America's Achilles Heel
The Hidden Costs of Imported Oil
A Strategy for Energy Independence

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The National Defense Council Foundation
Washington, D.C.
October, 2003

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October, 2003

For more than two decades, the National Defense Council Foundation has maintained an ongoing Energy and National Security Program. While the importance of assuring abundant, affordable energy has long been recognized as a national security concern today it takes on an even more important aspect, especially where crude oil and refined products are concerned.

There are several reasons why this is the case.

First, the evolving doctrine of "Rapid Decisive Operations" cannot be implemented without the fuel necessary to power the ships, aircraft, armored and wheeled vehicles on which it depends.

Secondly, our economy is more dependent on petroleum for domestic transportation, and if workers cannot get to work, they cannot provide the materiel necessary for any military establishment.

Third, and from our perspective perhaps most important, is the fact that the financial underpinnings of international terrorism rest on two pillars: the drug trade and oil dollars. The threat terrorism poses to our nation will be diminished in direct proportion to the degree these sources of funds can be reduced. Therefore, reducing the nation's dependence on imported oil not only yields the obvious benefits in terms of economic and military security, but also directly reduces the ability of terrorists to operate.

But to accomplish this goal will require national commitment. One thing that can foster that commitment is a better understanding of the terrible economic toll our continuing oil import dependence exacts. That is why our organization has prepared this document. In the final analysis, its purpose is to show how we can eliminate external influences that manipulate our system.

We hope it will help to further understanding of this critical issue.

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INTRODUCTION

It would be difficult to imagine the advent of any commodity that has had the impact of oil on virtually every area of human endeavor. From transportation to medicine to agriculture to materials, petroleum-derived products have had a profound impact. Moreover, these products have been readily available at bargain-basement prices through most of our history. Indeed, the pump price of a gallon of gasoline is only a little more than half the price of a gallon of milk. Yet, the price for a gallon of gasoline a consumer pays at the pump is in fact only a fraction of the real cost of the fuel. It does not reflect the enormous burden of external costs that arise from the military, economic, environmental and health outlays directly resulting from our dependence on foreign oil. If our nation is to make rational policy decisions regarding the rising tide of imports, it is essential that decision-makers fully understand what these costs are, and how they are incurred.

THE FIRST OIL SHOCK

Gasoline lines resulting from the oil shortage.

On October 17, 1973 Americans were shocked out of their energy complacency when the Arab Organization of Petroleum Exporting Countries (AOPEC) (1) announced it would impose an embargo on oil sales to the United States and raise the price of crude oil to other customers by some 70%. To enforce this action, AOPEC further announced it would cut production by 5% from the previous month's levels and reduce production by an additional 5% each succeeding month.

Overnight, crude oil prices rose 70% to $5.28 per barrel. (2) By May of the following year the price peaked at $12.60 per barrel, more than four times the pre-embargo level. (3) Gasoline prices skyrocketed as well and filling stations were plagued with long lines of desperate motorists panicked over short supplies. The economy soon fell into a deep recession caused in part by an 11% inflation rate. (4) Unemployment, which had been declining over the past two years shot up by more than one full percentage point by January of 1974, (5) and nearly doubled by January of 1975. (6) Over 1.2 million people lost their jobs. (7)

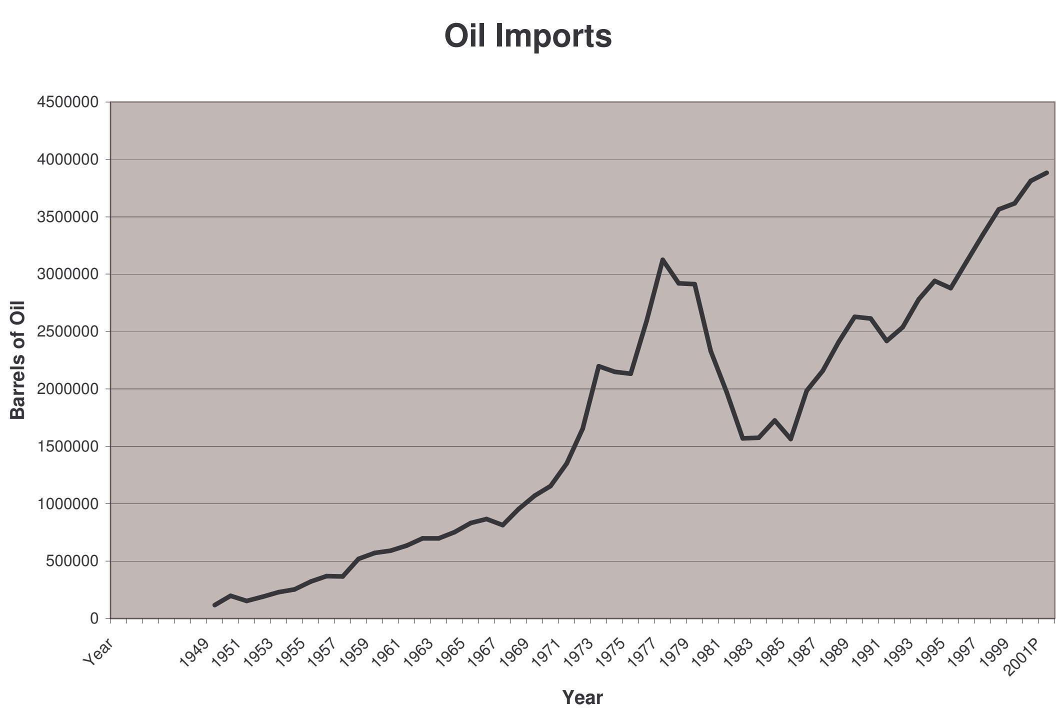
The psychological impact on the United States was incalculable.

Americans had long believed themselves immune from oil supply disruptions – and with cause. World oil supplies had been severely disrupted several times (8) with negligible impact on the U.S. economy because domestic producers were able to increase production to make up the shortfall. In two notable instances, the 1951 embargo of Iranian oil and the 1967 Suez Crisis, (9) increased U.S. production not only alleviated domestic shortfalls, but those of its allies as well.

But, 1973 was different.

Until 1947, the United States had been a net exporter of oil. (10) But beginning in 1948, America's longstanding oil self-sufficiency began to erode. By 1973, the nation was importing almost 35% of its crude oil and its "surge" capacity (the ability to quickly increase oil production from existing wells) had greatly diminished. (11)

Unaware of these statistics, the public was unprepared for what would come in the aftermath of AOPEC's move. Pundits were quick to point fingers of blame, and conjure up images of hidden conspiracies, but most missed the point. The real cause was right in front of them. Our import vulnerability was the inevitable consequence of America's love affair with the automobile.



