Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2007-02

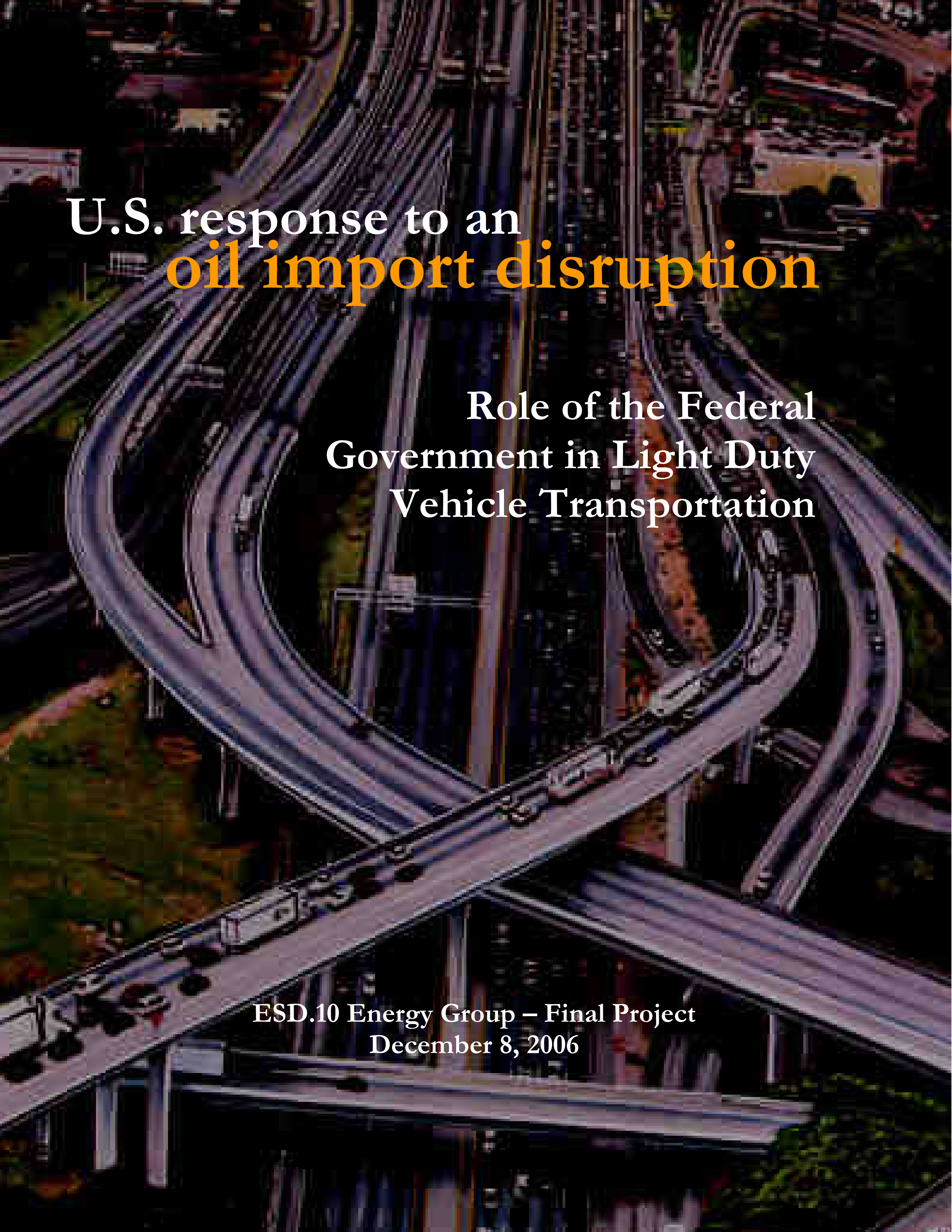
U.S. RESPONSE TO AN OIL IMPORT DISRUPTION ROLE OF THE FEDERAL GOVERNMENT IN LIGHT DUTY VEHICLE TRANSPORTATION

Final Report – ESD.10 Energy Group

Kyle Frazier
Romain Lacombe
Dai Ohama
Faaiza Rashid
Monica Rush

Massachusetts Institute of Technology
Technology and Policy Program

January 2007



U.S. response to an oil import disruption

Role of the Federal Government in Light Duty Vehicle Transportation

ESD.10 Energy Group – Final Project
December 8, 2006

U.S. Response to an Oil Import Disruption

Role of the Federal Government in Light Duty Vehicle Transportation

ESD.10 – Introduction to Technology & Policy
Professor Annalisa Weigel
End-term project – Energy Committee

Acknowledgement and Preface

This study was motivated by concerns about the current geopolitical tensions in the Middle East, especially standoff between Iran and the United States over Iran's pursuit of a nuclear program that some analysts think could potentially be used for military purposes. Should this conflict escalate beyond rhetoric to open hostilities, including military operations, the effect on the world supply of oil could be quite dramatic. While the United States does not import oil directly from Iran because of an embargo, Iran possesses the power to severely disrupt oil shipments in the Persian Gulf, and global oil markets are so deeply integrated that a major curtailment of oil supply from the Persian Gulf region would inevitably lead to a major disruption of U. S. oil imports.

This report is intended to summarize the technical and policy options available to the United States to mitigate the effects of such an event within the light duty vehicle transportation sector, which consumes more imported oil than any other segment of the American economy. While an oil disruption scenario is presented, it is used only to provide general framing for the consideration of options. Quantitative relationships between disruption size and specific responses would require rigorous economic modeling and are outside the scope of this study.

In addition to accounting for well over 40 percent of U.S. oil consumption in 2005, the light duty vehicle transportation sector has a strong symbolic importance in American culture; the freedom to drive is widely seen as a symbol of individual liberty in the United States. Thus, the topic provides ample opportunities to explore the interactions between public and private interests and among technical options, social policies, economics, and politics.

We are deeply thankful to the faculty of Engineering Systems Division Course 10: Introduction to Technology and Policy, especially to Professor Annalisa Weigel and Professor Daniel Roos for their advice during the preparation of this report. We are also appreciative of the guidance provided by Dr. Richard Rowberg of the National Research Council, from whom the theme of this report originated. We

Opinions expressed in this report are the responsibility of the authors alone and do not necessarily represent the opinions, views, or policies of the Massachusetts Institute of Technology, the National Research Council, or any other individual or institution quoted herein.

The authors:

Kyle Frazier
Romain Lacombe
Dai Ohama
Faaiza Rashid
Monica Rush

Content

Cover picture courtesy of L.J. Lindhurst © 2005

Executive Summary

This report analyzes technological and policy options for the U.S. federal government response within the light duty vehicle (LDV) sector in the event of a 5 year sustained U.S. oil import curtailment of 5 MMB/D and a global supply disruption of roughly 18 MMB/D. The cause of the oil disruption is damage to the oil production infrastructure in the Middle East; therefore, it is public knowledge that the disruption will be sustained.

LDV transportation was chosen as the scope of this report's policy analysis since it accounts for over 42 percent of total U.S. petroleum products. Within LDV transportation sector, three main avenues of action namely vehicle efficiency, alternative fuels and efficient use of vehicles were examined for policy options. The first two avenues are technological and the third is behavioral in impact. Since the options are numerous within each of these avenues, a policy decision analysis was performed to scope the policy options to ones that were pertinent to government intervention and the 5 year disruption time horizon.

Within fuel efficiency of vehicles there is not a strong case for government intervention primarily because irrespective of the oil disruption, manufacturers will continue to make efficiency gains. In the event of an oil supply disruption, savings could be achieved using a combination of more stringent CAFE standards and market forces to encourage continued development and adoption of fuel saving technologies. These incentives could be put in place within one year after start of the disruption, allowing results within the five-year time frame.

Key findings of the report show that within alternative fuels there is a case for government intervention. In alternative fuels the largest barrier to commercialization is lack of critical mass and lack of infrastructure—a problem often known as the chicken and the egg dilemma. Government can play a key role post oil disruption to target investment in alternative fuels to begin to solve the chicken and the egg dilemma. Other barriers to alternative fuels are related with cost; however, in the case of a disruption these barriers will cease to be major barriers due to the rise in prices of gasoline.

A third area of oil consumption reduction in the light duty vehicle sector is through vehicle usage efficiency. This includes a consideration of public transportation, high occupancy vehicle use, speed limits and vehicle turnover rate. This report finds that in the context of the disruption there is a case for government action in each of these areas.

The overall timeline of policy implementation has regulations being made within the first year after the disruption in each of the three areas. However, no substantial gains will be seen in either alternative fuels, vehicle fuel efficiency and public transportation until the third year and after wards. Leading up to the third year, there could be government action in vehicle usage efficiency, specifically speed limits, HOV policies as well as in employing E85 in the flex-fuel vehicles that are already part of the vehicle fleet.

The policy options considered within this report aim to generate an implementation momentum rather than simply cause short-term behavior changes in stakeholders due to unsustainable cost-incentives. This report does not seek to recommend certain policies over others, instead it is meant as a portfolio of policy tools that could be employed in the context of the disruption scenario and could be used as a framework for policy analysis at a level other than the federal government.

Report Road Map

Chapter 1 – Background: highlights the historical and contemporary context that motivates this report. The 1973 oil embargo, 1979 Iranian hostage crisis, 1991 Gulf War, 2005 Hurricane Katrina all resulted in oil supply disruptions in the U.S. In light of current tensions in the Middle East and Iranian aspirations for nuclear weapons, this report develops a set of policy options for the federal government in the event of a 5 year, sustained oil supply disruption. The chapter then relates previous work on the subject by the Office of Technological Assessment (OTA) and outlines the novel contributions of this report. It poses the research question of the project, defines the project bounds and outlines the methodology that was used to answer the research question.

Chapter 2 – U.S. Transportation Sector: Reliance on Oil Imports: establishes how oil supply and consumption patterns in the U.S. lead to the scope and research question of this report. It successively disaggregates the demand for petroleum products and the demand for transport, exposes why LDV transportation has the highest potential of impact for curtailment alleviation among all end-uses. The chapter then identifies three main avenues for action within LDV.

Chapter 3 – Vehicle Fleet Efficiency: This chapter evaluates options for the federal government to achieve oil savings through increasing vehicle fleet efficiency. It first assesses the status of current technological options and then discusses the barriers to growth. Based on the effect of oil disruption on stakeholders and these barriers, policy options are developed for the federal government. This chapter concluded that the likely role of the federal government would be to push the industry toward adoption of fuel saving technologies.

Chapter 4 – Alternative Fuels: evaluates options for the federal government to target its response within the alternative fuels sector to overcome barriers that arise from technology development, multiple stakeholders, and economic feasibility. The chapter highlights the historical context that spurred the growth of alternative fuel vehicles in the U.S. A dynamic analysis of stakeholders is followed by identification of barriers to the growth of alternative fuels. Based on the effect of oil disruption on stakeholders and the barriers to growth policy options are developed for the federal government. The federal government could help alternative fuel technologies reach critical mass and sustainable commercialization.

Chapter 5 – Efficient Use of Vehicles: evaluates the options for reducing oil consumption through increasing the efficiency of vehicle usage. Four main objectives are considered: high occupancy vehicle use, public transportation, speed limit adjustments and increasing the vehicle turnover rate. Through a stakeholder and implementation issues analysis, this section concludes that there is a justification for federal government action in these four areas in the context of the oil disruption scenario.

Conclusion: the conclusion synthesizes the key findings of chapter 3, 4 and 5 to develop a cumulative implementation timeline.

Chapter 1
Background

This chapter includes historical and contemporary context relevant to this report. The 1973 oil embargo, 1979 Iranian hostage crisis, 1991 Gulf War, and 2005 Hurricane Katrina all resulted in oil supply disruptions in the U.S. In light of current tensions in the Middle East and Iranian aspirations for nuclear weapons, this report examines a set of reactive policy options for the federal government in the event of a 5 year, large-scale, sustained oil supply disruption. It identifies previous work on the subject by the Office of Technological Assessment (OTA) and outlines the novel contributions of this report. Finally, this chapter poses the research question of the project, defines the project boundaries and outlines the methodology that was used to evaluate potential courses of government action.

1.1 Motivation

This chapter includes historical and contemporary context relevant to this report. The 1973 oil embargo, 1979 Iranian hostage crisis, 1991 Gulf War, and 2005 Hurricane Katrina all resulted in oil supply disruptions in the U.S. Table 1-1 shows the scale, duration, and oil price variation due to the three aforementioned global oil supply disruptions.

Event	Global oil disruption	Duration of disruption	World oil consumption	Share of world oil consumption	Oil price variation
1973 Oil Embargo	1.6 MMB/D	5 Months	58.2 MMB/D	2.7 %	+ 276 %
1979 Iranian Hostage Crisis	3.7 MMB/D	6 Months	65.1 MMB/D	5.7 %	+ 82 %
1991 Gulf War Crisis	4.9 MMB/D	7 Months	60.2 MMB/D	8.1 %	+ 130 %

Table 1-1: Major global oil supply disruptions[1]

In light of current tensions in the Middle East and Iranian aspirations for nuclear weapons, a possibility of a major oil supply disruption again becomes probable. Though the U.S. has banned oil imports from Iran since the 1979 Iranian revolution, there are specific concerns that a U.S. military action against Iran might result in a significant disruption of the global oil supply leading to domestic oil shortages and price hikes. Because oil use is omnipresent in the American economy and way of life, the dependence on the global market for petroleum has been and continues to be an area of concern for the U.S.

[1] Table adapted from: (OTA, 1991)

Historic events of oil disruption and the current geopolitical atmosphere in the Middle East motivate this report to develop a set of policy options for the federal government in the event of a severe oil disruption due to oil production infrastructure damage in the Middle East. The oil disruption is assumed to be a sustained 5 year curtailment of 5 MMB/D of U.S. oil imports, stemming from a global oil supply disruption of unprecedented scale (approximately 18 MMB/D, to be compared with the world production of 80 MMB/D). Since the cause of the disruption is assumed to be a large scale destruction of oil production infrastructure in the Middle East, the long duration of the disruption is known shortly after the outbreak of hostilities.

1.2 Previous Work

In 1984, Congress of the United States, Office of Technology Assessment (OTA) examined U.S. potential to cope with sustained disruptions in oil supply. The reports assessed the technologies that could counter a curtailment of 3 MMB/D in U.S. oil supply over a 5-year period. In 1991, OTA updated the report in light of the evolving world oil market and geopolitical factors in the oil supplying nations (OTA, 1991).

The purpose of these reports was not to examine and propose emergency responses to oil shocks like the drawdown of the Strategic Petroleum Reserve (SPR) and private oil stockpiles. Rather, the effort focused on long term development of energy technologies to replace curtailed oil. The reports were in the meantime an assessment of the cost effectiveness of various short-term solutions, and their emphasis was on the assessment of the impact of the disruption on the U.S. economy, including only minimal development of policy tools and strategies.

Since 1991, significant changes have occurred in terms of technological capabilities and political environment. As a result, Dr. Richard Rowberg from the National Research Council (NRC) suggested that Massachusetts Institute of Technology's "Technology and Policy Energy Team" could build upon the 1984 and 1991 OTA reports and develop a project with specific focus on the policy options for the federal government in the event of a major oil disruption.

1.3 Research question

A global oil disruption equating to a U.S. oil import curtailment of 5 MMB/D raises a breadth of issues in the arena of policy making. Many issues are relevant for the researchers to tackle when framing a response to an oil import shortfall, and several levels of analysis are valid, specifically in the U.S. where disparities among States drastically alter the point of view of the regional policy makers vis-à-vis the federal government. A single report, with its specific hypothesis and objectives, cannot do justice to all the legitimate points of view embedded in such a broad issue. Moreover, devising high impact policy options requires a concentration of inducement means along a few selected options.

The research question addresses two concerns. The first is the breadth of applicability of the policy tools and options it develops. Therefore, the policies are formulated at the broadest level, providing federal policy makers with tools to address nation-wide issues. The second concern is the potential of impact of the policies. Chapter 2, which provides an overview of oil in the U.S. economy, shows that the bulk of oil consumption, and the largest stand-alone end-use of petroleum products, is light duty vehicle transportation (LDV). Figure 1-1 shows the process that leads to the elimination of supply-side ramp-up and other end-uses of oil products, and the focus on LDVs as the sector where concentrated federal policies could create the maximal impact to mitigate the curtailment.

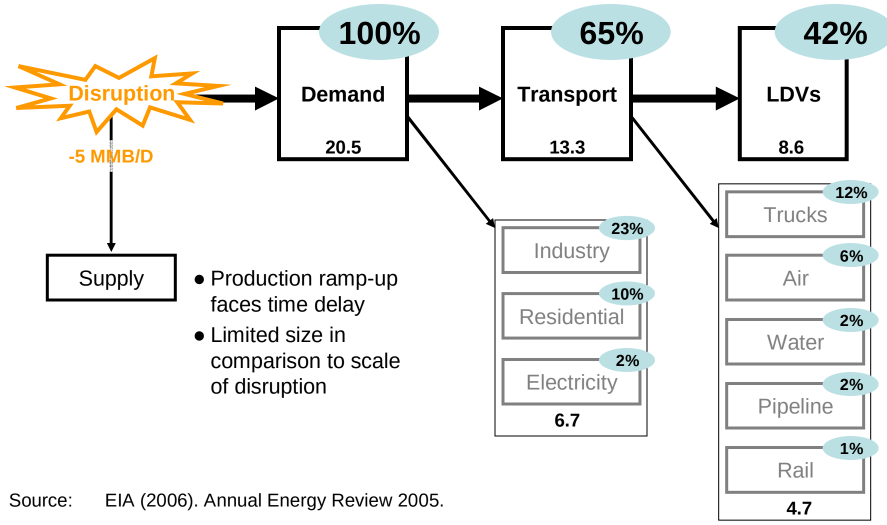


Figure 1-1: Impact-driven focus of project leads to target light duty vehicles transportation

Based on this rationale, the scope of this report was defined by the following research question:

> **Project research question:**
> Within light duty vehicle transport, how would the federal government respond to a severe oil import disruption?

1.4 Methodology

The objective of the report is hence not only to assess technological and political options, but to qualitatively assess their potential impact in terms of oil savings and implementation time frame, as a tool allowing policy-makers to pursue their objectives. This raised the need to focus this report on a limited set of measures and technologies relevant at the federal level, with which the policy makers could fine tune their response to the curtailment.

The goal of the senior federal policy-makers involved in the decision process in the context of an oil disruption would be first and foremost to secure the U.S. against the adverse effects of the import shortfall by achieving a right balance between efficiency and equity among the various stakeholders. The case for government intervention in the markets for transport in such a context is moreover to seek an inter-temporal balance between two public mandates: spending economic and political resources to alleviate the crisis in the short term and pushing the industry and the consumers toward long term sustainable change.

The objective of this report is to build a portfolio of technology and policy options: broad enough so that they address federally-relevant issues, with sufficient flexibility for its users to adapt them to evolving contingencies, but focused and powerful enough so policymakers can achieve maximum impact.

Figure 1-2 outlines the frameworks developed in Massachusetts Institute of Technology's Engineering Systems Division Course, "Introduction to Technology and Policy" (Annalisa Weigel, 2006). This framework was applied to run a decision analysis on the technological and policy options in light duty vehicle transport in order to let emerge the most valuable options in terms of expected oil savings impact, time frame of implementation, and value for the policy-makers.

The avenues of action were selected from transportation policies and technologies based on a top-down assessment of their potential impact. For each specific option, an analysis of its current status, power structure among the stakeholders and the technology and policy barriers to growth was performed. An assessment of the expected modification of these barriers under the effect of the disruption window was used to screen the options where potential significant impact linked with need for nation-wide push made the case for government intervention. Through this decision analysis three avenues of policy action were identified: improvement in vehicle fleet efficiency, development of alternative fuels, and efficient usage of vehicles.

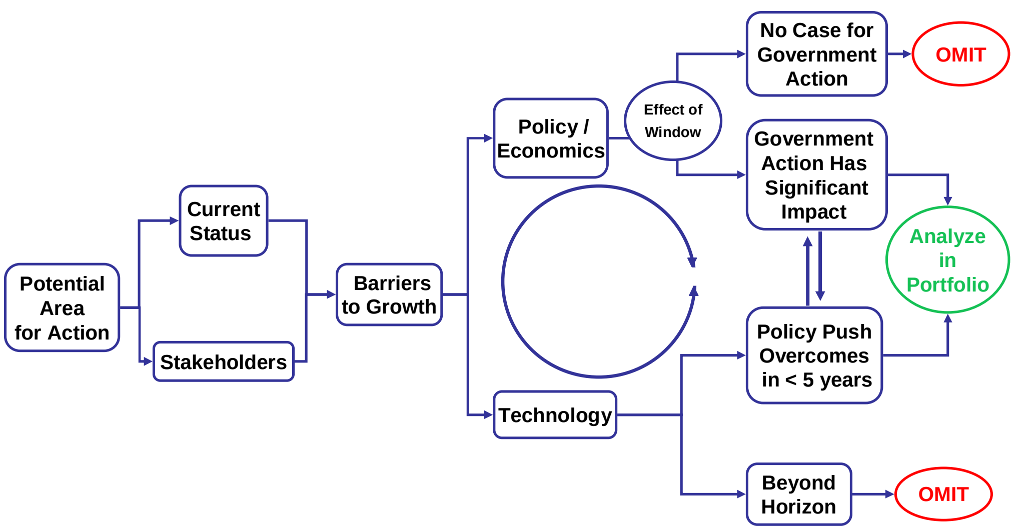


Figure 1-2: Decision tree to build our portfolio of options

1.5 Project Boundaries

To understand the boundaries of the scope, the project identifies what lies outside of them. Specifically, this project is not a survey of an emergency response in the immediate aftermath of the oil supply disruption. Therefore it does not discuss the Strategic Petroleum Reserve (SPR).

