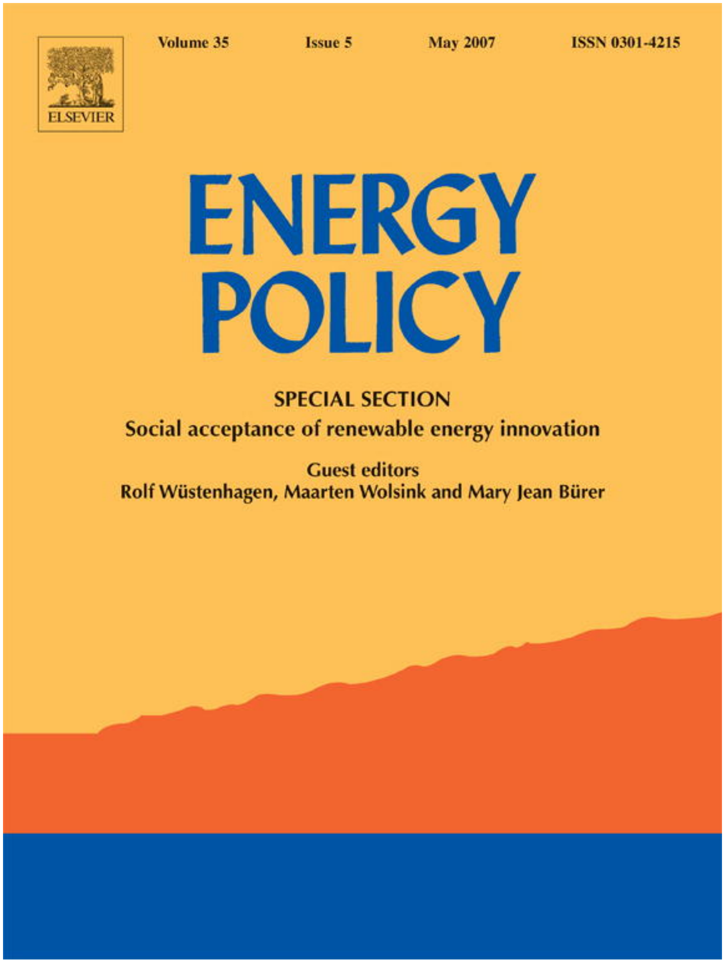
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The Energy Policy Act of 1992 and Executive Order 13149: Proposed compliance strategies and process improvements for federal agencies

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Abstract

Under the Energy Policy Act of 1992 (EPAct), 75 percent of Light Duty Vehicle acquisitions by federal agencies must be Alternative Fuel Vehicles (AFVs). EPAct's intent was to reduce United States reliance on oil imports, with federal agencies assuming a leadership role in acquiring AFVs and using alternative fuel in those AFVs. Executive Order (E.O.) 13149, issued in 2000, required federal agencies to reduce petroleum consumption 20 percent relative to a 1999 baseline and use alternative fuels the majority of the time in their AFVs by 2005. Most federal agencies met the EPAct 75 percent acquisition requirement in 2004, however, most will not achieve the petroleum reduction and alternative fuel use requirements. Frequently, federal agencies acquire the relatively expensive AFVs and then fuel those vehicles with gasoline. Besides wasting taxpayer dollars, this approach does not meet the intent of EPAct. It was surmised that federal agencies lack an objective, quantitative methodology for AFV acquisitions and Executive Order 13149 compliance. Several types of optimization models were constructed, using the United States Navy as a test case, for models focusing on EPAct and/or E.O. 13149 compliance. Results of a tiered set of models indicate there are efficiencies that federal agencies could take advantage of when developing EPAct and E.O. 13149 compliance strategies that are not currently being exploited.

Keywords: EPAct; Alternative fuel vehicles; Executive order 13149

1. Introduction

The Energy Policy Act of 1992 (EPAct) requires that 75 percent of Light Duty Vehicle (less than 8500 pounds or 3856 kg) acquisitions by federal agencies in 1999 and beyond must be alternative fuel vehicles (AFVs). EPAct requirements apply to centrally fueled federal fleets consisting of 20 or more light duty vehicles (LDVs) operating primarily in a Metropolitan Statistical Area (MSA) with a population of more than 250,000 based on the 1980 census, and that are owned or operated by an entity controlling at least 50 vehicles nationwide. The intent of EPAct was to reduce United States dependence on petroleum imports and to improve air quality. Nearly 20 federal agencies are subject to EPAct. Federal agencies were to assume a leadership in petroleum displacement by acquiring AFVs and then using alternative fuel in those AFVs.

A fundamental flaw in EPAct with respect to reduction of petroleum imports was the fact that the Act mandated acquisition of AFVs but did not mandate the use of alternative fuels. Therefore, President Clinton signed Executive Order (E.O.) 13149 on April 21, 2000 directing agencies with 20 or more vehicles in the Unites States to reduce their fleet's petroleum consumption by 20 percent by the end of fiscal year 2005 compared to a 1999 baseline. Significant requirements of E.O. 13149 (entitled "Greening the Government Through Federal Fleet and Transportation Efficiency") include the development of a compliance strategy for agencies to meet the 20 percent reduction goal, the inclusion of medium and heavy-duty vehicles in the 20 percent reduction requirement, and mandatory vehicle acquisition, vehicle inventory and fuel consumption reporting to the Department of Energy (DOE). Unlike EPAct, which mandated AFV acquisitions, E.O. 13149 requires agencies to use alternative fuel in AFVs the

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majority of the time the vehicles are in operation by the year 2005, and also requires agencies to increase the fuel efficiency of new LDVs by 1 mile per gallon (mpg) by 2002 and 3 mpg by 2005 compared to a 1999 baseline (or equivalently, 0.425 km/l by 2002, and 1.275 km/l by 2005). E.O. 13149 forces agencies to achieve fuel use reduction by acquisition and use of AFVs and alternative fuels, and by acquisition of higher fuel economy vehicles (say a hybrid vehicle, for example, which won't help an agency meet EPAct goals but could assist in meeting E.O. 13149 goals).

This paper describes our work to capture EPAct and E.O. 13149 compliance data from federal agency annual reports, examine current compliance strategies, and analyze the results of a series of tiered integer optimization models that were created to improve federal agency EPAct and E.O. 13149 compliance. The United States Navy is used as a test case to compare its current compliance strategy with those developed by the series of tiered optimization models.

2. EPAct and E.O. 13149 compliance

In the year 2000, only seven of the 18 covered federal agencies met the 75 percent EPAct acquisition requirement, and at least nine federal fleets actually increased petroleum consumption from 1999 to 2000, resulting in an overall two percent increase in federal fleet petroleum consumption from 1999 to 2000. DOE reports that some data may be inaccurate, including year 2000 petroleum consumption and the 1999 baseline consumption data. This is not surprising, given that year 2000 was first year that agencies were required to collect and submit petroleum consumption data, and some 1999 baseline data has since been adjusted. Subsequent data submissions were expected to be more accurate, and improvements in AFV acquisition percentages and reductions in petroleum consumption were expected, as fleet managers focused on EPAct and E.O. 13149 requirements.