THE ROLE OF THE TRANSPORTATION SECTOR

In 1900, there were only about 8,000 automobiles registered in the United States. (12) Five years later, that figure grew to nearly 78,000. (13) By 1925, it had risen to 17 million and by1950, more than 40 million. (14) But it was in the Post-WWII period that privately owned cars and light trucks saw their real growth. By 1970 over 108 million privately owned cars and light trucks were registered in the United States (15) and today that number has burgeoned to over 220 million, (16) making per capita vehicle ownership in the U.S. more than 47% higher than the average for the industrialized nations of Western Europe. (17)

The widespread ownership of personal vehicles by Americans has provided an unprecedented degree of mobility – and Americans make full use of it. Americans travel roughly 44% (18) more miles in their automobiles each year than do citizens of the industrialized nations in Western Europe, and more than twice the distance by citizens of Japan. (19) But this freedom of movement is not without a price.

Despite significant improvements in vehicle efficiency, increases in the number of vehicles and the number of vehicle miles traveled have negated any potential benefits. The reason is that, even though each vehicle might use less fuel per mile, there are so many more vehicles and so many more miles traveled that oil used in the transportation sector has continued to grow – and grow dramatically. This steep rise in consumption in turn has served to worsen America's oil import vulnerability. Notably, the increase occurred during a period when most other sectors of the economy dramatically reduced or substantially curtailed their dependence on petroleum products.

Between 1973 and 2001, the actual amount of oil consumed by the utility sector dropped by 76%, (20) the amount consumed in the commercial sector fell by 52% (21) and the amount consumed in the residential sector declined by 43%. (22) Although industrial oil use increased by roughly 8.5%, the increase was substantially below the 13.8% overall increase in petroleum consumption during the same period. (23)

As noted, these impressive reductions in petroleum dependence were more than offset, however, by a 46.4% increase in oil use in the transportation sector. (24)

Significantly, had the amount of oil used in the transportation sector merely remained constant, U.S. domestic oil consumption would actually have declined by some 24.3% from 1973 levels. (25) Indeed, between 1973 and 2001, the proportion of domestic petroleum consumption accounted by the transportation sector from rose from 52.3% to 67.3%. (26) During that same period, the transportation sector's share of total domestic energy use increased from 18.6% to 27.1%. (27)

To put these figures in perspective, if a substitute could be found for the petroleum used in the transportation sector, there would be no need to import oil. In fact, if necessary America could again become a net oil exporter.

The increase in transportation sector petroleum use is best understood in the context of evolving driving patterns. The total number of vehicle miles traveled (VMT) has increased an average of 3.6% annually since 1950. (28) More important, the average number of vehicle miles traveled per capita increased dramatically as well. Between 1975 and 2000 alone, the increase in VMT was 63.2%. (29) Part of this increase was the natural consequence of a dramatic increase in vehicle ownership. In 1960, more than one-fifth of all families only owned one automobile. (30) By the year 2000, less than ten percent did. (31)

It is not just the growth in vehicles and the number of miles traveled that is affecting transportation sector energy consumption. Another important change is in the make-up of the U.S. motor vehicle fleet.

THE GROWTH OF LIGHT TRUCK OWNERSHIP

Since the initial introduction of automobile emission control equipment, no trend has had a larger effect on transportation sector energy efficiency than the dramatic increase in the use of light trucks as personal vehicles. In 1978, light trucks accounted for just 9.8% of the total vehicle fleet. (32) By 2001, however, light trucks constituted 46.7% of personal vehicles (33) – this due primarily to the growing popularity of Sport Utility Vehicles and Minivans among suburban households. Over time, these light trucks have largely replaced the traditional station wagon as a second vehicle for suburban families. It is particularly noteworthy that, as of 2001, Sport Utility Vehicles became the leading choice among female new vehicle purchasers – the market segment that most generally guides buying decisions related to "family" transportation. (34)

The effect of this shift in the makeup of the vehicle fleet cannot be overestimated. Whereas the average fuel economy of passenger cars was 28.6 mpg in 2001, (35) the average for light trucks was only 20.9 mpg. (36) As a result, the combined fuel economy of the U.S. domestic fleet is only 24.4 mpg (37), 14.7% less (38) than the average for passenger cars alone.

The increasing proportion of the motor vehicle fleet accounted for by light trucks has significant implications for energy consumption – especially if the per capita ownership of motor vehicles in the United States continues to increase – and persistent trends in population movement suggest that it will.

THE IMPACT OF CHANGING DEMOGRAPHICS

Many factors contributed to the growth of automobile use. Among the most significant was urban sprawl, i.e. the movement of populations out of central cities to suburbs – a trend that has continued since the end of World War II. As the population has dispersed, commuting distances have increased. Indeed, in the dozen years between 1983 and 1995 alone, commute distances grew by 36.4%. (39) In addition the time required for an average commute also increased. The movement away from central cities, however, is not the only significant demographic change to take place.

Another important trend has been the concentration of America's population in coastal areas. Although coastal areas comprise just 17% of the total U.S. land area (40) they hold 53% of the nation's population. (41) The population of these areas is currently increasing by 3,600 people per day (42) and is projected to increase by 27 million over the next dozen years. (43) This movement has created an imbalance in population densities with high concentrations on both coasts and large relatively thinly populated regions in the balance of the country. Yet, even in coastal areas, much of the population lives in relatively small communities where dependence on the automobile for transportation is the only viable option. In addition, compared with much of the world, the United States is not densely populated. Its average of 74 persons per square mile (44) remains far below Europe's 429 per square mile (45) or Asia's 300. (46) As a result, many people view automobile ownership as a necessity.

The dramatic rise in per capita income, which, for example, more than doubled in real terms between 1967 and 2000, has served to greatly facilitate the rise in automobile ownership. (47) The contribution of two-income families to this increase – which also creates an additional commuter in the family unit – has further sparked the growth of vehicle ownership.

The impact of these changes on energy use is clear. While the fuel efficiency of the U.S. passenger car fleet more than doubled between 1974 and 2001, (48) rising from an average of 12.9 mpg to 28.6 mpg, the benefits of this improvement were largely offset. (49) The savings in fuel consumption simply could not keep pace with burgeoning demand resulting from the higher number of miles traveled and the increased number of cars on the road.

IMPORT DEPENDENCE AND DEFENSE: HIDDEN COSTS, HIDDEN DANGERS

In an ideal world, energy supplies would be secure, clean and affordable. If this were the case, the rising tide of imports would give little concern. The world, however, remains a very dangerous place. Competition over scarce energy supplies contributes to that danger and access to energy supplies is a critical element in our capability to respond to it.