This project also does not include technologies that will mature beyond the five year time horizon. It is not a laundry-list addressed to the policy-makers, detailing the cost-benefit assessments of various unrelated technologies. Cost estimates in the case of an oil disruption of such an unprecedented scale are difficult to quantify with any realistic value. The project, therefore, assesses the quality of various technology and policy options in terms of value for policy-makers seeking balanced policy strategies, and equips them with tools such as the decision analysis framework that will allow them to generate policy options at any level of analysis. Lastly, the report is not a set of preemptive measures, but rather a post crisis response.

Within the project boundaries lies a set of short to medium term reactive measures and long term sustainable policy options. The report is grounded in cost effective options and technologies available today, or near-term.

1.6 Novel Contributions

The added value of this report is that it advocates neither a pure "technology policy" aiming at developing a set of technologies picked for their resonance, neither a "policy technology" approach where a single technology (Intelligent Traffic System, or transport demand management) would be deployed to pursue political goals. This report instead develops a portfolio of policy options for federal policy-makers handed along with a decision analysis framework that can be applied to any level of implementation. In contrast to the 1984 and 1991 OTA reports, this report embeds technological choices in political decision options. Additionally, it applies non-quantitative methods to screen options that are the most efficient and valuable for policy makers. Further, it develops an implementation timeline post oil disruption, and develops a value balance between efficiency and equity across the three avenues of action in order to enhance the overall goal of achieving U.S. security.

Chapter 2
U.S. Transportation Sector: Reliance on Oil Imports

This chapter aims at establishing how oil supply and consumption patterns in the U.S. lead to the scope and research question of this report. It successively disaggregates the demand for petroleum products and the demand for transport, exposes why LDV transportation has the highest potential of impact for curtailment alleviation among all end-uses. The chapter then identifies three main avenues for action within LDV.

2.1 Introduction

The objective of this chapter is to set the stage of the project through background information about U.S. oil production and consumption. More specifically, this chapter will establish how oil supply and consumption patterns in the U.S. lead to the scope and research question of this report.

Research question:
How oil supply and consumption patterns in the U.S. lead to the scope and research question of this report?

The first section of the chapter shows the limited use of supply-side options for import shortfall mitigation in the wake of the disruption, and the vulnerability of the U.S. economy to an oil disruption. By disaggregating the demand for crude oil and petroleum products, the second section shows the potential for effective and focused actions in the transportation sector, as it is the major petroleum product end-use sector. Figure 2-1 details the process of development of the project scope, based on the differences in relative importance of each type of oil end-usage sector.

The third section of this chapter finally shows how cars and light trucks used for passenger transportation purpose stand out among other transportation modes in terms of share of overall petroleum products consumption, and how this leads to further scoping of the report to light duty vehicles (LDVs) transportation. The section then identifies three main avenues for action within LDV.

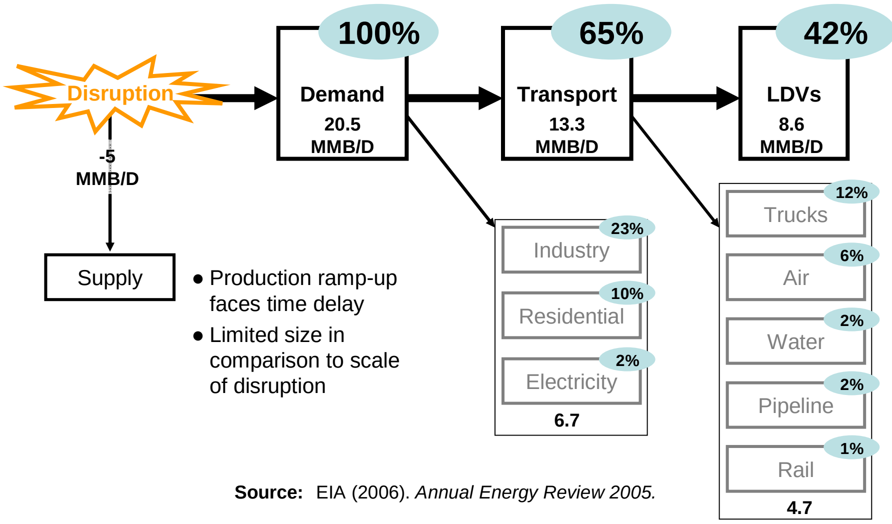


Figure 2-1: Impact-driven Focus Leads to the Project Scope of Light Duty Vehicles Transportation

2.2 Oil Supply to the U.S.

This section details the important shifts in production and imports of oil and petroleum products that occurred since the 1991 OTA report (OTA, 1991). It highlights the U.S. vulnerability to import shortfalls. More specifically, in the context of the project, it assesses the potential for supply-side-based import disruption mitigation options.

2.2.1 Oil Supply in its Context

Since the U.S. Congress Office of Technology Assessment (OTA) published its 1991 report (OTA, 1991), the U.S economy has undergone a continuing and steady growth of its energy consumption, with annual energy demand rising from 81.2 quadribillion Btus (quads) in 1989 to 99.8 quads in 2005, after a peak at 100.4 quads in 2004[2]. Petroleum products derived from crude oil still accounted for 40 percent of total energy consumption in the U.S. in 2005, down from 49 percent in 1978 and 42 percent in 1989. The subsequent steady consumption growth combined with a decline in domestic production since 1980 considerably increased the reliance of the U.S. on imported oil.

[2] All energy, oil and petroleum data in this section, unless otherwise noted, stems from U.S Department of Energy, Energy Information Administration (EIA) (2006), *Annual Energy Review 2005* (DOE/EIA Publication No. DOE/EIA-0384(2006)), referred to as (EIA, 2006a).

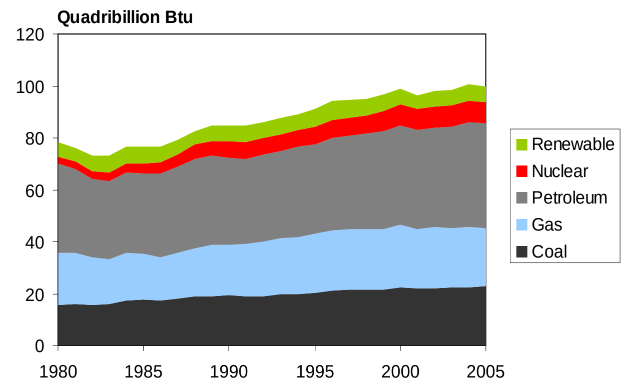


Figure 2-2: U.S. Primary Energy Consumption by Source 1980-2005
From (EIA, 2006b)

Figure 2-3 shows the extent of the U.S. oil dependency. With 20.7 MMB/D of petroleum products consumption, the U.S. consumes about a quarter of the global supply of oil. Moreover, in terms of per capita consumption, this translates to a consumption per capita of 25 barrels per year, which is on average about the double of other industrialized countries per capita consumption (USCB, 2006). This section will more specifically show the extent to which the U.S. depends on imports to supply its petroleum markets.

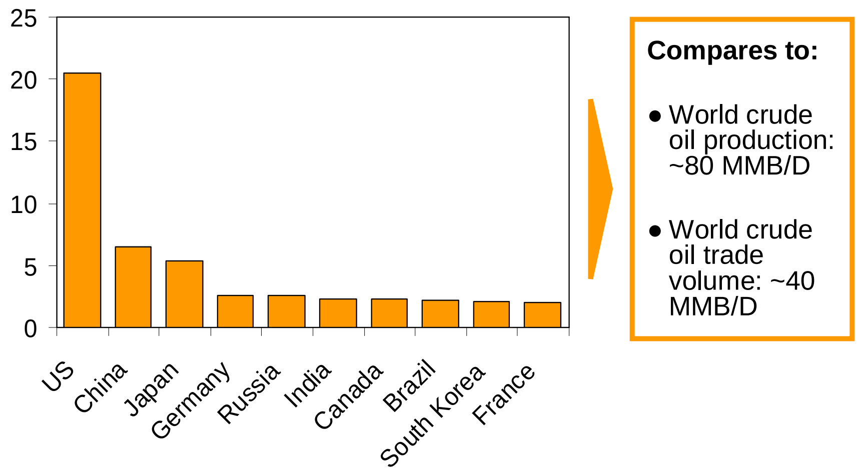


Figure 2-3: U.S. and the top 10 other biggest oil consumers (MMB/D)
From (EIA, 2006b) and (USCB, 2006)

2.2.2 Domestic and Foreign Oil Production

Figure 2-4 shows the steady decrease of the U.S. crude oil domestic production since the peak production in 1985 (9.0 MMB/D). In 2005, domestic production reached only 5.2 MMB/D, from 5.4 MMB/D in 2004. This decrease is partly explained by the consequences of Hurricane Katrina, and, even though most fields in the U.S. are mature or maturing, enhanced exploitation techniques may allow domestic oil production to be sustained in the next years.

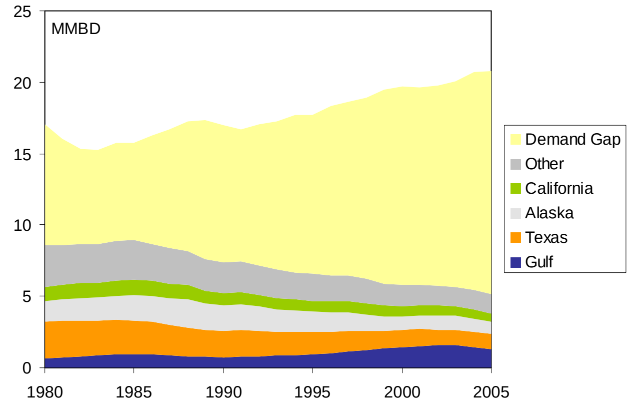


Figure 2-4: Domestic Crude Oil Production and Demand Gap
From (EIA, 2006b)

To bridge the growing gap between demand for petroleum products and domestic production of crude oil (shown on figure 2-5), the U.S. has experienced a sharp increase in crude oil and hydrocarbon imports over the past ten to twenty years, from less than 4 MMB/D in 1982 to 11 MMB/D in 2005. Other hydrocarbons sources, such as Natural Gas Liquids (NGL), have been increasingly used as inputs for the refining process. Even though imports are increasing, the situation has improved since the 1991 OTA report, in the sense that the U.S. has become relatively less dependent on Middle-Eastern geopolitics by diversifying the origin of its oil (Figure 2-5).

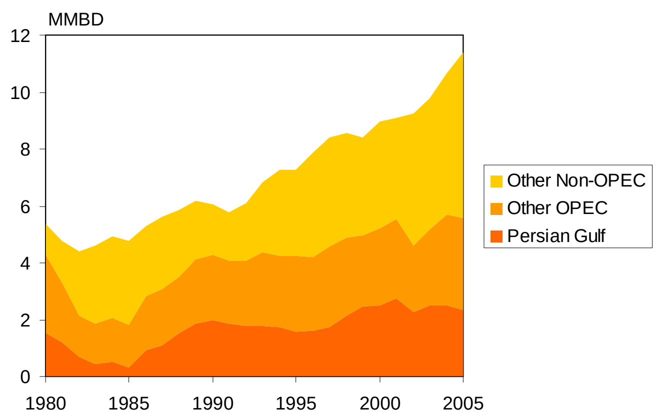


Figure 2-5: Crude Oil and NGL Imports to the U.S.
From (EIA, 2006a)

2.2.3 Petroleum Products Production and Imports

Most petroleum products consumed in the U.S. are produced by domestic refineries. In 2004, however, 2 MMB/D of processed products were imported in the U.S. The United States relies on the import of processed petroleum products as well as of crude oil. Table 2-1 presents a comprehensive overview of the national oil trade balance for year 2004. It clearly shows that the supply of petroleum products to the end-user market in the U.S. depends heavily on imports for supply of crude oil to the refineries (67 percent of crude oil supply is imported). Moreover, the U.S. is also a net importer of processed petroleum products, with net imports exceeding 1 MMB/D.

Table 2-1: U.S. Oil Trade Balance in 2004 (MMB/D)[3]

	Produced	Refined	Imported	Exported	Stocked	Consumed
Crude Oil						
Crude Oil	**5.42**		**10.05**	**0.09**	**0.20**	**16.21**
NGLs	2.23		1.03			3.26
Petroleum products						
Gasoline		8.72	0.50	0.12	-0.01	9.11
Jet Fuel		1.55	0.13	0.04		1.63
Kerosene		0.06				0.06
Distillate		3.81	0.33	0.11	-0.03	4.06
Residual		0.66	0.43	0.20	0.01	0.86
Liquified Petroleum Gas		1.94	0.26	0.04	0.03	2.13
Other		2.92	0.39	0.43	0.01	2.87
Total		**19.66**	**2.03**	**0.95**	**0.00**	**20.73**

2.2.4 Production Ramp-up: Supply-side Curtailment Mitigation Policies

In the context of a disruption, the steeply rising cost of energy will most likely initiate a major economic slowdown in the short term. This would hinder production ramp-up efforts, as the cost of infrastructure construction would rise accordingly. Given the scale of the global disruption, production could ramp-up during the five-year window as to substantially mitigate the effect of the curtailment. The changing economics of energy are likely to make it profitable to exploit remote or non-conventional sources. This phenomenon will however have little significant impact, mostly because non-conventional sources of crude require extraction technologies that are not developed yet. Moreover, their development is highly capital intensive, which will be an additional barrier in the context of the economic crisis. As a conclusion, oil production ramp-up will be delayed, and constrained by the availability of new reserves to tap into with solid economic prospects. An overall ramp-up of production is likely to occur, but with a limited scale and significant delay.

With petroleum products consumption growing to 20.7 MMB/D, and domestic production of crude oil decreasing to 5.2 MMB/D, the U.S. oil industry is relying increasingly on imports, which account for 67 percent of its crude oil consumption. In such a context and in case of a disruption, supply-side policies have limited and delayed alleviation effects.

2.3 U.S Oil Consumption

This section presents the evolution and current status of U.S. oil consumption by product and sector, and highlights the major role of the transportation sector in the U.S. petroleum products consumption.

2.3.1 U.S Oil Consumption in its Historical Context

Down from a high of 18.8 MMB/D in 1978, U.S. oil consumption was 15.2 MMB/D in 1983 and recovered slowly to reach 17.2 MMB/D by 1989, the last year for which complete data

[3] Difference between crude oil consumption and refined products output stems from refinery yield gain and addition of non-petroleum hydrocarbons such as Natural Gas Liquids used to produce Liquid Petroleum Gases.

was available to the authors of the 1991 OTA report (OTA, 1991). Since then, despite the two Gulf Wars of 1990 and 2003 and the temporary decrease they entailed, steady economic growth and the sustained energy intensity of the U.S. economy has spurred domestic oil consumption up to 20.7 MMB/D in 2005.

Oil prices have experienced a spectacular rise since the 1991 OTA report, from a spot price of around USD 20 per barrel in 1989 (historic dollars) to USD 70 per barrel during the summer 2006 (EIA, 2006d).

Figure 2-6: Cushing, OK - WTI Spot Price Free on Board
(Historical USD per barrel - From (EIA, 2006b))

2.3.2 Petroleum Products Consumption

Figure 2-7 shows the evolution of petroleum products consumption from 1980 to 2005. The main evolution in the product mix since the 1991 OTA report is the notable decrease of residual fuel oil consumption alongside an increase of transportation-related fuels (gasoline, jet fuel, and LPG).

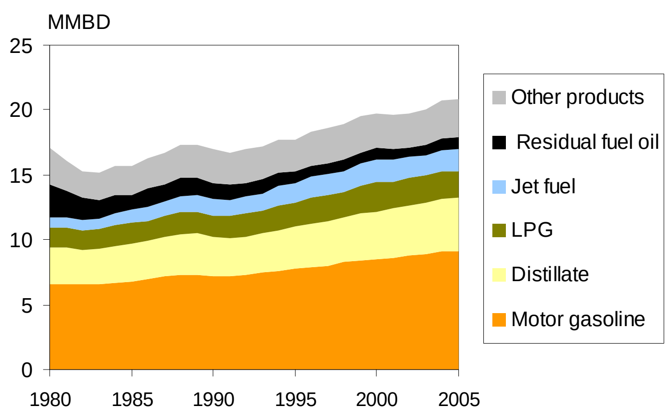


Figure 2-7: U.S. Oil Consumption by Product 1980-2005
From (EIA, 2006a)

Figure 2-8 shows the evolution of petroleum products consumption by sector from 1980 to 2005. Since the 1991 OTA report, no major change in the relative importance of each sector has occurred. With 64.5 percent of oil consumption, transportation is still the majority outlet for oil and petroleum products in the U.S.

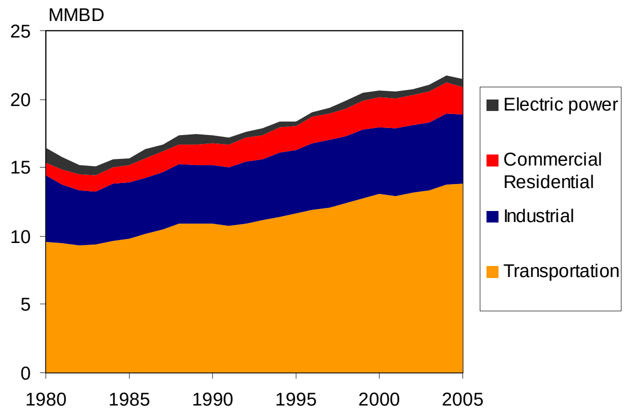


Figure 2-8: U.S. Petroleum Products Consumption by Sector 1980-2005
From (EIA, 2006a)

The four major outlets for petroleum products in the U.S. are the following sectors of the economy:

- **Electric power generation:** Electric power generation from oil or petroleum products is now extremely marginal. From a level of 7 percent of the total oil consumption, the share of electric power generation fell down during the 1980s and passed below the 3 percent level in 1992. In 2005, it accounted for 2.5 percent of the total consumption of oil products.

- **Commercial/Residential:** Oil and petroleum products use in commercial and residential sectors are mostly for space heating in homes, buildings, and offices. This sector accounts for around 10 percent of the overall oil consumption. This share grew steadily from 5 percent in 1980 and now represents 2.0 MMB/D. The main fuels that are consumed are distillate and LPG (50 percent each for residential sector, mostly distillate in the commercial sector), alongside with smaller fraction of heavy fuels. A noticeable trend is the amount of oil (1.1 MMB/D) that is consumed in Combined-Heat-and-Power (CHP) plants.

- **Industrial:** Industrial sector includes manufacturing, mining and construction, agriculture and other natural resources activities. It relies on petroleum products for three main applications: as a feedstock in chemicals, as a boiler fuel to produce steam and power generation, and as a fuel for industrial equipment. Since 1980, the share of the industrial sector in crude oil and processed petroleum products consumption has decreased continuously from 29.5 percent to 23.5 percent. Today, it accounts for 5.0 MMB/D (the 2004 figure was a historical high with 5.2 MMB/D).

- **Transportation:** The bulk of oil consumption in the U.S. is transportation, and primarily on-road transportation. With 64.5 percent of total consumed volume (compared to 62.6 percent in 1989), is still, despite increasing political awareness and industry effort on fuel efficiency, the majority end-use of petroleum products in the U.S. Among this sector, it is noticeable that gasoline, which is used almost only by passenger cars and light trucks, represents, by itself, 44 percent of total petroleum product consumption. This is the largest stand-alone end-use of petroleum products.

> The majority end-use of petroleum products in the U.S. lies within the transportation sector, with a 65 percent share. Gasoline, which is used almost only by passenger cars and light trucks, represents the largest stand-alone end-use of oil, with a share of 44 percent of petroleum products consumption.

Since gasoline-based transportation represents such as massive share of oil consumption, this sector would be critical for an efficient response to an oil import disruption. Consequently, the oil consumption savings potentially captured through technological and political options linked to gasoline-based transportation are crucial to frame an impact-driven response. The next section of this chapter presents the main features of the U.S. transportation system, and the data basis on which we build our analysis, with an emphasis on gasoline-based transportation.

2.4 U.S. Transportation Sector

This section details the important trends of the U.S. transportation sector. It presents the evolution and current status of energy consumption by the U.S. transportation system, and highlights the role of light duty vehicles (LDVs) for a response to an oil import disruption.

2.4.1 Energy Consumption in the U.S. Transportation Sector

The largest sector in terms of oil consumption is transportation. In 2005, it accounted for 64.5 percent of the total volume of oil and petroleum products consumed, and of 28.1 percent of the total energy demand in the U.S. Figure 2-9 shows the share of each mode of transport in the total U.S. energy consumption for transportation.

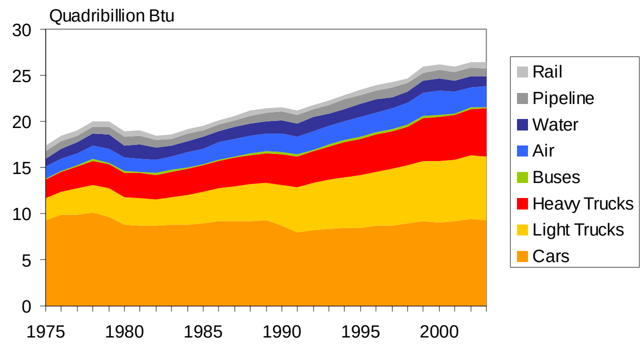


Figure 2-9: Energy Consumption by Transport Type
From (ORNL, 2006)

In the on-highway transportation sector, most of the consumption is under the form of motor gasoline, consumed by cars and light trucks. These account for 42 percent of total oil consumption, 68 percent of transportation consumption and 76 percent of on-highway transportation consumption of oil and petroleum products. Distillate fuels such as diesel are, however, used by buses and heavy trucks, and account for 24 percent of on-highway consumption. Natural gas and liquefied petroleum gas (LPG) account for a marginal amount of road transportation fuels.

