9. 替代燃料和新能源汽车政策

替代燃料是指替代传统燃料即柴油和汽油的车辆替代能源。由于汽车保有量快速增长而石油供应相对有限，世界许多国家的政府都已经开始考虑推进非石化燃料和国产燃料作为适当的替代选择。除了能源安全问题，环保部门一定不能忽视这些替代燃料车的环境影响，包括其排放的空气污染物和温室气体排放。特别是在考虑燃料的全生命周期排放时，有些替代燃料对环境造成的影响可能比传统燃料还要大。

本章提供了一些基础信息，介绍了中国目前正在使用或计划使用的替代燃料带来的环境影响优势和缺点。这里主要包括甲醇、天然气（CNG/LNG）、乙醇和多种新能源汽车。中国定义的四种新能源汽车是传统混合动力车（HEV）、插入式混合动力车（PHEV）、氢燃料电池车（FCEV）和电池电动车（BEV，又称纯电动车）。

替代燃料可以根据原料（化石、生物质、风能等）的最终形态（液态、气态、电能）分类。最终的燃料的燃烧（或使用）决定尾气排放，而燃料的原料和生产过程决定其生命周期排放和能源消耗。本节在介绍各种燃料时，也会介绍车辆尾气排放及能效性和全生命周期影响。

替代燃料车辆的设计根据它们对燃料的不同使用方式而不同。其中，有只能使用单一替代燃料的车，有可以同时使用传统或替代燃料并储存在不同的燃料箱中的双燃料车，或只有一个燃料箱但可以既使用传统燃料又使用替代燃料的灵活燃料车。对于非单一燃料的替代燃料车而言，确保这些车真正使用了替代燃料是很重要的，这样才能实现节能和减排的双重目标。

另外，不是所有替代燃料车都是原厂设备制造商（OEM）生产的。传统的汽油或柴油发动机可以进行改造，适应燃烧替代燃料。但是，通常来讲，OEM生产的替代燃料车的发动机和排放性能会更好，因为它们的发动机设计和标定都是充分考虑发挥替代燃料优势的。

下面的各个段落从不同角度总结了国际和中国在推进使用替代燃料方面的经验和政策设计。基于各种燃料的排放特征和国内外的经验，每一节中都会为环保部提出建议，说明环保部在发展和实施各可持续替代燃料的各项政策中可能起到的作用。

9. Alternative fuels and new energy vehicle policies

Alternative fuels for vehicles refer to the replacements for conventional fuels such as diesel and gasoline. With rapidly growing vehicle population and limited oil supplies, many governments around the world have sought to promote non-petroleum and often home-grown fuels as suitable alternatives. Looking beyond energy security, environmental authorities must not overlook the environmental impacts, both in terms of the emissions of toxic air pollutants and in terms of greenhouse gas emissions, of these vehicles. Especially when taking into consideration the full fuel life cycle emissions, some alternative fuels may have greater negative impact on the environment than conventional fuels.

The chapter provides basic information on the environmental advantages and drawbacks of a range of alternative fuels and vehicle currently used or planned to be deployed in China. These include methanol, natural gas (CNG/LNG), ethanol and various new energy vehicles. The four types of vehicles defined as new energy vehicles in China are conventional hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), hydrogen fuel cell electric vehicles (FCEV) and battery electric vehicles (BEV, also often called pure electric vehicles).

Alternative fuels can be distinguished by their feedstock (fossil, biomass, wind energy,etc.) and their final form (liquid, gaseous, electrons). While the final fuel determines the tailpipe emissions and efficiency of vehicles, the fuel's feedstock and production process determine its life cycle emissions and energy use. Each fuel section discusses both vehicle emissions and efficiency and full life cycle impacts.

Alternatively fueled vehicles are designed differently depending on how they use the fuel. There are dedicated vehicles that only use one alternative fuel, dual fuel vehicle that can use either a conventional or an alternative fuel stored in separate tanks, or flexible fuel vehicles that can use either a conventional or an alternative fuel stored in the same tank. For non-dedicated alternative fuel vehicles, ensuring the actual use of the alternative fuels will be important to realize both energy consumption and emissions reduction goals.

In addition, all alternative fuel vehicles are not produced by original equipment manufacturers (OEMs). Conventional gasoline or diesel engines can be modified to accommodate the combustion of alternative fuels. However, generally speaking, OEM alternative fuel vehicles have better engine and emissions performance given the engine design and calibration are optimized alternative fuels.

Each of the following subsection summarizes the relevant aspects of international and Chinese experience and policies designed to promote the use of these fuels. Based on the emissions features of each fuel type, as well as the lessons learned in China and abroad, each section concludes with recommendations on MEP's potential role in the development and implementation of policies that support sustainable alternatives to petroleum fuels.

9.1 甲醇汽车

尽管理论上可以使用有机质生产甲醇，但出于价格的原因，通常绝大多数的甲醇是使用煤和天然气制得的。目前，甲醇可以适用于专用车或按一定比例在汽油中掺烧（通常是以5％到85％的比例，这些车辆称成为M5至M85车）。加州在上世纪90年代推行过甲醇燃料，当时甲醇汽车主要使用含15%汽油的M85燃料。中国目前大多数使用甲醇的汽车其实是使用M15燃料的普通汽油车。甲醇汽车可能可以减少特定的空气污染物，使用甲醇的潜在空气质量收益是推动使用该燃料的主要原因之一。加州1980年至1990年之间进行的M85试点方案显示，生产企业可以生产出满足加州低排放车辆标准的M85汽车，且非甲烷有机物排放量低于0.125克/英里，能减少氮氧化物和一氧化碳排放。特别是重型发动机的排放，与传统汽油车相比，颗粒物排放大幅降低并几乎消除了甲醛以外的所有空气有毒物质[97]。

但是，使用甲醇作为机动车燃料也存在一些问题。甲醇燃烧会排放大量的有毒物质甲醛，甲醛被世界卫生组织划归为致癌物。在美国，对甲醛排放的担忧是影响甲醇使用的主要因素。

甲醇是一种有毒物质。摄入10毫升的甲醇可致盲，而摄入60毫升以上可致命。除了直接摄入，液态甲醇会通过皮肤吸收，其挥发的气体也可以吸入肺部。甲醇蒸气比空气重，如果通风不够良好就会停留在近地面高度。如果空气中的甲醇浓度超过6.7%，就可能被火花点燃，并且在54 F / 12 C 以上会发生爆炸。一旦着火，火焰的光很淡，很不容易看见从而不能用肉眼估计火势大小。另外，甲醇的挥发度低，会导致冷启动困难。如果混合30%或更多的汽油则可以忽略这个问题[98]。安全隐患和燃烧特性都给采用甲醇作为车用燃料提出了挑战，特别是甲醇专用车。

甲醇还具有腐蚀性会侵袭和腐蚀特定金属，如镁和铝。 如使用高比例甲醇（如M85），还须车辆燃料系统使用不锈钢或碳素钢，并配备独立的燃料供给基础设施来防止腐蚀 。使用汽油与甲醇低比例混合（如M15），如果没有专门选择燃料系统的材料，长时间使用可能也会导致腐蚀和生锈问题。甲醇还会侵蚀合成橡胶，如橡胶、聚氨酯和一些塑料，推荐使用氟含量较高的合成橡胶、特氟隆和其它耐醇材料[99]。

最后，从生命周期角度考虑，如果使用煤作为原料，与传统燃料相比，甲醇在减少生命周期温室气体排放方面没有太多优势。据估计，使用煤基甲醇汽车的全生命周期温室气体排放，与传统汽油内燃机汽车的全生命周期排放量持平[100]。

国际经验

加州积极推广甲醇汽车来应对烟雾问题，应该在世界上具有最广泛的甲醇使用经验。为应对石油危机，早在70年代末起，加州就开始开展甲醇试点项目。早期的绝大多数甲醇都是煤制甲醇，依赖周边各州充沛的煤炭储备。80年代初，原油价格开始回落，空气污染取代能源安全成为使用甲醇的主要推动力。因此，加州政府从高污染的煤制甲醇转为天然气制甲醇。

97 Dolan, G. 2005年，《甲醇交通燃料：回顾和展望》（ “Methanol Transportation Fuel: A Look Back and Look Forward” ），国际醇燃料专题讨论会上的发言，圣地亚哥，加州，网址http://www.methanol.org/pdf/MIPaperforISAF.pdf。

98 Brustar, M. 和M. Bakenhus. 《配合醇燃料的经济、高效的发动机技术》（Economical, high-efficiency engine technologies for alcohol fuels.） (http://www.methanol.org/pdf/ISAF-XV-EPA.pdf。

99 Dolan, G. 2005年. 《甲醇交通燃料：回顾和展望》（ “Methanol Transportation Fuel: A Look Back and Look Forward” ），国际醇燃料专题讨论会上的发言，圣地亚哥，加州，网址http://www.methanol.org/pdf/MIPaperforISAF.pdf,2010年4月20日查阅。

100 同上。

9.1 Methanol vehicles

Though theoretically methanol can be made from any organic material, it is most commonly produced from coal and natural gas for cost reasons. Methanol is currently used in dedicated vehicles or blended at a range of ratios with gasoline (most commonly M5 to M85). In the State of California, when methanol fuel was promoted during the 1990s, methanol vehicles mainly used M85 with 15 percent of gasoline. In China, most so-called methanol vehicles to date are normal gasoline engine vehicles but use M15 as the motor fuel. Methanol vehicle may reduce certain regulated air pollutants and the potential air quality benefits from using methanol remains one of the key drivers for promoting its use. A M85 pilot program in California from 1980 to 1990 showed that manufacturers could produce M85 that met California's Low Emission Vehicle Standards, with non-methane organic gas emissions less than 0.125 grams per mile (g/mile), reduced NOx and CO emissions, especially from heavy-duty engines, dramatic reduction in PM compared with traditional gasoline vehicles, and almost eliminated all air toxics except formaldehyde[97].

However, there are several barriers to use of methanol as motor fuels. Combustion of methanol emits a lot of toxic formaldehyde, which is classified as a carcinogen by the World Health Organization's International Agency for Research on Cancer. Formaldehyde emissions, therefore, are a major concern surrounding the use of methanol in the US.

Methanol is a poisonous substance. Ingestion of only 10 ml can cause blindness and of above 60 ml can be fatal. In addition to direct ingestion, the liquid can be absorbed through the skin, and the vapors through the lungs. Methanol vapor is heavier than air and it will linger close to the ground without good ventilation. If the concentration of methanol is above 6.7% in air, it can be lit by a spark, and will explode above 54 F / 12 C. Once ablaze, the flames give out very little light making it very hard to see the fire or even estimate its size. In addition, the low volatility of methanol leads to cold start difficulties. This is less of an issue if methanol is blended with 30% or more gasoline[98]. These potential safety concerns and combustion characteristics are challenges to adapting methanol as a motor fuel, especially for dedicated methanol vehicles.

Methanol is also corrosive and will attack and corrode certain metals such as magnesium and aluminum. To prevent corrosion, stainless steel or carbon steel has to be used for the vehicle fuel system and separate fuel supply infrastructure has to be set up when fuel with high methanol concentration (e.g., M85) is used. Using gasoline with lower methanol blends (such as M15) might still lead to corrosion and rusting problems when used in the longer term if special attention is not given on the choice of materials for the fuel systems. Methanol will also attack elastomers, such as rubber, polyurethane, and some plastics, and it is recommended that high fluorine content elastomers, Teflon, and other methanol compatible materials be used[99].

Finally, from a life cycle perspective, if coal is used as a feedstock, methanol does not hold much promise in reducing life-cycle GHG emissions compared to conventional fuels. It is estimated that the well-to-wheel GHG emissions of coal-based methanol vehicles are equivalent to the life cycle emissions of gasoline-fueled ICEs[100].

International experience

California, which was the most aggressive state promoting methanol vehicles to address its smog problems, has probably the most extensive experience with methanol internationally. The state ran a pilot methanol program starting in the late 1970s as a response to the oil crises. In the early years most of the methanol was produced from coal relying on the access to abundant coal reserves in the nearby states. As oil prices started to fall in early 1980s, air pollution replaced energy security as the primary driver for the methanol program. Therefore, the Californian government turned away from highly polluting coal to natural gas as the preferred source of the fuel.

97 Dolan, G. 2005. "Methanol Transportation Fuel: A Look Back and Look Forward", presentation made on International Symposia on Alcohol Fuels, San Diego, California. Online available at: http://www.methanol.org/pdf/MIPaperforISAF.pdf

98 Brustar, M. and M. Bakenhus. " Economical, High-efficiency Engine Technologies for Alcohol Fuels." (http://www.methanol.org/pdf/ISAF-XV-EPA.pdf. Accessed on April 23, 2010).

99 Dolan, G. 2005. "Methanol Transportation Fuel: A Look Back and Look Forward", presentation made on International Symposia on Alcohol Fuels, San Diego, California. (http://www.methanol.org/pdf/MIPaperforISAF.pdf, accessed April 20, 2010).

100 Ibid.

考虑到甲醛排放、毒性、冷启动、火焰能见度和腐蚀问题，加州对甲醇或甲醇汽车提出了以下要求：

- 针对甲醇乘用轿车、轻型卡车和中型卡车，尾气甲醛排放标准设置为0.15毫克/英里[101]。

- 甲醇按85%的比例与汽油混合，加入添加剂帮助冷启动和使甲醇火焰更易被使用者看见。要采取特别的措施，确保这种有毒的燃料不会被误当做可食用的乙醇。

- 在加州销售的所有可以使用甲醇汽油的灵活燃料车（可以任意切换使用汽油和M85的车辆）都被要求采用不锈钢油路。

1998年，美国通过了《车用替代燃料法》，允许车辆制造商通过生产灵活燃料车（FFV）来获得额外的燃料经济性信用额度，用以满足企业平均燃料经济性（CAFE）标准。这一立法加速了甲醇FFV在加州的发展，如福特、克莱斯勒这样的大型汽车制造商积极的生产并在加州销售了大量车辆，以帮助他们减轻CAFE标准的负担，因为与普通同类汽油车相比，生产一辆FFV成本增加200美元，这比通过其它方法真正提高燃料经济性要便宜[102]。但是，立法到底增加了多少甲醇使用量是无法确定的，直到2007年进行修订，无论替代燃料车是否真的使用了替代燃料，都可以获得FFV信用额度（更多介绍详见乙醇部分）。

除了上面提到的环境和毒性问题，炼油企业开始通过争相生产新配方汽油来反击针对甲醇的优惠政策，这也导致了加州对于甲醇的热情的消退。燃烧新配方汽油的减排程度不亚于甲醇，这样一来使用甲醇的主要缘由，即改善空气质量，就不再有说服力了。另外，加甲醇的基础设施发展滞后，以及由于90年代中期生产甲基叔丁基醚（MTBE)需求大量甲醇造成的甲醇价格攀升，最终导致加州将甲醇作为替代燃料的方案失败。90年代末期，许多甲醇燃料站都关闭了并且新甲醇替代燃料车的销售量也直线下滑。在加州的经验中，甲醇所带来的一项持久贡献就是让石化行业和汽车行业发明了新配方汽油和灵活燃料车。

中国经验

由于中国的煤储量充沛，所以已经在通过推动生产煤基液体燃料从而减少原油进口。90年代中期，在中央政府的支持下，山西省进行甲醇燃料汽车试点。自此以后，中国的甲醇产量翻了几番。山西和陕西省政府已经开始推广甲醇作为交通燃料。2005年，中国煤基甲醇生产量达到350万吨。在2006年煤炭工业中长期发展计划当中，预期到2010年、2015年和2020年，产量可分别实现1600万、3800万和6600万吨。

中国甲醇燃料主要的混合比例是15%（即M15），这主要有两个原因。首先，汽油中混入15%的甲醇用于传统汽油车，一般认为是可不用对车进行任何改造，这样是最经济性的技术。其次，低比例混合的燃料抗爆性比较好[103]。

101 佛罗里达环保局。加州低排放汽车管理 (http://www.dep.state.fl.us/air/rules/ghg/california/62-285_rules_080908.pdf, (2010年4月23日查阅)及Nichols, Roberta. 2003年，《甲醇的故事：未来的可持续燃料》（The Methanol Story: A Sustainable Fuel for the Future.）《科学与工业研究》（Journal of Scientific & Industrial Research.）第62期，2003年1-2月刊，第97-105页。

102 Sperling, D.和Gordon D. 2009年，《20亿辆轿车》（Two Billion Cars），牛津大学出版社；生产FFV的最低成本，详见EIA2007年交通生物燃料部门，EIA网站，2月http://www.eia.doe.gov/oiaf/analysispaper/biomass.html. 2010年4月6日查阅。

103 Cheng, Y., Kang, L.,等人. 2008年，《中国低碳燃料标准和政策的背景与战略》（Background and Strategy of Chinese Low Carbon Fuel Standards and Policy）能源与交通创新中心 (iCET)。

To address concerns around formaldehyde emissions, toxicity, cold-start, flame visibility and corrosion problems, the following requirements were put in place for methanol or methanol vehicles in California:

- Formaldehyde exhaust emission standards of 0.15mg/mile was set for methanol-fueled vehicles passenger cars, light-duty trucks and medium-duty vehicles[101].

