本适用于轻型车的排放浓度和燃料经济性测试负载车重=空载质量和最大总质量的平均值

CH_4 –甲烷

CO – 一氧化碳

CV – 商用车

DI – 直接喷射

ECE R-49 –稳态柴油发动机13-工况 (速度和负载)

ECE15 –城市行驶工况, 也被称为UDC,是欧洲开发用于描述城市行驶条件的工况

EEV –环境友好汽车

ELR – 发动机烟雾测试试验

ESC – 欧洲稳态工况，也被称为OICA/ACEA 工况，稳态发动机测试13-工况代替了 R-49工况

EUDC – 额外城市行驶工况：变速更迅速、高速行驶工况

FTP Transient – 用来模拟重型卡车和巴士城区和高速公路行驶情况的发动机台架试验

FTP-75 – 美国的轻型车测试工况，分为三个部分： 1) 冷启动, 2) 瞬态， 3) 热启动

GVWR – 额定车辆总质量=车辆最大负荷质量

HC – 碳氢化合物

HCHO – 甲醛

HLDT –轻型卡车（重型）；最大总质量为 6,001至8,500磅, 包括LDT3和LDT4

IDI – 间接喷射

JC08 –日本开发的排放和燃料经济性测试的新的城市行驶工况，从2011年起将完全替代10-15工况

JC08C – “冷的”JC08试验

JC08H – “热的”JC08试验

LCV – 轻型商用车; 最大总质量小于3,500千克 (2005年之前为2,500千克)

LDT1 – 轻型卡车1; 最大总质量小于6,000磅，满载车质量小于3,750磅

LDT2 –轻型卡车2; 最大总质量小于6,000磅，并且满载车质量为3,750至5,750磅

LDT3 –轻型卡车3; 最大总质量为6,001至8,500磅，并且满载车质量为3,750至5,750磅

LDT4 –轻型卡车4; 最大总质量为6,001至8,500磅，并且满载车质量大于5,750磅

LDV – 轻型车

Light LCV – 轻型商用车（轻型）; 最大总质量< 1,700 千克

LLDT – 轻型卡车（轻型）：最大总质量小于6,000磅，包括 LDT1和LDT2

Acronyms

10-15 mode – cycle used in Japan for emission certification and fuel economy for light duty vehicles; derived from the 10-mode cycle by adding another 15-mode segment of a maximum speed of 70 km/h

11-mode – a cold start cycle used in Japan for emission certification and fuel economy for light duty vehicles

ALVW – adjusted loaded vehicle weight = average of the curb (empty) weight and the GVWR

CH4 – methane

CO – carbon monoxide

CV – commercial vehicle

DI – direct injection

ECE R-49 – 13-mode (speed and load) steady-state diesel engine test cycle

ECE15 – urban driving cycle, also known as UDC, devised to represent city driving conditions in the EU

EEV – enhanced environmentally friendly vehicle

ELR – engine test for smoke opacity measurement

ESC – European Stationary Cycle, also known as the OICA/ACEA cycle, 13-mode steady-state engine test that replaces the R-49

EUDC – Extra Urban Driving Cycle; more aggressive, high speed driving modes

FTP Transient – an engine dynamometer test designed to simulate both urban and freeway driving for heavy-duty trucks and buses

FTP-75 – test cycle for light-duty vehicles in the US consisting of three phases: 1) cold start, 2) transient, and 3) hot start

GVWR – gross vehicle weight rating = maximum fully leaded vehicle weight

HC – hydrocarbon

HCHO – formaldehyde

HLDT – heavy light-duty truck; between 6,001 and 8,500 lbs GVWR, includes LDT3 and LDT4

IDI – indirect injection (s)

JC08 – new urban driving cycle for emission and fuel economy measurement that will fully replace the 10-15 mode cycle by 2011

JC08C – JC08 test performed'cold'

JC08H – JC08 test performed'hot'

LCV – light commercial vehicle; GVWR less than 3,500 kg (2,500 kg before 2005)

LDT1 – light-duty truck 1; up to 6,000 GVWR and up to 3,750 lbs LVW

LDT2 – light-duty truck 2; up to 6,000 GVWR and between 3,750 and 5,750 lbs LVW

LDT3 – light-duty truck 3; between 6,001 and 8,500 lbs GVWR and between 3,750 and 5,750 lbs ALVW

LDT4 – light-duty truck 4; between 6,001 and 8,500 lbs GVWR and over 5,750 lbs ALVW

LDV – light-duty vehicle

Light LCV – light light commercial vehicle; GVWR < 1,700 kg

LLDT – light light-duty truck; up to 6,000 lbs GVWR, includes LDT1 and LDT2

LVW –满载车质量=整车整备质量 + 300 磅

M1 – 指包括驾驶员座位在内，座位数不超过九座的载客汽车

M2 – 指包括驾驶员座位在内座位数超过九座，且最大质量（”最大设计总质量”）不超过5吨的载客汽车

M3 –指包括驾驶员座位在内座位数超过九座，且最大设计总质量超过5吨的载客汽车

MDPV – 中型乘用车，最大总质量为8,500至10,000磅的卡车

Medium LCV – 轻型商用车（中型）：1,700 千克<最大总质量< 3,500 千克

N1 – 最大设计总质量不超过3.5吨的载货汽车

N2 – 最大设计总质量超过3.5吨，但不超过12吨的载货汽车

N3 – 最大设计总质量超过12吨的载货汽车

NMHC –非甲烷碳氢化合物

NMOG – 非甲烷有机气体

NOx – 氮氧化物

OBD – 车载诊断系统

PC – 乘用车

PM –颗粒物

PMP –颗粒物测试方法

SET – 补充排放试验(SET); 美国用于认证的稳态发动机台架试验

LVW – loaded vehicle weight = nominal empty vehicle weight + 300 lbs

M1 – vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat

M2 – vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 5 tonnes

M3 – vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tonnes

MDPV – medium-duty passenger vehicle; light truck (SUV or minivan) between 8,500 and 10,000 lbs GVWR

Medium LCV – medium light commercial vehicle; 1,700 kg < GVWR < 3,500 kg

N1 – vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes

N2 – vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tons but not exceeding 12 tonnes

N3 – vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes

NMHC –non-methane hydrocarbons

NMOG – non-methane organic gas

NOx – oxides of nitrogen

OBD – on-board diagnostics

PC – passenger car

PM – particulate matter

PMP – Particle Measurement Programme

SET – Supplemental Emission Test (SET); steady-state engine dynamometer test used for certification in the US

附录D: 达到欧4/IV, 5/V, 6/VI 所需的技术

轻型车

表 D-1 介绍了达到欧4，欧5和欧6常规污染物排放水平的基本技术。

表 D-1. 轻型车常规污染物控制技术要求

柴油车	轻型车. (1.2<排量<2.0 升) 轻型卡车最大总质量< 2.5 吨		
	欧 3 到欧4	欧4到欧5	欧 5到欧6
控制的污染物	(NOx/PM/CO)	(NOx/PM/CO)	(NOx/PM/CO)
排放目标克/公里	0.25/0.025/0.5	0.18/0.005/0.5	0.08/.0045/0.5
排放削减比例	50% / 50% / 22%	28% / 80% / 0	66% / 10%/ 0
基本技术	*电控燃料定时和定量 *电控EGR, 加装冷却系统 *直接喷射 (DI) 燃烧和高压喷油 (HPFI) * 柴油车氧化催化装置 (DOC)	欧4装置基础上增加	欧5装置基础上增加
发动机排出的污染物 空燃比控制	* 4 气门技术 *涡轮增压中冷（TCI）	-	*燃烧研究 PCCI, LTC *可变截面涡轮增压器 (VGT)
后处理装置	-	轻型车 Class B,C级: DOC + DPF 或者仅 DPF	DOC + DPF + LNT 或者 DPF + LNT

Appendix D- Technologies required to meet Euro 4/IV, 5/V, 6/VI

Light Duty Vehicles

Table D-1 presents the basic technologies required to comply with Euro 4, Euro 5 and Euro 6 emission levels of conventional pollutants.

Table D-1. LDV Technology requirements for control of conventional pollutants

DIESEL	LDVS. (1.2<VD<2.0 LITERS) LDTS GVW < 2.5 TONS		
	EURO 3 TO EURO 4	EURO 4 TO EURO 5	EURO 5 TO EURO 6
Reg. pollutants	(NOx/PM/CO)	(NOx/PM/CO)	(NOx/PM/CO)
Emissions target, g/km	0.25/0.025/0.5	0.18/0.005/0.5	0.08/.0045/0.5
Emissions reduction	50% / 50% / 22%	28% / 80% / 0	66% / 10%/ 0
Base technology	*Electric fuel timing & metering *Electric EGR, with cooling system *Direct injection (DI) combustion and High pressure fuel injection (HPFI) * Diesel Oxidation Catalyst (DOC)	Euro 4 equipment plus	Euro 5 equipment plus
Engine -out emissions A/F control	* 4 valves per cylinder *Turbocharging with intercooling	-	*Combustion research PCCI, LTC *Variable geometry turbocharger (VGT)
Aftertreatment System	-	LDVs Class B,C: DOC + DPF or DPF only	DOC + DPF + LNT or DPF + LNT

汽油车	轻型车. (1.2<排量<2.0 升) 轻型卡车最大总值< 2.5 吨		
	欧 3 到欧4	欧4到欧5	欧 5到欧6
控制的污染物	CO/NOx/HC	CO/NOx/HC	CO/NOx/HC
排放目标克/公里	1.0/0.08/0.1	1.0/ 0.06/ 0.1	1.0/ 0.06/ 0.1
排放削减比例	57% / 50% / 50%	0 / 25% / 0	0 / 0 / 0
基本技术	*配比燃烧 *电子喷射 *电子点火 *多点喷射 (MPI) *OBD要求额外的一个氧传感器 *改善控制器和硬件 *三元催化器(车底)	-欧 4 装置 -增加缸内直喷 (GDI) -稀薄燃烧- 加强对GDI车颗粒物排放水平的控制	欧 5 装置
发动机排出的污染物 空燃比控制	与欧 3装置相同： *改善燃料策略来保证冷启动排放控制中紧密耦合(CC)催化器在合理的温度范围内 *增加EGR的使用来控制NOx	与欧4车相同，再加上： *改善燃烧系统 *可变气门正时系统(VVT) -缸内直喷的要求: *改善喷嘴 *高压喷射 *空燃比控制的线性范围氧传感器	与欧5车相同，再加上： *改善燃烧系统 *涡轮增压，降低排量(燃料经济性效益) *混合动力 (燃料经济性效益) -缸内直喷的要求: *空燃比控制的线性范围氧传感器, 闭环控制下通常要求有两个
后处理装置	-测试循环中去除了预热阶段并且对HC 和CO排放控制要求增加紧密耦合(CC)冷启动催化器	*紧密耦合催化器要求使用储氧装置 *缸内直喷要求安装稀燃氮氧化物吸附装置(LNT)	与欧5车相同