2.4.2 Light Duty Vehicle Fleet

The difference in fleet turnover time between different transportation modes further advocates the focus on LDVs: planes average 25 to 35 years (IPCC, 2006) and heavy trucks average 29 years (ORNL, 2006), where as cars and light trucks average 16.9 years and 15.5 years respectively (ORNL, 2006). Thus, changes in this light trucks and cars production would become effective much faster at the level of the whole fleet. The LDV fleet is comprised of:

- **Cars:** In 2003, the estimated fleet accounted for 130 million light, medium and heavy cars on the road (ORNL, 2006).
- **Light trucks:** In 2003, the estimated fleet of two axle four tires trucks comprised of about 87 million light-duty trucks (ORNL, 2006).

The average rate of turnover is 16 million vehicles a year (ORNL, 2006), which entails that the impact of any modification of the production lines is significantly delayed. In the context of an oil disruption, however, the fact that LDVs are the largest coherent set of end-users with a stand-alone 42 percent of U.S. oil consumption makes them the central target of government action. For this reason, the focus of the report is set exclusively on LDVs.

2.4.3 Framing Issues in Light Duty Vehicles Transportation

2.4.3.1 Alternative Fuels and New Technologies for Transportation

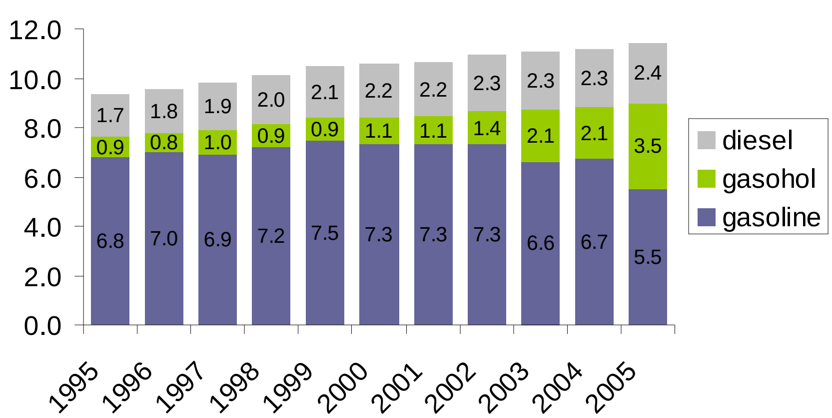


Figure 2-10 : Gasoline, Gasohol and Diesel in Highway Transportation (MMB/D) From (ORNL, 2006)

Alternative fuel technologies have made increasing in-road since the EPA Act of 1992, that we will present in chapter 4. However, the major issue of LDVs in the context of disruption is its reliance on gasoline only. Developing alternative fuels to mitigate the effect of the disruption is a central technological option of the project, and the first avenue of action, developed in chapter 3.

2.4.3.2 Fleet Efficiency and Light-truck Penetration

During the last thirty years, large scale deployment of sports utility vehicles (SUVs) on the roads has profoundly changed the structure of the LDV fleet. Market share of heavy vehicles rose from 20 percent in 1975 to 50 percent today (ORNL, 2006).

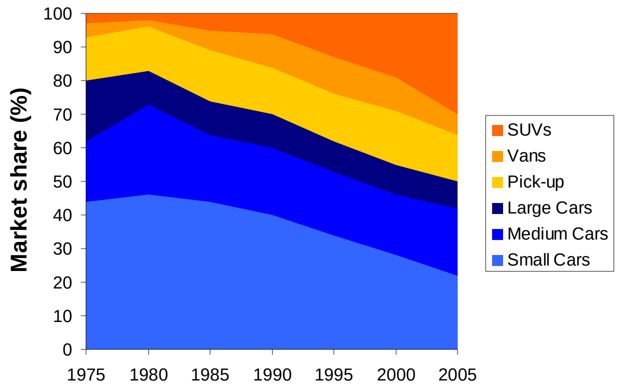


Figure 2-11: Fleet Penetration by SUVs 1975-2005 (5 year moving average)
From (ORNL, 2006)

Figure 2-11 shows this shift toward a heavier fleet. Light trucks have a worse fuel economy than cars (sales-weighted 2005 estimates are 21.8 mpg vs. 30 mpg (ORNL, 2006)), which implies that this strong penetration of light trucks on the roads has pushed the average fuel economy of the fleet downwards. A lever for action in the context of the disruption could thus be to reverse this trend and force more efficient vehicles to hit the road. Vehicle efficiency technologies are our second avenue for action, discussed in chapter 4.

2.4.3.3 Transportation Patterns and Behaviors

A last set of issues with LDV passenger transportation system is related to the usage of the network by drivers and passengers. The following chart highlights the issue of single-occupancy in work-related commuting. More generally, behavioral change can be a very powerful tool for policy-makers. Chapter 5 will discuss the last avenue for action: efficient use of vehicles.

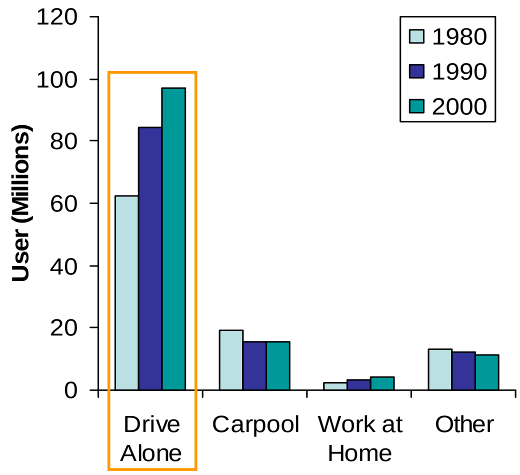


Figure 2-12: Commuter Transportation Mode Choice in the U.S.
From (ORNL, 2006)

LDVs passenger transportation is the largest coherent set of end-users of petroleum product, with 42 percent of U.S. oil consumption by itself. In the context of the disruption, this makes LDV transportation the central target for government action. It will hence be the exclusive focus of our project, which will frame policy options around three avenues of action: vehicle fleet efficiency, use of alternative fuels and efficient use of vehicles.

2.5 Conclusion: Scoping of the Report

This chapter sets the background of the report, by synthesizing facts and figures about oil supply and imports in the U.S. It explains the rationale for setting the specific focus of the project on light duty vehicle transportation (LDVs), and the specificities of LDVs among the end users of petroleum products.

The U.S., with a petroleum products consumption of 20.7 MMB/D and a domestic production of 5.4 MMB/D of crude oil, is highly dependant on net imports (11 MMB/D of crude oil, 1 MMB/D of petroleum products). Growing demand and declining domestic production exacerbate the exposure of the U.S. economy to an oil import disruption.

In the context of the curtailment, supply-side solutions such as oil extraction capacity ramp-up will be limited in scale and delayed until the end of the 5 year window. The main opportunity of action lies in demand-management in the transportation sector, which accounts for 65 percent of petroleum products consumption. With 42 percent of the global oil consumption, LDV transportation has the highest potential of impact for curtailment alleviation among all end-uses. This makes them the central target for government response, and sets the focus of the report.

The LDV transportation fleet suffers from three system-wide issues: the lack of alternative sources of fuel, the overall inefficiency of the fleet due to a historic shift toward heavier vehicles, and the dominant preference for single-occupancy commuting among users. In the context of an oil disruption, they provide avenues for action for the federal government.

Chapter 3

Vehicle Fleet Efficiency

Technological and Policy Options

This chapter evaluates options for the federal government to achieve oil savings through increasing vehicle fleet efficiency. It first assesses the status of current technological options and then discusses the barriers to growth. Based on the effect of oil disruption on stakeholders and these barriers, policy options are developed for the federal government. This chapter concluded that the likely role of the federal government would be to push the industry toward adoption of fuel saving technologies.

3.1 Introduction

Improving fuel efficiency for vehicles is a potential strategy to reduce U.S. oil reliance in the transport sector. This chapter discusses the potential to achieve oil savings through implementing more efficient technologies in new vehicles and explores the federal government's role in promoting or directing this change.

After the 1973 oil disruption, the U.S. federal government developed Corporate Average Fuel Economy (CAFE) standards[4], which went into effect five years later (NHTSA, 2006). CAFE standards apply to all vehicles sold in the United States, regardless of the nationality of the manufacturer.

Vehicle fuel efficiency can be improved by making modifications to a variety of vehicle systems, including engines, transmissions, and structural components. This chapter neither identifies nor assesses every available technology. Instead, eight technologies affecting different vehicle systems are briefly introduced to provide a technological basis from which to proceed with an analysis of the potential role of the federal government in responding to an oil crisis by promoting or mandating vehicle fleet efficiency improvements.

3.2 Issue Framing

In keeping with the broad goals of this project, the objectives of policy options in this section are twofold: 1) to exploit any short-term savings that can be achieved through vehicle fleet efficiency and 2) to assess the potential for achieving sustainable savings in this sector. The

[4] The CAFE standard is the sales weighted average fuel economy of a manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating (GVWR) of 8,500 lbs. or less, expressed by miles per gallon (mpg); the standards apply to all vehicles manufactured for sale in the U.S. for any given model year (MY). The subjects of CAFE are passenger cars and light trucks, and light trucks such as sport utility vehicles and large vans that exceed 8,500 lbs. gross vehicle weight rating (GVWR) do not have to comply with CAFE standards.

overall analysis in this chapter focuses not on evaluating particular options but on identifying any barriers to progress in this sector to which government resources can be effectively applied.

In the context of an oil supply disruption, two main stakeholders – the federal government, in its role as industry regulator, and vehicle manufacturers – are central to changing technologies in the vehicle fleet. Naturally, the alignment of interests between these two stakeholders brings to light debate about the appropriate role of government intervention within a market economy. Accordingly, the role of government in guiding the economy in a national emergency is a framing consideration for this section. The federal government has formal resources such as regulatory and legislative powers to mandate fuel efficiency standards. However, in a supply-constrained market, vehicle manufacturers will have natural market incentives to continue to develop and adopt efficiency-improving technologies. Many technologies to enhance vehicle fleet efficiency are already being incorporated in a growing number of vehicles. If the interests of market-driven stakeholders are already aligned with those of the government, the debate about government intervention becomes especially relevant.

Vehicle development, production, distribution, and use are characterized by a simple, linear flow model (for a single development cycle). In this model, introducing technologies to improve efficiency in new vehicles is an "upstream" activity, yet the desired effect – reduction of the amount of oil consumed by vehicles on the road – is a "downstream" activity separated from upstream technological changes by a considerable time delay. Because of the time to impact, only technologies that can be implemented in vehicle designs almost immediately after the disruption event are useful options for responding to the oil supply shortfall.

Chapter Research Question:

How can the federal government shape its post-oil disruption response with respect to saving oil through light duty vehicle fuel efficiency improvements?

3.3 Status of Selected Technological Options

In this section, the technological feasibility of improving fuel efficiency in the vehicle fleets is explored through consideration of a few selected technologies.

3.3.1 Engine Technologies

Engine technologies that can improve fuel economy relative to baseline, conventional-technology gasoline engines include gasoline direct injection (GDI), variable valve timing (VVT) and diesel engines. Since late 1990s, several vehicle manufacturers, such as Toyota and Nissan, have developed GDI technology and applied it to new production vehicles. The current GDI technology improves vehicle fuel efficiency by up to five percent, and this technology can be used in combination with other technologies such as VVT and continuously variable transmission (CVT).[5] In 2003, Honda developed the i-VTECH I engine, which included not only GDI but also VVT and was coupled with a CVT. VVT is a generic term for an automobile piston engine technology that has been applied to vehicles since early 1990 (EPA, 2006; Nikkei Automotive Technology, 2006).

Diesel engines are more efficient than gasoline engines of the same power, resulting in lower fuel consumption (Wikipedia, 2006b). Diesel engines are much more economical than gasoline engines when at low power and at engine idle, and diesel cars and trucks deliver great fuel economy, 20 to 30 percent better than comparable vehicles with gasoline engines. In the U.S., diesel market share in LDVs has historically been small but has increased gradually since the late 1990s, although it is still very limited (Bankrate.com, 2004).

3.3.2 Efficient Design Technologies

Efficient designs can also incorporate technologies such as CVT and lighter body vehicles that replace steel in the vehicle structure with less dense materials. A CVT is a type of automatic transmission that can change the "gear ratio" (gears are not generally involved) to any arbitrary setting within design limits (Wikipedia, 2006a). The advantages of CVT include fuel efficiency and improved accelerating power. Currently CVT is thought to improve fuel efficiency by approximately 8 to 10 percent (HONDA, 2006). Market penetration by CVT is currently low, but the technology has potential to expand to wider application in vehicle fleets. CVT use is already incorporated in some production plans; for example, Nissan plans to sell quadruple the number of vehicles offered with CVT in 2007 (Nissan, 2004).

Vehicle weight reduction is one of the most effective ways to improve fuel efficiency of the vehicles. Recently, aluminum has surpassed cast iron as the second-most-used material in automobile production. Aluminum has been applied in all areas of the vehicle: engines, transmission, chassis, suspension, and body structure (Metal Center News, 2006). Aluminum components can weigh as much as 30 to 45 less than steel components of equivalent strength. However, high material costs have hindered further replacement of steel with aluminum in vehicle designs.

Magnesium has the lowest density of the common engineering metals and has a great possibility in automotive applications despite its high cost and limited supply (The Minerals Metals & Materials Society, 2002). During the 1990s the market for automotive magnesium parts grew rapidly, at nearly 15 percent per year. But, application of magnesium to automotive has lots of uncertainty despite the positive trends. The main reasons are its high cost and relative immaturity of the supply structure. Steel is 1,400 times more plentiful than magnesium, and the supply of aluminum is 45 times that of magnesium for automotive components.

3.3.3 Other Technologies

Other technologies that reduce the consumption of energy include idling stop system (ISS) and electric power steering (EPS). ISS is to stop engine idling while a vehicle stops and to restart engine by treading on a clutch when a driver wishes to resume movement. This technology reduces the fuel consumption during idling and can contribute to greater fuel efficiency, especially in congested urban areas.

EPS is a system for reducing the steering effort on cars by using an external power source to assist in turning the wheels. EPS achieves improvement of fuel efficiency by 3 to 5 percent compared to conventional power steering. Due to the operational feeling, EPS struggled to gain driver acceptance when it was first introduced, but it has become increasingly popular because handling feel has improved, demand for fuel efficiency has increased, and computerized cars have become popular (Wikipedia, 2006c).

3.4 Stakeholders Analysis

Governments and consumers require safety and environmentally-friendly vehicles from the manufacturers, while these vehicle manufacturers face trade-offs between the cost of corporate social responsibility and profit maximization. Table 3-1 compares these two stakeholders and includes a third group: vehicle operators, In the context of a severe oil disruption, vehicle manufacturers are likely to respond primarily to shifting market demand when designing product lines and deciding how many lighter body vehicles to produce and market. The federal government has the authority to regulate the industry using tools like CAFE and can further encourage manufacturers to develop more fuel efficient vehicles by employing incentives such as tax breaks. Given the uncertainty of markets and public expectation for leadership from the government, the federal government should carefully consider employing tools to encourage fleet efficiency improvements, but it must be cautious when employing CAFE, incentives tax incentives, or distributing development funds.

Table 3-1: Stakeholder Analysis

	Federal Government	**Vehicle Manufacturers**	**Vehicle Owners**
Values/ Concerns	Economic and energy security; political price	Maximizing profit; competitiveness	Reliability; convenience; vehicle safety
Resources and channels	Formal, legislative; regulatory	Informal, lobbying, media advertising	Informal; purchasing power; votes
Influence Concentration	Concentrated	Concentrated	Diffused
Capacity for internal change pre oil disruption	Medium	Medium	Medium
Power over stakeholders pre oil disruption	High	Medium to low	Medium
Capacity for internal change post oil disruption	High	High to medium	Medium
Power over stakeholders post oil disruption	High to medium	Medium initially	Low

Vehicle owners are diffused in influence both before and after an oil disruption. Because they are the source of vehicle demand, they have medium to high power over other stakeholders before the disruption in a market model, but after the disruption this power is lower as the need for alleviating oil consumption precedes vehicles preferences. If the price of vehicles increases, consumers can defer purchases of new cars because vehicles are durable goods. Consumers face the tradeoff between cheaper, relatively less efficient and expensive but relatively more efficient vehicles. Post-disruption the rise in oil price will somewhat dissolve that trade-off in favor of more efficient cars, although not for all consumers.

The most important stakeholders in the development of efficient vehicle fleets include the federal government due to its regulatory authority and ability to set efficiency standards and the automakers that have control over vehicle designs and production schedules.

3.5 Technology and Policy Interactions and Barriers

Most of the fuel efficient technologies discussed have already been incorporated into the design of new vehicles but do have technological or economic constraints such as emission levels and high cost compared to les efficient, standard technologies. Table 3-2 shows the relative evaluation of each technology based on fuel efficiency, time frame to implementation, and cost. As can be seen from the table, GDI contributes significantly to fuel efficiency; however, this technology is constrained by its gas emission levels. Diesel engine vehicles are not popular among consumers in the U.S. but may become a preferred consumer option in an oil disruption because of diesel's fuel economy improvements over gasoline. CVT market penetration is constrained by drivers' reluctance to accept the driving feel of the technology. In order to spread lighter vehicles, there are big barriers such as cost, material rarity, and safety. With respect to idling stop system which is thought to be the most effective and easiest way to respond oil disruption in that it can be fit in after purchasing vehicles, drivers have concerns that idling stop systems will result in traffic congestion.

Table 3-2: Relative Evaluation of Each Technology

Technologies	Category	Results	Fuel Efficiency	Time Frame	Cost	Barrier/ Constraint
Engine Improvement	Gasoline Direct Injection (GDI)	B	B	B	B	Gas emission
	Variable Valve Timing (VVT)	A	C	A	B	-
Alternative Engine	Diesel Engine Vehicle	B	A	B	B	Public opinion, image
Efficient Transmission	Continuously Variable Transmission (CVT)	C	B	C	B	Comfort for drivers
Lighter Body Vehicle	Aluminum	B	A - B	B	C	Cost, supply, safety
	Magnesium	D	A – B	C	D	Cost, supply, safety
Energy Consumption Reduction	Idling Stop System	B	B	A	A	Concern of congestion
	Electric Power Steering	B	C	B	B	-
* A (greatest) to D (worst)						

Policy is not a major constraint for advancements in vehicle fleet efficiency. However, the federal government can employ policy tools to "push" the pace of efficiency gains through technological change in vehicle fleets.

In a competitive business setting, manufacturers devote resources to improving vehicle technologies and often improve vehicle fuel economy with such technologies. Policy is not a constraint for advancements in vehicle fleet efficiency; however it is an incentive that will have pronounced power in the case of an oil disruption.

3.6 Policy Options

The federal government has several options available to increase light duty vehicle fleet efficiency when crafting a response to an oil import disruption. Four broad courses of action are presented in Table 3-3 on the following page.

Because the vehicle manufacturers have considerable power and resources to change the technological designs of their vehicle models, the federal government may choose to allow market forces to drive change in vehicle fleet efficiency. This is the first option presented in Table 3-3 and results in low direct costs to government but may not result in the savings potential of efficient vehicle technologies being achieved in the short run. A second option is for the government to use all available tools to encourage or mandate incorporation of new technologies at the maximum possible rate. Such a course of action would deplete government resources and incur many opportunity costs with uncertain returns on the investment. Significant effects on oil savings likely would still be delayed for one or two years due to the time delay before new vehicle designs reach the on-road LDV stock.

The last two options presented in Table 3-3 involve government limiting expenditure of resources while still pushing change within the vehicle manufacturing industry. If financial incentives such as tax breaks and subsidies were to be applied to specific technologies, economies of scale within certain technologies may be exploited; this benefit is not necessarily greater than the cost to government.

A fourth option is to use the existing CAFE standards program to push change through regulation; manufacturers can earn CAFE "credits" to offset deficiencies in their CAFE performances[6] (NHTSA, 2004). Raising CAFE standards would involve little direct cost to government, but expedited promulgation of ambitious, new standards would likely require significant expenditure of political capital.

[6] Specifically, when the average fuel economy of either the passenger car or light truck fleet for a particular model year exceeds the established standard, the manufacturer earns credits. The amount of credit a manufacturer earns is determined by multiplying the tenths of a mile per gallon that the manufacturer exceeded the CAFE standard in that model year by the amount of vehicles they manufactured in that model year. These credits can be applied to any three consecutive model years immediately prior to or subsequent to the model year in which the credits are earned. The credits earned and applied to the model years prior to the model year for which the credits are earned are termed "carry back" credits, while those applied to model years subsequent to the model year in which the credits are earned are known as "carry forward" credits. Failure to exercise carry forward credits within the three years immediately following the year in which they are earned will result in the forfeiture of those credits.

Using a fleet fuel economy standard to achieve oil savings may be attractive to government and palatable to industry. Manufacturers can comply with CAFE in two ways: by implementing technological change in their vehicles and by adjusting production schedules of existing vehicles to change the composition of the marketed fleet. (For instance, producing more compact cars and fewer full-size, luxury sedans would raise the fleet fuel economy for a given manufacturer.)