Many believed that the collapse of the Soviet Empire and the end of nearly half a century of geopolitical stalemate would dramatically end the prospects of conflict around the world. Although this dramatic event did greatly reduce the likelihood of a global thermonuclear conflagration, it did little to enhance international stability. The threat of a superpower confrontation was quickly replaced with the onset of myriad smaller conflicts in geographically diverse locations and at varying degrees of intensity. Moreover, in the new threat environment, these conflicts could arise with little warning – at times requiring troop deployments within a matter of days, or even hours.

In FM-100, the U.S. Army Statement of Doctrine, this change was acknowledged:

> *"…The global realities of today are in a period of significant change. Army forces may find themselves called upon to fight under conditions of rapid force projection, that can build to major sustained operations in war and peace or that can terminate quickly only to lead to other commitments elsewhere."* (50)

One inherent consequence of the new threat environment is that energy, and in particular refined petroleum products, while always an important military commodity, have taken on an even greater significance.

Some salient facts illustrate this point:

- A contemporary U.S. Army Armored Infantry Division comprised of 17,500 soldiers uses roughly twice the fuel of two World War II field armies which, taken together, would comprise nearly 200,000 troops. (51)

- During Operation Desert Storm, the 582,000 U.S. forces that participated consumed more than 450,000 barrels of refined petroleum products per day – more than four times the amount used daily by the entire 2 million man Allied Expeditionary Force that liberated Europe in World War II. (52)

- During Operation Iraqi Freedom, one of the principal immediate goals was to secure that nation's oil fields.

But even these facts do not tell the whole story.

Two important changes have also taken place within the national defense establishment since the fall of the Soviet Union. The first of these has been the reduction of troop strengths overseas and the closing of overseas bases. Throughout the Cold War period, the U.S. military maintained substantial "forward positioned" forces at bases in Europe and the Far East. As the overall size of the military has decreased, so, too, has its forward posture. Bases in the Philippine Islands were closed and force levels throughout the rest of the world were reduced.

In addition, the military has come increasingly to rely on National Guard and Reserve components to "round out" active duty divisions. Today 48.3% (53) of America's military forces are in either Guard or Reserve units. Moreover, many comprise key functions such as chemical, biological and nuclear decontamination, medical services and civil engineering. As a consequence, they are not merely "weekend warriors" but rather integral elements of any sustained military operation. This new reality was underscored during Operation Iraqi Freedom. But, because Guard and Reserve units are by definition based in the Continental United States, or "CONUS" in military parlance, this shift in force structure further diminishes the military's forward posture. This means that there will be additional fuel requirements to transport these forces and their equipment and materiel to the theater of operations. During the first Gulf War an average of 2,400 tons of materiel were airlifted to the theater of operations daily. (54) In future conflicts the greater dependence on forces stationed in the United States are likely to greatly increase this figure. Indeed, FM-100 emphasizes *"…The CONUS base is the strategic foundation for the logistical system…"* (55)

The energy implications of this new strategic doctrine are evident in the fact that the Department of Defense accounts for nearly 91% of all petroleum consumed by the federal government. (56) Peacetime use alone is more than 277,000 barrels per day. (57) The question is what will be the source of fuel to transport these troops?

During both World War I and World War II, the United States was the world's largest oil producer, and as such was able to provide not only for its own needs, but for over eighty percent of its ally's needs as well. (58) During Operation Desert Shield/Desert Storm, the first Persian Gulf War, surge production by Saudi Arabia (59) helped offset the loss of Kuwaiti and Iraqi oil. In the future, however, domestic production would not be able to make up any substantial loss of foreign oil, and there is no assurance that overseas producers would be willing to increase their output. Therefore, as long as America remains heavily dependent on imported crude, its national security remains jeopardized. Since the bulk of U.S. petroleum use today lies in the domestic transportation sector, the answer to the question of how to address our energy vulnerability must be found there.

ECONOMIC IMPACTS

It is not just in relation to the defense sector, however, that America's import dependence imposes hidden costs and dangers. In addition to the implications for national defense, America's chronic reliance on imported crude oil and refined petroleum products also has had significant negative economic consequences for the domestic economy.

Even in the absence of a specific supply disruption, the economic penalty is substantial. Paying for imports diverts billions of dollars from domestic investment and leaves U.S. financial markets subject to the whims of a foreign cartel. The volatility of oil prices resulting from foreign control of supplies creates uncertainties that hinder business planning. Federal, state and local government tax coffers are deprived of revenues that otherwise would have been generated by domestic economic activity. In essence, petroleum imports constitute a hidden tax on every American.

What makes reducing the burden of oil import costs even more important is that if we could eliminate the need for foreign oil, and we could generate almost $160 billion in new economic activity in the U.S. economy each year – far more than any economic stimulus plan ever considered by policymakers. (60)

When oil supply disruptions do occur, the economic impact is devastating. The combined economic effects of the 1973 and 1979 oil supply disruptions cost the U.S. economy between almost $2.3 and $2.5 Trillion. (61) Even the relatively short-term price spike that accompanied the first Persian Gulf War cost Americans $39 billion in higher prices alone. (62)

ENVIRONMENTAL CONSEQUENCES

It would be difficult to overstate the negative impact of transportation sector petroleum use on the environment. Vehicular emissions are the largest source of air pollution in the United States. (63) Automobile exhausts contribute 50% or more of smog precursors in many areas, (64) 28% of particulate emissions (65) and from 60% to 90% of air pollution in major cities. (66) Further, automobile pollution imposes a variety of direct and indirect costs on state and local governments. Areas that fail to comply with the National Ambient Air Quality Standards must implement programs such as vehicle emission testing that can be costly for both government and consumers. Restrictions can be imposed on economic activity that leads businesses to move to other locales. Higher priced fuels may be required increasing vehicle operating costs for both businesses and individual consumers.

Public health also is affected by mobile source pollution. One area of particular concern is asthma, which is growing at an alarming rate. According to the Centers for Disease Control, the incidence of asthma has increased from 6.8 million in 1980 to 31.3 million today – 460 percent. (67) Moreover, the incidence of asthma in children may be as high as 6.9 percent among children under 18 years of age. (68) Mobil source pollution is suspected as contributing to this rise.

The periodic "pollution alerts" common in many cities during the summer months are another clear indication of the dangers mobile source pollution poses to public health. Significantly, these warnings often contain specific restrictions for older citizens – those dependent on Medicare and Medicaid for health care. The increased costs resulting from pollution-related illness contribute to the burden of maintaining these programs.

FINDING A SOLUTION

Over the past few decades, leaders in government, business and the academic community have gradually come to recognize the danger that America's undue reliance on petroleum for transportation presents. Still, until recently, a solution for the problem remained elusive.

