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GAO

Report to Congressional Requesters

June 2009

FEDERAL ENERGY AND FLEET MANAGEMENT

Plug-in Vehicles Offer Potential Benefits, but High Costs and Limited Information Could Hinder Integration into the Federal Fleet

GAO-09-493

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Highlights

Highlights of GAO-09-493, a report to congressional requesters

Why GAO Did This Study

The U.S. transportation sector relies almost exclusively on oil; as a result, it causes about a third of the nation's greenhouse gas emissions. Advanced technology vehicles powered by alternative fuels, such as electricity and ethanol, are one way to reduce oil consumption. The federal government set a goal for federal agencies to use plug-in hybrid electric vehicles—vehicles that run on both gasoline and batteries charged by connecting a plug into an electric power source—as they become available at a reasonable cost. This goal is on top of other requirements agencies must meet for conserving energy. In response to a request, GAO examined the (1) potential benefits of plug-ins, (2) factors affecting the availability of plug-ins, and (3) challenges to incorporating plug-ins into the federal fleet. GAO reviewed literature on plug-ins, federal legislation, and agency policies and interviewed federal officials, experts, and industry stakeholders, including auto and battery manufacturers.

What GAO Recommends

GAO recommends the Department of Energy (DOE)—in consultation with other agencies—propose legislative changes to resolve conflicts among energy and vehicle acquisition requirements. GAO also recommends DOE and the General Services Administration (GSA) provide guidance to help agencies make decisions about acquiring plug-ins. GSA agreed with our recommendations, and DOE did not comment.

View GAO-09-493 or key components.
For more information, contact Susan Fleming at (202) 512-2834 or flemings@gao.gov or Mark Gaffigan at (202) 512-3841 or gaffiganm@gao.gov.

What GAO Found

Increasing the use of plug-ins could result in environmental and other benefits, but realizing these benefits depends on several factors. Because plug-ins are powered at least in part by electricity, they could significantly reduce oil consumption and associated greenhouse gas emissions. For plug-ins to realize their full potential, electricity would need to be generated from lower-emission fuels such as nuclear and renewable energy rather than the fossil fuels—coal and natural gas—used most often to generate electricity today. However, new nuclear plants and renewable energy sources can be controversial and expensive. In addition, research suggests that for plug-ins to be cost-effective relative to gasoline vehicles the price of batteries must come down significantly and gasoline prices must be high relative to electricity.

Auto manufacturers plan to introduce a range of plug-in models over the next 6 years, but several factors could delay widespread availability and affect the extent to which consumers are willing to purchase plug-ins. For example, limited battery manufacturing, relatively low gasoline prices, and declining vehicle sales could delay availability and discourage consumers. Other factors may emerge over the longer term if the use of plug-ins increases, including managing the impact on the electrical grid (the network linking the generation, transmission, and distribution of electricity) and increasing consumer access to public charging infrastructure needed to charge the vehicles. The federal government has supported plug-in-related research and initiated new programs to encourage manufacturing. Experts also identified options for providing additional federal support.

To incorporate plug-ins into the federal fleet, agencies will face challenges related to cost, availability, planning, and federal requirements. Plug-ins are expected to have high upfront costs when they are first introduced. However, they could become comparable to gasoline vehicles over the life of ownership if certain factors change, such as a decrease in the cost of batteries and an increase in gasoline prices. Agencies vary in the extent to which they use life-cycle costing when evaluating which vehicle to purchase. Agencies also may find that plug-ins are not available to them, especially when the vehicles are initially introduced because the number available to the government may be limited. In addition, agencies have not made plans to incorporate plug-ins due to uncertainties about vehicle cost, performance, and infrastructure needs. Finally, agencies must meet a number of requirements covering energy use and vehicle acquisition—such as acquiring alternative fuel vehicles and reducing facility energy and petroleum consumption—but these sometimes conflict with one another. For example, plugging vehicles into federal facilities could reduce petroleum consumption but increase facility energy use. The federal government has not yet provided information to agencies on how to set priorities for these requirements or leverage different types of vehicles to do so. Without such information, agencies face challenges in making decisions about acquiring plug-ins that will meet the requirements, as well as maximize plug-ins' potential benefits and minimize costs.

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Abbreviations

AFV	Alternative Fuel Vehicle
ARRA	American Recovery and Reinvestment Act of 2009
CO_2	carbon dioxide
DOD	Departments of Defense
DOE	Department of Energy
EISA	Energy Independence and Security Act of 2007
EPA	Environmental Protection Agency
EPAct 1992	Energy Policy Act of 1992
EPAct 2005	Energy Policy Act of 2005
EPRI	Electric Power Research Institute
FEDFLEET	Federal Fleet Policy Council
E85	Ethanol
GSA	General Services Administration
INTERFUEL	Interagency Committee for Alternative Fuels and Low-Emission Vehicles
mpg	miles per gallon
SUV	sport utility vehicle
USPS	United States Postal Service

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United States Government Accountability Office
Washington, DC 20548

June 9, 2009

The Honorable Henry Waxman
Chairman
Committee on Energy and Commerce
House of Representatives

The Honorable Edolphus Towns
Chairman
The Honorable Darrell Issa
Ranking Member
Committee on Oversight and Government Reform
House of Representatives

The nation faces a number of energy-related challenges, including heavy reliance on oil, environmental stress from greenhouse gas emissions caused by burning fossil fuels, and public health problems associated with local air pollution. While many sectors of the economy contribute to these problems, the transportation sector poses particular challenges because of its nearly exclusive reliance on oil. Stakeholders from industry, environmental groups, and others, as well as Congress, are working to identify strategies to address these challenges, including the development of vehicles that use advanced technology to make substantial improvements in fuel economy.

Plug-in vehicles, which use electricity to charge a battery that helps to power the car, are one type of these advanced technologies. Manufacturers plan to introduce plug-ins—a term that encompasses several vehicle designs—into the market in the next few years, and federal agencies have already been directed to adopt this technology into the federal fleet. Specifically, Executive Order 13423[1] calls for federal agencies to begin using plug-in hybrid electric vehicles when they become commercially available and can be procured at a reasonably comparable life-cycle cost to conventional gasoline-powered vehicles. In this context, you asked us to determine (1) potential benefits and challenges associated with plug-ins; (2) current status of development and factors that could either delay availability or encourage development, including those

[1]Strengthening Federal Environmental, Energy, and Transportation Management, Exec. Order No. 13423 (Jan. 24, 2007).

available to the federal government; and (3) challenges to incorporating plug-in hybrids or all-electric vehicles into the federal fleet.

To address these objectives, we reviewed the goals outlined in Executive Order 13423 that encourage the integration of plug-in hybrid vehicles into federal fleets, as well as federal statutory requirements related to the acquisition of alternative fuel vehicles. To broaden our understanding of the potential benefits, current status of development, and factors that could delay availability of plug-ins, we analyzed research studies and interviewed experts from industry, academic, and government sources. To determine the current status of plug-in vehicles, we obtained information directly from Chrysler, Ford, General Motors, Phoenix Motorcars (a small manufacturer of all-electric vehicles), Toyota, and the Association of International Automobile Manufacturers. We also reviewed published material on other auto manufacturers' Web sites about the plug-ins that manufacturers plan to bring to market. To identify factors affecting availability and development of plug-ins that could be addressed by the federal government, we analyzed and synthesized information from experts and recent research. We considered these in light of the potential costs of federal government actions, as well as what role the government might play relative to other stakeholders who also stand to benefit from this technology. We used professional judgment in identifying the relative benefits and limitations of these options. To identify the challenges of incorporating plug-in hybrids or all-electric vehicles into the federal fleet, we reviewed federal fleet documents and relevant laws and regulations governing fleet management and procurement. We interviewed officials from the General Services Administration (GSA) about the federal motor vehicle procurement process and spoke with fleet managers from a selected group of agencies—namely, the Departments of Defense (DOD) and Energy (DOE), the General Services Administration (GSA), and the United States Postal Service (USPS)[2]—about the challenges plug-ins might pose for the federal fleet. We chose DOD and USPS because they have the largest federal fleets, while DOE and GSA have much smaller fleets, which provided perspective on the challenges agencies with different sized fleets and resources could have in meeting the executive order. Finally, we conducted nine visits to organizations that are conducting research on plug-in vehicle technology or are field testing plug-in vehicles through

[2]While USPS is considered part of the federal fleet in terms of complying with the government's alternative fuel vehicle acquisition requirements, it is not subject to Executive Order 13423. However, USPS officials indicated they would make every effort to comply with the executive order.

demonstration fleets. We conducted this performance audit from July 2008 to June 2009, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. (For more information on our scope and methodology, see app. I.)

Background

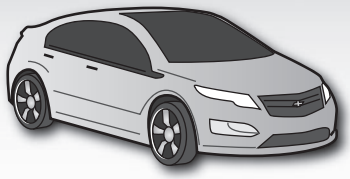
"Plug-ins" refer to vehicles that can be plugged into an electrical outlet to charge the car's battery. The option to plug in and charge is also the basic difference between a plug-in and a "conventional hybrid," which uses both gasoline and stored energy in a battery to power the vehicle. Battery technology plays an important role in the development of plug-ins. Nickel metal hydride batteries—such as those currently used in existing conventional hybrid vehicles—can only store enough energy for limited all-electric driving without the batteries being made so large as to affect the vehicle's fuel economy. As a result, many manufacturers are developing lithium-ion batteries because they have the potential to store more energy and are typically smaller and lighter than batteries currently in use.[3]

Plug-ins are expected to come equipped with a 110-volt plug that can be used with any standard electrical outlet. Some manufacturers also plan to make 220-volt charging an option, which requires the same type of outlet as used for household appliances like clothing dryers. With a 110-volt plug, manufacturers estimate that most plug-ins will reach a full charge if the vehicle were plugged in overnight (estimates are 8 hours depending on the size of the battery). A 220-volt plug can reduce that time by at least half. Technologies to further shorten the length of time needed to charge a plug-in are being explored. See figure 1 for descriptions of several types of plug-ins.

[3]USPS has about 30 all-electric delivery vehicles in Manhattan that use lead acid batteries.

Figure 1: Types of Plug-in Vehicles

Plug-in hybrid electric vehicle (PHEV)



Sample vehicle:
Chevrolet Volt

Drive power:	Electric motor (internal combustion engine can charge the battery but does not turn the wheels)
Fuel sources:	Gasoline pump and plug
Expected electric range:	About 40 miles

Sample vehicle:
Saturn Vue Green Line (plug-in version)

Drive power:	Electric motor and internal combustion engine
Fuel sources:	Gasoline pump and plug
Expected electric range:	About 10 miles

All-electric vehicle

Sample vehicle:
Phoenix Motorcars Sport Utility Truck

Drive power:	Electric motor
Fuel sources:	Plug
Expected electric range:	More than 100 miles

Neighborhood electric vehicle (NEV)

Sample vehicle:
Zenn Motor Company ZENN

Drive power:	Electric motor (maximum speed 25 mph)
Fuel sources:	Plug
Expected electric range:	30-50 miles

Source: GAO.

These plug-ins are powered differently:

- Plug-in hybrid electric vehicles (referred to as "plug-in hybrids" in this report) have both an internal combustion engine and a battery pack that

can power the vehicle.[4] Unlike conventional hybrid vehicles, plug-in hybrids offer drivers an "all-electric range" of driving powered by the battery, with an internal combustion engine that extends the overall range of the vehicle. Plug-in hybrids can be designed to use the two power sources in different ways. For example, as shown in figure 1, the plug-in version of the Saturn Vue Green Line can use its electric motor or gasoline-powered engine either separately or simultaneously to drive the vehicle's wheels. The Chevrolet Volt only uses power from the electric motor to drive the wheels. The gasoline engine in the Volt is used to generate additional power for the electric motor, but it does not use gasoline to power the wheels.

- All-electric vehicles, also known as battery electric vehicles, have an electric motor to turn the wheels powered by a battery. They do not have a backup gasoline-powered engine so they consume no liquid fuel and do not emit greenhouse gases. Unlike a plug-in hybrid, the driving distance of these vehicles is limited to the storage capacity of the battery, which, once reached, must be plugged back into an outlet before the car can be driven further.
- Neighborhood electric vehicles, also known as low-speed vehicles, are all-electric vehicles that cannot travel faster than about 25 miles per hour and are subject to different federal safety standards from normal cars.[5] These vehicles are suitable for use on campuses, military bases, and—because they tend to be small and do not produce emissions by burning fuel—inside buildings like warehouses. Some states also permit the use of these vehicles on state highways.

The development of plug-ins is, in part, a response to federal and state actions to address growing concerns over the reliance of the transportation and automotive sectors on petroleum and the resulting environmental effects of fuel consumption. Two of the key efforts to get auto manufacturers to produce more fuel-efficient and low-emitting vehicles include corporate average fuel economy standards—which have been raised to require auto manufacturers to achieve a combined fuel economy average of 35 miles per gallon (mpg) for both passenger and non-passenger vehicles beginning in model year 2020[6]—and California's Zero

[4]Plug-in vehicles may also have other components that recapture energy to charge the battery. For instance, regenerative brakes capture energy generated from deceleration and use that energy to recharge the car's battery.