Table 3-3: Analysis of Options

Policy Option	Pros	Cons
No change—business as usual. Free market.	• No direct political cost to government • No non-market pressure on stakeholders to bear cost. • Market has self interested actors that maximize profit. Efficiency is maximized. • Liberty is maximized in the short run.	• Volatility and uncertainty of market makes coherent action unlikely. • Manufacturers lack cooperation in technological development leading to suboptimal combination technology growth. • Government can mobilize public sentiment and bring about nationwide awareness.
Government supports all possible avenues for vehicle fuel efficiency enhancement such as fee-bates, tax credits, regulation through CAFE, grants, leverage partnerships and coalitions, clear policy leadership	• Maximum short term gains. • No option is ruled out. Through trial and error most effective avenues will be discovered. Equivalent to a large pilot run. • Greater set of initiatives caters to the needs of more actors enhancing equity.	• Short term gains on existing technology. • Lack of coordination will lead to unsustainable progress. • Comprehensive support dilutes chances of concentrated development in a technology that may yield larger returns on efficiency gains. • Reallocation of funds by the government will result in lower investment in other sectors. • Little protection against abuse of incentives. • Overinvestment in incentives; incentives may be in effect even when they become unnecessary.
Government targeted support in terms of tax breaks, subsidies, research grants	• Long term market penetration more likely. • Economies of scale in specific technologies are exploited. • R&D will close the efficiency and economic gaps.	• Viable technological gains may be excluded from targeted options. • Erosion of government authority if other stakeholders negatively perceive government plan. • May not maximize short term potential due to high focus on long term gains. • Reallocation of funds by the government will result in lower investment in other sectors.
Raising the CAFE standards	• Little to no material cost • Reliance on market to drive technological innovations.	• Political cost to the government from vehicle manufacturers. • Vehicle efficiency gains depend on enforceability. Progress is not guaranteed. • Development of new standards can be time consuming

3.7 Conclusion

Because of the time constraints posed by the need to respond to the oil supply disruption, potential gains of this avenue are bounded by technological limitations at the time of the disruption. Technological changes will yield small impact on a per vehicle basis, but these changes can be applied to a large number of new vehicle models. The effects of improved vehicle technologies are mostly limited to new vehicles, and there is an immense vehicle stock already on road. Since vehicles are durable goods requiring relatively large user capital investments, vehicle rolling stock (vehicles in use on the roads) will be dominated by current-technology vehicles for years to come, even if ambitious programs to increase the rate of replacement with newer alternative fuel and more efficient vehicles are introduced.

Power and resources to implement change in vehicle fleet efficiency are concentrated in vehicle manufacturers and in the federal government, which can regulate the industry through imposing safety, environmental, efficiency, and other standards on vehicles. Reluctance to incur the capital costs required for large-scale incorporation of new, efficient technologies into vehicle design and production could slow industry response in the case of an oil supply disruption. Should the federal government decide to apply its resources to push change in the industry, it has several tools available. The existing Corporate Average Fuel Economy standards are a regulatory approach to encouraging adoption of efficient technologies in vehicle fleets; CAFE may be a particularly useful tool in for disruption response because it involves very little cost to the government and does not require the government to evaluate and select specific technologies; this task remains with the industry, in which the necessary technical knowledge is concentrated. Raising the CAFE standards would not have immediate effects, but manufacturers can meet the standard by adjusting current production schedules as well as by implementing technological changes, either of which has the same effect on oil savings if the standards are met.

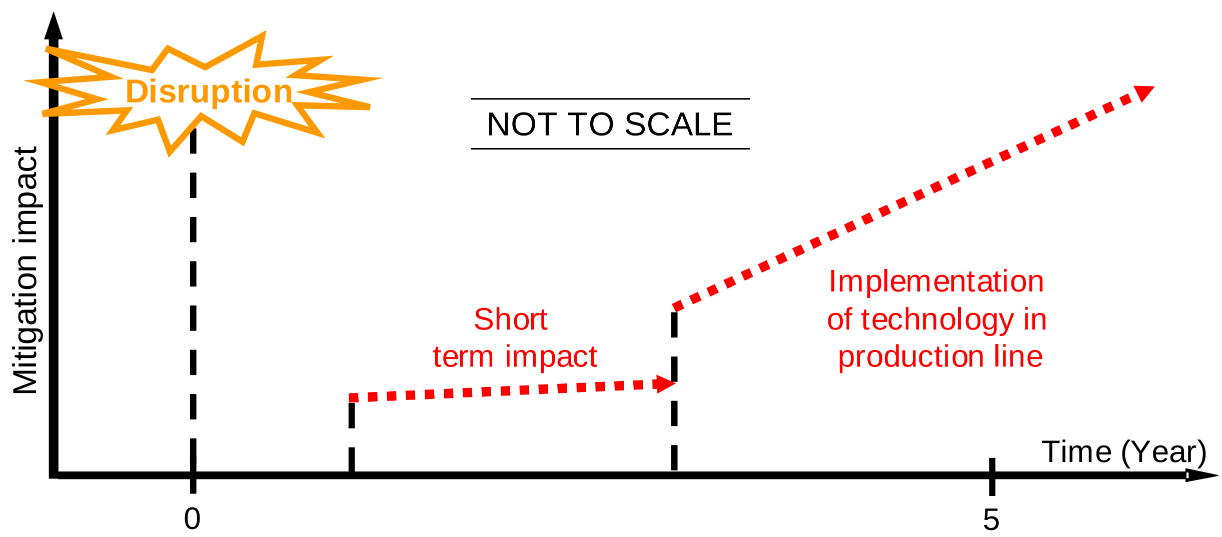


Figure 3-1 Alternative Fuels Impact on Oil Savings Over Time

Chapter 4

Alternative Fuels

Technological and Policy Options

> This chapter evaluates options for the federal government to target its response within the alternative fuels sector to overcome barriers that arise from technology development, multiple stakeholders, and economic feasibility. The chapter highlights the historical context that spurred the growth of alternative fuel vehicles in the U.S. A dynamic analysis of stakeholders is followed by identification of barriers to the growth of alternative fuels. Based on the effect of oil disruption on stakeholders and the barriers to growth policy options are developed for the federal government.

4.1 Introduction

Use of non-petroleum-based fuels is an avenue to reduce U.S. reliance on oil – and thus the impact of an oil disruption - in the transport sector. This section explores current alternative fuel technologies and possible actions by the federal government in the case of an oil disruption.

Alternative fuels have long been used in limited applications; predictably, alternative fuels use often peaks after disruptions in oil supply. In the Energy Policy Act of 1992 (EPAct), the U.S. Congress made a concerted legislative effort to encourage the development and commercialization of alternative fuels[7]. The law designated ethanol, natural gas, propane (liquefied petroleum gas), hydrogen, biodiesel, electricity, methanol, and, later, p-series fuels as alternative fuels (EERE, 2006). This chapter includes hybrid electric vehicles as well, although these vehicles are not considered alternative fuel vehicles under EPAct.

The federal government encouraged development of alternative fuel vehicles (AFVs) using a fuel economy credit (a maximum of 1.2 mpg per manufacturer) towards the Corporate Average Fuel Economy (CAFE) standards for production of flexible fuel vehicles (FFVs) or AFVs in addition to the EPAct initiatives. This credit, which actually preceded EPAct, was established in 1988 in the Alternative Motor Fuels Act (AMFA) and was extended in 2004; the program is commonly referred to as AMFA CAFE (NHTSA, 2002). A host of other regulations and tax incentives at the federal and state level target specific alternative fuel technologies. For instance, the Energy Policy Act of 2005 created a Hybrid Motor Vehicle Credit based on the life-time fuel savings potential of hybrid electric vehicles (EERE, 2006).

The AMFA CAFE incentives and EPAct-mandated policies have succeeded in spurring market experimentation with a variety of alternative fuels, removing many technological

[7] EPAct was designed to promote reduction of petroleum usage in the transportation sector both through dedicated alternative fuels and alternative fuel vehicles and through increased use of alternative fuels as components blended with gasoline and used in conventional vehicles.

obstacles associated with these fuels. Not all alternative fuels currently in development have equal potential to impact U.S. oil consumption within the constraints of the given disruption scenario. This chapter does not include quantitative analysis of the potential of each fuel, but relative contributions possible from each fuel did factor into the fuels selected for further discussion.

4.2 Issue Framing

In keeping with the broad goals of this project, the objectives of policy options in this section are twofold: 1) to exploit any short-term savings through the use of alternative fuels and 2) to attain transition momentum towards sustainable market commercialization of one or more alternative fuels to reduce long-term reliance on imported oil beyond the five-year disruption scenario. Analysis of the role of the federal government in setting policy within the alternative fuels sector explores trade-offs that exist between these two goals.

The issue of transition to alternative fuels can be cast in terms of energy security, promoting growth and stability of the U.S. economy, and environmental responsibility. Stakeholders' priorities are reflected in the ways in which they frame the issue. Energy security advocates are likely to support reliance on domestic sources – including some alternative fuels – and diverse foreign sources. Supporters of the domestic economy are likely to support home-grown solutions like corn ethanol and biodiesel production, both of which benefit the rural, agricultural sector, a traditional, all-American constituency. The environmental movement is likely to be more selective in its support of alternative fuels, showing greater concern for the emissions and other effects of certain new fuels. Differences may also arise in the degree of oil replacement advocated depending on the framing of the issue; for instance, energy security may encourage only partial replacement of gasoline equal to imports, while environmentalism may encourage a full transition to alternative, low-carbon fuels.

The alignment of various interests within the alternative fuels sector, which provides insight into the actions that will likely take place in the free market and the potential benefits of government involvement, is discussed herein. The debate about the appropriate role of government intervention within a market economy has a central place in American political life, and the related issue of government control of sectors of the economy in a national emergency is a framing consideration for this chapter. The federal government has various resources that it can bring to bear on alternative fuels commercialization, including, but not limited to, legislative and regulatory authority, tax policy and other fiscal incentives, and the ability to leverage media access to disseminate information to the American public.

While relative benefits and costs of various courses of action are a guiding factor in the analysis, quantitative cost-benefit analyses are not included.

Chapter Research Question:

How can the federal government target its response within the alternative fuels sector to overcome barriers that arise from technology development, multiple stakeholders, and economic feasibility?

4.3 Status of Fuel Technology and Infrastructure

This section provides a brief overview of alternative fuel technologies, including their current degree of technological development, the number of vehicles on the road using various alternative fuels, prices of each alternative fuel, and infrastructure availability.

4.3.1 Recent Trends in Availability of Alternative Fuel Vehicles

The incentives and targets established by EPAct have resulted in notable growth in the AFV fleet over the past decade. Figure 4-1 illustrates the overall growth trend and shows the availability of AFVs using various fuels. The figure shows the number of vehicles actually using a given alternative fuel, not the number of vehicles in the fleet that are capable of using a given fuel. Many alternative fuel-capable vehicles are on the road but are still operating on conventional gasoline; these are commonly called flexible fuel vehicles (FFVs).

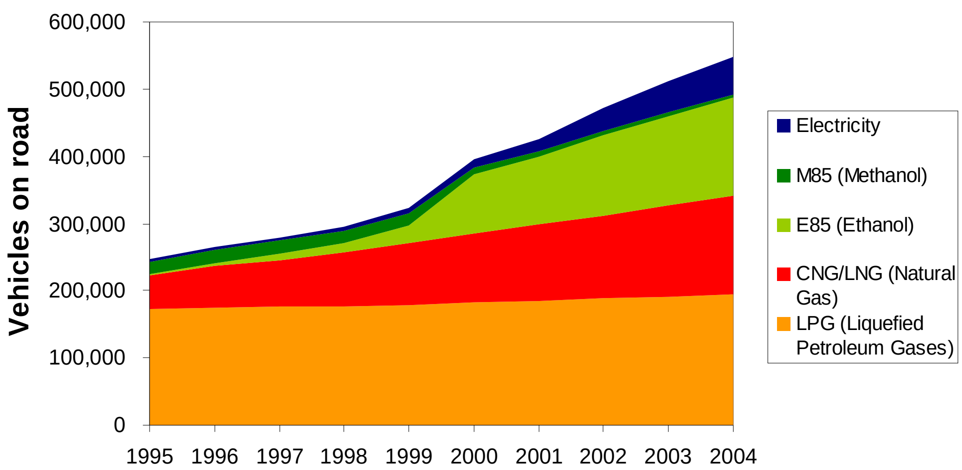


Figure 4-1: Number of Alternative-Fueled Vehicles in Use in the U. S., by Fuel, 1995-2004 (EIA, 2006c)

While Figure 4-1 shows trends in general AFV availability, it is necessary to know the breakdown of these vehicles by weight category, since only LDVs have direct relevance to this report. Figure 4-2 presents data for model years (MY) 2005 and 2006. Currently, the largest impact of AFVs is in the LDV sector, which appears on the chart in the automobiles, pickup trucks, and SUVs categories. By extrapolation, in the event of a disruption the AFV industry is better positioned in the LDV market than in other vehicle markets to exploit opportunities to achieve oil savings.

The number of FFVs on the road exceeds the number of FFVs actually using alternative fuels. Market availability of AFVs is increasing, with vehicle availability increasing nearly 70% between MY 2005 and 2006.

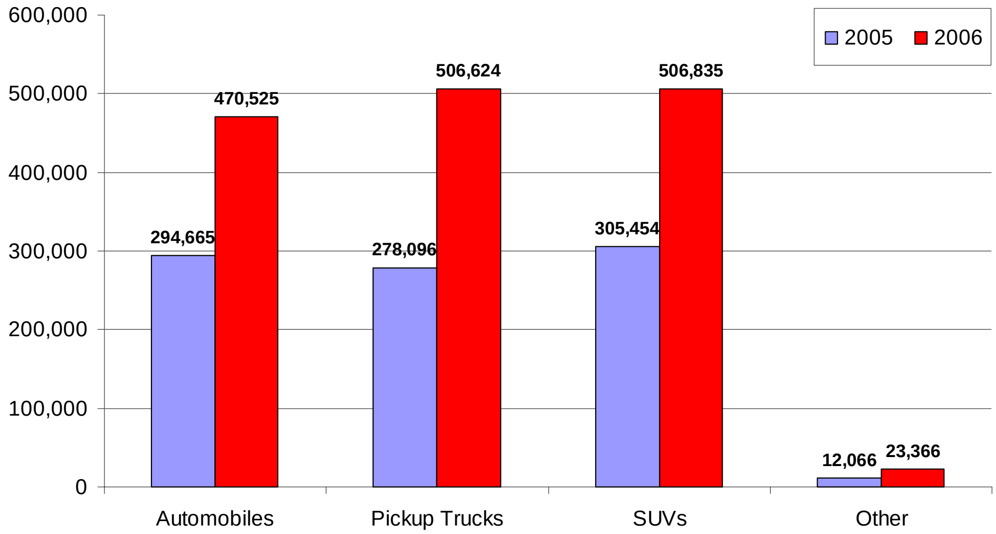


Figure 4-2: Alternative Fuel and Hybrid Vehicles Available, 2005 & 2006 (EIA, 2006c)

Two other important insights can be gained from data comparing availability of AFVs with the number of AFVs in the current fleet that are actually using alternative fuels. First, the number of vehicles capable of using alternative fuels available on the market and in the vehicle fleet is higher than the number of AFVs actually operating on fuels other than gasoline. In 2004, the Energy Information Administration (EIA) estimated that fewer than 150,000 E85 FFVs were on the road burning E85, yet the vehicle fleet included some 4.1 million E85-capable vehicles (EERE, 2006). Secondly, the data in Figure 4-2 show that the market availability of AFVs increased 69 percent between 2005 and 2006. This does not indicate that the industry has the capacity to repeat such increases in a single model year, but it does suggest production expansion capacity within the alternative fuels sector.

In

Table 4-1, on the following page, the availability of alternative fuel LDVs is summarized alongside the average annual growth rate for the period 1995-2004 for each alternative fuel. This table includes all of the original EPAct alternative fuels as well as hybrid electric vehicles. P-series fuels are not included in this table or elsewhere in this report; the category was only added to EPAct in 1999, and p-series fuels are not produced in sufficient quantities to warrant further analysis (EERE, 2006). The table also includes other information relevant to the potential of these fuels, such as their source, infrastructure costs, and suitability for use in fuel blends with conventional gasoline.

Table 4-1: Summary of AFV Availability and Growth Rates

Fuel Type	LDVs Available (2005)	Growth Rate, % (c. 2004)*	Other Factors Affecting Impact Potential
Liquefied Petroleum Gas (LPG)	439	1.3	Derived from petroleum; U.S. manufacturers phasing out production of LPG vehicles
Compressed Natural Gas (CNG)	1922	12.4	Vehicle conversions possible
Liquefied Natural Gas (LNG)	0	20.1	High infrastructure costs
Methanol	0	-14.3	Phased out in favor of ethanol
Ethanol (E85 and low-level blends)	735,693	78.8	Domestic production; increases tied to agricultural growing seasons and refinery capacity; can be blended with conventional gasoline
Biodiesel	-	-	Domestic production; does not require dedicated vehicles; can be blended with conventional diesel
Electricity	2277	39.1	Batteries expensive; limited range
Hybrid Electric	139,518	-	Commercial availability rapidly expanding; no dedicated infrastructure required
Hydrogen	61	-	Commercial technology development estimates beyond disruption time horizon

* Includes medium and heavy-duty AFVs as well as light-duty AFVs. The growth rate is the average annual growth rate between 1995 and 2004.
(-) denotes no data available

Red frame indicates fuels selected for further analysis in this project. Although these selections roughly correspond to the fuels with the greatest current market share and growth momentum, their inclusion should not be interpreted as an endorsement of these fuels as the best candidates for federal support in the event of a severe oil import disruption. Rather, the combination has been selected because of specific characteristics that allow important comparisons to be made in the analysis that follows. The four fuels will be shown to complement each other because of differences in their infrastructure requirements and the vehicles in which they can be used.

4.3.2 Ethanol

In the United States, ethanol is produced primarily from corn. The vast majority of feedstock corn is raised in the Midwest, the nation's agricultural heartland. At present, ethanol production facilities and fueling infrastructure are also concentrated in the Midwest region. The domestic sources of this fuel make it appealing to energy security advocates and are especially important in the oil disruption scenario. While there is not an environmental consensus on the fuel, it does enjoy substantial support from environmentalists because it is a crop-based, renewable fuel with potential for long-term sustainability. Current corn ethanol production is expected to be supplanted by production of ethanol from cellulosic feedstock as technology develops, yielding even greater efficiency in production and lessening the need to displace other crops with corn (EERE, 2006).

Ethanol vehicle technology is essentially the same as that in conventional gasoline-powered vehicles, with minor material changes in fuel system components for compatibility with the E85 blend. Present flexible fuel vehicles (FFV) technology is sufficient for consumers to use E85. FFVs have a lower operating range compared to gasoline per unit of fuel consumed, but E85 vehicle cost is comparable to that of gasoline vehicles (EERE, 2000). Thus, economics is not a barrier to consumer choice to purchase FFVs. E85 fueling infrastructure is also similar to gasoline fuel stations, and E85 capability can be added to existing conventional refueling stations at relatively low cost.

Ethanol can also be blended with gasoline in smaller ratios like E10, which is 10 percent ethanol and 90 percent gasoline. These blends can be used in any conventional gasoline internal combustion engine, allowing ethanol to be used to replace gasoline in conventional vehicles as well as dedicated FFVs (EERE, 2006). The supply of ethanol, however, is limited, as is its production capacity. Trade-offs exist between using ethanol in low-level blends to achieve oil savings in conventional vehicles and focusing the supply on providing E85 to push the FFV markets toward critical mass (self-sustainability) as quickly as possible.

4.3.3 Biodiesel

Biodiesel, like ethanol, is a renewable fuel that can be produced domestically from a variety of sources, including vegetable oils and animal fats. It can be used in unmodified diesel engines at low concentrations in blends with conventional diesel fuel (up to B20, which is 20 percent biodiesel). Minor modifications can equip diesel engines to use higher concentrations of biodiesel. Biodiesel provides added safety over conventional diesel due to lower combustibility, and pure biodiesel provides 75 percent reduced carbon dioxide emissions over petroleum diesel. The market share of diesel vehicles is small in light-duty transport, with only approximately 5 percent of the new MY 2004 light trucks powered by diesel and an even lower percentage in passenger cars (ORNL, 2006).

According to EPAct, pure biodiesel (B100) is an alternative fuel, but lower-level blends are not. Due to the Energy Policy Act amended by the Energy Conservation Reauthorization Act of 1998, biodiesel use has grown dramatically in the last few years. Currently, the U.S. Postal Service, the U.S. Departments of Defense, Energy, and Agriculture, many transit authorities, national parks, and public utility companies use biodiesel. Cost-competitiveness of the fuel is assumed to increase relative to conventional diesel according to the economic assumptions used in this report.

4.3.4 Natural Gas

Natural gas fuel is produced primarily from domestic resources, and the U. S. natural gas pipeline infrastructure can deliver the fuel widely across the country (EERE, 2006). Natural gas vehicles boast the lowest emissions of any internal combustion engine vehicle type.

Conventional LDVs can operate on natural gas with minor modifications to the engine and fuel system. Natural gas also reduces the life-span of the engine, and reduces the power output of the car by 15 to 20 percent. As of 2005, costs for converting midsize gasoline cars to operate on natural gas were about $3400 per car.

Expansion of natural gas fuel usage in the U.S. is limited by fuel availability, vehicle and fuel prices, vehicle warranties, resale value, driving range, and refueling infrastructure availability; it is not constrained by technical challenges on the vehicle side, except to the extent that technological innovations could improve prices relative to conventional vehicles. Development of infrastructure is the single largest hurdle to increasing use of natural gas AFVs, but, as shown in Figure 4-3, natural gas infrastructure is more developed at present than infrastructure for several other alternative fuels (IEA, 2005).

4.3.5 Electricity and Hybrid Electric Vehicles

In traditional alternative fuels literature, electricity refers only to dedicated electric vehicles powered by batteries. However, battery-powered electric vehicles are commercially available only in very limited numbers; due to a need for technological development, these vehicles are unlikely to have a significant impact in mitigating the impact of an oil disruption.

