Optimizing Federal Fleet Vehicle Acquisitions: An Eleven-Agency FY 2012 Analysis

Mark Singer and Ryan Daley

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Technical Report
NREL/TP-5400-62264
February 2015

Contract No. DE-AC36-08GO28308

NATIONAL RENEWABLE ENERGY LABORATORY

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Prepared under Task No. 5400.2000

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All judgments in the final analytic methodologies and interpretations are the responsibility of the authors and not of the experts acknowledged above.

Acronyms

AFV	alternative fuel vehicle
BEV	battery-electric vehicle
B100	pure biodiesel
CNG	compressed natural gas
DOE	U.S. Department of Energy
ECRA	Energy Conservation and Reauthorization Act
EISA	Energy Independence and Security Act
EPAct	Energy Policy Act
EV	electric vehicle
FEMP	Federal Energy Management Program
FFV	flex-fuel vehicle
FSR	Field Service Representative
FY	fiscal year
GGE	gasoline gallon equivalent
GHG	greenhouse gas
GSA	General Services Administration
GVWR	gross vehicle weight rating
HEV	hybrid electric vehicles
LDV	light-duty vehicles
MCDM	multi-criteria decision making
MPGGE	miles per gasoline gallon equivalent
NDAA	National Defense Authorization Act
NOVA	NREL Optimal Vehicle Acquisition
NREL	National Renewable Energy Laboratory
PHEV	plug-in hybrid electric vehicles
SSPP	Strategic Sustainability Performance Plan
VAM	Vehicle Allocation Methodology
VMT	vehicle miles traveled

Executive Summary

Over the past two decades, numerous mandates focusing on environmental sustainability and energy management in federal fleets have created a complex regulatory landscape. It has proven challenging for federal fleet managers to effectively prioritize and make progress toward these mandated goals. This is particularly true when considering that the primary task of federal fleet managers is to ensure that the fleet meets the mission objectives of their agency and that a smaller fraction of fleet manager time is spent on achieving mandates.

Prior research has identified methodologies and tools to help managers efficiently prioritize and understand tradeoffs between different mandate attainment strategies. The vehicle acquisition process has been a particular focus of prior investigations as it is a key decision point with a high impact on the ability of fleets to meet mandates. This report focuses on a fiscal year (FY) 2012 effort that used the NREL Optimal Vehicle Acquisition (NOVA) analysis to identify optimal vehicle acquisition recommendations for eleven diverse federal agencies. The recommendations were completed in time to inform the agencies' final FY 2013 vehicle acquisition plans. In this way, the effort showed that the theoretical benefits of a vehicle acquisition optimization effort could be applied during the ordering cycle.

Results of the study show that by following a vehicle acquisition plan that maximizes the reduction in greenhouse gas (GHG) emissions, significant progress is also made toward the mandated complementary goals of petroleum use reduction and alternative fuel use increase. In addition to the specific vehicle recommendations, results showed that agencies could benefit from more generalized guidance of:

1. Targeting flex-fuel vehicles (FFVs) in locations where E85 is available
2. Targeting hybrid electric vehicles (HEVs) when budget allows, where E85 is not available, and when driving routes involve stopping and starting that enables HEVs to achieve their full fuel economy benefit.
3. Targeting the most efficient conventional gasoline vehicles or FFVs available where E85 is not available and the budget is constrained.

Following the specific vehicle recommendations proved challenging for the agencies. Fleet organization structures, mission nuances, and user preferences were found to vary widely among fleets from the national to the local levels. Additionally the General Services Administration (GSA) has to manage its own constraints and is not always able to deliver specific vehicle makes and models in the exact numbers chosen by the model. Efforts that take into account the varied organizational structures of federal fleets and the constraints on vehicle availability from GSA would have a greater potential to positively affect fleet performance toward mandated goals. In addition, future studies supporting the federal fleet ordering process would benefit from an effort to define vehicle capability standards precise enough to ensure that replacement recommendations meet highly specific mission requirements.

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1 Introduction

Beginning with alternative fuel vehicle (AFV) acquisition requirements in The Energy Policy Act of 1992 (EPAct 1992), numerous mandates have focused on energy management of the federal fleet during the past two decades. This has created a complex regulatory landscape where achieving compliance must be balanced with a wide variety of agency mission objectives and operational needs, organizational structures, and budgets. The combination of competing regulatory and operational priorities during the vehicle acquisition process make it challenging for federal fleet managers to make progress toward the goals of alternative fuel and advanced vehicle technology deployment, energy security, environmental sustainability, and cost savings.

This paper discusses the results of a fiscal year (FY) 2012 study to support the vehicle acquisition process for eleven federal agencies. Using the NREL Optimal Vehicle Acquisition (NOVA) analysis, the study produced specific, individual vehicle recommendations determined by integer optimization models for each agency, in consideration of the wide array of competing acquisition requirements for these fleets. Development and use of the NOVA analysis expands on previous work by Helwig and Deason (2007) and Deason and Jefferson (2010).

Benefits of a NOVA Analysis

- **Maximize budget:** Get a more efficient fleet for your money
- **Minimize waste:** Place the optimal vehicle at the optimal location
- **Achieve targets:** Efficiently plan for compliance.

The General Services Administration (GSA) manages standardized data for all vehicles leased through GSA by federal agencies. We drew from these GSA leased vehicle data sets to feed the NOVA models for a diverse group of eleven agencies. Running analyses for each agency based on standard data allowed us to consider the nuances of each specific agency, arrive at conclusions that cross all the agencies, and show the scale of impact an optimization effort can have in the federal fleet. Yet the benefits of any optimization effort are inherently dependent on the strict enforcement of the outputs generated – any deviation from that output necessarily constitutes a suboptimal implementation.

In order for mandates to have the intended impact, they must account for the context in which the fleets operate. Accordingly, we also discuss the setting in which fleet managers approach the vehicle ordering process: we estimated the theoretical impacts of the optimized recommendations on mandated goals, but the actual impacts are difficult to predict primarily due to variances across and within agencies related to (1) specific mission requirements and (2) centralization or de-centralization of decision-making authority. These factors contributed to numerous instances where the 'optimized' acquisition recommendations likely were not chosen to be followed. These hurdles could be overcome if more specific mission requirements could be defined, as the model can handle the more detailed requirements, and if agencies chose to have a more centralized vehicle acquisition process. Applied use of optimization models in federal fleets shows significant benefits are possible, but fleet managers face challenging operational hurdles in achieving the theoretical improvements that the models predict.

2 Background

2.1 History of Federal Fleet Regulations

Federal fleets are looked upon to be leaders in fleet energy management. Because of this, there have been numerous legislative and executive efforts to support the implementation of alternative fuel and advanced vehicle technology, energy security, and environmental sustainability. The U.S. Department of Energy (DOE) (2010, 2011), as well as Deason and Jefferson (2010), provide a comprehensive overview of these regulations and their applicability to federal agencies. Table 11 in appendix A as adapted from DOE (2010) provides a brief overview of these requirements and covers the following statutes and Executive Orders (EOs):

- EPAct 1992, as amended by the Energy Conservation and Reauthorization Act (ECRA) of 1998 and Section 2862 of the National Defense Authorization Act (NDAA) of 2008
- The Energy Policy Act of 2005 (EPAct 2005)
- E.O. 13423 *Strengthening Federal Environmental, Energy, and Transportation Management,* signed on January 24, 2007
- Energy Independence and Security Act (EISA) of 2007
- E.O. 13514, *Federal Leadership in Environmental, Energy, and Economic Performance,* signed on October 5, 2009.

While each of these regulations and specific mandates broadly share a sustainability focus, progress toward one mandated goal did not guarantee success amongst the others. This made for a complex environment for fleet managers that also had to consider fleet mission objectives and budgets. Without clear direction, fleet managers individually had to weigh the relative importance of mandates and accept the tradeoffs for prioritizing one over another. Deason and Jefferson (2010) as well as Helwig and Deason (2007), have shown that fleet manager opinions have varied widely on the relative importance of mandated objectives. In an effort to support fleet manager decision-making, Deason and Jefferson (2010) developed a multi-criteria decision making (MCDM) approach to help fleet managers weigh the perceived importance of mandates and help them create structured fleet management strategies.

In this complex setting, E.O. 13514, *Federal Leadership in Environmental, Energy, and Economic Performance,* signed on October 5, 2009, established "an integrated strategy toward sustainability in the federal government and makes reduction of greenhouse gas (GHG) emissions a priority for federal agencies." Additionally E.O. 13514 required DOE to issue comprehensive guidance on sustainability in the federal fleet in coordination with GSA – *Guidance for Federal Agencies on E.O. 13514, Section 12, Federal Fleet Management* (DOE, 2010) and *Comprehensive Federal Fleet Management Handbook* (DOE 2014)[1] fulfilled this requirement.

Through these documents, DOE has established a de facto prioritization of federal fleet sustainability mandates where reducing GHG emissions is the top priority and reducing petroleum consumption is the primary mechanism to achieve this goal; the remaining mandates support this overarching metric. Figure 1 (DOE 2014) summarizes the organization of these mandates.

[1] FEMP's *Comprehensive Federal Fleet Management Handbook* was originally published in 2011 and last updated in 2014.

