Quantifying the Impact of Vehicle and Motor Fuel Provisions from the Energy Policy Act on the Sustainability and Resilience of U.S. Cities

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Abstract

The Energy Policy Act of 1992 (EPAct), with later amendments, was enacted with the goal of reducing U.S. petroleum consumption by building a core market for alternative fuels and alternative fuel vehicles (AFVs). The U.S. Department of Energy (DOE) manages three federal programs that Congress authorized through EPAct: the Sustainable Federal Fleets Program, the State and Alternative Fuel Provider Fleet Program, and Clean Cities. Certain federal agencies and state and alternative fuel provider (SAFP) fleets are required to document their compliance with EPAct's vehicle-acquisition requirements. Clean Cities is a voluntary program aimed at building partnerships and providing technical expertise to support end-users who implement technologies that reduce petroleum use in transportation.

This study reviews the evolution of these three programs in relation to alternative fuel and vehicle markets and private sector adoption of AFVs, and assesses the impact of the programs on petroleum use and greenhouse gas emissions both within the regulated fleets and through development of alternative fuel and vehicle markets. The increased availability of alternative fuels and use of alternative fuels in regulated fleets is expected to improve cities' ability to respond to and quickly recover from both local disasters and regional or national fuel supply interruptions (short- and long-term). Our analysis examines the benefits as well as potential drawbacks of alternative fuel use as it relates to the resiliency of U.S. cities.

List of Acronyms

AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool
AFV	Alternative Fuel Vehicle
B100	Neat/pure Biodiesel
BPCD	Barrels per Calendar Day
CNG	Compressed Natural Gas
DNRR	Depletion of Non-Renewable Resources
DOE	U.S. Department of Energy
E85	85% Ethanol
EERE	Office of Energy Efficiency and Renewable Energy
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 1992, as amended
EV	Electric Vehicle
FFV	Flexible Fuel Vehicle
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicle
JEDI	Jobs and Economic Development Model
LD	Light-Duty
MHD	Medium and Heavy-Duty
NCSFA	National Conference of State Fleet Administrators
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
PHEV	Plug-In Hybrid Electric Vehicle
RFS	Renewable Fuel Standard
SAFP	State and Alternative Fuel Provider
VMT	Vehicle Miles Traveled
VTO	Vehicle Technology Office
WTW	Well to Wheels

Keywords

Energy Policy Act
AFV
Transportation
Sustainability

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1 Background

1.1 Energy Policy Act Programs and Goals

The Energy Policy Act of 1992 (EPAct) directed the U.S. Department of Energy (DOE) to create three separate programs that touch upon the issue of alternative fuel deployment in vehicle fleets and more generally. Initiated in the 1990s, these programs—the State and Alternative Fuel Provider Fleet (SAFP) program, the Sustainable Federal Fleets program, and the Clean Cities program—focus on the replacement of petroleum transportation fuels with alternative fuels and conventional/alternative fuel blends, all with the goal of advancing the nation's economic, environmental, and energy security.

The SAFP fleet program (DOE 2016a) focuses on state government fleets and commercial entities that provide alternative fuel. Because electricity and natural gas are considered alternative fuels, electric and natural gas utilities comprise the majority of the alternative fuel providers included in the program. The Sustainable Federal Fleets program (DOE 2016b) covers 28 federal agencies, including the U.S. Postal Service, which makes up over one third of the vehicles in the program. The Clean Cities program (DOE 2016c) includes private companies, local communities, and various government entities. Since their inception, these three programs have facilitated the development of alternative fuel demand while allowing for the germination and growth of advanced vehicle technologies in fleets that have served successfully as laboratories for deployment.

While all three programs share similar and mostly common goals, they approach the goals in different fashions. The SAFP and the Sustainable Federal Fleets programs are considered the mandated-fleet programs, and Clean Cities is the voluntary arm of the effort. The two mandated-fleet programs focus on the earning of credits, each a bit differently, by covered fleets for their vehicle acquisitions and fuel use. Both the SAFP and the Sustainable Federal Fleets programs require that certain fleets acquire alternative fuel vehicles (AFVs) as part of their annual light-duty (LD) vehicle acquisitions. These fleets may earn credits toward their LD AFV-acquisition requirements in various ways as explained later in the paper.

Congress has amended the SAFP fleet program several times. The amendments have allowed covered fleets (fleets subject to the program) to earn additional credits for the use of biodiesel in blends of 20% biodiesel or greater, and have provided an alternative compliance option under which fleets count their alternative fuel use in lieu of vehicle acquisitions. Additionally, under the SAFP fleet program, DOE allocates credits for covered fleets that acquire various types of electric drive vehicles, and for covered fleets that invest in qualified alternative fuel infrastructure, non-road equipment, and emerging technologies related to those electric drive vehicles. Each congressional amendment has allowed the fleets to explore the viability of expanded use of AFVs and alternative fuels and thereby promotes the use of alternative fuels.

The federal government is subject to various statutory and executive order mandates related to its vehicles and the fuels used in them.[1] These federal fleet mandates include LD AFV-acquisition requirements, petroleum reduction requirements (removed after 2015), and alternative fuel

[1] FEMP Federal Fleet Management Laws and Requirements: https://www4.eere.energy.gov/femp/requirements/requirements_filtering/fleet_management.

increase/use requirements. More recently, increased efficiency, as viewed by reductions in greenhouse gas (GHG) emissions per mile driven, has been included in the mandates. Because the federal fleet as a whole is required to acquire AFVs, including plug-in hybrid electric vehicles (PHEVs), as part of its annual LD vehicle acquisitions, and operate its flexible fuel vehicles (FFVs) on alternative fuel unless a waiver has been granted; individual federal fleets provide a consistent demand for alternative fuels, fueling infrastructure, and vehicles.

DOE's Clean Cities program works to advance the EPAct goals by supporting nearly 100 local coalitions and their actions to cut petroleum use and GHG emissions in transportation throughout the United States. DOE created Clean Cities in 1993 to provide informational, technical, and financial resources to EPAct-regulated fleets and voluntary adopters of alternative fuels and AFVs. Clean Cities has saved more than 7.5 billion gallons of petroleum since its inception in 1993.

Clean Cities coalitions are comprised of businesses, alternative fuel providers, vehicle fleets, state and local government agencies, and community organizations. Each coalition is led by an on-the-ground Clean Cities coordinator who tailors projects and activities to capitalize on the unique opportunities in their communities. With nearly 15,000 stakeholders participating in Clean Cities coalitions, their collective efforts work to transform local and regional transportation markets.

At the national level, the program develops and promotes partnerships, publications, tools, and other unique resources. At the local level, coalitions leverage these resources to create networks of local stakeholders and provide technical assistance to fleets implementing alternative and renewable fuels, idle-reduction measures, fuel economy improvements, and emerging transportation technologies.

1.2 Fuel Use in the United States

The U.S. Energy Information Administration (EIA) estimates that in 2014, approximately 28% of the total energy consumed in the United States was used to transport people and goods (EIA 2015). Roughly 60% of that amount was used as gasoline (blended with 10% ethanol) in cars, motorcycles, and light trucks. The remaining 40% is distributed among a variety of fuels that are used in heavy trucks, buses, trains, airplanes, and ships, as well as LD vehicles. Diesel fuel (or distillate fuel), used primarily in heavy trucks, buses, and trains, and kerosene, used in jet fuel, make up about 33% of the total. The remaining 7% is distributed between natural gas and liquefied petroleum gas (propane), which are also used primarily in heavy-duty vehicles; electricity used mostly for public mass transit systems; and other fuels. The distribution of fuel types is shown graphically in Figure 1.