In 2002, at least nine agencies failed to meet the 75 percent acquisition requirement, and in 2003, at least five agencies failed to meet EPAct acquisition requirements. Federal agency compliance with EPAct for 2004 by agency is illustrated in Table 1, as is the number of EPAct-covered LDV acquisitions for each agency for the year 2004. Seven agencies failed to comply with EPAct's statutory 75 percent requirement in 2004. Table 1 also illustrates federal agency compliance in 2004 with two requirements of E.O. 13149: the requirement to use alternative fuel in AFVs at least half the time by 2005 and the requirement to reduce overall petroleum consumption by 20 percent relative to 1999, also by 2005. Note that the Army, Navy, Air Force and Marines are broken out separately, although technically they belong to one federal agency—the Department of Defense (DoD). In practice, however, these four departments report EPAct and E.O. 13149 compliance separately. DOE (2006b) provides an EPAct Annual Reports web site that links to federal agency annual reports where most of Table 1 data was accessed, and whenever possible, data were used from these annual agency reports.

Federal agencies are even more challenged in meeting E.O. 13149 requirements than they are in meeting EPAct requirements. Table 1 illustrates that almost all agencies have not attained E.O. 13149 alternative fuel use and petroleum reduction goals. Since agencies were to use alternative fuel in their AFVs at least 50 percent of the time by 2005, and agencies were charged with reducing petroleum consumption by 20 percent relative to a 1999 baseline, it is apparent that E.O. 13149 goals will not be reached by 2005. It is possible that there are some errors in reported alternative fuel consumption, however, the fact remains that almost every federal agency will not approach E.O. 13149 goals in 2005.

There are several negative side effects for federal agencies in not meeting EPAct and E.O. 13149 requirements. The first is that it can be embarrassing for an agency not to meet the statutory EPAct requirement, and it opens up the door for criticism of the agency and other negative consequences like law suits, which have occurred. Another side effect is that, while most federal agencies are meeting EPAct requirements (acquiring 75 percent AFVs), they are not meeting the intent of EPAct, which was to reduce United States dependence on foreign oil, because many agencies acquire AFVs and then use only conventional fuel in them. This is clear from Table 1, which illustrates the relatively low percentage of time that AFVs actually use alternative fuel. What is happening, then, is that in many cases, federal agencies are spending taxpayer money on more expensive AFVs that will never use alternative fuel and will therefore never provide any of the intended benefits of using alternative fuel, such as less pollution and reduced dependence on petroleum. Federal agencies often offer the lack of alternative fuel infrastructure, higher incremental cost of some AFVs, and difficulties in tracking alternative fuel use as excuses for not meeting EPAct and/ or E.O. 13149 requirements, although nothing precludes agencies from tracking their own alternative fuel use, and estimates of alternative fuel use do not necessarily appear unreasonable. Improving the process of acquiring AFVs and complying with E.O. 13149 is the focus of the research described in this paper.

The General Services Administration (GSA) has purchased thousands of AFVs that are available for leasing for federal agency customers, and there are thousands of AFVs in federal fleets today. Nevertheless, compliance with EPAct and E.O. 13149 will remain a challenge for federal fleet managers. Compliance strategies can change on short notice as inventory requirements change, and alternative fuel availability can change as well. Increased incremental costs of the relatively more expensive AFVs often cause fleet managers to make compromises. The General Accounting Office reported that the fleet manager's primary responsibility "is to acquire the number of vehicles that will satisfy their agency's mission. Buying alternative fuel vehicles has a lower priority. Thus, when budget

Table 1
Federal Agency EPAct and E.O. 13149 Compliance for 2004

Agency	2004 EPAct covered LDV acquisitions	2004 EPAct compliance percentage	% of time alternative fuel used in AFVs	% petroleum reduction () means increase
DoD Army	4773	99	0.8	(16.8)
DoD Navy	1529	100	9.1	13.9
DoD Air Force	1450	96	9.9	5.3
Postal Service	1434	79	5.4[a]	0.2[a]
Agriculture	1350	95	7	8.6
VA	1093	24	1.5	(12.3)
Energy	1065	99	21	1.8
Transportation	753	29	10.1[a]	11.7
Interior	653	106	64.3[a]	1.8[a]
Labor	526	19	—[a]	(2.5)[a]
Commerce	327	46	10.3[a]	(51.9)[a]
DoD Marines	289	243	21.4	27.5
Justice	254	86	21.7[a]	17
CIA	198[b]	8[b]	1[b]	—[a]
GSA	191	91	12	52
HHS	177	60	34	10
NASA	167	198	27.6	15.3
EPA	118	83	15	17.7
State Department	84	110	20.7	1.2
EOP	7[a]	29[a]	76.8[a]	69.6[a]
Treasury	5	2480	16.3[a]	20.1[a]
HUD	0	—[c]	0.4	15.8[d]

[a]Data not clear from agency annual report. Used DOE (2006c) FY04 summary data if available.
[b]CIA 2004 data based on 2004 and part of year 2005.
[c]HUD earned 2 EPAct credits and had 0 covered LDVs, resulting in an "infinite" compliance percentage.
[d]HUD's reported petroleum reduction is being questioned by DOE.

constraints make it impossible to satisfy both the agency's mission and the act's mandates to acquire alternative fuel vehicles, fleet managers obtain conventional vehicles" (GAO, 2000).

Finally, developing an annual cost-efficient acquisition strategy for a large number of vehicles can just plain be difficult when considering the large numbers of vehicles that are being replaced annually, fluctuating AFV budgets and replacement requirements, AFV and alternative fuel availability, fleet manager time constraints and certain anomalies in the acquisition process.

3. Compliance strategies

DOE provides assistance to federal agencies in understanding the various compliance requirements associated with EPAct and E.O. 13149 through a variety of publications and informational sites on the internet. DOE (2006d) also provides agencies with examples of compliance strategies and guidance documents for EPAct and E.O. 13149 under the "Resources" section of their website. Two of these documents located at this site are particularly relevant when considering compliance strategies.

3.1. The Federal Fleet Strategy Development Supplement

In the year 2000, DOE (2000) provided fleets with *The Federal Fleet Strategy Development Supplement*—a publication designed to assist agencies in developing a compliance strategy for E.O. 13149 and to a lesser extent, EPAct. Agency "X" was used as a hypothetical agency in the supplement, and DOE made some basic assumptions in developing a strategy for Agency "X," including that biodiesel and ethanol (E-85) supplies are available or would become available in the near future and that compressed natural gas (CNG) is currently available.

DOE also assumed that AFV acquisitions would be 75 percent at all fleet locations for fiscal year 2001–2005. In all likelihood, this strategy will not optimize EPAct compliance. It is probably more economical to achieve 100 percent compliance at some locations (perhaps by acquiring less expensive vehicles) and less compliance at other locations for an aggregate compliance rate of 75 percent.

Agency "X" has 14 major fleet locations, and DOE's strategy entailed constructing 10 E-85 refueling stations and three CNG refueling stations to be shared among 10 fleet locations (four fleets already have alternative fuel available). It is perhaps surprising that in all but two locations, DOE planned to have *both* major alternative fuels available (CNG and E-85). It is highly unlikely that the relative costs of the two alternative fuels are equal, especially considering that DOE's estimated costs for each of the three proposed CNG stations was at least $250,000 and the cost for an E-85 station was at most $40,000.