GASOLINE	LDVS. (1.2<VD<2.0 LITERS) LDTS GVW < 2.5 TONS		
	EURO 3 TO EURO 4	EURO 4 TO EURO 5	EURO 5 TO EURO 6
Reg. pollutants	CO/NOx/HC	CO/NOx/HC	CO/NOx/HC
Emissions target, g/km	1.0/0.08/0.1	1.0/ 0.06/ 0.1	1.0/ 0.06/ 0.1
Emissions reduction	57% / 50% / 50%	0 / 25% / 0	0 / 0 / 0
Base technology	*Stoichiometric combustion *Elec. Injection *Elec. ignition *Multi-point injection (MPI) *A second O_2 sensor is required for OBD *Improved controller and Hardware *Three way catalyst (underbody)	-Euro 4 equipment -Increased use of gas direct injection (GDI) -lean combustion- forces regulations to include PM emissions levels for GDI vehicles	Euro 5 equipment
Engine -out emissions A/F control	-Same as Euro 3 plus: *Improved fueling strategy to keep closed coupled (CC) catalyst at right temperature range for cold start emissions control *Increased use of EGR for NOx control	-Same as Euro 4 vehicles plus: *Comb. Syst. improvements *Variable valve timing (VVT) -GDIs require: *Improved injectors *Higher press. Injection *Linear range O_2 sensor for A/F control	-Same as Euro 5 vehicles plus: *Comb. Syst. improvements *Turbo. and downsizing (FE) *Hybridization. (FE) -GDIs require: *Linear range O_2 sensors for A/F control, usually two under closed loop control
After-treatment system	-The elimination of warm up period during the test cycle and increased restriction on HC and CO emissions required the addition of a closed coupled (CC) cold start catalyst	*CC catalyst require the use of oxygen storage components *GDIs require Lean NO_x Traps (LNT)	Same as Euro 5 vehicles

重型车

表 D-2 总结基本排放控制技术和实现每种技术要求的燃料硫含量。

表D-2: 基本排放控制技术

技术	控制效率，% 削减				燃料硫含量要求, ppm	备注
	PM	NOX	HC	CO		
三元催化器	-	>90	>90	>90	<500	适用于配比燃烧的汽油和天然气发动机 是一种成熟的技术
EGR (带有冷却系统)	(a)	20-80	(a)	-	<500	NOx 的削减取决于负载的情况： 高的负载可以进行更高的削减 (a) 不使用空燃比控制系统发动机内的颗粒物和碳氢化合物会增加：电子燃料定时和定量系统和可变截面涡轮增压系统(VGT) 装有适当的空燃比控制系统的美国2010年型发动机和欧V发动机有可能实现氮氧化物和颗粒物的缸内共同削减。 在中等负载的汽油和天然气配比发动机中使用EGR
柴油车氧化催化装置 (DOC)	20-25 (a) ~50 (b)	-	>80	>80	<500 可行 <350 推荐	(a) 高负载试验 (b) 低负载试验 DOC只能减少总颗粒物中的可溶性有机组分 (不能减低细颗粒) 可以削减甲醛和乙醛达 50%-90%
部分流捕集器(PFF)	40-70	-	>80	>80	<350	也被称为部分流技术 (PFT),这种催化捕集器是直流式的DPF.位于尾气上游的DOC提供NO_2，用来在下游通过金属或者纤维网涂层上的接触反应来氧化碳烟。 PFF产生的背压较低，不需要维护

Heavy Duty Vehicles

Table D-2 summarizes the basic emission control technologies and the fuel sulfur levels required for implementing each technology.

Table D-2: Basic emission control technologies

TECHNOLOGY	CONTROL EFFICIENCY, % REDUCTION				FUEL SULFUR REQUIRE-MENT, PPM	COMMENTS
	PM	NOX	HC	CO		
Three Way Catalyst	-	>90	>90	>90	<500	Applies to gasoline and natural gas engines with stoichiometric combustion Well established technology
EGR (w/ cooling)	(a)	20-80	(a)	-	<500	NOx reduction depends on load conditions: higher loads provides higher reductions (a) PM and HC increases in engines without A/F management systems: electronic fuel timing and metering and variable geometry turbocharger (VGT) US2010 engines and Euro V engines with proper A/F management systems may be able to achieve in-cylinder reduction of both NOx and PM EGR is used at mid loads in Stoichiometric engines, both gasoline and NG
Diesel oxidation catalyst (DOC)	20-25 (a) ~50 (b)	-	>80	>80	<500 viable <350 preferred	(a) High load tests (b) Low load tests DOC only reduces SOF out of the total PM (no fine particles reduction) Formaldehyde and acetaldehyde can be reduced by 50%-90%
Partial Flow Filter (PFF)	40-70	-	>80	>80	<350	Also known as Partial Flow technologies (PFT), this catalyzed filter is a flow-trough DPF. It is composed of a DOC upstream which provides NO_2 for soot oxidation downstream in catalytic coated metallic or fiber mesh. PFFs generate lower exhaust back-pressure and no maintenance is required.

柴油车颗粒捕集器(DPF)	>70-95 (a) 50-90 (b)	-	60 (c)	-	<50 必需	是指催化颗粒物捕集器，及与DOC联合使用不进行催化的壁流式捕集器—商业上称为CRT 唯一能够削减超细颗粒的技术。低硫燃料可以改善DPF的效果 (a) 元素碳过滤 (碳烟) (b) 可溶性有机组分(SOF). 通过催化氧化机型转化 (c) 催化器再生可以由氧化反应对HC进行削减 对燃料中的硫引起的硫酸盐没有过滤效果 可以削减甲醛和乙醛达 50%-90% DPF在低负载工况-低排气温度下可能增加纳米级颗粒物的数量
稀燃氮氧催化器	-	5-15 (a) 50-60 (b)	-	-	<50必需	正在开发的技术 (a) 被动再生 (基于催化) (b) 主动再生. 需要延迟燃料喷射或者在上游增加燃料
氮氧化物吸附器或稀燃氮氧吸附装置	-	70-90	-	-	<50 必需	再生阶段燃料经济性会下降 在缸内直喷发动机上已经商业化 在道奇和奔驰 E320上商业化应用 重型车上的应用仍在开发中
选择性催化还原装置(SCR)	(a)	50-95%	-	-	不要求	(a) 燃料硫含量水平会影响颗粒物排放 削减水平取决与控制系统的构造 可以改善发动机效率(燃料经济性) 要求尿素供应的基础设施和对适当操作和防止系统失灵的详细规定

Diesel particle filter (DPF)	>70-95 (a) 50-90 (b)	-	60 (c)	-	<50 required	It refers to catalyzed particle filters and the combination DOC+uncatalyzed wall- flow filter –commercially known as CRT- Only technology that significantly reduces ultra-fine particles. Low sulfur fuels improve DPF performance (a) Elemental carbon filtration (soot). (b) Solid organic fraction (SOF). Conversion by catalytic oxidation (c) HC reduction due to catalytic oxidation intended for catalyst regeneration No filtration capabilities for sulfate particulates from fuel sulfur. Formaldehyde and acetaldehyde can be reduced by 50%-90% DPFs may increase nanoparticle number emissions during low load cycles –low temp. exhaust gases-
Lean NOx catalyst	-	5-15 (a) 50-60 (b)	-	-	<50 required	Technology in development (a) Passive regeneration (catalyst based) (b) Active regeneration. It requires late fuel injection or upstream fuel addition
NOx adsorber or Lean NOx traps	-	70-90	-	-	<50 required	Fuel economy penalty associated with regeneration periods Commercialized in GDI engines Commercial applications in Dodge Ram and Mercedes-Benz E320 Heavy duty application still in development
Selective catalytic reduction (SCR)	(a)	50-95%	-	-	No require-ments	(a) PM emissions may be affected by fuel sulfur level Reduction levels depend on control system configuration Allows improved engine efficiency (fuel economy) Require urea supply infrastructure and special provisions for proper operation avoiding system tampering

表D-3 目前达到欧 IV, 欧 V 和欧 VI常规污染物排放水平的基本技术。

表D-3: 中型车常规污染物控制技术的要求

柴油车	规定		
	欧 3 到欧4	欧4到欧5	欧 5到欧6
控制的污染物	NOx/PM/HC/CO	NOx/PM/HC/CO	NOx/PM/HC/CO
排放目标, 克/千瓦时 (a)	3.5 / 0.02 / 0.46 / 1.5	2.0 / 0.02 / 0.46 / 1.5	2.0 / 0.02 / 0.13 / 1.5
排放削减比例 (a)	30%/80%/30%/30%	43% / - / - / -	80%*/ 50%* / 70%/-
基本技术	* 高压喷油 *电控燃料定时和定量 *带冷却系统的电控EGR * DOC	欧4的装置	欧5的装置
空燃比控制和发动机排出的污染物	* 改善发动机燃烧和标定 *涡轮增压中冷 *NOx控制 (b): 带冷却装置的EGR	*改善发动机燃烧和标定 *多点燃料喷射系统(预-主-后喷射) 可变截面涡轮增压器 (VGT) * NOx控制 (b): 带冷却装置的EGR	*可变截面涡轮增压器（VGT) *燃烧研究PCCI, LTC
后处理装置	NOx 控制 (b): SCR 系统(开环) PM控制l: DOC+ 流通式DPF (PFF)	NOx 控制 (b): SCR 系统(开环) PM控制l: DOC+ 流通式DPF (PFF)	NOx 控制: SCR系统(闭环) PM 控制: DOC+ DPFs

*ETC 测试工况

(a) ESC/ELR工况

(b) 生产制造商选择EGR或者SCR作为NOx的控制手段

PCCI: 预混合压燃. 包括多个燃料的定时和定量控制，允许了多燃烧方式内燃机的使用

LTC: 低温燃烧.针对高温造成NOx形成的空燃比控制的改善

Table D-3 presents the basic technologies required to comply with Euro IV, Euro V and Euro VI emission levels of conventional pollutants.

Table D-3: HDV Technology requirements for control of conventional pollutants

DIESEL	REGULATION		
	EURO III TO EURO IV	EURO IV TO EURO V	EURO V TO EURO VI
Reg. pollutants	NOx/PM/HC/CO	NOx/PM/HC/CO	NOx/PM/HC/CO
Emissions target, g/kWh (a)	3.5 / 0.02 / 0.46 / 1.5	2.0 / 0.02 / 0.46 / 1.5	2.0 / 0.02 / 0.13 / 1.5
Emission reduction (a)	30%/80%/30%/30%	43% / - / - / -	80%*/ 50%* / 70%/-
Base technology	* High pressure fuel injection *Electric fuel timing & metering *Electric EGR, with cooling system * DOC	Euro 4 equipment	Euro 5 equipment
A/F control & Engine -out emissions	* Improvements in engine combustion and calibration *Turbocharging with intercooling *NOx control (b): EGR cooled	* Improvements in engine combustion and calibration *Multiple injection fuel system (pilot-main-post) Variable geometry turbocharger (VGT) *NOx control (b): EGR cooled	*Variable geometry turbocharger (VGT) *Combustion research PCCI, LTC
Aftertreatment System	NOx control (b): SCR systems (open loop) PM control: DOC+ flow trough DPFs (PFF)	NOx control (b) : SCR systems (closed loop) PM control: DOC+ flow trough DPFs (PFF)	NOx control: SCR systems (closed loop) PM control: DOC+ DPFs

*ETC test cycle

(a) ESC/ELR cycle

(b) NOx control through EGR or SCR is manufacturers choice

PCCI: Premixed charge compression ignition. Includes multiple fuel timing and metering, allowing for multimodal combustion engine

LTC: Low temperature Combustion. A/F management improvements aiming to avoid high temperatures that led to NOx formation.

