U.S. Department of Transportation

Alternative Fuels

ITS Benefits, Costs, and Lessons Learned: 2017 Update Report

Alternative Fuels

Charging / Fueling Information
Charging / Fueling Payment
Inductive Charging

Highlights

- In-vehicle navigation systems equipped with knowledge of battery capacity, remaining distance, and the locations of charging/fueling stations can help minimize range anxiety.
- Inductive Charging technologies will allow drivers to charge their electric vehicles in small amounts fairly often. Dynamic charging may complement local stationary charging, removing range anxiety. As a result, electric batteries could be smaller with the resulting reduction in electric vehicle cost and weight.
- The potential benefits of a catenary-accessible hybrid truck platform may be significant. Trucks, when connected to the catenary system, will have zero-emissions which can significantly reduce emissions along a corridor.

Introduction

This factsheet is based on past evaluation data contained in the ITS Knowledge Resources database at: www.itskrs.its.dot.gov. The database is maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The factsheet presents benefits, costs and lessons learned from past evaluations of ITS projects.

Alternative fuels offer significant benefits over more conventional petroleum fuels, producing lower emissions and fewer toxic contaminants than gasoline and diesel vehicles, helping to reduce impacts on air quality, global warming, the environment and public health. According to the U.S. Department of Energy (DOE), more than a dozen alternative fuels are in production or already in use in alternative fuel vehicles (AFVs). The six predominant alternative fuels used in the United States are biodiesel, electricity, ethanol, hydrogen, natural gas, and propane. Of these fuels, electricity is the most widely used – primarily in hybrid electric vehicles (HEVs) or all electric vehicles.

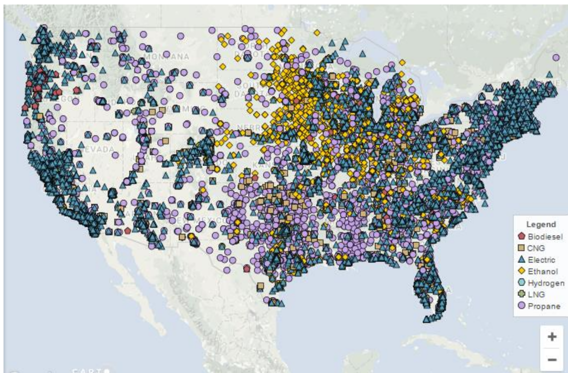
To date, government and private-sector vehicle fleets have been the primary users of these fuels and vehicles, but recently consumers are becoming increasingly interested in them as well. Fleet operators including long-haul trucking, taxi services, law enforcement, public transit, and school transportation services have seen environmental benefits from AFVs. In addition to reducing the organization's carbon footprint, AFVs have helped to reduce operating costs for many of these organizations. Over the last decade, the City of Sacramento successfully transitioned its entire diesel refuse-hauler fleet to clean-burning liquefied natural gas (LNG). The fleet operator worked with Sacramento Clean Cities, the local air district, and other fleets in the area to systematically roll out 113 side- and rear-loader LNG refuse trucks, as well as the fueling stations and maintenance facilities to support them. This effort contributed to millions of dollars saved and more than 1,900 tons of annual greenhouse gas (GHG) emissions averted [1].

The popularity of AFVs with consumers has increased over the past 20 years. This increase in popularity can be attributed to many factors including more environmentally conscious consumers as well as stricter federal fuel efficiency standards (which will rise from 2016's fleet average of 34.5 mpg to 54.5 mpg by 2025). The automotive industry has responded to these trends by enhancing the fuel efficiency of conventionally fueled light passenger vehicles, as well as introducing new AFV models into the market. In 1991, there were only two models of AFVs offered by automobile original equipment manufacturers (OEMs). In 2015, 28 OEMs offered 191 models of AFVs [2].

HEVs, powered by both electricity and gasoline, which get upward of 50 miles per gallon, are by far the most common type of AFV. OEMs are also beginning to offer battery electric vehicles (BEVs) that rely completely on an electric battery to power its electric motor.