Battery electric vehicles may not presently be well positioned to contribute to oil savings in the event of an oil disruption, but the technology has been a key driver in development of hybrid-electric vehicles (HEVs). These vehicles use an electric motor to augment power from a gasoline engine, enabling greater gasoline fuel economy to be achieved in certain configurations (NREL, 2006a). U.S. market availability of HEVs has expanded from three models in MY 2004 to thirteen offerings in MY 2007, including both passenger cars and light sport utility vehicles (EERE, 2006).

In the context of a disruption scenario, HEVs can be deployed on the market without the need to develop an alternative fuels infrastructure. They are more costly than conventional gasoline vehicles, but consumers may be more willing to shoulder these costs given the high prices of gasoline during the disruption and the improved gasoline fuel economy of HEVs. The continued reliance of HEVs on gasoline as the sole fuel input may be perceived negatively by some consumers.

4.3.6 Current Alternative Fuel Prices

Demand for (and subsequently supply of) alternative fuels is dependent on the price of the fuel relative to gasoline as well as the cost of the AFV compared to the cost of a conventional vehicle. Table 4-2 summarizes average fuel prices for several alternative fuels and is based on data collected by the U. S. Department of Energy's Clean Cities program during 2006.

Table 4-2: Nationwide Average Fuel Prices (April-June 2006) (EERE, 2006)

Fuel	Price per gallon, $	Price in gasoline-gallon equivalents, $
Gasoline	$2.84	$2.84
Diesel	$2.98	-
CNG	$1.90	$1.90
Ethanol (E85)	$2.43	$3.43
LPG	$2.08	$2.88
Biodiesel (B20)	$2.92	$2.67
Biodiesel (B2-B5)	$2.97	$2.67
Biodiesel (B99-B100)	$3.76	$3.71
*CNG price per gasoline gallon equivalent		

The fuel price provided above is intended to set the current context only. Dynamic shifts in price are almost certain to occur during a severe oil supply disruption, and detailed modeling of the resulting prices is outside the scope of this report. However, it is clear from Table 4-2 that poor price competitiveness with gasoline and diesel is currently a barrier to alternative fuels market growth. The economic assumptions made in this report suggest that prices of alternative fuels will likely improve relative to gasoline and diesel prices during the oil disruption time frame.

4.3.7 Infrastructure

Support infrastructure for vehicles includes fueling stations, maintenance and repair shops, and related facilities. Here, only availability of refueling stations, a key infrastructure component, is discussed. Extensive fueling infrastructure for conventional gasoline-powered vehicles has been developed over the past century, but there is no comparable infrastructure in place to support AFVs. At present, there are nearly 170,000 gasoline refueling stations in the United States, yet fewer than 5,500 alternative fuel stations are presently operational. Over the years, American drivers have become accustomed to the convenience afforded by ready availability of fueling points for conventional gasoline-powered vehicles, and lack of a similarly ubiquitous alternative fuels infrastructure is a major barrier to mass market acceptance of AFVs.

> There are over 170,000 gasoline refueling stations but fewer than 5,500 AFV refueling stations in the U.S.

Infrastructure development trends show a gradual decline in the number of conventional refueling stations over the past decade. In 2004, the National Petroleum News Survey identified 167,346 gasoline retail outlets nationwide, down from approximately 207,000 operational stations in 1993 (ORNL, 2006). Alternative fuels infrastructure development has made significant progress during the same time period, but the absolute number of stations is still too low to support a sustainable market. There were only 5,020 alternative fuels stations of all types in 2004; this number grew to 5,261 by 2006, a modest but positive step.

Figure 4-3 illustrates relevant trends in alternative fuel infrastructure development, most notably that the number of E85 refueling stations nationwide more than tripled between 2004 and 2006. Biodiesel infrastructure is also expanding, with the number of stations having more than doubled in the same period. Geographical distribution of alternative fuels infrastructure is not uniform; E85 refueling stations are concentrated in the Midwest region (EERE, 2006), and many alternative fuel stations are currently located in metropolitan areas where they service vehicle fleets and may not be available to average drivers (EERE, 2006).

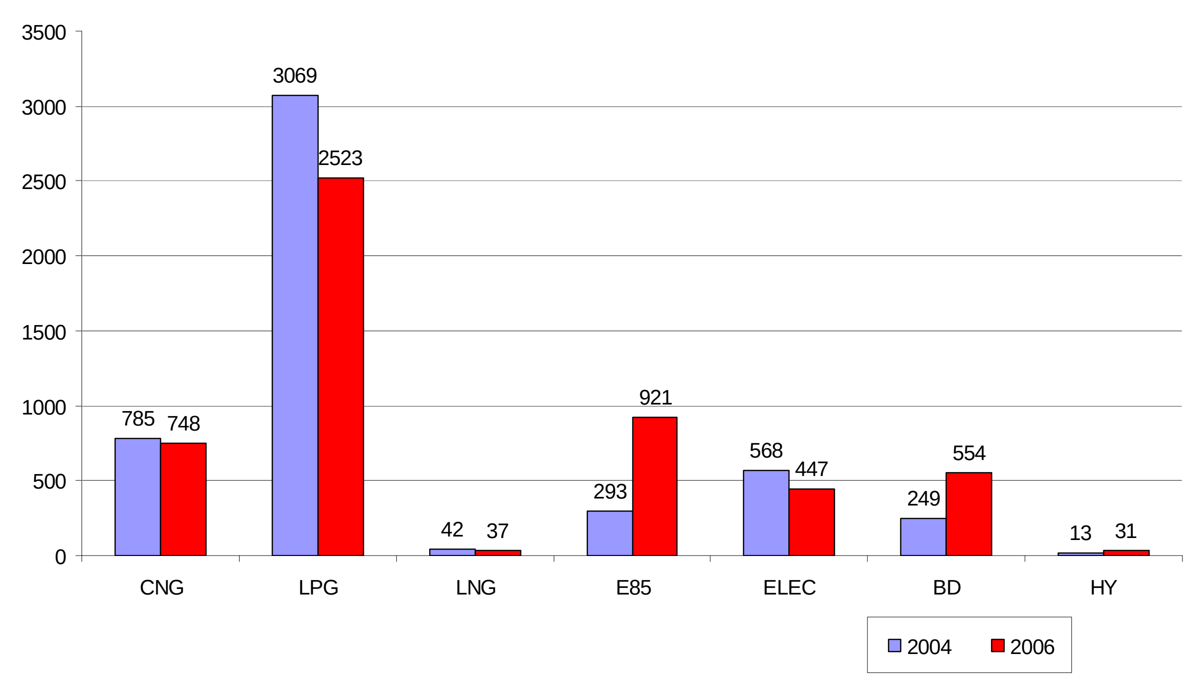


Figure 4-3: Alternative Fuel Stations in the United States by Fuel, 2004 & 2006 From (ORNL, 2006)

4.4 Stakeholders

Transitioning to alternative fuels requires changing many elements of the transportation system: vehicles, fuel production facilities and distribution infrastructure, fueling stations, and other support facilities. Technology development is critical to the process, as are the economic relationships between conventional fuel and vehicle technologies and the corresponding alternative fuels and vehicles. This section examines the relationships between stakeholders involved in the systemic change necessary for alternative fuels transition. An oil supply disruption would result in some dynamic shifts of power and motivation for change; the analysis presented herein assumes a post-disruption state.

Stakeholders in alternative fuels include vehicle users, automobile dealers and distributors, vehicle manufacturers, fuel station operators, fuel suppliers, and various government agencies - primarily at the federal and state levels. (The ability and motivation of local governments to influence system-wide change is negligible.) Table 4-3 illustrates the complexity of an alternative fuels transition by identifying the stakeholders who are critical decision makers for a transition to each of the alternative fuels analyzed in this chapter. The fuels which require specialized, dedicated vehicles and infrastructure (E85 and CNG) predictably involve significantly more stakeholders in transition than the fuels that can be used in existing vehicles or do not have specialized infrastructure requirements (hybrid electric, biodiesel, and low-level ethanol blends). All options require the alignment or cooperative action of multiple stakeholders.

Table 4-3: Critical Decision Makers in the Alternative Fuels Transition[8]

Decision Maker	Alternative Fuel				
	Hybrid Electric	Biodiesel	Ethanol Blends	E85	CNG
Auto manufacturer	X			X	X
Auto purchaser	X			X	X
Auto driver					X
Auto regulator	X			X	X
Fuel producer		X	X	X	
Fuel distributor		X	X	X	X
Fuel station operator				X	X
Fuel regulator		X	X	X	X
Fuel purchaser		X	X	X	X
* X denotes decision makers required to make behavioral changes to allow for a transition to the given fuel.					

The values, resources, influence, and powers of various stakeholders are summarized on the following page in Table 4-4. The blue colored arrow indicates a relative shift from concentrated to diffused influence across the stakeholder categories. The yellow and red arrows illustrate the general right to left trend of decreasing power over the system and other stakeholders. These trends are not without exception, and the values on which they rely are not absolute but relative to other stakeholders. Stakeholder values differ, with clear divisions among those of government, vehicle and fuel suppliers, and end users. Government, especially the federal government, clearly holds the power and has the concentrated influence necessary in the case of an oil disruption.

All transition options within alternative fuels require the alignment or cooperative action of multiple stakeholders.

[8] Matrix adapted from M. Melendez (NREL, 2006b)

Table 4-4: Stakeholders in Alternative Fuels

	Federal Government	State Government	Fuel Suppliers	Automobile Manufacturers	Automobile Dealers	Fuel Station Operators	Vehicle Users
Values/Concerns	Security; economic growth; political price; societal issues	Security; economic growth; political price; societal issues	Maximizing profit; competitiveness	Maximizing profit; competitiveness	Maximizing profit; competitiveness	Maximize profit Minimize upfront and variable costs	Reliability; accessibility; convenience; vehicle safety
Resources	Formal, legislative; regulatory	Formal, legislative; regulatory	Informal, lobbying	Informal, lobbying	Informal; purchasing power	Informal; infrastructure	Informal; purchasing power; votes
Influence	[illegible]	[illegible]	[illegible]	[illegible]	Diffused [illegible] degrees)	[illegible]	[illegible]
Pre-disruption capacity for internal change	Medium	Medium	Medium	Medium	Low	Medium	Medium
Pre-disruption power over other stakeholders	Medium	Low	Medium to low	High	Medium to low	Medium to low	Medium
Post-disruption capacity for internal change	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] medium	High
Post-disruption power over other stakeholders	[illegible]	medium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

4.5 Barriers to Alternative Fuel Market Growth

Increasing the market share of alternative fuels is a challenging undertaking. Gasoline is deeply entrenched as the primary motor fuel in the American way of life and economy. Throughout the United States, gasoline production and distribution infrastructure is well-developed, and the vehicle fleet is overwhelmingly equipped to operate using gasoline. Transition to use of alternative fuels in the U. S. transportation sector thus faces many challenges arising not only from the difficulties of alternative fuels market but also from the powerful interests of corporations and consumers vested in the conventional gasoline fuel economy.

A range of barriers must be overcome for a successful transition to alternative fuels. In "Transitioning to a Hydrogen Future: Learning from the Alternative Fuels Experience," M. Melendez of the National Renewable Energy Laboratory (NREL) examines many of the issues encountered in deployment and market commercialization of alternative fuels and analyzes results of a survey of experts in the field (NREL, 2006b). The following is an ordered list of the top five barriers to alternative fuel commercialization, as identified in this report:

Table 4-5: Barriers to Commercialization of Alternative Fuels

Barrier	Description
Availability of alternative fuel infrastructure	There are 770 natural gas stations and 550 E85 stations in the U.S., but there are more than 170,000 conventional gas stations nationwide.
High cost of constructing infrastructure	Adding E85 pumps to existing gas stations costs only a few thousand dollars, but a natural gas refueling island can cost up to $1 million. The low market demand for these fuels can make such investments difficult to justify economically, as profits are hard to achieve.
Availability of AFVs	Compared to approximately 1,000 conventional fuel vehicle models available in the U.S. in a given year, there are currently only about 20 models of AFVs. Selection is limited, and absolute numbers of AFVs are also low compared to the total number of vehicles sold.
Inconsistent public policy and leadership messages	The transition to alternative fuels can be cast in several different ways, and each carries its own set of specific priorities. Complex issues are further complicated by shifting political goals and corresponding funding fluctuations.
Higher cost of purchasing AFVs	Although long-term operating costs may be lower than for conventional vehicles, initial capital investment in an AFV is significantly higher than for conventional vehicles (10-15 % higher for a natural gas vehicle). Consumers often base decisions on up-front costs rather than on more abstract life-cycle costs.

These are current barriers and do not reflect the changes to the market incentives and stakeholder motivations that would occur in the context of a major oil supply disruption. The two cost-related barriers above – high cost of infrastructure development and higher cost of purchasing AFVs relative to conventional vehicles – are likely to change most dramatically in the event of an oil disruption because higher gasoline prices will reduce the economic advantages of using conventional gasoline-powered vehicles. If gasoline prices rise above alternative fuel prices – and are perceived to be likely to remain high for some time – then incentives for consumers to purchase higher-cost AFVs increase. Subsequently, the increasing market penetration of AFVs will make higher levels of investment in alternative fuel infrastructure more economically viable.

Achieving a sustainable market for any alternative fuel requires adequate levels of supply and demand - more specifically, availability of fuel and fueling infrastructure on one hand and availability of AFVs on the other. Together, these two barriers form a case of the classic "chicken or the egg" dilemma. This dilemma is hugely important in the transition to alternative fuels, and, unlike the economically-driven barriers, barriers arising from absolute lack of vehicle and infrastructure availability are unlikely to change significantly during a disruption. Currently, the development of AFVs is hindered by the lack of infrastructure to support such vehicles on the road, yet the development of infrastructure is lagging largely because of low demand due to the low number of AFVs on the road.

Flexible fuel vehicles (FFVs) are part of an innovative strategy that has the potential to solve the "chicken and the egg" dilemma and help ease the transition to E85 ethanol fuel, although the numbers of such vehicles actually on the road remain limited. Almost all FFVs still use gasoline as the primary fuel, but they are fully capable of running on alternative fuels, primarily E85. Thus, in the event of an oil supply disruption, adding fueling infrastructure would be easier because of the demand stimulated by idle capacity of AFVs in the existing vehicle fleet. According to the U.S. Department of Energy, approximately 5 million FFVs were in the hands of drivers by 2005 (EERE, 2006).

> Consumers will not demand, or buy, alternative fuel vehicles (AFVs) unless there is an infrastructure in place to support those vehicles. However, fuel distributors and retailers have no incentive to invest in alternative fuel production and stations unless drivers using alternative fuel vehicles create a demand for that fuel. The need for stakeholder alignment and coordination to overcome this barrier is a potential motivation for government involvement in alternative fuels industrv.

Another significant barrier to success in an alternative fuels transition is inconsistent public policy. The process of developing any alternative fuel supply and stimulating market demand is incredibly complex, with no single actor able to completely drive the process. Thus, strong policy coordination is vital.

4.6 Technology and Policy Interactions

This section briefly analyzes the technology and policy interactions embodied in each of the alternative fuel transition barriers identified in the previous section. Each constraint is classified as major if its linkage to the interaction is strong or minor if its ability to instigate change is marginal or secondary to another constraint; no modifier is applied if two or more constraints contribute similarly to the barrier.

1. **Availability of alternative fuel infrastructure**

   Major Constraint: Policy/Economics

   The chicken or the egg dilemma is unlikely to be solved without clear policies, especially in the short time frame and chaotic markets of an oil supply disruption. The need to develop infrastructure in parallel with fuel supply and AFVs makes alignment of the multiple stakeholders critical to a timely solution. A number of policy options exist, ranging from creating economic incentives to mandating a minimum level of alternative fuel infrastructure availability (by requiring, for example, that fuel station operators maintain at least a specified ratio of E85 fuel pumps to conventional fuel pumps).

2. **High cost of constructing infrastructure**

   Major Constraint: Policy/Economics

   Infrastructure development is naturally a capital-intensive undertaking. Without developed markets for alternative fuels, economic risks to infrastructure developers are high. Furthermore, as long as the gasoline economy maintains its current strength and growth, there is little incentive to diversify fueling infrastructure. Presently, public policies, including subsidies and other incentives to encourage investment, are necessary to overcome this barrier; indeed, the federal government currently offers a tax credit of up to 30 percent of alternative fuel infrastructure development costs, capped at $30,000[9].

   In an oil disruption scenario that significantly reduces availability of gasoline and increases demand for alternative fuels, the economic incentives for investment in new infrastructure improve, but policies may still be useful to push to development toward sustainable, critical mass levels.

   Minor Constraint: Technology

   One component of the high cost of infrastructure is the higher cost of the technology for alternative fuel stations relative to conventional gasoline stations. Improving technologies to make alternative fuel infrastructure more price-competitive with conventional gasoline refueling infrastructure would help overcome this barrier.

3. **Availability of AFVs**

   Major Constraint: Policy/Economics

   Since EPAct, progress has been made through policy; however, there has not been an aggressive policy push to achieve critical mass that leads to a sustainable and growing market share. The market experimentation model has been successful in encouraging development of AFVs in the absence of an urgent time constraint, but in a time-critical disruption, clearer, targeted policies might more effectively move the market toward significant adoption of AFVs. Coordination with infrastructure developers is critical to overcoming this barrier.

[9] Alternative Fuels Data Center

Minor Constraint: Technology

While some AFVs have become price competitive with conventional vehicles as technologies have improved, factors such as reduced driving range per unit of fuel continue to plague some AFVs. Technological developments would improve marketability of these vehicles, likely leading to increasing number of AFVs supplied.

4. **Higher cost of purchasing AFVs**

Constraint: Technology and Policy/Economics

Hybrids electric, natural gas, and other AFVs tend to be more expensive, and consumers generally shy away from incrementally higher up-front investment costs; life-cycle savings costs are less certain than the high cost of initial purchase and are often discounted in consumer buying decisions. Reduction in the cost of AFVs through technological change is expected, but will take time. In the meantime consumers can be encouraged through policy measures such as tax incentives.

In the context of an oil disruption and rising gasoline prices, the life-cycle savings afforded by AFV use will increase and may partially or completely offset the higher investment costs in consumer buying decisions. (Heightened fears and uncertainty associated with the disruption are also factors.)

5. **Inconsistent public policy and lack of clear leadership**

Constraint: Technology and Policy/Economics

Diversity of technological choice and lack of a clearly superior technological alternative has impeded the emergence of a consistent, targeted public policy. Conversely, lack of consistent policy has continued to encourage parallel development of technologies and has impeded the emergence of a single, superior technology. While exploration of various technologies is a valuable enterprise in the long run, in the context of an immediate need for savings it could have a detrimental effect on overcoming other barriers such as the need for critical mass within certain alternative fuel markets.

While the state of technology has affected formulation of clear public policy in a business as usual, incremental change environment, technologies have developed to a point that clear policies can reasonably expected to achieve oil savings in a severe disruption scenario.

In the previous section, the federal government was identified as the stakeholder with the greatest capacity to influence other stakeholders and effect systemic change. In a serious disruption scenario in which society needs to move quickly to reduce consumption of oil, the need for effective leadership and direction in alternative fuels will be even more important. The potential benefits – as well as potential costs – of decisive action by the federal government increase as well.

4.7 Policy Options and Implementation Considerations

The federal government can respond to the disruption scenario in multiple ways. Three broad courses of action are presented below in Table 4-6: no government action, government support for all possible or potential avenues to achieve savings through alternative fuels, and targeted allocation of government resources to one or more potential savings options.

Table 4-6: Analysis of Options

Policy Option	Pros	Cons
No government action	• No direct cost to government. • Stakeholders experience only natural market pressures to make investments in alternative fuels. • Self-interested actors are free to maximize profit. • On a macro-level, market efficiency is maximized. • Liberty of individual actors is maximized within the constraints of market behavior.	• Volatility and uncertainty of market makes coherent action unlikely. • Lack of alignment among stakeholders persists. • Long-term sustainability of widely dispersed initiatives is questionable. • Stakeholder equity is not guaranteed. • Lack of strategic direction and market volatility may result in negative and unforeseen consequences.
Government support for all possible savings in alternative fuels; no screening of options[1].	• Maximum short term market penetration of alternative fuels. • Development of all options continues, minimizing chance of unintentional elimination of potentially valuable options. • Infusion of government resources into alternative fuels markets may offset some conventional economic losses.	• As above, lack of coordination may impede sustainable, long-term change. • Investment efficiencies not guaranteed. • Potential economies of scale for specific alternatives are not exploited. • Reallocation of funds by the government will result in lower investment in other sectors (opportunity costs of investment).
Government allocates resources to specific savings options.	• Careful selection of options can maximize opportunity for long-term market penetration. • Coordination enhances the potential for sustainable transition. • Economies of scale for specific fuels are exploited.	• Viable alternatives may be excluded from targeted options. • Erosion of government authority if other stakeholders negatively perceive government plan. • Short term response may be sub-optimal because of trade-offs with long-term focus. • Reallocation of funds by the government will result in lower investment in other sectors.
[1] – No distinction is made here between government mandating action on all options (top-down) and government freely supporting all initiatives originating from the market (bottom-up).		

If targeted federal government action is assumed (allocation of resources to one or more selected options), a number of evaluation and implementation considerations must be addressed; a few of these are discussed in the following paragraphs. Any portfolio of options supported is likely to be opposed by stakeholders whose interests are not advanced by the plan, and federal policymakers must be prepared to vigorously defend decisions about the state and potential of alternative fuel technologies or pay the political price. Thus, the government must ensure that it has access to enough reliable technical knowledge and advice to efficiently and effectively select the portfolio.