[5]*See generally* 49 C.F.R. Part 571.

[6]Pub. L. No. 110-140, §102, 121 Stat. 1498 (Dec. 19, 2007).

Emission Vehicle program—which has a goal of increasing the number of low-emission vehicles in California and was recently modified and includes plug-in hybrids, conventional hybrids, and all-electric vehicles.

The federal government is also trying to reduce petroleum consumption in federal fleet vehicles by requiring agencies to take several actions and by setting a number of goals and requirements for federal agencies, as follows:

- *Begin acquiring plug-in hybrid electric vehicles:* Executive Order 13423 sets a goal for federal agencies operating fleets of 20 or more vehicles to begin using plug-in hybrids when these vehicles become commercially available and can be purchased at a cost reasonably comparable to conventional vehicles based on life-cycle costs.
- *Acquire low greenhouse gas emitting vehicles:* The Energy Independence and Security Act of 2007 (EISA) prohibits agencies from acquiring any light-duty motor vehicle or medium-duty passenger vehicle that is not a "low greenhouse gas emitting vehicle."[7]
- *Decrease petroleum consumption:* EISA also establishes the requirement of decreasing annual vehicle petroleum consumption at least 20 percent relative to a baseline established by the Energy Secretary for fiscal year 2005.
- *Acquire alternative fuel vehicles (AFV):* The Energy Policy Act of 1992 (EPAct 1992) requires that 75 percent of all vehicles acquired by the federal fleet in fiscal year 1999 and beyond be AFVs. Eligible vehicles include any vehicle designed to operate on at least one alternative fuel,[8] including electric vehicles and plug-in hybrids. GSA considers neighborhood electric vehicles to be equipment, rather than vehicles;

[7]The Environmental Protection Agency (EPA) is in the process of defining low greenhouse gas emitting vehicles. An agency may instead demonstrate that it has adopted cost-effective policies to reduce its petroleum consumption sufficiently to achieve a comparable reduction in greenhouse gas emissions.

[8]Alternative fuel under EPAct 2005 includes: methanol; ethanol; and other alcohols; blends of 85 percent or more of alcohol with gasoline; natural gas and liquid fuels domestically produced from natural gas; liquefied petroleum gas (propane); coal-derived liquid fuels; hydrogen; electricity; biodiesel (B100); fuels (other than alcohol) derived from biological materials; and p-series fuels, which are fuel mixtures designed to operate in extreme cold weather conditions.

acquiring them does not help agencies meet the AFV acquisition requirement.[9]

- *Use alternative fuel with AFVs:* The Energy Policy Act of 2005 (EPAct 2005) requires that all AFVs be fueled with alternative fuel. However, DOE guidance grants an agency a waiver from meeting the requirement if it can prove that alternative fuel is not available within 5 miles of or 15 minutes from a vehicle's address, or if the cost of alternative fuel exceeds that of conventional fuel.
- *Increase consumption of alternative fuels:* EISA requires that no later than October 2015 and each year thereafter, agencies must achieve a 10 percent increase in vehicle alternative fuel consumption relative to a baseline established by the Energy Secretary for fiscal year 2005.

The American Recovery and Reinvestment Act of 2009 (Recovery Act)[10] appropriated funding to help agencies meet some of these goals and requirements. For example, it provided $300 million for GSA to purchase vehicles with higher fuel economy.

Several federal agencies and offices play key roles in ensuring agency compliance with fleet related requirements. The Council on Environmental Quality is responsible for issuing instructions regarding implementation of Executive Order 13423.[11] DOE is responsible for issuing guidance to agencies relative to EPAct 1992 and 2005, and EISA; compiles an annual report on agencies' progress in meeting facility and fleet energy requirements that it submits to Congress; and promotes the development of plug-in technology. For example, DOE's Vehicle Technologies Program is actively evaluating plug-in hybrid technology and researching the most critical technical barriers to commercialization. Moreover, DOE performs battery testing and evaluation, vehicle simulation, and plug-in hybrid system testing through its work at Argonne and Idaho National

[9]The requirement covers federal fleets with 20 or more vehicles that are capable of being centrally fueled and operate in metropolitan statistical areas with a population of more than 250,000. Certain law enforcement, emergency, and military tactical vehicles are exempt from this requirement.

[10]Pub. L. No. 111-5, 123 Stat. 115 (Feb. 17, 2009).

[11]The Office of the Federal Environmental Executive, under the Council on Environmental Quality, is responsible for monitoring and reporting on agency's implementation of the executive order regarding plug-in vehicles governing the federal fleet, while DOE is primarily responsible for overseeing and administering the requirements under the law. In practice, however, according to the Office of the Federal Environmental Executive, it has delegated much of its responsibility to DOE.

Laboratories. DOE also provides financial support to promote the development of plug-in hybrid technology. For example, the department will contribute up to $30 million over 3 years for three cost-shared plug-in hybrid demonstration and development projects. These projects are expected to accelerate the development of plug-in hybrids capable of traveling up to 40 miles on electricity only without recharge.

The Office of Management and Budget (OMB) oversees agencies' implementation of fleet goals. Specifically, it provides recommendations to help agencies overcome barriers in meeting these goals and requirements through transportation management scorecards it issues semiannually. These scorecards track agencies' performance on a number of indicators.

GSA is responsible for acquiring vehicles for agencies to use in the federal fleet. Federal agencies may choose to purchase or lease vehicles for their motor vehicle fleets. With the exception of USPS, which can acquire its own vehicles or use GSA, agencies that choose to purchase vehicles are required by federal regulation to obtain them through GSA, which is able to acquire vehicles at significant discounts.[12] Although federal agencies may lease vehicles from whatever source they choose, including commercial lessors, most agencies lease from GSA because of the significant discounts it is able to offer. In addition to motor vehicles, GSA also lists specialized vehicles, such as neighborhood electric vehicles, on its supply schedules. Lastly, GSA also provides fleet management consulting services and guidance for federal agencies.

Three additional organizations of federal fleet managers exist to help agencies manage their fleets and facilitate information sharing. The Interagency Committee for Alternative Fuels and Low-Emission Vehicles (INTERFUEL) offers a forum for fleet managers to understand statutory requirements and rule-making processes, discuss policy implications and barriers, and develop comments on legislation, executive orders, and new regulations related to the use of alternative fuels and reductions in petroleum consumption among the federal fleet. The Federal Fleet Policy Council (FEDFLEET) consists of representatives from agencies operating a federal motor vehicle fleet and provides a focal point to federal agencies for the coordination of vehicle management problems, plans, and programs common to all federal fleets. Finally, the Motor Vehicle

[12]Under GSA regulations, the Department of Defense is authorized to acquire its own tactical vehicles. See 41 C.F.R. §§101-26.500-26.501-1.

Executive Council establishes a long-term strategic vision for the management of government wide motor vehicles and develops interagency planning in conjunction with FEDFLEET.

The federal fleet currently numbers about 645,000 vehicles, according to fiscal year 2008 data—the most recent data available—and includes a wide range of vehicles from large trucks to small sedans, many of which are alternative fuel vehicles such as flex-fuel vehicles, which can be fueled with gasoline or ethanol (E85). The fleet may be roughly divided into three sectors: DOD as a whole operates 30 percent of the fleet, USPS operates 34 percent of the fleet, and all other civilian agencies operate the remaining 36 percent. From fiscal years 2004 through 2008, the overall size of the fleet increased about 4 percent.

Most vehicles in the federal fleet are owned by the agencies that operate them—for example, in fiscal year 2008 about 69 percent of vehicles were owned. The remaining 31 percent were leased almost entirely from GSA rather than commercial lessors. The number of leased vehicles as a proportion of the overall fleet remained essentially unchanged from fiscal years 2004 through 2008, showing a slight overall increase of 1 percent. In addition, federal agencies placed orders for 70,865 vehicles through GSA in fiscal year 2008, or approximately 11 percent of the overall fleet. This figure includes vehicles purchased by GSA for lease to agencies, as well as those purchased by USPS. The majority of vehicles in the federal fleet are light duty trucks—44 percent—with passenger vehicles making up 36 percent of the fleet, and medium and heavy duty trucks, buses, and ambulances making up the remaining 20 percent.

Plug-in Vehicles Offer Environmental and Other Benefits, but These Benefits Depend on Several Factors

The adoption of plug-ins could result in several benefits by reducing petroleum consumption, such as reduced emissions of greenhouse gases and air pollutants. However, the environmental benefits depend on whether the electricity used to power plug-ins emits fewer greenhouse gases and pollutants than the fuel it replaces, as well as on consumers adopting plug-ins, who may be deterred if plug-ins are not cost-effective. The cost-effectiveness of plug-ins will be determined by the cost of batteries and trends in the price of gasoline relative to the price of electricity to charge the vehicles.

Plug-ins Offer Environmental Benefits, but These Benefits Depend on Shifting to Lower-Emission Fuel Sources to Generate Electricity

Through their potential to make substantial reductions in oil consumption, plug-ins could produce environmental benefits such as reducing greenhouse gas emissions. All-electric vehicles will consume no gasoline, and the fuel economy of plug-in hybrids is expected to be high, which means these vehicles will consume limited amounts of gasoline. For example, in tests that mimic the driving patterns of a typical driver, a test fleet of hybrids converted to plug-in hybrids operated by Google's RechargeIT program[13] averaged 93.5 mpg. Plug-in hybrids also have the potential to operate without consuming any gasoline. Specifically, planned plug-in hybrids will be able to operate on electric power for 10 miles to about 40 miles, depending on the specific design of the vehicle.[14] The vehicle would consume no petroleum at all if drivers could limit their driving between charges to the vehicle's all-electric range.

Burning fossil fuels, including gasoline, accounts for most of the world's manmade greenhouse gas emissions, primarily carbon dioxide (CO_2), which have been linked to global climate change.[15] According to the Environmental Protection Agency (EPA), the transportation sector accounted for about 28 percent of the total U.S. greenhouse gas emissions produced in 2006.[16] That number rises to 36 percent if nonroad mobile sources such as construction, farm, lawn, and garden equipment and upstream transportation fuel-related emissions such as extraction, shipping, refining, and distribution are included.[17] Within transportation,

[13]Google's RechargeIT program is an initiative within Google's nonprofit arm that aims to reduce carbon dioxide emissions, reduce oil use, and stabilize the electrical grid—the network linking the generation, transmission, and distribution of electricity—by accelerating the adoption of plug-in vehicles.

[14]One design challenge for auto manufacturers is finding a balance between the size of the battery and weight of the vehicles. Larger batteries can store more energy, which extends the all-electric range of a vehicle. However, larger batteries are also heavier, and weight depresses the fuel economy of a vehicle.

[15]According to EPA's *Inventory of Greenhouse Gas Emissions and Sinks 1990-2006*, about 83 percent of energy consumed in the United States in 2006 came from fossil fuels. The remaining 17 percent came from energy sources such as hydropower, biomass, nuclear, wind, and solar energy.

[16]By comparison, the 2006 World Energy Outlook from the International Energy Agency estimated that worldwide transportation will account for about 20 percent of carbon dioxide emissions in 2010, which suggests that reducing emissions from transportation presents an opportunity in the United States.

[17]EPA included information on nonroad mobile sources in its Advanced Notice of Rule making, 73 Fed. Reg. 44354 (July 30, 2008).

passenger cars and light duty trucks, which include sport utility vehicles (SUV), minivans, and other vehicles commonly used for personal transportation, produced 62 percent of greenhouse gas emissions.

Recent research suggests that plug-ins could produce substantial reductions in CO_2 emissions through reductions in fossil fuel consumption by passenger vehicles. For example, a 2008 study by researchers at the University of California, Berkeley, estimated a range of potential CO_2 reductions—depending on the size of the vehicle and energy source used to generate electricity—when plug-in hybrids driven within their all-electric range (in this case either 20 or 60 miles) were compared with gasoline-powered vehicles (see table 1).[18]

Table 1: Estimates of the Percentage Decrease in Carbon Dioxide Emissions from Plug-in Hybrids with 20- or 60-mile All-Electric Range Compared with Gasoline-Powered Vehicles

Fuel source used to generate electricity to charge the vehicle	Coal	Natural gas	Low carbon sources (e.g., nuclear or wind)
Plug-in compact car vs. compact gasoline car	4-5	54	85-100
Plug-in SUV vs. gasoline SUV	19-23	61-63	85-100

Source: Kammen, Arons, Lemoine and Hummel (2008).

Note: Estimates are based on driving the plug-in hybrids within their all-electric range.

As the table indicates, reductions in CO_2 emissions depend on generating electricity used to charge the vehicles from lower-emission sources of energy. Natural gas is widely used for electricity generation, though its emissions benefits are less than those of other low-carbon sources. Energy sources with even lower emissions include nuclear, hydropower, solar, wind, and, if the technology develops, fossil fuel plants equipped to capture and sequester (store) CO_2 before it is emitted into the atmosphere. However, shifting to these sources will require new power plants that can be expensive to build, as well as investments to develop, test, and equip coal and other fossil fuel plants with carbon sequestration technology. In addition, the construction of new nuclear plants can be controversial

[18]D.M. Kammen, S.M. Arons, D. Lemoine, and H. Hummel, *Cost-Effectiveness of Greenhouse Gas Emission Reductions from Plug-in Hybrid Electric Vehicles*, GSPP08-014 (University of California, Berkeley, 2008).

because of public concern about safety. Similarly, construction of some renewable energy sources, such as wind turbines, can be controversial.