- Methanol fuel was blended at 85 percent with gasoline and additives to assist with cold start and impart visibility to the methanol flame. Special care was taken to assure that the poisonous fuel wasn't mistaken for ethanol, a drinkable alcohol.

- All methanol-gasoline flexible fuel vehicles (i.e., vehicles that could switch to use gasoline and M85 at any time) sold in California were required to have stainless-steel fuel lines.

In 1988, the Alternative Motor Fuels Act was passed in the United States allowing automobile manufacturers to make flexible fuel vehicles (FFVs) and receive extra fuel economy credits to comply with their Corporate Average Fuel Economy (CAFE) standards. This legislation sped up the deployment of methanol FFVs in California. Large-car makers such as Ford and Chrysler soon became eager to produce and sell large amounts of vehicles to the State to help relief their CAFE compliance burden because the additional cost of producing a FFVs, compared to a comparable gasoline model, is about $200 USD, a cheap modification than other options for actually improving fuel economy[102]. However, it was uncertain how effective the legislation have induced methanol use because, until a recent revision in 2007, FFV credits were offered regardless of whether alternative fuels were actually used (see further discussion in the ethanol section).

In addition to the environmental and toxicity concerns mentioned above, enthusiasm for methanol faded in California when oil industry fought back by producing reformulated gasoline, which when burned emit similarly low level of emissions as methanol, and therefore eliminated the compelling air quality rationale for methanol. In addition, the lack of refueling infrastructure, the price spike of methanol in the mid-1990s triggered by demand of methanol to produce MTBE also contributed to the failure of methanol as an alternative fuel in California. By the late 1990's many fueling stations had closed and new vehicle sales had plummeted. One of the lasting contributions of the methanol experience in California is the important innovation in the oil and automotive industries with the development of RFG and FFVs.

Experience in China

With abundant coal reserves, China has been pursuing the production of coal-based liquid fuels to reduce its oil imports. In mid-1990s, the central government supported the demonstration of methanol vehicles in Shanxi Province. Since then, methanol production in China has increased by several folds. Provincial governments in Shanxi and Shaanxi have been promoting methanol as a transportation fuel. In 2005, China had coal-based methanol production capacity of 3.5 million tons. In the proposal of the Mid to Long-Term Coal Industry Development Plan in 2006, the production capacity was expected to be further expanded to 16, 38 and 66 million tons in 2010, 2015 and 2020 respectively.

The dominant blend ratio of methanol in China is 15 percent (M15) for two reasons. First, it is believed that the methanol can be directly blended into gasoline and be used in traditional gasoline vehicles without any vehicle conversion needed and thus is the most economic technology. Second, the low blend fuel has better antiknock performance[103].

101 Florida Department of Environmental Protection . The California Low-Emission Vehicle Regulations (http://www.dep.state.fl.us/air/rules/ghg/california/62-285_rules_080908. pdf, accessed on April 23, 2010) and Nichols, Roberta. 2003. "The Methanol Story: A Sustainable Fuel for the Future".Journal of Scientific & Industrial Research. Vol. 62, January-February 2003, pp.97-105.

102 Sperling, D. and Gordon D. 2009. "Two Billion Cars". Oxford University Press. ; for marginal cost of producing FFVs, see EIA. 2007. Biofuels in the Transportation Sector. EIA website. February. http://www.eia.doe.gov/oiaf/analysispaper/biomass.html. Accessed April 6, 2010

103 Cheng, Y., Kang, L., et al. 2008. "Background and Strategy of Chinese Low Carbon Fuel Standards and Policy". The Innovation Center for Energy and Transportation (iCET)

2009年，中央政府批准了M85（85%体积的甲醇和15%体积的汽油）燃料（混合）标准。有关部门正在批准M15燃料标准。尽管官方统计不跟踪汽油中使用的甲醇数量，加油站监测数据显示，部分地区的汽油中确实混合了甲醇。这主要是因为对于加油站经营者而言，甲醇比汽油便宜。2010年初，山西等五省发布了一个方案，计划推进跨地区的甲醇汽车示范项目[104]。

总结与建议

下表总结了主要从环保性能角度考虑，甲醇汽车的优势和劣势。

表9.1: 使用甲醇汽车的优势和劣势总结

优势	劣势
▪ 能源安全：对煤和天然气丰富的国家来说是较好的石油替代燃料的选择（技术成熟成本低）。 ▪ 单价比汽油便宜 。 ▪ 相对于非新配方汽油，能够减少氮氧化物、一氧化碳和颗粒物排放。	▪ 有毒并具有腐蚀性。车辆使用高比例甲醇燃料必须采用特殊的设计和使用耐甲醇材料；即使低比例混合，长期使用也可能出现腐蚀问题 。 ▪ 甲醛排放。 ▪ 煤制甲醇会增加上游的温室气体排放。从全生命周期来讲，温室气体排放不比汽油车少。 ▪ 有了新配方汽油以后，使用甲醇就不存在排放优势了 。

鉴于一些省份对使用甲醇（特别是M15）作为车用燃料具有很大兴趣，以下建议主要针对如何优化甲醇汽车的环境影响：

▪ 应开展研究，量化研究使用M15的空气质量收益。之前美国进行的研究表明，与非新配方汽油相比，使用甲醇能够减少空气污染，不过随着美国提高了汽油标准，这些优势明显减少。分析甲醇（特别是M15）的空气质量收益能帮助环保部权衡大范围使用甲醇的环境收益和推广这种燃料的成本（包括经济和环境影响成本）。如果证明M15不能被用于现有燃料供应基础设施和普通汽油车，并需要特殊的燃料供应系统和车辆的话，这种分析就显得更加有用了。

▪ 应考虑腐蚀性和材料耐受性的问题。由于对M15的研究比较有限，应要求主张M15可以用于普通车辆并使用现有燃料供应系统进行传输的甲醇生产商和部分省份进行实验，证明常规汽油车和燃料供应系统长期使用M15不会出现腐蚀或耐久性问题。在山西和其它使用甲醇燃料车的地区进行的示范项目的结果可能能为这方面的分析提供一些优质数据。另外一个途径就是支持使用特殊设计的纯甲醇汽车，比如采用不锈钢油箱来装载甲醇燃料。不过，这样的车会比较贵，降低了甲醇的全生命周期价格优势。

▪ 必须有甲醛排放标准来控制这种危险污染物的排放。加州的方案可以提供有益的指导。

104 网址：http://chemease.cbichina.com/News/2566988,0,0,0,0.htm。

In 2009, a fuel (blending) standard for M85 (with 85% of methanol and 15% of gasoline by volume) was approved by the central government. Efforts are under way to approve an M15 fuel standard. Even though official statistics do not track methanol use in gasoline, station-monitoring data has shown that methanol is indeed blended into gasoline in some regions. This is primarily because methanol is typically cheaper than gasoline for fuel station operators. In early 2010, Shanxi and five other provinces unveiled a plan to promote a cross-regional methanol-fueled vehicle demonstration program [104].

Summary and recommendations

The table below summarizes the pros and cons of methanol vehicles.

Table 9.1: Summary of advantages and disadvantages of methanol in vehicle applications

ADVANTAGES	DISADVANTAGES
▪ Energy security: good substitute for petroleum for coal and natural gas-rich countries ▪ Typically cheaper than gasoline ▪ Potential reduction in tailpipe NOx, CO and PM emissions compared to non-reformulated gasoline	▪ Poisonous and corrosive. Vehicles using high blend methanol fuel must be specially designed using methanol-compatible materials; even for low blend there might be corrosion problems if for long-term use ▪ Formaldehyde emissions ▪ Methanol from coal will increase GHG emissions from upstream. No life cycle GHG improvements compared to gasoline vehicles. ▪ With reformulated gasoline available, the emissions benefit from using methanol is not significant

In view of the strong interest in some provinces in using of methanol (especially M15) as a motor fuel, the following recommendations are aimed at optimizing the environmental impacts of methanol vehicles:

▪ Research to quantify air quality benefits of using M15 should be conducted. While previous research conducted in the US has shown that use of methanol resulted in less air pollution compared to non-reformulated gasoline, those advantages diminished significantly as the US gasoline standards improved. Analysis of the air quality benefits of methanol (M15 in particular) could help MEP weight the environmental benefits of expanded use of methanol and costs for adopting this fuel. Such analysis would be particularly useful if M15 is shown to not be compatible with existing fuel infrastructure and normal gasoline vehicles, and special fuel supply system and vehicles are needed to enable the use of this fuel.

▪ Corrosion and material compatibility issues should be addressed. Because of the limited study on M15, methanol producers or provinces advocating that M15 could be used in normal vehicles and be distributed via the existing fuel supply system should be required to conduct testing to demonstrate no long term corrosion or durability problem would be caused by the use of M15 in regular gasoline vehicles and the fuel supply system. Findings from the pilot projects undergoing in Shanxi province and the cross-regional methanol-fueled vehicle demonstration program might offer good data for such analysis. Another solution would be to support neat methanol vehicles with specialized designs, such as using stainless steel tanks, for methanol fuel. However, these vehicles will be more expensive reducing the methanol life cycle cost advantage.

▪ A formaldehyde emission standard is also necessary to control the emission of this dangerous pollutant. California's program provides useful guidance.

104 http://chemease.cbichina.com/News/2566988,0,0,0,0.htm

▪ 如果中国选择扩大煤基甲醇的使用范围，需要实施相关规定有效捕集和封存煤制甲醇过程中产生的大量碳排放。碳捕集和封存（CCS）过程要求有适当的封存地点，安装良好的二氧化碳泄漏监测系统，最后还要设立应急预案，一旦发生碳泄漏予以阻止和控制。中国政府还需要建立有效的管理和实施体系，确保CCS工程严格的依照政府制订的指导方案和操作程序开展和实施 [105]。

9.2 天然气汽车

本节所指的天然气单指从天然气田中提取的，不讨论其它原料（如沼气）生产的甲烷。

天然气汽车使用的燃料是压缩天然气（CNG）或液化天然气（LNG）。与传统汽柴油车相比，由于燃烧性质清洁，天然气汽车排放的氮氧化物和颗粒物明显低得多。拿轻型车来说，美国EPA的研究显示，与没有三元催化器的汽油车相比，CNG车辆能实现一氧化碳和氮氧化物分别减排97%和60%，且几乎没有颗粒物排放 [106]。对重型车而言，从2002年-2004年开始，在美国一些城市已经进行了多项试点研究，涵盖城市运输巴士、商业运输卡车（邮政运输车）、清洁车和货车，结果显示纯粹使用CNG或LNG的重型车与柴油卡车和巴士相比，能实现明显的减排。尽管实际的减排收益情况取决于车辆的用途和行驶工况，与同级别的传统柴油车相比，研究结果还是显示出天然气车在氮氧化物和颗粒物排放方面减排的总体趋势。表9.2总结了这些研究的主要结果。该表的注释中给出了参照组车辆安装减排装置（如果有这些装置的话）的信息。

105 IPCC关于二氧化碳捕集和封存的特别报告，建议一旦实施此方面的要求，“地下封存二氧化碳的健康、安全和环境风险应提升至与天然气封存、强化采油和酸性气体深埋相同的高度。”更多信息详见IPCC. 2005年，《IPCC特别报告-二氧化碳捕集和封存》（IPCC Special Report – Carbon Dioxide Capture and Storage.）《政策制定者概要》（ Summary for Policymakers.）。

106 减排数据来源于美国能源部http://www.afdc.energy.gov/afdc/vehicles/natural_gas_emissions.html. 20105年5月2日查阅。

- If China chooses to expand the use of methanol derived from coal, provisions need to be put in place to effectively capture and store the large amount of carbon emissions from coal-to-methanol production. Those carbon capture and storage (CCS) programs would require appropriate site storage, installation of good CO_2 leakage monitoring system, and finally a remediation program to stop and control carbon releases should it arises. The Chinese government also needs to establish an effective regulatory and enforcement system to assure these CCS projects are developed and operated following strict government-developed guidelines and operation procedures[105].

9.2 Natural gas vehicles

This section focuses on natural gas extracted and processed from natural gas fields and does not discuss methane produced from other feedstocks such as biogas.

Natural gas vehicles (NGVs) are fueled with compressed natural gas (CNG) or liquefied natural gas (LNG). Compared with conventional gasoline or diesel vehicles, NGVs produce significantly lower NOx and PM emissions due their clean burning properties. For light-duty vehicles, the US EPA studies showed that CNG vehicles can reduce CO, NOx by up to 97% and 60%, respectively compared with gasoline counterparts without three-way catalysts, and almost eliminate PM emission[106]. For heavy-duty vehicles, a variety of pilot studies, involving urban transit bus, commercial delivery truck, sanitation truck and freight truck fleets, conducted about the beginning of the past decade (2002-2004) in a number of US cities indicated that dedicated CNG or LNG heavy-duty vehicles could also result in significant emissions reduction over diesel trucks and buses. Though actual emissions benefits depend on what the vehicles were used for and their driving cycles, the studies showed a trend of emission reduction for NOx and PM of the NGVs compared with conventional diesel vehicles for the same duties. Table 9.2 summarizes the key results of these studies. Information on emission control technologies adopted on the reference group vehicles is also provided in the notes below the table.

105 The IPCC Special Report on Carbon Dioxide Capture and Sequestration suggested that if these requirements are in place, “the health, safety and environment risks of geological storage [of carbon dioxide] would be comparable to the risks of current activities such as natural gas storage, EOR and deep underground disposal of acid gas." For more information, see "IPCC. 2005. "IPCC Special Report – Carbon Dioxide Capture and Storage." "Summary for Policymakers."

106 Emission reduction data are from US DOE. Online available at http://www.afdc.energy.gov/afdc/vehicles/natural_gas_emissions.html. Accessed: May 2nd, 2010.

表9.2: 美国重型天然气车车队工作结论汇总[107]

车辆类型	CNG 邮政车	LNG 公交车*	LNG 半挂卡车	LNG 双燃料垃圾车**
车辆群体	联合邮政速递公司 (UPS)	达拉斯地区快速公交车 (DART)	Raley's	洛杉矶市环卫局
替代燃料车数量	7	15	8	10
柴油车数量	3	5	3	3
驾驶工况	城市郊区重型车线路	中心商务区	5英里固定线路	空气质量管理区垃圾车线路
颗粒物减排	95%	NSS****	96%	NSS****
氮氧化物减排	49%	17%	80%	23%
非甲烷有机物减排	4%	96%	比参照柴油车总碳氢减少59% 以上	NSS****
一氧化碳减排	75%	95%	–263%***	NSS****

*在DART的研究中，采用带氧化催化器的柴油巴士。

** 洛杉矶环卫局的测试用柴油卡车装有颗粒物捕集器。

*** 带负号的减排数字表示污染物增长。

****NSS: 无明显统计数据是因为LNG巴士或LNG及柴油垃圾车（使用了颗粒物捕集器）的排放过低测试设备检测不出。减排百分比是以柴油车排放为基础，以克/英里为单位。

在发展中国家，为了在没有低硫燃料的情况下满足排放标准，一种很普遍的做法是用天然气车替代重型柴油车。分析表明传统柴油发动机使用高硫燃料 108时氮氧化物和颗粒物排放都无法达到欧IV标准，而这一标准即将在中国和印度两国全国范围内实施。要进一步减少氮氧化物，需要“先进”的发动机，包括电控喷油、废气再循环（EGR）和选择催化还原（SCR）。而进一步削减颗粒物则需要柴油车颗粒物捕集器（DPF），而如果没有硫含量低于50ppm的燃料，DPF将无法有效工作。相反，稀燃CNG发动机（发展中国家的常见技术）的颗粒物和氮氧化物排放水平在没有后处理系统的情况下就可以比传统的欧III柴油发动机排放更低。如果要求达到欧IV，在稀燃CNG车辆上加装一个为CNG车辆特别设计的氧化催化器，就可以达到先进的带有DPF的柴油发动机的排放水平。这就是为什么如今一些没有低硫燃料的城市会考虑增加重型CNG车辆来减少城市空气污染并满足排放目标的原因。不过，要说明的是，要达到更严格的标准（欧V以上），还是需要先进的CNG发动机（如闭环电控稀燃发动机或理论空燃比发动机）和三元催化器[109]。.