This strategy appears to be indifferent to the large incremental costs associated with it – the very same incremental costs that agencies often cite as an impediment to achieving EPAct compliance. Consider the Navy, which had 1529 EPAct-covered LDV acquisitions in 2004. The Navy is one of the largest agencies in terms of covered LDVs, and achieving 75 percent EPAct compliance at a cost of $1,000 per EPAct credit (for example), would cost the Navy $1.15 million in incremental vehicle costs. Yet in its *The Federal Fleet Strategy Development Supplement*, DOE proposed to spend nearly $1.1 million *on infrastructure costs alone*. Agency X would spend $775,000 on three CNG stations in locations that don't even use CNG AFVs exclusively. Local fleet managers were determining the relative percentages of AFV mixes but weren't applying any optimization to do so. DOE does not even directly address Agency X's AFV incremental costs, which are sure to be large since they are acquiring a significant number of AFVs, and CNG-fueled AFVs are often much more expensive than E-85-fueled AFVs. The point is that it appears that no rigor was applied in determining an optimal compliance strategy and that, while Agency X may have deep pocketbooks, "real-world" agencies don't, and so this document provides a less than ideal example of an optimal AFV acquisition strategy.

3.2. US Department of Energy Compliance Strategy for E.O. 13149

DOE's *US Department of Energy Compliance Strategy for E.O.* 13149 was consistent with the format provided by DOE in *The Federal Fleet Strategy Development Supplement,* including assumptions and strategy development (DOE 2001). DOE's strategy is especially important because it is an agency charged with taking the lead in strategy development, and its strategy should serve as a model for other agencies to follow. DOE's strategy is a five-year plan beginning in the year 2000, and DOE often mentions the *Compliance Strategy* in their annual compliance reports. The *Compliance Strategy* was published in June of 2001, but it is still applicable since it and other compliance documents are listed under "Guidance Documents" and/or "Compliance Tools" on DOE's "resources" web site (DOE, 2006d).

The four-part strategy includes using biodiesel, using other alternative fuels and acquiring AFVs, acquiring LDVs with higher fuel economy, and implementing efficiencies in the fleets—all part of an overall sound strategy. DOE's entire vehicle fleet is located in more than 50 sites scattered throughout the United States, so DOE decided to focus on 16 locations that had characteristics like large numbers of vehicles, high fuel consumption (responsible for more than 90 percent of DOE fleet petroleum consumption) and vehicle maintenance availability.

A query using DOE's Alternative Fuel Data Center locator tool (DOE, 2006a) in February of 2006 indicated that, in several instances, there did not appear to be an alternative fuel station within 25 miles of the city that DOE's 2004 annual report (DOE, 2005) states is the location of a DOE alternative fuel site. In other cases, there are alternative fuel sites within 25 miles of a "DOE Alternative Fuel Site," but they often appear to be a private or commercial station only. DOE's *Compliance Strategy* indicates that there are no E-85 stations at the Idaho, Morgantown or Pittsburgh labs, *nor was any construction planned*, but DOE's 2004 annual report indicates that all three sites are an E-85 DOE Alternative Fuel Site. Finally, DOE's *Compliance Strategy* entailed using biodiesel fuel "at the 16 fleet locations" (DOE, 2001) except that six of the 16 sites queried in February of 2006 did not have biodiesel available. Since these sites were to account for 38 percent of DOE's biodiesel savings, achieving the hoped-for petroleum displacement due to biodiesel use appears problematic. (Biodiesel fuel can displace diesel fuel in diesel vehicles and earn an EPAct credit for every 450 gallons (1703 l) of pure biodiesel used, but diesel vehicles are not considered AFVs for EPAct purposes.)

DOE's second strategic approach was the use of alternative fuels, which would result in a 1,222,511 gallons of gas equivalent (GGE) petroleum reduction by 2005 (or equivalently, 4,627,568 l of gasoline). A successful implementation of this strategy *alone* would amount to more than the 20 percent reduction required by E.O. 13149. However, DOE's alternative fuel use in 2004 (exclusive of biodiesel) was less than 400,000 GGE (about 1.5 million l), and DOE had actually been using less and less alternative fuel from 2002 to 2004. Compounding the issue for DOE is the fact that total covered fuel use at DOE actually had increased over 4.5 percent from 1999 to 2004. In a perfect world, every gallon of alternative fuel would displace a similar amount of conventional fuel, but this does not seem to be occurring. As a result, DOE's conventional fuel consumption dropped only 1.8 percent in 2004 from the 1999 baseline.

DOE's *Compliance Strategy* indicates that DOE planned to spend over $2.7 million on infrastructure costs alone. This figure is consistent with that stated in DOE's 2003 annual report (DOE, 2004), but had dropped to $2.1 million in DOE's 2004 report (DOE, 2005). DOE's incremental AFV costs will be significant and DOE does not even address them except to say that they will be spread throughout the fleet via a Surcharge Program that ensures fleets leasing vehicles from GSA pay the same rate as those leasing conventionally fueled vehicles. This is not a trivial issue for typical agencies though, who frequently cite "high AFV incremental costs" as a reason for failing to comply with EPAct. DOE's proposed infrastructure construction would result at lest seven sites having both E-85 and CNG infrastructure, which is almost certainly economically sub-optimal.

The final part of DOE's strategic approach involved the acquisition of higher fuel economy vehicles and fleet efficiency improvements. New LDV acquisitions were to be acquired annually that had increased fuel economy relative to the 1999 baseline, and local fleets were to develop a fleet efficiency improvement plan. Since overall DOE petroleum consumption reduction goals have not been met, and this third part of the reduction strategy only composes 14 percent of the anticipated petroleum reduction anyway, it is likely that fuel economy and fleet efficiency improvements have had little overall effect on DOE's inability so far to meet petroleum reduction goals as delineated in the *Compliance Strategy*.

It appears that sometime between the release of the 2003 and 2004 annual reports, DOE adopted a major strategy shift. As mentioned, there are many instances where current DOE infrastructure does not match that of the *Compliance Strategy*. Clearly DOE has adopted a more efficient EPAct and E.O. 13149 strategy, whether intentionally or unintentionally, but the question is "Why doesn't DOE advise other agencies of the potential process improvements that DOE has implemented?" That is, why is DOE's old, inefficient *Compliance Strategy* still serving as a model for other agencies on DOE's web site?

3.3. National Defense Authorization Act (NDAA) For Fiscal Year 2002

The *National Defense Authorization Act For Fiscal Year* 2002 included a provision requiring that all new light duty truck acquisitions not covered by EPAct (i.e., not in Metropolitan Statistical Areas) be hybrid vehicles for 2005 and beyond. Also, an additional 5 percent of light truck acquisitions in MSAs must be AFVs or hybrids in 2005, in addition to the 75 percent EPAct requirement. The availability of GSA to provide hybrid light trucks for agencies to lease and the incremental costs associated with hybrids are likely to be large factors in the ability of the Services to meet this requirement.