In addition, in regions of the country that are heavily reliant on coal for power generation, conventional hybrids might offer greater CO_2 reductions than plug-in hybrids. For example, a study by the Electric Power Research Institute (EPRI) estimated that, with electricity provided by current coal technology, a plug-in hybrid with a 20-mile all-electric range had slightly higher CO_2 emissions than a conventional hybrid. Thus, in the immediate future, plug-ins could be used to reduce greenhouse gas emissions—relative to conventional hybrids—in regions of the country where electricity is already generated from low-carbon energy sources. For example, a plug-in vehicle charging in a coal-reliant state may not reduce greenhouse gas emissions relative to a conventional hybrid. But a plug-in charging in a state that relies heavily on hydropower would substantially reduce greenhouse gas emissions. However, developing policy or incentives to encourage consumers to buy plug-ins only in regions with low-carbon energy sources could be difficult and may not correspond with manufacturers' business plans.

Plug-ins could also reduce emissions that affect air quality. About 50 percent of Americans live in areas where levels of one or more air pollutants are high enough to affect public health. Research we reviewed indicated that plug-ins could shift air pollutant emissions away from population centers even if there was no change in the fuel used to generate electricity (e.g., if low-emitting renewable sources were not substituted for higher-emitting sources). For example, a study from the University of Texas modeled the potential impact plug-in hybrids could have on the formation of smog in a region of the country that relies heavily on coal for power generation.[19] Specifically, the study estimated that using plug-in hybrids substantially reduced smog in major cities if they were charged at night. These benefits remained even if nighttime power generation had to be increased to full capacity to meet additional demand. One potential downside the study identified was that rural areas near power plants could experience an increase in the overall amount of airborne emissions. However, since power generation would be increased at night, pollutants would not be exposed to sunlight, which would limit the production of

[19]T. Thompson, M. Webber, and D.T. Allen, "Air quality impacts of using overnight electricity generation to charge plug-in hybrid electric vehicles for daytime use." *Environmental Research Letters*, vol. 4, no. 1 (2009).

smog. This benefit would depend on consumers adopting a substantial number of plug-ins.

Finally, plug-in vehicles, which are expected to use lithium-ion batteries, could also provide environmental benefits by reducing toxic waste that would otherwise be generated from car batteries. Compared with lead acid batteries in gasoline vehicles and nickel metal hydride batteries used in conventional hybrid vehicles, lithium-ion batteries produce insignificant levels of toxic waste, which means they are less likely to pose environmental challenges in disposal. However, extracting lithium from locations where it is abundant, such as in South America, could pose environmental challenges that would damage the ecosystems in these areas. Furthermore, lithium-ion batteries can pose challenges and potential costs and risks related to safety and transport. For example, lithium-ion batteries have previously posed a risk of "thermal runaway," in which the batteries overheat and catch fire. Mitigating this safety issue is a priority of battery manufacturers, and one battery manufacturer we visited showed us several innovations to ensure that this would not be a risk while operating the vehicle. In addition, because of the current risks, there are restrictions on the transportation of lithium-ion batteries, which could pose challenges for consumers—including the federal government—in maintaining these vehicles.

Plug-ins Could Reduce Oil Dependence, Although They Could Create a Reliance on Imported Lithium

Besides offering environmental benefits, reduced oil consumption from plug-ins could help to limit U.S. vulnerability to supply reductions and subsequent oil price shocks. A study by the EPRI estimated that if plug-in hybrid vehicles grew to compose about 62 percent of the cars on the road, they could help save about 3.7 million barrels of oil per day by 2050[20] (about 9.3 million barrels of oil were consumed per day by automobiles in the United States in 2007).[21] Research from the National Renewable Energy Laboratory found that a plug-in hybrid with a 60-mile all-electric range could reduce gasoline consumption by 53 percent to 64 percent over a gasoline vehicle. By comparison, a conventional hybrid compared with

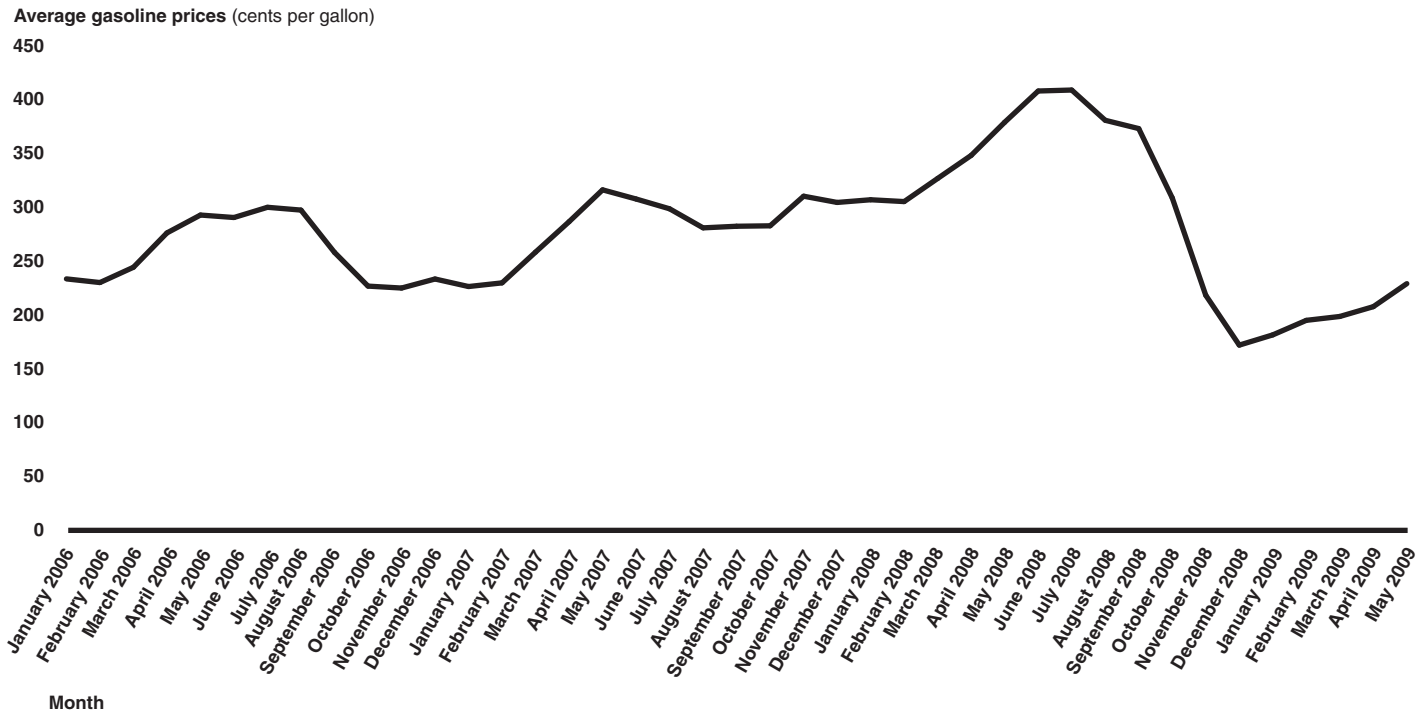
[20]Electric Power Research Institute, *Environmental Assessment of Plug-in Hybrid Electric Vehicles, Volume 1: National Greenhouse Gas Emissions* (2007). We presented information from the study's midrange scenario, which, as noted, assumed that plug-in vehicles would compose 62 percent of the fleet by 2050.

[21]Energy Information Administration 2007 data.

the same gasoline vehicle would reduce consumption by 21 percent to 28 percent.

Since 1973, supply constraints have contributed to several energy price shocks. The most recent price spike not only increased basic costs for consumers but also increased operating costs for organizations like USPS, which operates a large fleet of vehicles. Although gas prices declined steeply in late 2008 (see fig. 2), worldwide demand for oil is expected to grow, and gas prices are expected to rebound as economic conditions improve.

Figure 2: Changes in U.S. Retail Gasoline Prices, January 2006 through May 2009



Source: Energy Information Administration.

The administration, in an effort to strengthen national security, has set as one of its objectives decreasing U.S. reliance on foreign sources of energy. According to the Energy Information Administration, in 2007 about 58 percent of the oil consumed in the United States was imported. Through their potential to reduce oil consumption overall, plug-ins could help to reduce consumption of oil coming from foreign sources, but they could also create a reliance on another foreign resource. Specifically, most of the

world's reserves of lithium, which is needed to manufacture batteries for plug-ins, are located abroad, predominately in South America and China (see table 2). The United States has supplies of lithium, but if demand for lithium exceeded domestic supplies, or if lithium from overseas is less expensive, the United States could substitute reliance on one foreign resource (oil) for another (lithium). The consequences of relying on foreign sources of lithium could vary. On one hand, to the extent that this product is less expensive and readily available, as has often been the case for foreign sources of oil, manufacturers would be able to produce batteries at lower cost. On the other hand, if lithium supplies prove unstable—for example, due to political unrest in the countries in which they are located—or follow a similar pattern of price shocks as has oil, cost and risk for battery and plug-in manufacturers would increase.

Table 2: Lithium Reserve Base as of January 2009

Country	Reserve base[a] in tons
Bolivia	5,400,000
Chile	3,000,000
China	1,100,000
Brazil	910,000
United States	410,000
Canada	360,000
Australia	220,000

Source: U.S. Geological Survey.

[a]The reserve base is the part of the resource that meets specified minimum physical and chemical criteria related to current mining and production practices.

Furthermore, manufacturing batteries to mass produce plug-ins could be limited by the amount of lithium that can be extracted and produced. According to EPA officials, there is considerable disagreement on the ultimate worldwide supply of lithium, making it difficult to determine how many (or how few) batteries for plug-in vehicles could be manufactured in the long term. In addition, while current levels of global production (mining and refining) of lithium are measurable, other uncertainties—such as how much lithium will be needed in each battery—make it difficult to determine whether current levels of lithium production will need to be increased to meet demand.

Despite these issues, reliance on foreign sources of lithium may not pose the same dependence issues as oil. For example, industry officials told us that lithium, including that from spent car batteries, is highly recyclable, so

some future demand could be met by ensuring that sufficient recycling processes are in place. Industry officials also noted that the current recycling process used for car batteries—which has a high rate of participation by consumers, auto dealerships, and parts suppliers—could be adapted to lithium ion batteries. In addition, technology such as ultracapacitors, which are energy storage devises that are an alternative to batteries and that do not need lithium, or batteries that use materials besides lithium, which are being researched by at least one auto manufacturer, could be used in plug-ins. If these options prove viable, it would help avoid reliance on a single commodity for the production of plug-ins.

Plug-ins' Benefits Will Only Be Cost-Effective with Lower-Cost Batteries and Higher Gasoline Prices

Environmental and other benefits will depend on consumers adopting plug-ins, and consumers may be deterred if plug-ins are not cost-effective. The cost of lithium based batteries will make plug-ins more expensive than other vehicles, including conventional hybrids. According to industry participants we interviewed and recent research, the current cost of lithium batteries is about $1,000 to $1,300 per kilowatt hour.[22] Depending on the size of the battery pack, which is a key factor in the all-electric range of plug-in hybrids and all-electric vehicles, the additional cost per vehicle can be substantial at this price. Ultimately, however, these batteries may become more affordable. A study by Carnegie Mellon University researchers found that if the cost of lithium batteries could be reduced to $250 per kilowatt hour, plug-in hybrids could become cost competitive with both conventional hybrids and gasoline vehicles. [23] Industry observers from one organization we interviewed thought that $250 is an aggressive target, while a report from the Massachusetts Institute of Technology indicated that this price could be attainable in 20 to 30 years as manufacturers achieve economies of scale. [24] However, if this price could be achieved, it would substantially reduce the cost battery packs add to the price of plug-in vehicle. Table 3 illustrates how

[22]See Kammen, Arons, Lemoine and Hummel, *Cost-Effectiveness of Greenhouse Gas Emission Reductions from Plug-in Hybrid Electric Vehicles*, which used $1300 from Hymotion and found that $500 per kilowatt hour was the target for plug-in hybrids to be economical.

[23]Ching-Shin Norman Shiau, Constantine Samaras, Richard Hauffe, and Jeremy J. Michalek, "Impact of battery weight and charging patterns on the economic and environmental benefits of plug-in hybrid vehicles," *Energy Policy* (February 2009).

[24]M.A. Kromer, and J.B. Heywood, Sloan Automotive Laboratory, Massachusetts Institute of Technology, *Electric powertrains: Opportunities and challenges in the U.S. light duty fleet*, Publication no. LFEE 2007-02 RP (Cambridge, MA, 2007).

the total cost of a battery pack can change depending on its size and the per kilowatt hour cost.

Table 3: Potential Total Costs of Battery Packs Based on Size and per Kilowatt Hour Cost

Battery size	Estimated all-electric range in miles	$1,000/kwh	$500/kwh	$250/kwh
5	10	5,000	2,500	1,250
10	30	10,000	5,000	2,500
20	60	20,000	10,000	5,000
30	100	30,000	15,000	7,500
50	200	50,000	25,000	12,500

Source: GAO analysis of Kromer and Heywood data.