107 美国能源部http://www.afdc.energy.gov/afdc/vehicles/emissions_natural_gas.htm。

108 如果燃料硫含量大于500ppm，柴油车氧化催化器（DOC）无法有效工作。柴油车颗粒物捕集器的硫含量上限是50ppm。

109 Posada F. 2010年，CNG巴士减排技术路线图：从欧III到欧VI（CNG Bus Emissions Roadmap: from Euro III to Euro VI）, 2009年，国际清洁交通委员会 第5-6页。

Table 9.2: Summary of key findings in US heavy-duty NGV working fleets[107]

VEHICLE TYPE	CNG MAIL DELIVERY TRUCKS	LNG BUSES*	LNG SEMI-TRUCKS	LNG DUAL-FUEL REFUSE TRUCKS**
Fleet	United Parcel Service (UPS)	Dallas Area Rapid Transit (DART)	Raley’s	City of Los Angeles Bureau of Sanitation
Number of Alternative Fuel Vehicles	7	15	8	10
Number of Diesel Vehicles	3	5	3	3
Drive Cycle	City Suburban Heavy Vehicle Route	Central Business District	Five-Mile Route	Air Quality Management District Refuse Truck Cycle
PM Reduction	95%	NSS****	96%	NSS****
NO_x Reduction	49%	17%	80%	23%
NMHC Reduction	4%	96%	59% Less Than Diesel THC	NSS****
CO Reduction	75%	95%	–263%***	NSS****

*Diesel buses in DART study used oxidation catalysts.

** Diesel trucks in the Los Angeles Bureau of Sanitation test used catalyzed particulate filters.

*** Negative reduction values indicate an increase in pollutants.

****NSS: Not statistically significant because emissions were too low for the testing equipment for the LNG buses or both LNG and diesel (due to the use of catalyzed particulate filters) refuse trucks. Emission given in percentage reduced from diesel emissions, based on grams emitted per mile driven.

NGVs are a popular substitute for diesel heavy-duty vehicles in developing countries to meet emissions standards when low sulfur fuel is not available. Analysis shows that conventional diesel engines operated on high sulfur fuel108 cannot achieve Euro IV emission levels for NOx and PM, which is the forthcoming standard for new engines in China (nationally) and India. To further reduce NOx, "advanced" engine including electronic control of fuel injection, and exhaust gas recirculation (EGR) and/or selective catalytic reduction (SCR) is needed. To further cut PM, diesel particulate filters (DPF) are needed, but which cannot effectively function without fuel with less 50-ppm sulfur content. In contrast, the engine-out PM and NOx emission levels from a lean-burn CNG engine (most common technology in developing countries) without any after-treatment system are low enough to outperform a conventional diesel engine (Euro III). If Euro IV is required, then the lean burn CNG vehicle fitted with an Oxidation Catalyst (OC) specially designed for CNG operation would be needed, providing the same level of performance of an advanced diesel engine with DPF. This is the primary reason why cities without low sulfur fuel are considering increasing their CNG heavy-duty fleet to reduce urban air pollution and to meet emissions target today. However, as indicated, to meet more stringent standards (above Euro V), a modern CNG engine (like close-loop electronically controlled lean-burn engine or stoichiometric engine) and a three-way catalyst will still be needed[109].

107 US DOE. Online available at http://www.afdc.energy.gov/afdc/vehicles/emissions_natural_gas.html.

108 If the fuel sulfur content is above 500 ppm, diesel oxidation catalysts (DOC) cannot effectively function. The sulfur level threshold for diesel particulate filters to function well is 50 ppm or lower.

109 Posada F. 2010. CNG Bus Emissions Roadmap: from Euro III to Euro VI, 2009, International Council on Clean Transportation, p5-6.

根据阿贡国家实验室的数据，天然气车的全生命周期温室气体排放大体上比传统燃料车少20%[110]。并且因为压缩过程消耗的能源比液化过程少，所以在生产CNG过程中使用的石油能源和排放的温室气体也比LNG少。

天然气汽车比较不利的方面包括：地域限制、动力损耗和负载限制、甲醛排放和柴油发动机改造上的难度。首先，对于距离天然气田较远的地区来说，架设长距离的管路是很贵的。不过，如果这些管路可以同时用来传输居民做饭和取暖用的天然气，那么在交通领域应用天然气的成本就会明显降低。

由于每千克天然气蕴含的能量比汽柴油要低，因此天然气汽车输出的动力也比较低，可能在上坡、加速或负载较重时比较困难。CNG储存在特别设计的气罐中（200巴压强），这会增加车辆的重量并降低负载或载客能力或进一步降低燃料经济性。通常，由于这些限制因素，使CNG车辆不得不用于特定车辆，如用于固定线路、或能确保燃料补给线路的城市公交车和重型车。LNG车辆的能源密度要高的多，比CNG车更适合长距离使用。

如之前所述，越来越多的发展中国家有兴趣将柴油巴士转换为天然气汽车，从而获得排放收益。在加气设施不很充足的情况下，柴油巴士通常会被改造成既可以使用天然气也可以使用柴油的双燃料车。不过，在传统改造技术条件下，双燃料发动机使用天然气并不能最好的发挥性能。因此，双燃料车的燃料灵活反而常常会以发动机性能恶化和降低燃料经济性为代价。一些新技术，如高压直喷技术（HPDI)，可能会提供更好的发动机能效性并实现天然气对柴油的高度替代，但是其相应的保养成本会比较高。最终，改造双燃料车的成本效益可能还不如生产企业直接生产纯粹使用CNG的CNG专用汽车。

国际经验

美国的天然气汽车主要用作公交车或垃圾车。1992年《能源政策法》将CNG和LNG纳入替代燃料范畴并对燃料、燃料基础设施和替代燃料车实施税收鼓励（大部分鼓励方案现在已经期满）。在过去的20年中，尤其是轻型车，新发动机排放标准的不断加严刺激了新柴油和汽油发动机以及燃料技术的发展，使其在排放水平上能够与CNG发动机媲美。因此，对轻型CNG汽车的兴趣大大衰退。目前，只有本田仍然在生产一款CNG思域轿车，并且这款车型是唯一还符合条件，能够获得新替代能源汽车减税激励的轻型车。不过，在重型车市场还有一些可以选择的产品。

纵观世界，天然气汽车在阿根廷、巴西等南美国家最为流行，这些国家天然气资源丰富但缺少石油。阿根廷并没有对天然气汽车实施鼓励政策，但通过对汽油征收很高的税，使得天然气的售价只是汽油的四分之一[111]。

本世纪初，印度的首都德里建立世界上最大的CNG公交车队[112]。90年代，德里经历了私人车辆保有量飞速上涨，导致空气质量和公众健康严重恶化。为应对这一问题，印度国会下令要求2001年3月以前将德里所有的公交车（柴油）全部换成CNG专用车，自此以后，各项空气污染物表面上看有所改善[113]。但是，拥堵、路况差、超载和缺乏保养等问题逐渐抵消了CNG公交车带来的收益。近年来，人们认识到使用超低硫柴油和DPF能够更进一步的减少传统柴油车的排放，不过直到2010年为止，印度还没有引入这种燃料的计划。在此期间，CNG公交车依然是德里限制空气污染的主要战略之一。并且，印度还计划在该国的另外300个城市使用CNG汽车。

110 减排数据来源于美国能源部http://www.afdc.energy.gov/afdc/vehicles/natural_gas_emissions.html。

111 Sperling, D., Gordon, D.,《20亿辆轿车》（Two Billion Cars）, 牛津大学出版社，第93页。

112 德里交通公司http://dtc.nic.in/ccharter.htm。

113 由于可用数据的数量和质量都有限，不能完全确定德里的空气质量实质上是否切实改善。

According to Argonne National Lab, the life cycle GHG emissions from NGVs are generally about 20% less than the conventional fuel vehicles[110]. And CNG uses less petroleum and emits fewer GHGs than LNG because the compression requires less energy than liquefaction.

On the downside NGVs are associated with geographical limitation, power loss and load limitations, emissions of formaldehyde, and issues associated with diesel engine conversion. For regions far from natural gas field, building long-distance pipeline can be expensive. But if the pipeline will also be used to deliver natural gas for residential cooking and heating, the marginal cost of transportation applications could be significantly brought down.

Because of natural gas' lower energy content per kilogram compared with gasoline or diesel, NGVs yield lower power output, which may cause difficulties in climbing, accelerating, or driving with heavy loads. CNG is stored in specially designed tanks (at 200 bar pressure), which increase vehicle weight and may displace load or passenger capacity or further reduce fuel economy. In general these limitations has reduced CNG vehicles to niche applications such as city buses or heavy vehicles with fixed route and secured refueling sources. Vehicles fueled with LNG, which has a much higher energy intensity, are better suited to long-haul applications.

As indicated previously, there has been a growing interest in developing countries in converting diesel buses into NGVs for their emissions benefit. When refueling facilities are scarce, the diesel buses are often modified to be bi-fuel vehicles running either on natural gas or diesel. However, with the conventional conversion technologies, bi-fuel engines cannot be optimized for use with natural gas. Thus the flexibility of bi-fuel vehicles often comes at a cost of worse engine performance and lower fuel economy. Newer technologies, such as high-pressure direct injection, may provide better engine efficiency and realize high diesel replacement, but are also associated with high maintenance costs. In the end, retrofitted bi-fuel vehicles might not be as cost-effective compared to OEM built dedicated CNG vehicles.

International experience

In the US, NGVs are primarily used in bus or refuse truck applications. The "Energy Policy Act" of 1992 included CNG and LNG as alternative fuels and provided tax incentives for the fuels, fueling infrastructures and the alternative fuel vehicles (most of the incentive programs have now expired). Especially for light-duty vehicles, the imposition of more stringent emission standards for new engines over the last 20 years has stimulated the development of new diesel and gasoline engine and fuel technologies that are competitive with CNG engines from an emissions standpoint. As a consequence, interest in light-duty CNG vehicles has waned. Currently, only Honda is still producing a CNG-based light-duty model (Civic) and that model is the only one that is still eligible for the new alternative fuel vehicle tax credit for light-duty vehicles. However, there are more product options on the heavy-duty market.

Worldwide, NGVs are most popular in South American countries like Argentina and Brazil that are rich in natural gas but not petroleum. Rather than providing incentives to natural gas vehicles, Argentina assessed a high tax on gasoline so that natural gas sells for one-fourth of the price of gasoline[111].

Delhi, the capital city of India, built the world's largest CNG bus fleet early in this century [112]. Delhi experienced skyrocketing growth of private vehicles in the 1990s that resulted in worsened air quality and severe public health deterioration. In response, the Supreme Court of India issued an order that required the entire (diesel) bus fleet of Delhi to be converted to dedicated CNG vehicles by March 2001, and since then there has been apparent decline of various air pollutants [113]. However congestion, poor road conditions, overloading and lack of maintenance have gradually eroded the benefits of the CNG buses. In recent years, it was recognized that the use of ultra low sulfur diesel and DPF could make further emission reduction possible for conventional diesel vehicles, however suchfuel is not scheduled to be introduced until 2010. In the meantime, CNG buses are still one of the main strategies Delhi is deploying to limit air pollution. Furthermore, the use of CNG vehicles is scheduled to be spread to 300 other cities in India.

110 Emission reduction data is from US DOE. Online available at http://www.afdc.energy.gov/afdc/vehicles/natural_gas_emissions.html

111 Sperling, D., Gordon, D., Two Billion Cars, Oxford University Press 2009. Page 93.

112 Delhi Transport cooperation. http://dtc.nic.in/ccharter.htm

113 Given the limited data availability and poor data quality, it is not completely certain whether the air quality has improved in Delhi.

中国经验

中国的天然气资源和天然气田主要位于西南部各省（四川、新疆等）。90年代中期，科技部宣布了清洁空气行动计划，在中国主要城市推广替代燃料车。自此以后，中国在西南部的一些城市推广了天然气汽车，在这些地区天然气与汽油相比有明显的价格优势（天然气的价格是汽油的40-50%）。本世纪初，由于西气东输工程，天然气在上海和北京这样的东部城市也成了容易获得能源，为这些地区发展天然气汽车提供了基础。到2008年底，已经有80个城市推广了天然气汽车，总计超过17万辆，在全国有500家以上的CNG加油站，其中四川省仍然拥有中国最大的CNG车队。在重庆市（位于四川省内的直辖市），到2009年，共有CNG汽车5-6万辆，其中约有1万辆是双燃料CNG出租车，有7000至8000辆是CNG专用公交车。全市共有约70家CNG车辆加气站。

总结与建议

表9.3总结了天然气汽车在环保方面的优势和劣势。

表9.3: 天然气汽车优势和劣势汇总

优势	劣势
▪ 与欧III技术的汽柴油车辆相比，无论是轻型或重型CNG汽车，颗粒物和氮氧化物排放都明显减少。没有黑炭排放。 ▪ 在没有低硫燃料的发展中国家，稀燃天然气汽车是满足更严格的排放标准（欧III和欧IV) 的过渡技术（若稀燃天然气汽车加装氧化催化器可达欧IV）。相比之下，传统柴油车要达到这些标准比较困难。 ▪ 先进的CNG技术加上后处理技术（理论空燃比发动机加装三元催化器）几乎能够实现目前世界上最严格的排放标准（欧VI）。 ▪ 与传统燃料车相比，全生命周期温室气体排放减少约20%。 ▪ 在离天然气供应点较近的地方，天然气的价格比传统燃料便宜很多。	▪ 地域限制-只有离天然气供应点较近的地方才具有较高的成本效益。 ▪ 动力损失，对山地或丘陵地区、长距离或高负载运输来说并不理想（LNG车辆会好一些），还会降低公交车（巴士）的载客能力。 ▪ 如果不是HPDI的原装CNG发动机，燃料经济性会比传统汽车低（油耗高）。不过，如天然气的价格显著低于汽柴油价格，可以抵消加装HPDI和维护的成本。对于原装CNG发动机来说，燃料经济性与相应的柴油车相仿或稍高。 ▪ 增加甲醛排放 。 ▪ 改造的双燃料车(CNG/柴油)发动机性能和排放都较差。

下列建议的主要目的是减少天然气汽车的环境影响：

▪ 天然气汽车在临近天然气供应点的地区推广具有很高的成本效益。

▪ 鉴于CNG汽车动力和范围方面的限制，它们更适合用于固定线路的交通运输，如城市公交、快递、垃圾车或其它可以返回总站集中加气的车辆。LNG可以更好的应用于长距离交通。

▪ 相对而言，支持制造商生产专门的天然气汽车会有更高的成本效益，相比之下，改造的天然气汽车（或双燃料车）在发动机性能、排放和燃料经济性方面都比较差。

China's Experience

Most of China's natural gas resource and fields are located in its southwest provinces (Sichuan, Xinjiang, etc). In mid 1990s the Ministry of Science and Technology (MOST) announced the Clean Air Action Plan to promote AFVs in major Chinese cities. Since then, China has promoted NGVs in a number of southwest cities, where there is significant price premium for gasoline compared to natural gas (natural gas price is about 40%-50% of that of gasoline). At the beginning of the new century, enabled by the East Gas Line Project, natural gas became a commonly available energy source for eastern cities like Shanghai and Beijing, which also laid a ground for developing NGVs in these regions. By end of 2008, NGVs were being promoted in 80 cities, with more than 170,000 NGVs and more than 500 CNG refueling stations nationwide, while Sichuan province still maintained the largest CNG fleet in China. In Chongqing city (a municipality neighboring Sichuan province), there were 50,000-60,000 CNG vehicles by 2009; of those, about 10,000 were dual-fuel CNG taxi cars and 7,000-8,000 were dedicated CNG buses. The city had about 70 CNG refueling stations to serve CNGVs.