表 D-4: 达到欧1,2,3摩托车排放标准所需的技术

	欧1之前至欧1	欧1 至欧 2	欧 2 至欧 3
控制的污染物	NOx/HC/CO	NOx/HC/CO	NOx/HC/CO
排放水平	0.3/3/13	0.3/1.2/5.5	0.15/0.8/2
排放削减比例	/	0%/60%/60%	50%/33%/63%
基本技术	化油器	/	/
空燃比控制和发动机排放污染物	/	化油器或开环燃料喷射	闭环燃料喷射
后处理装置	催化氧化器	带有二次空气喷射的催化氧化器或三元催化器	带有二次空气喷射的催化氧化器三元催化器

Table D-4: Motorcycles technology requirement to meet Euro 1, 2, and 3

	PRE-EURO TO EURO 1	EURO 1 TO EURO 2	EURO 2 TO EURO 3
Reg. pollutants	NOx/HC/CO	NOx/HC/CO	NOx/HC/CO
Emission levels	0.3/3/13	0.3/1.2/5.5	0.15/0.8/2
Emission reduction	/	0%/60%/60%	50%/33%/63%
Base technology	Carburetor	/	/
A/F control & Engine -out emissions	/	Carburetor OR Open loop fuel injection	Closed loop fuel injection
Aftertreatment System	Oxidation catalyst	Oxidation catalyst with secondary air injection OR Three –way catalyst	Oxidation catalyst with secondary air injection OR Three-way catalyst

附录 E:燃料参数对排放水平的影响

表 E-1: 汽油组分对轻型车排放的影响

汽油	不装催化器	欧1	欧2	欧 3	欧4	欧 5/6[173]	备注
铅↑	Pb, HC↑	随着催化器的失效CO, HC, NO_x全部增加					中国自2000年起禁止使用含铅汽油
硫↑ (50至450 ppm)	SO_2↑	CO, HC, NO_x增加15%-20% SO_2和 SO_3增加					可能引起OBD指示灯误报
烯烃↑	增加1,3-丁二烯,增加HC反应性, NO_x, 欧3及以后阶段HC会有少量增加						可能形成积碳沉积
芳烃↑	增加尾气中的苯含量						增加进气阀和燃烧室的积碳
	可能引起HC, NO_x增加	HC↑, NO_x↓, CO↑		HC, NO_x, CO ↑			
苯↑	增加尾气和蒸发排放中的苯含量						
乙醇↑小于 3.5% O_2	降低 CO, HC, NO_x略微增加，(当大于2%氧含量), 醛排放增加	对装有氧传感器和适应性记忆控制系统的新车的影响很小					如果不调整RVP，会增加蒸发排放，可能对燃料系统组件造成影响，可能造成积碳，及少量燃料经济性的损失
MTBE甲基叔丁基醚↑小于 2.7% O_2	降低CO, HC,增加醛类	对装有氧传感器和发动机控制单元设有适应性记忆控制系统(adaptive learning system)的新车的影响很小					引起水污染
蒸馏特性 T50, T90↑	可能引起 HC↑	HC↑					/
MMT甲基环戊二烯三羰基锰↑	增加锰排放	/	/	可能引起催化器堵塞	可能引起催化器堵塞		可能损坏氧传感器和OBD, 引起故障指示灯误报
RVP雷氏蒸汽压↑	增加HC的尾气和蒸发排放						由于亚洲环境温度高，所以是亚洲国家最严格控制的参数
防积碳添加剂↑	/	可能会减低HC, NO_x排放					有益于减少燃料喷嘴，化油器，进气阀，燃烧室的积碳

173 计划2000年执行欧5排放标准，2005年执行欧6标准。

Appendix E: Impacts of fuel specifications on emission performance

Table E-1: Impact of Gasoline Composition on Emissions from Light Duty Vehicles

GASOLINE	NO CATALYST	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5/6[173]	COMMENTS
Lead ↑	Pb, HC ↑	CO, HC, NO_X all increase dramatically as catalyst destroyed					Lead is banned in China since 2000
Sulfur ↑ (50 to 450 ppm)	SO_2 ↑	CO, HC, NO_X all increase 15%-20% SO_2 and SO_3 increase					Onboard Diagnostic light may come on incorrectly
Olefins ↑	Increased 1,3 butadiene, increased HC reactivity, NO_X, small increases in HC for Euro 3 and cleaner						Potential deposit buildup
Aromatics ↑	Increased benzene in exhaust						Deposits on intake valves and combustion chamber tend to increase
	potential increases in HC, NO_X	HC ↑ , NO_X ↓ , CO ↑		HC, NO_X, CO ↑			
Benzene ↑	Increased benzene exhaust and evaporative emissions						
Ethanol ↑ up to 3.5% O_2	Lower CO, HC, slight NO_X increase (when above 2% oxygen content), Higher aldehydes	Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems					Increased evaporative emissions unless RVP adjusted, potential effects on fuel system components, potential deposit issues, small fuel economy penalty
MTBE ↑ up to 2.7% O_2	Lower CO, HC, higher aldehydes	Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems					Concerns over water contamination
Distillation Characteristics T50, T90 ↑	Probably HC ↑	HC ↑					/
MMT ↑	Increased Manganese Emissions	/	/	Possible Catalyst Plugging	Likely Catalyst Plugging		O_2 sensor and OBD may be damaged, MIL light may come on incorrectly
RVP ↑	Increased evaporative and exhaust HC Emissions						Most critical parameter for Asian countries because of high ambient temperatures
Deposit control additives ↑	/	Potential HC, NO_X emissions benefits					Help to reduce deposits on fuel injectors, carburetors, intake valves, combustion chamber

173 Euro 5 emissions standards were adopted for implementation in 2010; Euro 6 was also adopted for 2015 implementation.

表 E-2: 汽油组分对摩托车排放的影响

汽油	不装催化器	印度 2005	欧 3	印度2008	中国3阶段	备注
铅↑	Pb, HC↑	随着催化器的失效CO, HC, NO_X全部增加				
硫↑（50至450 ppm)	SO_2↑	CO, HC, NO_X增加 SO_2和SO_3增加				/
烯烃↑	增加1,3-丁二烯,增加HC反应性, NO_X					可能形成积碳沉积
芳烃↑	增加尾气排放中的苯含量					/
苯↑	增加尾气和蒸发排放中的苯含量					/
乙醇↑小于 3.5% O_2	减少 CO, HC, 略微增加NO_X	对装有氧传感器的车影响很小				如果不调整RVP，会增加蒸发排放, 可能对燃料系统组件造成影响，可能造成积碳，及少量燃料经济性的损失
MTBE甲基叔丁基醚↑小于2.7% O_2	减少CO, HC	对装有氧传感器的车影响很小				引起水污染，略微降低燃料经济性
蒸馏特性 T50, T90 ↑	可能引起 HC↑	HC↑				不像乘用车那样可以量化
MMT 甲基环戊二烯三羰基锰↑	增加锰排放	可能引起催化器堵塞				孔密度越小催化器堵塞的风险越小，但是对火花塞和燃烧室也有影响
RVP 雷氏蒸汽压↑	增加HC的蒸发排放					
防积碳添加剂↑	/	减低排放				有益于减少燃料喷嘴，化油器的积碳

注: CO =一氧化碳; HC =碳氢化合物; Pb = 铅; RVP = 雷氏蒸汽压; MMT =甲基环戊二烯三羰基锰; MTBE =甲基叔丁基醚; NOX =氮氧化物; O_2=氧气; SO_2= 二氧化硫; T50 =汽油50%馏出温度; T90 =汽油90%馏出温度。

Table E-2: Impact of Gasoline Composition on Emissions from Motorcycles

GASOLINE	NO CATALYST	INDIA 2005	EURO 3	INDIA 2008	CHINA STAGE 3	COMMENTS
Lead ↑	Pb, HC ↑	CO, HC, NO_x all increase dramatically as catalyst destroyed				
Sulfur ↑ (50 to 450 ppm)	SO_2 ↑	CO, HC, NO_x all increase SO_2 and SO_3 increase				
Olefins ↑	Increased 1,3 butadiene, HC reactivity and NO_x					Potential deposit buildup
Aromatics ↑	Increased benzene exhaust					
Benzene ↑	Increased benzene exhaust and evaporative emissions					
Ethanol ↑ up to 3.5% O_2	Lower CO, HC, slight NO_x increase	Minimal effect with oxygen sensor equipped vehicles				Increased evaporative emissions unless RVP adjusted, potential effects on fuel system components, potential deposit issues, small fuel economy penalty
MTBE ↑ up to 2.7% O_2	Lower CO, HC	Minimal effect with O_2 sensor equipped vehicles				Concerns over Water Contamination small fuel economy penalty
Distillation characteristics T50, T90 ↑	Probably HC ↑	HC ↑				Not as quantifiable as in passenger cars
MMT ↑	Increased Manganese Emissions	Possible Catalyst Plugging				With low cell density, catalyst plugging risk seems small but there are concerns regarding deposits on spark plugs and in the combustion chamber
RVP ↑	Increased evaporative HC Emissions					/
Deposit control additives ↑		potential emissions benefits				Help to reduce deposits on fuel injectors, carburetors

Notes: CO = carbon monoxide; HC = hydrocarbon(s); Pb = lead; RVP = Reid vapor pressure; MMT = methylcyclopentadienyl manganese tricarbonyl; MTBE = methyl tert-butyl ether; NOX = oxides of nitrogen; O_2 = oxygen; SO_2 = sulfur dioxide; T50 = temperature at which 50% of the gasoline distils; T90 = temperature at which 90% of the gasoline distils.