3.4. Department of Defense Compliance Strategy

The Department of Defense (DoD) released its *Department of Defense Compliance Strategy for Executive Order* 13149 *Alternative Fuel/Hybrid Vehicle Requirements* in 2003, which DoD views "is a general alternative fuel/hybrid vehicle implementation strategy for the Department of Defense" (DoD, 2003). It is interesting to note that DOE reviewed this compliance strategy and that "minor changes" recommended by DOE were incorporated (Woodley, 2003). Since DOE reviewed this strategy, one would expect the strategy to be fundamentally sound and based on realistic assumptions. This does not appear to be the case, however. DoD's strategy would result in a more than 35 percent reduction in petroleum consumption by 2005, except that DoD (2003) believed that "continued lack of widespread infrastructure, increasing incremental vehicle costs, and vehicle available will likely have a dampening effect on our estimate."

DoD anticipated saving 10 million GGE (37.9 million l) by acquiring vehicles with increased fuel economy, but assumed that the vehicle manufacturers would supply these fuel-efficient vehicles in sufficient numbers and in appropriate classes to accomplish the 3 mpg (0.425 km/l) increase required for the savings—a big assumption. What may have been an even bigger assumption was assuming that fleet managers will acquire high fuel economy vehicles even if they are available. The onus to acquire more fuel efficient vehicles is on DoD, not on GSA as DoD implies.

DoD's strategy of using hybrids will save 5.4 million GGE (20.4 million l) by 2005 if implemented successfully. In its savings calculations, DoD opted to use a fuel efficiency increase value of 50 percent for light trucks—at the extreme high end of estimates. DoD's calculations could use a re-look as well—a 50 percent savings estimate used a "1.50" value instead of "0.50" in a few spots. A few other logical errors are apparent as well.

DoD's strategy of using alternative fuels would displace 11.5 million GGE (43.5 million l) of petroleum if successfully implemented—the largest reduction of petroleum consumption of any of the three-part strategy. DOD's savings calculations due to biodiesel use reveal a lack of understanding of EPAct requirements as well as practical biodiesel use. In general, there are no EPAct covered fleets when it comes to diesel vehicles as DoD assumed, because they are not considered AFVs. An optimizing agency would attempt to maximize biodiesel use and not limit it to some arbitrary percentage as DoD did, because biodiesel use is a relatively cheap EPAct credit. It is highly unlikely that vehicle operators would use biodiesel in a vehicle half of the time and regular diesel the other half of the time as DoD suggests—fuel storage and engine operation issues would make this impractical.

Other savings likely are overstated as well, since it appears that some savings due to increased fuel economy for conventionally fueled vehicles using gasoline 100 percent of the time are assumed, and savings for E-85 use are assumed in some of these same sedans. DoD also assumed a 2 percent savings due to electric and CNG vehicles that were undocumented.

Assumptions used by DoD in developing their strategy include the following:

- vehicles within the EPAct MSAs were assumed to have access to alternative fuel;
- use of alternative fuel in dual fuel vehicles will meet or exceed 51 percent of the time by 2005;
- a significant alternative fueling infrastructure will be available.

Since the percentage of alternative fuel use in AFVs in 2004 was 21.5 percent, 10 percent, 9 percent and less than 1 percent for the USMC, Air Force, Navy and Army, respectively, the likelihood of DoD using alternative fuel in AFVs 51 percent of the time by 2005 is remote. DoD (2003) acknowledges that it's not likely that the number of alternative fueling stations will meet EPAct's original goal (although they assume this), and that the agency's "hybrid goal is very aggressive as hybrid trucks are not currently available and may not be available in the required styles in the near future." DoD's other assumptions (listed above) appear unrealistic and are part of what seems to be a strategy that is not executable.

Perhaps most notably lacking was the reference to cost. DoD did make vague references to funding issues but did not take full advantage of biodiesel credits, and didn't recommend optimal allocation of Service resources. Fleet managers were not instructed on how best to utilize limited funding assets or how to maximize EPAct compliance for a given budget. And finally, again, it's important to note that DOE reviewed this strategy and did not make significant changes. The largest single agency in terms of AFV acquisitions (DoD) and the agency in charge of EPAct implementation (DOE) both published strategies that could have tremendous influence on how AFVs are to be acquired for the future, both agencies used assumptions that are likely unattainable, and both organizations missed an opportunity to publish a compliance strategy that would make the most use of scarce dollars allocated to AFV acquisitions and E.O. 13149 compliance.

4. Model development

In 2004, the Navy acquired over 1500 LDVs that were covered by EPAct. Acquisitions of this size make it difficult for fleet managers to develop optimal acquisition and compliance strategies, but lend themselves well to a dedicated optimization program. The Navy is a typical agency in that, while it may exceed EPAct acquisition requirements, the agency finds it very difficult to even approach meeting E.O. 13149 requirements. Typically, agencies are acquiring AFVs and then not using alternative fuel in those vehicles, leading to several less-than-desirable results that have been mentioned earlier.

Federal fleet managers were asked to participate in a survey that would be used to identify criteria that are important to them when developing an AFV acquisition strategy. A total of 29 optimization models were then constructed, focusing on the criteria identified by fleet managers and delineated in their agency's annual EPAct compliance reports. The US Navy was used as a test case for models that were designed to (1) meet EPAct requirements at a minimum cost, (2) maximize EPAct compliance subject to a given budget, and (3) maximize alternative fuel use. Model iterations that allowed for the construction of alternative refueling stations, required acquired AFVs to actually use alternative fuel, and/or subjected the Navy to military-specific requirements also were created and used. In addition, a few excursions were undertaken to capture costs of selected externalities like pollution and energy security.

4.1. General model construction

The following definitions and indices were found to be useful when constructing the series of optimization models:

AF = "Alternative Fuel"

i = AFV type available for leasing from GSA	$i = 1\ldots41$
j = vehicle type being replaced in the Navy inventory	$j = 1\ldots59$
k = AF access type (1 = has access to existing AF stations, 2 = has access to constructed AF station only, 3 = does not have access to any AF stations)	$k = 1,2,3$
l = AF type (1 is E-85, 2 is CNG, 3 is HEV)	$l = 1,2,3$
m = zip code of garaged Navy vehicles	$m = 1\ldots883$
o = zip code of AF station potential sites	$o = 1\ldots8$

It is clear from the indices above that there are a total of 41 different AFVs available for leasing from GSA that could replace one of 59 vehicle types currently in the Navy fleet in one of 883 zip codes where the vehicles are garaged. It was helpful in the model construction process to classify "HEV" as an alternative fuel, although this of course is not the case. The decision variables in the model are "Construct" and "AFVsAcquired." "Construct (l,o)" is a binary variable that will take a value of "1" if an alternative fuel station of type l is to be constructed in zip code o, and obviously is used in cases where construction is allowed. "AFVsAcquired (i,j,k,l,m)" provides the number of acquired AFVs of type i replacing vehicle type j in zip code m that have alternative fuel access type k and use alternative fuel type l. Note that "AFVsAcquired" is an array of dimension ($41 \times 59 \times 3 \times 3 \times 883$) meaning the initial solution space encompasses over 19 million variables; however, most of these variables were eliminated from consideration because most of the variables would always take on the value of "0." None of the many pickup truck AFVs would be allowed to replace a sedan or van, for example. We used a dedicated integer optimization package from Dash Optimization called *Xpress-MP* that provided techniques for working with "sparse data" like this, and the result was that the initial "AFVsAcquired" solution space universe was narrowed down to a few thousand integer variables. A solution space of this size is probably too large for fleet managers to work with by hand or for a common spreadsheet application like Microsoft Excel, but it was not too large for a dedicated optimization software package.