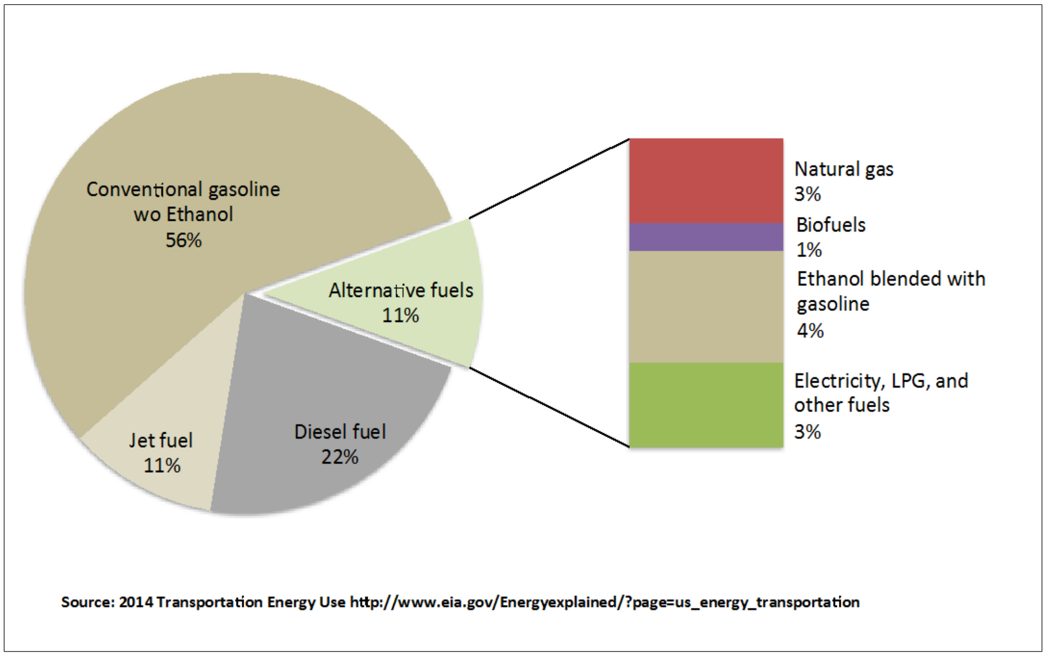

Figure 1. Volume distribution of fuel types in 2014

The Renewable Fuel Standard (RFS) program was created under the Energy Policy Act of 2005, and amended thereafter. The RFS program, implemented by the U.S. Environmental Protection Agency (EPA), seeks to replace or reduce the nationwide quantity of petroleum-based transportation fuel, heating oil, and jet fuel. The RFS program sets annual volume and percentage standards for renewable fuels, including conventional renewable fuel (e.g., corn-based ethanol) and more advanced biofuels such as cellulosic ethanol and biodiesel. The RFS and other government mandates and incentives have contributed to large increases in the use of ethanol and biodiesel biofuels, which are mostly blended with conventional gasoline and diesel. The amount of fuel ethanol added to motor gasoline consumed for transportation went from about 1 billion gallons in 1995 to about 13 billion gallons in 2014. Biodiesel consumption increased from 10 million gallons in 2001 to about 1.4 billion gallons in 2014 (EIA 2015). The SAFP and Sustainable Federal Fleets programs have facilitated these transitions by providing leadership in demonstrating the use of alternative fuels in advance of national implementation of the RFS mandates.

1.3 Transportation Sustainability and Resilience

> Sustainability is "the capacity for continuance into the long term future. Anything that can go on being done on an indefinite basis is sustainable. Anything that cannot go on being done indefinitely is unsustainable." (Litman 2008)

Sustainability analysis or planning seeks to evaluate and minimize the risk that current resource consumption will adversely affect ecological integrity, human communities (local or distant), and future generations. Although the term "sustainability" could encompass almost all human activities, sustainability analysis usually focuses on three broad categories of impact—environmental, economic, and social. Transportation has significant impacts on sustainability in all three categories as listed in the sampling from Litman and Burwell below (Litman and Burwell 2006).

Economic:

- Traffic congestion
- Accident damages
- Facility costs
- Consumer costs
- Depletion of non-renewable resources (DNRR).

Social:

- Inequity of impacts
- Human health impacts
- Community livability.

Environmental:

- Air and water pollution
- Habitat loss
- Hydrologic impacts
- DNRR.

Sustainability analysis and policy initiatives concerning transportation in the United States have focused almost exclusively on reduction of GHG emissions over the life cycle of the fuels and vehicles (Elgowainy, Han et al. 2016) and economic competitiveness (Haas, McAloon et al. 2005), although several studies have addressed broader ecological concerns, especially water impacts (NRC 2008, NRC 2010, Pool 2014).

Resilience has been defined as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (NAS 2012). For transportation systems, resilience involves both the ability to maintain or quickly restore mobility for goods and people during and after a disaster, and the ability to adapt to long-term changes in the availability of energy resources for fuels.

Disasters, such as Superstorm Sandy in 2012 and earlier Gulf Coast hurricanes, affect transportation systems in a variety of ways, including disruptions in raw material supply (e.g., the interruption of production from offshore oil platforms), damage to infrastructure (e.g., refineries and public transportation systems/networks), damage to fuel transport systems (e.g., roadways and pipelines), and interruptions to distribution of fuel (e.g., power outages that prevent filling stations from pumping fuel).

The alternative and renewable fuel supply chain and infrastructure can be affected by short-duration disasters in the same way that conventional fuel systems are affected. However, because of fundamental differences in the resources used as well as the rest of the supply chain, alternative and renewable fuel supply systems would experience different impacts than conventional fuel supply systems. Although quantitative comparisons are difficult, this analysis explores the qualitative resiliency implications of differences between conventional fuel and several alternative/renewable fuel pathways.

Assessing a fuel's sustainability also captures many of the long-term resilience implications for the fuel's supply chain(s). For example, disagreements over the use of a potential food crop for production of fuel ethanol highlight the overlap between sustainability and resilience. While production of ethanol from a potential food source like corn may not be sustainable in the future, the use of ethanol as a fuel may be both sustainable and resilient if it can be produced in large quantities from a variety of cellulosic feedstocks.

2 Methodology

2.1 Vehicle and Alternative Fuel Data

Starting in 1997, the SAFP Fleet program has collected information about covered fleets' acquisitions of AFVs. After regulatory amendments that went into effect in 1999, fleets were also able to obtain credit for purchasing and using biodiesel in their medium and heavy-duty (MHD) vehicles in blend levels of B20 and higher, that is, in mixtures of 20% or greater neat biodiesel (B100) with conventional diesel. Beginning in 2014, fleets were able to obtain credit for the installation of alternative fueling infrastructure, and for investments in non-road equipment and emerging technologies. The fuels defined as alternative fuels under the SAFP and federal fleet programs include methanol, ethanol, and other alcohols, blends of 85% or more of alcohol with gasoline, natural gas and liquid fuels domestically produced from natural gas, liquefied petroleum gas (propane), coal-derived liquid fuels, hydrogen, electricity, fuels (other than alcohol) derived from biological materials (including neat/pure biodiesel (B100)), and P-Series fuels. The SAFP and federal fleets have not reported use of coal-derived liquid fuels or P-Series fuels and hydrogen has only been reported in very small quantities in the last couple of years. These three fuels and AFVs using them have generally been excluded from the analysis.

Each fleet reporting under the SAFP program reports details about its acquisitions of LD and MHD AFVs and its biodiesel purchases during the model year (September 1 through August 31 of the following calendar year), as well as information about the total number of LD vehicles the fleet acquired during the year. The National Renewable Energy Laboratory has been contracted by DOE to administer the program and maintains an extensive database of the vehicles that have been reported during the lifetime of the program. This database was queried to obtain summary information about the types of AFVs acquired, and other program information including the total number of LD vehicles acquired, biodiesel purchased, and exemptions that fleets have requested when they were not able either to obtain alternative fuel in their area or acquire AFVs in vehicle models that met their needs.

Federal fleets track both vehicle acquisitions and alternative fuel usage under the EPAct Sustainable Federal Fleets program (DOE 2016d). These data are published in summary annual spreadsheets that cover the period from 2008 through 2014. The federal fleet fuel usage data and fleet vehicle data were used to estimate GHG savings for the federal fleets.

Information about national AFV and alternative fuel markets was derived primarily from the EIA. The Energy Policy Act of 1992 requires EIA to collect AFV inventory and fuel consumption data as well as the supply of AFVs made available by original equipment manufacturers (OEMs) and conversion facilities (EIA 2014). The EIA collects data on the AFV inventory for federal, state, and transit agency fleets, which are the primary purchasers of AFVs. However, the EIA inventory is not a comprehensive inventory of all AFVs in the nation.

2.2 Clean Cities

Clean Cities funds transportation projects through its coalition partners. Since the program's inception in 1993, more than 500 projects have been launched, totaling $377 million in DOE funding, which leveraged an additional $740 million in matching and in-kind funds from the private sector (DOE 2016c). In addition to petroleum savings and GHG emissions savings estimates for AFVs, the Clean Cities program has achieved GHG reductions through a wide variety of other technologies and outreach efforts. Table 1 lists the GGEs displaced and GHG reductions achieved through the use of alternative fuel in non-road vehicles and other petroleum reduction technologies by Clean Cities Coalition members in 2014. Although Clean Cities reports petroleum reduction and GHG savings for AFVs in annual metrics reports, the reports do not provide vehicle-level data comparable to the SAFP and Sustainable Federal Fleets programs. Therefore, Clean Cities impacts will not be included in the vehicle and fuel use results.

Table 1. Clean Cities Program Gasoline Gallon Equivalents and Greenhouse Gas Reductions Achieved Through Other Technologies in 2014 (Johnson and Singer 2015)

	GGE Displaced (million gallons)	GHG Displaced (tons CO_2eq)
VMT Reduction	24	296,329
Idle-Reduction	38	465,544
Fuel Economy	21	259,846
Off-Road	9	72,436

2.3 Estimation of Gasoline Gallon Equivalents Use and Greenhouse Gas Emissions Savings

The SAFP program database provides detailed information about vehicle acquisitions and other program information, but vehicles are not tracked in the program after a fleet acquires them. Therefore, estimates were needed for the typical lifespan, annual vehicle miles traveled (VMT), fraction of the time that alternative fuel was used, and fuel economy for the vehicles in order to estimate fuel use and GHG savings. The sources for each of these estimated values are listed in Table 2.