In his 2003 State of the Union message, President Bush proposed a bold answer to America's energy dilemma: the development of a hydrogen fuel cell powered vehicle. Once in widespread use, hydrogen fuel cells could provide a virtually limitless source of power to meet America's transportation needs. Moreover, such a change also would reap enormous environmental benefits, eliminating a leading source of pollution and dramatically enhancing national security.

Accomplishing such a fundamental change in the transportation sector, however, will not be an easy task. A source of hydrogen must be identified. Fuel cell technology must be refined. An infrastructure for the production and delivery of hydrogen fuel must be put in place, and the public must be introduced to the notion of using a gaseous fuel. Achieving these objectives may seem a daunting task, but it is not insurmountable. Moreover, given the enormous benefits that will be derived, it is well worth the effort.

While it will take time to resolve the technical and institutional issues related to a shift to a hydrogen fuel cell economy in the transportation sector, it is not necessary to maintain the status quo. Indeed, the process of making the transition itself presents an opportunity to make great strides in enhancing America's military and economic security and its environmental quality in the near term. The key is to implement a strategy that uses the transition period to expedite the development of the institutional and infrastructure capabilities that will ensure the nation is capable of switching to hydrogen fuel cells when the technology is fully developed. The marriage of two readily available technologies provides the basis for such a strategy.

The first of these is the development of so-called "hybrid electric" vehicles. These vehicles represent a test bed for all of the peripheral components that will eventually be necessary to manufacture a hydrogen fuel cell vehicle. The fundamental difference between these hybrids and an automobile powered by a hydrogen fuel cell is the engine. In addition, as the number of hybrids manufactured grows, so, too, will the manufacturing base for the components used in electric vehicles. This will ensure that when the time comes to introduce hydrogen fuel cell vehicles, American industry will have the capability to build them.

The second existing technology is the use of natural gas as a vehicle fuel. Worldwide, millions of vehicles powered by natural gas already exist, so there is a vast base of experience in using it as a vehicular fuel. Further, because it is a gaseous fuel, over time, the infrastructure initially developed to deliver natural gas for vehicular use can be adapted to deliver hydrogen at relatively little cost. Also, using natural gas as a fuel will help develop public confidence in the use of gaseous fuels in their vehicles.

But this strategy does more than provide for a smooth transition to hydrogen. It also will yield substantial environmental, economic and security benefits on its own.

Since natural gas is the cleanest burning of all fossil fuels, wider use of natural gas will significantly reduce mobile source pollution. Also, the United States holds substantial natural gas resources so it largely will be a domestically based fuel. Finally, the development and manufacture of the technologies associated with fueling facilities, electric components and other elements of hybrid and hydrogen vehicles will create new domestic employment and export opportunities.

In short, the nexus of these two existing technologies represents an ideal opportunity to accomplish the transition to the fuel cell and to obtain substantial benefits while so doing.

Not the least of these benefits will be to enhance the ability of America's Armed Forces to implement their new strategic doctrine of Rapid Decisive Operations.