Note: Battery size and all-electric range estimates are from Kromer and Heywood (2007).

Until the cost of batteries comes down, the Carnegie Mellon study concluded, the weight and size of the battery is a key consideration in the extent to which plug-in hybrids are cost-effective methods of reducing greenhouse gas emissions. For example, this study concluded that plug in hybrids with smaller batteries that are charged frequently—every 10 miles or fewer—are less expensive and release fewer greenhouse gases than conventional hybrids, but plug-in hybrids with larger batteries and all-electric ranges may not offer the same advantages.

General Motors has contested the per kilowatt hour cost of batteries used in the Carnegie Mellon study, stating that the cost of the Volt's battery pack is hundreds less than $1,000 per kilowatt hour—the baseline case used in the study to evaluate cost-effectiveness. General Motors further noted that its battery research team has already started work on new concepts that will further decrease the cost of the Volt battery pack substantially in a second-generation Volt pack.

Gasoline and electricity costs will also determine whether plug-ins are cost-effective. Specifically, even if plug-ins have higher upfront costs, lower overall fueling costs relative to a gasoline-powered vehicle could offset the purchase price over time. For this to occur, the price of gasoline must be high relative to the cost of electricity to charge the vehicles. However, gasoline prices have varied greatly in the last few years, and if consumers do not believe that prices will return to previous highs, they may be unwilling to purchase a plug-in. Also, if power companies construct new power plants, including plants that use low-carbon power

sources, these investments may increase the cost of electricity, which could offset the savings from reduced gasoline consumption, making plug-ins less appealing to consumers.

Several Factors Could Delay the Widespread Availability of Plug-in Vehicles, and the Federal Government Has Options to Provide Support

Manufacturers plan to introduce several types of plug-in vehicles over the next 6 years. However, certain factors, such as the limitations of current battery technology, could delay availability of plug-ins, and the current financial situation could prevent consumers from purchasing plug-ins. The federal government has taken steps to encourage the development and manufacturing of plug-ins and has additional options for furthering this goal.

Although Plug-ins Are Not Yet Widely Available, Manufacturers Plan to Introduce Plug-in Hybrids and other Plug-in Vehicles through 2014

Plug-in vehicles are not widely available. Currently available plug-ins include neighborhood electric vehicles, which have limited uses, and all-electric vehicles being made in limited numbers by small auto manufacturers. In addition, kits are currently available that allow consumers to convert conventional hybrids into plug-in hybrid vehicles, although there are several problems with more widespread adoption of conversions. First and foremost, a conversion typically voids the warranty on the vehicle. Second, not all of the conversion kits available have been crash tested to ensure they will meet safety requirements set by the National Highway Traffic Safety Administration for operating a vehicle on public roads. Third, EPA officials noted that conversions constitute tampering with emissions control systems, which creates an uncertified vehicle, can lead to increased emissions, and may cause warning lights to fail even if there is a serious problem with the engine or emissions system. Although officials stated that companies can certify a converted vehicle and obtain a certificate of conformity for their product, which would enable them to legally sell their plug-in hybrids, none of the companies offering conversions have done so. Finally, conversion kits cost at least $10,000, in addition to the cost of the vehicle. These factors could create a deterrent for consumers who might otherwise consider converting their vehicles and, according to GSA and DOE officials, have prevented the federal fleet from using this option to save fuel.

However, both domestic and foreign auto manufacturers have announced plans to develop plug-in hybrids and mass produce additional all-electric vehicles. In the near term—2009 through 2012—plug-ins are expected to

include sports cars, compact sedans, SUVs, at least one all-electric pickup truck, and a commercial all-electric van. In 2013 and 2014, the number of models of cars and SUVs—both plug-in hybrids and all-electric vehicles—will expand, and a minivan may be introduced (see table 4). Information from the Association of International Automobile Manufacturers suggests that Asian manufacturers will focus on producing all-electric and conventional hybrid vehicles and that only one plug-in hybrid is currently being planned. Domestic auto manufacturers are planning more plug-in hybrids, in addition to all-electric vehicles, and plan to expand conventional hybrid technology to existing gasoline-fueled models. However, the bankruptcy and restructuring of Chrysler and General Motors could affect these plans. As explained in the note in table 4, we received information on these plans directly from Chrysler, General Motors, and other auto manufacturers.

Table 4: Types of Plug-in Vehicles and Years in Which They Are Expected to Be Available for Sale, 2009 through 2014

Vehicle type	Number of planned all-electric vehicles (years of introduction)	Number of planned plug-in hybrids (years of introduction)
Sportscar	2 (Tesla 2009, Chrysler 2010)	1 (Fisker Automotive 2010)
Compact and subcompact	1 (Chrysler 2011)	1 (General Motors 2010)
Sedan (midsized or larger)	2 (Ford 2011, Tesla 2011)	1 (Chrysler 2013)
Compact SUV	0	3 (General Motors 2011, Chrysler 2013, Chrysler 2014)
SUV	1 (Phoenix Motorcars 2009)	0
Wagon	0	1 (Volvo 2012)
Pickup truck	1 (Phoenix Motorcars 2009)	0
Minivan	0	1 (Chrysler 2013)
Commercial van	1 (Ford 2010)	0

Source: Alliance of International Automobile Manufacturers, Chrysler, GM, Fisker Automotive, Ford, Mini-E, Phoenix Motorcars, Tesla Motors, and Toyota.

Notes: Mini is conducting a pilot test in which it will lease 500 of its all-electric Mini-E cars to consumers for 1 year. Toyota also has announced that it will begin leasing a plug-in hybrid version of the Prius late in 2009. These vehicles were not listed in the chart above.

We limited our information sources to data provided directly from manufacturers or information published on manufacturer Web sites. Specifically, we obtained data from Chrysler and General Motors in June 2009; the Alliance of International Automobile Manufacturers, Ford, and Phoenix Motorcars in February 2009; and Toyota in April 2009. We also viewed information on the Web sites of Tesla Motors, Fisker Automotive, and Mini-E in April 2009 and from Volvo's Web site in June 2009. Because of our approach to obtaining data, the information presented here may differ from news sources.

The planned vehicles will have a range of capacities. The expected all-electric driving range of plug-in hybrids varies from a low of 10 miles per charge for the planned plug-in version of the Saturn VUE to a 50-mile all-electric range per charge for the Fisker Automotive Karma. Many of the planned all-electric vehicles are expected to have a driving range of about 100 miles on a single charge, although Tesla Motors plans to introduce an all-electric sedan with a range of 300 miles. As discussed earlier, the larger batteries necessary for plug-in vehicles will result in these initial vehicles being considerably more expensive than comparable vehicles. For example, Phoenix Motorcars' all-electric pickup truck is expected to retail for $47,500, which is about 81 percent higher than the $26,175 suggested retail price of the comparably sized Ford F-150 pickup truck. Similarly the Chevrolet Volt is expected to retail for about $40,000 when it is first marketed, and it will be sized somewhere between a Chevrolet Cobalt and Pontiac G6. The Volt's retail price is about $25,000 higher than the Chevrolet Cobalt and about $20,000 more than the Pontiac G6.

Development of Battery Technology, Limited Charging Infrastructure, and Current Economic Conditions Could Delay Plug-ins and Affect Consumer Demand

Factors Associated with Battery Development

Achieving economies of scale to help lower the cost of plug-in batteries will be difficult. For example, industry experts told us that manufacturing high-quality batteries requires considerable skill and sophisticated, precision-oriented manufacturing processes. Inadequate manufacturing processes will likely result in batteries that are more likely to fail. In addition, industry officials told us that most battery component manufacturing and assembly of battery packs is done abroad, and there is

limited manufacturing capacity worldwide. While some manufacturers have announced plans to establish battery plants domestically, the capital investments will be significant. Congress established a program to assist companies interested in developing these plants in the Recovery Act. In addition, some industry participants told us that the purchasing power of the federal fleet could help manufacturers achieve economies of scale in battery manufacturing. However, with a total purchase of about 70,000 vehicles in 2008, and with only about 20,000 passenger sedans being purchased annually, the purchasing power of the federal government is small relative to the overall auto market. For example, about 13 million vehicles were sold in the United States in 2008 and about 16 million in 2007.[25]

In addition, questions about the potential longevity of lithium batteries remain and have caused at least one prominent manufacturer to be conservative in its plans to develop plug-ins. In early tests, and under testing conditions, lithium-ion batteries have been shown to last for a sufficient number of charging cycles to enable plug-ins to have a comparable lifetime to conventional automobiles. However, if the batteries prove unreliable in real world conditions, manufacturers could be exposed to significant costs associated with warranties. In addition, if consumers believe they may have to replace the battery after the warranty expires, the cost of doing so may discourage them from buying plug-ins or could drive down vehicle resale prices.

Factors Associated with Charging Infrastructure

As plug-ins reach a significant level of market penetration, additional infrastructure to charge them will likely be needed. One study estimated that about 40 percent of consumers do not have access to an outlet near their vehicle at home. Consumers without ready access to an outlet, such as those who only have street parking, would need public charging infrastructure, which manufacturers and others told us could be installed at the relatively low cost of perhaps a few thousand dollars for a new charging box. By comparison, ethanol (E85), another alternative to petroleum, has struggled to make inroads as an alternative transportation fuel, in part because it can cost up to $62,400 to install a new E85 fuel

[25]Data taken from the Department of Commerce' Bureau of Economic Analysis. To the extent that the number of vehicles federal agencies purchased has remained essentially steady between fiscal years 2004 and 2008—averaging around 64,000—the total federal purchase represents less than 1 percent of vehicles sold in the United States in 2008.

pump.[26] However, public charging infrastructure would require establishment of a new system for building outlets and billing for the power dispensed, whereas fueling stations for gasoline vehicles are already widely available.

In addition, plug-ins could increase demand for electrical power and, over time, power companies may have to generate more electricity to meet this demand, depending on when and how often vehicles were charged. Results from a Duke University study suggested that if plug-in hybrids reached 56 percent of the cars on the road by 2030, they would require an increase in electricity production, much of which would likely come from additional coal plants. Although an increase in coal consumption would produce additional carbon dioxide emissions, the study noted that if this increased consumption came during off peak hours, power companies would likely build additional capacity that produces electricity more efficiently and—excluding upfront capital costs—at lower cost on a daily operational basis. In the near term, a study by the World Wildlife Federation using 2005 levels of power generation estimated that 1 million plug-in hybrids would demand 0.04 percent of the nation's power. In addition, a 2006 analysis by the Pacific National Laboratory estimated that, if plug-ins were charged during off-peak hours, about 84 percent of cars, SUVs, and pickup trucks on the road in 2001 could be supported without building new electricity-generation capacity. The variations in these studies are a consequence of different assumptions, and ultimately only real-world experience will show the actual demand for power.

Thus, a large number of plug-ins could be put into use with available power, if consumers charge their plug-ins during off-peak hours. To encourage consumers to do so, cheaper rates for electricity could be charged after a certain hour at night. However, power companies would need to be able to apply different rates during off-peak hours and would need to make this cost advantage evident to consumers on their bills or through some other means, such as new technology. Such technology, or "smart charging infrastructure," would likely need to include features that allow consumers to indicate by what time the car needs to be charged and a way to meter and bill consumers different prices for on- and off-peak

[26]USPS officials voiced additional concerns regarding the use of ethanol, such as the lower fuel economy of ethanol compared with gasoline (ethanol provides 20 percent to 25 percent fewer miles per gallon).

consumption. Power companies, start-ups, and others have been working on smart charging infrastructure, but it is still under development.[27]

Factors Associated with Current Economic Conditions

The economic recession has put the auto industry under significant financial stress, which could affect plans to introduce and mass-produce plug-ins over the next few years.[28] In addition, if the following conditions are still present when manufacturers introduce plug-ins, consumers may also be discouraged from purchasing these vehicles.

- *Declining sales:* Auto sales declined in 2008 and early 2009, and while most auto manufacturers have been affected, declines have been more substantial for the "Detroit 3"—Chrysler, Ford, and General Motors. For example, Detroit 3 sales in the United States dropped by nearly 50 percent from February 2008 through February 2009, whereas U.S. sales for Honda, Nissan, and Toyota dropped 39 percent during this period. To stabilize their operations, Chrysler and General Motors will receive a total of about $13 billion and $50 billion in assistance, respectively, pending approval of the bankruptcy court and finalization of related transactions. To the extent that auto manufacturers have limited cash to continue developing plug-ins, as well as the capital to build or retrofit manufacturing plants to produce them, the development and availability of plug-ins could be hindered.
- *Reduced consumer confidence:* Deteriorating financial, real estate, and labor markets have reduced consumer confidence, which could make it difficult for manufacturers to market plug-in vehicles because of their significant price premium compared with less expensive gasoline-powered vehicles in the same class.
- *Tight credit markets:* Tightening credit markets have also limited the availability of loans for consumers to finance car purchases, even from the financial arms of the car companies. Should this continue, consumers may have difficulty financing the purchase of a plug-in.