The model included the following definitions…

- EPActCredit (i) = number of EPAct credits earned for AFV acquisition i
- Cost (i) = incremental cost of acquire AFV i
- StationCost (l) = cost to construct alternative fuel station of type l

- Budget = maximum budget that can be spent (user editable)
- NumberReplaced (j,m) = number of outgoing vehicles of type j garaged in zip m…and, as mentioned, the model included the following decision variables:
- AFVsAcquired (i,j,k,l,m) = Number of AFVs of type i replacing vehicle type j in zip code m that have AF access type k and use AF type l
- Construct (l,o) = 1 if zip o is to have station of AF type l constructed, 0 else

Three of the various objective functions used in the 29 optimization models are illustrated below:

(1) Maximize the number of acquired EPAct credits

$$\text{Maximize} \sum_{ijklm} AFVsAcquired(i,j,k,l,m) \times EpactCredit(i)$$

(2) Minimize overall cost

$$\text{Minimize} \sum_{ijklm} AFVsAcquired(i,j,k,l,m) \times Cost(i) + \sum_{lo} Construct(l,o) \times StationCost(l)$$

(3) Maximize the number of acquired AFVs that have access to alternative fuel

$$\text{Maximize} \sum_{ijm} \sum_{k=1}^{2} \sum_{l=1}^{2} AFVsAcquired(i,j,k,l,m)$$

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

(1) Budget is not exceeded (includes AFV and infrastructure costs)

$$\sum_{ijklm} AFVsAcquired(i,j,k,l,m) \times Cost(i) + \sum_{lo} Construct(l,o) \times StationCost(l) \leqslant Budget$$

(2) The number of incoming vehicles doesn't exceed outgoing vehicles in each zip code

$$\sum_{ikl} AFVsAcquired(i,j,k,l,m) \leqslant Numberreplaced(j,m),$$

for all j, m

Other constraints, when applied, ensured that the 75 percent EPAct requirement be met, that an AFV that can only use alternative fuel will not be acquired unless alternative fuel is available, and appropriate integer, binary, and non-negativity constraints are applied.

Some basic assumptions were used in the models, including a determination that alternative fuel was "available" if it were located within 5 miles of a garaged vehicle. This 5 mile number was based on input from the Navy feet manager. Navy had over 100 unique vehicle types needing replaced, and they were combined into 59 types—similar pickup trucks were combined into one category, for example. Also, a determination was required as to what was an acceptable replacement for an outgoing vehicle. In most cases it was very simple—sedans replace sedans, vans replace vans of similar weight, and incoming pickup trucks were allowed to replace outgoing trucks of similar weight as well.

A limitation of the model is that it assumes alternative fuel stations would be constructed in areas where it is optimal to do so. Economically, it is not expensive to construct an E-85 station or to convert a conventional gasoline station to an E-85 station for example, but E-85 is not available everywhere in the United States. Ethanol use and availability is increasing and should alleviate this problem to some degree, however, alternative fuel availability (both E-85 and CNG) must be checked for infrastructure construction sites that are selected by the model.

4.2. Model variations

Table 2 provides a brief summary of the 29 model variations that were constructed. These model runs were separated into five classes, and incorporated various unique constraints in an attempt to reflect choices or preferences of fleet managers. Some basic constraints applied to every model number and therefore are not listed in Table 2.

The first major group of models was the "EPAct Class." Run number 1-1 focused on maximizing EPAct compliance, subject to a given budget ($1.2 million for the Navy). This would be the model of choice for a fleet manager concerned only with achieving the highest possible EPAct compliance rate and seems to be a common approach for fleet managers. A second run attempted to meet the EPAct 75 percent requirement at the cheapest possible cost. This run establishes a baseline as the minimum an agency must spend to be compliant with EPAct.

The "E.O. 13149 Class" of models encompassed 12 different models and focused on compliance with E.O. 13149, namely displacing petroleum by using alternative fuel in acquired AFVs. These models are important not only because of potential efficiencies they will provide, but because they actually can assist in meeting the intent of EPAct. These models eliminate some of the waste that currently is prevalent in most agencies that acquire more expensive AFVs and then don't use alternative fuel in them.

In actuality, determining alternative fuel use is often impossible due to the fact that there is no guarantee that an AFV will use alternative fuel even if it is available. Therefore, comparing alternative fuel use "before" and "after" model runs was impractical. Rather, a more appropriate metric was "opportunity to use alternative fuel" instead of actual alternative fuel consumption. As a

Table 2
29 model variations

Model class	Model number/objective	Constraints and assumptions
EPAct	1–1: Maximize EPAct compliance	Notes[a,d,e]
EPAct	1–2: Minimize cost	Notes[a,c]
E.O. 13149	2–1: Maximize alternative fuel use	Notes[a,d,e,f]
E.O. 13149	2–2: Maximize alternative fuel use	Notes[a,d,e,g,h]
E.O. 13149	2–3: Maximize alternative fuel use	Notes[a,d,e]
E.O. 13149	2–4: Maximize alternative fuel use	Notes[b,d,e,f]
E.O. 13149	2–5: Maximize alternative fuel use	Notes[b,d,e,g]
E.O. 13149	2–6: Maximize alternative fuel use	Notes[b,d,e]
E.O. 13149	2–7: Maximize alternative fuel use	Notes[a,c,e,f]
E.O. 13149	2–8: Maximize alternative fuel use	Notes[a,c,e,g]
E.O. 13149	2–9: Maximize alternative fuel use	Notes[a,c,e]
E.O. 13149	2–10: Maximize alternative fuel use	Notes[b,c,e,f]
E.O. 13149	2–11: Maximize alternative fuel use	Notes[b,c,e,g]
E.O. 13149	2–12: Maximize alternative fuel use	Notes[b,c,e]
Must Use Alt. Fuel	3–1: Maximize EPAct compliance	Notes[a,d,e]
Must Use Alt. Fuel	3–2: Maximize EPAct compliance	Notes[b,d,e]
NDAA 2002	4–1: Maximize EPAct compliance	Notes[a,e,i,j]
NDAA 2002	4–2: Maximize EPAct compliance	Notes[a,e,i,k]
NDAA 2002	4–3: Minimize cost	Notes[a,i,j]
NDAA 2002	4–4: Minimize cost	Notes[a,i,k]
NDAA 2002	4–5: Minimize cost	Notes[a,i,l]
NDAA 2002	4–6: Maximize alternative fuel use	Notes[b,e,f,i,j]
NDAA 2002	4–7: Maximize alternative fuel use	Notes[b,e,f,i,k]
Agency/Public Good	5–1: Minimize cost	Notes[a,c,m]
Agency/Public Good	5–2: Maximize alternative fuel use	Notes[b,c,e,m]
Agency/Public Good	5–3: Minimize cost	Notes[a,i,j,m]
Agency/Public Good	5–4: Maximize Public Good	Notes[b,c,e,n]
Agency/Public Good	5–5: Maximize Public Good	Notes[a,c,e,n]
Agency/Public Good	5–6: Maximize Public Good	Notes[b,d,e,n]

Notes:
[a]Construction of alternative fuel infrastructure is not allowed.
[b]Construction of alternative fuel infrastructure is allowed.
[c]The 75% EPAct acquisition requirement holds.
[d]The 75% EPAct acquisition requirement does not hold.
[e]Total spending is constrained to a budget (typically $1.2 million).
[f]There is a small "total cost" penalty in the objective function.
[g]Hybrids (HEVs) count in the objective function.
[h]Acquired AFVs must use alternative fuel.
[i]NDAA 2002 requirements are in effect.
[j]Only HEV pickups can replace pickups in non-MSAs.
[k]AFVs can replace pickups in non-MSAs.
[l]AFVs can replace pickups in non-MSAs only if alternative fuel is available.
[m]Fuel and maintenance costs considered.
[n]Carbon costs, energy security and supply chain externalities considered.

result, the objective function for all of all "E.O. 13149 Class" runs was to maximize the number of AFVs that had access to alternative fuel.