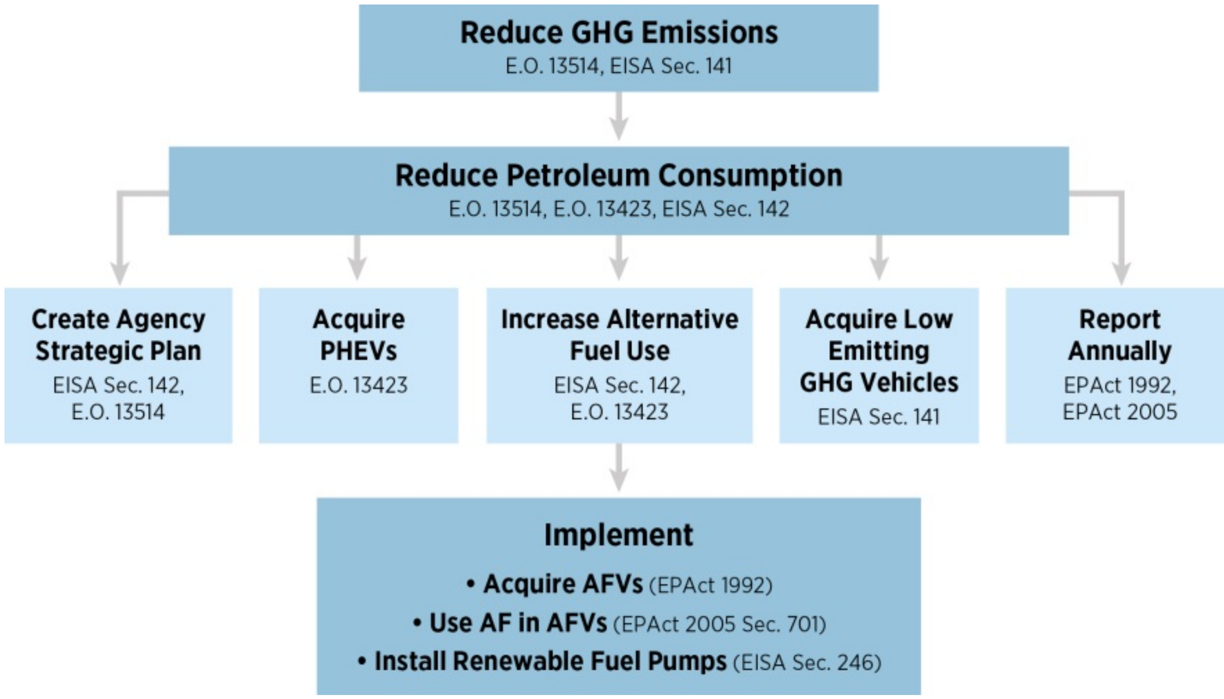

Figure 1. Organization of mandates

In accordance with the direction of E.O. 13514 and the framework developed by DOE, the study discussed in this paper prioritized reducing GHG emissions.

2.2 Reduce GHG Emissions

E.O. 13514 required federal agencies to establish aggressive targets for reducing GHG emissions throughout the operation of the federal government by January 4, 2010. GHG emissions are split into three source categories, or "scopes" (White House 2010):

- Scope 1 includes GHG emissions from sources owned or controlled by a federal agency: vehicles and equipment, stationary combustion for buildings, on-site landfills and wastewater treatment, and fugitive emissions.
- Scope 2 includes GHG emissions from electricity, heat, or steam purchased by federal agencies; includes electricity used in the operation of Electric Vehicles (EVs).
- Scope 3 includes GHGs from sources not directly owned or controlled by federal entities (e.g., business travel, employee commuting, contracted waste disposal, etc.).

GHG emission reduction requirements for federal fleet vehicles fall under both Scope 1 and Scope 2 emissions.

E.O. 13514 further required agencies to establish baseline inventories of GHG emissions based on FY 2008 operations, establish organizational GHG reduction targets, create (and update annually) a Strategic Sustainability Performance Plan (SSPP)[2], and report GHG emissions annually (White House 2012). E.O. 13514 touched on agency vehicle acquisition efforts in

[2] Federal agency SSPPs are available through the White House at http://archive-sustainability.performance.gov/.

Section 2(a) iii, *Goals for Agencies,* which requires the head of each agency to consider reducing the use of fossil fuels by (White House 2009):

A. Using low GHG-emitting vehicles and AFVs.

B. Optimizing the number of vehicles in the agency fleet

C. Reducing, if the agency operates a fleet of at least 20 motor vehicles, the agency fleet's total consumption of petroleum fuel by a minimum of 2 percent annually through the end of FY 2020, relative to a baseline of FY 2005.

2.3 Vehicle Acquisition

The acquisition of new fleet vehicles is an operational effort that plays a critical role in the federal fleet's ability to meet sustainability mandates; it is the primary focus of this study. The following regulations cover the acquisition of vehicles in the federal fleet:

- EPAct 1992 requires that 75% of all light-duty vehicles (LDV) acquired in metropolitan statistical areas (MSA) must be AFVs.
- ECRA 1998 states that for every 450 gallons of pure biodiesel (B100) used in agency fleets received a credit equal to one AFV acquisition.
- NDAA 2008 added hybrid electric vehicles (HEV) to the definition of an AFV, and "any other type of vehicle that EPA demonstrates to DOE would achieve a significant reduction in petroleum consumption" (DOE 2014).
- EISA 2007 requires agencies to acquire only low-GHG emitting vehicles; "…any low GHG-emitting vehicle acquired in lieu of a [Flex Fuel Vehicle (FFV)] that an agency reasonably determines qualifies for a fuel waiver under EPAct 2005 § 701 is now included in the expanded definition of an AFV" (EPA 2012).
- E.O. 13423 requires the acquisition of plug-in hybrid electric vehicles (PHEVs) when they are commercially available at costs reasonably comparable to non-PHEVs.

While the focus of this study touches on all of these requirements, it is more specifically concerned with acquiring the appropriate AFVs in locations where agencies can reap the most benefit from a particular technology. Acquiring the appropriate AFVs in optimal locations sets agencies up to achieve the overarching goals of GHG emission reductions, petroleum reduction, and alternative fuel use over the lifetime of their vehicles. Conversely, suboptimal vehicle acquisitions can impede a fleet's ability to meet sustainability mandates and lead to unnecessary costs for agencies operating under highly scrutinized and constrained budgets.

Helwig and Deason (2007) noted the lack of a requirement to actually use alternative fuel in federal AFVs as a core deficiency of EPAct 1992. This shortcoming was first remedied via E.O. 13149, *Greening the Government through Federal Fleet and Transportation Efficiency,* and subsequently addressed in Section 701 of EPAct 2005. Section 701 requires that all dual-fueled AFVs in the federal fleet only be operated on alternative fuel unless they received a waiver from this requirement through DOE if (1) alternative fuel is not reasonably available within 5 miles or a 15-minute drive from the vehicle's garage location, or (2) alternative fuel is unreasonably more expensive than gasoline (DOE, 2011).

In addition to Section 701, the *Presidential Memorandum – Federal Fleet Performance* was issued on May 24, 2011. This memo requires federal agencies to complete an annual Vehicle Allocation Methodology (VAM), which was developed and distributed to the fleets through GSA. In addition, "by December 31, 2015, all new light-duty vehicles leased or purchased by agencies must be alternative fueled vehicles, such as hybrid or electric, compressed natural gas, or biofuel. Moreover, agency alternative fueled vehicles must, as soon as practicable, be located in proximity to fueling stations with available alternative fuels, and be operated on the alternative fuel for which the vehicle is designed. Where practicable, agencies should encourage development of commercial infrastructure for alternative fuel or provide flex fuel and alternative fuel pumps and charging stations at federal fueling sites" (White House 2011).

While the passage of requirements to use alternative fuel has addressed some of the initial shortcomings of EPAct 1992, underuse of alternative fuel and the suboptimal placement of AFV technologies continue to hamper federal fleet efforts to reduce GHG emissions and petroleum use.

2.4 Federal Fleet Mandate Performance

The federal fleet has exceled in meeting the EPAct 1992 AFV acquisition requirement in recent years as can be seen in Figure 2.

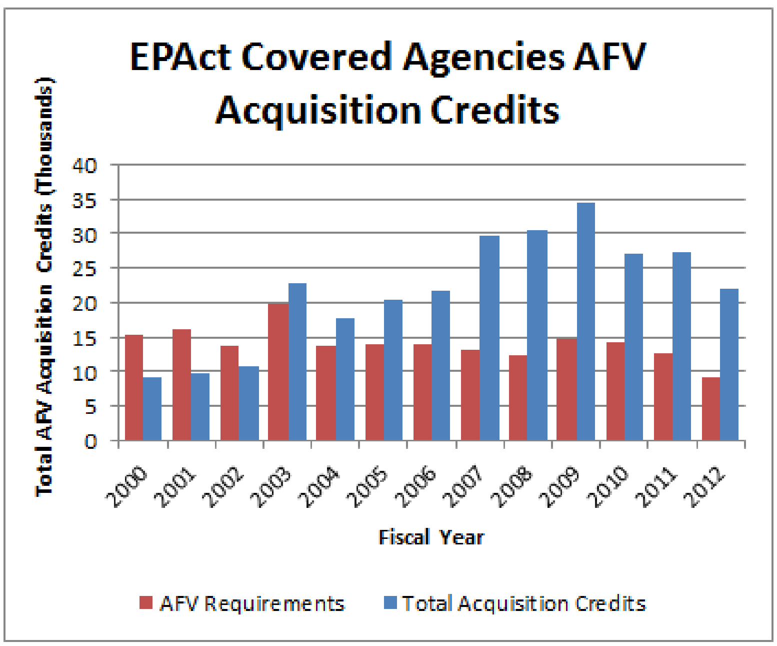

Figure 2. Acquisition credits[3]

Further, Figure 3 shows the federal fleet has consistently increased the portion of the fleet that is comprised of AFVs. In 2012, this AFV percentage reached 33 percent.

[3] http://federalfleets.energy.gov/performance_data/afv_acquisition_compliance. Accessed May 20, 2014.

Figure 4 shows that petroleum consumption has slightly increased since 2000. During the same time period, the percentage of total fuel use that is alternative fuel has steadily increased, but the percentage remains relatively low.

There are multiple reasons for the stark difference between the percentage of the fleet that is comprised of AFVs and the percentage of fuel use that is alternative fuel. Daley (2014) investigated federal fleet fueling behavior and found that drivers consistently miss opportunities to use available alternative fuel. Additionally, AFVs have not always been located where they have access to alternative fuel infrastructure. The challenge of better locating AFVs is a focus of the study that follows.