There are numerous trade-offs among specific implementation options. For instance, E85 might be promoted nationally to ensure equitable access to petroleum alternatives for all drivers, but fuel distribution costs increase with distance from the production centers in the Midwest. Focusing on encouraging regional transitions may also improve the chances of attaining critical mass for a given alternative fuel in a given market; attaining critical mass enhances the prospects for long-term sustainability of alternative fuels and reduces the need for continued government subsidies, but regional alternative fuel nodes within an integrated national transportation system may themselves prove to lack sustainability in the long run.

Studies of the alternative fuels transition to date have identified vehicle fleets, especially those operating within a small area proximate to a fleet center of operations as easy targets for AFV penetration[10]. For instance, a police force's vehicles operate mostly within city limits and are rarely or never out of range of police facilities; thus, the same stakeholder (the police force) can purchase vehicles and invest in a fleet refueling station to service its vehicles, overcoming some of the chicken and the egg dilemma. However, many suitable fleets have already transitioned to AFVs, reducing the potential to achieve further savings using only this strategy.

Targeting urban areas over rural areas is another strategy akin to regional or fleet-based promotion of alternative fuels. The concentration of drivers and shorter vehicle trips that characterize an urban area reduce the importance of several of the barriers to alternative fuels transition (such as reduced vehicle range associated with some AFVs); similar issues of creating fuel-differentiated nodes within the transportation system are raised, however.

4.8 Conclusion

Alternative fuels have high per-vehicle oil savings potential, but their impact on an oil supply disruption is limited by the relatively low number of vehicles produced each year and the time required for changes in vehicle technology to impact on-road fuel consumption. Figure 4-4 illustrates the predicted trends in oil savings over the disruption period; no quantification of savings is implied. While short-term savings can be realized by exploiting idle capacity in flexible fuel vehicles, oil savings begin to increase noticeably only after systemic changes have overcome the chicken and the egg problem and AFV production increases have disseminated through dealers to the on-road vehicle population.

While short-term savings potential from transitioning to alternative fuels is limited, a successful transition has significant long-term implications for oil dependency, even at relatively low – but sustainable – levels of market penetration. Barriers posed by multiple stakeholder involvement can be overcome by decisive federal government action in the case of a severe oil disruption.

[10] NREL - Lessons Learned from Alternative Transportation Fuels: Modeling Transition Dynamics

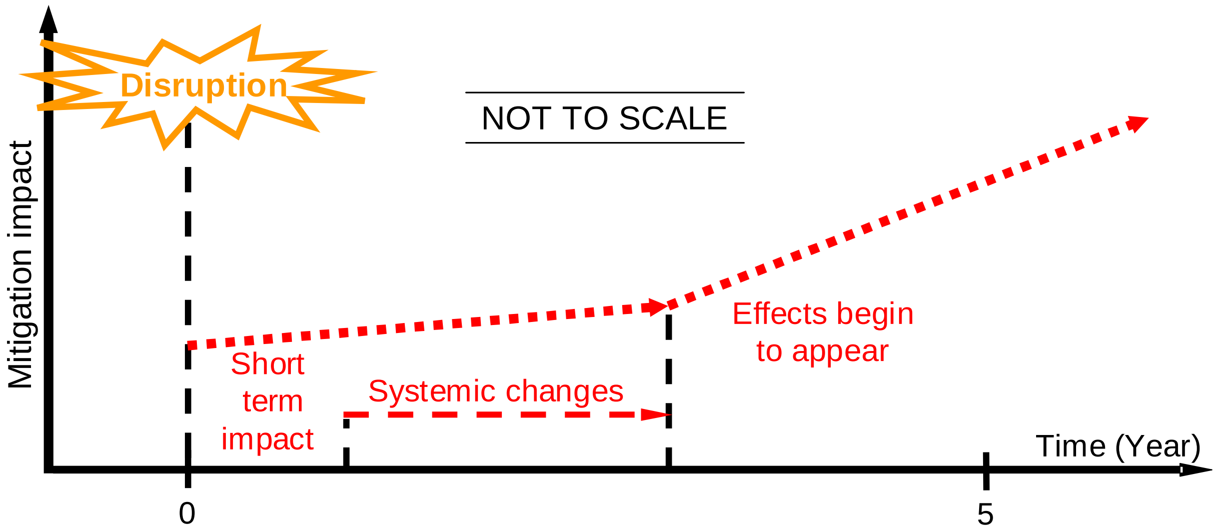


Figure 4-4: Alternative Fuels Impact on Oil Savings Over Time

Chapter 5

Efficient Use of Vehicles

Policy Options

This chapter evaluates the options for reducing oil consumption through increasing the efficiency of vehicle usage. Four main objectives are considered: high occupancy vehicle use, public transportation, speed limit adjustments and increasing the vehicle turnover rate. Through a stakeholder and implementation issues analysis, this section concludes that there is a justification for federal government action in these four areas in the context of the oil disruption scenario.

5.1 Introduction

Due to deployment time of technology-enabled policies, there is a two to three year lag between the oil disruption and returns on technological solutions. In order to balance government response on a time scale, policies that impact the use of the vehicles currently on the road must be considered. This section will assess the barriers to implementation as well as opportunities for action for policy options within efficient use of vehicles.

The opportunities for addressing the oil demand associated with usage patterns are numerous. These options include reduction of traffic through intelligent transportation systems (ITS), decreasing the number of single occupancy vehicles (SOVs) on the road, moving vehicle usage into its most efficient range of 35 - 60 mph and influencing consumers' vehicle purchasing patterns. With the exception of ITS, most of these options require deliberate behavioral changes by the American public. Such changes may be less difficult to implement during the window of an energy crisis, as shown by public response to the 1973 oil crisis and oil prices spike in 1990. Accordingly, the measures investigated in this section are considered as responses to an oil crisis rather than preemptive measures to reduce oil dependency.

A certain amount of change in usage patterns will be the direct result of the price changes in gasoline, however price changes are likely to impact various sectors of the American public in very different ways. For instance, individuals who can afford to switch to a fuel efficient vehicle will do so, whereas low-income individuals may be forced to cut back on driving or find employment near their residences. Mitigating the impact of an oil crisis across a broad spectrum of the American population ensures a greater amount of security for the nation as a whole. The analysis here will focus on an analysis of the stakeholders, distribution of costs and benefits in each area, and also discuss some implementation issues.

5.2 Issue Framing

The overall goal of this report is to ensure national security in the face of an oil import disruption. In previous chapters, the potential to ensure security is presented through the efficient allocation of resources to targeted technologies that reduce U.S. oil consumption. In this chapter, security is viewed through the lens of social stability. Hence, this chapter's central research question is "In the efficient use of vehicles, how can the federal government's response balance the values of security and efficiency while ensuring equitable access to transportation?"

Chapter Research Question:

In the efficient use of vehicles, how can the federal government's response balance the values of security and efficiency while ensuring equitable access to transportation?

There are many avenues for action within the scope of efficient usage of vehicles. Three criteria were used as outline in the decision matrix of Chapter 1: the stakeholders and their interests, the implementation time and cost, and a qualitative assessment of the potential for impact on national oil consumption. Based on this criteria, high occupancy vehicle use, speed limits, public transportation and vehicle turnover rate are identified as areas with potential and are studied in this section.

These four areas are not meant to be an exhaustive list of technologies and policies available, nor are they meant to be seen as ideal in all localities. Several other options exist, such as intelligent transportation systems, telecommuting and congestion pricing, however the options studied here represent ones of national relevance and substantial history of use within the United States. Local initiatives to curb vehicle usage are encouraged in the context of a severe national oil import disruption of this size and length.

5.3 Background and Status of Vehicle Use

In order to elucidate ways to influence modal choice and driving patterns, how and why Americans use their vehicles must be considered. Two extensive documents depict trends and status of vehicle usage: the Transportation Research Board's 2006 report "Commuting in America III" (TRB) and the Transportation Energy Data Book published by Oak Ridge National Lab(ORNL). Relevant statistics are summarized on the following page.

Table 5-1: Trip Statistics by Trip Purpose, 2001 NHTS (ORNL, 2006)

Trip Purpose	Share of Trips	Share of Vehicle-Miles Traveled	Trip Length (miles)	Trip Duration (minutes)
To/from work	22.1%	27.0%	12.1	22.3
Work-Related Business	4.1%	8.4%	20.3	30.9
Shopping	21.1%	14.5%	6.7	14.4
Other Family/Personal Business	24.7%	18.7%	7.5	15.2
School/Church	4.9%	3.7%	7.5	15.8
Medical/Dental	2.2%	2.2%	9.9	20.7
Vacation	0.4%	1.8%	47.4	59.6
Visit Friends/Relatives	6.3%	9.4%	14.9	24.4
Other Social/Recreational	13.7%	13.2%	9.6	18.2
Other	0.5%	1.0%	18.1	31.4
All	99.9%	100.0%	9.9	18.7

Table 5-1 shows that a large number of vehicle-miles traveled are for work-related purposes, specifically commuting to and from work. Aside from work-related purposes, the next largest shares are family or personal business and shopping.

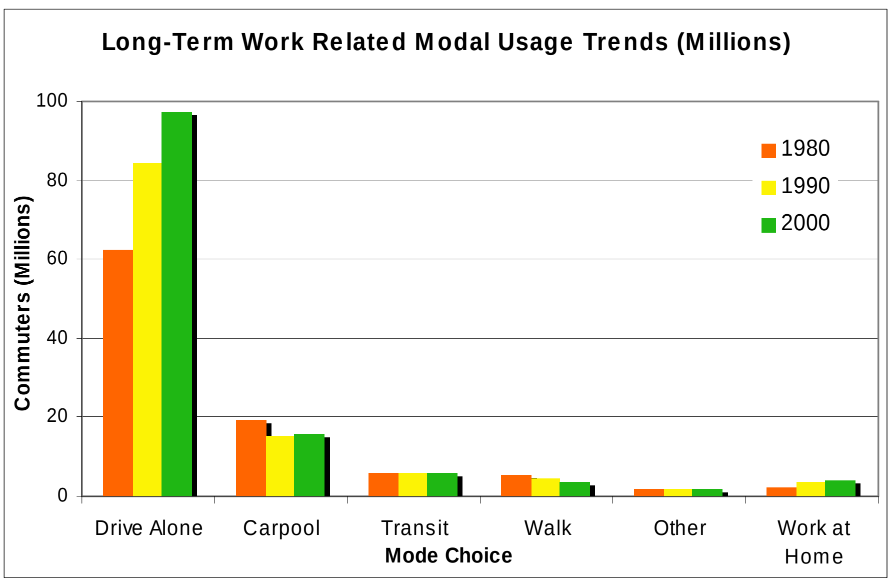


Figure 5-1: Commuting Modal Trends Summary, 1980 – 2000 (TRB, 2006a)

Figure 5-1 shows that an increasing majority of work-related commuting travel is "drive alone". Trends include the small but increasing share of work-at-home activities, as well as the stagnation of drop in carpool numbers – something that is largely attributed to the share of immigrants on the road (TRB, 2006a).

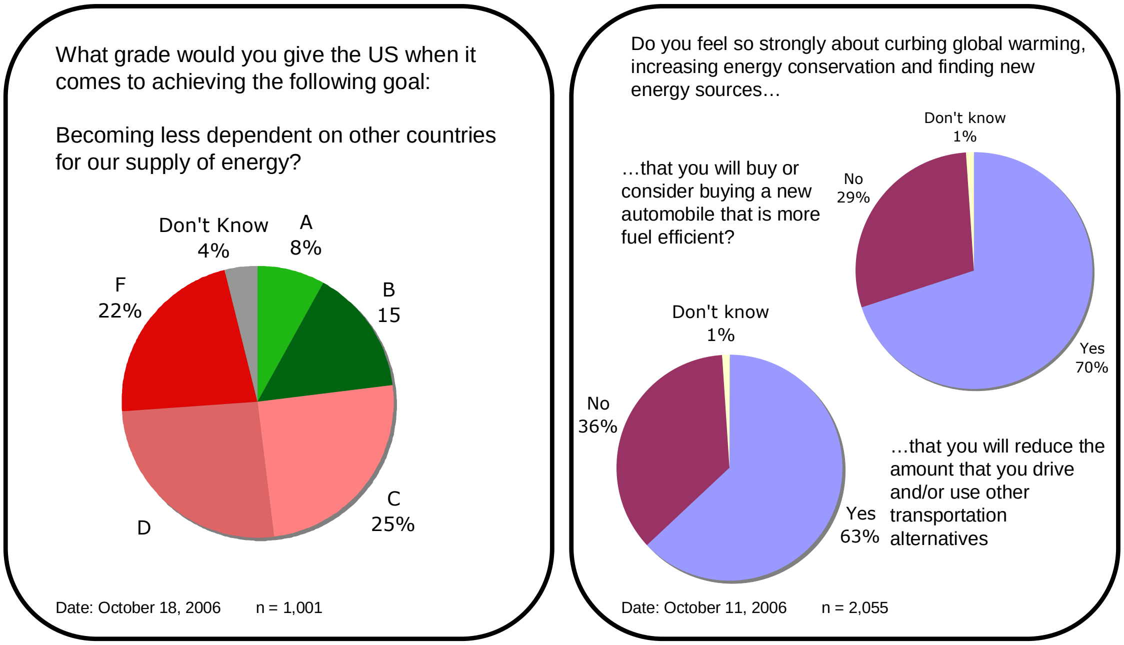


Figure 5-2: Public Opinion (ORC, 2006; PAF, 2006)

A look at public opinion clarifies receptiveness to policy changes in America in the area of vehicle use and energy demand. Few Americans are receptive to stricter mileage standards, 8 ± 3 percent, according to an August 1, 2006 Los Angeles Times Poll (iPOLL, 2006). Figure 5-2 shows that a larger percentage, 73 percent , would give the US government a grade of C or below in ensuring energy independence. Overall, Americans are aware of their energy intensive transportation habits, they are reluctant to accept policies to instigate change. However, in figure 5-2, it is also shown that 70 percent of Americans would consider buying a more fuel efficient car, and 63 percent would consider driving less or shifting to other forms of transportation. It is likely that public opinion would strengthen these views in light of an energy crisis, as it did after the 1973 oil embargo. In order to be favored by the American public, preemptive movements to change vehicle use would require incremental or convenient changes. Reactive measures would have more freedom to restrict and shift modal usage, due to the window of opportunity presented by the oil import disruption.

Single occupancy vehicle (SOV) use accounts for a large and increasing number of vehicle-miles traveled. American opinion shows opportunities for action in usage patterns and vehicle purchasing patterns.

5.4 Policy Options

There are several options that could be implemented in the event of an oil supply disruption that could mitigate the disruption's effects. The options included in this section based on their potential for impact, potential for timely response to an oil import disruption and national relevance. This section outlines each option and discusses the current state of such policies in the United States. These options are presented as examples, not necessarily as recommendations.

5.4.1 High Occupancy Vehicle Policies

Currently, there are 2500 lane-miles of HOV facilities that serve approximately 3 million commuters each day. These facilities are spread over 30 U.S. cities, and are for the most part considered to be underused (TRB, 2006b). HOV lanes have primarily been used as a method of managing congestion in urban areas. In the context of an energy supply shock, HOV policies could be implemented in urban transportation networks without additional construction of facilities, provided the presence of law enforcement on highways was increased legislations were passed in a timely manner.

Using policy measures to discourage single occupancy vehicle commuting and/or encourage ride sharing could affect about 35 percent of energy demanded by light duty vehicles. Such measures would not be unprecedented: during the Second World War the government ran a public information campaign equating single occupancy vehicle use to supporting the Axis powers (NARA, 1943). There are several options open to policy makers: restrictions on SOV travel on highways during rush hour, worksite based incentives for carpooling, increasing cost of parking in urban areas, developing networks to connect ride-sharers to one another. In the policy analysis section, the relative pros and cons of implementation will be discussed.

Several implementation methods exist that would encourage high occupancy vehicle use. These options include but are not limited to:

- Restrictions on single occupancy vehicle use
- Increasing the cost of parking in cities
- Ride sharing networks
- Worksite based incentives for carpooling

5.4.2 Public Transportation

Public transportation is a small but important segment of American transit, accounting for 5.2 percent of trips to work in 2000 (ORNL, 2006). However, transit use has increased by 21.5 percent since 1995, which is a faster rate than highway use (APTA, 2006). Americans have consistently expressed favorable opinions of public transportation, with 67 percent saying they believe expanding public transportation would alleviate traffic congestion (UConn, 2006). There is opportunity to expand access to public transportation: 1 in 4 households lack access to public transportation and half have only limited public transportation service.

Public transportation is also credited with increasing commerce in areas with access to public transportation and enabling mobility of individuals who otherwise would not be able to travel on their own. However, it should be noted that public transportation systems are not self-sustaining, fares only account for 23 percent of operating budgets on average nationally (APTA, April 2006). Nevertheless, in the event of a disruption in oil supply, public transportation could be a viable alternative for many commuters in order to decrease national oil demand. Implementation options include expanding bus routes, developing more efficient usage of public transportation vehicles through intelligent transportation systems or increasing residential density around current public transportation routes. A possible incentive could also be lowered fares for public transportation, however the effect of the oil disruption on gasoline demand would likely transfer many users to public transportation if such routes were available.

5.4.3 Speed Limit

It is known that the most efficient range for vehicle operation is between 40 to 60 mph. Mandating a 55 mph speed limit was a strategy employed in response to the 1973 oil crisis, and could be reenacted in the event of another oil crisis. As shown in Figure 5-3 below, this could increase vehicle efficiency by a maximum of 6.5 mpg. Typical driving patterns estimate that 57 percent of driving is done on highway (EESI, 2006). It also allows for a relatively quick response. Although traditionally the federal government does not set speed limits because that power lies with the states, there is an opportunity for action since there is historical precedence in the oil supply crisis of 1973.

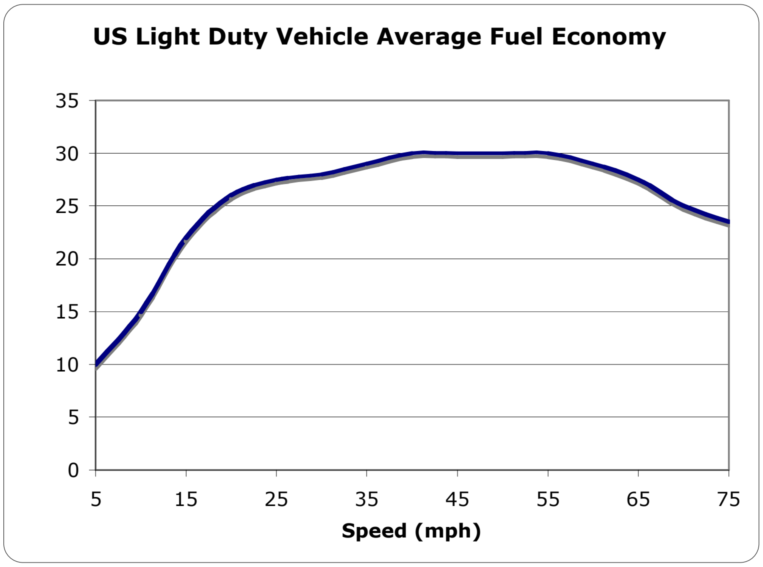


Figure 5-3 US Light Duty Average Fuel Economy vs. Speed (DOE, 2006)

5.4.4 Encouraging Vehicle Turnover

Improving the vehicle turnover rate would help get older, less efficient vehicles off the roads provided that these vehicles were replaced with more efficient models or not replaced at all. As we can see in Figure 5-4, fuel efficiency decreases significantly before 1988. Currently, the average lifetimes of light duty vehicles are 16.9 years and 15.5 years for cars and light trucks respectively (ORNL, 2006). Initiatives in this area could shorten these lifetimes.

An option for implementation is a "Cash for Clunkers" program, where drivers are given cash in exchange for their older, fuel-inefficient vehicles. Such programs are often tied to environmental measures to get polluting vehicles off the roads. There is a moderate history of this type of implementation in the United States: a 1992 Illinois Cash for Clunkers that retired 207 vehicles, and 1993 and 1994 Sun Company initiatives in the Philadelphia area (EPA, 2005). Feebates are another option: tax owners of fuel-inefficient vehicles and use the revenues to offer tax-incentives on new fuel efficient hybrid electric vehicles or alternative fuel vehicles. Taxes on cars that are less fuel-efficient than 22.5 mpg were introduced in 1978 and continue to exist in the U.S. today (Therese Langer, 2005). Feebates have also been introduced at the federal level in various forms starting in 1991 (Therese Langer, 2005). They have been implemented in two states: California and Maryland. An additional option to encourage adoption of more fuel efficient vehicles would be to offer pure financial incentives for purchase. Incentives such as these are in place or on the table at practically all 50 states, as well as at the federal level (UCSUSA, 2006).

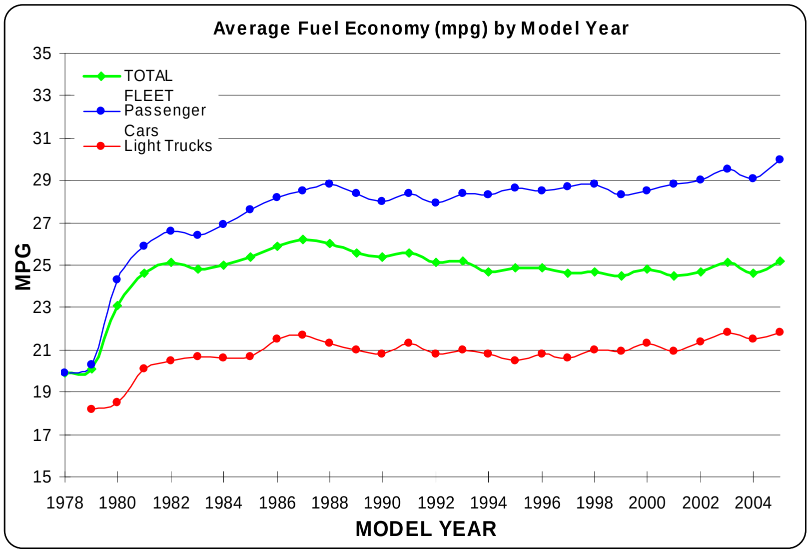


Figure 5-4: Average Fuel Economy by Model Year (NHTSA, 2005)

HOV usage, public transportation, speed limits and vehicle turnover rate are all options with a history of federal action in the United States.