In four of the 12 runs, hybrid electric vehicles (HEVs) were allowed to count in the objective function even though HEVs are not considered AFVs since they don't use alternative fuel. The reason that HEVs were counted as AFVs in a few runs was that some earlier draft versions of recent Energy bills contained this provision, and it makes sense because HEVs actually displace petroleum—not with alternative fuel, but with operational efficiency. Conversations with a Navy representative in early 2006 indicated that there were questions among federal agencies about HEVs offered for lease by GSA in 2005. Evidently these HEVs were considered "non-propulsion" HEVs in that they were not ever propelled by a battery, but always by an engine. As a result, the Navy did not attempt to meet NDAA 2002 HEV acquisition requirements (and was excused from this requirement by the Office of the Secretary of Defense), but the HEV excursions were included anyway to illustrate the cost of such a requirement, and because HEVs may be classified as AFVs for EPAct purposes in the future.

The intent of the two model runs in the "Must Use Alternative Fuel Class" was to illustrate the common problem of alternative fuel availability, or lack thereof.

In these two runs, no taxpayer dollars were wasted because no AFV was acquired unless it could use alternative fuel. Of course, EPAct compliance suffered as a result of this policy, and determining to what degree EPAct compliance did decline was the intent of these two runs. One variation allowed the construction of alternative fuel stations, which of course improved the number of AFVs with access to alternative fuel and improved EPAct compliance too.

The intent of the seven model runs in the ''NDAA 2002 Class'' was to illustrate possible compliance strategies for Navy subject to NDAA 2002 requirements, and to illustrate the costs of complying with the NDAA of 2002. Variations of NDAA 2002 runs modified those vehicles that could replace light trucks in non-MSAs since there was some ambiguity about this requirement, at least in one fleet manager's mind.

The ''Agency/Public Good Class'' of runs did not view objective functions and/or constraints from where the federal fleet managers sit, but from a ''bigger picture'' perspective of the entire agency, or from society's perspective. Model runs 5-1, 5-2 and 5-3 considered not only the incremental AFV acquisition cost that a fleet manager is concerned with when acquiring AFVs, but fuel and maintenance costs which are operating costs not associated with the AFV one-time incremental costs. GSA captures these costs via a ''mileage rate'' charge and a ''monthly rate'' charge for leased vehicles that covers these operating expenses. These runs, then, focused on achieving minimum cost or maximizing alternative fuel use, but from an overall agency perspective, not just that of the fleet manager.

Model number runs 5-4, 5-5 and 5-6 are from an even larger perspective than that of an agency: that of society. Costs and benefits from a societal perspective associated with AFVs would be different than those perceived by a fleet manager or by an agency. Six cost/benefits were used in developing these objective functions, and they were all considered relative to the base case of acquiring conventional vehicles only. The six cost/benefits considered are as follows:

- *Infrastructure cost*. This is the cost to build alternative fuel infrastructure and is itemized over a 10-year period.
- *AFV leasing cost*. This cost only applies to AFVs that don't use alternative fuel. The cost of AFVs that do use alternative fuel is assumed to be equal to the benefit provided by federal leadership demonstrated by using alternative fuel and therefore is not considered an incremental cost. It is itemized over a 4-year period since AFVs are assumed to last for four years before being replaced.
- *Incremental fuel cost*. This consists of costs (or savings) derived from using alternative fuel instead of gasoline. It assumes alternative fuel is used in AFVs 100 percent of the time.
- *Carbon cost*. This is a pollution cost/benefit associated with using alternative fuel instead of gasoline.
- *Supply chain cost*. This cost is associated with chemical releases in the oil recovery, delivery and distribution systems.
- *World oil cost*. This includes costs associated with the additional costs of importing more oil, and due to security costs.

Model number runs 5-4, 5-5 and 5-6 attempt to capture true incremental fuel costs based on actual estimated fuel cost differences between AFVs and conventional vehicles. This approach differs from that used in runs 5-1, 5-2 and 5-3, which used GSA mileage and monthly charges. GSA mileage rate charges by design do not differentiate between an AFV and a similar conventional vehicle and, as a result, do not capture true fuel cost differentials. Model runs 5-4, 5-5 and 5-6 attempt to capture these differences.

A ''carbon cost'' of \$50/tonne was used, as was a ''supply chain cost'' of \$0.02/gallon (about \$0.005/l) of gasoline and an externality cost of \$0.12/gallon (\$0.032/l) due to security costs and additional costs of importing more oil. These costs mirror those used in the National Academy of Sciences *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* study (Portney et al., 2002). It is acknowledged that these values arguably may be much higher or lower, but these cost values were not overly significant in the model runs in any case. These externality costs are often estimated by modeling increases or decreases of large amounts of oil—typically millions of cubic meters per day. Federal fleet petroleum consumption alone is simply not high enough that significant decreases in petroleum use are likely to make much of a difference in world oil prices. However, certainly there are benefits to reducing the demand for petroleum and the CAFE study externality costs were used as a proxy to capture those benefits.

5. Results

A summary of model results for all runs is provided in Table 3. Model number 1-1 established a baseline of 2209 EPAct credits as the maximum possible number of EPAct credits that could be earned by the Navy, which translates into a 134 percent EPAct compliance rate. The Navy is an agency that generally attempts to maximize EPAct compliance, meaning they would adopt a strategy similar to that of model number 1-1. Since the Navy's 2005 AFV acquisition report was recently released (February of 2006), it is possible to compare the Navy's actual 2005 compliance with that of model number 1-1. The Navy (2005) earned 2162 light duty AFV acquisition credits in 2005, which is roughly 98 percent of the 2209 EPAct credits produced by model number 1-1. Actual and theoretical AFV acquisitions seem to correspond well.