Table 2. State and Alternative Fuel Provider Vehicle and Fleet Estimated Values and Assumptions

Value	Description	Source
Vehicle lifespan	LD – 8 years MHD – 11 years	Fleet interviews and NCSFA Benchmarking Survey (Lee 2015)
VMT	LD – 14,000 miles MHD – 9,000 miles	Fleet interviews and NCSFA Benchmarking Survey
Alternative fuel usage percentage	E85 – 5% through 2007, 10% (2008 – 2011), 14% (2012 – 2015) based on averages reported by federal fleets CNG – 100% for dedicated vehicles (vehicles that can only operate on the alternative fuel), 50% for dual fuel vehicles (vehicles that can operate on either an alternative or conventional fuel or a mixture of alternative and conventional fuel) Electricity – 100% for dedicated vehicles, 30% for dual fuel vehicles Biodiesel – 100% of reported usage of B100 Other alternative fuels – 100%	Sustainable Federal Fleets Fleet Performance Data (DOE 2016d) and assumption of 500 GGE per year fuel usage for a typical LDV SAFP database ratio of dedicated to dual fuel vehicles by year SAFP database reported usage of B100
Fuel economy	National fleet average fuel economy by year was adjusted based on the AFLEET tool fuel economy multipliers for AFVs of various weight classes (see Appendix A)	Transportation Energy Data Book (Davis, Diegel et al. 2015) AFLEET tool (ANL 2016)

For the SAFP vehicles, the number of vehicles of each type in the fleet in a given year was determined based on the vehicle acquisitions from previous years and the expected lifespan of each type of vehicle according to equation 1.

$$\text{Number of vehicles} = \text{vehicles in the previous year} + \text{acquisitions} - \text{retirements} \quad (1)$$

The GGE of fuel use was then estimated using the average VMT, fuel economy, and fuel usage percentages from Table 2 and Tables A1–A3. Fuel use in GGE is equal to the GGEs of gasoline or diesel (for vehicles that operate partially on conventional fuel) plus the GGEs of alternative fuel (see equation 2).

$$GGE = \#\text{ of veh.} * VMT * (AFF/FE_{alt} + (1\text{-}AFF)/FE_{conv}) \quad (2)$$

Where

- AFF is the alternative fuel usage fraction from Table 3
- FE_{alt} is the fuel economy of the vehicle operating on alternative fuel (miles/GGE)
- FE_{conv} is the fuel economy of the vehicle operating on either gasoline (LD) or diesel (MHD) (miles/GGE)

Alternative fuel use is reported directly for federal fleet vehicles, so estimates of fuel use were not needed for those vehicles (DOE 2016d).

GHG emissions savings are calculated based on the amount of conventional fuel, either gasoline or diesel, displaced due to the use of the AFV and alternative fuel. The GHG emissions savings are the difference between the GHG emissions from a comparable conventional vehicle minus the GHG emissions from the AFV, including any conventional fuel used in that vehicle. The GHG emissions are equal to GGEs of fuel use for each type of fuel multiplied by the GHG emissions factor for that type of fuel. See Table A4 for the emissions factors used.

2.4 Economic Impact and Jobs

The Jobs and Economic Development Impact Model (JEDI) was used to estimate the jobs and economic impact of production of ethanol and biodiesel, which are the alternative fuels used in the largest volume by the SAFP and Sustainable Federal Fleet programs. These impacts are compared to the jobs and economic impact of conventional gasoline and diesel refining (NREL 2014). The JEDI models use project-specific information and industry-accepted default values to estimate the economic impact of project development, onsite labor, and local revenue and supply chain, as well as induced impacts on the broader local and regional economy. The published JEDI models for petroleum and corn ethanol were used for those technologies, and a new model was developed for biodiesel based on the process analysis performed by Haas et al. (Haas, McAloon et al. 2005).

The JEDI models estimate jobs and economic impact during construction and operations of the facility. Because the focus of this study is long-term sustainability, and because the incumbent conventional fuel supply chain is well established with few new refining facilities planned, only the local jobs and economic impact during operations of the facilities was included.

The JEDI model output is grouped into three categories: jobs, local revenue and supply chain impacts, and induced impacts. Job impacts relate to the workers at the facility, including administrative staff and managers. Local revenue and supply chain impacts refer to the expenditures related to on-site labor, production of raw materials, and services needed to operate the plant, as well as the inputs required to produce these goods and services. The value of these revenues flow to the local economy through fees, permits, licenses, utilities, insurance and other services. These would include, for example, suppliers of spare parts, local motor vehicle retailers, maintenance service providers, and agents at insurance companies. The final category, induced impacts, refers to economic activity that results from income (earnings) spent by workers involved in the first two categories (on-site labor and local revenue and supply chain impacts).

Table 3 lists the primary assumptions used for modeling of the facilities.

Table 3. Primary Assumptions for Jobs and Economic Development Impact Models

Facility Type	Description	Source
Petroleum Refinery	Louisiana	Based on Citgo Petroleum Corp. refinery in Lake Charles, LA (http: //www.eia.gov/energyexplained)
	427,800 barrels per calendar day (BPCD)	Citgo Petroleum Corp. refinery
	18.86 gallons of gasoline per barrel of crude oil	http://www.eia.gov/energyexplained
Ethanol Production	Iowa 30 million gallons per year	Default values for JEDI model (NREL 2014)
Cellulosic Ethanol	Iowa 69 million gallons per year	Default values for JEDI model
Biodiesel Production	Iowa 10 million gallons per year	Typical plant size from the Biofuels Atlas https://maps.nrel.gov/biofuels-atlas Biodiesel plant capital costs and process parameters from (Haas, McAloon et al. 2005)

2.5 Resilience

For the purposes of this study and its focus on alternative fuels, resilience metrics were selected to reflect the unique aspects of the alternative fuel supply chain from raw materials through processing into fuel. While transport and distribution of alternative fuels, especially for the special case of electricity, present both challenges and opportunities for resilience, the topic will be discussed only briefly in this study. This study focuses instead on the resilience aspects of alternative fuels and the ability to adapt to long-term changes in the availability of energy resources for fuels.

Resilience metrics include the following:

- Robustness—Abundance and diversity of raw material or energy resources derived from different materials or different sources (including importing of raw materials or finished product), processing facilities that are geographically dispersed, or a variety of transport options for raw materials and fuels
- Flexibility—Interchangeability of raw materials and energy resources, ability to process multiple or mixed feedstocks from different sources, ability to ramp production up and down and store raw materials or finished product for later use, vehicle operation on more than one fuel or a mixture of fuels

Qualitative analyses of robustness and flexibility for ethanol and biodiesel, which are the alternative fuels used in the largest volume by the SAFP and Sustainable Federal Fleet programs, are based on several studies and databases that evaluate the current and long-term availability of resources and associated environmental impacts (Cardno Entrix 2010, NRC 2010, Wu, Mintz et al. 2012, Pool 2014, Marshall, Aillery et al. 2015).

3 Results and Discussion

3.1 Program Impact

The number of federal and SAFP vehicles in operation are plotted in Figure 2. The number of federal and SAFP ethanol, compressed natural gas, electric and propane vehicles is plotted as a percentage of the total number surveyed by the EIA nationally on the right-hand vertical axis (EIA 2014). The number of AFVs in the federal and SAFP fleets has increased steadily over the past 15 years, driven initially by a mix of AFV types, and more recently and largely by the increase in the number of ethanol flex-fuel vehicles. Nevertheless, the federal and SAFP vehicles make up a decreasing percentage of the national AFV fleet over the same time period. The trend in the percentage suggests that the Sustainable Federal Fleets and State and Alternative Fuel Provider Fleet programs did provide an early and consistent market for AFVs and that the fleets became less important to vehicle and fuel markets as those markets matured.

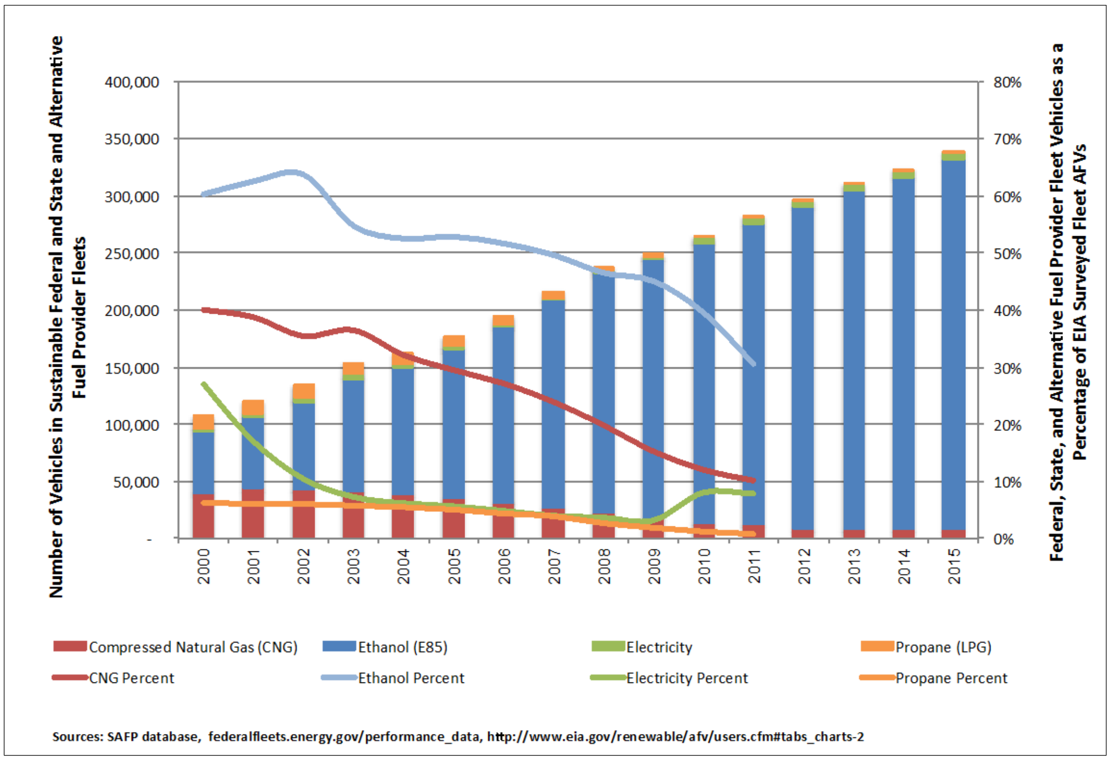

Figure 2. Federal and state and alternative fuel provider alternative fuel vehicles in comparison to EIA survey national totals

Figure 3 illustrates another way in which the SAFP fleets may have helped to encourage the AFV market. In the early years of the State and Alternative Fuel Provider Fleet program, a large fraction of the CNG and propane vehicles in the SAFP fleets consisted of conventional fuel vehicles that had been converted to use alternative fuel. Fleets acquired converted vehicles or converted them themselves because very few original equipment manufacturer (OEM) vehicles were available. As OEMs introduced CNG and propane vehicles, the fleets acquired them. In this case, the EPAct program clearly supported early markets for these vehicles.

