Contents lists available at SciVerse ScienceDirect

## **Energy Policy**



## Status of advanced light-duty transportation technologies in the US

David Andress<sup>a,\*</sup>, Sujit Das<sup>b</sup>, Fred Joseck<sup>c</sup>, T. Dean Nguyen<sup>c</sup>

<sup>a</sup> David Andress & Associates, Kensington, MD, USA

<sup>b</sup> Oak Ridge National Laboratory, Knoxville, TN, USA

<sup>c</sup> US Department of Energy, Washington, DC, USA

#### ARTICLE INFO

### ABSTRACT

Article history: Received 8 June 2011 Accepted 28 October 2011 Available online 26 November 2011

Keywords: Light-duty vehicles Transportation fuels Transportation policies The need to reduce oil consumption and greenhouse gases is driving a fundamental change toward more efficient, advanced vehicles, and fuels in the transportation sector. The paper reviews the current status of light duty vehicles in the US and discusses policies to improve fuel efficiency, advanced electric drives, and sustainable cellulosic biofuels. The paper describes the cost, technical, infrastructure, and market barriers for alternative technologies, i.e., advanced biofuels and light-duty vehicles, including diesel vehicles, natural-gas vehicles, hybrid electric vehicles, plug-in hybrid electric vehicles, and fuel-cell electric vehicles. The paper also presents R&D targets and technology validation programs of the US government.

© 2011 Elsevier Ltd. All rights reserved.

ENERGY POLICY

#### 1. Introduction

Since Richard Nixon first made the case for energy independence in the wake of the 1973 Arab oil embargo, every US president has recognized the importance of reducing the nation's dependency on petroleum. Still, oil consumption and imports

0301-4215/\$ - see front matter  $\circledast$  2011 Elsevier Ltd. All rights reserved. doi:10.1016/j.enpol.2011.10.056

have grown steadily. The transportation sector is responsible for about 67% of the oil consumed in the US, with on-road vehicles accounting for 80% of the transportation petroleum use (Davis, 2011). About 75% of the petroleum consumed in on-road vehicles is used in light-duty vehicles (LDV) and 25% used in medium-duty and heavy-duty vehicles (MDVs and HDVs). More recently concerns about climate changes have focused attention on the importance of reducing greenhouse gas (GHG) emissions. Almost 33% of the US carbon emissions come from the transportation sector, with LDVs accounting for about 59% of the transportation carbon emissions (Energy Information Administration, 2009).

The twin objectives of reducing oil consumption and GHG emissions are the key policy drivers for developing advanced vehicular technologies and low-carbon, sustainable transportation fuels. This paper looks at policies currently in place to promote advanced fuels and vehicles and the technical and cost challenges that need to be addressed for consumer to obtain embrace them.

Firstly, the paper reviews the current situation for LDVs in the US. Secondly, the paper presents an overview of the major policy initiatives currently in place to reduce oil consumption and GHG emissions and to encourage the development and deployment of alternative vehicles and low carbon fuels. Finally, the paper reviews the technical, cost, market, and infrastructure barriers and challenges for advanced technologies and fuels.

#### 2. LDVs and fuels—current situation

In 2000, 16.5 million light duty vehicles (cars and trucks) were sold in the US, of which 15.8 million were conventional gasoline



Abbreviations: AEO, Annual Energy Outlook; ANL, Argonne National Laboratory; BEV. battery-powered electric vehicle: CAFE. Corporate Average Fuel Economy: CARB, California Air Resources Board; CCS, carbon captures and sequestration; Cl, carbon intensity; CO<sub>2</sub>, carbon dioxide; CO<sub>2</sub> eq., carbon dioxide equivalent; DOE, US Department of Energy; E85, blend of 85% ethanol and 15% gasoline; EIA, Energy Information Administration; EISA, Energy Independence and Security Act of 2007; EER, energy economy ratio; EPA, US Environmental Protection Agency; EPACT, Energy Policy Act of 2005; EPRI, Electric Power Research Institute; EREV, extended range electric vehicle; EVSE, electric vehicle supply equipment; FCB, fuel cell bus; FCEV, fuel-cell electric-powered vehicle; FCMHE, fuel cell material handling equipment; FFV, flex-fuel vehicle; FT, Fischer-Tropsch; GEE, general electric energy; GGE, gasoline US gallon equivalent; GHG, greenhouse gas; GREET, greenhouse gases; regulated emissions, and energy use in transportation model; H<sub>2</sub>, hydrogen; HDV, heavy-duty vehicle; HEV, hybrid electric vehicle; FFV, flex-fueled vehicle; IEA, International Energy Agency; IGCC, Integrated Gasification Combined Cycle Power Plant; ICEV, internal combustion engine vehicle; LCFS, low-carbon fuel standard; LDV, light-duty vehicle; LHV, lower heating value; MDV, medium-duty vehicle; MJ, megajoule; mpg, miles per gallon; MWh, megawatt hour; NETL, National Energy Technology Laboratory; NGV, natural gas vehicle; NREL, National Renewable Energy Laboratory; NHTSA, National Highway Traffic Safety Administration; NiMH, nickel metal hydride; ORNL, Oak Ridge National Laboratory; PHEV, plug-in hybrid electric vehicle; RD&D, research, development, and demonstration; RFS, renewable fuels standard; SAE, Society for Automotive Engineers; SULEV, super low emission vehicle; USDA, US Department of Agricultures; VEETC, volumetric ethanol excise tax credit

<sup>\*</sup>Corresponding author. Tel.: +1 301 933 7179; fax: +1 301 933 7178. *E-mail address:* davidandress@msn.com (D. Andress).