The only discrepancy between model number 1-1 and Navy actuals was that the Navy reported 280 percent EPAct compliance while model number 1-1 calculated 134 percent. In the model it was assumed that all Navy vehicles

Table 3
Results

Model #	Object value	EPAct Credits/%	$ spent on infrastruct.	# E-85/CNG stations built	$M spent on AFVs/HEVs	AFVs/HEVs acquired	#AFVs with access to alt. fuel (%)
1–1	2209	2209/134	$0	0/0	$1.1959/$0	2182/0	285/13.1
1–2	$281,338	1239/75	$0	0/0	$0.2813/$0	1239/0	155/12.5
2–1	284.979	292/18	$0	0/0	$0.2099/$0	285/0	285/100
2–2	393	292/18	$0	0/0	$0.21/$0.985	285/108	393/100
2–3	285	309/19	$0	0/0	$0.4514/$0	285/0	285/100
2–4	507.973	516/31	$410,000	8/1	$0.2714/$0	508/0	508/100
2–5	592	513/31	$160,000	8/0	$0.26/$0.77	506/86	592/100
2–6	508	533/32	$410,000	8/1	$0.612/$0	508/0	508/100
2–7	284.959	1239/75	$0	0/0	$0.409/$0	1232/0	285/23.1
2–8	371	1239/75	$0	0/0	$0.43/$0.769	1232/86	371/28.1
2–9	285	1239/75	$0	0/0	$1.109/$0	1212/0	285/23.5
2–10	507.959	1239/75	$410,000	8/1	$0.4119/$0	1231/0	508/41.3
2–11	575	1239/75	$160,000	8/0	$0.42/$0.61	1232/69	575/44.2
2–12	508	1239/75	$410,000	8/1	$0.7896/$0	1231/0	508/41.3
3–1	312	312/19	$0	0/0	$0.4776/$0	285/0	285/100
3–2	540	540/33	$660,000	8/2	$0.5398/$0	508/0	508/100
4–1	2128	2128/129	$0	0/0	$0.74/$0.45	2122/46	317/14.6
4–2	2209	2209/134	$0	0/0	$1.111/$0	2182/0	285/13.1
4–3	$804,548	1321/80	$0	0/0	$0.35/$0.45	1321/46	267/19.5
4–4	$417,108	1368/83	$0	0/0	$0.4171/$0	1367/0	223/16.3
4–5	$794,077	1324/80	$0	0/0	$0.36/$0.434	1323/44	267/19.5
4–6	499.907	1362/82	$160,000	8/0	$0.47/$0.45	1356/46	546/39
4–7	507.946	1410/85	$410,000	8/1	$0.54/$0	1402/0	508/36.2
5–1	$353,466	1239/75	$0	0/0	$0.3535/$0	1236/0	146/11.8
5–2	508	1250/76	$410,000	8/1	$0.7876/$0	1242/0	508/40.9
5–3	$1.042M	1402/85	$0	0/0	$0.59/$0.453	1399/46	250/17.3
5–4	$46,524	1239/75	$0	0/0	$0.396/$0.80	1232/89	120/9.1
5–5	$46,519	1239/75	$0	0/0	$0.395/$0.80	1232/89	120/9.1
5–6	$145,485	35/2	$0	0/0	$0.09/$1.106	28/121	149/100

being replaced in MSAs were subject to EPAct, but that is true only if they are in fleets of 20 or more vehicles. Clearly there are some vehicles that the model considers subject to EPAct that in reality are not. There are 1651 covered vehicles in MSAs requiring replacement, so it was assumed that the 75 percent EPAct requirement was 75 percent of this number, or 1239 credits. The Navy reported 808 covered LDVs in 2005, which is about half the number the model used. When this difference was pointed out to a Navy representative, he advised that the 808 number used by the Navy for 2005 may be low. A review of Navy AFV acquisition reports for 2002, 2003 and 2004 indicates that the Navy averaged over 1500 covered LDVs in those three years, so the 808 number does appear low.

Model number 1-2 established the minimum cost required such that the EPAct 75 percent requirement could be met at $281,338. This result implies that the Navy could have achieved the 75 percent EPAct compliance requirement at a cost of less than 25 percent of their current budget of $1.2 million. A common anomaly in the federal budget process is that if an agency does not use all of the funds allotted to it in a particular fiscal year, these same funds will not be provided to an agency in subsequent years. Knowing this, it is common practice for many federal agencies to spend all of the funds allocated to them in a fiscal year, whether or not the money is actually required. Instead of spending all $1.2 million on AFVs, however, the Navy could have adopted model number 1-2 as its strategy and had nearly $1 million dollars left for items like fire trucks, which were anticipated not to receive full funding in the upcoming budget process. The Navy could have also used excess dollars to fund infrastructure and/or lease HEVs, contributing to the intent of EPAct, which was to reduce dependence on foreign petroleum.

Model numbers 2-1 through 2-12 focus on using alternative fuel and meeting E.O. 13149 requirements to the greatest extent possible. The 12 model runs in the "E.O. 13149" class of runs are important because they focus on the reduction in petroleum consumption, not EPAct credits like most federal agencies do. It is clear that the ability to construct alternative fuel stations can have a large impact on E.O. 13149 compliance, making it possible to use alternative fuel in AFVs over 40 percent of the time in some cases, while still meeting EPAct requirements. It is also clear that there is a "cost" in meeting EPAct requirements for federal agencies.

Of particular note is model number 2-10. This model maximizes the number of AFVs that have access to alternative fuel (good for E.O. 13149 compliance), but ensures that EPAct requirements are met (good for EPAct compliance), all at a minimum cost (good use of taxpayer dollars). However, this model constructs a CNG station that services just a few AFVs, so a prudent fleet manager would forego CNG infrastructure construction in this case and still achieve relatively high alternative fuel use, all well under budget. A fleet manager could look for other E-85 infrastructure construction options that have high concentrations of vehicles, and in the Navy's case, they do exist.

The "Must Use Alternative Fuel Class" of model runs (number 3-1 and 3-2) explored two cases where a fleet manager decided not to waste any dollars on AFVs that would not use alternative fuel. This fleet manager would attempt to maximize EPAct credits but only if the acquired AFV used alternative fuel, so any acquired AFV "must use" alternative fuel. Model number 3-1 does not allow construction and ends up producing a strategy that acquires the same 285 AFVs that a few other model runs produce, but earns 312 EPAct credits due to the acquisition of some "dedicated" AFVs (meaning that these AFVs can *only* use alternative fuel) that earn two EPAct credits instead of one. Acquiring "two for one" EPAct credits is tempting, but a smart fleet manager would look at incremental costs before making a decision, since they are not always economically cost effective.

Model 3-2 is the same as model 3-1, but allows for infrastructure construction. Model 3-2 also acquires dedicated AFVs that earn more EPAct credits than bi-fuel AFVs. As mentioned, this is not necessarily efficient. Perhaps the most interesting aspect about model 3-2 is that it is the only model that produces a strategy that constructs eight E-85 stations and two CNG stations. In no other cases are two CNG stations built but, as in all model runs that opt to construct CNG stations, relatively few AFVs would actually use the CNG station, making them extremely unattractive from a practical standpoint.

The "NDAA 2002 Class" of model runs consisted of a series of seven different runs that focused on the NDAA 2002 requirements, which, for military departments, were in addition to the standard EPAct requirements. NDAA 2002 required that 100 percent of light duty truck acquisitions outside of MSAs be HEVs. In 2005, the military departments were granted a waiver for this HEV acquisition requirement because HEV pickup trucks available for leasing from GSA were not technically HEVs, since no electrical motor was used in those vehicles. These seven runs are still valuable because NDAA 2002 requirements are applicable in future years, and because they can provide an estimate of the cost of complying with the NDAA 2002. Important conclusions of these runs are similar to those of model runs 2-1 through 2-12; namely that the ability to construct alternative fuel infrastructure can have a large impact on E.O. 13149 compliance, and that there is a cost incurred with meeting NDAA 2002 requirements.