5.4.5 Telecommuting

As illustrated in Figure 5-1, telecommuting/"work at home" is the only mode of commuting that is increasing other than "drive alone." In 2004, the Employment Policy Foundation found that 65 percent of American jobs are amenable to telework and approximately 19.8 million Americans telecommute to work (EPF, 2004). Increases in share of teleworkers would directly decrease oil consumption and indirectly decrease oil consumption by reducing travel times of all commuters. The federal government has a history in this arena since it has mandated telework implementation for federal agencies. However, the limited ability to deploy such policies widely puts this option outside the scope of this report.

5.4.6 Congestion Pricing & Intelligent Transportation Systems

Congestion pricing and intelligent transportation systems are areas with strong potential for reducing traffic on U.S. interstates in urban areas. However, the broad number of options that are specific to local networks created difficulties when looking at an oil disruption scenario from the federal level. Though the federal government does have history in intelligent transportation systems, it is mostly in funding research and development, and less on the implementation side. This is why this option is not considered herein.

5.5 Policy Analysis

In policies that depend on behavioral change much is contingent on the stakeholders involved. What follows here is a stakeholder analysis across all options as well as stand-alone discussion of each of the potential policies. Finally, there is a discussion of issues involved in combining these options.

5.5.1 Stakeholders Analysis

Table 5-2 shows the various stakeholders involved in efficient use of vehicles policies. This list is not exhaustive but is comprised of those stakeholders that are the most significant. Also shown are the interests of each stakeholder, as well as their receptivity to each of the proposed policies. Federal and local governments are not assessed in the receptivity matrix due to the ambiguous nature of their response in the context of the oil disruption scenario.

Table 5-2: Stakeholder Receptivity Chart in Efficient Use of Vehicles

Stakeholders			Interests	HOV Policies	Public Transportation	Speed Limit	Vehicle Turnover Rate
Concentrated	Government	Federal Government	National security, economic stability, funding large projects	~	~	~	~
		Local Governments	Local economic stability, funding and management of projects, revenues from fines	~	~	~	~
		Law Enforcement Forces	Increased workload	-		-	
	Industry	Auto Manufacturers	Economic – revenues		-		+
		Fuel Suppliers	Economic – revenues	-	-	-	-
		Local Commerce & Employers	Economic – revenues, need for parking infrastructure	+	+		
		Local Vehicle-based Commerce – (Gas Stations,etc)	Economic – revenues	-		-	
	Public	Vehicle Commuters	Lifestyle changes, convenience, economic	-	+	-	+
Diffuse		Non-Drivers	Lifestyle changes, convenience, economic		+		

As can be seen in the table above, most stakeholders are receptive to public transportation. This is most likely because majority of costs for public transportation are carried by federal governments, local governments and thus indirectly by taxpayers. HOV policies and vehicle turnover rate show moderate receptivity, while restrictions on speed limits show the least potential in terms of public reception. It is also shown that the majority of favorable opinions about each of the options occur in the more diffuse, less easy to mobilize stakeholders.

5.5.2 HOV Policies Analysis

There are several stakeholders when it comes to HOV policies. Any regulation that encourages or mandates HOV use highly impacts both vehicle and non-vehicle commuters, law enforcement forces, urban parking garages and gas stations, as well potentially generating revenue from fines for the state government, benefiting local taxpayers. In the following table, a brief summary of the issues with HOV policies is provided.

Table 5-3: HOV Policies Summary

HOV Policies

Pros	Methods of Implementation	Cons
Regulations and incentives can be relatively quick changes to implement	Mandate – regulations on SOV use	Commuters resistant to restrictive measures
Ability to impact a large number of commuters and thus VMT		Additional strain on law enforcement
Those impacted the most, commuters, are a relatively diffuse stakeholder set		Infrastructure development can be lengthy and costly
With the price response of gasoline to oil import disruption, incentive to drive alone will decrease	Incentives – financial or time benefits for HOV commuters	Cost of incentives
Regulations on SOV use require little additional funding other than training and compensation of law enforcement		Could be successful in short-term but long-term conversion of SOV commuters to HOV commuters unlikely
Could shift several commuters to public transportation	Infrastructure – creating lanes/facilities designated for HOV use	If public transportation is not prepared to take on additional users could be a capacity overload on the system
General decrease in traffic and congestion on the road		

As can be seen in Table 5-3, there are several issues to take into account when considering HOV policies. Implementation is key: Infrastructure construction is lengthy and may not be effective without restrictive policies on SOV use. Strict regulations would be controversial with the American public, but show great potential for impact. Incentive arrangements would be difficult to put into practice, and ride sharing networks have been used with unclear success. Generally, these policies would impact suburban populations to a greater degree than urban or rural residents. These are all issues to take into consideration when employing these policies.

5.5.3 Public Transportation Policy Analysis

Public Transportation has a clear advantage when it comes to public opinion. Many American commuters are in favor of more reliable & extensive public transportation networks, especially with the increases in commuting times due to increased congestion. The table that follows summarizes key points in considering public transportation as a response to an oil import disruption in the U.S.

Table 5-4: Public Transportation Policies Analysis

Public Transportation		
Pros	**Methods of Implementation**	**Cons**
Regulations and incentives can be relatively quick changes to implement	Build capacity: acquire additional buses	Not a self-sustaining operation
Ties to other forms of transportation – as personal vehicle commuting becomes less desirable, use of public transportation will increase	Build infrastructure: develop additional rail lines and buses, park and ride facilities	U.S. bus manufacturers would have difficulty in production capacity, restrictions on outsourcing bus production
Provide mobility to otherwise non-mobile individuals – rural access, the elderly, and physically challenged	Provide incentives: fare decreases	Economic cost of reducing fares in an already net-loss industry
Public favorability high	Restrictions on other forms of commuting: HOV policies	If public transportation is not prepared to take on additional users there could be a capacity overload on the system

As shown in Table 5-4 above, there are some clear benefits in public transportation for the general public in the context of an oil disruption. As driving becomes less favorable due to the price change of gasoline during an oil disruption, people will be looking to switch to other forms of transit and it is critical that there be other options available. This also forms a balance with more restrictive measures, both in that it offers commuters an alternative, and also in that rapid bus transit would benefit directly from the decrease in congestion on the highways. Implementation is an issue only in that acquiring the infrastructure needed to increase service will be challenging in the oil disruption scenario.

5.5.4 Speed Limit Policy Analysis

Speed limits are possibly the quickest and easiest option to implement of the four considered here. In the 1973 oil crisis, they were applied through federal mandate, with the threat of withholding highway funding from noncompliant states. As can be seen in Table 5-5, the problem with speed limit policies is the difficulty in enforcement. Also, given the use of this policy in response to the 1973 oil crisis, there is a small but important segment of the belief that this policy was moderately ineffective at conserving oil. However, if proper enforcement is attainable this should be a viable option.

Table 5-5: Speed Limit Policies Analysis

Speed Limit

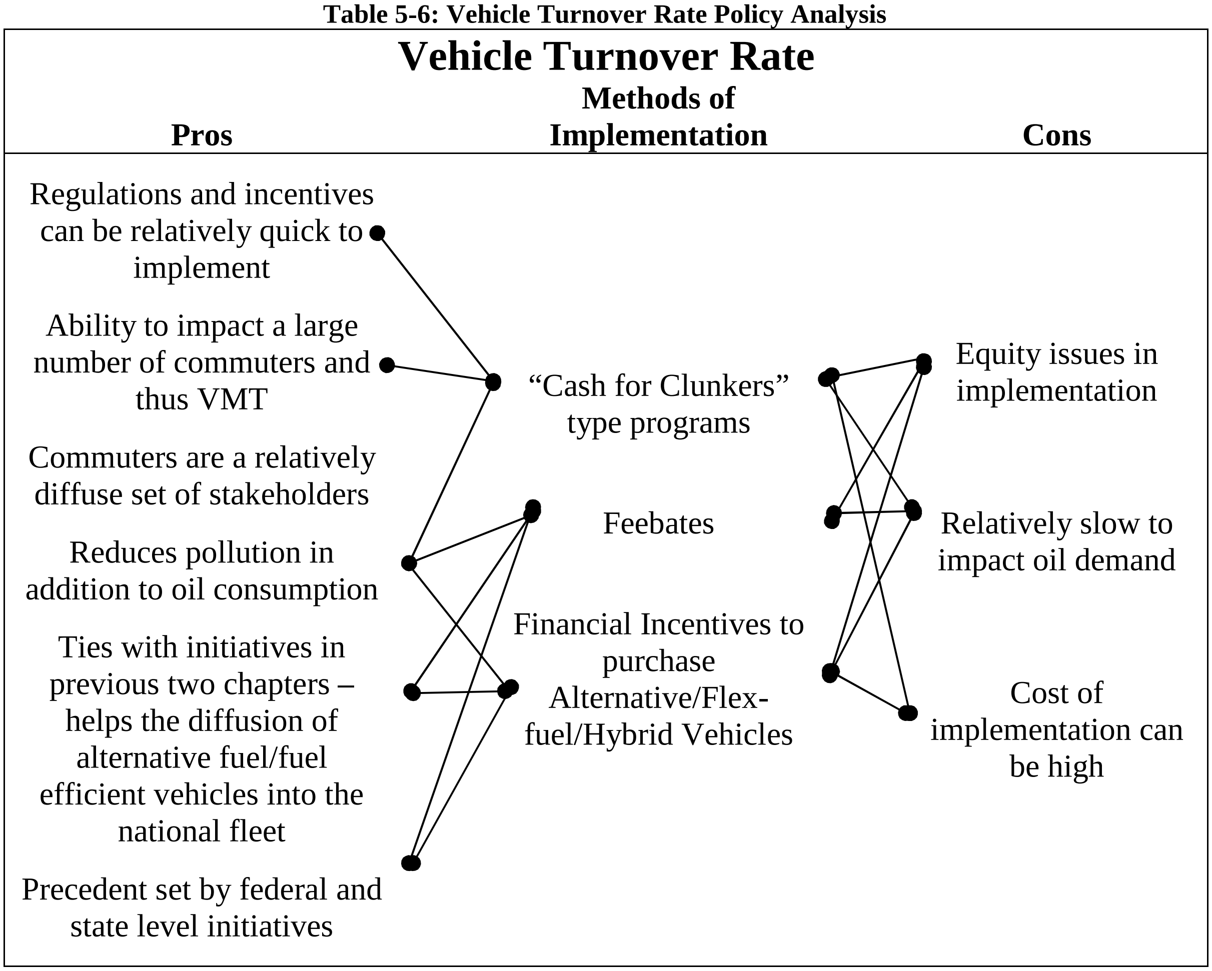
Pros	Methods of Implementation	Cons
Regulations and incentives can be relatively quick changes to implement	Mandate: federal regulations on speed limits	Commuters resistant to restrictive measures
Ability to impact a large number of commuters and thus VMT	Incentives: create financial incentives for state regulations on speed limits	Additional strain on law enforcement
Commuters a relatively diffuse stakeholder set		There is debate on how effective this measure was during the 1973 oil crisis
Precedent set by speed limit regulations during the 1973 oil crisis		

5.5.5 Vehicle Turnover Rate Policy Analysis

The equity issues in the implementation of increasing the vehicle turnover rate are significant. “Cash for Clunkers” programs aid low-income individuals, who may not otherwise get rid of their old vehicles. However, since financial incentives are often low, these individuals typically purchase used cars, which would keep inefficient vehicles on the road rather than replacing them with new, flex-fuel or hybrid options.

Feebates pose similar challenges – by taxing individuals with old inefficient vehicles, lower income individuals are targeted and then subjected to fines while higher income individuals receive the benefits. The other option of implementation of feebates shows more promise: taxing individuals who choose to purchase high-performance, fuel inefficient sports cars while offering rebates to individuals who choose to purchase new hybrid or flex-fuel cars. However, both feebates and simple rebates offer the same issue: they do not take into account populations that cannot afford to purchase new cars in the first place. However, this option is somewhat more promising because it reinforces the options put forward in Chapter 3 and Chapter 4: aiding technological diffusion into the on-road vehicle fleet.

Table 5-6: Vehicle Turnover Rate Policy Analysis



5.6 Conclusion

This chapter assessed four avenues for federal action in the efficient use of vehicles: HOV policies, public transportation, speed limits and vehicle turnover rate. The flexibility in the deployment of these options allows for action in the time lag before the technological solutions of alternative fuels, Chapter 3, and vehicle fuel efficiency, Chapter 4, can be deployed. It is also shown that certain options have strong links with one another. For instance, HOV implementation has a clear link with public transportation in attaining liberty for commuters and equity of opportunities to travel from one area to another. Links such as this are powerful tools when choosing a set of actions to take in a oil import disruption. The downstream nature of the options included in this chapter force consideration of all American citizens and how each may be impacted by an oil import disruption, unlike previous chapters.

The decision tree analysis outlined in Chapter 1 and Figure 5-5 below enabled the consideration of each of these options, informing the conclusions during analysis. This tool is shown to be a useful framework in shaping the portfolio of policies.

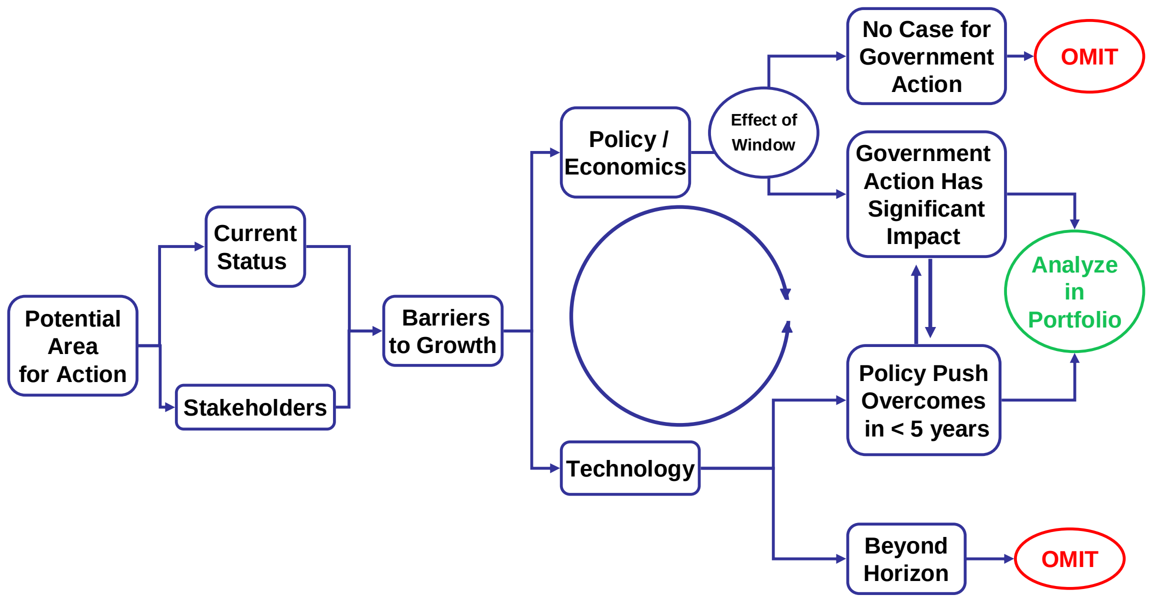


Figure 5-5: Decision Tree

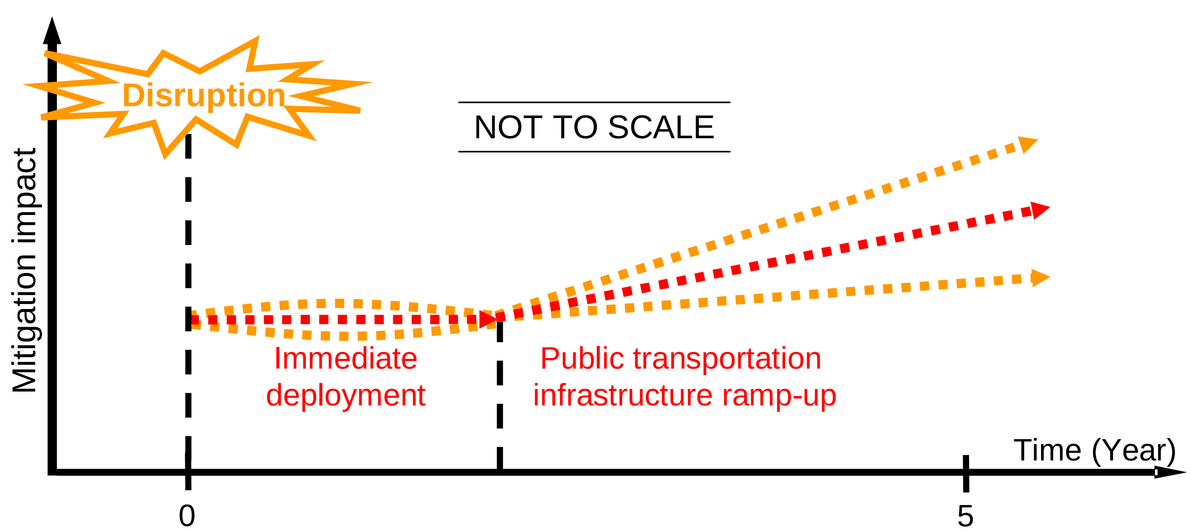


Figure 5-6: Timeline of Policy Deployment in Efficient Vehicle Usage

Chapter 6
Conclusion

This report develops policy options for the federal government within light duty vehicles (LDVs) to mitigate a 5 year sustained U.S. oil imports curtailment. The policy options were selected under three broad action avenues chosen through a qualitative impact driven decision analysis. The three avenues of action were vehicle fleet efficiency, alternative fuels, and efficient usage of vehicles.

The dynamic stakeholder analysis revealed that in the event of a sustained oil disruption there might appear a leadership and oversight gap that only the federal government will have the authority, power and influence concentration to fill. In the case of a sustained 5 year disruption it is the federal government that could most easily balance the trade-off between long-term sustainable gains versus short term benefits. Further, the social concerns emerging due to the oil disruption fall under the responsibilities of the government irrespective the oil curtailment scenario.

In the American political system, the federal government has legitimate authority to direct response to a national crisis, but it must be cautious of the fragility of its credibility. If the initial policy response has detrimental effects towards alleviating U.S. oil dependence, the credibility of federal government will erode. Policies may have such detrimental results either due to a misplaced focus or due to poor implementation. A misplaced policy focus may be a result of experimentation with unproven technologies or overinvestment in incentives such as tax credits that have a high opportunity cost in terms of resource allocation. It is in this light that the federal government may want to avoid experimentation in unproven technologies and choose options which have proven performance record such as E-85 in alternative fuels, CAFE standards in vehicle fleet efficiency, and public transportation in efficient usage of vehicles. These are considerations that the federal government should take into account when developing a policy response.

6.1 Balance of Policy Portfolio

The portfolio of policy options presented in this report aims to enhance U.S. security through a set of technological and policy options that have a two pronged balance; balance in terms of values and balance with respect to time frame.

The value balance between efficiency and equity to achieve overall national security is seen in the portfolio in two ways: alternative fuels and enhancements in vehicle fleet efficiency aim at achieving efficient allocation of resources, and behavioral shifts in vehicle usage aim at achieving equitable access of opportunities to the vehicle users.

As shown in Figure 6-1, the time frame balance is sought through a set of short, medium and long term options. The policy portfolio includes options that have a long term impact due to systemic changes such as development of public transport infrastructure, development of alternative fuels infrastructure and changes in vehicle manufacturing lines. These policy options will have no impact roughly until the first three years after the disruption. After three years they will gradually ramp up as the infrastructure develops and technologically efficient fleets penetrate.

The portfolio includes policy options that have a short to medium term impact such as switching the 5 million flex-fuel vehicles already on road to alternative fuels, production of lighter vehicles through CAFE mandate, and behavioral changes towards more efficient use of vehicles and means of transportation. Behavioral changes have an immediate implementation ability as seen in HOV policies and speed limit. These short term options have flexibility in terms of their implementation. Such flexibility was intentional, allowing for contextual factors to determine how best to implement each option. Policies inducing behavioral change also have a long term impact through development of public infrastructure and vehicle turn over.

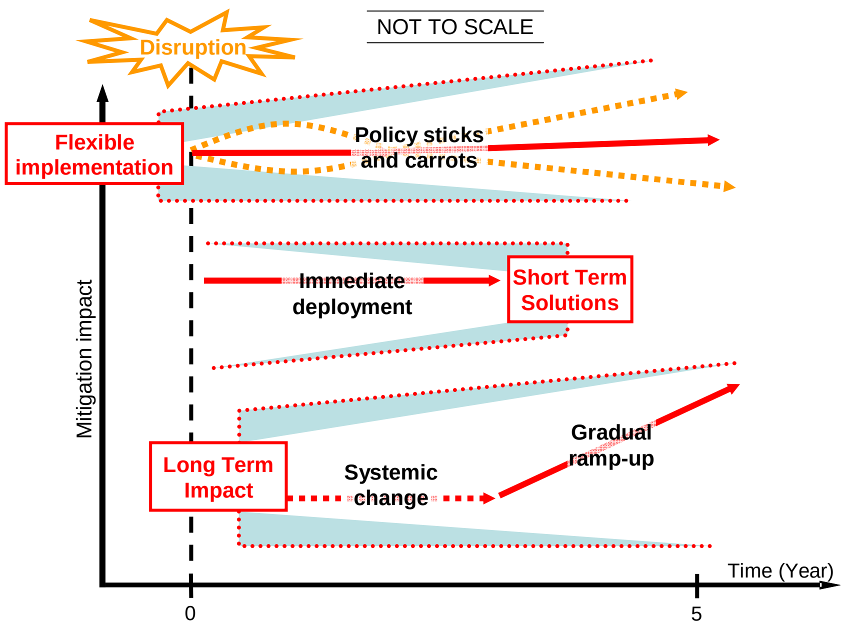


Figure 6-1: Policy Implementation Timeline

6.2 Report Contribution

Although a portfolio of policy options is presented within this report, the added value of this study is the methodology that was used to develop these options. Any framework operates amongst many contextual factors that are uncertain when performing preemptive analyses. The framework presented below in Figure 6-2 should be seen as a tool that can better inform policy makers in their decisions, but should not stand independent from analyses of other windows such as administration changes, the level of credibility of the government and standard economic cycles.

