Breaking Our Dependence on Oil by Transforming Transportation

Addendum to the IEEE-USA Position Statement on National Energy Policy Recommendations
About this IEEE-USA Position Statement

This statement, as approved by the IEEE-USA Board of Directors on 3 May 2012, was developed by the IEEE-USA Energy Policy Committee as an addendum to the IEEE-USA Position Statement on National Energy Policy Recommendations. It represents the considered judgment of a group of U.S. IEEE members with expertise in the subject field. IEEE-USA advances the public good and promotes the careers and public policy interests of 210,000 engineering, computing and technology professionals who are U.S. members of IEEE. The positions taken by IEEE-USA do not necessarily reflect the views of IEEE or its other organizational units.

Table of Contents

INTRODUCTION ......................................................................................................................................................... 3

1. ELECTRIFYING TRANSPORTATION: PLUG-IN ELECTRIC VEHICLES ......................................................... 4

2. DEVELOPING AND USING ALTERNATIVE TRANSPORTATION FUELS ................................................ 12

SUMMARY ...................................................................................................................................................................... 14
INTRODUCTION

The transportation sector is vital to our economy, yet it is one that is most exposed to all uncertainties in oil supply and cost. More than 96 percent of the energy used in transportation comes from oil. The transportation sector consumes about two-thirds of all petroleum used in the United States.¹ There are many reasons that collectively suggest that complete dependence on petroleum for our transportation needs is unwise. Some of these reasons are summarized below:

- In 2010, the United States imported about 49 percent of its petroleum, including crude oil and refined petroleum products.² Even though our dependence on foreign petroleum has declined since peaking in 2005, the funds spent for imported oil continue to adversely affect the U.S. economy; in 2010, oil imports accounted for about 40 percent of the U.S. trade deficit.³ Some of the money ends up in the hands of people who are unfriendly to the United States and its interests.⁴
- Rapid growth of transportation needs in emerging economies will continue the upward pressure on oil prices.⁵ Oil price increases would impact not only transportation, but also other sectors. About 15 percent of petroleum is used for non-fuel purposes — an amount of oil equivalent to about a third of current U.S. domestic production. The non-fuel uses include industrial feedstock for a variety of products such as plastics, detergents, and even aspirin.⁶
- Gasoline combustion is responsible for most precursors of urban smog. In addition, gasoline and diesel fuel combustion from transportation contribute about 30 percent of U.S. greenhouse gas emissions.

IEEE-USA recommends pursuing a dual approach to achieve the transformation away from oil, particularly substitution with alternative liquid fuels and/or electricity. Ideally, this transformation would be achieved by substituting a domestic liquid fuel for oil, preferably from a sustainable source and suitable for distribution via existing pipelines. Unfortunately, at this time there is no obvious large-scale substitute that would meet such requirements. The current approach to corn-based ethanol use in transportation drives up the cost of food and its production consumes almost as much energy as it provides.⁷ The United States must continue seeking sustainable biofuel options that do not compete with food or water use.

One of the most effective avenues for reducing near-term oil use in the transportation sector is electrification. The distribution infrastructure is in place and the vehicles are already entering the marketplace. In addition to substituting for oil, electrification increases overall transportation system efficiency.⁸ It can reduce greenhouse gas emissions and is one of the few technology options capable of directly using renewable generation for transportation. Furthermore, electrified transportation allows essential economic activity to continue even if major oil supply disruption occurs.

This document expands on the key actions and investments that IEEE-USA believes are necessary to reduce U.S. dependence on oil by transforming transportation.
ELECTRIFYING TRANSPORTATION: PLUG-IN ELECTRIC VEHICLES

Plug-in electric vehicles (PEVs) are a class of vehicles which can be charged by electricity through an electric plug. Specific vehicle types covered by this position statement include:

- Plug-In Hybrid Electric Vehicles (PHEV) – similar to conventional Hybrid Electric Vehicles (HEV) except for the ability to charge the battery directly from an electric socket,
- Extended Range Electric Vehicles (EREV) – electric drive vehicles with fuel-engine-driven generators capable of recharging their batteries,
- Battery Electric-only Vehicles (BEV) – all electric drive vehicles with no supplemental engine, and
- Pluggable fuel cell electric vehicles.