Model numbers 5-1, 5-2 and 5-3 consider EPAct and E.O. 13149 compliance from more of an overall agency viewpoint, not just that of a fleet manager. As such, not only are incremental AFV costs considered when acquiring AFVs, but operating costs are included as well. Of interest is the mix of the solution set in model 5-1 compared to that of model 1-2 (a similar model), especially the mix of compact and mid-size sedans. In model number 1-2, there were no compact sedans acquired, while there were 863 mid-size sedans acquired that replaced compacts and/or mid-size sedans. This makes perfect sense, since the incremental cost of the compact is \$807, but only \$326 for the mid-size sedan, and the fleet manager is not concerned with operating costs, only acquisition costs. Model 5-1 does consider operating costs though, and calls for acquiring 803 compacts and only 42 mid-size sedans, since the mid-size sedans are more expensive once operating costs are factored into overall costs. The lesson to be learned from model number 5-1 is that what seems optimal for the fleet manager in terms of AFV acquisitions may not be optimal for the entire agency, once other costs are factored in. Model numbers 5-2 and 5-3 also have solution sets that are different from their counterparts that do not consider mileage and maintenance costs.

Model numbers 5-4, 5-5 and 5-6 were different from previous runs in that they attempted to maximize "public good." The viewpoints of these models are not from that of a fleet manager or that of a federal agency, but might be considered from society's viewpoint. There are several things going on in models 5-4 and 5-5 that are interesting. First of all, they are both "HEV hungry," acquiring 85 of the expensive HEVs. In the "Public Good" class of runs, incremental costs are only considered if the acquired AFV/HEV does not use alternative fuel, and all HEVs are considered to "use" alternative fuel for these purposes. Again, the reason for not considering HEV/AFV incremental costs when alternative fuel is available is that the federal government is exercising EPAct leadership by acquiring HEVs/AFVs and using alternative fuel, which was the intent of EPAct. This is in contrast to acquiring AFVs that will not use alternative fuel, which is a waste of taxpayer dollars and exhibits poor leadership. HEVs are appealing because they save a significant amount annually in fuel costs as well as smaller amounts due to CO_2 emission avoidance and they provide small monetary world oil and supply chain benefits as well.

The bottom line for models 5-4 and 5-5 is that the acquired mix of AFVs and HEVs produce a public benefit of about \$105,000 in fuel cost savings, and another \$17,000 in benefits due to CO_2 emission reductions, world oil benefits, and supply chain benefits. There is a societal cost of about \$75,000 due to the acquisition of 922 mid-size sedans that don't use alternative fuel, and were acquired only to meet EPAct 75 percent requirements.

Model number 5-6 also maximized public benefit like models 5-4 and 5-5, but did not require the 75 percent EPAct requirement to be met. This model selects as few or as many AFVs and HEVs as desired, with no minimum number required, as long as the total cost is less than the overall budget. Model number 5-6 selected 121 HEVs, which was by far the highest total of any of the 29 models, and was the only model to select four different types of HEVs. The large annual gas savings for the incoming HEVs ranging from $229 to $1001 relative to the vehicles they were replacing made the HEVs attractive, as well as being able to ignore their incremental cost because they were ‘‘using’’ alternative fuel. Most of the public benefits of model 5-6 were due to the acquired 121 HEVs.

A fleet manager presented with the 29 model options developed in this research might wonder which model is most appropriate for his or her agency to adopt. The models that would be most appealing to a fleet manager would most likely depend at least somewhat on the individual preferences of fleet managers. Some of the 29 models used in this research made a determination for the fleet manager regarding what was important in an AFV acquisition strategy. For example, several model runs that attempted to maximize alternative fuel use or maximize public good contained constraints that required the minimum 75 percent EPAct requirement be met, and this is entirely reasonable. But what if a fleet manager were willing to accept a little less alternative fuel use in exchange for EPAct compliance that were a little bit higher than 75 percent? Or, what might be an acceptable tradeoff between the highest possible EPAct compliance and lowest overall cost? Problems like these lend themselves well to multiple criteria decision making (MCDM) techniques. MCDM problems were not explored in significant detail in this research, but should be in future research involving EPAct and E.O. 13149 tradeoffs.

6. Conclusions

Federal agencies need to adopt an optimal EPAct and E.O. 13149 compliance strategy that uses taxpayer dollars efficiently. As demonstrated in this paper, strategies are available that would displace more petroleum than is currently being displaced, at or below the current budget, while still meeting EPAct and/or NDAA 2002 requirements. Dollars saved due to efficiencies could be used for additional alternative fuel infrastructure or other pressing requirements.

It is clear that any federal agency must consider infrastructure construction in any reasonable EPAct and E.O. 13149 compliance strategy. Almost all model runs that allowed infrastructure construction did in fact opt for constructing alternative fuel stations, with large improvements in alternative fuel use. The recently passed Energy Policy Act of 2005 requires AFVs to use alternative fuel unless it is not available or unreasonably expensive. In order to avoid acquiring thousands of relatively expensive AFVs that will never use alternative fuel, agencies need to adopt strategies allowing for infrastructure construction. This research has demonstrated that reasonable, cost-efficient strategies are available.

Model solutions need to be evaluated for practicality and efficiency. It does not make sense, for example, to construct an expensive CNG facility only to fuel a few AFVs. Some solutions, while optimal, are not always cost-efficient. MCDM techniques could be employed to determine acceptable tradeoffs between cost, EPAct and E.O. 13149 compliance, for example. The ‘‘best’’ strategy depends on what one is trying to maximize or minimize, and whether one considers NDAA 2002 requirements, maintenance and fuel costs, construction options, EPAct requirements, public good, and similar considerations.

DoD and DOE need to update their compliance strategies so that they are realistic and achievable, and produce solutions that optimize the allocation of an agency's budget. Federal agencies need to adopt one or more of these strategies based on their individual goals and preferences.

Legislators must understand that there is a cost to EPAct and NDAA 2002 implementation for the agencies. When model variations that required 75 percent EPAct compliance were compared to iterations that did not require EPAct requirements to be met, there usually was an increase in costs associated with acquiring enough AFVs to meet the 75 percent requirement. These costs for Navy were as high as $655,000 for EPAct and $500,000 for NDAA 2002.

Further research is required in order to develop strategies that focus on a more global perspective. This research summarized herein was successful in demonstrating that compliance strategies are available that would improve compliance for a federal agency. A larger perspective might be that of the entire federal government. In that case, the optimization model would be considering a strategy for all federal agencies. For example, a model for an individual federal agency might not elect to construct an alternative fuel station because it is too expensive but, if several agencies were to use the station and each funded part of the construction costs, it might make sense to build the alternative fuel station. An even larger perspective might be that of the federal and state fleets combined, for example. Additional research needs to be conducted focusing on developing optimal strategies for federal agencies that incorporate MCDM techniques based on tradeoffs most acceptable to fleet managers and their associated agencies.

We are not aware of EPAct-like statutory requirements in other countries, but with the recent higher petroleum prices, alternative fuels are sure to be of continued interest for petroleum importers. AFV acquisition plans and infrastructure construction options for other countries might benefit from efficient strategies discussed in this paper.

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