[27]Over the long term, utility companies we interviewed highlighted the importance of developing vehicle-to-grid, or vehicle-to-home technologies, that can help utilities manage peak periods of electrical usage and can eventually result in additional financial incentives for consumers.

[28]GAO has published work monitoring the assistance provided to the auto industry, including *Auto Industry: A Framework for Considering Federal Financial Assistance*, GAO-09-242T (Washington, D.C.: Dec. 4, 2008); and *Auto Industry: Summary of Government Assistance and Automakers' Restructuring Efforts*, GAO-09-553 (Washington, D.C.: Apr. 23, 2009).

In addition to these issues, the recent spike and decline in gasoline prices may make it more difficult to market plug-ins in that consumers may be doubtful that they will recoup the high upfront costs of plug-ins through fuel savings over the life of the vehicle. However, industry stakeholders and researchers have pointed out that, in addition to fuel savings, buyers also consider performance, styling, and other intangibles—such as whether the vehicle makes a statement about its owner being "green"—when choosing between vehicles.

The Federal Government Has Encouraged the Development and Manufacture of Plug-in Vehicles, and Experts Identified Several Additional Options

The federal government has historically played a role in the research and development of plug-in vehicle technology and has recently provided grant funding for plug-in hybrid test fleets:

- *Funding for basic research to develop technology:* DOE funds basic research to develop battery technology for vehicles as well as other components necessary for electric-powered vehicles. DOE's annual budget for such research was about $101 million in fiscal year 2009. In addition, the national laboratories have ongoing work related to plug-ins. Argonne National Laboratory has been designated by DOE as the lead laboratory and is testing and evaluating plug-in vehicle technology, including batteries, components, and vehicles, to shed light on the reliability of the technology over its expected life.
- *Cost sharing for test fleets:* DOE also supports the introduction of plug-in hybrid test fleets. For example, the Idaho National Laboratory is coordinating the collection and analysis of data from more than 150 converted plug-in hybrids deployed across the United States to understand the effects of real-world use on the technology. To initiate this test fleet, DOE established partnerships with organizations such as power companies, local government agencies, and others across the United States and Canada. DOE covered half the cost of converting a conventional hybrid to a plug-in hybrid, as well as the cost of the devices to collect and transmit data on fuel economy, charging patterns, and driver behavior back to the lab. In addition, DOE is administering a $30 million grant program to facilitate the deployment of demonstration vehicles to accelerate improvements to plug-in vehicle technology. The program offers funding to a team of businesses, including an auto manufacturer and battery development company that is willing to cover half of the cost of the demonstration fleet and data collection.

In addition to research and development, the federal government has also taken steps to encourage the development and manufacture of plug-ins through a variety of programs, several of which were initiated by the

Recovery Act. While these programs are designed to either directly or indirectly support the development and manufacture of plug-ins, they are still being implemented.

- *Loans for modernizing manufacturing plants:* The government has sought to help manufacturers manage the capital costs associated with producing advanced technology vehicles. In 2007, Congress established the Advanced Technology Vehicle Manufacturing (ATVM) loan program, which offers low-cost loans to auto manufacturers and component parts suppliers to retool aging plants or build new plants that will lead to the production of advanced vehicles that are at least 25 percent more fuel efficient than current vehicles for sale or advanced technology components for these new vehicles.[29] Officials from the ATVM program noted that applicants include a wide range of technologies, from making improvements to components for gasoline vehicles to major technological breakthroughs in advanced vehicle technology. This program received an appropriation in the fall of 2008 of $7.5 billion, and DOE, which is tasked with administering the program, plans to offer the first round of loans in June 2009. In addition, Title XVII of the Energy Policy Act of 2005 established a loan guarantee program for innovative energy technologies. Congress has authorized this program to provide up to a total of $22.5 billion of loan guarantees for a category of renewable or energy efficient systems and manufacturing projects that could include production facilities for alternative fuel vehicles. Under the program, borrowers must pay the subsidy costs of the loan guarantees unless Congress appropriates funds to cover the costs, and it has not done so for alternative fuel vehicle production facilities.
- *Battery manufacturing:* To encourage the development of domestic manufacturing of advanced technology batteries, the Recovery Act appropriated $2 billion in grants for manufacturing batteries and related components. Battery technology to be targeted includes, but is not limited to, lithium-ion batteries, hybrid electrical systems, and related software. DOE will administer the program and released the solicitation on March 19, 2009.
- *Direct funding to purchase fuel-efficient vehicles for the federal fleet:* The Recovery Act appropriated $300 million to GSA for capital expenses associated with acquiring vehicles with high fuel economy, including conventional hybrids, plug-in hybrids, and all-electric vehicles. These funds must be used by September 30, 2011. GSA's April plan to Congress

[29]42 U.S.C §17013.

states that GSA intends to spend this funding by September 30, 2009, to help stimulate the economy and purchase more fuel-efficient vehicles. As of June 1, 2009, GSA officials told us that they had obligated $287.5 million, ordering 3,100 vehicles in April and 14,105 on June 1. Because GSA will spend most of the funding before many plug-ins are commercially available, it does not plan to purchase this technology, save for a few hundred neighborhood electric vehicles.

- *Tax credits for consumers purchasing plug-ins:* The Recovery Act established a tax credit to consumers for the purchase of a plug-in vehicle. The credit increases with the size of the battery up to $7,500 but is not applicable for vehicles over 14,000 pounds. In addition, the Recovery Act established a credit of up to $2,500 for two-wheeled, three-wheeled, and low-speed four-wheeled plug-in vehicles, such as neighborhood electric vehicles, and establishes a credit of 10 percent of the cost of converting a vehicle—up to $4,000—for the conversion of existing vehicles to run on battery power. One study has indicated that smaller batteries that are more frequently charged may be more cost-effective solutions for reducing greenhouse gas emissions, but this tax credit program benefits plug-ins with larger batteries. In addition, tax incentives aimed at consumers with the oldest and least fuel-efficient vehicles can encourage them to retire these vehicles and replace them with plug-ins, thus resulting in a greater public benefit than replacing vehicles with average or higher fuel economy. However, the existing tax credit program is not designed with the replacement vehicle in mind but rather focuses on encouraging the adoption of plug-ins regardless of the vehicles they would replace.
- *Transportation electrification:* DOE is utilizing $400 million of funding from the Recovery Act to support the integration of electric-drive vehicles and technologies into the United States' transportation sector. The Funding Opportunity Announcement that was released by DOE on March 19, 2009, includes a request for proposals to establish wide-scale demonstrations of electric-drive vehicles, including plug-in hybrid electric and battery electric vehicles.

Several additional steps the federal government could take to encourage the development, manufacture, and commercialization of plug-ins emerged consistently during our discussions with experts and reviews of recent literature. Most of these options would impose costs on the federal government or society at large and therefore would require additional analysis to determine whether the potential benefit would be worth the cost.

- To reduce cost and risk of investing in battery technology and manufacturing for auto manufacturers, the government could share the

cost of honoring warranties for plug-in batteries. However, if batteries prove to be unreliable, the government would be exposed to additional costs. To mitigate consumer reluctance to buy vehicles from a financially distressed company, Treasury provided $280 million to Chrysler and $360 million to General Motors to back warranties of these companies. As of June 2009, Treasury officials noted that Chrysler and General Motors continue to support their warranties and Treasury believes that the money provided to them will be returned to Treasury. We were not able to find estimates of the cost of this approach if it were to be applied to plug-in vehicles. Furthermore, if such funding were directed to troubled manufacturers, these costs would be in addition to the $17.4 billion already provided by the government to Chrysler and General Motors through the Troubled Asset Relief Program. Such a program could also be used to assist start-up companies specializing in all-electric vehicles, but we were not able to estimate the potential risk to the government.

- To reduce the cost of batteries by broadening the market for lithium batteries, the federal government could encourage the development of secondary uses for battery packs. Industry officials told us that lithium-ion batteries can be used to store energy—for example, from renewable sources like wind—which could then be used during a period of peak demand. These officials noted that both new batteries, and batteries that no longer had a useful life for a plug-in vehicle but that nonetheless could still retain a charge, could be used for this purpose. However, power companies also stand to benefit from developing this technology, and officials from some of the companies with whom we spoke indicated they were exploring this idea, which suggests that if government refrains from sponsoring such development, the private sector may do so.
- To encourage the continued development of low-carbon electricity, the government could institute a carbon pricing program, such as a carbon cap-and-trade program or carbon tax. [30] If a cap-and-trade program, or carbon tax, were applied to transportation fuels, it could make the life-cycle costs of plug-ins more competitive with other vehicles, depending on its effect in changing the price differential of gasoline relative to electricity. An energy bill that includes a carbon cap-and-trade program

[30]Cap-and-trade programs combine a regulatory limit or cap on the amount of a substance—in this case, carbon dioxide—that can be emitted into the atmosphere with market elements like credit trading to give industries flexibility in meeting the cap. The cap can be reduced in each subsequent year after its introduction in order to steadily decrease the total amount of carbon dioxide emitted; and, in this scenario, individual companies would comply with the cap by either reducing their emissions to the cap's limit or buying credits from a company that is below the cap.

was introduced in the 111th Congress,[31] and the administration has indicated an interest in supporting such a program. Some economists advocate using revenue from a cap-and-trade program to lower income taxes, which could offset some of the increased cost consumers would experience from higher fuel prices.

- To enhance consumer acceptance of the technology and once reasonably accurate information on the performance of plug-ins is available, the government could play a role in providing consumer education. At the most basic level, the government could provide information to help consumers make the decision to invest in plug-ins by, for example, showing the extent to which fuel savings may offset the initial higher cost of plug-ins. In addition, it could inform consumers of potential electrical updates that may be needed in a home, such as a dedicated circuit for charging a plug-in, to prevent consumers from becoming frustrated once they bring their vehicles home. Finally, the government could provide information to help consumers use the technology more wisely. For example, it could explain the effects of driving style on plug-in hybrid fuel economy and the potential cost savings of charging during off-peak hours. The government already provides similar types of information on vehicles through sources such as its fuel economy Web site.
- Government may also need to both provide and standardize how some information on the performance of vehicles is communicated to consumers. For example, car companies are currently required to post EPA-validated fuel economy labels on new cars, but consumers may need other kinds of metrics about plug-ins, such as the length of time it takes to charge one with a 110- or 220-volt plug, and how far the different vehicles can go before they require charging or will begin to rely on gasoline for additional power. Such options could increase the regulatory role played by the federal government. However, EPA already plays a role in providing information on vehicle fuel economy and may be able to adapt current processes to include information on plug-ins.
- In the longer term, government could help facilitate smart charging by helping to develop the necessary infrastructure, which includes meters and a standardized communications between power companies and consumers. This would help ensure the electrical grid could accommodate widespread use of plug-ins. Federal rules and regulations may be needed to support these standards.

[31]As of the publication of this report, H.R. 2454 has not been passed by either the House or the Senate.

Cost and Other Factors, Including Federal Requirements, Could Hinder the Integration of Plug-in Vehicles into the Federal Fleet

Once plug-ins become commercially available, agencies will face challenges related to cost, availability, planning, and federal requirements. Agencies may have difficulty making the decision to invest in these vehicles instead of less expensive gasoline vehicles, given that they have limited information to help them take the longer-term costs into account using life-cycle analysis. Agencies also have not formulated plans for incorporating plug-ins into their fleets, largely because information they would need is not yet available. Finally, agencies may have difficulty meeting the federal goal of acquiring plug-in hybrids, as it conflicts with some federal requirements and agencies lack guidance on how to negotiate this situation.

High Upfront Costs of Plug-ins Will Initially Create a Challenge for Agencies

Just as the high initial cost of plug-ins may hinder consumer adoption of these vehicles, it will also limit agencies ability to acquire them. Plug-ins are likely to cost significantly more than comparably sized gasoline-powered vehicles, and because the upfront cost of a vehicle is a key factor when agencies select a vehicle, federal customers will likely not be able to purchase or lease many of these vehicles without additional funding to help cover costs. Thus, as a practical matter, agencies' budgets will determine the extent to which they can integrate plug-in hybrids and all-electric vehicles into their fleets. GSA typically negotiates with auto manufacturers for significantly discounted prices for the vehicles it purchases and leases for federal agencies—typically more than 40 percent below the manufacturer's suggested retail price. (See app. II for more information on GSA procurement processes.) For example, GSA offers agencies a Ford F-150 pickup truck for $15,111 (about an $11,000 discount to the suggested retail price), a Chevrolet Cobalt for $12,600 (about a $2,400 discount), and a 4-cylinder Pontiac G6 for $14,000 (about a $6,000 discount). GSA officials did not think they would be able to obtain the usual discount for early plug-ins since auto manufacturers are often reluctant to offer the same discounts for new model lines because they can better recover their start-up costs in the retail market. Therefore, since discounted plug-in hybrids will not likely be offered to the government, the cost differential between plug-ins and comparable vehicles—including other alternative fuel vehicles such as flex-fuel vehicles—could be even greater for the government than it would be for an individual consumer.