**Recommendation:** Developing and pursuing a general strategy to electrify transportation, including mass transit, passenger and commercial vehicles, buses, and short- and long-distance rail.

The most important electrification target should be light duty and heavy-duty vehicles (primarily freight trucks, but also buses). These two uses represent about 60 percent and 20 percent of transportation energy use, respectively. Target markets should include both individual-owned vehicles as well as fleets, for example, delivery services, rental cars and buses.

Commercially available hybrid-electric vehicles (HEVs) are already starting to create benefits to U.S. energy use patterns through decreased oil consumption by light duty vehicles and associated enhancements to national security. The most energy efficient hybrids cut gasoline consumption by around 40 percent compared with similar conventional cars. As outlined below, aggressive pursuit of further electrification can result in major reduction in oil use, increased transportation energy efficiency, reduced maintenance costs, and reduced greenhouse gas emissions.

Plug-in electric vehicles (PEVs) reduce oil consumption by operating some or all of the time in an electric mode using grid-supplied electricity generated from diverse domestic energy sources such as renewables, nuclear, gas and coal. It has been estimated that PEVs with a 32 km (20 mile) battery would replace half of the gasoline consumption with electricity (IEEE Spectrum, July 2005). Electric-only vehicles completely eliminate the consumption of liquid fuels.

PEVs make possible the conversion of many vehicle functions that are currently either mechanical or hydraulic to electricity because of on-board electric power that well exceeds that available from a traditional alternator. This creates new avenues for reengineering the car, including new efficiency improvements and reduction in moving parts, with an attendant reduction of maintenance costs for the owner. For example, electromagnetic valve lifters designed to keep the engine operating at its optimal point are practical in PEVs. Use of electric motors and power electronics for the vehicle drive train can eliminate gear boxes and can greatly simplify transmission design and vehicle maintenance. PEV drive trains also permit capture of energy that would normally be expended
heating brake liners during vehicle slowing and the electric drive allows the vehicle’s combustion engine to be operated in a more efficient power cycle.

Electrified transportation can make a major contribution to meeting goals for reducing greenhouse gases. If the electricity to run the vehicles is produced by nuclear, hydro, wind, or solar, there is no carbon dioxide released in the electricity production and none while the electricity stored in the battery runs the vehicle. In fact, electric transportation reduces GHG emissions even when electricity is produced from currently installed generation capacity mix.8

Rail electrification offers further opportunities for zero-emission, zero-oil freight and passenger transportation. If high-traffic rail lines were electrified and powered in part by renewable energy sources, that investment would reduce nationwide carbon emissions and oil consumption. An obvious target is increased reliance on light rail, a form of urban rail public transportation that generally has a lower capacity and lower speed than heavy rail and metro systems, but higher capacity and higher speed than traditional street-running tram systems. The term is typically used to refer to rail systems with rapid transit-style features that usually use electric rail cars operating mostly in private rights-of-way separated from other traffic.12

Amtrak operates the busiest intercity electrified corridor in the nation from Boston to Washington, DC through New York City. Many other electrified rail lines serve both regional commuters and freight. Electrification should be extended to other parts of the country where passenger rail operations run on track owned by the freight railroads. The relationship with passenger rail operators enables partnerships that could take additional commuters out of their cars and onto trains.

The strategy must also recognize the challenges that have to be overcome before reaching a broad-based electrified transportation system. These challenges are detailed in further Recommendations offered below.

**Recommendation: Reducing the use of oil by promoting the rapid deployment of PEVs.**

Light duty vehicles are mainly used for passenger transportation and come in a variety of body styles, such as cars, vans, SUVs, and pickup trucks. Depending on other details, there are between 190 million and 230 million such vehicles registered in the United States.13 Sales of new vehicles of this type range from 7 million to 14 million per year,14 depending on economic and other conditions. At this rate it would take at least 10 years to electrify one half of the vehicles, even if the entire new car market were to be converted to PEVs. This hypothetical scenario illustrates the magnitude of the challenge and the importance of a rapid and sustained effort. The Administration’s initial goal is deployment of one million PEVs by 2015.