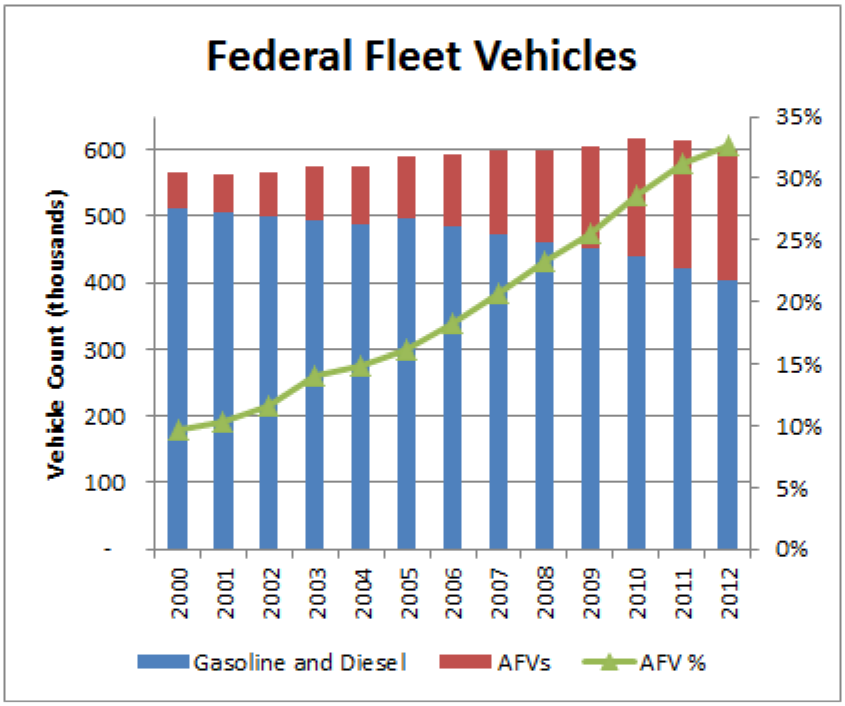

Figure 3. Federal fleet vehicles[4]

[4] http://federalfleets.energy.gov/sites/default/files/static_page_docs/ff3_vehicles_fuel_type_FY12.xls. Accessed May 20, 2014.

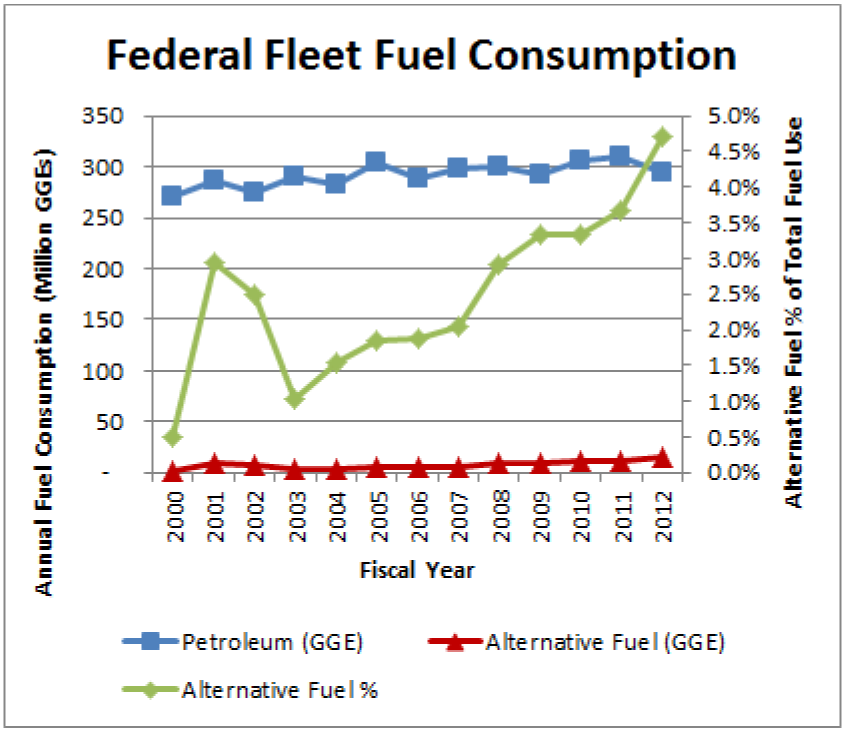

Figure 4. Fleet fuel consumption[5]

2.5 Fleet Management Operations and Organizations

Fleet operations across the federal government include management of vehicle inventories to efficiently meet agency mission objectives, maintenance of the vehicles, and acquisition and disposal of vehicles.

In comparison to private fleets that may support a relatively consistent function across an organization, federal fleets were found to support highly diverse mission requirements including:

- Passenger and cargo transport
- Low and high passenger-count transport
- Short distance and long-haul transport
- Rural, suburban, and urban transport
- On-road and off-road transport
- Highly routinized and highly irregular transport
- Mobile workstation transport.

Federal fleet missions are not entirely static and can expand and change. These changes are the consequence of shifting agency responsibilities due to specific legislative and executive actions

[5] http://federalfleets.energy.gov/sites/default/files/static_page_docs/ff9_covered_petro_alt_fuel_FY13.xlsx. Accessed May 20, 2014.

such as increased border security in response to national security needs or increased military activity in a time of war. Missions can also change as a consequence of providing services to a population with growing and shifting demographics, including a growing elderly population, a growing number of veterans returning from war, and a growing public population in general. Federal fleets may also encounter significant unscheduled mission requirements such as responding to natural disasters. Fleet missions can also often shrink over time as funding priorities change.

Federal fleet managers work to meet requirements within a variety of organizational structures. These structures can be highly centralized where national fleet management has visibility into operations through mid-levels and down to the local level. Mid-level and local fleet managers are accountable to the national management in these centralized structures. Alternatively, fleet management can often be highly decentralized where national fleet managers have little visibility into specific fleet operations. Mid-level and local fleet managers operate with a high degree of autonomy and have only cursory reporting requirements to higher levels in decentralized structures. Many federal fleets fall somewhere between the extremes of a highly centralized or highly decentralized structure.

It is within this operational setting that fleet managers often spend only a fraction of their time working to meet fleet sustainability mandates. The importance placed on meeting mandates varies across fleets. Those agencies that have chosen a more centralized organizational structure and have high level leadership focused on successfully meeting mandates tend to more aggressively pursue results.

2.6 GSA Leased Vehicle Ordering Process

Our study supporting the eleven federal agencies in FY 2012 focused on the GSA-leased portion of the fleets. Federal fleets are able to acquire vehicles by purchasing them directly through GSA, leasing them though GSA, or leasing them through commercial vendors. In FY 2012, as Figure 5 shows, 30 percent of all federal vehicles were GSA leased vehicles.

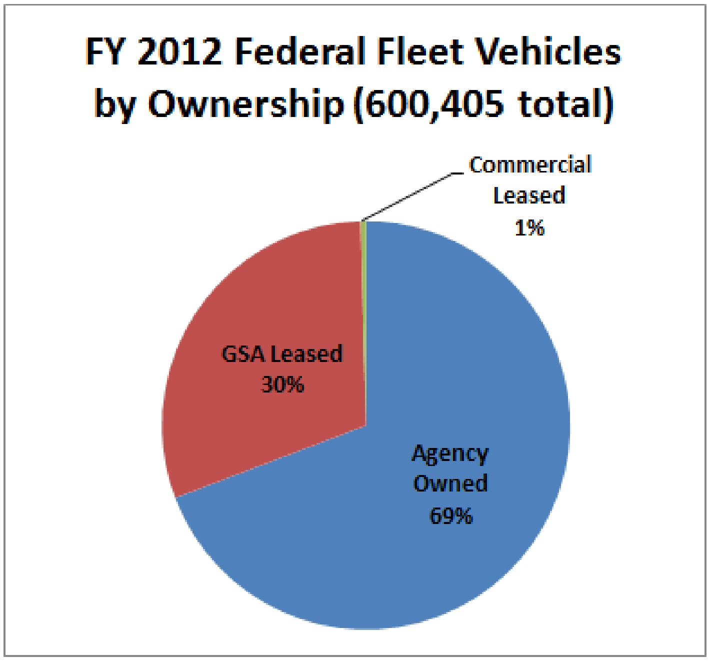

Figure 5. Fleet vehicles by ownership versus leased

Source: Federal Automotive Statistical Tool (FAST)

As a matter of scale and complexity, a single federal agency may manage between a couple dozen to more than 50,000 GSA-leased vehicles. Each year the GSA offers hundreds of lease vehicle models to choose from. Fleets may acquire and manage vehicles for locations numbering five or less to thousands across the country.

The GSA-leased vehicle ordering process is somewhat different for every agency and, in part, is a product of the individual agency organizational structure. Headquarters national fleet managers for each agency work with the GSA Fleet central office to set high level goals for a particular acquisition cycle. Local level fleet managers across the country work with their GSA Field Service Representatives (FSRs). Both the agencies and GSA have mid-level region or other organizational management levels that coordinate between the national and local levels.

The vehicle ordering timeline fluctuates, but generally begins late in the summer months when GSA identifies current agency vehicles as replacement-eligible. Local level fleet management works with their FSRs throughout the fall months to submit orders to GSA. Agency national management is able to review and change orders until orders are finalized in December or January. GSA then delivers newly leased vehicles throughout the year.

National fleet management in centralized fleet organizations will set goals for the fleet as a whole and distribute specific vehicle recommendations or generalized guidance to local fleet managers. Local fleet managers that wish to deviate from the national direction may then work within a defined structure to request an exception from higher-level management. Mid-level or national management closely review final vehicle orders prior to submittal to GSA.

Local fleet managers in decentralized agencies may receive general guidance from national management, but in practice have a great degree of freedom in the ordering process. National managers in this structure may or may not have timely and readily available visibility into the local vehicle ordering process. National managers that are able to review orders may not be in a position to change the orders prior to their submittal to the GSA.

GSA plays a vital customer service role throughout the ordering process, working to ensure that an agency receives their requested vehicles to meet mission requirements. However, GSA must balance the desires of fleet managers across the federal government, contract with vehicle manufacturers to provide the appropriate vehicles, and work within the constraints of its own operating environment. In some instances GSA may not be able to provide specified vehicle makes and models in the quantities requested by the agencies at every location. While GSA is highly supportive of agency efforts to achieve mandated sustainability goals, it is ultimately up to each agency management structure to determine the best way to reach those goals.