The additional expense of plug-in hybrids and all-electric vehicles could also make it more difficult to incorporate leased plug-ins into the fleet. GSA officials said that their authorization limits the agency's ability to replace existing vehicles with plug-ins in its leasing program, at least initially. Because the high cost of plug-ins will stretch thin GSA's revolving

fund's ability to absorb costs over the life of the lease, GSA would need additional funding upfront to cover the higher costs of plug-ins. It could subsequently recover some of these costs by setting the lease rates for agencies at a level that would replenish these funds. However, this additional cost would cause lease rates for plug-ins to not be competitive with lease rates for similarly sized vehicles. In addition, GSA determines its lease rates for vehicles not just based on the initial price but also the price they can get for the vehicle in the used car market. However, uncertainties regarding the resale value of plug-ins will make it difficult for GSA to lower the lease rate based on the amount of money it could recoup through resale.

Life-Cycle Cost Analysis Is Not Widely Used in Making Choices between Vehicles, and Agencies Do Not Have Information Needed to Compare Plug-ins with Other Vehicles

Executive Order 13423 directs agencies to begin purchasing plug-in hybrids once they are reasonably comparable on a life-cycle cost basis with conventional vehicles. A life-cycle cost analysis includes factors such as the expected total fuel and maintenance costs of a vehicle over the years that the agency would operate it.[32] This helps the purchaser determine the best long-term value for the investment. The Federal Acquisition Regulation does not explicitly require agencies to perform life-cycle cost analysis for their acquisitions, including vehicles they acquire, although agencies are free to do so.

Among the agencies we reviewed, the use of life-cycle cost analysis varied, and according to FEDFLEET, an organization representing federal fleet managers, most agencies do not use life-cycle costing when evaluating which vehicles to purchase. When selecting vehicles, fleet managers with whom we spoke said they primarily consider mission needs, upfront costs, and federal goals and requirements, rather than long-term savings. However, of the agencies we reviewed, only agencies within DOD—the Air Force, Navy, and Marine Corps—reported that they evaluate life-cycle costs to differentiate between multiple vehicles that met the agencies' needs.

In order to conduct analysis of life-cycle costs, agencies need access to information that would enable such an analysis, such as estimates of lifetime fuel economy, and ongoing maintenance and repair data for

[32]Although costs associated with greenhouse gas emissions are not considered in the life-cycle costing methodology currently used by GSA, GSA officials told us that they expect a requirement to include these in the future.

specific vehicles. GSA officials told us that some information on life-cycle costs of vehicles is available though a database that houses information on fuel consumption reported by agencies, and that GSA Fleet would have some information on lifetime maintenance costs of some vehicles. In addition, life-cycle cost estimates for existing vehicles are available from public sources of automotive information.[33] However, such information for specific vehicles is not readily available from GSA. For example, AutoChoice, a Web site developed by GSA to provide information to agencies on vehicles available for purchase, includes information about upfront costs and vehicle performance characteristics (such as engine size and fuel economy) but does not include information on total cost of ownership, such as estimated lifetime fuel or maintenance costs.

For comparable conventional gasoline vehicles in the same class, differences in life-cycle costs may not be significant, but differences could arise when comparing a conventional gasoline-powered vehicle to a plug-in hybrid or all-electric vehicle, depending on a number of factors. However, since plug-in hybrids are not currently available in the marketplace, much of the information about their lifetime ownership costs is unknown. First, the fuel economy of planned plug-in hybrids has not been announced and will vary greatly depending on how agencies plan to use them. For example, plug-in hybrids used only within the all-electric range will use no gasoline at all, while plug-in hybrids used for long-distance driving may not offer fuel economy much better than a conventional hybrid or highly fuel-efficient gasoline-powered vehicle. Secondly, their maintenance costs could be significantly more or less than conventional technology. For example, failure of vehicle batteries—which will likely be the vehicles' most expensive component—after warranties expire could entail significant costs for agencies. In addition, some maintenance issues may involve proprietary considerations or require additional specialized training for maintenance staff among agencies that service their own vehicles. Conversely, to the extent that plug-in vehicles will have fewer moving parts, they may offer significantly lower maintenance costs over the life of the vehicle. Finally, another important factor in determining vehicle life-cycle costs is resale value, which is also uncertain in the case of plug-ins. GSA officials said that past experience with advanced technology vehicles underscored the risk federal agencies might face when trying to resell the vehicles. For example, when GSA attempted to resell some of its compressed natural gas vehicles in the

[33]For example, Edmunds Inc. publishes total cost of ownership data on its Web site.

1990s, there was no market for them and the resale value was essentially zero. By comparison, information from public sources of automotive data suggests that the projected value of a Toyota Prius, a conventional hybrid, will hold up well over time compared with similarly sized gasoline vehicles.

We believe these uncertainties make it difficult for fleet managers to plan for the integration of plug-in hybrids in the early years of their commercialization and pose challenges for agencies in complying with the executive order. In addition, to compare plug-in hybrids with other vehicles available to them, agencies will need to make certain assumptions that can materially affect the estimation of whether the vehicles are comparable on a life-cycle cost basis. For example, factors such as agency policies about when and how often vehicles are charged, driving behavior and the types of trips plug-in hybrids are predominantly used for, and the potential for training needed to service the vehicles all can influence the costs of the vehicle to the agency over its lifetime. Currently there is no guidance on how to deal with these uncertainties and no further information about the performance of the vehicles.

GSA and DOD have started to explore options that would allow the agencies to acquire and use neighborhood electric vehicles while minimizing some of the risk associated with the uncertainties described above. Specifically, GSA, on behalf of the Department of the Army, is currently negotiating "pass-through lease agreements" in which it would lease neighborhood electric vehicles directly from manufacturers and pass the leases on to the customer. In its effort to reduce petroleum consumption, the Army would like to order 4,000 neighborhood electric vehicles over a 3-year period beginning in 2009 and replace gas-powered vehicles, where appropriate, on a one-for-one basis. Leasing, rather than purchasing, the neighborhood electric vehicles will help mitigate risks associated with their maintenance and their minimal resale value, according to GSA and DOD officials. The cost of the leases could be higher if manufacturers adjust the rate to account for risk associated with expected costs and performance of plug-in vehicles. However, if the government leased these vehicles, it would avoid liability of ownership, especially with regard to the maintenance and resale challenges GSA and federal agencies would otherwise face. GSA has not yet explored the possibility of leasing other plug-ins directly from manufacturers; however, GSA officials thought this option would be worth exploring.

Availability of Plug-in Vehicles to the Federal Fleet May Be Limited

Auto manufacturers may not make a high volume or wide range of plug-in vehicle models available to the federal government. The vehicles GSA is able to provide to its customers are limited to the models automakers are willing to sell to the government. Those offered have generally been limited to models that have been on the market for several years and are no longer at the peak of their retail sales. In addition, foreign manufacturers historically have not entered into procurement contracts with GSA. GSA officials informed us that although they have regularly pursued discussions with Toyota and Honda, both manufacturers have declined to submit proposals because of franchising and licensing agreements with their dealers in the United States. Of the large manufacturers that have announced plans to market plug-in hybrids in the next several years, only GM has said it would make these available to the government, but it has not indicated the quantities it would provide. The availability of plug-ins through smaller start-up manufacturers is also uncertain. For example, Phoenix Motorcars is marketing its all-electric pickup truck and SUV to fleets, and its first production run is scheduled to begin in 2009. GSA officials noted, however, that the Phoenix vehicles were not yet in production when it met with auto manufacturers to plan for fiscal year 2010.

Agencies Have Not Developed Plans to Incorporate Plug-ins Due to Uncertainties Surrounding Vehicle Performance and Infrastructure Needs

Almost all of the agency officials we interviewed stated they have not developed plans for incorporating plug-ins into their fleets, in some cases because of the uncertainties surrounding plug-ins. The Government Performance and Results Act of 1993 (GPRA) requires executive branch agencies to clearly establish their missions and goals. [34] In guidance GAO developed to assist agencies implement GPRA, we stated that plans can help clarify organizational priorities and unify agency staff in pursuit of shared goals, like integrating plug-ins into the federal fleet. As we have mentioned in previous reports, plans can help clarify organizational priorities and unify agency staff in pursuit of shared goals, like integrating plug-ins into the federal fleet. These plans also must be updated to reflect changing circumstances and should include a number of key elements, such as (1) approaches for achieving long-term goals; (2) linkages to goals; (3) frameworks for aligning agency activities, processes, and resources to attain goals; (4) consideration of external factors; and (5) reliable

[34]Pub. L. No. 103-62, 107 Stat. 285 (Aug. 3, 1993).

performance data needed to set goals, evaluate results, and improve performance.[35]

Agency officials told us that the uncertainties surrounding plug-ins, as discussed throughout this report, prevent them from developing plans for integrating plug-ins into their fleets. For example, agency officials reported that the performance characteristics of plug-ins—such as fuel economy, length of time to charge, and range—are still in question. While there is some preliminary information on performance characteristics and potential benefits, agencies cannot determine with certainty whether the vehicles will meet their mission, which is one of the most important criteria in purchasing vehicles. In addition, according to FEDFLEET, plug-in hybrids are a suitable option for agencies located in metropolitan areas, on military bases, and federal centers, but agency fleet managers noted that plug-in hybrids may not be appropriate for agency missions located in remote areas or that require long-distance driving without assurance that charging infrastructure will be accessible. Finally, the compact size of the first plug-in hybrids expected on the market may be problematic. For example, USPS officials stated that they are unlikely to acquire plug-in hybrids with limited cargo capacity, such as the Chevy Volt, but viewed plug-in vans with larger cargo space as an option.

Agencies are also uncertain how to plan for the integration of plug-ins because they have not determined whether additional charging infrastructure would be needed at federal facilities to accommodate the use of plug-ins. The first generation of plug-ins is expected to use ordinary plugs and outlets to recharge the vehicles, and agency officials expected that small numbers of plug-ins would not pose considerable infrastructure challenges. However, many agency officials we interviewed stated that they had yet to conduct any assessment of their current facilities to determine the extent to which they could support plug-ins and, thus, what modifications might be necessary. For example, according to several agency officials, federal agencies located in a commercially leased space may not have access to additional electrical infrastructure necessary to support vehicle charging, or the building owner may not be willing to provide it. Also, as the number of plug-ins used by federal agencies increases, it will likely become necessary to upgrade the facility's electrical service to accommodate the growing demand. In addition, some

[35]GAO, *Executive Guide: Effectively Implementing the Government Performance and Results Act*, GAO/GGD-96-118 (Washington, D.C.: June 1996); and GAO/GGD-10.1.16.

agencies with their own charging facilities may need to collaborate with the local utility to ensure transformers serving the building can manage additional load. Agencies may also need to collaborate with local power companies and be prepared to install smart charging capability to ensure that electrical power is being used in the most efficient manner possible. Finally, some officials emphasized that they may need funding for additional infrastructure, such as charging stations. Because of these uncertainties, agency officials informed us that it would be extremely difficult to develop a plan that successfully incorporates plug-ins into their mission and uses these vehicles as effectively as possible.

Incorporating Plug-ins into the Federal Fleet May Be at Odds with Other Federal Requirements

Agencies also face a challenge posed by the patchwork of existing federal requirements that covers energy use and vehicle acquisitions. In deciding whether to acquire plug-in hybrids and all-electric vehicles, agencies must also consider how this decision will affect their ability to meet these other requirements, some of which conflict with one another. These requirements are intended to further several important objectives, including reducing petroleum consumption and encouraging the use of alternative fuel vehicles and alternative fuel in the federal fleet. However, the current set of requirements does not provide agencies with a means to set priorities for these objectives and make complex decisions such as what vehicles to acquire under what circumstances.

Using plug-in vehicles could create several challenges related to meeting energy reduction and fuel consumption goals.

- *Consumption of electricity by plug-ins could conflict with energy reduction requirements for facilities:* Under Executive Order 13423 agencies are expected to reduce energy intensity in federal facilities by 3 percent per year through the end of fiscal year 2015; further, EISA requires a reduction in energy intensity in facilities by 30 percent by the end of fiscal year 2015, relative to the baseline of their energy use in fiscal year 2003. Energy intensity is defined as energy consumed per gross square foot of facilities. Because plug-ins are expected to rely on electricity from federal facilities while charging, they could increase energy consumption, particularly if plug-ins are used in large numbers. Such an increase could create a conflict with the requirement in EISA for federal facilities to reduce energy consumption of facilities.[36] If agencies do not have a means to determine the electricity used by plug-ins, they will have no way of

[36]Pub. L. No. 110-140, §431.

subtracting vehicle usage from facility usage to track their progress in meeting the facility requirement.