Critical for the rapid deployment of PEVs is the construction of the PEV charging infrastructure. This in turn presents numerous challenges in both technology and business models that will need to be addressed to achieve stable growth in PEV deployment. On the other hand, connecting transportation to the power grid creates new synergies and opportunities, such as electrified roadways, that will have to be exploited to accelerate progress. A period of intense innovation and experimentation can be expected.

One of the questions that arises in the context of broad deployment of electric transportation is its impact on the electric grid. As discussed in the IEEE publication, The Institute, for example PJM15 could
readily absorb its share of 1 million vehicles on the road without adding any new power plants.\textsuperscript{16} However, several electric vehicles on one residential street could overload the local distribution transformer\textsuperscript{17} unless demand control measures are implemented to enforce load diversity and prevent a possible overload. There is ample experience with success of such controls applied to off-peak heating and water heating.\textsuperscript{18}

It should also be noted that there is a high degree of synergy between PEVs and renewables. PEV batteries could serve as an energy storage network and enhance the integration of variable and uncertain energy sources into the electric power grid. Another form of synergy is in the timing of PEV charging and wind availability — battery charging is mostly an overnight activity and the wind resource tends to be strong at night. Even if all of the 190 million cars were replaced by PEVs, it may not be an insurmountable problem for the grid. A roughly 20 percent\textsuperscript{19} penetration of wind power could provide the entire electricity supply needed for battery charging.

With the appropriate technical and regulatory framework, the PEV batteries may also be able to provide services needed by the grid to balance the variability of wind power. For the near term, automobile manufacturers are concerned about the effects that providing such services may have on battery lifetime and warranties. In the longer term, as battery technology improves and the determinants of battery lifetime are better understood, these issues are expected to be manageable. Initial deployment for grid services is more likely with fleet vehicles, for which arrangements are more easily structured and experience is more easily documented.

Electrifying transportation would have additional benefits beyond national security and energy independence — it represents a major potential area of economic development and growth. The need for charging stations alone represents creation of an entire new industry for producing, maintaining, and managing the charging infrastructure.

**Recommendation: Promoting the development and deployment of battery charging infrastructure**

Having pluggable electric vehicles will require the broad deployment of infrastructure for vehicle charging. The charging does not necessarily require a wired connection; short-distance unwired charging (induction charging) should also be anticipated.

There are three broad classes of charging infrastructure:

- **Slow charging** (“Park-and-Charge”) - in which the vehicle is connected to the grid for a period measured in hours, allowing extensive interaction with the grid for vehicles appropriately equipped. Relatively simple charging stations at owners’ and/or employers’ premises will provide the basic requirement for charging PHEVs which can operate on gasoline, if needed.

- **Fast charging** (“Charge-and-Go”) - in which the vehicle is connected to the grid for a period measured in minutes. This type of charging is done at very high power rates and may be particularly useful for extending the range of BEVs and helping with “range anxiety.” It could also extend the electric range of plug-in hybrids and thereby displace more oil. However, this type of charging could also have an adverse impact on the battery life.

- **Battery exchange** - in which battery swapping stations are located along major highways to accommodate vehicles taking trips beyond their battery capacity. This approach may be difficult to standardize because of differences in vehicle design.
The challenge of charging infrastructure will need to be addressed at all levels of government, because in most cases the features of residential, commercial, and industrial properties and of public streets are matters controlled by state and local governments. Examples of issues that need to be addressed include:

- Whether or not charging stations are within the scope of electric utility services. (A recent decision of the California Public Utility Commission stated that charging stations are not public utilities, subject to utility regulations.)
- Building and zoning code issues related to residential charging stations in home garages and driveways. Examples of these issues include electric service requirements for residences and zoning rules (or permissible neighborhood covenant restrictions) that govern placement and allowable locations for ancillary structures, such as charging stations, on residential properties and building properties and building and zoning code requirements for charging stations in parking lots and parking structures of commercial, industrial, and multifamily residential buildings.
- Municipal deployment of charging stations along public streets, possibly incorporated into parking meters.
- Technologies for fast recharge (e.g., 480 volts, fast DC, and fast-pulsed recharge) and the development of the requisite power electronics.