Summary and recommendations

Some of the pros and cons of NGVs are summarized in Table 9.3

Table 9.3: Summary of advantages and disadvantages of natural gas in vehicles

ADVANTAGES	DISADVANTAGES
▪ Significant reduction of PM and NOx for both light-duty and heavy-duty CNG vehicles compared with conventional fuel vehicles with Euro III technologies. No black carbon emission. ▪ In developing countries without low sulfur diesel fuel, lean burn NGVs are a bridge technology to meet more stringent emissions norms (Euro III and Euro IV if the lean burn NGV is fitted with oxidation catalyst), which is more difficult for conventional diesel vehicles. ▪ Advanced CNG technologies together with after-treatment technologies (stoichiometric engines with three-way catalyst) will achieve the most ambitious emissions norms worldwide (Euro VI) ▪ About 20% life cycle GHG reduction compared with conventional fuel vehicles ▪ Natural gas can be much cheaper than conventional fuels near natural gas supply	▪ Regional limitation – only cost-effective for regions with NG supply ▪ Power loss, not ideal for hilly regions, or long-distance or heavy loading transportation (LNGV is better), or reduced passenger capacity for buses ▪ Lower fuel economy (more fuel consumption) than conventional vehicles for non-OEM CNG engines without HPDI. However, cost impact can be offset when NG price is lower than gasoline and diesel. For OEM engines, fuel economy can be similar to or a little bit higher than the diesel counterpart. ▪ Increased formaldehyde emissions ▪ Converted bi-fuel vehicles (CNG/diesel) have worse engine performance and emission.

The following recommendations are aimed at optimizing the environmental impacts of natural gas vehicles:

▪ NGVs are most cost effectively implemented in regions in proximity to natural gas supply.

▪ Given the power and range limitations of CNG vehicles, they are more suitable for fixed route transportation, such as urban buses, ground parcel delivery, refuse trucks, or other return to base fleets with central fueling. LNGVs perform better in long-distance hauling applications.

▪ It is relatively more cost-effective to support OEM dedicated NGVs with natural gas-optimized engines than converted NGVs (or bi-fuel vehicles) that have worse engine performance, emissions, and fuel economy.

- 当前的改造方案中应要求严格控制改造组件并进行认证测试，以便实现氮氧化物和颗粒物排放的改善。

9.3 乙醇汽车

和甲醇类似，乙醇也可以低比例（5-10%）、中比例（15-20%）或高比例（85%）的和汽油混合。低比例混合乙醇的燃料由于不能明显取代汽油，在美国，它不算是替代燃料。乙醇比汽油的辛烷值高，并有较好的抗爆性，因此在美国用它来取代MTBE使燃料燃烧氧化过程更充分。一般来说，使用乙醇燃料能够减少主要空气污染物的排放，包括一氧化碳、非甲烷碳氢化合物、颗粒物和苯之类的空气有毒物质。不过蒸发排放可能更会有所升高，升高情况根据混合的比例而定。

E10燃烧时会产生对人体有毒害作用的乙醛。根据发动机工作状况，燃烧E10排放出的氮氧化物可能比使用纯汽油还高[114]。另外，低比例混合乙醇会提高汽油的雷氏蒸汽压（RVP），产生更高的蒸发排放。如把燃烧排放和蒸发排放都考虑在内，E10只能减少一氧化碳，其碳氢化合物、非甲烷碳氢化合物、甲醛、乙醛和臭氧形成潜能都是增长的[115]。

E15和E20等中比例混合乙醇能更多的取代汽油，但是在美国，它们和E10一样都不算替代燃料，并且事实上联邦政府并不认为中比例乙醇混合燃料是合法燃料，即在没有获得EPA豁免的前提下是不能用于未经改造的传统燃料发动机的。在美国，明尼苏达州率先使用了中比例混合的乙醇燃料并于2005年通过法案要求2013年以前在该州的汽油中使用20%的乙醇。使用中比例混合的乙醇燃料的影响目前还没有研究定性。明尼苏达州进行的一项研究指出，使用E20不会对现有发动机或燃料传输系统造成直接影响[116]。然而澳大利亚环保部的一份文献评论指出，与使用E10相比，燃烧E20可能造成氮氧化物排放增加30%。研究还同时指出使用这种燃料可能增加蒸发排放、甲醛排放、降低燃料经济性和驾驶性能，并提出燃料可能有腐蚀性。根据该研究结果，E20的全生命周期温室气体排放很可能和E10没有太大差异，这是因为尾气的二氧化碳排放只占全部排放的很小一部分。美国对E20影响的研究仍在进行中[117]。

在美国，只有混合了85%（E85）或更高比例的乙醇的燃料才能被视为替代燃料。2008年，美国国家可再生能源实验室进行的一项研究表明，平均来看，E85的所有常规排放物与汽油相比或减少或没有明显变化。但是，使用E85会增加甲醛、乙醛和甲烷排放[118]。

乙醇汽车的其它问题包括降低燃料经济性，这是由于乙醇燃料的能量值比较低，和使用高比例混合的燃料会产生的冷启动困难。灵活燃料车在使用E85时，每加仑燃料行驶的英里数一般比使用汽油减少约20-30%。在美国部分州，在特定季节E85会被调整成E70来解决冷启动问题，虽然仍然叫做E85。

114 美国进行的部分研究认为E10会增加氮氧化物排放。但是另一些人反对这一说法，认为氮氧化物的排放取决于空燃比，认为根据E10特性而优化的发动机使用E10能够减少排放。

115 减排数据来源于美国能源部http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel_emissions.html。

116 明尼苏达农业局http://www.mda.state.mn.us/renewable/ethanol/e20testresults.aspx。

117 澳大利亚环境、水资源、遗产和艺术部http://www.environment.gov.au/atmosphere/fuelquality/publications/review-vehicle-fleet/index.html。

118 减排数据来源于美国能源部http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel_emissions.html。

▪ Existing conversion programs should require strict controls and certification testing for conversion kits and converted vehicles to realize improvements in NOx and PM.

9.3 Ethanol vehicles

Similar to methanol, ethanol can be blended with gasoline at low (5-10 percent), intermediate (15 to 20 percent) or high (85 percent) ratios. Since it does not significantly displace gasoline use, low blend ethanol is not considered as an alternative fuel in the US. Ethanol has higher octane rating than gasoline and offer some anti-knock benefits so have been replacing MTBE in the US for oxygenating fuel. Generally speaking, using ethanol fuel reduces tail pipe emissions of major regulated air pollutants including CO, NMHC and PM, and air toxics such as benzene. However, evaporative emissions may increase and the extent of increase depends on blend ratios.

Combustion of E10 emits acetaldehyde, which is toxic to humans. Depending on engine operating conditions, NOx emissions from burning E10 can be higher than that from pure gasoline [114]. In addition, ethanol at low-blend levels increases the Reid vapor pressure (RVP) of gasoline thus creates higher evaporative emissions. Combining combustion and evaporative emissions, E10 only reduces CO, but increases emissions of HC, NMHC, formaldehyde, acetaldehyde emissions and ozone forming potential[115].

Intermediate ethanol blends have higher gasoline displacement effect, but similar to E10, E15 to E20 blends do not qualify as alternative fuels in the US and are actually not considered by the Federal government as legal fuels for unmodified engines without a waiver from EPA. In the US, the State of Minnesota is at the forefront of efforts to use intermediate blends and passed a law in 2005 mandating use of 20% ethanol in the state's gasoline by 2013. Research on the impact of using intermediate blends of ethanol fuel so far has not been conclusive. A study sponsored by Minnesota suggests that using E20 will not cause immediate problems to current engine or fuel dispensing system [116]. While a literature review conduced by Department of Environment of Australia indicates that burning E20 may increase NOx emission by 30% compared with using E10. The same study also mentioned possible increase in evaporative emissions, formaldehyde emission, as well as reduced fuel economy and driveability, and also mentioned possible corrosive effect of the fuel. The life-cycle GHG emissions, also according to the study, is unlikely to be different from that of E10 vehicles given that the tail-pipe CO_2 emission is only a small fraction of overall emission. Federal studies on the impact of E20 are still underway[117].

Only ethanol blends of 85 percent (E85) or higher are considered alternative fuels in the US. A 2008 study conducted by US National Renewable Energy Laboratory showed that on average, all regulated emissions either decreased or showed no significant difference with E85 compared with gasoline. But using E85 increases emissions of formaldehyde, acetaldehyde and methane[118].

Other issues with ethanol vehicles include reduced fuel economy due to the lower energy content of ethanol fuel and difficulties with cold start while using high blend fuel. FFVs typically get about 20-30% fewer miles per gallon when fueled with E85. In some states in the US, E85 is seasonally adjusted to E70 to allow cold start, though it is still called E85.

114 A few studies conducted in the US concluded that E10 increases NOx. But others argue that NOx emissions strongly depend on the fuel/air ratio, implying that engine optimization for E10 could decrease emissions.

115 Emission reduction data are from DOE. Online available at: http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel_emissions.html

116 Minnesota Department of Agriculture. Online available at: http://www.mda.state.mn.us/renewable/ethanol/e20testresults.aspx

117 The Department of Environment, Water, Heritage and Art. Online available at http://www.environment.gov.au/atmosphere/fuelquality/publications/review-vehicle-fleet/index.html.

118 Emission reduction data are from DOE. Online available at: http://www.afdc.energy.gov/afdc/vehicles/flexible_fuel_emissions.html.

在从油箱到车轮的阶段，无论使用哪个混合比例的乙醇燃料，二氧化碳排放都会减少，但全生命周期（从油井到车轮）排放情况评估起来则比较复杂。这是因为有多种原料和方法可以生产乙醇。乙醇可以是炼油时生产的副产品（主要用于工业用途）。世界上最普遍的乙醇生产方法是通过将玉米（美国）、甘蔗（巴西）或陈化粮及木薯（中国）等碳基原料，经过发酵和蒸馏方法生产乙醇。目前还有技术可以将非粮原料转化为乙醇，如水藻、纤维素、动物粪便或庭院垃圾等，但是目前这些都不能实现经济性量产。原料种类和生产工艺决定了种植、生产和储运过程中的温室气体排放量。

土地使用方式的变化也会产生间接的温室气体排放（ILUC）。对乙醇燃料需求的增长可能导致更多原本生产粮食作物的农田转而生产乙醇原料。这会造成食品价格上涨，会刺激农民将雨林或草场转变成新的农场，这将大幅度削弱土壤吸收和封存碳的能力并由此增加温室气体排放。除了增加温室气体排放，开垦还会带来显著的环境和社会影响，包括对当地生物多样性、土壤、水质量和原始部族文化的延续性带来压力。政策制定者需要考虑生物燃料的直接和间接温室气体排放影响和其他影响，以确保旨在能源独立性的政策不会以环境为代价。

国际经验

世界乙醇燃料市场由美国和巴西两国主导——两国共计生产和消耗全世界90%的乙醇燃料。在美国，有半数以上的汽油中混合了10%的乙醇。在部分州和城市规定必须使用E10燃料。至今，美国还有800万辆灵活燃料车在路上行驶，这些车既可以使用汽油，也可以使用任何混合比例（最高E85）的乙醇燃料。E85灵活燃料车在美国中西部十分普遍，因为那里玉米是主要农作物并且是乙醇燃料的原料。

美国乙醇燃料和车辆的支持政策可以追溯至上世纪70年代。1988年的《车用替代燃料法》以企业平均燃料经济性（CAFE）信用额度的形式来鼓励车辆生产企业通过生产灵活燃料车来获得相对宽松的车辆平均燃料经济性目标值。与巴西的甘蔗乙醇相比，美国的玉米乙醇造价昂贵，因此政府给这种燃料提供了很多补贴。对于某些州来说，玉米种植是当地经济的重要组成部分，来自这些州的利益团体四处进行游说支持玉米乙醇，这些游说行为取得了很大的成功。2006年进行的一项研究表明，用于玉米乙醇的补贴总额高达50亿美元并还在持续增长[119]。

2008年10月，沿着I-65公路（贯穿玉米种植为主的中部多个州）开通了首条“生物燃料走廊”，这条公路是美国中部的主要州际公路。从北部的印第安纳延伸至南部的阿拉巴马，在这条走廊上有200家以上的乙醇加油站，使得从密西根湖驶到墨西哥湾的E85灵活燃料车总能在一箱乙醇燃料用完之前就能找到新的加油站加到乙醇汽油[120]。

尽管美国的许多车辆可以使用乙醇燃料，但事实上却并没有使用。这主要有三方面的原因。首先，最初的CAFE灵活燃料车方案并不要求证明确实使用了替代燃料，直到近期才根据《2007年能源独立与安全法案》（EISA）的要求对此进行了修订。第二，灵活燃料车销售量快速增长，但是燃料基础设施相对落后。截止至2010年，全美的12.1万家加油站中只有2000家向公众出售E85[121]，这些E85加油站还大部分集中在“玉米带”上的各个州[122]。在加州，只有44家E85加油站。最后一点是很多车主可能都不知道自己的车是灵活燃料车，因为灵活燃料车的外观和同类的非灵活燃料车是一模一样的。要想知道车辆是否可以使用乙醇燃料，需要查看油箱盖里面的指示标签或车辆说明书。相反，巴西要求生产企业在车身上设置明显标志，表明是灵活燃料车。

119 Sperling D., Gordon, D.,《20亿轿车》（Two Billion Cars）2009年，牛津大学出版社。

120 印第安纳能源发展办公室http://www.in.gov/oed/2396.htm。

121 加油站数字来源于美国统计局http://www.census.gov/econ/census02/data/us/US000_44.HTM#N447。

122 “玉米带”上的各州指主要生产玉米的各个州。减排数据来源于美国能源部http://www.afdc.energy.gov/afdc/fuels/stations_counts.html。

Although CO_2 emission from tank-to-wheel using fuels with all ethanol blend levels will be reduced, on life cycle basis (well-to-wheel) performance is not as straightforward. Ethanol can be produced from different feedstocks. It can be produced from a by-product in petroleum refining (mainly for industrial use). The common practice worldwide, however, is to make ethanol through fermentation and distillation of carbon-based feedstocks such as corn (in the US), sugarcane (in Brazil), or aged grain stock or cassava (in China). There are existing technologies to convert non-food feedstock like algae, cellulosic, animal or yard waste into ethanol, but currently none of them can be economically scaled up for mass production. The type of feedstock and processing methods determines GHG emissions during the cultivation, processing, storage and dispensing.

There are also indirect GHG emissions due to the changes in land use (ILUC). The growing demand for ethanol fuel may drive more conversion of croplands used for food into lands for ethanol feedstock. The resulting higher food price may incentivize farmers to convert rainforests or grasslands into new farms, which will largely undermine the soil's ability to sequester and store carbon and therefore increase GHG emissions. The clearing of wildness also induces significant environmental impact and social impact beyond increased GHG emissions. Such impacts include putting pressure on biodiversity, soil, water quality, and local communities and culture. Policy makers need to consider both direct and indirect GHG emissions impact from biofuels in order to ensure that policies securing energy independence do not come at a cost to the environment.

International experience

The US and Brazil dominate the world ethanol fuel market – together both countries produce and consume nearly 90 percent of world ethanol fuel. In the US, more than half of the gasoline is blended with 10 percent of ethanol. Some states and cities mandate the use of E10. The US also has about 8 million flexible fuel vehicles that can run either on gasoline or any blend levels up to E85 on the road today. E85 FFVs are extremely common in Midwest where corn is a major crop and feedstock of ethanol fuel.

The political support of ethanol fuel and vehicles dates back to the 1970s. The Alternative Motor Fuels Act of 1988 established vehicle manufacturer incentives in the form of Corporate Average Fuel Economy (or CAFE) credits, with which manufacturers can meet a less stringent fleet-average fuel economy target by producing FFVs. The fuel was also heavily subsidized given that producing ethanol from corn is quite expensive, especially when compared with Brazilian sugarcane ethanol. Interest groups from states with corn farming as an important economic activity have been lobbying strongly to support corn ethanol and such lobbying was quite successful. One study found that in 2006 total corn ethanol subsidies amounted to more than $5 billion and were growing[119].

In October 2008, the first "biofuels corridor" was officially opened along I-65, a major interstate highway in the central United States that passes through several major corn growing states. Stretching from northern Indiana to southern Alabama, this corridor consists of more than 200 individual fueling stations allowing flex-fueled vehicles no more than the distance of a tankful fuel away from the next biofuel pump when driving from Lake Michigan to the Gulf of Mexico[120].

Although many vehicles in the US can, they actually are not running on ethanol fuel. There are three major reasons. First, the initial CAFE FFV credit program did not require the proof of actual use of alternative fuel until its recent revision under the requirement of EISA 2007. Second, as the sales of FFVs grew rapidly, the fueling infrastructure lagged behind. By 2010 there were about only 2,000 filling stations selling E85 to the public in the entire US compared with over[121] thousand gasoline fueling stations[121], with a great concentration of E85 stations in the “Corn Belt” states [122]. In California, there are only 44 E85 stations. Lastly, flexible fuel vehicle owners may not know that they own one, since these flexible fuel vehicles have the exact same exterior look as their non-flexible fuel counterparts. To know if a vehicle is ethanol fuel compatible, one needs to check the inside of the vehicle's fuel filler door for an identification sticker or the car manual. In contrast, Brazilian automakers are required to show clearly with a mark on the body of the cars.