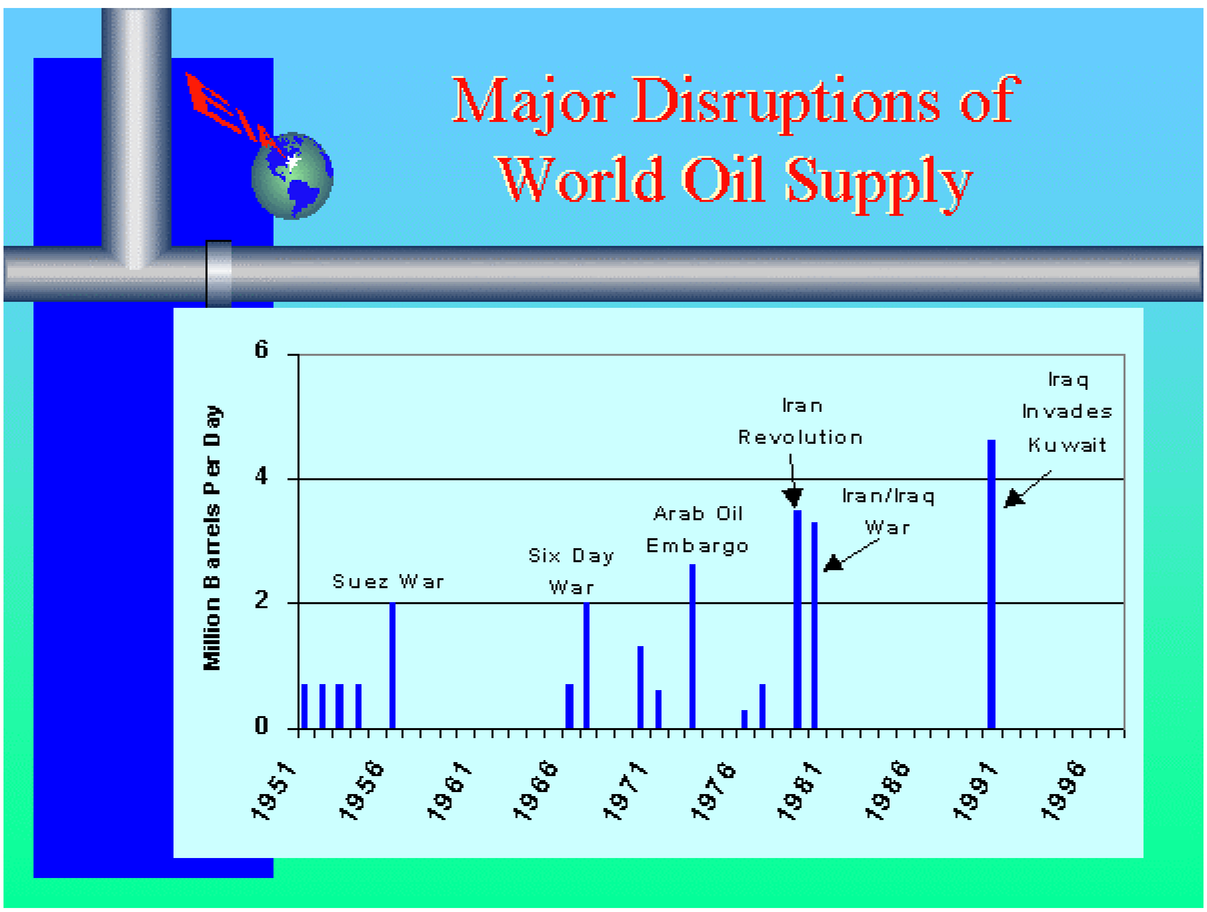
INTRODUCTION
NOTES

1. Yergin, Daniel, The Prize, pp. 607-608 Simon and Shuster, New York, 1991
2. Energy Information Administration, Historical Monthly Energy Review 1973-1992 p. 243
3. ibid.
4. Source: Bureau of Labor Statistics
5. ibid.
6. ibid.
7. ibid.
8. Presentation by EIA Administrator Jay E. Hayes, Slide 1 September 3, 1998
9. Yergin, Daniel, op. cit. PP 464-465 and 557
10. American Petroleum Institute Basic Petroleum Databook Table IX Section 1
11. Ibid.
12. Sitilgoe, John, Roads, Highways and Ecosystems, National Humanities Center 2003
13. ibid.
14. Transportation Energy Data Book, Edition 22 p. 6-2 Oak Ridge National Laboratories, Oak Ridge TN September 2002
15. ibid.
16. ibid.
17. International Energy Outlook 2002, Table E-10, United States Department of Energy, Energy Information Administration, Washington, D.C. February, 2003
18. Highway Statistics 2000, Table IN-4 Federal Highway Administration, Washington, D.C. October, 2002
19. ibid.
20. Energy Information Administration Monthly Energy Review, March, 2002, Tables 2-2 to 2-6
21. ibid.
22. ibid.
23. ibid.
24. ibid.
25. Based on calculations derived from Energy Information Administration Monthly Energy Review, March, 2002, Tables 2-2 to 2-6
26. Transportation Energy Data Book Edition p 1-18 Oak Ridge National Laboratory, Oak Ridge, TN, September, 2002
27. ibid.
28. Transportation Energy Data Book Edition p 11-2 Oak Ridge National Laboratory, Oak Ridge, TN, September, 2002
29. ibid.
30. Transportation Energy Data Book, op. cit., p 11-3
31. ibid.
32. Automotive Fuel Economy Program, Annual Update Calendar Year 2001, Department of Transportation, National Highway Transportation Safety Administration Table II-4, Washington D.C. September, 2002
33. ibid.
34. R.L. Polk & Co. press release dated January 6, 2002
35. Automotive Fuel Economy Program, Annual Update Calendar Year 2001, Department of Transportation, National Highway Transportation Safety Administration Table II-4, Washington D.C. September, 2002
36. ibid.
37. ibid.
38. ibid.
39. Sheet Pressures on Coastal Environments, p. 1 U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Washington D.C. 2001
40. ibid.
41. ibid.
42. ibid. Transportation Energy Data Book p. 11-3 op. cit.

43. ibid.
44. Population Reference Bureau 2000 World Population Data ibid.
45. ibid.
46. ibid.
47. Current Population Survey, Income Surveys Branch, U.S. Census Bureau, Washington, D.C., Table P-1
48. ibid. Bamberger, Robert, Automobile and Light Truck Fuel Economy: Is CAFÉ Up to Standards, Issue Brief, Library of Congress, Congressional Research Service Washington, D.C. August 9, 1999 and Automotive Fuel Economy Program, Annual Update Calendar Year 2001, Department of Transportation, National Highway Transportation Safety Administration Table II-4, Washington D.C. September, 2002
49. ibid.
50. FM-100 United States Army Statement of Doctrine, Department of the Army, Introduction, Washington, D.C. June, 1993
51. Goralski, Robert, Oil and War, William Morrow & Co. 1987 and Pagonis, Lt. Gen. William G., Moving Mountains, Lessons in Military Leadership and Logistics, Harvard Business School Press, Cambridge, MA, 1991
52. Ibid.
53. Defense Almanac, United States Department of Defense, Washington, D.C. 2003
54. Pagonis, op. cit. ibid.
55. FM-100 United States Army Statement of Doctrine, Department of the Army, Introduction, Washington, D.C. June, 1993
56. Annual Energy Review 2001, page 28 Figure 1.13 U.S. Department of Energy, Energy Information Administration, Washington, D.C. November 18, 2002
57. ibid.
58. Goralski, Robert, Oil and War, William Morrow & Co. 1987 and Pagonis, Lt. Gen. William G., Moving Mountains, Lessons in Military Leadership and Logistics, Harvard Business School Press, Cambridge, MA, 1991op. cit.
59. Pagonis, Lt. Gen. William G., Moving Mountains, Lessons in Military Leadership and Logistics, Harvard Business School Press, Cambridge, MA, 1991 op. cit.
60. Based on DOE estimate of current import expenditures and standard multiplier for secondary economic activity.
61. See chapter "The Economic Impact of Import Dependence. For an earlier estimate see: Factors Affecting U.S. Oil and Gas Outlook, National Petroleum Council, Washington, D.C. pp. 7-8 February, 1987
62. ibid.
63. Copulos, Milton R. Surge Production During Operation Desert Storm, The National Defense Council Foundation, Alexandria, VA May, 1993
64. Source: Environmental Protection Agency
65. ibid.
66. ibid.
67. ibid.
68. Source: Centers for Disease Control and Prevention
69. ibid.

CHAPTER 1: THE MILITARY SIGNIFICANCE OF MIDDLE EAST OIL

Although oil is produced in many places around the world, the huge volume of Middle East production – roughly 30% of the world total (1) – and the vast size of the oil reserves located there – roughly two-thirds of the world total (2) – endow the region with a unique importance. By virtue of its oil resources the Middle East also contains most of the world's "surge" oil production – the ability to increase the flow to offset shortages elsewhere. This capacity was demonstrated most dramatically during Operation Desert Shield/Storm, the first Persian Gulf War, when increased production from Saudi Arabia and other Gulf producers made up the loss of production from Iraq and Kuwait. (3) These facts underscore why, the "oil is just another commodity" approach to petroleum resources is flawed. It fails to distinguish between events that are primarily economic in nature and those that have military significance.



Source: United States Department of Energy, Energy Information Administration

During the half-century between 1951 and 2000, world oil supplies were disrupted no less than fourteen times. (4) The sources of disruption ranged from the nationalization of Iranian oil fields in May of 1951 to OPEC production cuts intended to shore up falling oil prices between April of 1999 and March of 2000. (5) Throughout that period, American military intervention only occurred twice – in 1987 when the U.S. re-flagged and provided escorts to Kuwaiti oil tankers to protect them from attack during the Iran-Iraq war, and in 1990 following Iraq's invasion of Kuwait.