While AFVs provide several environmental, economic, and societal benefits over internal combustion engine vehicles, there are also some limitations to these vehicles. The most obvious limitation is that these vehicles usually cannot be refueled at the corner gas service station. A report published by ITS America stated that there are approximately 30,000 gas service stations to support approximately 200 million vehicles in the United States, or about 6,000 vehicles per station. In comparison, according to the U.S. DOE there are now over 51,000 alternative fuel stations in the United States, excluding private stations. This number is up from only 12,000 is 2014 [1]. Table 1 depicts the number of alternative fueling stations in the United States.

Table 1: Alternative Fueling Stations in the United States as of 2016 (Source: U.S. DOE Alternative Fuels Data Center).



Fuel Type	Number of Stations in the United States
Biodiesel (B20 and above)	697
Compressed Natural Gas	1,725
Electric	42,011
Ethanol (E85)	3,090
Hydrogen	54
Liquefied Natural Gas	140
Liquefied Petroleum Gas	3,665
All Fuel Types	**51,382**

With AFVs, a lack of information provided to the driver can be a contributing factor to range anxiety, the fear that a vehicle has insufficient range to reach its destination and would thus strand the vehicle's occupants. Intelligent Transportation Systems (ITS) offer potential to support AFVs. Navigation systems equipped with knowledge of the vehicle's battery capacity, remaining distance, and the locations of charging/fueling stations can help minimize driver fear.

Charging / Fueling Information applications located on in-vehicle systems or on nomadic devices can inform travelers of locations and the availability of AFV charging and fueling stations. These applications may also allow drivers to make reservations to use charging stations before they start their trip or while en-route. Electronic payment cards—or applications on smart phones—may also be used to support the payment at charging and fueling stations.

Charging / Fueling Payment applications may be integrated with other transportation payment systems such as transit fares, parking, and electronic toll collection systems.

Inductive or Resonance Charging is another promising technology that has the potential to support AFVs. Inductive or resonance charging includes infrastructure deployed under the roadway that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables electric vehicles to charge their batteries once positioned over the charging station. Inductive or resonance charging may support static charging capable of transferring electric power to a vehicle parked in a garage or on the street and vehicles stopped at a traffic signal.

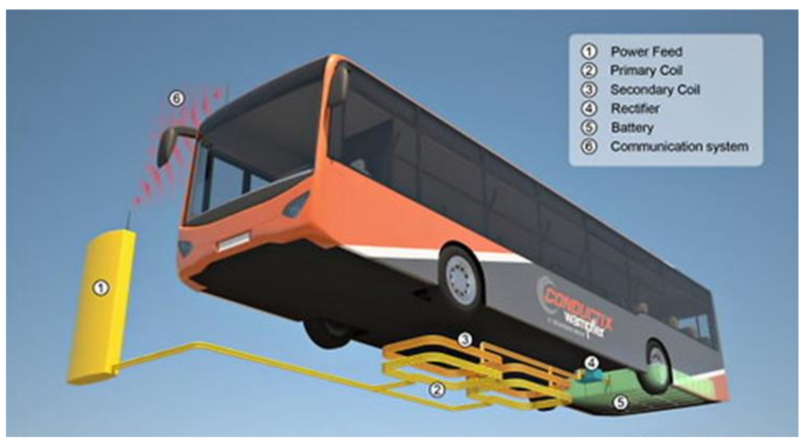


Figure 1: Inductive Charging. Position marking for a wireless charging system with coils integrated in the road surface (Source: Conductix-Wampfler).

A start-up at Utah State University (USU) named WAVE Inc. is commercializing Inductive Power Transfer (IPT) technology for electric buses after developing Wireless Advanced Electric Vehicles (WAVE) transit technology within its Electrodynamics Lab. Unveiled in 2012, the initial WAVE technology bus prototype was a USU campus shuttle, the Aggie Bus, which modified a 22-foot electric eBus to recharge its nickel cadmium battery (NiCd) for 5 minutes every 15 minutes.

USU's Aggie Bus has achieved several significant milestones including being the first bus developed and designed by a North American organization that is charged with Wireless Power Transfer (WPT) technology and being the world's first electric bus with WPT combining a power level up to 25 kilowatts, greater than 90 percent efficiency from the power grid to the battery and a maximum misalignment of up to six inches (2016-01120).

Looking down the road a few years, wireless charging technology may be able to support charging vehicle batteries while the vehicle is moving at highway speeds, without having to stop at all. This capability – known as dynamic wireless charging – is currently being researched. In 2013, the Korea Advanced Institute of Science and Technology (KAIST) developed the Online Electric Vehicle (OLEV) charging platform that allowed two buses in Gumi to run a continuous 24 km inter-city loop powered by charging apparatuses installed beneath the street [5].