119 Sperling D., Gordon, D., Two Billion Cars. 2009. Oxford University Press.

120 Indiana Office of Energy Development. Online available at: http://www.in.gov/oed/2396.htm.

121 Data on the number of gasoline stations are from US Census 2002. Online available at: http://www.census.gov/econ/census02/data/us/US000_44.HTM#N447.

122 “Corn Belt” states refer to those states that are major producers of corn. Emission reduction data are from US DOE. Online available at: http://www.afdc.energy.gov/afdc/fuels/stations_counts.html.

巴西经常被作为推动乙醇燃料政策的典范。70年代末石油危机的时候，巴西政府比所有其它国家都提早一步采取了替代汽油的措施。依靠良好的甘蔗工业基础，巴西开始推广甘蔗乙醇和乙醇专用车。为解决冷启动困难的问题，巴西的工程师在发动机舱内安装了一个小油罐可以直接喷出汽油帮助冷启动。随着政府提供大量补贴，到1984年，巴西销售的90%以上的轿车都是纯乙醇汽车（E100）。

但是，随着石油危机减退和糖价的上涨，许多甘蔗加工企业转而生产糖。这造成了80年代末期严重的乙醇短缺，乙醇轿车销售量几乎降至零点。经过这次教训，巴西从90年代开始推广从美国学到的灵活燃料车技术。在过去的30年里，巴西一直实施着可靠的乙醇政策，并提供可观的财政补贴。

美国联邦政府和加州政府在制订他们的生物燃料目标时（包括生物乙醇）已经考虑到了改变土地用途所带来的间接影响。2009年4月，加州通过了世界上第一个交通低碳燃料标准，要求到2020年，交通燃料的碳强度比当前的传统燃料即含10%乙醇的新配方汽柴油碳强度减低10%，这包括直接和间接的温室气体排放。2010年2月，美国EPA发布了新的可再生能源标准（RFS2）。其中规定了温室气体减排标准，根据燃料类型的不同，要求减排20-50%的直接和间接排放的温室气体，并且还设定了各种可再生燃料的供应量目标。例如，新建炼厂生产的可再生燃料必须比传统燃料温室气体减排20% 123, 才能符合RFS2对可再生燃料的定义。根据最终规定，2010年可再生燃料的总量目标是129.5亿加仑，到2022年会逐步增加至360亿加仑[124]。

EPA已经确认了几种原料和燃料生产方式，即使是加上ILUC排放，也至少可以让可再生燃料实现20%的温室气体减排。使用天然气作为能源，采用干铣削工艺生产的玉米乙醇的平均减排量处于20%的减排底限，而采用生物化学工艺生产的纤维素生物燃料温室气体排放强度最低。EPA的结论详见图9.1。

123 不过，EISA对大多数目前已经在生产的玉米乙醇的企业（非新建企业）豁免了温室气体减排20%的要求。2009年，美国约生产96亿加仑玉米乙醇。

124 美国EPA法规简介: EPA2010年及以后全国可再生燃料标准的最终管理办法http://www.epa.gov/otaq/renewablefuels/420f10007.pdf。

Brazil is often cited as a policy model for promoting ethanol fuel. When the world oil crisis hit in late 1970s, the Brazilian government took an earlier step than any other country to replace gasoline. Leveraging on a well-established sugarcane industry, Brazil began to promote sugarcane ethanol, and dedicated ethanol vehicles. To deal with the cold-start difficulty, Brazilian engineers built a small tank in the engine compartment that directly inject gasoline to help starting in cold weather. With large governmental subsidies provided, by 1984, more than 90 percent of cars sold in Brazil were neat ethanol vehicles (E100).

However, when oil crisis faded and price for sugar went up, sugarcane producers switched to sugar. This caused severe shortage of ethanol supply in late 1980's and ethanol car sales almost evaporated to zero. Learning from this lesson, Brazil adopted flexible fuel technology from the US starting in the 1990's. Brazil has maintained a durable ethanol policy for over three decades, providing considerable financial subsidies.

The US federal government and the state of California, when setting their bio-fuel targets (including bio-ethanol), have already included the indirect land use change effect criteria. In April 2009, California passed the world's first ever transportation low carbon fuel standard that requires 10 percent reduction in carbon intensity –with both direct and indirect GHG emissions included-- for transportation fuel compared to conventional fuels (reformulated gasoline and diesel with 10 percent ethanol blend) by 2020. In February 2010, the US EPA published its new Renewable Fuel Standard (RFS2). The rule imposes both a GHG reduction standard, requiring from 20 to 50 percent GHG reduction of combined direct and indirect emissions depending on the fuel category, and a set of volumetric targets for various renewable fuel supplies. For example, renewable fuels defined by RSF2 must cut GHG emissions by 20 percent compared to conventional fuels for newly established plants 123. According to the final rule, the volumetric target for renewable fuel for 2010 is 12.95 billion gallons, which will be gradually increased to 36 billion gallon in 2022[124].

EPA has identified several feedstocks and fuel pathways that can deliver renewable fuels with at least 20% GHG reduction threshold even after including ILUC GHG emissions. The average value for corn ethanol obtained from dry milling process with natural gas as process energy lies on the borderline of the 20% reduction threshold, while cellulosic biofuel produced using a biochemical process has the lowest GHG intensity. Figure 9.1 shows EPA's result.

123 However, EISA exempted the 20% GHG reduction requirement for almost all the existing corn ethanol produced in the U.S. About 9.6 billion gallons of corn ethanol was produced in the U.S. in 2009.

124 US EPA factsheet: EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond. Online available at http://www.epa.gov/otaq/renewablefuels/420f10007.pdf.

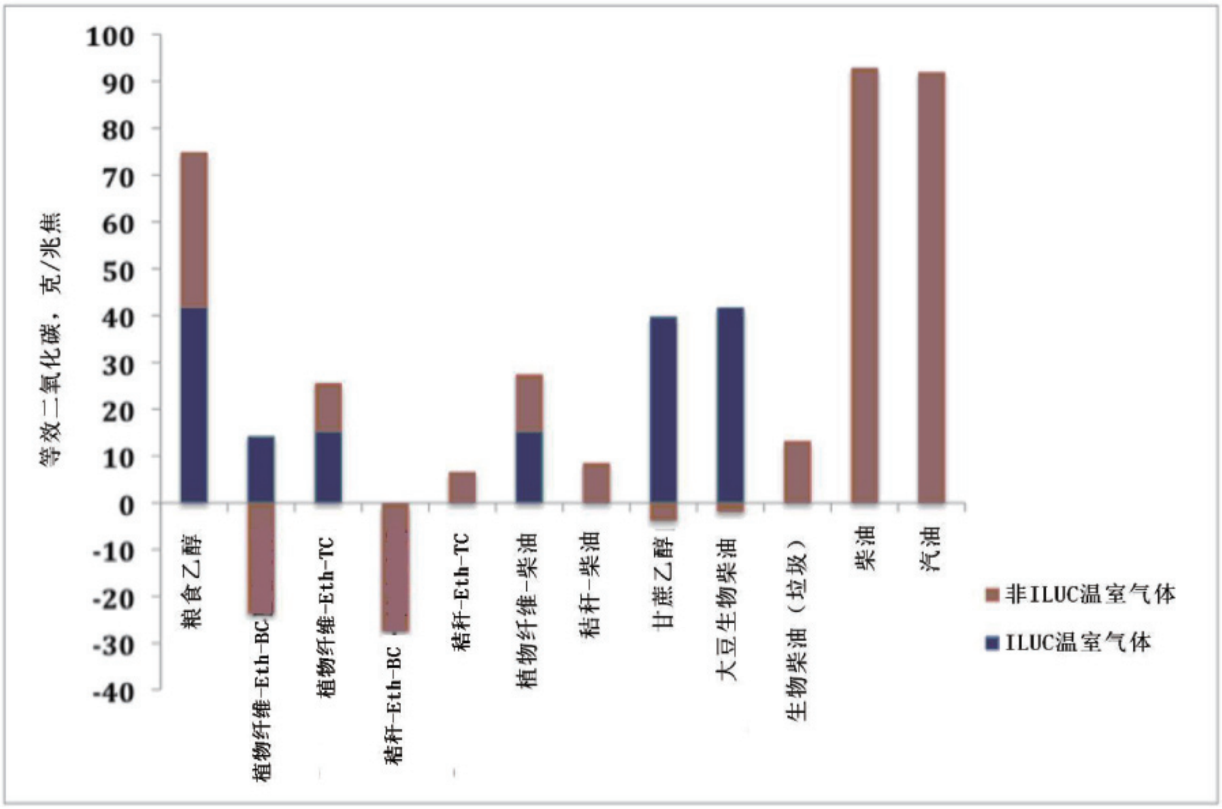

图9.1: 多种原料和生产方式的全生命周期温室气体排放评估[125]

Eth = 乙醇, BC =生物化学转化, TC = 热化学转化。评估基于30年的时间范围且假设贴现率为零。上图中玉米乙醇的数据是使用天然气的干磨粉工艺的平均值。

欧盟也考虑到了土地使用带来的间接影响，并纳入了下一次可再生燃料指令的修订当中。表9.2简要对比了世界各国的可再生或低碳交通燃料标准。

125 EPA. 油品和油品添加剂管理：可再生燃料标准的修改40 CFR Part 80 [EPA-HQ-OAR-2005-0161; FRL-XXXX-X], RIN 2060-A081. 交通与空气质量司，评估与标准处，EPA。

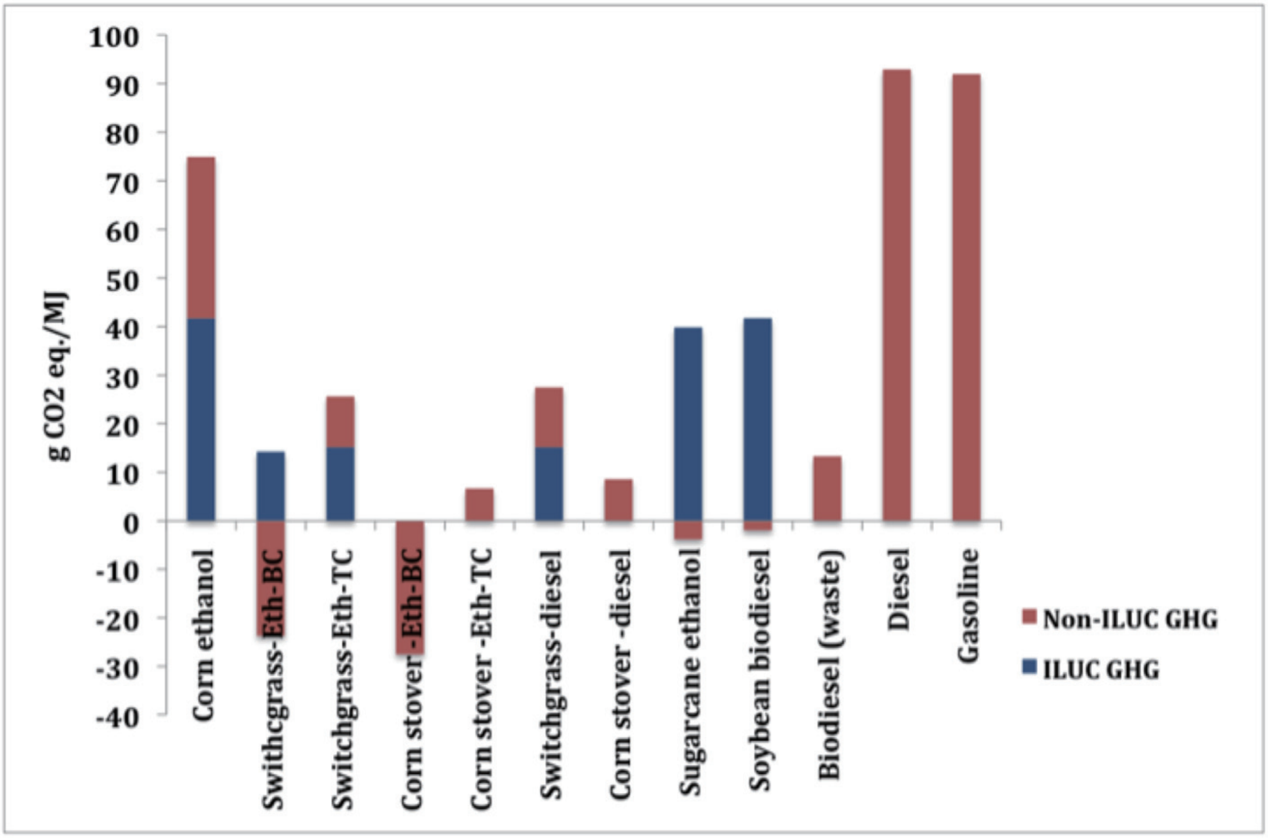

Figure 9.1: Life cycle GHG estimates of various feedstock and pathways[125]

Eth = ethanol, BC = biochemical conversion, TC = thermochemical conversion. Estimates are based on 30-year time frame and zero percent annual discount rate. Corn ethanol data in above figure refers to average value for dry milling process using natural gas.

The European Union is also considering an indirect land use impact analysis in its next revision of the Renewable Fuel Directive. Table 9.2 briefly compares world's renewable or low carbon fuel standards for transportation fuel.

125 EPA. Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program. 40 CFR Part 80 [EPA-HQ-OAR-2005-0161; FRL-XXXX-X], RIN 2060-A081. Assessment and Standards Division, Office of Transportation and Air Quality, EPA.

表9.4: 世界可再生或低碳交通燃料标准

特征	美国的RFS2	加州的LCFS	燃料标准指令(欧盟)	可再生能源指令 (欧盟)	英国可再生交通燃料规范 (RTFO)
基准燃料	柴油和汽油	含10%玉米乙醇的新配方汽油、柴油	柴油和汽油	柴油和汽油	柴油和汽油
目标	到2022年，实现360亿加仑生物燃料，温室气体减排5.6%	到2020年温室气体减排10%	到2020年温室气体减排10% (最低强制达到6%)	10% 生物燃料(能源含量)	2010/2011年达到5% 生物燃料 (能源含量)，温室气体减排1.9%
达标方式	纤维素乙醇，先进的生物燃料，可再生生物燃料	生物燃料、LPG, 天然气、电力和氢燃料	生物燃料、减少燃烧和排气、碳封存和碳捕集	生物燃料	可持续生物燃料
ILUC温室气体排放	计划中但尚不确定	已包括	待定 (计划到2010年12月)		无

在美国的RSF2中认为巴西的甘蔗乙醇是一种先进的生物燃料，根据评估，包括直接和土地使用带来的间接排放在内，该燃料可以减少61%的温室气体排放。由于巴西独特的气候条件适合甘蔗生产，并且使用甘蔗的残渣发电，巴西的甘蔗乙醇生产效率非常高，这些特点使世界其它国家很难照搬巴西的成功经验。

中国经验

中国生物乙醇产量居世界第三位，2006年年产量达到163万吨。中国生产生物乙醇的主要原料是陈化粮、木薯和甘薯。中国使用的乙醇燃料主要是E10，与前文介绍的M10相似，E10也是用于普通汽油车。

2001年，中央政府实施了中国第一个乙醇燃料方案，主要是为了减少陈化粮库存。在中国北方批准建立了四家谷物乙醇生产厂，每年可生产乙醇3500万加仑。中央政府为这四家乙醇工厂提供补贴，补贴额度与美国玉米乙醇补贴水平类似。目前有十个省在汽油中混合入10%的乙醇。由于意识到粮食乙醇的缺点，2008年起，中央政府决定推广生产非粮乙醇，同时允许这四家已有的粮食乙醇工厂继续正常生产。由于政府对非粮乙醇的鼓励政策，在广西已经建立投产了一个大型的木薯乙醇生产厂，并且另外一家工厂也正在建设中。此外，中国也已经建立了几家小规模的纤维素乙醇试点工厂。

Table 9.4: World's transportation renewable or low carbon fuel standards

FEATURES	US-RFS2	CA- LCFS	THE FUEL QUALITY DIRECTIVE (EU)	THE RENEWABLE ENERGY DIRECTIVE (EU)	UK RENEWABLE TRANSPORT FUEL OBLIGATION (RTFO)
Baseline fuels	Diesel and gasoline	Reformulated gasoline and 10% corn ethanol, diesel	Diesel and gasoline	Diesel and gasoline	Diesel and gasoline
Targets	36 billion gallons of biofuels by 2022, GHG emission reduction of 5.6%	10% reduction in GHG emissions by 2020	10% reduction in GHG emissions by 2020 (6% mandatory)	10% of biofuels (energy content)	5% of biofuels (energy content) by 2010/2011, GHG emission reduction of 1.9%
Compliance pathways	Cellulosic ethanol, advanced biofuel, renewable biofuel	Biofuels, LPG, NG, electricity, H_2	Biofuels, reductions in flaring and venting, carbon sequestration and capture	Biofuels	Sustainable biofuels
GHG emissions from ILUC	Proposed but uncertain	Included	TBD (proposal by Dec. 2010)		None

Brazilian sugarcane ethanol is referred to as an advanced bio-fuel under the US RSF2 due to its estimated 61 percent reduction in GHG emissions including both direct and indirect land use change emissions. Due in part to favorable climate for sugarcane growth and the use of the sugarcane residual (bagasse) for electricity generation, Brazil has a very efficient sugarcane ethanol production, which would be difficult to replicate in other parts of the world.