2.7 Technical Assistance Offer from the DOE Federal Energy Management Program

DOE is required by law to provide support to agencies during the vehicle acquisition process under EPAct 1992 § 305. Specifically, DOE is directed to "… provide guidance, coordination and technical assistance to federal agencies in the procurement and geographic location of alternative fueled vehicles purchased through the Administrator of General Services." Under this direction and in direct response to the May 24, 2011, *Presidential Memorandum – Federal Fleet Performance,* the DOE Federal Energy Management Program (FEMP) offered assistance to all federal fleets, and ultimately supported eleven fleets in FY 2012 by providing the NOVA analyses during the planning and execution of the GSA-leased vehicle acquisition process. GSA leased vehicles were the focus of this study due to the readily available and consistent datasets for GSA-leased vehicles across all agencies. These datasets are not always available for those portions of the federal fleet that are owned or commercially leased by the agencies.

The 2012 support provided agencies with specific optimal vehicle recommendations for each vehicle in the agency inventory prior to the beginning of the ordering cycle and the determination of the specific vehicles eligible for replacement. The intent of the recommendations was to help agency fleet managers make more informed decisions about how best to achieve sustainability goals during the vehicle ordering process. It was up to the national agency fleet managers to use and distribute the recommendations in their organization as they saw best prior to and during the ordering process.

3 Methodology: Model Structure and Assumptions

3.1 NOVA Analysis Description

NOVA analyses rely on a series of integer optimization models initially created by Dr. Michael Helwig (Helwig and Deason 2007) and further developed at the National Renewable Energy Laboratory (NREL). NOVA models consider an existing inventory of vehicles and determine a set of replacement vehicles that will achieve a specified optimal goal while considering fleet constraints, including vehicle locations, alternative fuel vehicle budgets, and compliance with fleet mandates.

As discussed earlier, DOE established that the reduction of GHG emissions is the primary fleet sustainability objective since the signing of E.O. 13514. In accordance with this prioritization, the NOVA model used for the FY 2012 study determines the set of replacement vehicles that maximizes the reduction in GHG emissions in comparison to the existing inventory while considering fleet constraints. The model results show significant progress is made toward the complementary goals of petroleum use reduction and alternative fuel use increase. This is due to the fact that GHG emissions from the federal fleet are primarily the result of burning traditional petroleum fuels (i.e., gasoline and diesel). The combination of using more efficient vehicles that burn less fuel in total and using more alternative fuels that emit fewer GHG emissions achieves the overall goal of reducing fleet GHG emissions.

3.2 Model Calculations

At a high level, the NOVA model calculates the estimated annual fuel consumption for each vehicle in the inventory and each replacement vehicle option. The fuel consumption estimates are then converted to GHG emissions estimates. The model compares these estimated values for the replacement vehicle options and determines the set of replacement vehicles that will maximize the reduction of GHG emissions for the inventory in total while staying under budget and within other model constraints.

3.3 Vehicle Availability

The primary inputs to the model are the agency's existing GSA-leased vehicle inventory and the list of vehicles available for lease to the agency from the GSA. The existing inventory vehicles are segmented into four primary vehicle types including sedan, pick-up, van, and SUV. The model primarily considers the light-duty (gross vehicle weight rating (GVWR) less than 8,500 lbs.) portions of the fleets because these vehicles have readily available fuel economy ratings by each vehicle make and model that allow for vehicle fuel consumption comparisons – the assumptions for vehicle fuel consumption is detailed below.

A portion of each fleet did not receive specific vehicle recommendations. These vehicles included special use vehicles, such as emergency response or law enforcement vehicles, as well as larger medium-duty (8,500 – 10,000 lbs. GVWR) and heavy-duty vehicles (greater than 10,000 lbs. GVWR). These vehicles did not have available replacement options with specific make and model fuel economy ratings. The general acquisition guidance provided for replacement of these vehicles is to acquire the most efficient vehicle available to meet mission requirements.

The model allows vehicles to only be replaced by vehicles of the same vehicle type (e.g., a pick-up can only be replaced by another pick-up). This replacement constraint ensures vehicles are replaced by vehicles of similar functionality and mission capability. A more specific designation of a mission requirement for each vehicle was not available at the time of this analysis across the fleets in a standard format. The constraint to ensure vehicles are replaced by the same vehicle type ensures the fleet capability is not drastically altered by the recommended vehicles.

The lack of visibility into the fleet mission requirements is a significant hurdle in evaluating the alignment of existing fleet capabilities to mission and to properly evaluate the viability of replacement options that may alter fleet functionality. However, the model can easily be updated to include more specific constraints and this occurred on several occasions where agencies were able to provide them. An example would be when an agency decided the smallest sedan allowed to replace an existing sedan be a compact sedan rather than allowing the NOVA model to choose from the smaller sub-compact sedan type. In this instance the larger compact sedan was required to meet mission requirements. These requests were incorporated into the model as requested by agency fleet managers.

The vehicles available for lease from GSA include a range of vehicle fuel technologies from traditional gasoline and diesel vehicles to AFV technologies including E85-capable FFVs, HEVs, compressed natural gas (CNG) vehicles, PHEVs, and battery-electric vehicles (BEV). AFVs, with the exception of HEVs, require access to alternative fuel infrastructure to use the appropriate alternative fuel. In addition to strict alternative fuel vehicles, diesel vehicles are “B20 capable,” meaning they can be fueled with a blend of diesel that is comprised of 20 percent biodiesel and 80 percent petroleum diesel. Diesel vehicles are primarily available in medium- and heavy-duty vehicle model types. As previously mentioned, this study primarily focused on the light-duty portion of the fleet, and therefore diesel technologies did not have a significant impact on the analysis outputs.

3.4 Vehicle Geography

The analysis effort assigned a geographic location to each vehicle in the existing inventory to determine the vehicle proximity to known, available, alternative fuel infrastructure. GSA provides each agency with fuel transaction history reports that include the specific station locations at which each vehicle has fueled. Previous studies have relied on the garage location of the vehicle listed in the GSA inventory reports (Helwig and Deason, 2007). We assumed the fuel transaction locations were indicative of where vehicles operated and relied on the fueling data to determine the vehicle geographies. The NOVA model itself can accept whichever location a fleet deems most accurate.

The analysis used the transaction dataset to assign each vehicle a location determined by the station location at which the vehicle most often fueled in the prior fiscal year, 2011. In some instances, vehicle locations were not able to be determined from the transaction data. These vehicles either did not appear in the transaction data, or the vehicle transaction locations could not be accurately assigned a latitude and longitude based on the station address information. In these instances, the vehicle location reverted to the most precise garage location available, the center point of the garage zip code in the inventory data.

The location of known alternative fuel infrastructure is available through the Alternative Fueling Station Locator on the Alternative Fuels Data Center[6]. The Station Locator is maintained by the DOE Clean Cities Program and is regularly updated as alternative fuel infrastructure becomes available or closes.

In order for the model to consider an alternative fuel to be to be available to a particular vehicle, the infrastructure must be within a predefined distance from the specific vehicle location as defined above – the station most often visited in FY 2011 or the garage zip code when a transaction location was not available. The model considers E85 and CNG to be available to a vehicle if known infrastructure of the fuel type is located within five miles. DOE FEMP uses the five-mile distance cutoff when determining EPAct 2005 § 701 waiver status, and therefore the same five-mile distance was used as a cutoff for this study (DOE 2014).

Electric charging infrastructure is considered to be available to a vehicle location if known infrastructure is available within one mile. At the time of the study, electric vehicles were not yet broadly available to the fleet. The details of how agencies planned to use and charge the vehicles were not yet fully understood. It was assumed that agencies would require vehicles to charge on a regular basis in a location convenient to the operating location. The one-mile cutoff to define availability was arbitrary but was intended to meet the regular charging requirement.

In addition to the distance requirement, agencies must be able to access the alternative fuel infrastructure for the analysis to consider the alternative fuel available. Agency fleet vehicles are considered to have access to the infrastructure if the station is publicly accessible and accepts the Wright Express credit card with which GSA-leased vehicles purchase fuel. Private infrastructure that is operated by an agency is also considered to be available to that agency's vehicles.

Alternative fuel infrastructure may open or cease operations over time and could impact the assumptions of alternative fuel availability; only infrastructure that was open and accessible at the time of the analysis was considered.

3.5 Annual Vehicle Fuel Consumption

The estimated annual fuel consumption for each vehicle was calculated by dividing the expected annual vehicle miles travelled for each vehicle by the vehicle fuel economy rating:

$$\begin{aligned} &Annual\ Fuel\ Consumption \\ &\qquad = (Estimated\ Annual\ Vehicle\ Miles\ Traveled) \\ &\qquad /(Vehicle\ Fuel\ Economy\ Rating) \end{aligned}$$

The fuel economy for each of the available vehicles for lease was determined by the combined fuel economy rating as reported for the vehicle in the GSA AFV Lease Guide[7] made available to agency fleets. Fuel economy ratings from the EPA–administered website http://www.fueleconomy.gov were used in instances where the ratings were not available in the GSA AFV Lease Guide. Existing inventory vehicles were assigned fuel economy ratings by vehicle segment based on an average of the ratings of all the available vehicles for lease in the

[6] http://www.afdc.energy.gov/locator/stations

[7] http://www.gsa.gov/portal/content/104224

segment in the 2011 GSA AFV Lease Guide. Future efforts could be improved by using a more specific vehicle fuel-economy rating for each vehicle in the existing fleet.

Each vehicle in an agency fleet was assigned the same annual-vehicle-miles-traveled value estimated by an average across all vehicles in the agency fleet. The inventory dataset contained a mileage field for each vehicle, but the raw data contained enough extreme and possibly invalid values for individual vehicles that the decision was made to use an average in place of the specific vehicle mileage. Some agencies preferred to use an internally created or known standard value to be used for the agency-wide vehicle miles traveled estimate.