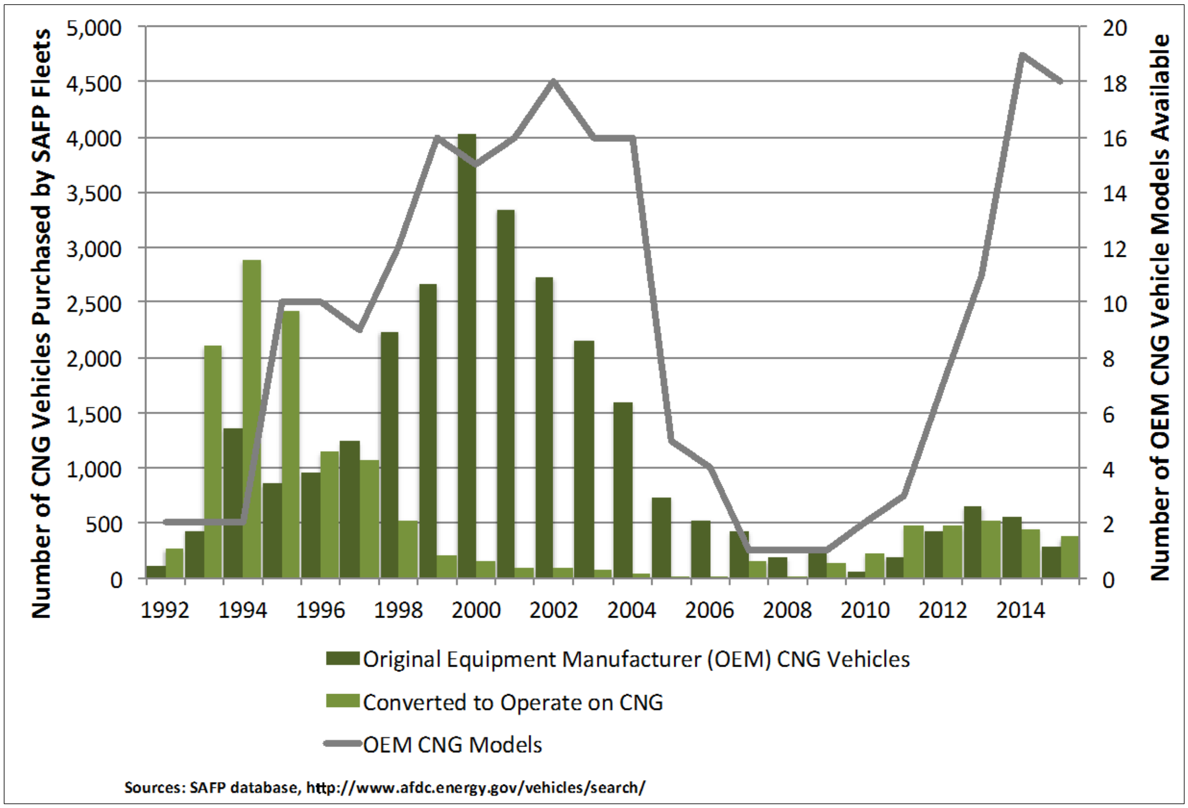

Figure 3. State and alternative fuel provider fleet conversions of compressed natural gas and propane vehicles and availability of original equipment manufacturer vehicle models

A similar trend is shown for electric vehicles (both gasoline electric hybrids and all-electric vehicles) in Figure 4. In the early years of the program, a significant number of electric vehicle acquisitions were converted vehicles. By 2000, no converted electric vehicles were being acquired or converted by the fleets. Figure 4 also illustrates another interesting trend in fleet electric vehicle purchases. As the number of manufacturers offering electric drive vehicles increased, the number of vehicles purchased from any one manufacturer decreased and visa versa. This trend was particularly noticeable in the period from about 2002 to 2010 in which the number of manufacturers offering electric vehicles declined sharply, but the fleets continued to buy them – i.e., the number of vehicles purchased by fleets varied much less than the "availability" of vehicles. It appears that fleets have been very willing to try small start-up vehicle manufacturers as evidenced by the low number of vehicles per manufacturer whenever there are more manufacturers to choose from. Very consistently, the number of vehicles per manufacturer only goes up when there are few manufacturers to choose from.

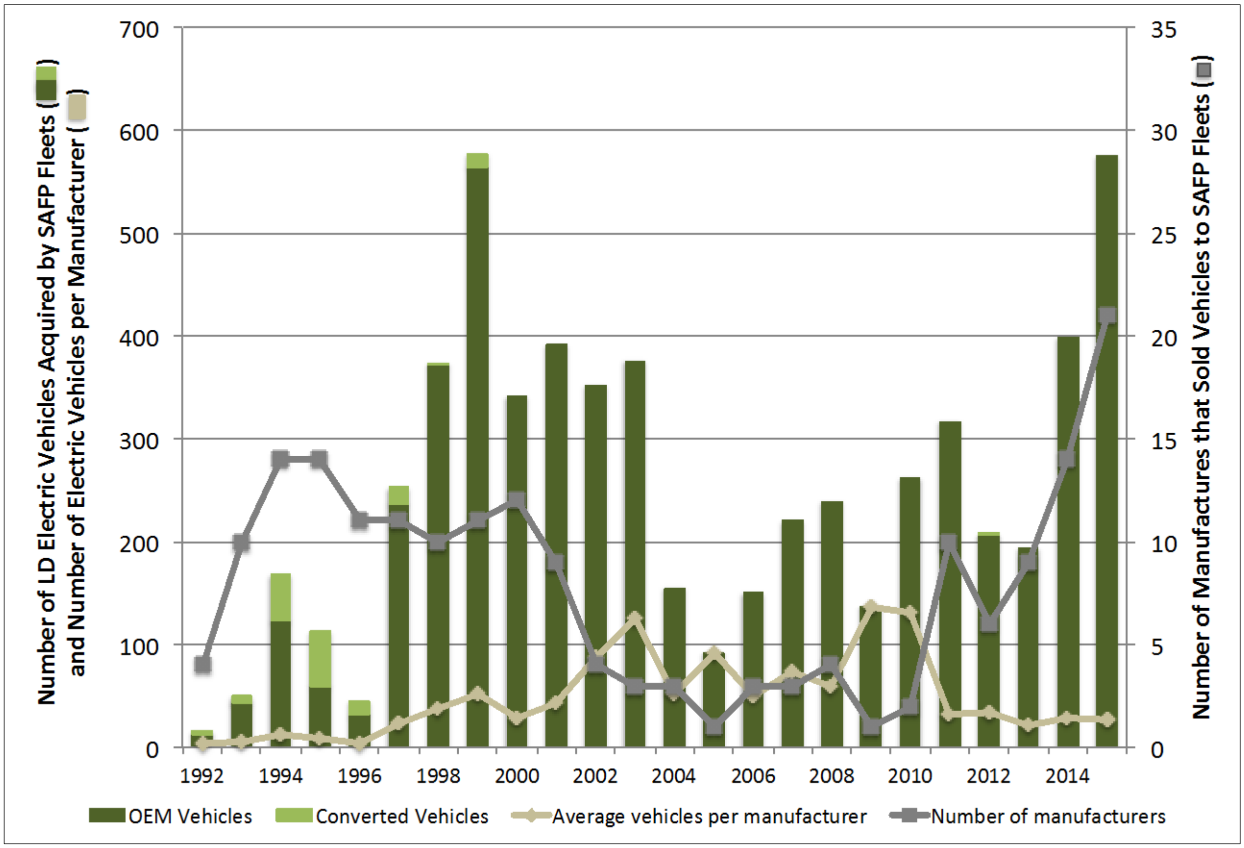

Figure 4. Comparison of state and alternative fuel provider fleet light-duty electric vehicle purchases and conversions to the availability of electric vehicle models

The number of exemptions and waivers from EPAct requirements are plotted against the number of alternative fuel stations in Figure 5. SAFP fleets can obtain exemptions from the EPAct requirements if they are not able to find AFV models that meet their needs or are not able to find refueling stations within a reasonable distance of where their vehicles operate. State fleets may also claim exemptions if purchasing AFVs would cause a significant financial hardship. Federal fleets may obtain exemptions if they are not able to find alternative fuel in their vicinity. Exemptions as a fraction of the total number of LD vehicle purchases (SAFP fleets) or LD vehicle inventory (federal fleets) have fallen over the last 10 years for both SAFP and federal fleets, which is a good indicator of significant improvement in the availability of AFV models and alternative fuels.