The Smart Grid teams of experts are considering the technologies for the charging infrastructure itself as well as metering, billing, and settlement of electric use by PEVs.

**Recommendation: Accelerating and diversifying research to improve battery technologies, to extend vehicle all-electric range; increasing energy storage density; decreasing cost; improving life and safety; and optimizing the associated power electronics and controls.**

Battery technology is a key component of electric vehicles and its cost is the principal barrier to rapid penetration of PEVs. There have been encouraging research announcements regarding battery technology and materials. As to materials, it has been said that much of the world’s lithium is produced in Chile, China and Bolivia, therefore its supply is subject to political considerations, however the lithium industry is expanding. Also, recent announcements include batteries made from much more common materials such as metals or silicon and air. Many of these advanced batteries are not yet rechargeable, but because of heavy research investment, battery innovation is moving rapidly and practical means may be developed for “renewing” some of these types of batteries.

Other materials concerns involve the need for rare earths in producing permanent magnet electric motors. However, alternatives are available in new motor technology (switched reluctance motors and induction motors) that have higher average efficiency and do not require rare-earths.

Advances in battery performance and technology are required to reduce cost, increase power density, extend life, reduce the probability of hazardous failure and promote consumer safety.
In the near term, improvements in engineering and management of lithium-ion battery systems are likely to deliver some of these needs.

For the longer term, novel battery chemistries, for example metal-polymer, metal-air and silicon-air, could yield more dramatic advances in performance as well as a potential to make batteries from more common materials.

In parallel with battery development, R&D is needed on power electronics for PEVs to reduce size and cost, improve fast-charging capability, and facilitate use of efficient motors (such as induction and switched reluctance technologies) that eliminate use of rare-earth materials.

**Recommendation:** Promoting research on the integration of PEVs on the electric grid and the development of industry consensus standards to realize their full potential benefits.

There are four potential levels of PEV-grid integration:

- **Constant rate charging with no grid coordination.** In this case, the PEV is plugged in as any other load and there is no communication with the grid. This is likely useful only for low power slow charging or low vehicle penetration.

- **Constant rate charging with grid coordination.** When the vehicle is plugged in, communication is started with the charging station and coordination is started with the grid. This enables either price or other demand response actions that help manage the overall PEV load on the grid.

- **Variable rate charging.** This approach allows the PEV to participate in grid balancing and other adjustments, including frequency regulation and voltage support, by varying the load they present to the grid.

- **Vehicle as grid energy storage.** The vehicle battery is either charged from the grid or provides power back to the grid, according to conditions and grid coordination.

It is expected that operational aspects of grid integration of PEVs will be handled mainly by the Smart Grid. The architecture being developed in the NIST-lead effort (http://www.nist.gov/smartgrid) identifies the actors and interfaces related to communications, control, metering, accounting, and settlement for PEVs. The relevant Domain Experts Working Group and Priority Action Plan teams are charged with identifying pertinent standards and unmet needs, and assigning the identified gaps to Standards Developing Organizations. Efforts are taking place with significant coordination and cross-participation in IEEE, SAE, the EPRI Infrastructure Working Council, IEC, ANSI, and other organizations.

PEVs are likely to have other technical impact on the grid that will need to be considered. For example, some utilities depend on overnight cooling of distribution transformers, cables and conductors to achieve reliability. As discussed earlier in this document, if overnight load levels remain high because of PEV charging, transformer reliability and lifetimes could be affected. Data on transformer and distribution system loading will be required to manage the PEV charging at higher saturations. New intelligent systems will be needed to optimize performance and reliability, minimize cost, diversify the load, manage potential cold load pick-up surges, and coordinate generation pricing and user decisions.
Pilot projects are ongoing to study the integration of PEVs into the grid and to learn the issues that must be addressed in widespread deployment. Some early results of these studies include:

- In a pilot study conducted by the PJM Interconnection, vehicles earned up to $200 per month by providing balancing and frequency regulation (ancillary services).