表 E-3:燃料对轻型柴油车的影响

柴油参数	欧1前	欧1	欧2	欧3	欧4	欧5/6	备注
硫↑	SO_2, PM↑		如果使用氧化催化器, SO_3, SO_2, PM↑		如果采用捕集装置, 燃料硫含量至多50 ppm, 推荐10-15 ppm		如果使用NO_X吸附器，要求硫含量基本为零(<10 ppm) 使用低硫燃料的同时，使用润滑添加剂
十六烷值↑	减少CO, HC, 苯, 1,3 –丁二烯, 甲醛和乙醛						十六烷值低的燃料会排放更多的白烟
密度↓	PM, HC, CO, 甲醛, 乙醛和苯↓, NO_X↑						/
挥发性 (T95由370至 325 C)	NO_X, HC增加, PM, CO降低						/
多环芳烃↓	NO_X, PM, 甲醛和乙醛↓但是HC, 苯和CO↑						一些研究表明总芳族与多环芳烃一样对排放有重要影响

注: CO = 一氧化碳; HC = 碳氢化合物; NO_X = 氮氧化物, PM = 颗粒物; ppm = 百万分之一; SO_2 = 二氧化硫; SO_3或三氧化硫是一种中间产物

表 E-4: 燃料对重型柴油车的影响

柴油参数	欧1前	欧1	欧2	欧3	欧4	欧5	备注
硫↑	SO_2, PM↑		如果使用氧化催化器, SO_3, SO_2, PM↑		如果采用捕集装置,燃料硫含量至多 50 ppm, 推荐10-15 ppm		如果使用NO_X吸附器，要求硫含量基本为零(<10 ppm) 使用低硫燃料的同时，使用润滑添加剂
十六烷值↑	减少CO, HC, 苯, 1,3 –丁二烯, 甲醛和乙醛						十六烷值低的燃料会排放更多的白烟
密度↓	HC, CO ↑, NO_X↓						/
挥发性 (T95由 370至325 C)	略微降低NO_X但是HC增加						燃料中在370 ℃仍不挥发部分过多造成黑烟和颗粒物的增加
多环芳烃↓	NO_X, PM, HC ↓						一些研究表明总芳族对排放有重要影响

注: CO = 一氧化碳; HC = 碳氢化合物; NO_X = 氮氧化物, PM = 颗粒物; ppm = 百万分之一; SO_2 = 二氧化硫; SO_3或三氧化硫是一种中间产物

Table E-3: Impact of Fuels on Light Duty Diesel Vehicles

DIESEL FUEL CHARACTERISTIC	PRE-EURO	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5/6	COMMENTS
Sulfur ↑	SO_2, PM ↑		If oxidation catalyst is used, SO_3, SO_2, PM ↑		If Filter, 50 ppm maximum, 10-15 ppm better		If NO_X adsorber used requires near zero sulfur (<10 ppm) With low S, use lubricity additives
Cetane ↑	Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde						Higher white smoke with low cetane fuels
Density ↓	PM, HC, CO, formaldehyde, acetaldehyde & benzene ↓ , NO_X ↑						/
Volatility (T95 from 370 to 325 C)	NO_X, HC increase, PM, CO decrease						/
Polyaromatics ↓	NO_X, PM, formaldehyde & acetaldehyde ↓ but HC, benzene & CO ↑						some studies show that total aromatics are important for emissions in a manner similar to polyaromatics

Notes: CO = carbon monoxide; HC = hydrocarbon; NO_X = oxides of nitrogen, PM = particulate matter; ppm = parts per million; SO = sulfur dioxide; SO_3 or sulfur trioxide is an intermediate compound.

Table E-4: Impact of Fuels on Heavy Duty Diesel Vehicles

DIESEL FUEL CHARACTERISTIC	PRE-EURO	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	COMMENTS
Sulfur ↑	SO_2, PM ↑		If oxidation catalyst is used, SO_3, SO_2, PM ↑		If Filter, 50 ppm maximum, 10-15 ppm better		If NO_X adsorber used requires near zero sulfur (<10 ppm) With low S, use lubricity additives
Cetane ↑	Lower CO, HC, benzene, 1,3-butadiene, formaldehyde & acetaldehyde						Higher white smoke with low cetane fuels
Density ↓	HC, CO ↑ , NO_X ↓						/
Volatility (T95 from 370 to 325 C)	Slightly lower NO_X but increased HC						Too large a fraction of fuel that does not volatilize at 370 C increases smoke and PM
Polyaromatics ↓	NO_X, PM, HC ↓						Some studies show that total aromatics are important

Notes: CO = carbon monoxide; HC = hydrocarbon; NO_X = oxides of nitrogen, PM = particulate matter; ppm = parts per million; S = sulfur; SO_2 = sulfur dioxide; SO_3 or sulfur trioxide is an intermediate compound

附录 F. 中国，欧盟，美国，加州燃料参数的对比

表 F-1. 选定的汽油参数

	国 III	欧 3	欧4	欧5	EPA新配方汽油平均值 (2005)[1]		EPA 传统汽油平均值 (2005) [2]		CARB [3] (CARFG3)			世界燃料宪章种类4 [4]
					夏季	冬季	夏季	冬季	下限	平均限值	上限	
芳烃, 体积分数%, 最大值	40	42	35	35	20.7 [5]	19.5 [5]	27.7	24.7	25	22	35	35
烯烃, 体积分数%, 最大值	30	18	18	18	11.9	11.2	12	11.6	6	4	10	10
苯, 质量分数%,最大值	1	1	1	1	0.66 [6]	0.66 [6]	1.21 [6]	1.15 [6]	0.8	0.7	1.1	1
硫, ppm, 最大值	150	150	50	10	71 [7]	81 [7]	106 [7]	97 [7]	20	15	30 20 [8]	10
RVP雷氏蒸汽压, 千帕	夏季: 72 冬季: 88	60/70 最大值	60/70 最大值	60/70 最大值	47.6 [9] (6.91 psi) 最大值	82.0 (11.89 psi) 最大值	57.2 [9] (8.3 psi)	83.6 (12.12 psi)	48.2 或 47.6 [10] 最大值 (7 或 6.9 psi)	NAP	44.1-49.6 (6.4-7.2 psi)	与国IV 推荐的相同
锰, 微克/升	16	NS	NS	MMT<6 (2011起) MMT<2 (2014起)	NA [11]	NA [11]	NA	NA	ND	ND	ND	ND
氧含量, 质量%	2.7 (最大值)	2.7 (最大值)	2.7 (最大值)	2.7 (最大值)	2.49	2.37	0.95	1.08	1.8-2.2	NAP	0 - 3.5 1.8[12] - 3.5	2.7

NS =未规定; NA = 无法获得; ND = 不能检测出; NAP = 不适用

Appendix F. Comparison between China, EU, US, California fuel specifications

Table F-1. Selected Gasoline Parameters

	CHINA III	EURO 3	EURO 4	EURO 5	EPA RFG AVERAGE (2005)[1]		EPA CONV. GASOLINE AVERAGE (2005) [2]		CARB [3] (CARFG3)			WORLDWIDE FUEL CHARTER GATEGORY 4 [4]
					SUMMER	WINTER	SUMMER	WINTER	FLAT LIMITS	AVERA-GING LIMITS	CAP LIMITS	
Aromatics, vol%, max	40	42	35	35	20.7 [5]	19.5 [5]	27.7	24.7	25	22	35	35
Olefin, vol%, max	30	18	18	18	11.9	11.2	12	11.6	6	4	10	10
Benzene, wt%, max	1	1	1	1	0.66 [6]	0.66 [6]	1.21 [6]	1.15 [6]	0.8	0.7	1.1	1
Sulfur, ppm, max	150	150	50	10	71 [7]	81 [7]	106 [7]	97 [7]	20	15	30 20 [8]	10
RVP, kPa	Summer: 72 Winter: 88	60/70 max	60/70 max	60/70 max	47.6 [9] (6.91 psi) Max	82.0 (11.89 psi) max	57.2 [9] (8.3 psi)	83.6 (12.12 psi)	48.2 or 47.6 [10] max (7 or 6.9 psi)	NAP	44.1-49.6 (6.4-7.2 psi)	Same as proposed China IV
Manganese, mg/liter	16	NS	NS	MMT<6 (by 2011) MMT<2 (by 2014)	NA [11]	NA [11]	NA	NA	ND	ND	ND	ND
Oxygen, % m/m	2.7 (max)	2.7 (max)	2.7 (max)	2.7 (max)	2.49	2.37	0.95	1.08	1.8-2.2	NAP	0 - 3.5 1.8[12] - 3.5	2.7

NS = Not specified; NA = Not available; ND = Non-detectable; NAP = Not applicable

注:

1. 这里是2005年新配方汽油调查数据的全国平均值。虽然EPA对新配方汽油（RFG）制定了硫含量，夏季RVP，芳香烃系族和苯的限值，但达标管理是依据一个复杂模型对挥发性有机化合物（VOC），有毒有害物质和氮氧化物排放的估计值与1990年基准汽油的情况相比而执行的。

2. 这里展示的是2005年传统汽油调查数据的平均值。EPA对苯含量，硫含量与夏季蒸汽压一样设定了限值，但是没有对其他的参数进行限定。个别的生产商和进口商通过证明其生产或进口的传统汽油产生的VOC, CO, NOx和有毒有害物质不比1990年生产或进口的传统汽油相应排放的水平高来达标。如果一个产品或进口商无法获得1990年的数据，就必须要使用一个“法定基准值”即1990年美国汽油的平均值。随着实施低硫汽油规定(80 ppm最大值, 30 ppm平均值), EPA不再强制执行VOC标准，因为硫含量达标即可满足VOC标准的要求。同样的，从2011年起，EPA将不再实施有毒有害空气污染物标准。这些标准会被更严格的年均为0.62%体积分数的苯含量标准替代。

3. 炼油厂和燃料进口商可以选择达到上限限值（单一值），或者带封顶的平均值限值。炼油厂和进口商也可以通过使用模型预测数据来证明其他组分的燃料排放量与可以达到上限标准或者平均值标准的汽油相同。

4. 美国EPA的Tier2或2007/2010车型道路重型车排放标准适用于要求欧4，欧5重型柴油车的市场。

5. 《清洁空气法》中规定新配方汽油的芳香烃系族体积含量不高于25%。

6. 《清洁空气法》中规定新配方汽油的苯含量限值为体积分数1%；《移动源空气有毒有害物质》最终标准将所有汽油（新配方汽油和传统汽油）的年平均苯含量限值加严到0.62%体积分数，并定于2011年1月1日起实施。0.62%的限值可以通过企业平均，信用预留和企业间信用额交易的灵活手段来达成，但是自2012年7月1日起所有生产商和进口商所生产和进口的汽油的实际年平均值必须小于1.3%。

7. 从2006年起，所有汽油的硫含量年平均限值为30ppm，所有产品的硫含量最大值不超过80ppm。

8. 2011年12月31日起实施。

9. 《清洁空气法》要求所有在高臭氧季节(6月1日至9月15日)销售的汽油达到62.1 kPa (9 psi)的限值。对新配方汽油设置了更加严格的挥发性（夏季蒸汽压）要求，这些要求随着区域，月份的不同在48.3-62.1 kPa (70-90 psi)范围内变动。EPA允许含有9-10体积百分比乙醇的汽油的雷氏蒸汽压高1.0-psi 。

10. 当生产上使用CaRFG3预测模型的蒸发排放单元时，47.6 kPa (6.9 psi) 适用；汽油不可以超过上限49.6 kPa (7.2 psi)；否则则适用48.2 kPa (7.00 psi)限值。

11. 《清洁空气法》要求新配方汽油不含有包括铅、锰的重金属。

12. 1.8%的冬季最小值适用于南海岸地区(South Coast Area)和因皮里尔郡(Imperial County)的11月1日至2月29日。

Notes:

1. National average of the 2005 RFG survey data are shown here. Even though EPA establishes limits on sulfur, summer RVP, aromatics and benzene for reformulated gasoline (RFG), compliance is determined based on the complex model estimates of VOC, toxic and NOx emissions relative to the emissions of the 1990 baseline gasoline.