China's experience

China is now the third largest producer of bio-ethanol with an annual production of 1.63 Mt in 2006. The main feedstock of bio-ethanol in China is aged grain stock, cassava and sweet potato. Ethanol-capable vehicles in China mainly run on E10.

In 2001, the central government established the first ever ethanol program in China with the intent of reducing aged corn stocks in China. Four grain-based ethanol plants were approved in Northern China with production of 350 million gallons of ethanol a year. The central government provided to the four ethanol plants a subsidy level similar to the U.S. corn ethanol subsidy. Ethanol is blended into gasoline at 10% by volume in ten provinces. Recognizing the limitation of grain-based ethanol in China, in 2008, the central government decided to promote non-grain-based ethanol production, while allowing the four grain-based ethanol plants to continue their operation. The government policy of encouraging non-grain-based ethanol resulted in a large cassava ethanol plant in Guangxi Province now in operation and another one under construction. Furthermore, several small-scale pilot cellulosic ethanol plants have been developed in China.

总结和建议

表9.5总结了车用乙醇从环保角度的优势和劣势。

表9.5: 车用乙醇的优势和劣势汇总

优势	劣势
■ 替代化石燃料。 ■ 可通过高能效生产方式，利用可再生原料和低碳原料生产。低碳乙醇燃料能够减少全生命周期温室气体排放量 。	■ 具有腐蚀性，特别是高比例混合要求特殊设计的油箱和油路。 ■ 高比例混合要求单独的供油基础设施。 ■ 根据发动机的情况，氮氧化物排放有可能增加。 ■ 增加乙醛排放。 ■ E10燃料的蒸发排放和车辆运行中的损失可能较高。 ■ 会造成冷启动困难。 ■ 与传统车用燃料相比，燃料经济性较低。 ■ 部分原料和生产方式会导致全生命周期温室气体排放（包括ILUC排放）增加。 ■ 纤维素、水藻和垃圾制乙醇成本很高。

以下建议的主要目的是减少乙醇汽车的环境影响：

从低碳视角出发来制订所有燃料和温室气体相关政策。必须建立方法论，计算因土地用途改变所带来的直接和间接的温室气体排放，并且在定义低碳燃料时要设定碳减排标准。

如使用中、高比例乙醇混合燃料，须要求适当的配套设备来解决腐蚀性问题。高比例混合的乙醇燃料需要单独的供油基础设施。 中比例混合的腐蚀问题也不容忽视。另一种方案是使用E20时，考虑对燃料油路系统进行金属表层特殊处理，使之能抵御燃料的腐蚀性。环保部在制订乙醇燃料相关政策时，应考虑专用燃料供应系统带来的成本。

监测氮氧化物和乙醛排放是很重要的。氮氧化物排放必须满足排放标准。关于乙醛，美国EPA正在进行一项关于乙醇燃料车乙醛排放的综合性研究。

目前中国没有E85或其它高比例混合的灵活燃料车。如果中国的政策今后将引导使用这些燃料，应当要确保替代燃料的切实使用。

9.4 新能源汽车

在中国，四种车辆被认为是新能源汽车：传统混合动力车（HEV）、插入式混合动力车（PHEV）、氢燃料电池电动车（FCEV）和电池电动车（BEV）。这一节论述发展与部署这类车辆的国际经验。鉴于有些技术类型的某些特性非常相似（例如，电池电动车和氢燃料电池电动车），在论述这些特征时，可能会将它们划分为一类。

传统混合动力车（HEV）和插入式混合动力车（PHEV）结合了内燃机（ICE）、电池和电动机，因此其同时具备了传统内燃机和电动车的优缺点。根据所采用的技术和混合动力程度，混合动力车的燃料经济性可以是传统内燃机车辆2-3倍。和其它三种新能源车辆不同，混合动力车并不是电驱动的，因为其推动力是由内燃机提供的。传统混合动力车不需要充电设施，而插入式混合动力车和电动车则需要。插入式混合动力车和某些传统混合动力车能够实现全电动模式运行，在此期间，电能会完全替代传统燃料的使用。和传统混合动力车不同，插入式混合动力车通过插头向车辆电池充电，从而使其全电动模式运行时间得以延长。要想充分利用插入式混合动力车的全电动模式优势，需要投资发展充足的充电基础设施。

Summary and recommendations

The following Table 9.5 summarizes the pros and cons of ethanol use in vehicles

Table 9.5: Summary of advantages and disadvantages of ethanol use in vehicles

ADVANTAGES	DISADVANTAGES
■ Displaces fossil fuel ■ Can be produced from renewable and low carbon feedstocks by energy-efficient pathways. Such low carbon ethanol fuel can reduce life-cycle GHG emissions.	■ Corrosive especially at high blend and requires specially designed tanks and fuel lines ■ High blend ethanol requires separate supply infrastructure ■ NOx may increase but also depends on engine condition ■ Increased emissions of acetaldehyde ■ E10 may emit more regulated exhausts from evaporation and running loss ■ Cold start difficulty with E100 ■ Lower fuel economy than conventional fueled vehicles ■ Life-cycle GHG emissions (including ILUC) may increase with certain feedstock and production pathways ■ High cost to produce ethanol from cellulosic, algae and waste

The following recommendations are aimed at optimizing the environmental impacts of ethanol vehicles:

A low-carbon perspective is necessary in all fuel and GHG related policy-making. It is essential to establish a methodology that counts both direct and indirect land use change emissions, and establish carbon reduction criteria when defining low carbon fuels.

For higher blends, corrosion issues must be addressed by requiring appropriate equipment. The possible corrosive effect of intermediate blend ethanol fuel should not be overlooked. Separate fuel supply infrastructure would be needed for high blended ethanol. Another option to consider is a special treatment on the metal surface within the fuel system to guard against corrosion with the E20 blend. MEP should take into account costs associated with the specialized fuel supply system in determining policies related to ethanol fuel.

It is important to monitor NOx and acetaldehyde emissions. NOx emissions must be maintained in line with emission standards. For acetaldehyde, the US EPA is undertaking a comprehensive study on emissions of ethanol-fueled vehicles.

Currently China does not have E85 or other high blend flexible fuel vehicles. If China's policy leads to these fuels in the future, they should ensure the actual use of the alternative fuel.

9.4 New energy vehicles

In China, four vehicle types are considered new energy vehicles: conventional hybrid vehicles (HEVs), plug-in hybrid vehicles (PHEV), hydrogen fuel cell electric vehicles (FCEV) and battery electric vehicles (BEV). This section also addresses international experiences in developing and deploying these vehicles. Given the similar characteristics of certain vehicle types (for example, battery electric vehicles and hydrogen fuel cell electric vehicles) they may be grouped together when certain features are discussed.

Conventional hybrid (HEV) and plug-in hybrid electric vehicles (PHEV) combine an ICE, a battery and an electric motor, and thus may share pros and cons of both traditional ICE vehicles and BEVs. HEV technologies can achieve two to three time higher fuel efficiency than conventional ICE vehicles depending on technologies adopted and degree of hybridization. Unlike the other three vehicle types, HEVs are not electric-drive because the propulsion energy is provided by the ICE. HEVs do not required recharging infrastructures,which is otherwise needed for PHEVs and BEVs. PHEVs and certain HEVs can all be operated on electric mode and during that time fully displace conventional fuel use. Unlike HEVs, the all-electric operation mode of PHEVs can be extended by plugging in to recharge the vehicle battery. To fully take advantage of the PHEV all-electric mode requires investment in developing an adequate charging infrastructure.

大范围推行氢燃料电池电动车（FCEV）和电池电动车（BEV）对城市空气质量的改善会有很大作用，因为这些车辆的尾气排放量为零。另外，内燃机的排放控制系统会随时间而劣化，FCEV和BEV则不会，因此不要求实施检测和维修保养方案。传统燃料车辆所面临的燃料和机油供应、储存、处理以及燃料污染等问题对BEV和FCEV来说都不再是问题。FCEV和BEV还有其它优势，包括在超静音环境下实现即时扭矩和平缓提速的卓越驾驶体验。

除了环保，发展FCEV和BEV各自还有一些其他的好处。BEV和PHEV一样，设计一个良好的充电方案能够填充电网电谷，从而优化用电负荷。氢燃料电池发动机比BEV行驶的距离更长，其能效性是传统内燃机的2-3倍，可以用于长距离或高负载的交通运输。较之BEV，氢燃料电池车更适合应用于巴士和卡车。要说明的是，至今为止，所有的FCEV都是混合动力的，除了燃料电池也有蓄电池。这样，交替蓄电可以提高行驶里程范围。

电力和氢燃料的生产和传输会产生上游排放。可以采用化石燃料、生物质或电解水制氢，生产过程中所使用的电能也可来自再生能源，如水力发电、风力和太阳能发电，制氢工艺也有多种方式。多种多样的原料和生产工艺会造成不同水平的上游排放。阿贡实验室对10种制氢方法进行了全生命周期温室气体排放分析。图9.2展示了研究结果，可以看出与传统汽油车相比，很多制氢方法都能够减少氢燃料电池车的全生命周期温室气体排放，当然也有一些方法，比如在美国典型的电网能源结构下，电解制氢就可能导致增加排放量。

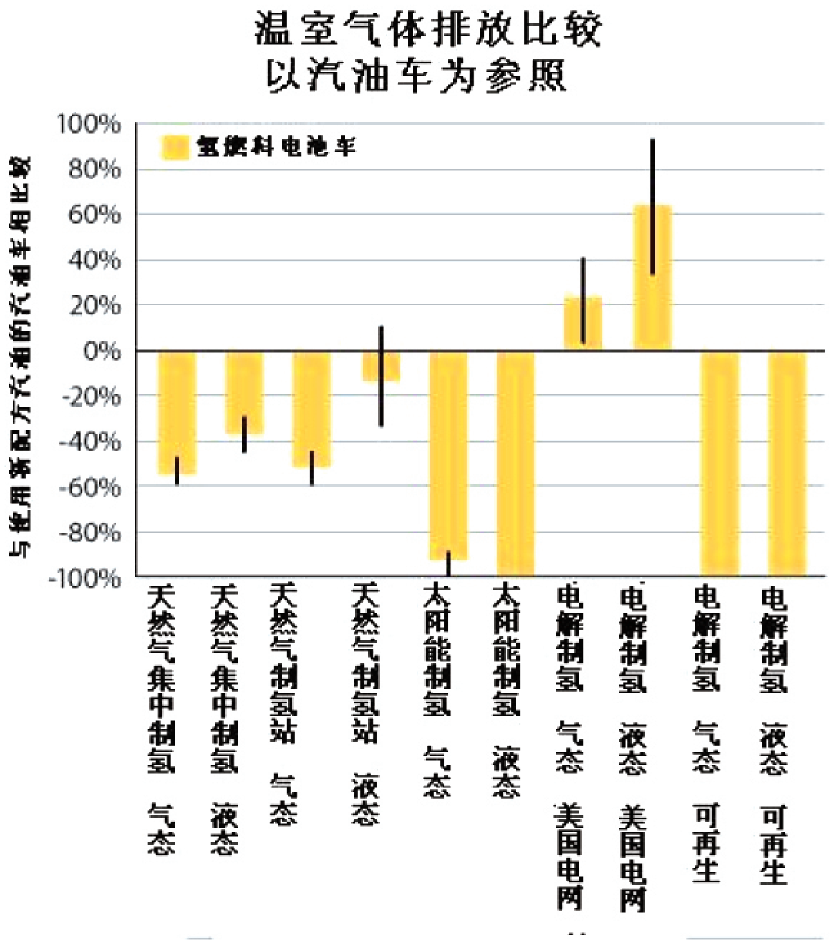

图9.2:以汽油车为参照，各种制氢方法全生命周期温室气体排放比较[126]

126 美国能源部，Online available at http://www.afdc.energy.gov/afdc/vehicles/emissions_hydrogen.html。

Large scale deployment of hydrogen fuel cell electric vehicles (FCEV) and battery electric vehicles (BEV) would have a dramatic impact on air quality in urban areas as they have zero tailpipe emissions. In addition, unlike ICE engines where emission control systems deteriorate overtime, a FCEV and BEV fleet does not require an inspection and maintenance program. Other issues related to fuel and motor oil supply, storage, disposal and contamination are also eliminated. Other general benefits of FCEVs and BEVs include a superior driving experience with instant torque and smooth acceleration in an ultra-quiet environment.

FCEVs and BEVs each offer some specific benefits as well. BEVs, like PHEVs, with well-designed charging schedule could fill the valley of the electricity grid thus help optimize electric load shifting. Hydrogen fuel cell engines can achieve longer ranges than BEVs and can be two or three times more efficient than the conventional ICE, thus can serve long-distance and/or high load transportation. This technology is better suited than BEVs to bus and truck applications. It also should be noted that to date, FCEVs are all hybrid, with batteries in addition to the fuel cell. In this way, advantage can be taken of regenerative breaking to increase their range.

Electricity and hydrogen production and delivery does generate upstream emissions. Hydrogen can be produced from fossil fuels, biomass or through the electrolysis of water using electricity from renewable sources such as hydroelectricity, wind and solar, and by a number of processes. This diversity of feedstock and production methods results in a wide range of upstream emissions levels. ANL analyzed the life-cycle GHG emissions of 10 pathways to produce hydrogen. As shown in Figure 9.2, the study found that most pathways will reduce life cycle GHG emissions from hydrogen fuel cell vehicles compared with life cycle GHG emissions from conventional gasoline vehicles, while certain pathways, such as when hydrogen is produced through electrolysis from typical US grid electricity, may increase the emissions.