Catenary Systems that use overhead wires to provide electricity for heavy duty vehicles have been in use for well over 100 years. Today, catenary systems can be found on urban light rail vehicles, city buses, and mining equipment. A recent demonstration shows how these systems may be used along truck corridors as part of a catenary based system for zero-emission trucks. While catenary system technology is very mature, it is only recently that hybrid/electric drive technology has matured to the point that a cost-effective hybrid system could be developed that allows for zero-emission operation on and off the catenary line. In the proposed system, a diesel or natural gas hybrid truck is envisioned that can operate solely on electrical power from the catenary lines. Additionally, an onboard battery will allow the truck to operate in electric mode for a limited distance after disconnecting from the catenary system [4].

Benefits

Transportation is the "fastest-growing source of U.S. GHG emissions, accounting for 47 percent of the net increase in total U.S. emissions since 1990, and is the largest end-use source of CO_2, which is the most prevalent GHG" [6]. Transportation activities accounted for 27 percent of all GHG emissions in the United States, with on-road vehicles contributing 84 percent to that total. Nearly "97 percent of transportation GHG emissions came through direct combustion of fossil fuels." Over 43 percent of surface transportation emissions are the result of passenger vehicles, 19 percent from light-duty trucks, and freight trucks account for another 22 percent. AFVs have the potential to reduce these numbers significantly and ITS is an enabling technology to make these vehicles more attractive to the traveling public.

To date, ITS technologies to support AFVs have not been widely deployed. As a result, there is limited data documenting the benefits of Charging/Fueling Information, Charging/Fueling Payment, Inductive or Resonance Charging, or Catenary Systems that support HEVs. While documentation of benefits is limited, ITS technologies relating to AFVs seem promising. Charging/Fueling information may help to reduce range anxiety which may result in more purchases or use of AFVs. Additionally, Inductive or Resonance Charging applications will allow drivers to charge their electric vehicles in small amounts fairly often. As a result, electric batteries could be smaller with the resulting reduction in electric vehicle cost and weight. These technologies will also make electric vehicles more attractive to consumers. Finally, the potential benefits of a catenary-accessible hybrid truck platform may be significant. Trucks, when connected to the catenary system, will have zero-emissions which can significantly reduce emissions along a corridor.

As these technologies mature and the number of AFVs on the roadway increase, it is expected that private and public agencies will begin deploying technologies to support the operations of these vehicles and more benefit data will become available.

Costs

A limited number of ITS applications have been deployed to support alternative fuels. However, there is a lot of available data related to charging infrastructure for electric vehicles. The National Renewable Energy Laboratory's handbook estimated that the costs involved in setting up the infrastructure and equipment for a charging station were between $15,000 and $18,000 for traditional public charging stations and between $65,000 and $70,000 for fast-charging stations [7].

Lessons Learned

The following lessons learned are gathered from the U.S. Doe's Office of Energy Efficiency and Renewable Energy:

- **Receive significant cost savings by driving AFVs instead of vehicles powered by internal combustion engines (ICEs).** The U.S. DOE's "Find a Car" tool allows consumers to compare fuel efficiency, costs, carbon footprints, and emissions of different vehicle makes and models (http://www.afdc.energy.gov/tools).

- **Convert petroleum-based fleet vehicles to AFVs to save operating costs and avert greenhouse gas (GHG) emissions.** The U.S. DOE's "Green Fleet Footprint Calculator" is a tool that can be used to estimate the potential savings for fleet operators (http://www.afdc.energy.gov/tools).
- **Minimize range anxiety with in-vehicle navigation systems equipped with knowledge of battery capacity, remaining distance, and the locations of charging/fueling stations.** As a result, consumers may be more likely to purchase and use AFVs.