More recently, when striking oil workers in Venezuela virtually shut down that nation's production in December of 2002, no military action was even contemplated. This, despite the fact that Venezuela is one of the major sources for U.S. oil imports, and that at its peak, the production loss approached 2 million barrels per day. (6)

Clearly, a distinction is made between supply disruptions that are the result of a direct military threat, and those that result from other causes. But even the presence of a military threat does not appear to be sufficient cause to contemplate a U.S. response. Guerillas in Colombia routinely destroy sections of oil pipeline there and are dealt with by local forces. In Mexico, another major source of U.S. imports, action by both insurgent and criminal elements is often directed against oil production facilities in the Yucatan Peninsula. As with the Venezuelan strike, however, these incidents do not spark a U.S. military response. Rather, they are treated as Mexican internal security problems.

Why do military threats to the Persian Gulf warrant a military response while threats to other regions do not?

One answer is that the magnitude of the Gulf's production and reserves make it uniquely important. Because of this fundamental fact, while losses from other oil producing areas can readily be offset by surge production from the Gulf, the loss of production from the Gulf could not be made up by surge production in other regions. This prospect raises the specter of shortfalls sufficient to seriously hinder, or even paralyze the ability of the Armed Forces to operate. To fully appreciate the concern defense planners have over such an eventuality; it is necessary to understand how the advent of oil transformed the face of the battlefield and how critical it is to contemporary military operations.

THE CHANGING ROLE OF ENERGY IN WARFARE

Until the 19th century, muscle, bone and sinew provided the only energy military forces required to fulfill their mission. The Industrial Revolution irreversibly altered that eons-long pattern, as machines replaced men and beasts-of-burden both on and off the battlefield. These machines needed energy – initially coal, and eventually oil – to produce the implements of war and to provide troop transportation. Over the ensuing years energy would become an increasingly critical military commodity, affecting tactical decisions and even becoming a factor in the initiation of hostilities.

Civil War Military Locomotive

The impact of industrialization on the conduct of conflict first became evident during the American Civil War. At the outset of hostilities, two-thirds of the nation's rail miles and four-fifths of its manufacturing capability were located in the North. (7) Throughout railroads in the North, gauges (the space between rails) were largely standardized, whereas in the South they varied widely. As a result, Northern forces could move troops and materiel more rapidly and with fewer transfers than Southern forces could.

The economic mismatch was also evident in industrial capacity with 86% of all manufacturing concerns located in states loyal to the Union. (8)

Over time, it proved impossible for the agricultural South to stand against the onslaught of men and materiel brought to bear by the industrial North. From that point forward, industrial strength, and the energy to drive it, would be the key factors in determining both economic and military power – and therefore, economic and military security.

ENTER OIL

Col. Edwin Drake's first oil well at Titusville, Pennsylvania

As the 19th century came to a close, yet another profound change was taking place in regard to the implications energy held for economic and military security – the advent of oil.

In 1859, "Col." Edwin Drake drilled the nation's first commercial oil well at Titusville, Pennsylvania and an industry was born.

Although oil had been used in small quantities for medicinal purposes and in lamps prior to 1859, it was normally obtained by digging pits around oil "seeps" and then skimming oil from them. In the 1850s, however, George Bissel, a New York lawyer, wanted to find a way to obtain oil in large quantities. He felt it could provide a replacement for the whale oil that was commonly used as an illuminant at the time. Whale oil had become increasingly expensive because unrestricted fishing had virtually destroyed the world whale population. With the results of research he had commissioned to prove a high-quality illuminant, kerosene, could be produced from petroleum, he put together the financing for Drake's well.

Overnight, the area around Titusville, Pennsylvania became the first of countless boomtowns that would grow up around oil discoveries. The oil regions of Pennsylvania would continue to produce half of the world's oil until the turn of the century. (9) What neither Drake nor Bissel could have envisioned, however, was the role oil would eventually play as a military commodity.

It would be during the First World War that oil began to come into its own as a factor in combat.

WORLD WAR I: OIL MAKES THE DIFFERENCE

Admiral Sir John "Jackie" Fisher

In the years leading up to the war, legendary British Admiral "Jackie" Fisher and his close ally, First Lord of the Admiralty Winston Churchill, pushed for construction of a so-called "Fast Division" of five oil powered battleships. Up to that time, all military vessels were powered by coal. (10)

Faster, more maneuverable and with greater cargo capacity, the new fleet assured British superiority on the waves. Every Navy in the world would have to follow the British example. But it was not just at sea that oil transformed warfare. On land, the advent of the gasoline engine to power automobiles and trucks permitted rapid troop movements that were not tied to rail lines. More ominously, on land it also powered the tank, and, in the skies, the airplane, creating a multidimensional battlefield.

None of these innovations were possible without oil. Indeed, at the end of the conflict, the British Cabinet's War Minister Lord Curzon was moved to assert "The Allies floated to victory on a sea of oil." He could just as easily have said "American oil," because over 80% of all Allied needs were met with oil from the United States.

WORLD WAR II: MECHANIZATION COMES INTO ITS OWN

While World War I served to introduce oil-dependent military systems to the battlefield, it was in World War II that they came to dominate military strategy and tactics. For instance, at the end of the First World War, the U.S. had produced 799 tanks, but only 64 were actually delivered to the front prior to the Armistice. (11) In contrast, during World War II, the U.S. would produce a total of 116,457 combat vehicles including 86,333 tanks. (12) Similarly, at the beginning of World War I, the U.S. military only had 55 serviceable aircraft, and, even by war's end would only have produced 4,100 combat aircraft and an additional 9,500 trainers. (13) During World War II, almost 300,000 aircraft would be produced. (14)

M-4 Sherman Tank

The new era of mechanized warfare would invest petroleum with a strategic importance that cannot be overestimated. By 1945, military operations would consume 520,523 barrels of refined petroleum products daily – accounting for fully 29% of total U.S. demand. (15) It was not just oil, per se, that would be important however. Advanced American refining technologies, too, contributed to the Allied victory, especially at key junctures such as the Battle of Britain. The high-octane fuel produced by U.S. refiners made it possible for British aircraft to climb higher and fly faster than their German adversaries. Its impact was so great that it moved Geoffrey Lloyd, the British Secretary of Petroleum to remark "I don't think we would have won the Battle of Britain without 100 octane … but we did have 100 octane." (16) Today, oil is an even more critical factor.

The "Spitfire" fighter aircraft that won the Battle of Britain – with the help of 100 octane

DESERT STORM AND BEYOND

Operation Desert Shield/Storm, the liberation of Kuwait that followed the Iraqi invasion, demonstrated in earnest the new military paradigm. No longer would the road to conflict be a slow and deliberate process. Instead conflict could arise with lightning speed. This change was described in the Army's new statement of doctrine, published two years after Operation Desert Storm/Shield, the first Persian Gulf War.