3.6 Percentage of Alternative Fuel Use

AFVs dedicated to a particular fuel type were only allowed by the model to be placed in locations where the fuel was available and were assumed to use the fuel 100 percent of the time. FFVs were allowed to be placed in any location; however, FFVs in locations without available E85 were assumed to not use any alternative fuel. FFVs in locations where E85 was available were assumed to be filled with the fuel 50 percent of the time and filled with traditional gasoline the remainder of the time. It can be seen in the fuel transaction reports that vehicles often operate over broad geographies with differing alternative fuel availability. The 50-percent-use assumption was intended to account for this reality and to not overstate the potential consumption of alternative fuel.

3.7 GHG Emissions

GHG emissions are calculated in terms of metric tons of carbon dioxide equivalents (MT of CO_2e), based on the annual quantities of fuel consumption for each vehicle by applying GHG conversion factors to the annual fuel consumption estimates. The federal fleet follows guidance from the White House Council on Environmental Quality (CEQ) on how to account for greenhouse gas emissions by calculating the tailpipe emissions that occur when the particular fuel is consumed by the vehicle during operation. The conversion factors used in the NOVA analysis are available in the Federal Fleet Handbook (DOE 2014) and are displayed in Table 1 and Table 2. The factors for CO_2, CH_4, and NO_2 are available for each fuel type in terms of gasoline gallon equivalents (GGE).

A singular GHG conversion factor to convert from GGEs to MT of CO_2e for each fuel type is calculated from the conversion factors as follows:

$$
\begin{aligned}
&GGE\ to\ MT\ of\ CO_2e\ Conversion\ Factor \\
&\qquad = kg/GGE\ CO_2\ emission\ factor + (kg/GGE\ CH_4\ emission\ factor * 21) \\
&\qquad + (kg/GGE\ N_2O\ emission\ factor * 310)
\end{aligned}
$$

Fuel consumption is first converted from the natural units of the fuel type to GGEs by applying a separate GGE conversion factor listed in the federal fleet guidance for E.O. 13514 (DOE 2010). The GGE conversion factors are displayed in Table 3.

Table 1. CO_2 Emissions Factors by Fuel Type

Source: DOE 2014

Fuel	kg/GGE CO_2 emission factors	Biogenic[a] kg/GGE CO_2 emissions factors
B20	7.396 kg/GGE	1.85 kg/GGE
B100	0 kg/GGE	9.23 kg/GGE
CNG	6.628 kg/GGE	n/a
Diesel	9.245 kg/GGE	n/a
E85[a]	1.317 kg/GGE	7.27 kg/GGE
Gasoline	8.778 kg/GGE	n/a
LNG	6.628 kg/GGE	n/a
LPG	7.873 kg/GGE	n/a

[a] CO_2 emissions from the biofuels portion of the fuel are known as biogenic emissions, and must be reported within the appropriate scope in which they occur and must be categorized as biogenic. Agencies are not required to include these emissions in their reduction targets under E.O. 13514 at this time.

Table 2. CH_4 and N_2O Emissions Factors by Fuel Type

Source: DOE 2014

Fuel	kg/GGE CH_4 emissions factors	kg/GGE N_2O emissions factors
B20	3.92×10^{-5} kg/GGE	2.04×10^{-5} kg/GGE
B100	1.38×10^{-4} kg/GGE	1.38×10^{-5} kg/GGE
CNG	1.25×10^{-4} kg/GGE	1.25×10^{-5} kg/GGE
Diesel	1.47×10^{-5} kg/GGE	2.20×10^{-5} kg/GGE
E85	1.53×10^{-4} kg/GGE	2.04×10^{-5} kg/GGE
Gasoline	2.40×10^{-4} kg/GGE	2.54×10^{-4} kg/GGE
LNG	1.25×10^{-4} kg/GGE	1.25×10^{-5} kg/GGE
LPG	3.75×10^{-4} kg/GGE	7.50×10^{-5} kg/GGE

Conversion Factors to CO_2 equivalents (CO_2e)

kg/GGE CH_4 x 21 = kg/GGE CO_2e

kg/GGE N_2O x 310 = kg/GGE CO_2e

Table 3. GGE Conversion Factors by Fuel Type

Source: DOE 2010

Fuel Type	Natural Units	Gasoline Gallon Equivalent
B20	gallons	112.6% (gal x 1.126 = GGE)
B100	gallons	101.5% (gal x 1.015 = GGE)
CNG	gallons at 2,400 psi	18% (gal x 0.18 = GGE)
	gallons at 3,000 psi	22.5% (gal x 0.225 = GGE)
	gallons at 3,600 psi	27% (gal x 0.27 = GGE)
	hundred cubic feet	83% (ccf x 0.83 = GGE)
E85	gallons	72% (gal x 0.72 = GGE)
Electricity	kWh	3% (kWh x 0.03 = GGE)
LNG	gallons @ 14.7 psi and – 234°F	66% (gal x 0.66 = GGE)
LPG	gallons	74% (gal x 0.74 = GGE)
M85	gallons	57% (gal x 0.57 = GGE)

3.8 AFV Incremental Budget

A primary management constraint for each agency is the AFV incremental budget. At the time of the study each AFV leased from GSA carried an incremental cost that represented the difference in cost between an AFV model and a base, low-cost option in each vehicle configuration. This incremental cost was listed for each AFV in the GSA AFV Lease Guide available from the GSA Alternative Fuel Vehicles website[8]. Incremental costs ranged from a hundred dollars or less for some E85 capable FFVs to more than twenty thousand dollars for some electric vehicles.

Agencies pay for this incremental cost in the form of a monthly AFV surcharge on all (both AFV and non-AFVs) vehicles in the fleet. Some agencies budget for a higher investment in AFVs and set a higher AFV surcharge. Other agencies spend less on AFVs and therefore have a lower AFV surcharge. The range of AFV surcharges for the 11 agencies is listed in Table 4. The NOVA model ensures that the incremental AFV costs of the recommended set of replacement vehicles will not result in an AFV surcharge higher than the budgeted level.

[8] http://www.gsa.gov/portal/content/104224

Table 4. Agency AFV Surcharges

Agency	AFV Surcharge
Agency 1	$20
Agency 2	$16
Agency 3	$6
Agency 4	$10
Agency 5	$7
Agency 6	$68
Agency 7	$12
Agency 8	$13
Agency 9	$9
Agency 10	$9
Agency 11	$21

3.9 Acquisition Mandates in the Model

The NOVA model ensures satisfaction of the EPAct 1992 requirement that 75 percent of all LDV acquisitions in MSAs are AFVs. The GSA inventory dataset identifies which vehicles are in MSAs and the model ensures that at least 75 percent of these vehicles are AFVs. The model includes HEVs and PHEVs as vehicles that are considered AFVs in accordance with NDAA 2008.

The EISA 2007 requirement to acquire only low-GHG vehicles is not directly accounted for in the model constraints. Low-GHG vehicles were not broadly available across all vehicle segments, and agencies frequently require vehicles that are not low-GHG vehicles in order to meet mission requirements. As an example, there were no low-GHG pickup truck options available for lease in FY 2012. The model does optimize the reduction of GHG emissions overall and therefore does support the spirit of the requirement. However, in order to produce recommendations that could meet agency mission requirements, the model does not explicitly enforce the requirement.

The model does not force the acquisition of PHEVs per E.O. 13423 as the current costs associated with available PHEVs were not considered to be comparable to non-PHEVs. As an example, a PHEV available for lease in FY 2012 carried an AFV incremental cost of over $20,000.

4 Model Development

4.1 Optimization Model Indices

The agency integer optimization models take advantage of the following indices:

- *i* = Agency, i = 1-11
- *j* = Vehicle type available for leasing from GSA *j* = 1-128
- *k* = Vehicle being replaced in agency inventory *k* = 1-number of vehicles in agency inventory
- *l* = Alternative fuel infrastructure access (1 = has access to existing AF stations, 2 = would have access only to newly constructed AF stations, 3 = does not have access to any AF stations, *l* = 1,2,3
- *m* = Vehicle fuel types (1 = CNG, 2 = LPG, 3=E85, 4 = LNG, 5 = Gasoline Hybrid, 6 = Biodiesel, 8 = Gasoline, 9 = Electricity) *m* = 1-9
- *o* = Vehicle location, *o* = 1-number of agency unique vehicle locations
- *p*= Fuel types used (1 = CNG, 2 = LPG, 3 = E85, 4 = LNG, 5 = Petroleum Diesel, 6 = Biodiesel, 7 = Gasoline, 8 = Electricity), *p* = 1-8

4.2 Optimization Model Decision Variable

The decision variable in the model is "AFVsAcquired (*i,j,k,l,m,o*)" which provides the vehicle type *j* of vehicle fuel type *m* to replace vehicle *k* in the inventory with alternative fuel access type *l* at location *o* for agency *i*.

AFVsAcquired takes the value of 1 for the optimized combinations of incoming and outgoing vehicles defined by the indices. All other combinations take the value of 0. The NOVA model has the capability to optimize across fleets, but this study considered each agency fleet individually and therefore *i* was always 1 and represented the single agency studied. The alternative fuel infrastructure access options include the option to construct new infrastructure, but this study did not consider options to build new infrastructure, and therefore the *l* index took the value of 1, "has access to existing AF stations," or 3, "does not have access to any AF stations."