2. Presented here are national average in 2005 based on conventional gasoline survey data. EPA sets limits on benzene and sulfur content as well as summer RVP, but not for other parameters. Individual producer or importer demonstrates compliance with the conventional gasoline standard by showing that emissions of VOC, CO, NOx and toxic air pollutants from conventional gasoline produced or imported do not increase over levels from the gasoline it produces or imports in 1990. If a producer or importer is unable to develop adequate 1990 data, it must use a "statutory baseline", which is the average quality of all 1990 U.S. gasoline. With the adoption of the low sulfur gasoline requirement (80 ppm maximum, 30 ppm average), EPA no longer enforces the VOC standards as compliance with the sulfur limit assures compliance with the VOC requirements. Also, starting 2011, EPA will begin to phase out the toxic air pollutant standards. These standards will be replaced by the more stringent benzene standard that requires annual average of 0.62% by volume.

3. Refiners and fuel importers could choose to comply with the maximum (flat) limit, or the averaging limit coupled with a cap limit. Refiners and importers could also certify alternative specification by using the predictive model to demonstrate that emissions are equivalent to those of a gasoline meeting the flat limits or the averaging limits plus cap values.

4. Applicable to markets requiring Euro 4, Euro 5 heavy duty, US EPA Tier 2 or 2007/2010 Heavy Duty On-Highway or equivalent emission standards.

5. The reformulated gas provision of the "Clean Air Act" (CAA) limits the aromatic content of RFG to 25% by volume.

6. CAA limits benzene content of RFG gasoline to 1% by volume; the Mobile Source Air Toxics final rule further tightens the benzene limit to 0.62% for all gasoline (reformulated and conventional) on an annual average basis beginning Jan. 1, 2011. While the 0.62% limits could be met through an averaging, banking and trading program, the actual annual average of gasoline produced or imported by any refiner or importer must not exceed 1.3% by volume beginning Jul. 1, 2012.

7. Effective from 2006, the gasoline sulfur limit for all gasoline is 30 ppm for the annual refinery average and a cap of 80 ppm for all production.

8. Applies on December 31, 2011.

9. "Clean Air Act" specifies a limit of 62.1 kPa (9 psi) for any gasoline sold during the high ozone season (Jun. 1 to Sept. 15). More stringent volatility (summer RVP) requirements are set for RFG, which vary by the region and month, and range from 48.3-62.1 kPa (70-90 psi). EPA provides a 1.0-psi RVP allowance for gasoline containing ethanol at 9 to 10 volume percent.

10. 47.6 kPa (6.9 psi) applies when a producer is using the evaporative emissions element of CaRFG3 Predictive Model; gasoline may not exceed a cap of 49.6 kPa (7.2 psi); otherwise, the 48.2 kPa (7.00 psi) limit applies.

11. CAA requires that RFG to contain no heavy metal, including lead and manganese.

12. 1.8% winter minimum applies from Nov. 1 to Feb. 29 in the South Coast Area and Imperial County.

表F-2: 选定的柴油参数

	国II	国III	欧 3	欧4	欧5	EPA	CARB		世界燃料宪章种类4[2]	美国卡车协会 ASTM D975 (美国)
	(有效至2011年6月)	(2009年6月发布实施)				传统柴油	基准燃料[1]	指定的等效限值[1]		
多环芳烃, 体积%, 最大值	NS	11	11	11	8	NS	1.4	3.5	2.0	
硫含量, ppm, 最大值	2000	350	350	50	10	15	15	15	10	500 / 15 (ULSD)
十六烷值, 最小值	45	49 (5, 0 和 -10°C PP) 46 (-20°C PP) 45 (-35 和 -50°C PP)	51	51	51	十六烷指数 >= 40 或芳香烃 <= 35%[3]	48	53	55	40
密度 @ 15°C, kg/m3,最小值	实际测试 @ 20°C	810 - 850 (5, 0 和 -10°C PP) 790 - 850 (-20, -35 和 -50°C PP)	820 - 845	845	845	NS	NS	NS	820 [4]	NS
闪点, °C, 最小值	55 (10, 5, 0, 10 和-20°C PP) 45 (-35 和 -50°C PP)	55 (5, 0 和 -10°C PP) 50 (-20°C PP) 45 (-35 和 -50°C PP)	55	与欧III相同	与欧 III 相同	NS	54	NS	55	52
灰分含量, 质量%, 最大值	0.01	0.01	0.01	与欧III相同	与欧 III 相同	NS	NS	NS	0.001	0.1
黏度 @ 40°C, mm2/s	3.0 - 8.0 (5, 0 和 -10°C PP) 2.5 - 8.0 (-20 °C PP) 1.8 - 7.0 (-35 和 50°C PP) @ 20°C	3.0 - 8.0 (5 和 0°C PP) 2.5 - 8.0 (-10 和 -20°C PP) 1.8 - 7.0 (-35 和 50°C PP) @ 20°C	2 - 4.5	与欧III相同	与欧 III 相同	NS	2 - 4.1	NS	2.0 [5]	1.9 - 4.1

PP = 柴油倾点（或凝点）; NS=未规定

Table F-2: Selected Diesel Parameters

	CHINA II	CHINA III				EPA	CARB			
	(EFFECTIVE THRU JUNE 2011)	(EFFECTIVE BEGINNING JULY 2011)	EURO 3	EURO 4	EURO 5	CONVENTIONAL DIESEL	REFERENCE FUEL[1]	DESIGNATED EQUIVALENT LIMIT[1]	WORLDWIDE FUEL CHARTER CATEGORY 4 [2]	AMERICAN TRUCK ASSOCIATION ASTM D975 (US)
Polyaromatics, vol%, max	NS	11	11	11	8	NS	1.4	3.5	2.0	
Sulfur, ppm, max	2000	350	350	50	10	15	15	15	10	500 / 15 (ULSD)
Cetane number, min	45	49 (5, 0 and -10°C PP) 46 (-20°C PP) 45 (-35 and -50°C PP)	51	51	51	Cetane index >= 40 or aromatics <= 35%[3]	48	53	55	40
Density @ 15 °C, kg/m3, min	Actual measurement @ 20°C	810 - 850 (5, 0 and -10 °C PP) 790 - 850 (-20, -35 and -50°C PP)	820 - 845	845	845	NS	NS	NS	820 [4]	NS
Flash point, °C, min	55 (10, 5, 0, 10 and -20°C PP) 45 (-35 and -50°C PP)	55 (5, 0 and -10°C PP) 50 (-20°C PP) 45 (-35 and -50°C PP)	55	Same as Euro III	Same as Euro III	NS	54	NS	55	52
Ash content, % m/m, max	0.01	0.01	0.01	Same as Euro III	Same as Euro III	NS	NS	NS	0.001	0.1
Viscosity @ 40°C, mm2/s	3.0 - 8.0 (5, 0 and -10°C PP) 2.5 - 8.0 (-20 °C PP) 1.8 - 7.0 (-35 and 50°C PP) @ 20°C	3.0 - 8.0 (5 and 0°C PP) 2.5 - 8.0 (-10 and -20 °C PP) 1.8 - 7.0 (-35 and 50°C PP) @ 20°C	2 - 4.5	Same as Euro III	Same as Euro III	NS	2 - 4.1	NS	2.0 [5]	1.9 - 4.1

PP = Diesel pour point; NS=Not specified

注:

1. 加州法规在芳香烃系族达标方面允许给予一定的灵活性。生产商和进口商生产的燃料需要达到指定的蒸发排放标准，或者通过论证指定燃料的排气污染物减排等效于基准燃料来认证该燃料；“低排放”燃料与基准燃料相比一般十六烷值更高，硫含量更低，但芳香烃系族含量、多环芳烃、氮含量更高。
2. 美国EPA的Tier2或2007/2010车型年道路重型车排放标准适用于要求欧4，欧5重型柴油车的市场。
3. EPA要求以下标准满足其一：十六烷最小值为40或者芳香烃系族含量最大值为35%。国家标准和技术所(NIST) 定义的优质柴油须满足十六烷最小值为47的标准。各州可以自行决定是否采用NIST优质柴油标准。
4. 当大气温度低于-30°C时，可以放宽至800kg/m^3 。从环境考虑出发，可以施行815 kg/m^{3}作为最小值。
5. 当大气温度低于-30°C时，可以放宽至1.5 mm^2/s ，当大气温度为-40°C时，可以放宽至 1.3 mm^2/s 。

Notes:

1. The California regulations allow flexibility in meeting the limit on aromatics. Producers or importers could either produce a fuel that meets the designated equivalent limits, or certify a fuel formulation by demonstrating that the exhaust emission reduction of a candidate fuel is equivalent to those with the reference fuel; the "low emission" fuels typically have much higher cetane number, lower sulfur, but higher aromatics, higher polycyclic aromatics and higher nitrogen than the reference fuel.

2. Applicable to markets requiring Euro 4, Euro 5 heavy duty, US EPA Tier 2 or 2007/2010 Heavy Duty On-Highway or equivalent emission standards.

3. EPA requires either a minimum cetane index of 40 or a maximum aromatic content of 35%. Premium diesel fuel defined by National Institute of Standards and Technology (NIST) requires minimum cetane number of 47.0. It is up to individual states to adopt the NIST premium diesel requirements.

4. Can be relaxed to 800 kg/m^3 when ambient temperatures are below -30°C. For environmental purposed, a minimum of 815 kg/m^3 can be adopted.

5. Can be relaxed to 1.5 mm^2/s when ambient temperatures are below -30°C, and to 1.3 mm^2/s when ambient temperatures are -40°C.