> *"…The global realities of today are in a period of significant change. Army forces may find themselves called upon to fight under conditions of rapid force projection, that can build to major sustained operations in war and peace or that can terminate quickly only to lead to other commitments elsewhere."* (17)

Between August 7, 1990 and November 8, 1990 the U.S. moved over 1,000 aircraft, 60 Navy ships, 250,000 tons of supplies and equipment and 240,000 military personnel to the Persian Gulf. (18) Never before had such a feat of logistics been attempted, much less accomplished. Even during 1965, the most intensive 1-year buildup of the Vietnam War, only 168,000 tons of supplies were airlifted. (19) The same was true of sealift. During just the first 30 days of the Gulf War, 300,000 tons of supplies were moved. (20) By comparison, during the first 30 days following the initiation of hostilities in Korea, 79,965 tons of supplies were delivered by sea. (21)

What is most important about these statistics is that the buildup for Operation Desert Storm – especially in the first critical months, relied increasingly on air transportation. More important, air transport needs far exceeded expectations. Prior to the conflict, military planners assumed that about 5% of the initial deployment of troops and materiel to a Medium Regional Conflict (MRC) such as the Gulf War would be accomplished with air assets. In actual practice the figure was 15% -- three times as great. (22) Although over the full course of the conflict, about 7% of total cargo shipments would go by air – still substantially more than planners anticipated – it was this early period that was a concern. The heavy initial reliance on air meant three times as much fuel. Moreover, the movement of supplies from the port of entry to the troops in the field was accomplished by truck transport – creating a further requirement for oil. But this was only the tip of the iceberg.

Air to air refueling during Operation Desert Storm.

Once actual combat began, the petroleum requirements skyrocketed. In the initial phase of the air war, over 48,000 air sorties were flown against some 1,200 targets (23) – the most massive air assault since World War II. Upon conclusion of the air campaign, during the 100-hour ground assault, EACH armored division consumed some 2.4 million gallons of diesel fuel. (24) This amounted to 13,714 barrels per day. (25) It should be noted that even while idle, a Heavy Armored Division still consumes 8,214 barrels of fuel daily. (26)

In total, U.S. forces in the Persian Gulf War consumed an average of roughly 450,000 barrels of oil daily (27) – more than four times as much as the entire 2 million man Allied Expeditionary Force that liberated Europe during World War II. (28)

As enormous as the oil requirements were for the Persian Gulf War, they will only increase in the future. A new warfighting concept, "Rapid Decisive Operations" has evolved that envisions lightening strikes at future adversaries employing a combination of airlift, rapid sealift and pre-positioned resources. As a recent white paper by the Joint Forces Command noted:

> *"We can no longer plan on having months or even weeks to deploy massive theater forces into a region rich in unthreatened infrastructure, while delaying offensive action until favorable force ratios have been achieved."* (29)

But implementing this approach means that in the future the military requirement for refined petroleum products will be even greater than it is today. The recent action to liberate Iraq, Operation Iraqi Freedom, illustrates this point. During Operation Desert Shield/Storm, the first Persian Gulf War, it was necessary to provide an average of 35.5 gallons of fuel per day per soldier. (30) In contrast, during Operation Iraqi Freedom, the Defense Logistics Agency purchased some 300 million gallons of oil to provide for the first thirty days of operations in anticipation of implementing the "Rapid Decisive Operations concept. (31) This works out to a daily requirement per soldier of 41.7 gallons – an increase of 17.5%. (32) In no small measure, the increase was a reflection of the lightening dash to Baghdad by the U.S. Army's U.S. 3rd Infantry Division – an assault unmatched in history in speed and daring, and a textbook example of "Rapid Decisive Operations."

Opening Naval Volley of Operation Desert Storm.

In the coming era of mobility warfare and lightning strikes, the military requirement for oil will only increase. The development of armaments such as the Joint Direct-Attack Munitions or "JDAM" that allow military units to operate under the cover of precisely targeted air support vastly increases mobility and the ability to maneuver – and concomitantly consume more fuel. In Operation Desert Storm, only about 7% of the bombs used were precision-guided munitions. (33) During Operation Allied Force in Kosovo, the proportion of precision weapons jumped to 30% (34) and in Operation Enduring Freedom in Afghanistan to 60%. (35) In Operation Iraqi Freedom, virtually all of the bombs dropped were precision-guided munitions.

It is not just actual combat operations that will require greater use of energy under the new operational doctrine. The movement of both troops and, to a lesser degree, materiel will rely increasingly on air transport that is far more fuel-intensive than sea transport. The need for increased reliance on air transport will be further heightened as the size of the Armed Forces is reduced and it becomes necessary to shift troops and equipment from one theater of operations to another as new threats emerge. This requirement was also illustrated during recent military operations as troops were moved from Afghanistan to Iraq.

Two fundamental factors underlie compound the logistical challenge presented by this new operational paradigm. The first of these is the growing reliance on reserve components.

The first of these is that today, almost half of U.S. Armed Forces are comprised of reserve components. By their very nature, these forces are based in the Continental United States (CONUS). (36) Therefore, in the event that reserve units are deployed, transport – much of it air transport – will be required to move their personnel and equipment to the theater of operations. This, in turn will correspondingly result in an increased need for fuel.

The second is that, as noted, the number of U.S. forces "forward positioned" e.g. stationed abroad has been dramatically reduced since their peak of around 300,000 (37) during the Cold war to around 100,000 today. (38) This means that as with reserves, many components of the active duty force will also be deployed from CONUS bases in the event of conflict.

The combined impact of these new factors such as the doctrine of Rapid Decisive Operations, the increased reliance on reserves and the reduction of overseas troop strength is to greatly increase mobility requirements, and with them the need for fuel. Moreover, for the foreseeable future this fuel will have to be in the form of traditional petroleum derived products such as JP4, JP8 and diesel.

CURRENT MILITARY PETROLEUM USE

M1A2 Abrams Tank

Currently, the Department of Defense accounts for 77.9% of all federal energy use. (39) The Department's share of petroleum use, however, is 90.7%. (40) It is also notable that 61.6% of federal petroleum use is accounted for by jet fuel, (41) a product primarily used by DOD.

At present, the United States maintains an inventory of over 150,000 tracked and wheeled tactical land vehicles. (42) Tracked vehicles include approximately 8,300 M1 Abrams heavy tanks and 24,075 Armored Infantry Fighting Vehicles (AFV's). (43)

The Department of Defense also maintains a huge fleet of other wheeled tactical NS non-tactical vehicles such as the M998 HMMWV, or Humvee, as it is popularly known, as well as its fleet of 2.5 ton and 5 ton trucks known as the Family of Light Tactical Vehicles or FMTV. Currently the Department is in the process of replacing its aging FMTV fleet with newer models. Approximately 17,000 have been delivered to date. (44) Ultimately, the FMTV acquisition program anticipates building an inventory of roughly

85,000 variants of the basic design. (45) Overall, DOD maintains a fleet of nearly 250,000 trucks that log over 820 million miles annually. (46)

Humvee

What is more important, though, is that many of the newer tactical vehicles consume fuel at a relatively high rate. For example, the M1A2 Abrams Tank's 1,500 turbine engine consumes about 60 gallons of fuel per hour in cross-terrain operations. (47)This equals a consumption rate of around 0.6 miles per gallon. (48) The other mainstay of armored forces, the Bradley, IFV, also has a high rate of fuel use.