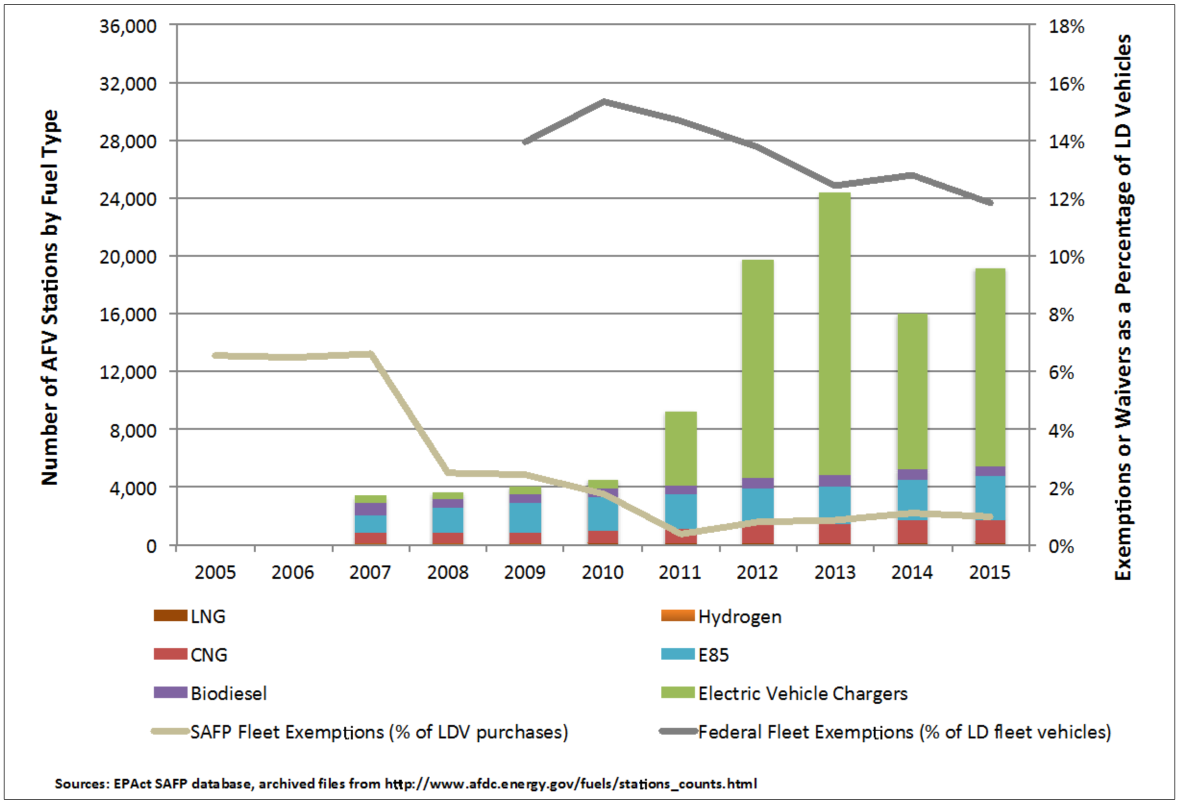

Figure 5. Number of EPAct State and Alternative Fuel Provider and Sustainable Federal Fleets program exemptions and number of alternative fuel stations

Total neat biodiesel (B100) purchased by SAFP Standard Compliance fleets and used in mixtures of 20% or greater in MHD vehicles is shown in Figure 4. SAFP fleets are able to use biodiesel in mixtures of at least 20% to meet up to half of their annual AFV-acquisition requirement. One credit, equivalent to the purchase of one AFV, is given for every 450 gallons of B100 used. Almost from the beginning of biodiesel's inclusion in the State and Alternative Fuel Provider Fleet program, SAFP fleets have been purchasing more biodiesel than they are able to get credit for. The fleets' commitment to using biodiesel has provided a reliable market for this fuel, especially in the early years as illustrated by the SAFP fleets' use as a percentage of the total domestic biodiesel production plotted on the right axis in Figure 6.

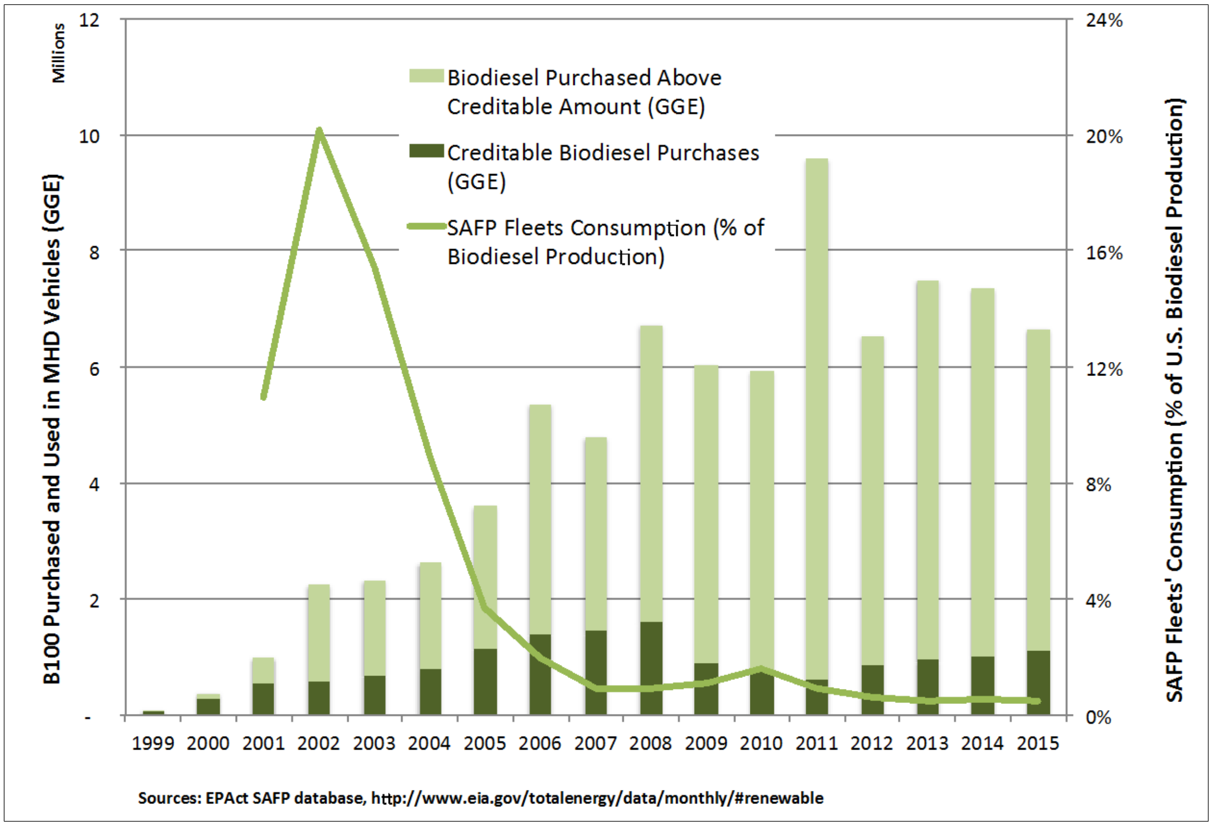

Figure 6. Total neat biodiesel purchased by state and alternative fuel provider fleets and used in mixtures of 20% or greater in medium- to heavy-duty vehicles

3.2 Greenhouse Gas Reductions Estimates

Use of alternative fuels, other than biodiesel, is not tracked for the SAFP fleets, and therefore estimates for these fleets are imprecise. However, interviews with several fleets helped to improve the estimates. Figure 7 shows the estimated yearly GHG savings, or avoided emissions for the federal and SAFP fleets. Biodiesel, which is used in MHD vehicles in mixtures of 20% biodiesel and 80% conventional diesel (B20) or greater, makes up a significant fraction of the emissions savings. This is due both to fleets' extensive use of biodiesel as discussed above as well as biodiesel's low WTW GHG emissions factor (6.3 lb CO_2eq/GGE). The emissions savings over the last 5 years are equivalent to taking more than 30,000 vehicles off the road each year.

Federal fleets do track their fuel use, and the percentage of total fuel use for federal fleets has improved over the last few years. This is due in part to increased outreach to the fleets and increased awareness by drivers (Daley, Nangle et al. 2014). This trend in fuel use and GHG reductions is expected to continue for federal fleets, particularly in the realm of electric vehicles, as federal fleets meet the mandates set forth in the 2015 Executive Order 13693, which sets specific EV acquisition and GHG emission reduction requirements.