- *Without means to measure electricity used to "fuel" plug-ins, agencies may underestimate progress toward alternative fuel consumption requirements:* EISA requires agencies to increase alternative fuel use by 10 percent annually. The electricity used to charge plug-in hybrids and all-electric vehicles, except neighborhood electric vehicles, can count toward this requirement. But according to agency officials, facilities are generally not equipped with dedicated meters or other means of measuring the amount of electricity used by vehicles. According to the DOE official responsible for federal fleet policy, electricity used by plug-in hybrids and all-electric vehicles could be estimated, but there is currently no guidance for how to do this.
- *The lack of guidance regarding alternative fuel use for plug-in hybrids could hamper agencies' ability to meet the 100-percent alternative fueling requirement:* EPAct 2005 requires that alternative fuel vehicles be fueled with alternative fuel 100 percent of the time, unless they qualify for a waiver. In the case of flex-fuel vehicles that are fueled by ethanol (E85) and gasoline, agencies can qualify for a waiver to use gasoline in flex-fuel vehicles if E85 is not readily available or costs too much. DOE guidance allows exceptions under certain conditions—for example, agencies may use gasoline, instead of E85, to complete the mission at hand if E85 is unavailable. According to DOE officials, similar guidance will be necessary to address conditions when alternative fuel, specifically electricity, is unavailable for plug-in hybrids.
- *The lack of guidance regarding the electricity used by neighborhood electric vehicles could lead to inaccuracies in alternative fuel consumption reporting:* According to DOE, neighborhood electric vehicles do not qualify as alternative fuel vehicles under EPAct 1992. However, because neighborhood electric vehicles are fueled with electricity, without a means of accounting for their electricity use separately from that of plug-in hybrids and other all-electric vehicles, agencies could be improperly counting the electricity used by neighborhood electric vehicles as alternative fuel. Neighborhood electric vehicles can, however, help agencies meet their petroleum reduction targets, and DOD and GSA plan to put more of these vehicles into use. DOE has not provided guidance to agencies on this subject. DOE's official responsible for fleet policy noted that because so few neighborhood electric vehicles have been used to date, the lack of policy has not been a problem. Now that neighborhood electric vehicles are becoming more popular, he said, DOE has begun developing guidance specifying how to account for the electricity used in neighborhood electric vehicles.

In addition, the various federal requirements that pertain to energy use and vehicle acquisitions do not provide agencies with a clear way to set priorities and effectively address conflicts between these requirements.

- *Until they are more affordable, plug-ins are unlikely to be the most cost-effective type of AFV for reducing petroleum consumption:* EPAct 1992 requires that at least 75 percent of all new vehicle acquisitions by agencies for EPAct-covered fleets be alternative fuel vehicles.[37] In addition, EISA requires agencies to reduce petroleum consumption. Acquiring plug-ins would be helpful in meeting both requirements. However, agencies would be able to replace more of their older, less-efficient vehicles by acquiring either less costly AFVs or fuel-efficient gasoline-powered vehicles. Depending on the circumstances, acquiring plug-ins could limit an agency's ability to meet the requirement to reduce petroleum consumption.
- *The new requirement to acquire low-emission vehicles creates an additional priority that agencies must manage:* EISA directs agencies to procure only low-emission greenhouse gas vehicles, and EPA is in the process of developing a definition for these vehicles. DOE officials noted that the EISA requirement may be at odds with the AFV acquisition requirement because most AFVs in use today, particularly flex-fuel vehicles, meet the EISA emissions requirement only if they are fueled with alternative fuel, not gasoline. In addition, the amount of emissions produced by a plug-in hybrid depends in part on the source of energy used to generate electricity, as well as how much gasoline it consumes. Once agencies have guidance defining low-emission vehicles, they may face similar conflicts in trying to meet the various vehicle acquisition requirements and goals.

Finally, in our 2008 report, which addressed the extent to which agencies were making progress toward meeting federal fleet energy objectives, we found several additional conflicts agencies experienced in trying to meet all of the current regulations. For example, we found that while agencies were able to meet the alternative fuel vehicle acquisition requirement, they were highly unlikely be able to meet the alternative fuel use requirement because of a limited supply of alternative fuel and an inadequate alternative fuel infrastructure. These issues were also factors in some agencies' inability to meet the petroleum requirements for fiscal year 2007. Accordingly, we suggested that Congress consider aligning the federal fleet AFV acquisition and fueling requirement with current alternative fuel availability and revising those requirements as appropriate.

[37]Pub. L. No. 102-486, §303, 106 Stat. 2871 (Oct. 24, 1992).

Conclusions

As federal agencies work to cost-effectively comply with requirements and goals for conserving energy in their facilities and vehicle fleets, a number of uncertainties hinder their efforts. Although, by making statutory requirements, Congress signified the importance of acquiring alternative fuel vehicles, using alternative fuel, decreasing petroleum use, decreasing greenhouse gas emissions, and improving energy efficiency in facilities, the requirements can be costly and are sometimes in conflict. As a result, agencies are uncertain about setting priorities and struggle to meet the overall intent of these requirements and goals. Executive Order 13423's directive to incorporate plug-in hybrids into fleets adds to the agencies' struggle to balance requirements and goals within their budgets. Without having clear priorities for the patchwork of requirements that compete for funding, agencies may miss opportunities to effectively use new technologies and maximize petroleum reduction. Alternatively, agencies may opt to meet the requirements that are most feasible for them, regardless of whether the actions match the priorities of Congress.

In the past, agencies chose among vehicles with internal combustion engines, which simplified the process of comparing the cost of vehicles and making cost-effective choices. With the advent of plug-in hybrids and all-electric vehicles, as well as new requirements such as reducing greenhouse gas emissions and petroleum consumption, the process has become more complicated. For several reasons, agencies lack information critical to making informed vehicle acquisition decisions that will meet energy-conservation requirements in a cost-effective manner. Specifically, agencies lack (1) data on how the different configurations of plug-ins will affect the costs of the vehicles over their life cycles, (2) strategic plans for how they will incorporate plug-in vehicles, and (3) guidance on how to account for the electricity plug-ins will use.

Plug-ins will be expensive relative to other vehicles until battery costs come down and challenges such as achieving economies of scale are met. These high upfront costs will prevent agencies from including plug-ins in large numbers in their fleets without additional funding. Furthermore, agencies will also be hindered from incorporating plug-ins because of uncertainties regarding their performance, the maintenance and reliability associated with the vehicles' batteries, and the resale value of the vehicles. Exploring the option of leasing the vehicles directly from manufacturers could help mitigate these risks and allow agencies to experiment with how well the vehicles perform within their fleet.

Recommendations for Executive Action

To enable agencies to more effectively meet congressional requirements, we recommend that the Secretary of Energy, in consultation with EPA, GSA, OMB, and organizations representing federal fleet customers such as INTERFUEL, FEDFLEET, and the Motor Vehicle Executive Council, propose legislative changes that would resolve the conflicts and set priorities for the multiple requirements and goals with respect to reducing petroleum consumption, reducing emissions, managing costs, and acquiring advanced technology vehicles.

We recommend that the Secretary of Energy begin to develop guidance for when agencies consider acquiring plug-in vehicles, as well as guidance specifying the elements that agencies should include in their plans for acquiring the mix of vehicles that will best enable them to meet their requirements and goals. Such guidance might include assessing the need for installing charging infrastructure and identifying areas where improvements may be necessary, mapping current driving patterns, and determining the energy sources used to generate electricity in an area.

We also recommend that the Secretary of Energy continue ongoing efforts to develop guidance for agencies on how electricity used to charge plug-ins should be measured and accounted for in meeting energy-reduction goals related to federal facilities and alternative fuel consumption. In doing so, the Secretary should determine whether changes to existing legislation will be needed to ensure there is no conflict between using electricity to charge vehicles and requirements to reduce the energy intensity of federal facilities, and advise Congress accordingly.

We recommend that the Administrator of the General Services Administration consider providing information to agencies regarding total cost of ownership or life-cycle cost for vehicles in the same class. For plug-in vehicles that are newly offered, the Administrator should provide guidance for how agencies should address uncertainties about the vehicles' future performance in estimating the life-cycle costs of plug-ins, so agencies can make better-informed, consistent, and cost-effective decisions in acquiring vehicles.

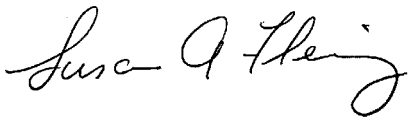
We also recommend that, once plug-in hybrids and all-electrics become available to the federal government but are still in the early phases of commercialization, the Administrator of GSA explore the possibility of arranging pass-through leases of plug-in vehicles directly from vehicle manufacturers or dealers—as is being done with DOD's acquisition of neighborhood electric vehicles—if doing so proves to be a cost-effective means of reducing some of the risk agencies face associated with acquiring new technology.

Agency Comments and Our Evaluation

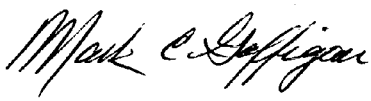
We provided a draft of this report to DOD, DOE, EPA, GSA, OMB, and USPS for review and comment. The audit liaisons from DOD, EPA, and USPS each provided comments via e-mail, and each agreed with the report findings and recommendations. In addition, EPA and USPS provided technical comments, which we incorporated into the draft. The Acting Administrator of GSA provided written comments and agreed with the findings and recommendations pertaining to GSA. The Deputy Associate Administrator for Procurement and Senior Budget Analyst responded orally on behalf of OMB and stated that OMB had no comment on the report's findings and recommendations. DOE did not provide comments on our report within the 30-day review period.

We are sending copies of this report to interested congressional committees and the Secretary of Defense, the Secretary of Energy, the Administrator of the Environmental Protection Agency, the Acting Administrator of the General Services Administration, the Director of the Office of Management and Budget, and the Postmaster General and Chief Executive Officer of the United States Postal Service. In addition, this report will be available at no charge on GAO's Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact Susan Fleming at flemings@gao.gov and (202) 512-2843 or Mark Gaffigan at gaffiganm@gao.gov and (202) 512-3841. Contact points for our Office of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.



Susan Fleming
Director, Physical Infrastructure Issues



Mark Gaffigan
Director, Natural Resources and Environment

Appendix I: Scope and Methodology

The scope of our work included all of the various plug-in hybrid electric vehicle designs as well as the full range of plug-in electric vehicles that are currently in development or already on the market. We defined this set of vehicles as "plug-ins" since they derive part or all of their energy from plugging into an electricity source. Although the United States Postal Service (USPS) is not subject to Executive Order 13423 as are other federal agencies, our review encompassed the fleet operations of USPS because of its size, its past experience in testing electric vehicles, and the potential of that fleet to utilize plug-in technologies. In addition, USPS officials indicated that they will try to comply with the executive order even though they are not required to do so. To inform each of our objectives, we conducted nine site visits with organizations that have test fleets of plug-in hybrids and all-electric vehicles (see table 5).

Table 5: List of Site Visits

Name	Type of organization	Location
Argonne National Lab	National laboratory	Argonne , IL
Austin Energy	Power company	Austin, TX
Google RechargeIT	Nonprofit research	Mountain View, CA
Johnson Controls Inc.	Battery manufacturer	Glendale, WI
Pacific Gas & Electric	Power company	San Francisco, CA
Reliant Energy	Power company	Houston, TX
Seattle City Light	Power company	Seattle, WA
Southern California Edison	Power company	Pomona, CA
USPS Manhattan Station	Government agency	New York, NY

Source: GAO.

To identify the potential benefits and trade-offs of plug-ins, we interviewed officials from power companies and other entities, such as the National Laboratories, currently testing plug-ins. We also reviewed data from these organizations on the performance of plug-ins when it was available. We analyzed the results of published studies from academic research centers and others that evaluated the potential benefits plug-ins can offer with respect to issues such as reducing fuel consumption and greenhouse gas emissions and identified trade-offs plug-ins could require compared to other alternative fuel vehicles and conventional gasoline vehicles. In addition, we used these articles to identify changes in current conditions—such as shifting power sources used to produce electricity from fossil fuels to low carbon energy sources—that would be needed to ensure that plug-ins realized their potential.

To determine the current status of plug-ins, in February 2009 we obtained information directly from Chrysler, Ford, General Motors, Phoenix Motorcars, and the Association of International Automobile Manufacturers. We also reviewed published material on Web sites of a variety of smaller manufacturers, such as Tesla Motors, Fisker Automotive, and others about the plug-ins that those manufacturers plan to bring to market. To understand the development of plug-in vehicle and battery development and identify any potential challenges to the development and commercialization of these technologies, we interviewed a wide variety of stakeholders, and reviewed documents from diverse stakeholders, including auto manufacturers, battery manufacturers, Department of Energy (DOE) and Environmental Protection Agency (EPA) officials, National Laboratory researchers, power companies, charging infrastructure equipment companies, and others. We reviewed published research related to plug-in technology, such as studies on vehicle and battery performance and consumer acceptance of plug-in technology. In addition, to examine the impact of rising or falling gasoline prices relative to electricity prices, different battery costs and prices of vehicles, and different assumptions regarding maintenance expenses and resale values, we developed a model to attempt to estimate the life-cycle and cost-effectiveness of plug-ins relative to conventional hybrids and conventional gasoline-powered vehicles. While our modeling effort highlighted the importance of certain variables, such as battery cost, because of the significant uncertainties regarding the estimates used in these models, we do not report specific results. We also tracked and analyzed developments related to the current economic crisis and financial stress facing the auto industry and the potential impact this crisis could have on plug-in vehicle development. In addition, we reviewed programs and incentives the federal government is using to assist auto manufacturers in developing and commercializing plug-ins, as well as incentives offered to consumers to purchase plug-ins.