4.3 Optimization Model Definitions

A sampling of the definitions in the model included:

- IncrementalCost(*j*) = The incremental cost to acquire vehicle type *j*
- EPActCredit(*j*) = The number of EPAct vehicle acquisition credits for acquiring vehicle type *j*
- IncrementalBudget(*i*) = The incremental budget for agency *i*
- TotalLDMSA(*i*) = The total number of light-duty vehicles in MSAs in agency *i*
- TotalAnnualOutgoingGGE(*k,o,p*) = The estimated annual fuel use in GGEs of fuel type *p* by vehicle *k* in the inventory at location *o*

- TotalAnnualIncomingGGE(j,o,p) = The estimated annual fuel use in GGEs of fuel type p by incoming vehicle type j at location o
- GHGFactor(p) = The GGE to MT of CO2e conversion factor for fuel type p

The “TotalAnnualOutgoingGGE” and “TotalAnnualIncomingGGE” metrics were calculated by taking into account the types of fuels each vehicle can operate with and the availability of the alternative fuel at each vehicle location. As an example, if vehicle k_1 in the inventory is an FFV capable of running on E85 or gasoline and is located at location o_1 which has E85 available, TotalAnnualOutgoingGGE($k_1,o_1,Gasoline$) and TotalAnnualOutgoingGGE($k_1,o_1,E85$) would be non-zero GGE values. If the same vehicle were operating at location o_2, which does not have E85 available, TotalAnnualOutgoingGGE($k_1,o_2,Gasoline$) would be a non-zero value while TotalAnnualOutgoingGGE($k_1,o_2,E85$) would be zero. The metric would carry a zero value of all other fuel types.

4.4 Optimization Model Constraints

Two of the constraints used in the models are illustrated below:

(1) Budget must not be exceeded:

$$\sum_{j,k,l,m,o} AFVsAcquired(i,j,k,l,m,o) * IncrementalCost(j) \leq IncrementalBudget(i), for\ all\ i$$

(2) EPAct vehicle acquisition credits must meet or exceed 75 percent of the number of light-duty vehicles in MSAs in the fleet:

$$\sum_{j,k,l,m,o} AFVsAcquired(i,j,k,l,m,o) * EPActCredit(j) \geq 0.75 * TotalLDMSA(i), for\ all\ i$$

Additional constraints ensured dedicated alternative fuel vehicles were not placed in locations where the appropriate alternative fuel was not available, as well as appropriate integer, binary, and non-negativity constraints.

4.5 Optimization Model Objective Function

The objective function maximizes the difference of GHG emissions of the outgoing vehicles and incoming vehicles as follows:

$$\text{Maximize} \left(\sum_{i,j,k,l,m,o,p} [AFVsAcquired(\mathrm{i,j,k,l,m,o}) \times TotalAnnualOutgoingGGE(\mathrm{k,o,p}) \times GHGFactor(p)] \right) - \left(\sum_{i,j,k,l,m,o,p} [AFVsAcquired(\mathrm{i,j,k,l,m,o}) \times TotalAnnualIncomingGGE(\mathrm{j,o,p}) \times GHGFactor(p)] \right)$$

Since the GHG emissions of the outgoing vehicles are fixed and known, maximizing this difference is equivalent to making incoming vehicle GHG emissions as small as possible, which is the goal of this model.

GHG emissions are calculated by applying the appropriate fuel-type GHG-emissions factors to the annual fuel consumption of each vehicle. The “TotalAnnualOutgoingGGE” and “TotalAnnualIncomingGGE” metrics take into account fuel availability at the location of each vehicle and the impacts, if any, that availability has on the quantities of alternative fuel and petroleum the vehicles are estimated to use.

5 Model Runs and Results

5.1 Optimization Model Results

NOVA model runs and analyses were completed for each of the 11 agencies individually. In a typical year, agencies replace about 10 to 30 percent of their vehicle inventories. However, analyses were completed to generate replacement recommendations for every vehicle in the agency inventories with a discernible light-duty replacement option. By analyzing the entire existing inventory, we were able to complete the study prior to the vehicle ordering cycle when specific vehicles are identified as replacement eligible. In addition, the study supported agency out-year planning by providing recommendations for vehicles that would be replaced in subsequent years.

Across the eleven fleets, 68,866 vehicle recommendations were developed, as shown in Table 5. The vehicle recommendations totaled 11% of all 600,405 federal fleet vehicles in FY 2012.

Table 5. FY 2012 GSA Leased Vehicle Inventories and Recommendations

Agency	Total Vehicles in Inventory	Vehicles Recommended	% of Inventory w/ Recommendation
Agency 1	18,726	15,414	82%
Agency 2	12,390	11,240	91%
Agency 3	10,675	8,241	77%
Agency 4	9,746	8,664	89%
Agency 5	7,580	6,831	90%
Agency 6	5,852	5,264	90%
Agency 7	4,177	3,736	89%
Agency 8	4,047	3,892	96%
Agency 9	3,626	3,339	92%
Agency 10	1,315	1,067	81%
Agency 11	1,199	1,178	98%
Total	79,333	68,866	87%

The final vehicle recommendations included FFVs, HEVs, and efficient conventional gasoline vehicles. These technologies were recommended after the model weighed the GHG savings benefits against the costs of acquiring large numbers of the vehicles across the fleet.

Table 6. NOVA Recommendations by Vehicle Fuel Type

Agency	FFVs Recommended	HEVs Recommended	Gas Vehicles Recommended	Total Recommended
Agency 1	12,148	3,266	-	15,414
Agency 2	7,960	2,051	1,229	11,240
Agency 3	7,923	318	-	8,241
Agency 4	6,319	1,420	925	8,664
Agency 5	6,320	66	445	6,831
Agency 6	3,743	1,521	-	5,264
Agency 7	3,050	22	664	3,736
Agency 8	2,674	91	1,127	3,892
Agency 9	2,898	71	370	3,339
Agency 10	793	274	-	1,067
Agency 11	739	393	46	1,178
Total	54,567	9,493	4,806	68,866

Table 6 shows how FFVs dominated the vehicle recommendations. This occurred for several reasons: (1) FFVs have a very low AFV incremental cost in comparison to other technologies. (2) FFVs have become available in highly efficient models that even when operated only on gasoline achieve higher mile-per-gallon ratings than other traditional gasoline only models. (3) The vehicles allow for significant petroleum displacement when fueled regularly with E85.

Highly efficient HEVs were recommended in smaller but significant numbers. HEVs were not recommended in higher numbers primarily due to high incremental costs. The model determined that the budget needed for the cost of acquiring a single HEV was better spent toward the goal of achieving overall fleet GHG reductions by spreading that cost across many efficient FFVs that can regularly fuel with E85.

CNG vehicles ultimately were not recommended. There was only a single light-duty CNG vehicle model available to the agencies, and it carried a high incremental cost. Additionally there was a relative lack of CNG infrastructure available to the fleet locations. Finally, the estimated GHG emissions from the CNG vehicle were higher than other vehicle alternatives, due in part to the lower fuel economy of the CNG vehicle.

At the time of the analysis, EVs and PHEVs were available to the fleets through GSA in small numbers only in a pilot program aimed at introducing the vehicle technology to the federal fleet. For this reason along with high incremental costs, these vehicles were not recommended to agencies.

While the model did not recommend CNG, PHEV, or BEV technologies, agencies were encouraged to pursue the technologies in instances where budget and the local vehicle operating environment could allow the technologies to succeed.

5.2 Vehicle Technology Comparisons

Figure 6 compares some of the different vehicle models and fuel technologies available through GSA in the sedan segment at the time of the study and displays why the chosen vehicle technologies dominated.

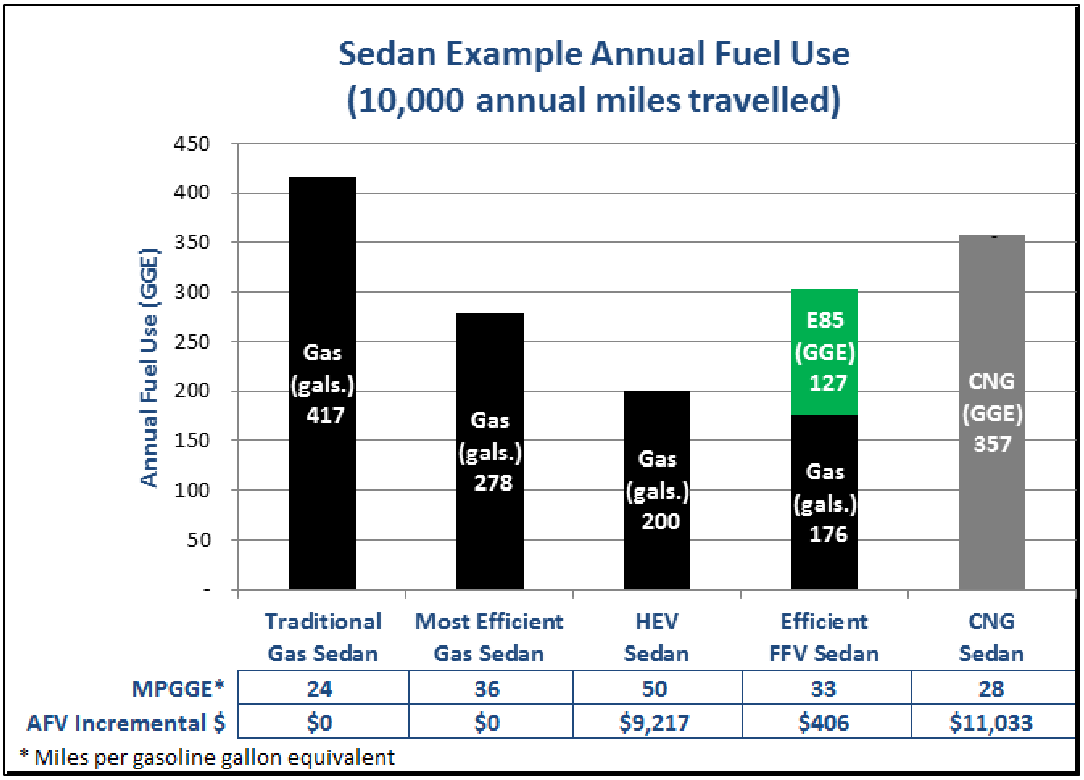

Figure 6. Sedan fuel consumption comparisons

Compared to a traditional gasoline-powered sedan, significant gasoline savings could be achieved through the use of the highest efficiency traditional gasoline vehicle available, which carried zero incremental cost. A higher level of fuel savings could be achieved through the use of an HEV, which carried a sizeable incremental cost. An efficient FFV could achieve an even greater gasoline savings if the FFV regularly used E85. Figure 6 employs the 50 percent use assumption for an FFV with available E85. Finally, a CNG vehicle would operate only on CNG and not use gasoline, but the vehicle carried a sizeable incremental cost.