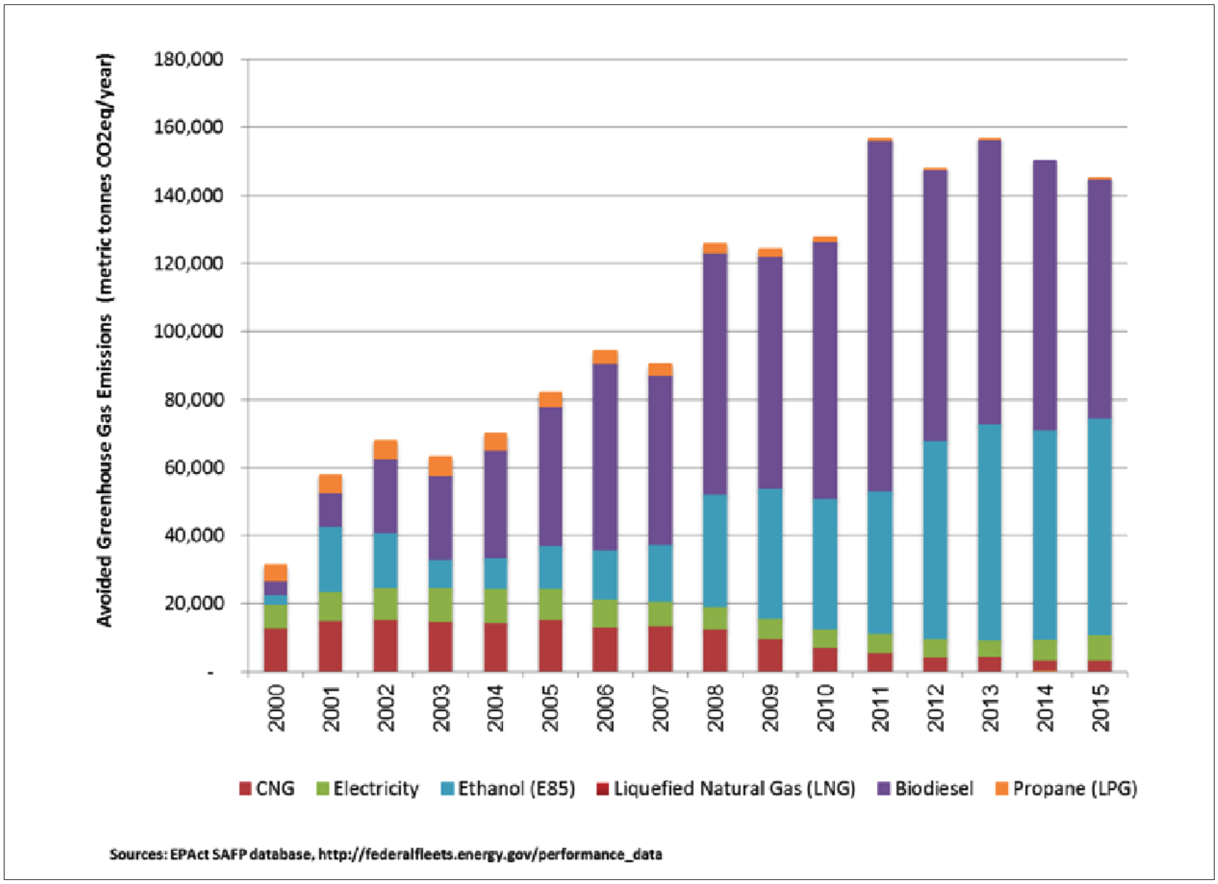

Figure 7. Avoided greenhouse gas emissions for state and alternative fuel provider and federal fleets

3.3 Jobs and Economic Impact

Table 4 summarizes the results obtained from the JEDI models for operation of ethanol and biodiesel production plants in comparison to operation of a typical large petroleum refinery. Although the petroleum refinery employs many more people than any of the other facilities (781 on-site employees in comparison to 10 (biodiesel) to 77 (cellulosic ethanol) for the biofuels facilities), the local and regional jobs and economic impact is much higher for the biofuels on a per GGE basis. The biofuels plants provide from 2 to 6 times the number of jobs and 2 to 5 times the total yearly economic benefit in comparison to the petroleum refinery. In total, the SAFP and federal fleets' use of ethanol and biodiesel directly and indirectly supported about 130 jobs and more than $20 million in economic activity each year.

Table 4. Jobs and Economic Impact of Alternative Fuels in Comparison to Petroleum Gasoline

Fuel	Total Jobs per GGE (multiple of jobs per GGE for gasoline or diesel)	Total Yearly Economic Benefit ($2015/Thousand GGE)	Total Yearly Economic Benefit (multiple of gasoline or diesel)
Ethanol	5.3	$750	4.2
Cellulosic Ethanol	5.9	$810	4.6
Biodiesel[a]	2.5	$500	2.1

[a] Compared to petroleum diesel fuel

3.4 Resilience

Figure 8 maps the locations and size (gasoline gallon equivalents/year) of refineries, ethanol plants, and biodiesel facilities in the lower 48 states. The size of the markers gives an indication of the plant capacities, although the refineries, shown in red, are orders of magnitude larger than the biodiesel and ethanol plants. There are 138 biodiesel plants relatively evenly distributed among 43 states, with an average capacity of about 7 million gallons per year. The 209 ethanol plants, with an average capacity of about 70 million gallons per year, are more concentrated in Iowa (41 plants), Nebraska (25 plants), Minnesota (22 plants), and other upper Midwestern states. There are ethanol plants in a total of 28 states, and the three states with the highest concentration of ethanol plants account for about 42% of the total capacity. There are petroleum refineries in 30 states. However, 30% of the refinery facilities and nearly 50% of the total capacity is concentrated in Texas and Louisiana.

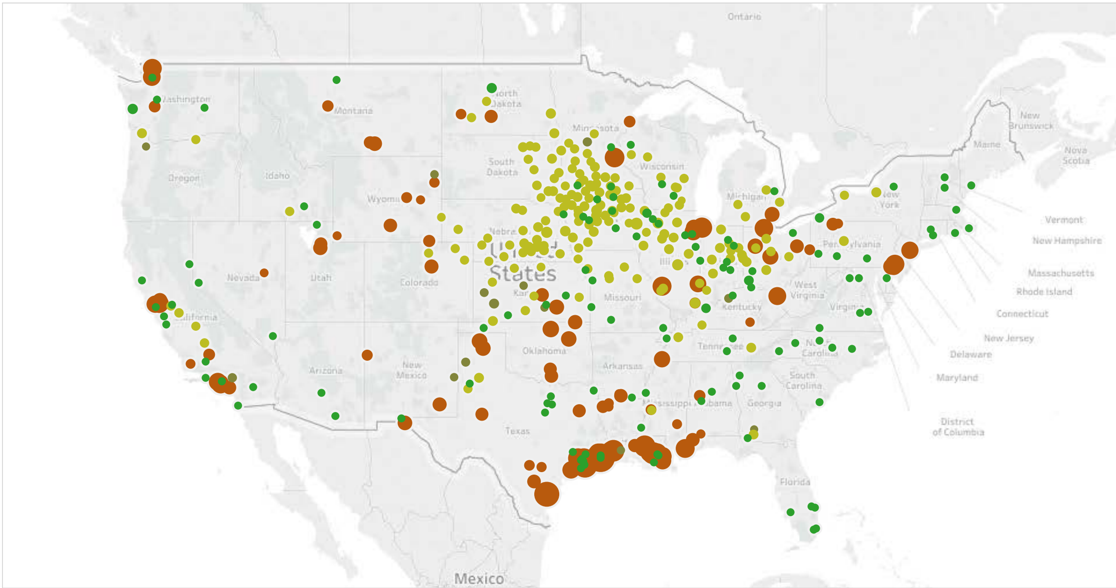

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Figure 8. Map of oil refineries, biodiesel plants, and ethanol plants in the continental United States

The tight clustering of refining capacity around the Gulf of Mexico makes the supply chain for conventional gasoline and diesel fuel especially vulnerable to disruption from hurricanes. Table 5 (adapted from (National Petroleum Council 2014)) lists the impacts to conventional fuel infrastructure from recent major storms.

Table 5. Impacts of Recent Storms (adapted from (National Petroleum Council 2014)

Event	Geographic Area	Energy Impacts
Superstorm Sandy, 2012	New York, New Jersey, Northeastern U.S.	• Extensive power outages in impacted areas • Local liquid fuel distribution interrupted • Natural gas distribution systems damaged • No impact to energy production systems; very limited impact to energy processing/refining complex
Hurricanes Gustav/Ike, 2008	Gustav – Louisiana Ike – Texas	• Extensive power outages in impacted areas • 14 refineries offline, primarily in Louisiana • Significant offshore oil and natural production shut-in but largely recovered within 12 weeks (12 weeks after Gustav, approximately 20% of production remained shut-in) • Hurricanes Gustav and Ike made landfall within two weeks of each other, increasing the impact across the energy producing and processing Gulf Coast
Hurricanes Katrina/Rita, 2005	Katrina – Louisiana Rita – Texas/Louisiana	• Extensive power outages in impacted areas • 27 refineries offline because of the combined impacts of both storms in Texas and Louisiana • Historic outage of oil and natural gas production from the Gulf of Mexico (12 weeks after Katrina, 90% of production remained shut-in) • Hurricane Rita made landfall 26 days after Hurricane Katrina, exacerbating the energy impact to the hub of natural gas processing and oil refining for the United States

The impact of these storms on oil production is illustrated in Figure 9.