附录 G. 加州和美国空气质量法规中移动源排放控制要求的发展进程

机动车排放和光化学烟雾的联系在1952年由Haagen-Smit教授首先提出。20世纪50年代中期，加州立法机关和美国国会提出了要求研究空气污染原因，影响和控制的法案。随后加州开展了一项机动车空气污染控制项目，但是直到1965年，国会才通过了《机动车空气污染控制法》，其中制定了第一套联邦机动车排放标准，联邦才对机动车开展了立法工作。1970年颁布了《清洁空气法》修订案，认识到机动车作为空气污染源的重要性，要求机动车排放要比未作要求以前的水平降低90%。1970年《清洁空气法》修订案及其后来1977年和1990年的修订，进一步加强了对机动车污染的控制，并且将环境部门的权限扩展到其他移动源。随着1970年《清洁空气法》的颁布，美国国家环境保护局（EPA）建立于1970年，是执行《清洁空气法》中各种要求的主管部门。迄今为止，美国国家环境保护局与各州政府合作，通过执行新车、在用车、发动机排放标准，燃料标准，在用车检查与维修保养制度，以及通过各州执行规划进行交通规划[174]来控制移动源的排放。

通过过去四十年的努力，美国空气质量立法中移动源的涵盖范围有所扩大（从起初关注道路源，扩展到非道路，船舶，火车机车和非道路源），将EPA的职权扩展到燃料方面，并且提高了违规的处罚。这些改变从很大程度上保证了更加严格的排放和燃料标准得以推行和有效的实施，来确保机动车保有量持续增加和运输量增长情况下的空气质量。所管辖的排放源覆盖面的扩大（包括非道路，船舶和火车机车），也保证EPA可以对这些方面设置更严格的标准，而不仅仅是局限于机动车方面，这样更加先进的排放控制技术和更加清洁的燃料会应用于控制几乎所有移动源排放。虽然1977年和1990年修订案中允许各州不遵从联邦标准而设置他们自己标准的规定有所变更，允许加州（和其他州来参照加州）设置至少与联邦标准同样严格的州标准来达到各州空气质量的要求的这一基本原则没有实质改变，甚至还得到了加强。

随着过去十几年中机动车保有量快速增长，中国在移动源排放控制方面正面临着与美国20世纪60年代相仿或更大的挑战。虽然目前的《大气污染防治法》（简称《大气法》）中对移动源的规定太过简单、涵盖内容有限、也并未具体化，该法规的修订工作目前已提上日程。美国空气污染立法的历程可以为《大气法》目前和未来的法规修订中提供宝贵的经验。

下面是美国及《清洁空气法》中开展空气质量控制计划中与移动源排放相关的重要里程碑的总结：

1955

- 《联邦空气污染控制法》颁布，授权对空气污染的原因，影响和控制进行研究。

174 尽管EPA没有直接参与交通规划中，但是各州执行规划提交规划分析包含了未来交通运输的飞速增长对空气质量的影响，表明了排放不可以超过空气质量限值，一旦超过，州政府如何对削减排放达到空气质量目标进行计划。

Appendix G. Evolution of mobile source emission control in California and US air quality laws

The relationship between motor vehicle emissions and photochemical smog was first established by Prof. Haagen-Smit in 1952. In the mid1950s, the California legislature and the US Congress introduced laws that mandated studies of the causes, effects and control of air pollution. An automobile air pollution control program was subsequently developed in California, but federal automobile legislation was not enacted until 1965 when the Congress passed the "Motor Vehicle Air Pollution Control Act", which established the first set of federal automobile emission standards. The "Clean Air Act" Amendments in 1970, recognizing the importance of automobiles as air pollution sources, mandated a 90% reduction of vehicle emissions from the levels previously prescribed. The 1970 CAA Amendments and its subsequent amendments in 1977 and 1990, further strengthened control of pollution from automobiles, and further expanded the legal authority of environmental agencies to regulate other mobile sources. The US Environmental Protection Agency (EPA), created in 1970 under "Clean Air Act Amendments" of 1970, is the primary agency charged with implementing various requirements included in the Clean Air Act[174].To date, US EPA, working with the state governments, control mobile source emissions through enforcement of emission standards for new and in-use vehicles and engines and fuel standards, in-use vehicle inspection and maintenance, as well as transportation planning via developing the State Implementation Plans.

Over the past four decades, the provisions on mobile sources in the US air quality legislation have widened in scope (from primarily focused on onroad sources to covering non-road, marine, locomotive and non-road sources), broadened EPA's authority over fuels, and heightened penalties for noncompliance. These changes were made largely to ensure that tighter emission and fuel standards could be introduced and effectively enforced to protect air quality even with continued vehicle population growth and increasing amount of travel. The broader coverage of sources (including non-road, marine and locomotive) also ensures that EPA sets stringent standards for those modes, not just motor vehicles, such that advanced emission control technologies are deployed and cleaner fuels are used to control nearly all sources of mobile emissions. While the provisions granting states exemptions to set their own standards have been revised in the 1977 and 1990 amendments, the fundamental principle of allowing California (and other states who choose to follow California) to set regulation at least as stringent as the federal regulation in order to meet its specific air quality needs has not changed and has even been strengthened.

China, with a rapidly growing vehicle population in the past decade or so, is facing similar if not more daunting challenges in mobile source emission control as what US faced back in the 1960s. While the motor vehicle provision of the "Air Pollution Prevention and Control Law" in its current form is brief, limited in scope and short of specificity, revision to the law is now underway. The evolution of the US air pollution legislation could offer valuable lessons learned to inform the current and future revisions of the law.

Below summarized the key milestones related to mobile source emissions in the evolution of the air quality control program in the US and the Clean Air Act:

1955

- "Federal Air Pollution Control Act" is enacted, which authorizes research on the causes, impacts and control of air pollution.

174 Although EPA is not directly involved in transportation planning, however an analysis of transportation plans submitted with the SIPs including impacts of future projection of traffic growth on air quality need to show that emissions do not exceed air quality limit, and if exceedences is shown, how the state is planning to reduce emissions to meet air quality goals.

- 在加州，洛杉矶空气污染控制区成立了加州洛杉矶市机动车污染排放实验室，湾区（旧金山湾区）空气污染控制区建立。这两个区域后来更名为南海岸空气质量管理区和湾区空气质量管理区。

1959

- 加州立法通过要求加州建立空气质量标准，和必要的排放控制措施；这引导了美国颁布其第一个全国范围的总悬浮颗粒物，光化学氧化剂，二氧化硫，二氧化氮和一氧化碳排放的标准。

1960

- 加州机动车管理局建立，其首要职能是测试和认证加州销售的汽车加装的装置。
- 国会通过联邦机动车法案，确定联邦对机动车造成的空气污染进行研究调查。

1963

- 美国国会通过第一版联邦《清洁空气法》。法案授权于健康，教育和社会福利部来根据科学研究的结果定义空气质量标准，并为州和地区空气污染控制区提供资金。

1965

- 美国国会通过机动车空气污染控制法案；随后颁布了首个联邦机动车标准于1968车型年生效。

1967

- 颁布了联邦空气质量法。它扩展了机动车的研究，要求对燃料添加剂进行登记，并且设立了一个资助州机动车检查计划的项目。1967年联邦法案也确立了新车排放控制项目的联邦授权制度，即除加州外，其余的州不允许设置自己的排放控制法规。加州由于空气质量问题的特殊性，以及其空气质量控制的领先行动，成为美国唯一一个可以设置更加严格标准的州。十年之后，其他的州也可以采用加州标准了，前提是这些标准至少应与联邦要求同样严格。
- 加州机动车污染控制局和空气卫生局及其试验室合并成为加州空气资源局。

1970

- 国家空气质量的持续恶化，加速了国会在1970年通过《清洁空气法》（CAA）的修订案，该法案是空气污染控制法律依据的首要来源，建立了美国空气污染控制体系的基本规模。

- In California, Los Angeles County Motor Vehicle Pollution Control laboratory is established within the Los Angeles Air Pollution Control District, and the Bay Area Air Pollution Control District was established. These two were later switched to South Coast Air Quality Management District (AQMD) and Bay Area AQMD.

1959

- Legislation is passed in California requiring the state to establish air quality standards and necessary controls for motor vehicle emissions; this leads to the promulgation of the first statewide air quality standards in the US for total suspended particulates, photochemical oxidants, sulfur dioxide, nitrogen dioxide and carbon monoxide.

1960

- The Motor Vehicle Control Board of California is established with a primary function of testing and certifying devices for installation on cars for sale in California.
- Federal Motor Vehicle Act is passed by the Congress stipulating federal research to address air pollution from motor vehicles.

1963

- US Congress passes the first federal "Clean Air Act". The Act empowers the Department of Health, Education and Welfare to define air quality criteria based on scientific studies and offers grants to state and local air pollution control districts.

1965

- US Congress passes the Motor Vehicle Air Pollution Control Act; the first federal vehicle standards apply to MY1968 vehicles is subsequently promulgated.

1967

- The federal Air Quality Act is enacted. It expands motor vehicle research, requires federal registration of fuel additives and establishes a grant program for state vehicle inspection programs. The 1967 federal statue also establishes federal preemption of new vehicle emission controls, i.e., states, except for California, are not allowed to set its own vehicle emission control regulation. California is the only state in the US that is allowed to set more stringent standards because of the state's special air quality problems, and pioneering efforts in the control of air quality. A decade later, other states are allowed to adopt California's standards if proven to be at least as stringent as federal requirements.
- The California Air Resources Board is created from the merging of the California Motor Vehicle Pollution Control Board and the Bureau of Air Sanitation and its Laboratory.

1970

- The country's air quality continues to deteriorate, prompting the Congress to pass the "Clean Air Act" (CAA) Amendments in 1970 which serve as the principal source of legislative authority for air pollution control and establish the basic US program for controlling air pollution.

- 在该法案下，美国EPA成立，要求EPA基于健康影响研究结果制定六种污染物(标准污染物包括颗粒物，二氧化硫，一氧化碳，氮氧化物，臭氧和铅)的国家空气质量标准（NAAQS），并授权EPA管理机动车排放。

- 修订案采用了通过四种途径管理移动源来控制大气污染的策略：
  - o 新车和发动机排放
  - o 油品质量和油品添加剂
  - o 在用车排放
  - o 交通规划

- 此外，《清洁空气法》1970版在1977年和1990年的修订中又进一步加严，通过以下步骤对移动源排放建立了双重策略：
  - o 由EPA牵头，强制实施新车和发动机排放标准，并管理油品及油品添加剂。
  - o 联邦和各州联合制定方案，控制固定源和在用车/发动机，使其达到空气质量标准，主要通过州执行规划(SIP)[175]实施。
- 1970年《清洁空气法》与移动源相关的其他主要规定：
  - o 以在1975/76年时间段实现HC，CO和NOx减排90%为目标制定联邦机动车排放标准[176]。
  - o 授权各州强制实施旨在削减在用车年行驶里程或保障在用车进行适当维护的项目。
  - o 要求燃料进行试验的额外规定，并且将民事罚款增加到10,000美元每天。
  - o 要求EPA禁止或者控制使公众健康福利受损或排放控制装置受损的燃料和燃料添加剂。
  - o 不允许各州制定不同于联邦政府的油品和油品添加剂标准。

1971

- 加州空气资源局在国内建立了第一个机动车NOx标准。

1977

1970年的《清洁空气法》在1977年进行了修订。添加了非达标区的规定，允许有达不到NAAQS要求区域的州用更长时间（更现实的时间表）来达标。下列是相关的机动车标准，燃料和在用车排放的关键环节的概述：

新车标准

- 在汽车制造商的反对之下，国会将更加严格的CO和HC标准延迟到1980车型年实施，并且将1981及以后车型年的NO排放标准从0.4 gpm轻微放宽倒1gpm[177]。

175 州执行规划SIP包括州政府为了达到以公众健康为基础的大气环境质量标准和清洁空气法要求的规定和其他项目 。

176 1970年清洁空气法修订案要求截止1975车型年车辆排放的HC和CO的排放比1970车型年削减90%。这些目标是EPA制定CO,HC和NOx新车排放标准的依据。

177 生产厂商争辩催化转化器，作为当时唯一的达标技术，还没有完全成熟并且费用昂贵。见 Gerard, D. 和 L.B。

Lave. 2003年.实施技术主导的政策： 1970年清洁空气法修订案和先进的机动车排放控制的介绍。五月。

http://www.epp.cmu.edu/people/bios/papers/gerard/Gerard_Lave%20TF1.pdf (2010年4月30日查得)。

- The Act establishes the US EPA, requiring EPA to set National Ambient Air Quality Standards (NAAQS) for six pollutants (criteria pollutants, including particular matters, sulfur dioxide, carbon monoxide, nitrogen oxides, ozone and lead) based on scientific studies on health impacts and giving it board responsibility for regulating mobile vehicle emissions.