Case Study – The I-710 Corridor Project: Zero Emissions Corridor

The California Department of Transportation (Caltrans), in cooperation with the Los Angeles County Metropolitan Transportation Authority (Metro), the Gateway Cities Council of Governments, the Southern California Association of Governments and the Ports of Los Angeles and Long Beach recently proposed improvements to Interstate 710. Interstate 710 is a major north-south interstate freeway connecting the city of Long Beach to central Los Angeles. The corridor serves as the principal transportation connection for goods movement between the Port of Los Angeles and the Port of Long Beach, located at the southern terminus of I-710 and the Burlington Northern Santa Fe (BNSF)/Union Pacific (UP) Railroad rail yards in the cities of Commerce and Vernon. The existing I-710 Corridor has elevated levels of health risks related to high levels of diesel particulate emissions, traffic congestion, high truck volumes, high accident rates, and contains many design features in need of modernization. The U.S. Environmental Protection Agency (EPA) has designated the South Coast Air Basin (Basin), which includes the Study Area, as an extreme ozone non-attainment area and a non-attainment area for small airborne particulate matter less than 10 and 2.5 microns (PM10 and PM2.5).

Figure 2: Proposed Catenary System for I-710 Zero-Emissions Corridor (Source: Siemens Mobility).

The proposed project recommends several alternatives to improve the corridor, including widening the corridor, providing improvements to the arterials, deploying ITS, and implementation of zero-emission electric truck technology. This proposed zero-emission truck technology is assumed to consist of trucks powered by electric motors and producing zero tailpipe emissions while traveling on the freight corridor. The zero-emission electric trucks would receive electric power while traveling along the freight corridor via an overhead catenary electric power distribution system (road-connected power) as depicted in Figure 2.

According to a presentation by the South Coast Air Quality Management District (SCAQMD), a demonstration project is being proposed to prove the catenary truck concept in real-world drayage operations. The catenary system would be one mile long with pole spacing similar to street lights and a DC power substation with remote monitoring. Four demonstration trucks - a diesel hybrid, CNG hybrid, battery electric, and another vehicle platform to be determined at a later date - would be used in the demonstration. Originally expected to start in 2015, the demonstration was delayed until 2017 and is expected to last for one year. Estimated project costs to plan, design, build, and conduct the demonstration of the catenary system are $16,682,795. If the system were implemented on the corridor, the potential benefits includes reducing emissions of 75,000 diesel heavy duty trucks in the basin and 12,120 trucks used in drayage that produce 17.7 tons on NOx per day and 0.2 tons of PM2.5 per day [8].

Case Study – Flash-Charging Electric Buses

In Switzerland, Asea Brown Bovery (ABB) Ltd. pilot tested an articulated electric bus serving the route from the Geneva Airport to the Palexpo Exhibition Center using a new "flash" charging concept named Trollybus Optimisation Système Alimentation (TOSA). Using a charging station that connects to the top of the vehicle, the TOSA system provides charges in 15-second bursts during stationing time at equipped bus stops. As the world's fastest flash-charging connection technology, the system takes less than 1 second to connect the bus to the charging point. At the end of the line, terminal feeding stations deliver prolonged charges of 4-5 minutes to fully top-off the on-board batteries.

In July 2016, three years after the pilot was initiated, ABB was awarded orders totaling more than $16 million by Transports Publics Genevois (TPG), Geneva's public transport operator, and Swiss bus manufacturer HESS, to provide flash charging and on-board electric vehicle technology for 12 TOSA fully electric buses that will connect Geneva's airport with suburban Geneva. The entire line is expected to be fully operational in 2018, after which performance monitoring will start.

The roof-mounted charging equipment does not appear to be an IPT mechanism, since conductive charging of the battery takes place when a robotic arm on the bus makes contact with the overhead charger in station stops; however, the TOSA electric bus recharge is referred to as "wireless" because of the absence of the usual overhead, continuous trolley wires common in a catenary system. The system for overhead flash high-power charging is inherently safe because the overhead connectors are only energized when they are engaged, and the electromagnetic fields associated with inductive charging concepts are therefore avoided.

It has been estimated that if Geneva were to replace all of its diesel buses with TOSA buses, there would be a reduction of 1,000 tons of CO_2 emissions every year [9]. This infrastructure of overhead lines and ultrafast charging times at bus stops is expected to pave the way for the next generation of silent, flexible, zero-emissions urban mass transit.

Figure 3: The TOSA electric bus stopped at a charging station in Geneva (Source: Asea Brown Bovery).

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All other data referenced is available through the ITS Knowledge Resources Database, which can be found at http://www.itsknowledgeresources.its.dot.gov/.