To determine the options that exist for the federal government to address challenges in the development, manufacture, and commercialization of plug-ins, we analyzed and synthesized the views of a wide range of stakeholders from interviews, published studies, and analyses regarding options for federal involvement. To ensure the studies we considered were of sufficient scientific rigor, we limited our review to articles published in well-respected peer-reviewed journals or those provided by experts or organizations because of their level of expertise in this area. Articles using cost-benefit analysis to describe the relative benefits of plug-ins were reviewed by an economist. The options selected for discussion represent those supported by many of these experts. In addition, we considered the potential costs the options could pose to the federal government as well as what role the government might play relative to other stakeholders who also stand to benefit from this technology.

Inherently there are certain limitations and variances in the quality of information available about these options. Therefore, we used professional judgment in identifying the relative benefits and limitations of these options. In addition, we identified steps already taken by DOE and others to hasten the development of plug-ins and reviewed recent legislation, including the Recovery Act, to describe the most recent actions taken by the government to forward this technology.

To describe how agencies are addressing the requirement to integrate plug-in hybrids into the federal fleet, we reviewed and analyzed plans and analyses prepared by the Department of Defense (DOD), DOE, EPA, the General Services Administration (GSA), USPS, and other agencies in order to represent a mixture of large and small fleets, vehicle use patterns, and types and conduct interviews with fleet managers from those agencies. We also interviewed officials from the Office of Management and Budget to understand their role in overseeing agency compliance with federal energy and fleet requirements and goals, including Executive Order 13423. To identify challenges related to integrating plug-in hybrids or all-electric vehicles into federal fleets, we interviewed fleet managers from DOD—including those of the Army, Navy, Air Force, and Marines—DOE, GSA, and USPS. We also attended and held discussions with those attending federal fleet manager meetings (FEDFLEET) organized by GSA. Furthermore, we used in-depth discussions with fleet managers from the selected agencies and our discussions at the FEDFLEET meetings to examine the life-cycle costing methodologies used by fleet managers to select vehicles for their fleets. To understand how alternative fuel vehicles and others are priced and made available to the federal fleet, we reviewed GSA's procurement process. We also analyzed and compared the requirements contained in various legislative mandates and executive orders related to (1) federal fleet use of alternative fuels, (2) reductions in agencies' overall energy consumption, and (3) increased reliance on renewable energy sources to identify how integrating plug-ins might help or hinder agencies' efforts to meet these requirements. Because we did not interview managers from all of the agencies operating vehicle fleets, our findings are not be applicable to all federal agencies.

We conducted this performance audit from July 2008 to June 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives

Appendix II: GSA Procurement Process

Federal agencies are required by regulation to purchase all nontactical vehicles through the General Services Administration (GSA), which leverages its status to procure vehicles at significant discounts. The United States Postal Service (USPS) is not subject to GSA's purchase restrictions as USPS can purchase its own vehicles or use GSA's services to do so. Motor vehicle supply activities are largely carried out by two units within GSA's Federal Acquisition Service—GSA Automotive, which is responsible for contracting with manufacturers and other suppliers for nontactical motor vehicles, and GSA Fleet, which leases a broad range of vehicles to federal customers and other eligible entities.

Using the previous year's purchase as a baseline, GSA Automotive contracts with auto manufacturers and other suppliers to procure vehicles for federal customers. This annual process begins each winter with discussions between GSA and auto manufacturers about anticipated federal needs, future vehicle availability, and any changes that have been made to federal vehicle standards. The purpose of the standards is to establish a practical degree of standardization within the federal fleet. The standards are organized by class of vehicle—such as sedans, trucks, and buses—and outline minimum criteria for vehicle characteristics such as engine horsepower, cabin space, and safety features. GSA publishes the standards and encourages the manufacturers to identify models they could offer at a competitive price to the government that meet or exceed the standards. If GSA modifies the standards to address, for example, new federal mandates or goals, GSA publishes a draft version and provides a comment period for stakeholders before finalizing them. Once the standards are finalized, GSA Automotive issues at least five solicitations in the FedBizOpps, the government portal for federal procurement opportunities to cover specific types of vehicles, such as sedans, trucks, buses and ambulances, reviews proposals, and awards contracts in time for the beginning of the fiscal year on October 1. The contracts are typically indefinite quantity/indefinite delivery contracts.

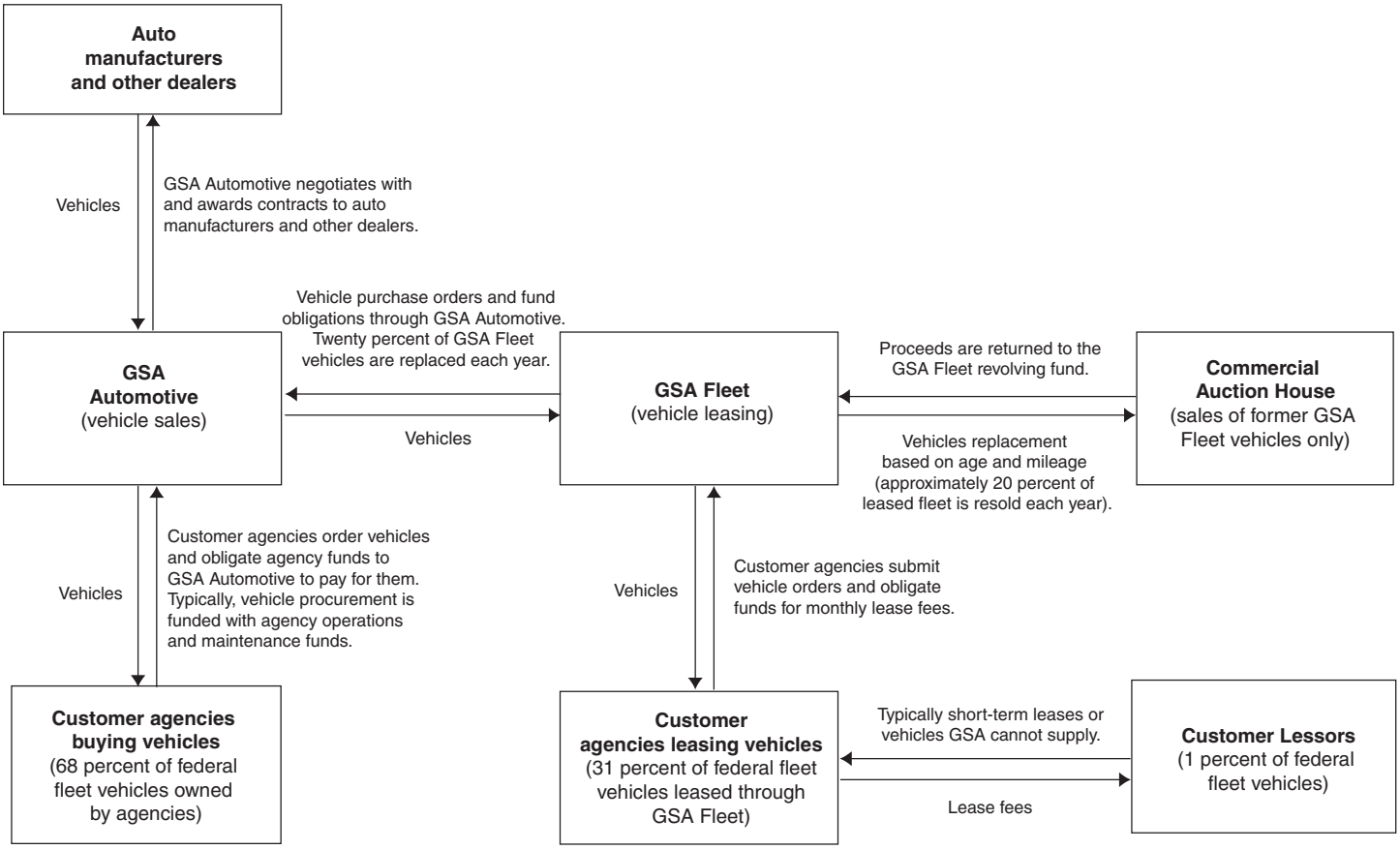
Although federal motor vehicle procurement has not been limited to purchasing vehicles made by domestic manufacturers by the Federal Acquisition Regulations, historically, only domestic automakers have submitted proposals. According to GSA officials, the agency may contract with auto manufacturers from any country with which the United States has a trade agreement if the order is greater than $194,000. However, foreign manufactures have not submitted proposals in the past, citing franchise and licensing agreements with their domestic dealers as preventing direct sales of vehicles to the government. Nonetheless, some foreign manufacturers have encouraged their dealers to contract with

GSA, which has allowed GSA to procure vehicles made by foreign manufacturers in limited numbers through domestic dealers.

GSA is required by law to recover all costs it incurs in providing vehicles and services to federal customers.[1] Since neither GSA Automotive nor GSA Fleet receives appropriations through the annual budget cycle, both the procurement and the leasing activities operate out of revolving funds that are reconciled each year. GSA Automotive awards contracts for vehicles, provides information to agencies on pricing for evaluation, and places orders against the awarded contracts using their agency funds. GSA Automotive applies a 1 percent surcharge to the final purchase price of each vehicle ordered. Similarly, GSA Fleet obligates money to GSA Automotive from its revolving fund to purchase the vehicles it leases to federal customers and recovers purchase and maintenance costs through lease fees and the resale of vehicles at the end of their life cycle. According to GSA Fleet officials, approximately 20 percent of the leased vehicles are replaced each year. GSA Fleet replaces the leased vehicles using several criteria, among which age and mileage are foremost. Since GSA Fleet needs to recover its costs to maintain the solvency of its revolving fund, it auctions off most of its sedans, for example, within 5 years of their purchase. Agency-owned vehicles are usually retained for longer periods, as are larger vehicles such as trucks and buses.

[1] 40 U.S.C. §605.

Figure 3: GSA's Acquisition Process



Source: GAO.

Federal customers purchase vehicles by using AutoChoice, an automated internet-based tool maintained by GSA Automotive. AutoChoice allows users to configure and evaluate the vehicles they would like to buy, by displaying side-by-side comparisons of vehicle models from several manufacturers. The side-by-side comparisons include costs, fuel ratings, and vehicle safety data, manufacturers' past performance, and comparisons between GSA's contract discounts and retail prices, among other features. Agency fleet managers place orders for most vehicles between October and May of each year, after which the manufacturers close their plants to prepare for the next model year's production which begins in August. GSA's AutoChoice Summer Program, however, allows federal customers to obligate current year funds during the summer to purchase next model year vehicles for delivery when production resumes

in the fall. According to GSA Automotive, the size of orders placed on AutoChoice ranged from 1 to 200 vehicles in fiscal year 2008 but averaged two vehicles per order.

Federal customers can purchase most types of vehicles—including sedans, heavy trucks, wreckers, and buses—through AutoChoice. However, for certain specialized vehicles, such as low-speed neighborhood electric vehicles, heavy vehicles such as those used for construction, or tankers, fire trucks, and trash collectors, GSA is not the mandatory source and these vehicles are not listed in AutoChoice. Instead, GSA makes these vehicles available through its Multiple Award Schedules program whereby it has negotiated long-term governmentwide contracts with a multitude of different commercial vendors—providing access to millions of commercially supplied products. Agencies are free to procure supplies from any of the vendors listed on GSA's multiple award schedules or contract with vendors on their own. In addition, for purposes of EPAct reporting requirements, the specialized vehicles sold through GSA multiple award schedules are considered equipment rather than vehicles.

GSA Fleet buys vehicles through GSA Automotive, then leases them to federal customers. The process used to lease vehicles from GSA Fleet is similar to purchasing vehicles with several exceptions. First, federal customers are not restricted by federal regulations from leasing vehicles through GSA but may choose to lease from commercial vendors, such as those listed on the multiple award supply schedules. Nonetheless, since GSA Fleet procures the vehicles it leases at discount and passes those savings on to customers, nearly all of the vehicles leased by federal customers are leased through GSA Fleet rather than commercial vendors, which accounted for only 1 percent of all federal fleet vehicles in fiscal year 2008. Fleet managers told us they typically lease vehicles from commercial vendors only in cases where GSA Fleet is unable to supply the vehicle, for overseas locations where GSA Fleet does not operate, such as in Southeast Asia, or for very short lease periods. Second, agencies negotiate leases for vehicles through GSA's Regional Offices or local Fleet Management Centers rather than using AutoChoice or online automated tools. GSA Fleet offers different leasing arrangements to meet customer needs. For example, because GSA Fleet vehicles are in high demand and some requests for additional vehicles must go unfilled, GSA Fleet offers customers the option of leasing from commercial vendors through its Schedule 751. Should the agency choose to open a commercial lease through GSA Fleet rather than on its own, GSA Fleet will manage the lease for the customer, including the provision of maintenance and fuel.

Appendix III: GAO Contacts and Staff Acknowledgments

GAO Contacts

Susan A. Fleming, (202) 512-2834 or flemings@gao.gov

Mark Gaffigan, (202) 512-3841 or gaffiganm@gao.gov

Staff Acknowledgments

In addition to the contacts named above, Andrew Von Ah, Assistant Director; Karla Springer, Assistant Director; Lindsay Bach; Nabajyoti Barkakati; Charles Bausell; David Hooper; Joah Iannotta; John Johnson; SaraAnn Moessbauer; Madhav Panwar; and Crystal Wesco made key contributions to this report.

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