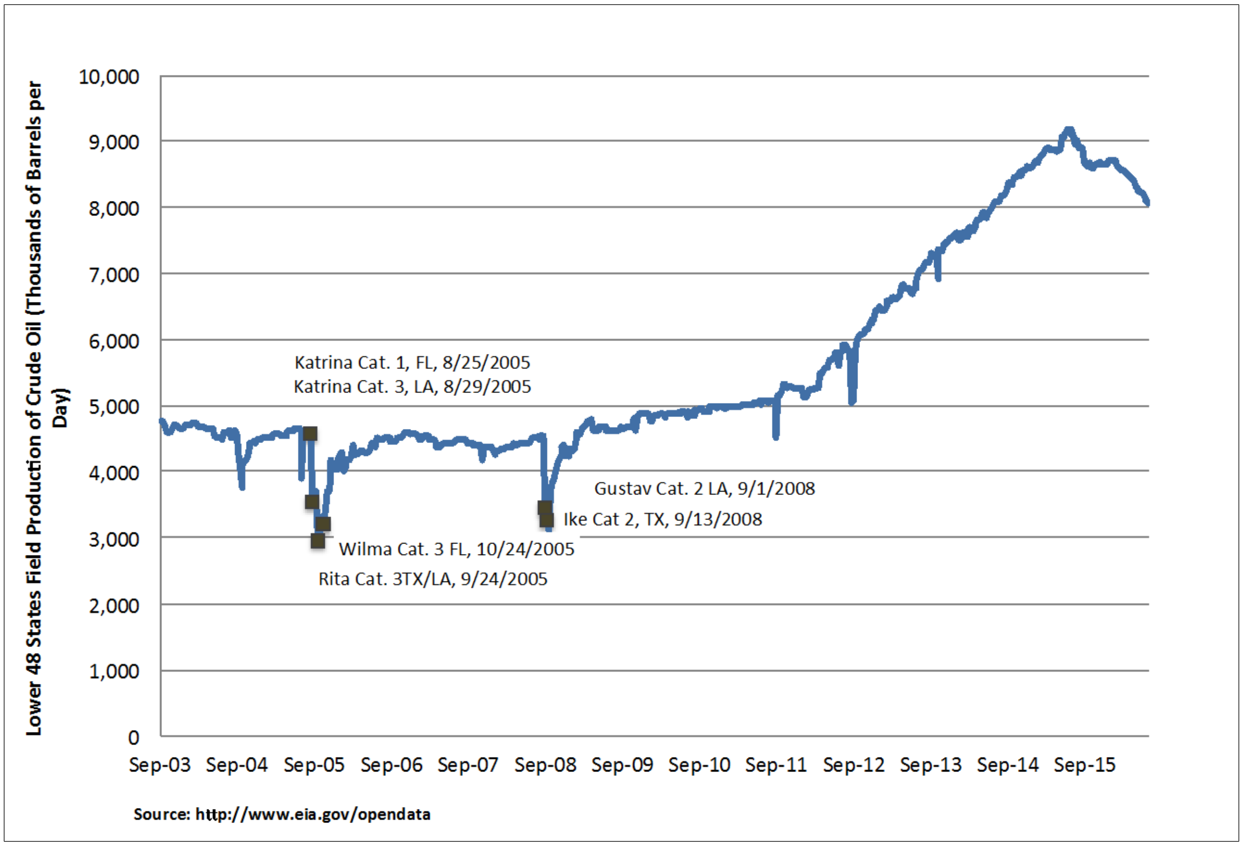

Figure 9. Impact of major storms on field production of crude oil in the lower 48 states

Ethanol and biodiesel plants are much less vulnerable to disruptions from short-term weather events because they are widely distributed and are, with a few exceptions, relatively small. However, biodiesel production (mostly from soybeans) and ethanol production (from corn) can be affected by longer-term weather and climate events as illustrated for ethanol in Figure 10.

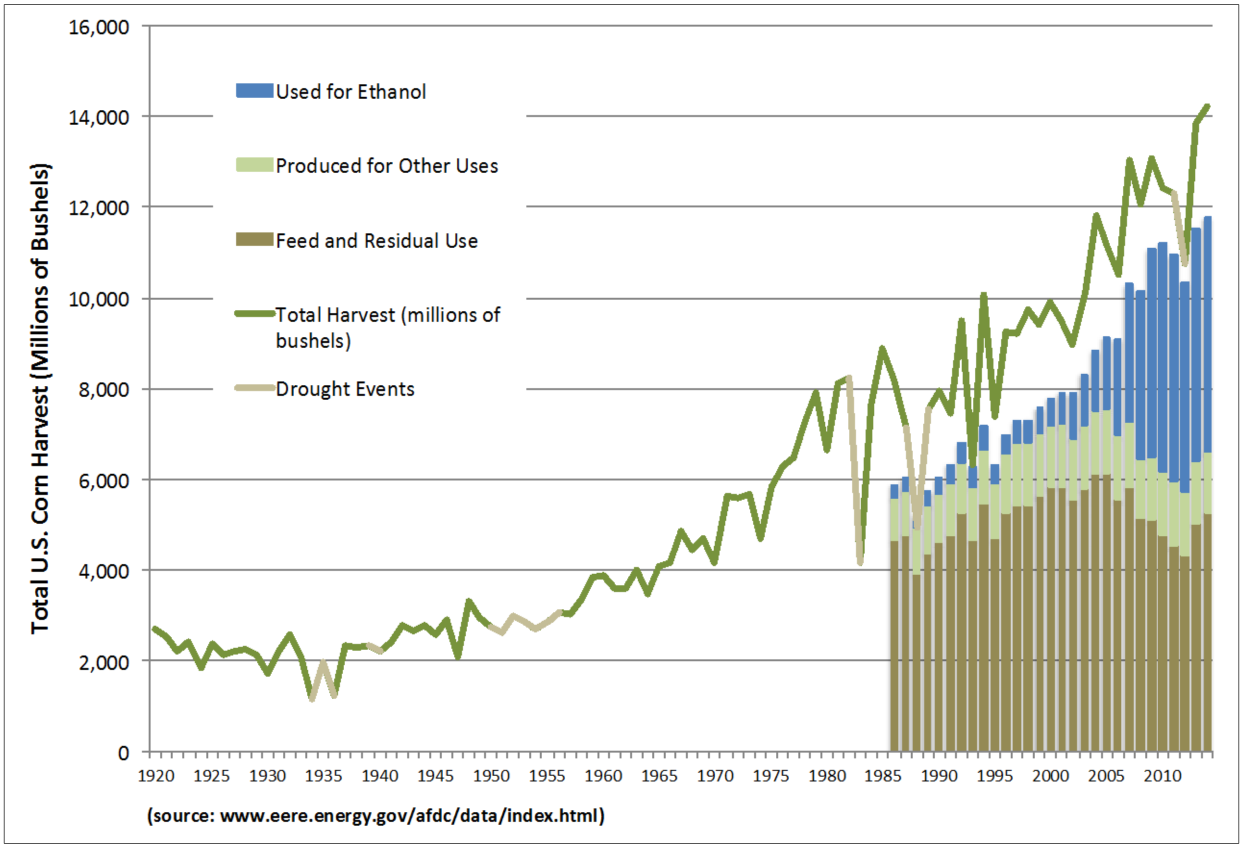

Figure 10. Major drought events and their impact on corn harvest and uses

DOE has long recognized the vulnerability of biofuels production to climate variability, and has actively sought alternative sources of feedstocks for the production of biofuels (Reed 2012). The primary replacements for corn being investigated are switchgrass, miscanthus, and corn stover (corn cobs). Research has focused on development of processes for converting these feedstocks to ethanol and evaluation of the environmental impacts of replacing corn with cellulosic materials that are either grown as bioenergy crops (switchgrass and miscanthus) or waste material (corn stover) (Sheehan 2002, Wu, Mintz et al. 2012, Dunn, Mueller et al. 2013). A 30-million-gallon-per-year cellulosic ethanol plant, the largest to date, was opened by DuPont in Nevada, Iowa in October 2015 (DOE 2015).

3.5 Summary

The three EPAct alternative fuel programs, Sustainable Federal Fleets, State and Alternative Fuel Provider Fleet, and Clean Cities, have provided a reliable early market for both alternative fuels and AFVs. As alternative fuel deployment and the number of AFV model offerings has increased over the years, the federal and SAFP fleets have purchased and used these vehicles and fuels. The SAFP fleets' switch from converting vehicles to use CNG, propane, and electricity to purchasing vehicles offered by OEMs (see Figures 3 and 4) and the dramatic decrease in the number of exemptions and waivers granted to SAFP and federal fleets over the course of the programs (see Figure 5) are strong indicators that the EPAct requirements helped to create and increase the market for AFVs and alternative fuels. There is anecdotal evidence that the State and Alternative Fuel Provider Fleet program helped biodiesel plants gain first a toe- and then a foothold as a national industry, as SAFP fleets can earn half of their credits for biodiesel use, and have far exceeded the creditable amount in many cases.

Although the fleets represent a small segment of the overall vehicle and fuel market, in local areas they can nonetheless serve as anchors that can catalyze markets for AFVs and alternative fuels. The approach taken in the Clean Cities program has been especially effective in developing local and regional hubs that serve as test beds for OEMs and alternative fuel providers to become established. The fleets represent significant opportunities and can serve as partners with the non-governmental sector to help establish a demand for fuels, vehicles, and technologies. Utilities, which make up many of the SAFP fleets, are looking for opportunities to expand their markets and have indicated not only a willingness but also a desire to help build out electric vehicle charging infrastructure to support fleets' deployment of PHEVs.

SAFP and federal fleets have used alternative fuel in their AFVs and have reduced GHG emissions by replacing gasoline and diesel fuel. The emissions savings for these fleets over the last 5 years are equivalent to taking more than 30,000 vehicles off the road each year. Federal fleets have increased their alternative fuel use over the last few years. This is due in part to increased outreach to the fleets and increased awareness by drivers. Greater availability of alternative fuel has also played a role in improved compliance by drivers. Additional new requirements for federal fleets set forth in the 2015 Executive Order 13693 will also lead to mandated increases in the deployment of EVs and decreases in GHG emissions, and are expected to lead to regional expansions of infrastructure necessary to support EVs.