- The amendments adopt a four-pronged approach to control air pollution from mobile sources through regulating:
  - Emissions from new engine and vehicle
  - Fuel quality and fuel additives
  - Emissions from in-use vehicles
  - Transportation planning

- In addition, the Clean Air Act Amendments of 1970, which was further strengthened by the amendments in 1977 and 1990, established a dual strategy to control mobile source emissions through:
  - A federal program led by EPA to adopt and enforce emission standards applicable to new motor vehicles and engines, and to regulate fuels and fuel additives.
  - A joint federal and state program to control stationary sources and in-use motor vehicles and engines to meet atmospheric air quality standards, which is implemented primarily through the State Implementation Plan (SIP) process[175].

- Other key elements in the 1970 CAA amendments related to mobile sources include:
  - Establishing the federal motor vehicle emission standards with the goal of reducing HC, CO, and NOx emissions from automobiles by 90% in the 1975/76 timeframe[176].
  - Authorizing states to impose programs aimed at in-use vehicles to reduce the VMT or to keep in- use vehicles properly maintained.
  - Adding provisions to allow fuels to be tested, and increasing civil penalties to USD10,000 per day.
  - Demanding EPA to prohibit or control fuels or fuel additives if public health or welfare was endangered or emission control devices would be impaired.
  - Preempting states from setting separate standards for fuels and fuel additives.

1971

- California Air Resources Board adopted the first automobile NOx standards in the nation.

1977

The Clean Air Act of 1970 was amended in 1977. Provisions on nonattainment are added, allowing states with areas not meeting the NAAQS a much longer and realistic time frame to comply. The following summarizes the key elements related to vehicle standards, fuels and in-use vehicle emissions:

New vehicle standards

- Under the opposition of the automakers, congress delays the more stringent CO and HC standards until MY1980 and slightly relaxes the NO emission standard from 0.4 gpm to 1 gpm for MY1981 and thereafter[177] .

175 A SIP includes regulations and other programs a state government will carry out for meeting health-based ambient air quality standards and the associated Clean Air Act requirements.

176 The 1970 CAA amendment requires a 90% reduction by MY 1975 of HC and CO emissions that were emitted from 1970 cars, and 90% reduction by 1976 of NOx that was allowed for MY 1971 cars. These goals led EPA to set new vehicle emissions standards for HC, CO and NOx.

177 Automakers argued that catalytic converters, the only technology that could meet the standard at that time, were not yet ready and would be too costly to be used. See Gerard, D. and L.B. Lave. 2003. Implementing Technology-Forcing Policies: The 1970 Clean Air Act Amendments and the Introduction of Advanced Automotive Emissions Controls. May. http://www.epp.cmu.edu/people/bios/papers/gerard/Gerard_Lave%20TF1.pdf (accessed April 30, 2010).

- 以推迟和放宽全国排放标准为（与汽车制造商的）交换条件，国会允许加州继续保有更加严格的排放标准，其他存在有非达标区的州可以在EPA的认证下采取加州标准，只要他们不要求制造“第三种车”（《清洁空气法》177节). 这个规定一方面允许难以达到联邦空气质量要求的州施行比联邦要求更加严格的标准，另一方面也把对生产企业的影响降到最低（因为这样一来美国就只有两套车辆排放标准）。
- 修订了加州特权的条件，要求加州标准如联邦标准一样保护公众健康和福利。
- 放宽高海拔地区销售的机动车的标准。
- 简化小型生产企业的试验要求。
- 要求EPA制定重型车和摩托车的标准。
- 允许对加油进行相关要求。

在用车排放

- 添加了保证书和防篡改措施。
- 在臭氧和CO非达标区要求检查和维修保养(I/M)计划。

燃料和燃料添加剂

- 加严了燃料和燃料添加剂的相关规定，包括授予EPA权力管理某种燃料成份（如铅）。事实证明这一举措对催化转化器的广泛使用十分重要。
- 放宽小型炼油厂含铅添加剂的要求。

1990

1990年《清洁空气法》修订案对1970年《清洁空气法》修订案中移动源的规定进行修订并增加了两倍内容。法律主要的补充和修订包括:

对常规污染物更加严格的控制:

- 加强轻型车(LD)和轻型卡车的排放控制。控制包括限制低温工况下的排放，控制蒸发损耗 (包括加油中的损耗)[178]。
- 加强重型发动机的标准，来缩小重型发动机标准和相应轻型车标准的差异。
- 要求机动车加装车载诊断系统(OBD) 来确保在机动车使用生命周期中符合排放标准，确保贯彻新的质保书要求。
- 增加了新的一节 (217节)，允许EPA向生产制造商收费来支付认证和召回试验的费用。

为减少空气污染而对汽柴油设置的新控制方案

- 要求燃料燃烧的排放更少
- 扩展EPA管理非道路机动车使用的燃料或燃料添加剂的权力。
- 指导EPA研究控制机动车排放的危险大气污染物的需求，确定控制的手段和方法。这些要求推进了EPA国家空气有毒有害物质项目，该项目管理移动源的危险大气污染物 (包括苯和甲醛)。
- 通过允许各州为了达到特定的空气质量要求采用特有的燃料要求，来减少联邦优先执行权规定的影响。
- 将民事处罚的金额上限由10,000美元每日上调到25,000美元每日（包括通货膨胀的调节表）。
- 要求使用预防发动机和燃料系统积碳的汽油清净剂。
- 要求臭氧非达标区使用新配方汽油。
- 提高高臭氧季节使用的燃料所允许的雷氏蒸汽压（RVP）水平。

178 CAA中涉及的标准的修订比清洁空气法主体的修订更频繁。

- In exchange for delaying and relaxing emission standards, congress allows California to continue to have more stringent emissions standards, and other states with nonattainment areas can adopt California standards with EPA's approval as long as they do not require the creation of a "third car" (Sec. 177 of Clean Air Act). This provision allows states with difficulties achieving the federal air quality requirements to adopt standards more stringent than the federal requirements, but at the same time limits the impacts on manufacturers as there are only two sets of vehicle emission standards in the U.S.
- The waiver condition for California is modified, requiring the state's standards to be as protective of the public health and welfare as federal standards
- The standards applicable to vehicles sold at high altitudes is relaxed
- Testing requirements for small manufacturers is reduced
- EPA administrator is required to set standards for heavy duty vehicles and motorcycles
- Refueling requirements is allowed to be imposedIn-use vehicle emissions

In-use vehicle emissions

- Warranty and tampering provisions are added
- Inspection and maintenance (I/M) programs in ozone and CO nonattainment areas is required

Fuels and fuel additives

- Provisions concerning fuels and fuel additives are tightened, including granting EPA authority to regulate certain fuel content (such as lead). This proves to be important in the wide adoption of catalytic converters.
- Lead additive requirements for small refineries are relaxed.

1990

The 1990 CAA Amendments revised and tripled the size of the mobile source provisions in the 1970 CAA Amendments. Key additions and revisions to the law include:

More stringent control on conventional vehicle emissions:

- Strengthening the emissions control for light-duty (LD) vehicles and LD trucks. These controls include limiting emissions from cold temperature operation, control of evaporative losses (covering losses during refueling)[178].
- Strengthening the standards for HD engines to reduce the disparity between the standards for HD engines and those applied to LDVs.
- Demanding vehicles to have onboard diagnostic (OBD) system to ensure emissions standards are met throughout vehicles' useful life and ensuring compliance with the new warranty requirements.
- Adding a section (Sec. 217) allowing EPA to collect fees from manufacturers to cover expenses of certification and recall testing.

New control on gasoline and diesel fuels to reduce air pollution emissions:

- Requiring fuel combustion to result in fewer emissions.
- Expanding EPA's authority to fuels or fuel additives used in non-road vehicles.
- Directing EPA to study the need to control hazardous air pollutants emitted from vehicles, and identifying means and measures for control. This led to the launch of EPA's National Air Toxics Program that regulates mobile source hazardous air pollutants (including benzene and formaldehyde).
- Limiting the effect of the preemption provision by allowing states to adopt unique fuel requirements if it is necessary to achieve specific air quality needs .
- Raising the maximum civil penalty from USD 10,000 per day to USD25,000 per day (an adjustment schedule for inflation was included).
- Mandating the use of detergents in gasoline to prevent deposits in engine or fuel systems.
- Demanding the use of reformulated gasoline in ozone nonattainment areas.
- Raising the allowable Reid Vapor Pressure (RVP) levels for fuels used during the high ozone season.

178 Standards revisions that are included as revision of CAA occur more often than major revisions of the act.

对包括非道路机动车和发动机、船舶、机车和移动设备的移动源加强控制：

- 要求EPA制定摩托车、重型发动机、非道路机动车和船用发动机的标准。

鼓励“清洁燃料”汽车的发展

- 制定“清洁燃料”汽车的排放标准：“清洁燃料”汽车是可以达到更加严格的“清洁燃料”汽车标准的某类或某个（排放）等级的机动车。

1990-1999及2000+

随着1990年《清洁空气法》法赋予的权力和职责的扩充，EPA引进了更加严格的机动车和燃料标准，并于90年代和本世纪初先后颁布了新的非道路、船舶和机车发动机标准。针对最高法院裁定温室气体属于《清洁空气法》中大气污染物定义范围，EPA在美国历史上首次颁布了轿车和轻型卡车的温室气体标准。

- 1991年颁布了更低的HC和NOx 尾气标准，从1994车型年实施，1992年首次实施了低温CO标准。
- 1992-1993年进行了冬季含氧燃料计划，并且在1993年实施了燃料硫含量的限制。
- 1995年在10个有严重光化学烟雾问题的大城市实施了新配方汽油 (RFG) 项目。
- 1996-2000年间颁布了船舶发动机，机车发动机和用于非道路建筑，农业和工业设备上的柴油发动机的排放标准。
- 1999年EPA宣布SUV和轻型卡车采用与轿车相同的（排放）标准：第一次将车和燃料作为同一系统考虑，并且宣布更低的汽油硫含量来保证低排放控制技术和降低空气污染的效果。
- 2000年，EPA提出了一个全国控制计划来对重型柴油车和他们所使用的燃料作为一个系统进行管理：提出2007车型年重型道路机动车适用的新的重型车排放标准，连同提出一个在2006年将硫含量降低到15ppm的道路柴油方案。
- EPA颁布了减少移动源21种危险污染物（大气有毒有害物质）的最终规定，并制定了新汽油有毒有害物质排放标准。
- 2007年，最高法院裁定温室气体符合《清洁空气法》中对大气污染物的定义，并要求EPA计算温室气体对美国公民健康和福利的影响。
- 2009年，EPA宣布了温室气体威胁公众健康和环境的结论，为EPA按照《清洁空气法》管理温室气体提供了法律依据。
- 2010年4月，EPA和交通部颁布了一个联合规定，为2012-2016车型年的轿车和轻型卡车制订温室气体排放和燃料经济性联合标准。

More control on mobile sources including non-road vehicles and engines, ships, trains and mobile equipment:

- Requiring EPA to set standards for motorcycles, heavy-duty (HD) engines, non-road vehicles, and marine engines.