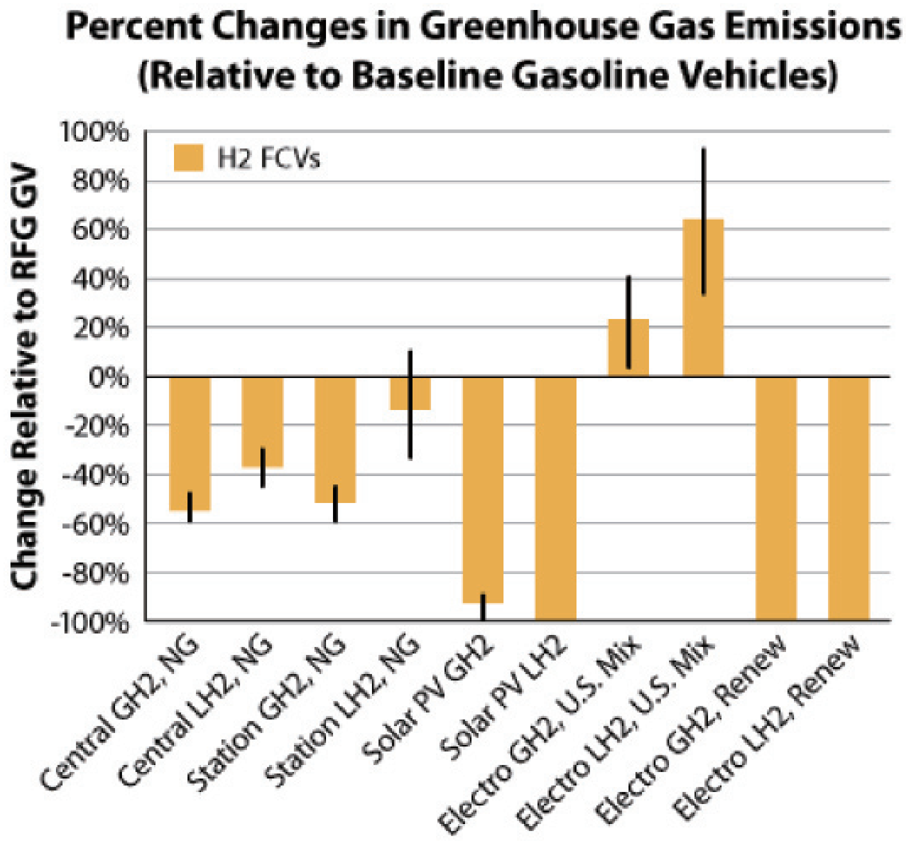

Figure 9.2: Life-cycle GHG emissions change relative to baseline gasoline vehicles[126]

126 US DOE. Online available at http://www.afdc.energy.gov/afdc/vehicles/emissions_hydrogen.html.

同样,BEV的电力来源也可以很广泛，这些车辆的全生命周期排放取决于当地电网能源结构、主要充电时间以及电网特点。以目前的美国电网为例，根据阿贡实验室的研究，使用BEV替代一辆传统汽车，整个生命周期可以实现城区内挥发性有机化合物、一氧化碳、硫氧化物、氮氧化物和颗粒物分别减排100%、100％，75%、69%和31% [127]。研究还指出，鉴于大部分电厂都在郊区，使用BEV（无论在哪里使用）可能增加远郊区部分常规污染物的排放（硫氧化物、氮氧化物和颗粒物）。在美国典型的电网结构下，BEV的全生命周期温室气体排放比汽油车下降19%，而如果使用加州电网，由于该州的电力能源更清洁，可以实现74%的减排[128]。对于采用火力发电来供应用电高峰期额外电量的地区，如果给BEV充电需用这部分额外电量，则BEV的温室气体排放可能会较高。

除了上游排放的不确定性，发展氢燃料电池车和电池电动车还面临着技术与管理方面的双重挑战。在目前和今后一段时期内，利用可再生资源生产氢燃料都将十分昂贵。车载储氢技术，特别是对于轻型车而言，还依然面临着储量、耐久性和成本方面的挑战。BEV的主要技术挑战包括电池容量和行驶范围的限制，还有高成本的问题。尽管低容量电池能够满足用于短途和低速交通的城市轿车的需求，但电动车电池依然无法以具有竞争力的价格达到传统车辆每次加油可以行驶300英里以上的水平。

要适应FCEV、BEV（和PHEV）的新特征，必须修订目前以内燃机车辆为主导的管理规定。修订内容包括燃料（或能源）能效性行驶测试工况、纳入从油井到车轮这部分排放在内的全生命周期的新排放标准以及适用于电动推进系统的安全标准。电动车还需要有新的设定充电系统、电池回收和处理标准的管理规定，目前美国正在制订这些方面的管理规定。

充电基础设施的缺乏和滞后是发展BEV和FCEV的重大障碍。当然，建设充足的基础设施需要相当可观的投资。另一方面，值得一提的是，从长期来看，维护现有的汽柴油设施和安装新的汽柴油设施（包括修理泄漏油罐）也一样需要大量资源。

国际经验与政策

美国主要出于对能源安全的考虑，在2005年《能源政策法》中将多种电驱动车纳入替代燃料车名单，并且开始对购买HEV和FCEV新车的消费者实施税收鼓励。2007年《能源独立与安全法》将插入式混合动力车也纳入了税收鼓励范围。之后，2009年《美国复苏与再投资法》又加上了低速电动车（LS EV）。表9.6展示了近年来电动车税收鼓励的具体细节。这些法案还授权联邦支持制造先进汽车和零件、进行研发、建设基础设施和开展示范项目。

127 减排数据来自美国能源部http://www.afdc.energy.gov/afdc/vehicles/emissions_electricity.html。原始信息：GREET 1.5交通燃料周期模型。网址：Online available at http://www.transportation.anl.gov/modeling_simulation/GREET/pdfs/esd_39v1.pdf。模型的生命周期排放包括主要燃料获取、制备、运输和车辆使用过程的排放。他们并没有计算生产车辆所使用的能源。

128 美国能源部Online available at http://www.afdc.energy.gov/afdc/vehicles/emissions_hydrogen.html。

Similarly, electricity for BEVs can be generated from a wide spectrum of sources, thus these vehicles' life cycle emissions depend on the local grid mix, the timing when most recharging take place and the grid characteristics. For example, with the current US grid mix, replacing a conventional vehicle with a BEV could reduce life cycle VOCs, CO, SOx, NOx and PM emissions by 100%, 100%, 75%, 69% and 31% respectively in urban settings, according to an ANL study[127]. The same study also suggests that using BEVs may increase certain conventional pollutants (SOx, NOx and PM) in suburban areas given that it is usually where the power plants are located. The life cycle GHG emissions of BEVs is 19% lower than a gasoline vehicle with the US average grid mix, and is 74% lower with California's grid mix since the state uses more clean electricity [128]. For regions where marginal power generation are provided by coal-fired power plants, the GHG emissions from BEVs could be higher if recharging lead to additional power generation.

In addition to the uncertainty about upstream emissions, the development of hydrogen fuel cell and battery electric vehicles still faces both technological and regulatory challenges. Hydrogen fuel produced with energy from renewable sources is and will be quite expensive for some time. On-board hydrogen storage technologies, especially for light duty vehicles, are still facing volume, durability, and cost challenges. Major technological challenges for BEVs include battery capacity and limited driving range, as well as costs. Although low capacity batteries may be sufficient to operate city cars with short driving range and lower maximum speed, they still cannot compete with the 300 plus miles driving range per fueling offered by conventional vehicles, at a competitive price.

Existing conventional ICE-focused regulations must be modified in order to accommodate the new features of FCEVs, BEVs (and PHEVs). Such modifications include redetermination of fuel (or energy) efficiency driving test cycle, new emissions standards that accounts for the well-to-wheel emissions, and safety standards adapted to the electric propulsion system. The various electric vehicles also require new regulations on a standardized recharging system, and on battery recycling and disposal, which are under development in the US.

Lack or delay of charging infrastructure could be a great barrier to the development and deployment of BEV and FCEV vehicles. Of course, building an adequate infrastructure will require significant investment. On the other hand, it should be noted that maintaining the existing and installing new infrastructure (including treatment for leaking in tanks) for gasoline and diesel also requires large amount of resources over the long run.

International experience and policies

Driven mainly by energy security concerns, the US includes the various forms of electric vehicles in the list of alternative fuel vehicles and began to provide consumer tax incentives for new purchases of HEVs and FCEVs under the "Energy Policy Act" of 2005. The "Energy Independence and Security Act" of 2007 expanded the tax credits to plug-in hybrids. Low-speed electric vehicles (LS EV) were later added under the "American Recovery and Reinvestment Act" of 2009. Table 9.6 details the tax incentives for electric vehicles in recent years. These bills also provide federal grants to support the manufacturing of these advanced vehicles, parts, R&D, infrastructures and demonstration programs.

127 Emission reduction data are from US DOE. Online available at: http://www.afdc.energy.gov/afdc/vehicles/emissions_electricity.html. Original source: GREET 1.5 Transportation Fuel-Cycle Model. Online available at http://www.transportation.anl.gov/modeling_simulation/GREET/pdfs/esd_39v1.pdf. Lifecycle emissions in the model account for primary fuel recovery, preparation, delivery, and use by the vehicle. They do not account for energy used to produce the vehicle.

128 US DOE. Online available at http://www.afdc.energy.gov/afdc/vehicles/emissions_hydrogen.html.

表 9.6: 替代燃料车税收鼓励方案总结

类型	税收鼓励方案（个人所得税抵扣）[129]	立法
HEV	轻型车 (车辆额定总质量（GVWR）≤ 8,500磅) 根据与同级别汽油车相比所提升的燃料经济性和使用周期内所节约的汽油数量，减税额度为650美元至3400美元不等。每家企业在售出6万辆车后不再享受全额的减税激励。 中重型车 (GVWR>8,500磅) 减税额度基于采用混合动力技术增加的成本，有一定限制： <14,001 GVWR: 7,500美元 14,001-26,000 GVWR: 15,000美元 26,001 + GVWR: 30,000美元	《能源政策法》2005
FCV	轻型车(GVWR≤ 8,500磅) 2010年以前购买为8000美元，2010年以后为4000美元。 中重型车(GVWR>8,500磅) 根据车重决定数额	《能源政策法》2005
PHEV	轻型和中型车(GVWR≤14,000磅) 2010年及以后购买的符合条件的车辆，电池容量在4千瓦/时或以上，并且能满足尾气排放标准。减税额度根据额定质量和电池容量，从2500美元至7500美元不等。每家生产企业销售出20万辆车以后不再享受全额的减税激励。	《能源独立与安全法》
BEV	2010年及以后购买的电池电动车（EV）可享受联邦所得税优惠，最高额度为7500美元。具体额度由为车辆提供动力的电池的容量决定。	《能源独立与安全法》
LS EV	2011年以前，低速电动车、两轮及三轮电动车可享受总车价10%，最高2500美元的税收优惠。	《美国复苏与再投资法》2009

除了财政鼓励，美国政府还设定了一系列定额市场销售目标，意在提高先进车辆的市场竞争力。2003年，布什总统在发表国情咨文时强调要强力支持氢燃料电池车。2009年奥巴马总统也宣布了到2015年将100万辆环保汽车推向美国道路的目标（每年新车的1.25%）。加州非常重视排放并早在1990年就制订了零排放车（ZEV）规定。在最近的修订中（2003年），ZEV规定设置了宏大的目标，从2012年到2014年，实现6万辆PHEV。目前，加州空气资源局正计划进一步修订规定，要求到2035年，80%的新车为PHEV、EV或燃料电池车。

为了鼓励电动车商业化，美国在温室气体排放和燃料经济性标准上对轻型电动车也设有“特殊待遇”。2010年4月发布的最终法规中规定，各家生产企业在生产包括PHEV、BEV和FCEV在内的先进技术车辆时，根据他们生产的电动车总量，将其生产的前20万辆或前30万辆车视为0克/英里排放的车辆，并以此来计算这些企业的平均GHG排放水平（用于判断达标）。当生产企业的PHEV、BEV和FCEV产量超过这些上限时，计算它们的公司平均GHG排放水平时，则需要进一步估算这些车辆的上游二氧化碳排放量。

129 各项方案的详细信息来源于美国能源部联邦鼓励政策和法律中心，网址：http://www.afdc.energy.gov/afdc/laws/fed_summary。

Table 9.6: Summary of alternative fuel tax credit programs

TYPE	TAX CREDIT PROGRAMS[129]	LEGISLATION
HEV	Light-duty vehicle (≤ 8,500 lb GVWR) Amount of credit varied from $650 to $3,400 dependent on fuel efficiency gains and lifetime gasoline saved compared to vehicles of the same weight class. Phase out after 60,000 sales per manufacturer. Mid to heavy-duty vehicles (>8,500 lb GVWR) Amount of credit is based on incremental cost limitations: <14,001 GVWR: $7,500 14,001-26,000 GVWR: $15,000 26,001 + GVWR: $30,000	EPAct 2005
FCV	Light-duty vehicle (≤ 8,500 lb GVWR) $8,000 if purchased before 2010, $4,000 after 2010 Mid to heavy-duty vehicles (>8,500 lb GVWR) Amount is determined by vehicle weight	EPAct 2005
PHEV	Light and medium-duty vehicles (≤14,000 lb GVWR) Qualified vehicles purchased in or after 2010 must have at least 4 kWh battery capacity and meet certain emission standards. Credit amount is based on weight rating and battery capacity and is from $2,500 to $7,500. Phase out after 200,000 sales per manufacturer.	EISA
BEV	Battery electric vehicles (EVs) purchased in or after 2010 may be eligible for a federal income tax credit of up to $7,500. The credit amount will vary based on the capacity of the battery used to fuel the vehicle.	EISA
LS EV	10% of cost of qualified low-speed electric vehicles, electric 2 and 3 wheelers, up to $2,500, expires 2011.	ARRA 2009

In addition to the financial incentives, a series of targets were set to boost the market penetration of the various advanced vehicles. President George W. Bush in his 2003 State of Union speech expressed strong support to hydrogen fuel cell vehicles. President Barack Obama in 2009 announced a target of putting a million environmental friendly vehicles on US roads by 2015 (1.25% of the new fleet each year). California has a strong focus on emissions and established the Zero Emission Vehicle (ZEV) mandate in 1990. In its recent revision in 2003, the ZEV mandate sets up ambitious target of 60,000 PHEVs for the 2012-2014 timeframe. Now, California Air Resources Board is proposing to further revise the mandates to require 80% of new vehicles to be PHEVs, EVs or fuel cell vehicles by 2035.

The US light-duty vehicle GHG emissions and fuel economy standard also treats electric drive vehicle differently in order to encourage their commercialization. In the final rule making released in April 2010, advanced technology vehicles including PHEVs, BEVs and FCEVs are assigned for the corporate average standard compliance a 0 g/mil value for the first 200,000 or 300,000 vehicles produced by each manufacturer depending on the total number of electric vehicle they produced. Fleet average GHG emissions would include calculated upstream CO_2e emission values when a manufacturer's PHEV, BEV and FCEV production exceeds these caps.

129 Detailed information about each program is from US DOE's Federal Incentives and Laws Center. Online available at: http://www.afdc.energy.gov/afdc/laws/fed_summary

除了美国以外，各国政府也越来越多地关注HEV和电驱动车，并有越来越多的鼓励方案。表9.7列举了部分欧洲国家和日本鼓励购买新电驱动汽车的实例。尽管一些鼓励政策是针对特定技术的使用，也就是说只要是HEV或BEV就有条件获得鼓励，但在另一些国家，激励力度是和车辆的二氧化碳减排性能挂钩的。例如，在法国是通过以二氧化碳为基础的奖惩机制来确定电驱动车补贴的多少，这一奖惩机制适用于所有燃料类型的轻型车。具体的说，一辆HEV只有在其尾气二氧化碳排放低于60克/公里，才可以获得5000欧元的补贴。

表9.7: 欧洲和日本购买电动车的消费者鼓励政策[130]

国家	消费鼓励政策
法国	在以二氧化碳为基础的奖惩机制下，二氧化碳排放低的车辆（低于60克/公里），包括各种电驱动车，可以获得最高5000欧元的补贴。政府还计划免收电动车的停车费。
德国	电动车在购买后的前五年可以免交每年的流通税。
英国	私人电动车可以免交流通税。企业购买的电动车在购买后的前五年可以免交每年的流通税。从2011年起，BEV和PHEV购买者可以获得车辆标价25%的折扣，最高5000英镑。
日本	如果能达到一定的燃料经济性和排放要求，BEVs, HEVs和PHEVs可免收购置税和每年的吨位税。(自2009年起)

中国的经验与政策

尽管中国早在上世纪90年代就开始发展电动汽车，可直到本世纪初，电动汽车才开始成为汽车工业的焦点。2001年（“十五”计划初），中国首次将多个电动汽车研发项目作为重点内容纳入国家高技术研究发展计划（又称863计划）。自此以后，政府设置了“三纵”（即燃料电池车、混合动力车和纯电动车）和“三横”（多能源动力总成系统、驱动电机和动力电池）战略，并且向电动汽车领域投入大量资金。截止至2008年，共计向替代能源汽车研发投资20亿人民币。在接下来的“十一五”期间（2006-2010年），中国政府加强了电动汽车研发活动并开始开拓商业化路径。

首次公开广泛的应用电动车是为2008年北京夏季奥运会部署的新能源汽车示范项目，共计595辆新能源汽车——主要是纯电动车、燃料电池车和混合动力车一共行驶370万公里，运送乘客440万人次。

2008年底，国内生产企业经历了全球经济危机的影响。在此背景下，中国发布了《汽车产业调整和振兴规划》，其中再次强调推进新能源汽车将是中国长期工业战略的关键。因此，2009年12月，由科技部（MOST）牵头，中国启动了大范围的试点方案，称为“十城千辆”计划—是广泛应用新能源汽车的第二次主要尝试。这一项目的目的是在近期内刺激中国汽车工业，为将来把中国汽车企业打造成世界电动汽车技术的领跑者。

130 法国、德国和英国的政策信息来源于：欧洲汽车工业协会（ACEA），2010年，《欧盟的电动汽车财税鼓励概况》，网址：http://www.acea.be/images/uploads/files/20100420_EV_tax_overview.pdf。日本能源政策来源于：日本自动车协会，2009年，《2009年日本汽车工业》。

There are increasingly more attention and programs to encourage HEVs and electric-drive vehicles outside the US. Table 9.7 lists some examples of consumer incentives for purchasing new electric vehicles in selected European countries and Japan. Though, in many cases the incentives are technology-specific, meaning as long as a vehicle is a HEV or BEV it will be eligible for the incentives, in some nations, the amount of incentive is tied with emission reduction performance of a vehicle. For example, in France, the subsidy to various electric drive vehicles is integrated in a CO_2-based bonus-malus system that applies to light-duty vehicles of all fuel types. Specifically, only if a HEV emits less than 60 g/km of CO_2 from tailpipe emissions, it can receive a subsidy of 5,000 Euro.