Figure 7 displays a similar comparison after the fuel consumption values are converted to GHG emissions. In this comparison, the FFV filling with E85 50 percent of the time could produce the least amount of GHG emissions of any of the vehicle options. The HEV could produce the least amount of GHG emissions in instances where vehicles do not have access to E85. As previously stated, the available CNG vehicle was not recommended due to several reasons. In this view, it can be seen that the estimated GHG emissions from the CNG vehicle, while lower than the traditional gasoline vehicles, were higher than other vehicle alternatives.

Noticeably, the E85 GHG impact is very small. Per the Federal Fleet Handbook (DOE 2014) "CO_2 emissions from the biofuels portion of the fuel are known as biogenic emissions, and must be reported within the appropriate scope in which they occur and must be categorized as biogenic. Agencies are not required to include these emissions in their reduction targets under E.O. 13514 at this time." The federal fleet methodology of accounting for GHG emissions from burning E85 considers the ethanol portion of the fuel to be produced from a biogenic source. The biogenic portion of the GHG emissions are not counted as emissions against agencies' emission inventories and reduction targets. Therefore, the GHG conversion factor used in this study excludes the biogenic emission factors in Table 1.

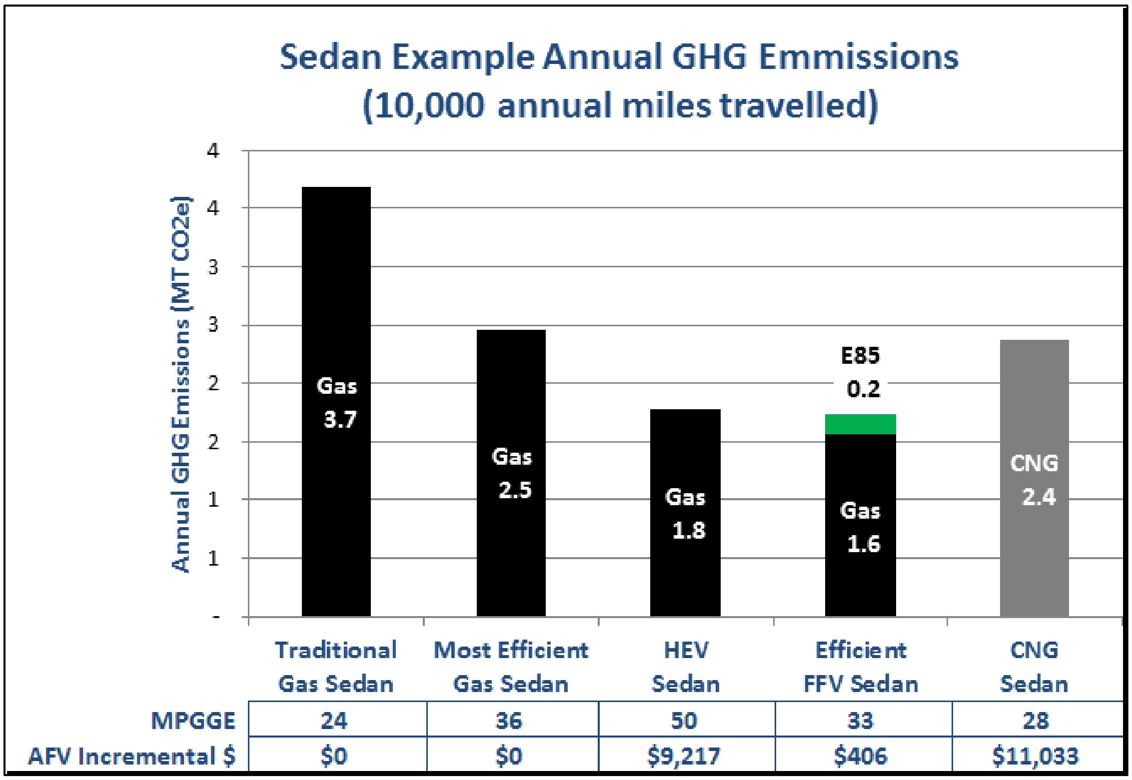

Figure 7. Sedan GHG emissions comparisons

5.3 Estimated Impacts of Recommendations

The potential impact of replacing existing inventory vehicles with the recommended vehicles on the metrics of overall fleet petroleum use, alternative fuel use, and GHG emissions was estimated for each agency. These metrics were estimated for both the current vehicle inventory as well as the recommended vehicles, and then compared. The comparisons were not related back to observed or officially reported fuel use. The comparisons represented theoretical maximums for the portion of the fleet receiving recommendations after one year of operation. The comparisons rely on a number of assumptions including (1) all vehicles receiving a recommendation are replaced, (2) all vehicles travel the fleet average annual miles, and (3) the vehicles achieve the assigned fuel economy ratings.

Estimates for petroleum reduction, GHG emission reduction, and alternative fuel increase are summarized in Table 7, Table 8, and Table 9 respectively. Petroleum reductions range from 19 to 30 percent for each fleet. GHG emission reductions closely mimic the petroleum reductions and range from 19 to 29 percent. Alternative fuel increases range from 18 to 84 percent. The large range in estimated alternative fuel increase is due to high variability in how well existing fleet inventory AFVs are aligned with available infrastructure. Those agencies that already had FFVs located near available E85 infrastructure would see lower gains in comparison to agencies that did not have many fleet FFVs near available E85 infrastructure.

Table 7. Estimates of Petroleum Reduction

Agency	Existing Fleet Annual Petroleum Use Estimate (GGE)	Petroleum Reduction GGE	Petroleum Reduction %
Agency 1	4,715,126	1,413,572	30%
Agency 2	4,444,667	1,060,182	24%
Agency 3	2,978,035	814,377	27%
Agency 4	3,927,660	879,360	22%
Agency 5	3,352,609	805,231	24%
Agency 6	2,213,995	626,807	28%
Agency 7	2,106,833	502,526	24%
Agency 8	1,648,972	353,983	21%
Agency 9	1,841,989	491,255	27%
Agency 10	346,592	104,825	30%
Agency 11	347,720	67,360	19%

Table 8. Estimates of GHG Emissions Reduction

Agency	Existing Fleet Annual GHG Emissions Estimate (MT CO2e)	GHG Reduction (MT CO2e)	GHG Reduction %
Agency 1	42,671	12,469	29%
Agency 2	40,472	9,210	23%
Agency 3	27,147	7,210	27%
Agency 4	36,112	8,356	23%
Agency 5	30,017	7,073	24%
Agency 6	19,925	5,529	28%
Agency 7	18,955	4,413	23%
Agency 8	14,814	3,057	21%
Agency 9	16,883	4,741	28%
Agency 10	3,172	905	29%
Agency 11	3,137	584	19%

Table 9. Estimates of Alternative Fuel Increase

Agency	Existing Fleet Annual Alternative Fuel Use Estimate (GGE)	Alternative Fuel Increase (GGE)	Alt Fuel Increase %
Agency 1	462,300	244,503	53%
Agency 2	746,011	204,382	27%
Agency 3	430,326	140,782	33%
Agency 4	472,767	83,342	18%
Agency 5	150,602	126,422	84%
Agency 6	190,072	57,622	30%
Agency 7	195,218	47,851	25%
Agency 8	142,630	67,987	48%
Agency 9	78,894	50,654	64%
Agency 10	70,343	23,072	33%
Agency 11	40,413	11,118	28%

In practice, agencies replace just 10 to 30 percent of their fleet in a given year, and it is unlikely vehicles will all travel the same distance or achieve the rated fuel economy. However, when taken in context, these theoretical estimates allow for comparisons of vehicle replacement strategies and provide a scale for potential impacts.

As discussed above, E.O. 13514 requires federal fleets to achieve a two percent reduction in petroleum consumption per year. Assuming the percent of the fleet that is replaced in a given year is comprised of a mix of vehicle segments representative of the fleet in total, then the expected petroleum reduction after a year of following the vehicle replacement recommendations can be estimated by multiplying the percent of the fleet replaced by the model petroleum reduction-percentage estimate. Table 10 shows that by completing this effort for a range of 10 to 30 percent the fleets could expect to meet or exceed the 2 percent petroleum reduction mandate by closely following the vehicle recommendations without additional fleet operations efforts to reduce petroleum consumption.

Table 10. Partial Fleet Replacement Petroleum Reduction

Agency	Fleetwide Model Estimated Petroleum Reduction %	Estimated Petroleum Reduction % for 10% Fleet Replacement	Estimated Petroleum Reduction % for 30% Fleet Replacement
Agency 1	30%	3%	9%
Agency 2	24%	2%	7%
Agency 3	27%	3%	8%
Agency 4	22%	2%	7%
Agency 5	24%	2%	7%
Agency 6	28%	3%	8%
Agency 7	24%	2%	7%
Agency 8	21%	2%	6%
Agency 9	27%	3%	8%
Agency 10	30%	3%	9%
Agency 11	19%	2%	6%

5.4 Sources of Impact

Estimated petroleum reductions are derived from three primary segments of vehicle recommendations including (1) efficient FFVs able to use available E85 50 percent of the time, (2) highly efficient HEVs using gasoline 100 percent of the time, and (3) efficient FFVs and traditional gasoline vehicles in locations without available E85 and using gasoline 100 percent of the time.