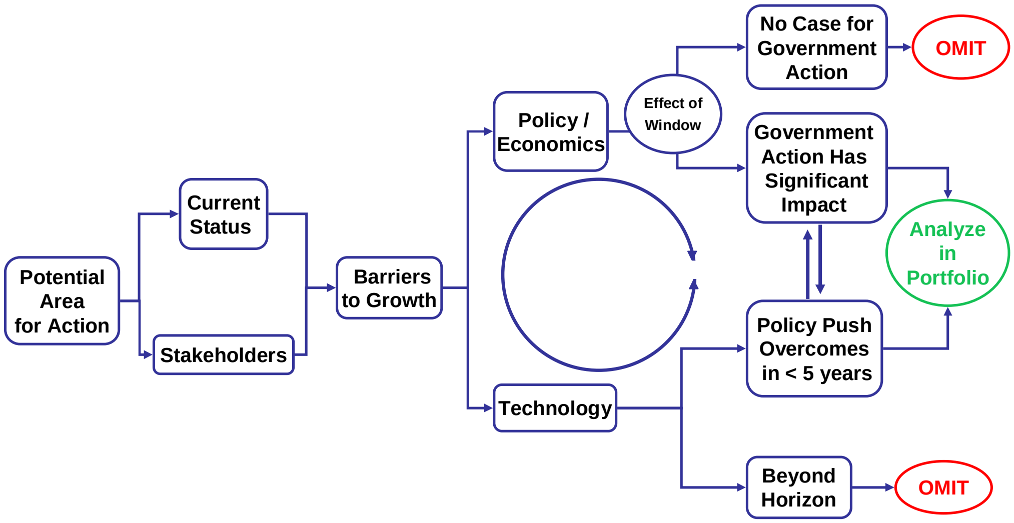


Figure 6-2: Decision tree to build our portfolio of options

6.3 Areas of Further Research

This project is a federal response and the policy options provide a broad analysis. While this report provides a qualitative policy analysis, a quantitative assessment of each policy option's technical replacement capacity would be a valuable area of future research.

Also, this report is written from the vantage point of the federal government. There is a substantial amount of research associated with local level initiatives that could further elucidate the United States' ability to cope with a major oil import disruption and aid local governments in the context of response.

Appendices

Figures

Tables

Acronyms and Abbreviations

ACEEE	American Council for an Energy Efficient Economy
APU	Auxiliary power unit
B100	Transportation fuel with 100% bio-diesel
B2	Transportation fuel with 2% bio-diesel and 98% conventional diesel
B20	Transportation fuel with 20% bio-diesel and 80% conventional diesel
Bbl	Barrel
Bbl/d	Barrel per day
BTU/Btus	British Thermal Unit (1 BTU = 1,055.06 J = 0.293 Wh)
CAFE	Corporate Average Fuel Economy
CAFE	Corporate Average Fuel Economy
CALSTART	Non-profit organization that works with the public and private sectors to develop advanced transportation technologies.
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CARB Diesel	Diesel fuel that meets specifications set by the CARB
CCGT	Combined-cycle gas turbine (power generation plant)
CEQA	California Environmental Quality Act
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CTL	Coal-to-liquids
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
E85	Alcohol fuel blend containing of 85% ethanol and 15% gasoline
EEA	Energy and Environmental Analysis Inc.
EIA	Energy Information Agency (U.S. Department of Energy)
EPA	U.S. Energy Protection Agency
EPACT	Energy Policy Act of 1992
EV	Electric vehicle
FCV	Fuel cell vehicle. A fuel cell is a device that converts fuel into electrical power through an electrochemical reaction. Hydrogen Fuel Cells convert hydrogen (H_2) and oxygen (O_2) into electrical power.
FFV	Flexible fuel vehicle
FreedomCAR	Cooperative Automotive Research Initiative sponsored by the U.S. Department of Energy
GTL	Gas-to-liquids
GVWR	Gross Vehicle Weight Rating
H_2	Hydrogen
HDVs:	Heavy-duty vehicles. Generally defined as vehicles that weigh over 10,000 pounds, this category includes medium and heavy-duty trucks and buses. A much smaller number account for passenger transport.
HOV	High Occupancy Vehicles
Hybrids	Gasoline-electric hybrid vehicles

ICE	Internal combustion engine
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle (power generation plant)
Jones Act	Fleets loaded at a U.S. port that sail to another U.S. destination must be shipped on a domestic flag vessel in accordance with federal law.
LDVs	Light Duty Vehicles
LNG	Liquefied natural gas
LPG	Liquefied petroleum gases
MBTU	Million British Thermal Unit (1 MBTU = 1,055.06 MJ = 293.08 kWh)
MMBD	Million Barrels per Day (1 Barrel = 42 Gallons = 6.29 Cubic Meters)
MY	Model Year (CAFE standards)
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic Safety Administration
NRC	National Research Council
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
ORNL	Oak Ridge National Laboratory
OTA	Office of Technology Assessment (U.S. Congress)
Quads	Quadribillion BTUs
SNG	Synthetic Natural Gas, a mixture of petroleum or synthetic gases with air that reaches the same calorific value as methane, which allows it to be used within the same infrastructures.
SUVs	Sports Utility Vehicle
Syngas	A synthetic gas created through the gasification of heavy fossil hydrocarbons. It contains varying proportions of carbon monoxide and dioxide and hydrogen, and is used to produce electricity or as a feedstock to produce SNG.

Committee Charge

In 2005, the United States imported 59.8 percent[11] of its net consumption of petroleum. United States' total consumption represents on average 20,656,000 barrels per day, making it the world's single largest consumer and importer of oil. Because oil use is omnipresent in the American economy and way of life, the dependence on the global market for petroleum has been and continues to be an area of concern for the U.S. A disruption in the global oil supply could cause a crisis in the United States similar to the world oil shock of 1973. Though the U.S. has banned oil imports from Iran since the 1979 Iranian revolution, there are specific concerns that a U.S. military action against Iran's nuclear aspirations might result in a significant disruption of the global oil supply.

With the integration of the world energy market, the use of energy as a weapon is a national security concern. In 1984 and 1991 similar studies were conducted by the Office of Technological Assessment to determine how the U.S. can replace sudden, sizable disruptions in the global oil market. Significant changes have occurred since then in terms of technological capabilities and political environment. This report aims to evaluate the technology and policy options in the U.S. transportation sector to reduce America's dependence on foreign oil.

Specific goals of this project are:

1. To examine the U.S. oil economy in the past ten years.

2. To estimate the technical oil replacement potential that will be needed in the case of a severe cutoff of imported oil.

3. To generate scenarios of severe cut off of imported oil in case of U.S. military action against Iran. Based on the scenarios, estimate a time frame of imported oil cut off.

4. To assess commercially viable technologies today and within the next ten years that can replace oil in various sectors and industries.

5. To propose cost-effective methods to implement new technologies to replace oil in the sectors and industries under (3) in the next 5-10 years.

6. To analyze avenues through which the adoption of oil replacement technologies can be accelerated.

Question for the Teaching Team: Our group is uncertain whether the committee charge needs to be updated to reflect the current project direction or it is meant to show how we have evolved in developing the scope of our project. Please advise accordingly. Thank you!

---

[11] Energy Information Administration, Available WWW: http://www.eia.doe.gov/neic/quickfacts/quickoil.html Accessed September 28, 2006.

References

References are sorted in alphabetical order by author name. Entries are referenced to by authoring agency abbreviation.

APTA (2006). ***APTA: American Public Transportation Association***.
Retrieved Nov. 22 from:
http://www.apta.com
General information about public transportation in the U.S. is described in this report, which includes the current status of public transportation in the U.S.

[APTA] (April 2006). ***Public Transportation Fact Book*****.** No. 1-931594-21-X.

Bankrate.com (2004). ***The pros and cons of going diesel***.
Retrieved November 2 from:
http://www.bankrate.com/brm/news/auto/20030804a1.asp?prodtype=auto
Recently, the number of diesel engine vehicle increases, and Pros and cons of diesel engine are discussed in this home page.

[DOE] (2006). ***Fuel Economy*****.** U. D. o. Energy Publication.
Retrieved December 1, 2006 from:
http://www.fueleconomy.gov

U. S. Department of Energy, Energy Efficiency and Renewable Energy [EERE] (2000). ***Replacement Fuel and Alternative Fuel Vehicle: Technical and Policy Analysis*****.**
Retrieved October 2006 from:
http://www.eere.energy.gov/afdc/pdfs/section506.pdf
This report represents a technical and policy analysis, which addresses the actual and potential role of replacement fuels and alternative fueled vehicles in significantly reducing U.S. reliance on imported oil and discusses some additional issues and perspectives.

U.S. Departement of Energy, Energy Efficiency and Renewable Energy [EERE] (2006). ***Alternative Fuels Data Center Home Page*****.**
Retrieved November 2006 from:
http://www.eere.energy.gov/afdc/
The Alternative Fuels Data Center is a vast collection of information on alternative fuels and the vehicles that use them. Alternative fuels described here are biodiesel, electricity, ethanol, hydrogen, natural gas, and propane. This site has more than 3,000 documents in its database, an interactive fuel station mapping system, current listings of available alternative fuel vehicles, and lots of alternative fuels information and related link.

Environmental and Energy Study Institute [EESI] (2006). ***Response to A CEEE Report: "Plug-In Hybrids: An Environmental and Economic Performance Outlook".***

U.S. Department of Energy, Energy Information Administration [EIA] (2006a). ***Annual Energy Review 2005.*** DOE/EIA Publication No. DOE/EIA-0384(2005).
Retrieved October 2006 from:
http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5.pdf
This report from the Energy Information Agency compiles national, regional and international data for consumption, production and trade of main sources of energy in the US. Its section on oil and petroleum product proved extremely useful to understand the current role of petroleum in the US economy. It also provides thorough time series for consumption, production and trade of all of these sources. The data in this report serves as the basis of our assessment of the reliance of the U.S. on imported crude oil and petroleum products.

U.S. Department of Energy, Energy Information Agency [EIA] (2006b). ***Petroleum Summary Data & Analysis Webpage.***
Retrieved Octobre 2006 from:
http://tonto.eia.doe.gov/dnav/pet/pet_sum_top.asp
This web portal is the most comprehensive source of data on petroleum and its usage in the United States. It gives access to numerous time series about production, consumption and trade of crude oil and its processed products and end-usages.

U.S. Department of Energy, Energy Information Agency [EIA] (2006c). ***Renewable & Alternative Fuel Data, Reports, Analysis, Surveys Webpage.***
http://www.eia.doe.gov/fuelrenewable.html
This web portal is a source of data on alternative and renewable energies and its usage in the United States. It gives access to numerous time series about renewable and alternative sources of energy. It has proved very useful to study alternative fuels vehicles and infrastructures.

U.S. Department of Energy, Energy Information Administration [EIA] (2006d). ***Short Term Energy Outlook – October 10, 2006 Release.*** DOE/EIA Publication No. DOE/EIA-0384(2005).
Retrieved October 2006 from:
http://www.eia.doe.gov/emeu/steo/pub/oct06.pdf
This report from the Energy Information Agency, as well as the Annual Report, compiles national, regional and international data for consumption, production and trade of main sources of energy in the US, and its section on oil and petroleum product also proved extremely useful to understand the current role of petroleum in the US economy. This report is more precisely focused on the new data available as of October 2006, and

provides useful insights about energy trends for 2006 and beyond, as well as seasonal production and consumption data.

U.S. Environmental Protection Agency [EPA] (2005). ***Accelerated Vehicle Retirement Technical Information Summary.*** EPA Publication.
http://yosemite.epa.gov/aa/tcmsitei.nsf/Pages/AccVehInfoDoc

U.S. Environmental Protection Agency [EPA] (2006). ***Light-Duty Automotive Technology and Fuel Economy Trends: 1975 through 2006.*** EPA Publication.
Retrieved October 2006 from:
http://www.epa.gov/otaq/cert/mpg/fetrends/420r06011.pdf
This report summarizes key fuel economy and technology usage trends related to model year (MY) 1975 through 2006 light-duty vehicles sold in the United States. Light-duty vehiclesare those vehicles that EPA classifies as cars or light-duty trucks. It allowed us to find useful information about fuel efficiency of light duty vehicle.

[EPF] (2004). ***Telework: Part of the Work-Life Balance.***
The Employment Policy Foundation collects statistics on employment in the United States. Stastistics from this website were used to assess the state of telework in the U.S.

HONDA (2006). ***HONDA's Technology Transmission***.
Retrieved November 22 from:
http://www.honda.co.jp/tech/auto/transmission/cvt/index.html
This is a press release from manufacturer about Continuously variable transmission, which improve vehicle fuel efficiency.

International Energy Agency [IEA] (2005). ***Alternative Fuels: An Energy Technology Perspective.*** IEA Publication No. ETO/2005/01. Unpublished work by Dolf Gielen and Fridtjof Unander.
Retrieved November 2006 from:
http://www.iea.org/textbase/papers/2005/ETOAltFuels05.pdf
This report examines the possibility of alternative fuels for vehicle fleet efficiency.

Intergovernmental Panel on Climate Change [IPCC] (2006). ***Aviation and the Global Atmosphere*** Retrieved November 3rd 2006 from:
http://www.grida.no/climate/ipcc/aviation/092.htm

iPOLL (2006). ***Survey by Bloomberg and the Los Angeles Times***.
http://www.ropercenter.uconn.edu/ipoll.html

Therese Langer (2005). ***Vehicle Efficiency Incentives: An update on Feebates for States.*** ACEEE: American Council for an Energy-Efficient Economy.

NARA (1943). ***Powers of Persuasion Intro Page***.
Retrieved November 29 from:
http://www.archives.gov/exhibits/powers_of_persuasion/use_it_up/images_html/ride_with_hitler.html

Metal Center News (2006). ***End-Use Outlook: Automotive***.
Retrieved November 2 from:
http://www.metalcenternews.com/2006/April/mcn0604Automotive.htm#Aluminum
This is a press release about lighter body vehicle which improve vehicle fuel efficiency.

U.S. Department of Transportation, National Highway Transportation Security Administration [NHTSA] (2002). ***Report to Congress: Effects of the Alternative Motor Fuels Act CAFE Incentives Policy*.** Published by U.S. Department of Transportation, U.S. Department of Energy and U.S. Environmental Protection Agency.
Retrieved November 2006 from:
http://www.nhtsa.dot.gov/cars/rules/rulings/CAFE/alternativefuels/index.htm
This report evaluates the availability to the public of alternative fuel vehicles and alternative fuels, energy conservation and security, environmental considerations, and other relevant factors. This study also indicates that the AMFA CAFE credit incentive program for producing dual-fuel vehicles has had mixed results.

U.S. Department of Transportation, National Highway Traffic Safety Administration [NHTSA] (2004). ***Automotive Fuel Economy Program Annual Update Calendar Year 2004*.** NHTSA Publication No. DOT HS 809 512.
Retrieved November 2006 from:
http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Vehicle%20Safety/CAFE/2004_Fuel_Economy_Program.pdf
This report presents CAFE values and the passenger car fuel economy performance by manufacturer MYs 2003-2004 which are used to determine manufacturer compliance with fuel economy standards.

U.S. Department of Transportation, National Highway Traffic Safety Administration [NHTSA] (2005). ***Summary of Fuel Economy Performance*.** NHTSA Publication.
Retrieved October 2006 from:
http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/Vehicle%20Safety/Articles/Associated%20Files/SummaryFuelEconomyPerformance-2005.pdf

This is database of the fuel economy standards which provides useful information about the CAFE standards from 1978 to 2006.

U.S. Department of Transportation, National Highway Traffic Safety Administration [NHTSA] (2006). ***CAFE Overview*****.**
http://www.nhtsa.dot.gov/Cars/rules/CAFE/overview.htm
This web page, set by the National Highway Traffic Administration to communicate about the CAFE Standards, provides data and information about the current status and future projection of the CAFE standards.

Nissan (2004). ***Technology for fuel efficiency***.
Retrieved November 22 from:
http://www.nissan-global.com/JP/ENVIRONMENT/CAR/FUEL_COST/TECHNOLOGY/CVT/index.html
This is a press release about Continuously variable transmission which improve vehicle fuel efficiency.

U.S. Department of Energy, National Renewable Energy Laboratory [NREL] (2006a). ***Advanced Vehicles & Fuel Research Webpage*****.**
http://www.nrel.gov/vehiclesandfuels/hev/
This web portal proved to be a useful source of information on Hybrid-Electric Vehicles.

U.S. Department of Energy, National Renewable Energy Laboratory [NREL] (2006b). ***Transitioning to a Hydrogen Future: Learning from the Alternative Fuels Experience*****.** NREL Publication No. NREL/TP-540-39423. Main author: M. Melendez.
Retrieved November 2006 from:
http://www.eere.energy.gov/afdc/pdfs/39423.pdf
This report exmines assessing relevant knowledge within the alternative fuels community and recommending transitional strategies and tactics that will further the hydrogen transition in the transportation sector and help avoid stranded assets in the alternative fuels industry.

[ORC] (2006). ***Energy Sources Survey*****.** O. R. Corporation Publication.

Oak Ridge National Laboratory [ORNL] (2006). ***Transportation Energy Data Book: Edition 25*****.** ORNL/EST/CTA Publication No. ORNL-6974 (Edition 25 of ORNL-5198). Prepared for the Office of Planning, Budget Formulation and Analysis, Energy Efficiency and Renewable Energy, U.S. Department of Energy, by the Oak Ridge National Laboratory/UT-Battelle under Contract No. DE-AC05-00OR22725.
Retrieved November 2006 from:
http://cta.ornl.gov/data/index.shtml

This transportation data book summarizes all important data about transportation use of energy use, with time series for consumption data split by type of fuel, transportation and trips. It serves as the main basis on which we construct our analysis of the importance of petroleum products in the American road transportation sector.

U. S. Congress, Office of Technology Assessment [OTA] (1991). ***U.S. Oil Import Vulnerability: The Technical Replacement Capability*.** OTA Publication No. OTA-E-503.
Retrieved October 2006 from:
http://govinfo.library.unt.edu/ota/Ota_2/DATA/1991/9143.PDF
This report from the Congressional Office of Technology Assessment builds on the 1984 report from the OTA, and provides a new estimate of the political and technological potential for a response to an oil import disruption on the world market, leading to different disruption scenarios for the United States. It is more specifically aimed at understanding the risks stemming from the 1990-1991 events in the Gulf region.

[PAF] (2006). ***Public Agenda Confidence in US Foreign Policy Index Poll*.** P. A. Foundation Publication.

The Minerals Metals & Materials Society (2002). ***Market Model Simulation: The Impact of Increased Automotive Interest in Magnesium***.
Retrieved October 29 from:
http://www.tms.org/pubs/journals/JOM/0208/Urbance-0208.html
This is a current status about lighter body vehicle, which serves the latest information about fuel efficient vehicle.

Nikkei Automotive Technology (2006). ***Next generation's engine***.
Retrieved November 21 from:
http://techon.nikkeibp.co.jp/article/HONSHI/20060326/115400/
This is cover story of the magazine about next generation's engine for vehicle, which serves the latest information about engine for vehicle.

Transportation Research Board [TRB] (2006a). ***Commuting in America III*.**
This is an extensive collection of data about commuting in the U.S. Data was used from this source in order to clarify vehicle usage patterns.

TRB (2006b). ***TRB HOVworld***. Last update: 2006.
Retrieved November 29 from:
http://www.hovworld.com/index.html

UConn (2006). *iPOLL Database*.
http://www.ropercenter.uconn.edu/ipoll.html
This home page contains nearly half a million survey questions and answers asked in the US over the last 65 years by more than 150 survey organizations from which it is possible to access the catalog and questionnaire directly.

Union of Concerned Scientists [UCSUSA] (2006). *Hybrid Center :: Incentives*. UCSUSA Publication.
Retrieved December 4, 2006 from:
http://go.ucsusa.org/hybridcenter/incentives.cfm

U.S. Bureau of Census [USCB] (2006). *IDB - International Data Base*.
Retrieved December 2006 from:
http://www.census.gov/ipc/www/idbnew.html

Annalisa Weigel (2006). *ESD.10 - Introduction to Technology & Policy*.

Wikipedia (2006a). *Continuously variable transmission*.
Retrieved October 29 from:
http://en.wikipedia.org/wiki/Continuously_variable_transmission
This is a general information page about Continuously variable transmission, which provides useful information about vehicle fuel efficiency technology.

Wikipedia (2006b). *Diesel engine*.
Retrieved November 1 from:
http://en.wikipedia.org/wiki/Diesel_engine
This is a general information page about Diesel engine, which provides useful information about vehicle fuel efficiency technology.

Wikipedia (2006c). *Power steering*.
Retrieved November 23 from:
http://en.wikipedia.org/wiki/Power_steering
This is a general information page about power steering, which provides useful information about vehicle fuel efficiency technology.