- For operational purposes related to variable generation (such as solar and wind) PJM is considering a 5-minute-ahead market that would likely increase the value of PEV-supplied ancillary services as compared to conventional generation.

For the near term, automobile manufacturers are concerned about the effects that providing ancillary services will have on battery lifetime and warranties. In the longer term, as battery technology improves, these issues are expected to be manageable. However, there has been interest by fleet vehicle owners in supplying ancillary services while their vehicles are charging.

An important consideration is that batteries are no longer suitable for vehicle use when their capacities fall below about 70 percent of design capacity. However, even at that level the batteries are suitable for use in stationary storage applications, and may eventually contribute to the need for large scale energy storage identified in the IEEE-USA National Energy Policy Recommendation on “Building a Stronger and Smarter Electrical Energy Infrastructure”. Also, products are coming to market for use on distribution systems that have storage using PEV-type batteries and “four quadrant” charger/inverter electronics. Such devices can perform advanced functions similar to those anticipated for PEVs. The use of PEV-type batteries in coordination with the electric grid contributes to production economies of scale. Smart Grid technology will be needed to fully exploit these opportunities.

Recycling of EV batteries is likely to be easier than lead-acid, but must be addressed.

Regulatory issues also affect the extent to which it will be possible to integrate PEVs with the electric grid. Without an effort to standardize the processes drivers will inevitably encounter problems as they travel between jurisdictions. Examples include:

- Differences in rules for vehicle-to-grid relationships. In some jurisdictions vehicles may participate in ancillary services markets. In other jurisdictions such markets do not exist. A vehicle roaming from one jurisdiction to another will encounter a variety of rules.

- Lack of cross-jurisdictional arrangements for payment and settlement. This especially applies to vehicles that roam from one jurisdiction to another.

- Determination of whether charging infrastructure is a utility function or not. Again, each jurisdiction makes its own rules. In some jurisdictions a vehicle owner may deal with a utility and in others the vehicle owner may need to make private arrangements. This issue is further discussed below.

- Differences in possible market structures in various jurisdictions. Some jurisdictions might allow aggregators, others might require them to meet minimum market participation size requirements, and still others might not allow them. Aggregators can act as critical intermediaries between vehicle owners and complex market structures.
Recommendation: Encouraging the development of secure communication and control systems that permit full realization of all the potential benefits of vehicle-to-grid energy exchange functions.

The levels of grid interaction described above require increasing levels of communication and control. There are a number of elements involved in these functions, including:

- The vehicle
- The charging station
- The premises network (home, building, commercial or industrial site)
- The Load Serving Entity and/or aggregator that coordinates numerous loads for the grid
- Transmission and distribution grid operator
- Entities that manage accounting, billing, and settlement

Proper coordination among these elements will be needed to fully realize the benefits of vehicle-to-grid energy exchange functions. Some of that coordination will need to take place as often as every four seconds.

IEEE-USA endorses FERC’s emphasis on electrification of transportation as one of the priority areas in its Smart Grid policy statement (http://www.ferc.gov/whats-new/comm-meet/2009/071609/E-3.pdf). This FERC policy resulted in electric transportation becoming a priority issue in the NIST Smart Grid efforts (http://www.nist.gov/smartgrid/). These efforts have resulted in:

- Definition of a conceptual architecture for communications, control, and integration of PEVs into the grid. For example, the architecture includes separate sub-metering of the PEV to support pricing arrangements and vehicle-to-grid accounting.
- Acceleration of standards development to support PEV-related requirements.
- Identification of cybersecurity issues related to PEV communications and incorporation of PEV standards into the Smart Grid Catalog of Standards after cybersecurity review.
- Identification of the significant privacy issues associated with communications, control, and especially metering and accounting related to PEVs.
- Development of a draft four stage roadmap for electric vehicle deployment that identifies the challenges and issues to be addressed to reach each stage including elimination of barriers and advancement of functionality.