Table 9.7: Consumer incentives for purchasing EVs in Europe and Japan[130]

COUNTRY	CONSUMER INCENTIVES
France	Under a CO_2-based bonus-malus system, a subsidy of up to €5,000 is provided to low CO_2 emissions (below 60g/km) vehicles including various electric-drive vehicles. The government is also planning to exempt EVs from parking fees.
Germany	EVs are exempt from annual circulation tax for the first five years after purchase.
United Kingdom	Private EVs are exempt from annual circulation tax. Company EVs are exempt from annual circulation tax for first five years after purchase. From 2011, BEV and PHEV buyers will receive a discount of 25% of vehicle's list price with a maximum of £5,000,
Japan	BEVs, HEVs and PHEVs are exempt from acquisition tax and annual tonnage tax if they meet certain fuel economy and emissions standards. (as of 2009)

China's experience and policies

Although the initial efforts to develop EVs in China date back to early 1990s, they were not a focus of the auto industry's strategy until early this century. In 2001 (the beginning of the tenth Five Year Plan), China included for the first time various EV R&D projects as a key component in the National High-tech Development Plan (usually called the 863 Program). Since then, the government has established a so-called "Three Transverses" (i.e., Fuel Cell Vehicles, Hybrid Electric Vehicles, and Pure Electric Vehicles) and "Three Longitudes" (i.e., Multi-Energy Powertrain System, Drive Motor and Power Battery) strategy and a massive amount of investment began to flow into EV development. A total of 2 billion RMB was invested on alternative vehicle R&D including EVs by the end of 2008. In the following five-year period (2006-2010), the Chinese government reinforced the EV R&D activities and also started to explore initial paths for commercialization.

The first attempt of wide and public application of EVs was the demonstration new energy vehicle fleet deployed for the 2008 Summer Olympic Games in Beijing. During the Games, a total of 595 new energy vehicles -- mainly battery, fuel cell and hybrid electric vehicles -- operated for 3.7 million kilometers transporting 4.4 million passengers.

Towards the end of 2008, domestic auto manufacturers began to experience the effects of the extended global economic crisis. In this context, China announced the Auto Industry Adjustment and Revitalization Plan, which reasserted that promoting new energy vehicles would be the key for China's longer-term industrial strategy. As a result, in December 2009, China launched a large-scale demonstration program called "Ten Cities by Thousand"—a second major attempt of wide application of new energy vehicles, led by the Ministry of Science And Technology (MOST). This program aims to stimulate China's auto industry in the near term, and to promote the Chinese automakers to be the world leader on electric-drive technologies in the long term.

130 Source of French, German and UK's policies: ACEA (European Automobile Manufacturer's Association), 2010. Overview of Tax Incentives for Electric Vehicles in the EU. Online available at: http://www.acea.be/images/uploads/files/20100420_EV_tax_overview.pdf. Source of Japanese policy: JAMA (Japan Automobile Manufacturer Association) 2009. The Motor Industry in Japan 2009.

这个项目计划在选定的10个城市向购买电动汽车的政府部门和商业企业提供财政补贴，在三年之内每年每个城市引入至少1000辆新能源汽车。补贴金额取决于新能源汽车（与同类传统车辆相比）的燃料能效性收益、技术类型和成本增量。表9.8列出了不同车型的补贴金额。2010年1月，这个项目扩展到20个城市。目前，参与的城市正处于计划采购过程中。最近，政府宣布一项计划，要在选定的另外五个试点城市，向私人购买者提供类似的补贴。因此，许多汽车生产企业已经设立了子公司，专门研发和生产电动汽车。

表9.8: 中国“十城千辆”计划下HEV和电动车技术补贴金额（人民币每车）

车辆类型	成用轿车和轻型车	巴士
HEVs	最高 50,000[a]	80,000-420,000[b]
BEVs	60,000	500,000
FCVs	250,000	600,000

a 实际补贴金额取决于HEV的燃料能效性收益大小。

b 实际补贴金额取决于混合动力巴士使用的电池类型。

尽管已经设置了有利的财政补贴，但技术标准仍然滞后。这些标准是必要的，用来定义新能源汽车的关键技术要求并协助判定哪些新能源汽车（技术）应当推广。在淘汰技术落后的电动车（使用过时的低能效电池对车辆进行改造，当做“电动汽车”出售）方面，标准将起到重要作用，这种落后的电动汽车在郊区越发普及。在本文撰写时，尚没有针对BEV的最终的技术标准。

总结与建议

下面的表9.9总结了混合动力车和电动汽车在环保方面的优势和劣势：

表 9.9: 混合动力车（HEV）和电动汽车（BEV）的优势和劣势总结

优势	劣势
■ HEV: 燃料经济性和排放性能提高。提高幅度取决于所采用的技术。不需要充电设备。 ■ PHEV: 燃料经济性提高。在一定里程范围内，可以像BEV一样 在全电动模式下行驶，在这一范围内具有BEV的所有优势。 ■ BEV:零尾气排放。没有内燃机相关的各种问题（I/M、排放劣化、传输过程中的油品污染）。可在帮助电网削峰填谷，实现双赢。 ■ FCEV: 享有BEV的所有收益。因为氢的能源密度高，可提高能效性，比BEV更适合长距离行驶或中等及高负载运行。	■ HEV: 拥有大多数内燃机车的相关问题。成本高。 ■ PHEV: 同时拥有内燃机和电动机双方面的问题。需要充电系统（包括住宅充电系统）。电池模式行驶范围有限。车辆和基础设施成本高。和BEV一样，上游排放具有不确定性。 ■ BEV: 根据原始发电能量源和发电方法，上游排放可能会很高。行驶范围有限（无法和内燃机相比）。车辆和基础设施成本高。需要更换电池。由于需要为车辆增加额外的发电量，会增加郊区的排放。 ■ FCEV: 除了行驶里程范围问题外，面临和BEV一样的挑战。轻型车需要更高效的氢燃料运输和储存方法。

The program is intended to introduce at least 1,000 new energy vehicles per year in each of the ten selected cities (later expanded to more than 20 cities) by providing financial subsidies to new governmental and commercial electric vehicle purchases. The amount of subsidies is determined by the fuel efficiency gain, type of technology and cost difference between the new energy vehicle and a comparable conventional vehicle. Table 9.8 shows the current amount of subsidies for various types of vehicle. As of January 2010, the program was extended to twenty cities. At present, the participating cities are in the process of vehicle procurement. Most recently, the government announced a plan to introduce similar subsidies for private purchases and has selected five pilot cities for the demonstration. As a result, many vehicle manufacturers have established subsidiaries with focus on research, development, and production of EVs.

Table 9.8: Subsidy Levels for HEVs and electric drive technologies under the Chinese "Ten Cities by Thousand" program (RMB per vehicle)

VEHICLE TYPE	PASSENGER CARS AND LIGHT DUTY VEHICLES	BUSES
HEVs	Up to 50,000[a]	80,000-420,000[b]
BEVs	60,000	500,000
FCVs	250,000	600,000

a The actual subsidy level depends on fuel efficiency gain of a given HEV.

b The actual subsidy level depends on the type of batteries used in a given hybrid electric bus.

While favorable financial subsidies have been established, technology standards still lag behind. These standards are supposed to define the key technological requirements for new energy vehicles and help determine what types of new energy vehicles (technologies) should be promoted. The standards are important to help filter out dead-end technology EVs (vehicles modified with outdated and inefficient battery technologies but sold as "electric vehicles"), which are increasingly common in rural areas. The Technology Standard for BEVs has still not been finalized at the time when this paper is written up.

Summary and recommendations

The following Table 9.9 summarizes the pros and cons of HEVs and electric-drive vehicles.

Table 9.9: Summary of advantages and disadvantages of HEVs and electric-drive vehicles

ADVANTAGES	DISADVANTAGES
■ HEV: Improved fuel economy and emissions performance. The level of improvement depends on technology. No recharging facilities needed. ■ PHEV: Fuel economy improvement. Has the potential to function like a BEV for a limited range, thus may share all benefits of BEVs when driven on all-electric mode. ■ BEV: Zero tailpipe emissions. No ICE-related issues (I/M, emission deterioration, oil contaminant of dispense issues). May realize co-benefit of filling grid valley. ■ FCEV: Share all benefits of BEVs. Improved efficiency due to high energy density of H_2, better for long-distance or medium and heavy load than BEV.	■ HEV: Suffer from most ICE-related problems. High cost. ■ PHEV: May suffer from both ICE and electric motor issues. Need recharging system (including residential). Limited range on battery mode. High cost in both vehicle and infrastructure. Uncertainty in upstream emissions as BEVs. ■ BEV: Upstream emissions can be high depending on original energy sources and processing. Limited range (cannot compete with ICE vehicles). High Cost in both vehicles and infrastructure. Need battery recycling. Increased emissions in rural area due to extra electricity generation for the vehicles. ■ FCEV: Similar challenges as BEVs except for the range issue. Need more efficient hydrogen transportation and storage for light-duty vehicles.

以下建议的主要目的是减少混合动力车和电动汽车的环境影响：

- 尽管应该让市场来做出选择制定先进技术汽车政策的总原则，但考虑近期和长期的战略对中国而言十分重要。例如，相对于其它类型的技术，混合动力车辆技术更加成熟，可实现商业化，这可能不需要政府过多的投入，就能在短期内产生影响。但是，从长期角度，以清洁能源为基础的电动车和燃料电池车才能真正实现零排放。

- 环保部应同时考虑各种新能源车辆的尾气排放收益和全生命周期排放影响。环保部应带头进行这些车辆的全生命周期排放综合研究，并考虑中国国情下的电网能源构成情况。这些研究结果将为今后制订新能源汽车政策奠定基础。

- 在中国，PHEV、BEV和FCEV的长期环境影响取决于上游排放的不断改善，包括更多的依赖于可再生资源产生的能源。环保部应与其它部委合作，在引进PHEV、BEV和FCEV的同时扩大对可再生能源的支持。

- 需要针对电池回收和处理的管理规定。

- 随着中国车辆保有量的增长，相对于继续大量投资于建设更多的传统汽柴油基础设施，中国的发展战略可以考虑将未来的投资主要用于为电动汽车建设电力或氢能基础设施，这可以被当做一个实现跳跃发展的契机。

9.5 综合性建议

除了针对各类燃料车辆提出的专门建议外，下面还提供了一些全局性建议，适用于所有替代燃料和新能源汽车方案中：

- *环保部应发展自身能力和专业技术，评估各种替代燃料汽车的环境影响。*综合分析这些燃料的全生命周期排放，在分析时要着重考虑中国特殊的能源原料情况，以供制定这一领域的政策所需。

- *替代燃料车应当被纳入普通车辆的常规污染物和温室气体/燃料能效性管理框架和财政政策体系。*替代燃料车应遵守适用于所有其它车辆的排放性能（包括可能的二氧化碳排放性能）标准规定。应尽量对减排性能较好的车予以奖励，以便鼓励其商业化进程。同样，财政鼓励也应当和替代燃料车的减排幅度挂钩，而不是单纯针对替代燃料技术的使用。

- *一旦环保部有更强的能力分析燃料的全生命周期环境影响，环保部应考虑采纳低碳燃料标准（LCFS），在其中对不同的燃料的碳影响进行规定，并推广使用低碳车用燃料。*在好的LCFS和车辆温室气体标准的共同作用下，可以促成持续推动汽车低碳化。

- *大体而言，原装（OEM）替代燃料车的发动机排放性能更好，其长期性能比改造车更有保障。*因此，在适用的情形下，政策制定者应鼓励使用原装车辆。应开展认证和达标方案，确保改造组件和改造车能满足环境、安全和其它方面的要求。

- *投资基础设建设应与替代燃料车同步发展。*根据现实案例，加油基础设施滞后于车辆普及，灵活燃料车或双燃料车车主就经常会不使用替代燃料。电动车缺少充电设施会妨碍这类车辆的发展乃至技术创新。应制订政策确保切实使用替代燃料。例如，美国实施了强制规定，要求联邦政府机构的双燃料车必须使用替代燃料。各州和地方政府也必须提交计划，说明鼓励切实使用替代燃料的方法，包括向替代燃料提供减税鼓励，加强替代燃料基础设施建设和增加加油站点。

The following recommendations are aimed at optimizing the environmental impacts of HEVs and electric-drive vehicles:

- Although the general principle for developing advanced technology vehicles should be to let the market choose, it is important for China to consider both short- and long-term strategies. For example, HEV technologies are currently more mature than the other types for commercialization, thus may make an impact in the near term without significant governmental input. But in the long-run, BEVs and FCEVs based on clean energy sources will truly realize low to zero emissions.

- MEP should consider tail-pipe emissions benefits as well as the life cycle emissions impact of these vehicles. MEP should take the lead in conducting comprehensive studies on life-cycle emissions of these vehicles, taking consideration of China's specific grid mix situations. The results of these studies will serve as a ground for future policy making regarding new energy vehicles.

- The long-term environmental impacts of PHEV, BEV and FCEVs in China depend on the continuous improvement of upstream emissions including a greater reliance on renewable sources of energy. MEP should work with other ministries on expansion of renewable energy supply that go in parallel with the introduction of PHEVs, BEVs and FCEVs.

- Regulations addressing battery recycling and disposal are needed.

- As the Chinese vehicle population grows, investment in electricity or hydrogen infrastructure for electric drive vehicles can be seen as a leapfrog opportunity, in contrast to building more conventional fuel-based infrastructure.

9.5 Overall recommendations

In addition to the specific recommendations for each fuel/vehicle type, the following overarching recommendations apply to all alternative fuels and new energy vehicle programs:

- *MEP should develop in-house capacity and expertise in evaluating the environmental impacts of various alternative fuel vehicles.* A comprehensive analysis of life-cycle emissions of these fuels, taking consideration of the China-specific energy feedstock profile is needed to set priorities and inform policy efforts in this area.

- *Alternatively fueled vehicles should be incorporated into the general vehicle conventional pollutant and GHG/fuel efficiency regulatory framework and fiscal policies.* Alternatively fueled vehicles should comply with the performance standards applicable to all other vehicle types. Whenever possible, better performing vehicle should be rewarded for emission reduction benefits in order to encourage their commercialization. Similarly, fiscal incentives for various alternative fuel vehicles should be linked to their emissions reduction contribution, rather than simply being technology-specific.

- *As MEP develops more capacity in life cycle environmental impacts of fuels, the ministry should consider adopting a low carbon fuel standard (LCFS) that characterizes the carbon profile of various fuels and promotes the use of low carbon vehicle fuels.* A well-designed LCFS and a vehicle GHG standard can work together to promote continuous decarbonization of automobiles.

- *In general, manufactured (OEM) alternative fuel vehicles have better engine and emissions performance, and their longer term performance is more guaranteed than retrofitted vehicles.* Therefore, when applicable, policy makers should encourage the use of OEM vehicles. Certification and compliance programs should be developed to ensure that retrofit kits and retrofitted vehicles meet environmental, safety and other requirements.

- *Infrastructure investment should go hand-in-hand with the development and deployment of alternative fueled vehicles.* Real world cases suggest that when refueling infrastructures lags behind vehicle adoption, owners of flex-fuel or dual fuel vehicles often will not use the alternative fuel for their vehicles. Lack of recharging infrastructure for electric drive vehicles will also inhibit the deployment and even technology innovation of such vehicle types. There should be policies to assure the actual use of the alternative fuels. For example, the US issued mandatory requirements for federal fleets to use alternative fuel in dual-fuel vehicles. State and local governments must submit plans of measurements to encourage actual use of alternative fuels including providing tax incentives on alternative fuels, expanding alternative fuel facilities and charging stations.