Fig. 1. Annual sales of light duty cars and trucks (millions). Note: 2000 and 2009 data are actual historical numbers. Data for other years are from EIA's 2011a, 2011b Annual Energy Forecast.

Source: EIA, Today in Energy, February 10, 2011, http://www.eia.gov/todayinenergy/detail.cfm?id=70#.

internal combustion engines and 0.7 million were E85 flex-fueled vehicles (FFVs). About 30,000 diesel internal combustion engines,<sup>1</sup> 10,000 hybrid electric vehicles (HEVs), and 10,000 natural gas vehicles were also sold. In 2009, LDV sales plummeted to 9.8 million vehicles on the heels of the worldwide financial crisis. Out of 9.8 million vehicles, 8.3 million were conventional gasoline internal combustion engines and 1.0 million were E85 FFVs. Sales of HEVs increased to 250,000, sales of diesel vehicles increased to 170,000, while sales of natural gas vehicles stayed around 10,000. EIA classifies HEVs as hybrids or mild hybrids. A (full) hybrid<sup>2</sup> vehicle can be driven for short distances solely on battery power, as opposed to a mild hybrid vehicle, where the battery assists the internal combustion engine under acceleration and supplies energy when the engine shuts down when the vehicle stops (e.g., at stop lights). Most of the HEV sales in 2009 were (full) hybrids.

The Energy Information Administration (EIA), an independent forecasting and analytic agency within the US Department of Energy, projects that LDV sales will revert back to historical trends once the effects of the financial crisis abate, but the product mix will change (Fig. 1). For example, EIA projects that LDV sales in 2015 will total 16.2 million, consisting of 10.9 million conventional gasoline internal combustion engines, 3.5 million E85 FFVs, and 1.0 million HEVs (0.4 million mild hybrids and 0.6 million full hybrids). Diesel LDV sales will increase to 650,000, plug-in hybrid vehicle (PHEV) sales will reach 70,000, and natural gas vehicle sales will remain at about 10,000 (EIA 2011a). The EIA projections, which extend through 2035, assume progress is made in reducing costs for advanced technologies and fuels and are displayed in this paper because they are widely used by transportation analysts. However, this paper focuses on describing the current state of the technologies and the technical, cost, and infrastructure barriers that must be overcome before advanced technologies are commercialized, and not on the assumptions of a particular study.

Gasoline is currently the predominant fuel used in LDVs, followed by ethanol. In 2010, the US transportation sector consumed 13.2 billion gal of fuel ethanol (includes denaturant), up from 10.6 billion gal in 2009 (Renewable Fuels Association). About 99% of the ethanol was used in E10; with the other 1% of the ethanol used in E85 (Davis et al., 2011). In 2008, the US consumed 700 million gal of biodiesel, but most diesel fuel in the US is used in heavy-duty vehicles (National Biodiesel Board).

#### 3. National strategies for fuels and LDVs

At the national level, the US transportation energy policy focuses on two major objectives: (1) reducing the use of petroleum as a transportation fuel and (2) reducing emissions of GHGs from the transportation fuels. Current policies are aimed at improving vehicular efficiency; subsidizing alternative vehicles, fuels, and infrastructure improvements, funding research, development and demonstration (RD&D) of advanced vehicle and fuel technologies, and outreach, training and workshops along with technical and financial assistance to various "Clean Cities" coalitions throughout the country. In addition to grants, loans and other forms of financial awards, the government is implementing a loan guarantee program for demonstration plants and pioneer plants.

The American Recovery and Reinvestment Act of 2009 is worth noting for the large funding (\$2.4 billion) that was made available to establish 30 electric vehicle battery and component manufacturing plants and support some of the world's first electric vehicle demonstration projects. For every dollar of the \$2.4 billion, the companies have matched it at minimum dollar for dollar. In addition, DOE's Advanced Research Projects Agency-Energy (ARPA-E) is providing over \$80 million for more than 20 transformative research and development projects related to batteries and electric drive components, and the Advanced Energy Manufacturing Tax Credit program helped to expand US-based manufacturing operations for advanced vehicle technologies. The Obama Administration has also provided nearly \$2.6 billion in Advanced Technology Vehicle Manufacturing (ATVM) loans to Nissan, Tesla and Fisker to establish electric vehicle manufacturing facilities in Tennessee, California and Delaware, respectively.

The major policy initiatives are summarized below.

3.1. CAFE

Corporate Average Fuel Economy (CAFE) is the sales weighted average fuel economy, expressed in miles per gallon (mpg), of

<sup>&</sup>lt;sup>1</sup> Diesel engines are used primarily in medium- and heavy-duty vehicles.

<sup>&</sup>lt;sup>2</sup> Often, HEVs are classified full hybrids and mild hybrids. The full hybrid corresponds to EIA's designation of hybrid. When HEVs are discussed later in this paper, the terms full hybrid and mild hybrid are used.

# دريافت فورى 🛶 متن كامل مقاله

- امکان دانلود نسخه تمام متن مقالات انگلیسی
  امکان دانلود نسخه ترجمه شده مقالات
  پذیرش سفارش ترجمه تخصصی
  امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
  امکان دانلود رایگان ۲ صفحه اول هر مقاله
  امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
  دانلود فوری مقاله پس از پرداخت آنلاین
  پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات
- ISIArticles مرجع مقالات تخصصی ایران