While it is important to integrate PEVs with the Smart Grid, such integration raises numerous cybersecurity and privacy issues, which have to be addressed. Examples include:

- Implementing Smart Grid cybersecurity requirements as these apply to PEVs. These requirements are outlined in NISTIR 7628, Guidelines for Smart Grid Cyber Security: Vol. 1, Smart Grid Cyber Security Strategy, Architecture, and High-Level Requirements
- Implementing Smart Grid privacy requirements, involving access control or tamper protection of the data, as these are developed in detail. Some of the implementation will be accomplished through the cybersecurity requirements (such as encryption protecting confidentiality) but others will be specific to market arrangements.
• Integrity of the supply chain for the hardware and software that implements PEV communications and control, especially as it applies to interactions with the grid.

• Management of cryptographic keys for encryption and authentication of PEV-related messages.

• Methods for secure upgrade of PEV software to support improvements in PEV integration and procedures for grid interaction.

• Implications of recent news reports regarding studies by the Transportation Research Board that indicate the possibility of malicious access to on-board vehicle systems. The access was reportedly achieved by exploiting vulnerabilities of wireless features on the vehicles.

Examples of privacy issues include:

• Location and movement tracking — concern that a PEV could be tracked via an electronic “trail,” opening up a variety of privacy issues common to numerous systems.

• Retention in back-end enterprise networks of information that includes sufficient personal identification to make it potentially suitable for numerous privacy-invading purposes. Examples of such back-end networks could include systems for billing and settlement as well as systems that retain grid operational history.

• Basic issue in PEV travel across jurisdictions of whether the vehicle roams or the driver roams, and the privacy impacts of being able to track them either individually, or both in conjunction.

• Cost and settlement infrastructure for roaming. There are numerous examples, such as credit cards, cell phones, and multi-jurisdictional toll road payment systems. However, such a system needs to be worked out for PEVs and its privacy implications evaluated.

• Identity theft, facilitated by misuse or intrusion on back-end systems, communications, or the devices in the PEV.
As discussed above, liquid fuel alternatives are needed to complement oil displacement accomplished by electrified transportation and to extend the range of PEVs beyond the limits imposed by their battery capacity.

**Recommendation: Passing legislation to mandate fuel flexibility.**

Vehicle fuel flexibility — the ability of a vehicle to operate with multiple fuels, such as gasoline, ethanol, methanol, natural gas, and others — is a well understood technology in common use in many countries. Brazil is a leading country in modern deployment of this technology. The Brazilian government mandated fuel flexibility in the early 1990’s, and several generations of the technology have been deployed. Fuel flexible vehicles have been sold in the United States. In fact, the first flexible fuel vehicle was the Ford Model-T although most modern U.S. vehicles allow only up to a 10 percent ethanol blend. There is minimal impact on the cost of the vehicles, and the technology could easily be provided as a standard feature of all vehicles. All that is needed to move toward nationwide fuel flexibility is a legal mandate to provide the technology in vehicles sold in the United States.

Various potential liquid fuels, as well as natural gas, have widely varying attributes regarding production requirements, costs, impact on the vehicle performance, the fuel distribution system, and emissions. For example, ammonia can be produced directly from natural gas or from water using electricity and has no carbon emissions when burned, but requires different characteristics of the vehicle engine and fuel distribution system. Also, the car’s NOx emissions would increase. We need to aggressively explore the universe of potential choices and their implications and focus the R&D accordingly.

**Recommendation: Promoting fuel flexibility in the fuel distribution system and advanced control technologies to maximize efficiency and minimize emissions across the spectrum of fuels.**

Having fuel flexibility in vehicles has no value unless alternative fuels are widely available. A flexible fuel distribution system must be in place as well so as to deliver the alternative fuels to vehicles. Currently even diesel fuel is not widely available in some areas of the United States. Promotion of the availability of alternative fuels could include a variety of incentives and mandates, but this is a challenge that should be addressed as part of a fuel flexibility mandate. Fuel flexibility may also require advances in vehicle controls to maximize efficiency and minimize emissions while using multiple fuels that may be mixed in vehicle fuel tanks.
**Recommendation: Pursuing aggressive new R&D to convert sustainable biomass (including algae) to transportation fuels.**

Sustainability is a factor that must be incorporated into biomass use for fuel. It may well require that no arable land be used for biofuel production. At the minimum, the fuel production should be based on biomass that does not compete with food and does not increase water use. Some of the considerations include:

- The widely reported impact of food-based biofuel production on worldwide food prices. This is caused by tightening the market for food and switching farmland from production intended for food to production of biofuel feedstock. This is generally referred to as indirect land-use impacts.