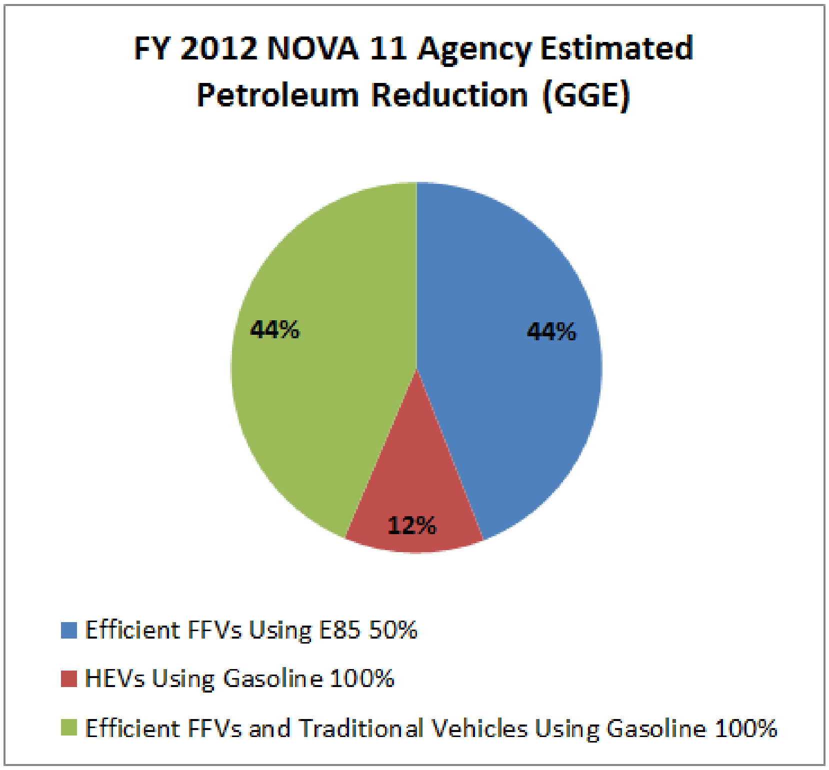

Figure 8. Sources of petroleum reduction

Figure 8 shows that while the advanced technologies of FFVs regularly using E85 and HEVs efficiently using gasoline reduce petroleum consumption, considerable petroleum savings are achieved simply by using more efficient traditional vehicles operating on gasoline. In total, across all agencies studied, efficient FFVs and traditional vehicles using gasoline 100 percent of the time accounted for 44 percent of the overall petroleum reduction. FFVs using E85 50 percent of the time accounted for an additional 44 percent of the petroleum reduction. This share of the total would be greater if E85 fueling infrastructure were more widely available nationwide. The final 12 percent of overall petroleum reduction was due to HEVs.

Figure 9 breaks out the petroleum reduction for each agency, and includes the AFV surcharges for each agency. The surcharges are a measure of how much an agency spends on the acquisition of AFVs per vehicle per month in the inventory. Those agencies that have higher AFV surcharges, and therefore larger per vehicle budgets to cover the high incremental costs associated with HEVs, are often able to acquire relatively higher numbers of HEVs that can contribute significantly to petroleum reduction.

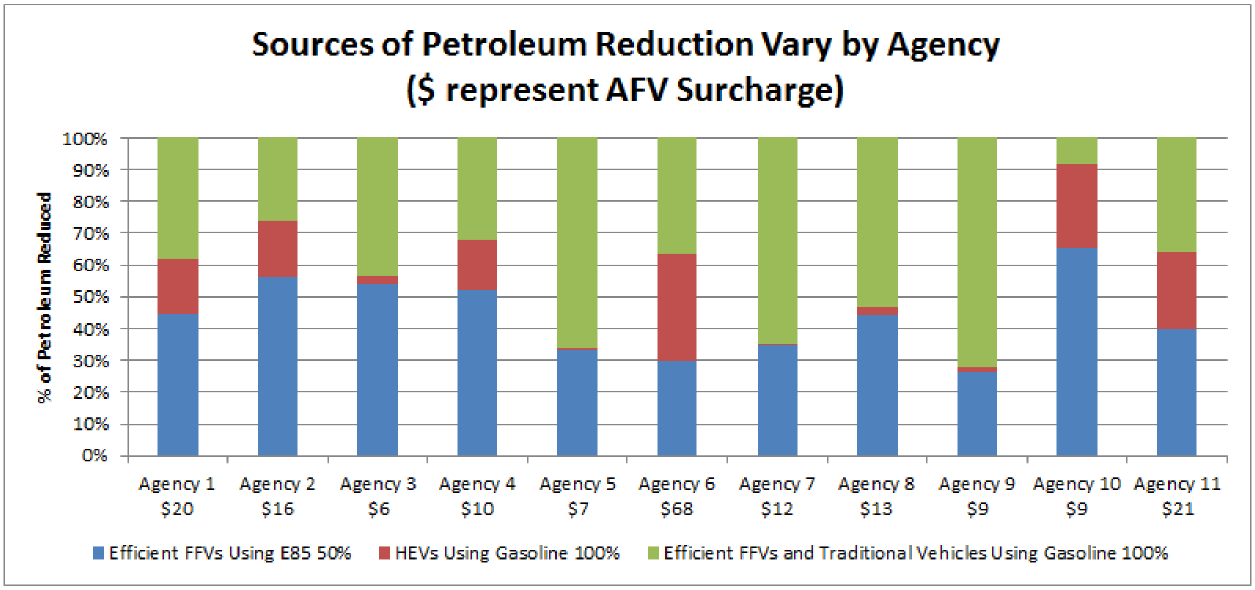

Figure 9. Sources of petroleum reduction by agency

The broader lesson learned from this study is that to efficiently take advantage of the three primary sources of petroleum reduction, agencies would be best served by: (1) Targeting FFVs in locations where E85 is available. (2) Targeting HEVs when budget allows, where E85 is not available, and when driving routes involve stopping and starting that enables HEVs to achieve their full fuel economy benefit. (3) Targeting the most efficient traditional gasoline vehicles or FFVs available where E85 is not available and the budget is a constraint.

6 Conclusions

Federal agency fleets can make progress toward fuel use goals through strategic vehicle acquisitions that efficiently meet mission requirements and achieve mandated acquisition goals while staying under budget. The results of this study show the theoretical benefits of following the vehicle recommendations of an optimized vehicle acquisition.

However, fleet management has been challenged to implement the specific vehicle recommendations of NOVA. A variety of non-energy factors make specific choices challenging, such as organizational structure, mission nuances, vehicle availability, and user preferences—all of which vary widely among fleets, both nationally and locally.

The model assumes a fleet with a centralized organizational structure could place one order for all vehicles in the fleet. In practice, many agency fleet organizations are decentralized and can submit orders at various times for portions of the fleet. Further there can be extensive back and forth within a fleet organization as well as with GSA representatives before orders are finalized. This more complex ordering process makes it challenging for a fleet to follow the vehicle recommendations in their entirety.

Federal fleets can benefit most from an optimization model decision-support tool during the vehicle ordering process in instances where the fleet management structure is centralized and national management can distribute vehicle recommendations to all levels of the fleet organizational structure. Additionally agencies can define specific vehicle mission requirements to ensure the appropriate constraints are included in the model and results provide an appropriate recommendation.

Findings from this study provided generalized vehicle ordering guidance appropriate until there are significant changes in vehicle technology availability and cost. The study shows that to efficiently meet mandates, agencies should prioritize placing FFVs in locations where E85 infrastructure exists and regularly fuel the FFVs with E85. HEVs are most beneficial in locations where E85 does not exist, when the budget allows for increased AFV incremental costs, and when driving routes involve stopping and starting—enabling HEVs to achieve their full fuel economy benefit. Efficient traditional gasoline vehicles should be targeted where alternative fuel does not exist and budget dollars are tight. CNG and electric vehicles were not widely available across federal fleet vehicle segments and carried high incremental costs. These technologies were viewed as best suited for specialized applications or pilot efforts where budget is available and unique local conditions were favorable to the technology success.

Federal fleets are subject to a myriad of sustainability mandates ranging from high-level goals to specific operational targets. While these mandates are often complementary, an optimized fleet is likely to contain a different composition of vehicles depending on the mandate that is given priority. Helwig and Deason (2007) showed that by varying the prioritization of mandates, the scope of vehicles defining an optimal fleet could be drastically affected.

In this study, the NOVA model optimized the reduction of GHG emissions based on the guidance of E.O. 13514. The goal of reducing GHG emissions is achieved through the complementary mandated goals of acquiring AFVs, increasing the use of alternative fuels, and reducing petroleum use. Any mandate changes that affect this prioritization could have a significant impact on how fleets meet the mandated goals.

7 References

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Appendix A. Federal Fleet Requirements

Table 11. Summary of Primary and Supporting Federal Fleet Requirements

	Statute or Exec. Order	Requirement
Primary Federal Fleet Requirements		
GHG Reduction	E.O. 13514	Sets a percentage reduction target for reductions of Scope 1 and 2 GHG emissions from FY 2008 to FY 2020
Petroleum Reduction	E.O. 13514	Requires 2 percent annual reduction from FY 2005 to FY 2020
	E.O. 13423	Requires 2 percent annual reduction from FY 2005 to FY 2015
	EISA § 142	Requires 20 percent total reduction from FY 2005 to FY 2015
Supporting Federal Fleet Requirements		
Agency Sustainability Plan	E.O. 13514	Establishes the fleet component of an overall agency plan to achieve E.O. 13514 sustainability goals and targets for FY 2011 to FY 2021
Alternative Fuel Use Increase	E.O. 13423	Requires 10 percent annual increase (from previous year), starting from the FY 2005 baseline through FY 2015
	EISA § 142	Requires 10 percent total increase from FY 2005 to FY 2015
Alternative Fuel Use	EPAct 2005 § 701	Requires all dual-fueled AFVs to use alternative fuel unless waivered
Renewable Fuel Infrastructure	EISA § 246	Requires every federal fueling center without renewable fuel availability to install a renewable fuel pump
Vehicle Acquisition	EPAct 1992	Requires 75 percent of light-duty vehicles acquired in metropolitan statistical areas to be AFVs
	EISA § 141	Prohibits agencies from acquiring vehicles that are not low GHG-emitting vehicles
	E.O. 13423	Requires agencies to use plug-in hybrid electric vehicles (PHEVs) when commercially available at a cost reasonably comparable to non-PHEVs
Agency Fleet Plan	EISA § 142	Establishes an agency plan to meet required petroleum reduction and alternative fuel-use increase requirements
Reporting	EPAct 1992, ECRA 1998	Requires agencies to report to Congress annually on their compliance with the federal fleet requirements (by February 15 of each year)