The ethanol and biodiesel fuel use by SAFP and federal fleets has also directly and indirectly supported about 130 jobs and more than $20 million in economic activity annually. The jobs and benefits to the economy are distributed over a number of sectors of the economy, including farmers, employees of production facilities, and the communities they live in. The relatively large number of small biofuel facilities and their geographic distribution also makes the supply chain for biofuels less vulnerable to disruptions from short-term weather events. The long-term vulnerabilities of biofuels supply chains have been aggressively addressed by the DOE and other government and private partners, resulting in the opening of a 30-million-gallon-per-year cellulosic ethanol plant in 2015.

Appendix

U.S. fleet average fuel economy values from 1970 to 2013 for LD and MHD vehicles (Davis, Diegel et al. 2015) were used in combination with fuel economy multipliers for AFVs from the AFLEET model (ANL 2016) to derive estimated fuel economy values for vehicles of each type in each year. Excerpts from the base tables and final fuel economy values are shown in Tables A1 through A3.

GHG emissions factors from the AFLEET tool were converted from units of g/Btu of fuel to lb/GGE using the lower heating value of fuels (also listed in the AFLEET tool). Table A4 lists the final derived values used in this analysis.

Table A1. Summary Statistics for Light-Duty Vehicles (excerpted from (Davis, Diegel et al. 2015))

Table 4.1

Summary Statistics for Cars, 1970–2013

Year	Fuel economy (miles per gallon)
1970	13.5
1971	13.5
1972	13.5
1973	13.4
1974	13.6
1975	13.9
1976	13.8
1977	14.0
1978	14.2
1979	14.5
1980	15.9
1981	16.4
1982	16.8
1983	17.0
1984	17.4
1985[c]	17.4
1986	17.4
1987	18.0
1988	18.7
1989	19.0
1990	20.2
1991	21.1
1992	21.0
1993	20.5
1994	20.7
1995	21.1
1996	21.2
1997	21.5
1998	21.6
1999	21.4
2000	21.9
2001	22.1
2002	22.0
2003	22.4
2004	22.5
2005	22.1
2006	22.5
2007	22.5
2008	22.6
2009	23.5
2010	24.0
2011	24.4
2012	24.9
2013	25.2

Table 4.2

Summary Statistics for Two-Axle, Four-Tire Trucks, 1970–2013

Year	Fuel economy (miles per gallon)
1970	10.0
1971	10.2
1972	10.3
1973	10.5
1974	11.0
1975	10.5
1976	10.8
1977	11.2
1978	11.6
1979	11.9
1980	12.2
1981	12.5
1982	13.5
1983	13.7
1984	14.0
1985[a]	14.3
1986	14.6
1987	14.9
1988	15.4
1989	16.1
1990	16.1
1991	17.0
1992	17.3
1993	17.4
1994	17.3
1995	17.3
1996	17.2
1997	17.2
1998	17.2
1999	17.0
2000	17.4
2001	17.6
2002	17.5
2003	16.2
2004	16.2
2005	17.7
2006	17.8
2007	18.0
2008	18.1
2009	17.3
2010	17.8
2011	18.1
2012	18.5
2013	18.8

Table A2. Fuel Economy Multipliers for Alternative Fuels (derived from (ANL 2016)

Fuel	Fuel Economy Multiplier
Compressed Natural Gas (CNG)	0.95
Diesel	1.20
Electricity	3.30
Ethanol (E85)	1.00
Gasoline	1.00
Liquefied Natural Gas (LNG)	0.95
M85	–
Other Bioderived Fuels	1.20
Petroleum Liquids	
Propane (LPG)	1.00
Hydrogen	–
Gasoline HEV	1.40
Gasoline PHEV	1.49

Table A3. Harmonized Fuel Economy Values for State and Alternative Fuel Provider Light-Duty Vehicles (in miles per gallon)[a]

Year	*Harmonized FE for SFP LD Fleet*	*Diesel*	*Electricity*	*Ethanol (E85)*	*Gasoline*	*Gasoline HEV*	*Gasoline PHEV*	*Liquefied Natural Gas (LNG)*	*Other Bioderived Fuels*	*Propane (LPG)*
1970	11.36	13.6	37.5	11.4	11.4	15.9	16.9	10.8	13.6	11.4
1971	11.50	13.8	37.9	11.5	11.5	16.1	17.1	10.9	13.8	11.5
1972	11.56	13.9	38.2	11.6	11.6	16.2	17.2	11.0	13.9	11.6
1973	11.66	14.0	38.5	11.7	11.7	16.3	17.4	11.1	14.0	11.7
1974	12.06	14.5	39.8	12.1	12.1	16.9	18.0	11.5	14.5	12.1
1975	11.83	14.2	39.1	11.8	11.8	16.6	17.6	11.2	14.2	11.8
1976	11.99	14.4	39.6	12.0	12.0	16.8	17.9	11.4	14.4	12.0
1977	12.35	14.8	40.8	12.3	12.3	17.3	18.4	11.7	14.8	12.3
1978	12.68	15.2	41.8	12.7	12.7	17.7	18.9	12.0	15.2	12.7
1979	12.99	15.6	42.9	13.0	13.0	18.2	19.4	12.3	15.6	13.0
1980	13.67	16.4	45.1	13.7	13.7	19.1	20.4	13.0	16.4	13.7
1981	14.04	16.8	46.3	14.0	14.0	19.7	20.9	13.3	16.8	14.0
1982	14.84	17.8	49.0	14.8	14.8	20.8	22.1	14.1	17.8	14.8
1983	15.05	18.1	49.7	15.0	15.0	21.1	22.4	14.3	18.1	15.0
1984	15.39	18.5	50.8	15.4	15.4	21.5	22.9	14.6	18.5	15.4
1985	15.58	18.7	51.4	15.6	15.6	21.8	23.2	14.8	18.7	15.6
1986	15.77	18.9	52.0	15.8	15.8	22.1	23.5	15.0	18.9	15.8
1987	16.19	19.4	53.4	16.2	16.2	22.7	24.1	15.4	19.4	16.2
1988	16.76	20.1	55.3	16.8	16.8	23.5	25.0	15.9	20.1	16.8
1989	17.32	20.8	57.2	17.3	17.3	24.2	25.8	16.5	20.8	17.3
1990	17.76	21.3	58.6	17.8	17.8	24.9	26.5	16.9	21.3	17.8
1991	18.67	22.4	61.6	18.7	18.7	26.1	27.8	17.7	22.4	18.7
1992	18.83	22.6	62.1	18.8	18.8	26.4	28.1	17.9	22.6	18.8
1993	18.70	22.4	61.7	18.7	18.7	26.2	27.9	17.8	22.4	18.7
1994	18.72	22.5	61.8	18.7	18.7	26.2	27.9	17.8	22.5	18.7
1995	18.87	22.6	62.3	18.9	18.9	26.4	28.1	17.9	22.6	18.9
1996	18.84	22.6	62.2	18.8	18.8	26.4	28.1	17.9	22.6	18.8
1997	18.95	22.7	62.5	18.9	18.9	26.5	28.2	18.0	22.7	18.9
1998	18.98	22.8	62.6	19.0	19.0	26.6	28.3	18.0	22.8	19.0
1999	18.78	22.5	62.0	18.8	18.8	26.3	28.0	17.8	22.5	18.8
2000	19.22	23.1	63.4	19.2	19.2	26.9	28.6	18.3	23.1	19.2
2001	19.42	23.3	64.1	19.4	19.4	27.2	28.9	18.5	23.3	19.4
2002	19.32	23.2	63.8	19.3	19.3	27.1	28.8	18.4	23.2	19.3
2003	18.57	22.3	61.3	18.6	18.6	26.0	27.7	17.6	22.3	18.6
2004	18.60	22.3	61.4	18.6	18.6	26.0	27.7	17.7	22.3	18.6
2005	19.49	23.4	64.3	19.5	19.5	27.3	29.0	18.5	23.4	19.5
2006	19.70	23.6	65.0	19.7	19.7	27.6	29.3	18.7	23.6	19.7
2007	19.83	23.8	65.4	19.8	19.8	27.8	29.5	18.8	23.8	19.8
2008	19.93	23.9	65.8	19.9	19.9	27.9	29.7	18.9	23.9	19.9
2009	19.70	23.6	65.0	19.7	19.7	27.6	29.3	18.7	23.6	19.7
2010	20.21	24.2	66.7	20.2	20.2	28.3	30.1	19.2	24.2	20.2
2011	20.55	24.7	67.8	20.5	20.5	28.8	30.6	19.5	24.7	20.5
2012	20.99	25.2	69.3	21.0	21.0	29.4	31.3	19.9	25.2	21.0
2013	21.29	25.6	70.3	21.3	21.3	29.8	31.7	20.2	25.6	21.3
2014	21.29	25.6	70.3	21.3	21.3	29.8	31.7	20.2	25.6	21.3
2015	21.29	25.6	70.3	21.3	21.3	29.8	31.7	20.2	25.6	21.3
2016	21.29	25.6	70.3	21.3	21.3	29.8	31.7	20.2	25.6	21.3

[a] Weighted by the ratio of LD trucks to LD autos in SAFP fleets

Table A4. GHG Emissions Factors Used in this Study

Fuel	WTW GHG (lb CO_2eq/GGE)
Gasoline	23.5
Gasoline HEV	23.5
Diesel	23.8
Diesel HEV	23.8
Other Bioderived Fuels	6.3
Ethanol (E85)	17.3
Compressed Natural Gas (CNG)	19.9
Liquefied Natural Gas (LNG)	19.6
Propane (LPG)	20.7
Electricity	44.4
Hydrogen	30.2

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