- The greater productivity feasible with non-food-stock biofuel. For example, according to a report prepared for the Chesapeake Bay Commission, corn produces only 30 gallons of ethanol per acre per year, but a properly operated algae facility can produce fuel in the range of 3,000 to 5,000 gallons per acre per year.

Indeed, algae, while a long-term option, appears to be a very promising alternative. Processing of algae can produce oils by squeezing and ethanol by fermentation processes using the residue after the oils have been squeezed out. Chemical processes provide additional options for extracting fuel from algae. This will require R&D, some of which is already being pursued under ARRA grants for reuse of carbon dioxide. For example, carbon dioxide output of power plants is being used experimentally to grow algae as feedstock for transportation fuel production. Target fuels include both surface transportation fuels and aircraft jet fuel. The U.S. Department of Defense is particularly aggressive in planning to switch to renewable biofuels. The Navy and Air Force are testing biofuels for aviation and shipboard use and are planning to use at least 50 percent biofuels by 2020.
Summary

Electrified transportation and liquid fuel alternatives are complementary technology paths to oil displacement. Electric transportation in particular can:

- Increase transportation energy efficiency
- Reduce urban smog and
- Reduce greenhouse gas emissions

However, achieving significant penetration of these technologies requires a sustained effort aimed at resolving a number of research, engineering, and business issues. One of the most significant needs is the development of less expensive, higher performance batteries.
Endnotes


3 See, for example, “U.S. International Trade in Goods and Services (FT900), April 2011,” U.S. Census Bureau, June 2011

4 R. James Woolsey, How to End America’s Addiction to Oil, Wall Street Journal, April 15, 2010


6 See, for example “A partial list of products made from Petroleum” at http://www.ranken-energy.com/Products%20from%20Petroleum.htm


8 See, for example, Environmental Assessment of Plug-In Hybrid Vehicles, Vol. 1: Nationwide Greenhouse Gas Emissions, EPRI-NRDC July 2007


10 See, for example, comparison of 2011 conventional and hybrid Honda Civic in city driving (http://www.afdc.energy.gov/afdc/vehicles/electric_benefits.html)

11 Increased use of natural gas resources in contrast to coal would also contribute to lowering greenhouse gasses.


14 Ibid, Table 1-12: U.S. Sales or Deliveries of New Aircraft, Vehicles, Vessels, and Other Conveyances (Updated April 2011), http://www.bts.gov/publications/national_transportation_statistics/html/table_01_12.html

15 PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.


18 See, for example, IEEE Tutorial Course: Fundamentals of Load Management/89Eh0289-9-Pwr (1988)

19 The above estimate is based on a 16 kilowatt-hour battery. To fully charge all batteries every day would take about 1 billion megawatt hours annually. Added to the current total U.S. electric generation of about 4 billion megawatt hours, this represents about 20% of electricity needs.

20 California Public Utilities Commission, Rulemaking 09-08-009, Decision in Phase 1 On Whether a Corporation or Person That Sells Electric Vehicle Charging Services to the Public Is a Public Utility, Decision 10-07-044, July 29, 2010

21 http://www.nist.gov/smartgrid/sgip-072611-factsheet.cfm


23 See also DOE’s Quadrennial Technology Review 2011, DOE/S-0001, September 2011 (http://energy.gov/sites/prod/files/ReportOnTheFirstQTR.pdf), for an excellent description of battery research needs.

24 IEEE Computational Magazine, special issue on the Smart Grid, August 2011


28 Chesapeake Bay Commission and Commonwealth of Pennsylvania, Next-Generation Biofuels: Taking the Policy Lead for the Nation, September 2008