Encouraging the development of "clean-fuel" vehicles

- Setting emission standards for "clean-fuel" vehicles; "clean-fuel" vehicles could be any category or class of vehicles that could meet the more stringent "clean-fuel" vehicle standards.

1990s and 2000+

With the expanded responsibility and authority granted by the 1990 CAA, EPA introduced more stringent standards for vehicles and fuels and issued new standards for non-road, marine and locomotive engines in the 1990s and 2000s. Responding to the Supreme Court decision that greenhouse gases fall under the definition of air pollutants in the CAA, EPA recently issued GHG standards for cars and light-trucks for the first time in the US history.

- Lower tailpipe standards for HC and NOx were issued in 1991 to take effect beginning with 1994 models, and standards for CO at cold temperatures were established for the first time in 1992.
- Wintertime oxygenated fuel program began in 1992-1993 and limits on fuel sulfur content took effect in 1993.
- Reformulated gasoline (RFG) program began in 10 metropolitan areas with severe smog problems in 1995.
- Emissions standards were issued for marine engines, locomotive engines, and diesel engines used in non-road construction, agricultural and industrial equipment in 1996-2000.
- In 1999 EPA announced that SUVs and other light-trucks are to be subject to the same standards as cars; vehicles and fuels are considered one system for the first time, and tighter sulfur level in gasoline were announced to ensure the effectiveness of low emission-control technology and lower air pollution.
- In 2000, EPA introduced a national control program to regulate heavy-duty diesel vehicles and the fuel they used as one system; new HDV emissions standards applicable to MY2007 heavy-duty on-road vehicles were introduced together with a plan to lower onroad diesel sulfur to 15 ppm by 2006.
- EPA issued a final rule to reduce emissions of 21 hazardous pollutants (air toxics) from mobile sources and set new gasoline toxic emission performance standards.
- In 2007, Supreme Court determined that greenhouse gases (GHGs) fit within the "Clean Air Act" definition of air pollutants, and demanded EPA to evaluate the impacts of GHGs on human health and welfare of US citizens.
- In 2009, EPA announced the findings that GHGs threaten public health and the environment, which establishes the legal basis for EPA to regulate GHG emissions under the CAA.
- A joint final rule was issued by EPA and the Department of Transport in April 2010 that sets GHG emission and fuel economy standards for MY2012-16 cars and light-trucks.

图 G-1. 美国国家环境保护局制定执行机动车和燃料标准的部门组织图

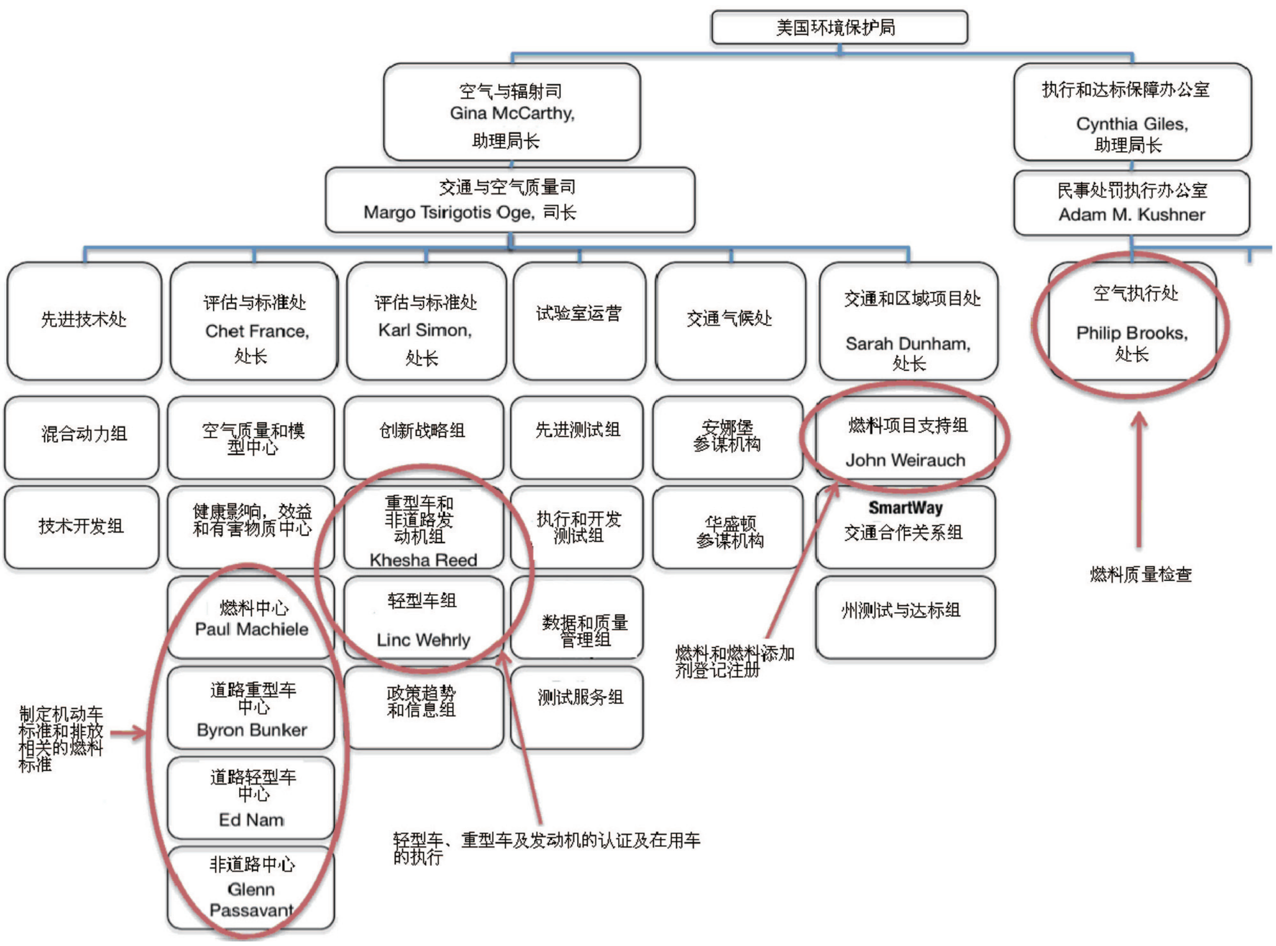
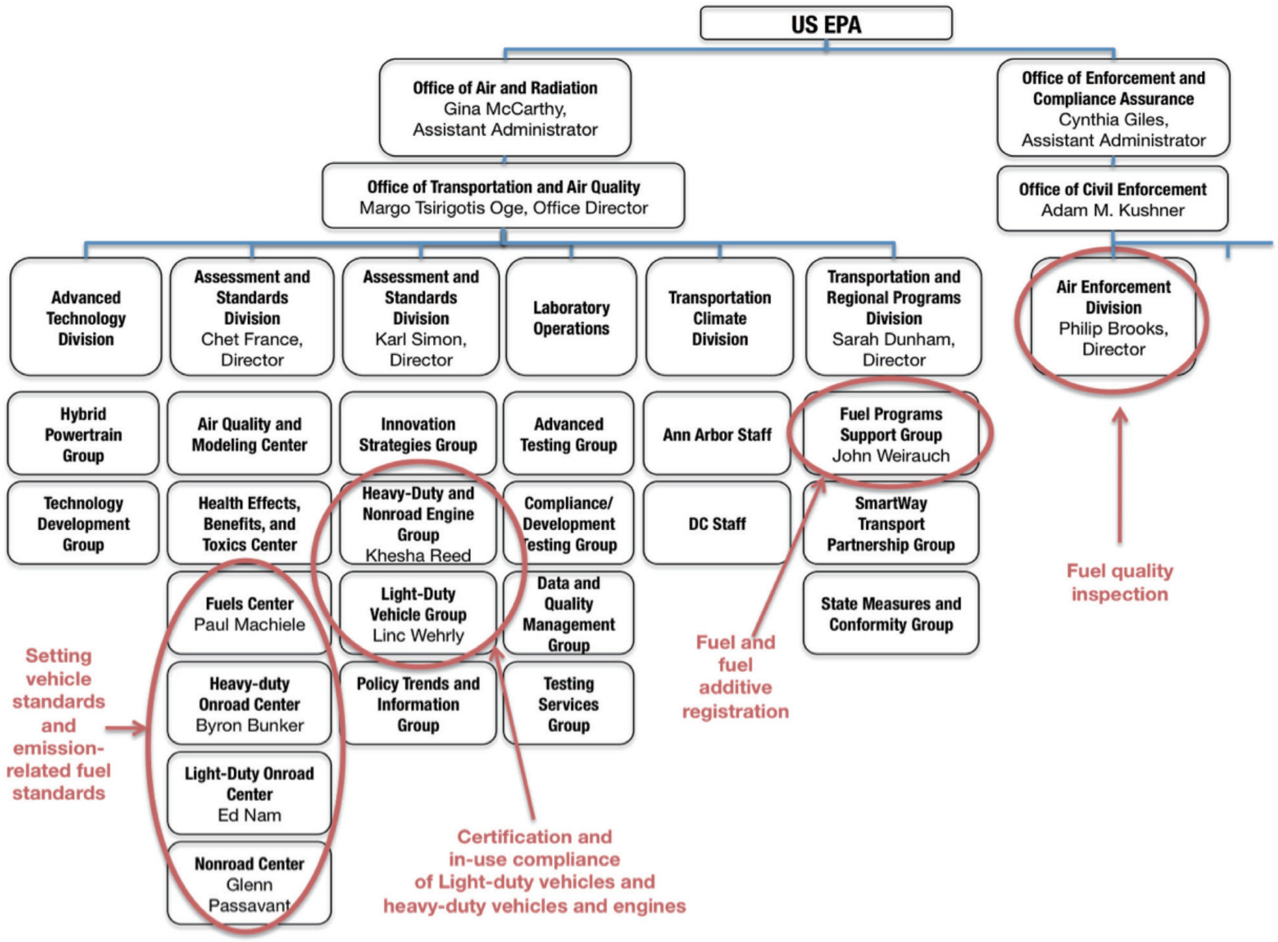


Figure G-1. Organization chart of US EPA divisions responsible for setting and enforcing vehicle and fuel standards



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