ENHANCING THE FUEL EFFICIENCY OF MILITARY VEHICLES

There is little doubt that the prodigious fuel use of the current fleet brings with it significant economic penalties. But, there are a number of ways, beyond issues of cost, in which improving fuel efficiency serves to enhance military operations.

To begin with, fuel comprises70% of the bulk tonnage required to sustain military operations. (49) To the extent that this requirement can be reduced, everything from equipment to personnel levels is affected.

Reducing fuel consumption also enhances mobility. It means that vehicles can travel further on the same fuel load, and reduces the size of the logistical "tail" that must accompany combat forces. It also dramatically reduces the overall transport required to deploy a unit to the designated theater of operations. Moreover the advantages of some advanced designs go beyond their fuel efficiency. For example, hybrid-electric vehicles are capable of operating for limited periods of time on electricity alone – making them virtually silent. This in essence provides them with a "stealth" mode that can be used to approach enemy positions without detection.

Tank-automotive and Armaments Command

Recognizing both the economic and tactical benefits of improving fleet efficiency, the Department of Defense has undertaken a number of programs through the Army's National Automotive Center and other Service organizations to enhance and improve the performance of its fleet. (50)

CURRENT RESEARCH

COMBATT Prototype

One of the most important is the Commercially Based Tactical Truck, or "COMBATT" program. The aim of the program is to develop military vehicles from the architecture of existing commercial trucks. Ultimately, the program hopes to develop fuel efficient, inexpensive hybrid vehicles. (51) DaimlerChrysler, Ford and GM have all built prototypes for the program. In addition, Dodge and Chevrolet have built hybrid-electric versions of military trucks. (52)

A key aspect of the COMBATT program is that the technologies it develops will also be available to the civilian market. DaimlerChrysler hopes to market a version of the Dodge RAM 2500 truck it developed for the COMBATT program for "severe" off-road uses such as mining, logging and construction. (53) Although such vehicles would cost from \$3,000 to \$5,000 more than their conventional counterparts, (54) the savings they realize in fuel and lower maintenance costs may make added investment worthwhile.

Much of the hybrid-electric technology is being developed through the National Automotive Center's 21st Century Truck Program. This further enhances the potential for reciprocal technology transfer between the military and civilian sectors.

The priority given to mutual technology transfer is not new. Four years ago, during a visit by the Army Chief of Staff, Maj. Gen. Roy E. Beauchamp, who was then commander of the U.S. Army Tank, Automotive and Armaments Command (TACOM) stated:

> *"Spinning off our military-specific technology to the commercial sector just makes sense. … By the same token, spinning on their technology to military applications makes sense too. … Besides improving battlefield mobility, lethality and survivability for the soldiers, we'll also be able to [share new technology] with commercial-automobile consumers. It's a win-win situation."* (55)

The focus on research that has potential for broad applications is evident in other National Automotive Center efforts. For example, the NAC is also involved in the Improved Materials Powertrain Architectures for 21st Century Trucks or IMPACT program. The aim of this research is to develop lighter and corrosion resistant materials for both military and commercial consumers.

LOOKING AHEAD

Although significant progress in demonstrating technologies that can lead to reduced military fuel use, they will take time to fully develop and put in place. The question that remains is what must be done until that goal is accomplished.

The tactical vehicle inventory maintained by the Department of Defense provides the United States with the most modern and effective armored force in existence. But it represents more than just the military capability. It also represents an investment of hundreds of billions of dollars in development and acquisition outlays that the nation can ill-afford to abandon. At the same time, however, the vehicles and other equipment this huge investment represents can only be used if the petroleum products necessary to fuel their operation are available. Therefore, ensuring a secure flow of fuel is of critical importance. But accomplishing this goal is becoming increasingly problematical for several reasons.

The most obvious problem is the continuing growth of U.S. reliance on imported crude oil and refined petroleum products to meet its needs. According to the Department of Energy, for the first eight months of 2003, imports of crude oil and refined petroleum products equaled over 61% to total consumption. (56) More important, the total volume of imports increased from 11,504 MBD for the same period in 2002 to 12,143 MBD in 2003. (57) This represents a change of almost 5.6% in a single year.

It is not just the volume of imports that is a matter of concern. An increasing proportion of imports are now in the form of refined petroleum products. For the first eight months of 2003, refined petroleum products averaged 2,680 MBD. (58) This represents a one year increase of 12.4%, or more than double the overall rate at which petroleum imports are rising. (59) Since crude oil is only useful after it is transformed into specific refined products, this accelerated increase in imports of refined products is of particular concern. The increase also points to a third problem area: refining capacity.

Currently there are a total of 149 oil refineries in the United States (60) of which 145 are operating. (61) Total operating capacity is 16,483,970 barrels per day. (62) Another 273,400 B/D/ of capacity remained idle. (63) Demand for refined products, however, averaged 19,899,000 B/D for the first eight months of 2003. (64) This means that even if all refineries were operating at 100% of capacity, their output would still fall short of meeting domestic demand by roughly 15.8%. (65)

But as a practical matter, refineries cannot operate at 100% of capacity at all times. Routine maintenance, minor problems that cause temporary outages and other factors inevitably reduce utilization rates to some degree. During the first eight months of 2003, refinery utilization averaged 92.9%, (66) an improvement over 2002's average of 90.8%, (67) but still substantially short of full utilization. At this utilization rate, domestic refineries fell more than 24.1% short of meeting domestic demand. (68)

A final problem area is the size of crude oil and refined product stockpiles. Over the past several decades, major refiners have adopted "just in time" inventory systems in order to cut costs. As a result, petroleum stocks are substantially smaller than they were in the past. Whereas prior to the change in inventory practices, U.S. refiners routinely maintained a roughly 90 day supply of crude oil and refined petroleum products in their stockpiles, at present stockpiles equal roughly a 45 day supply. (69)

There is also one other factor that must be taken into account: the competing needs of a modern economy. While petroleum supplies for military operations must receive a high priority, other sectors such as manufacturing and agriculture also require refined petroleum products to function. Our Armed Forces cannot operate without fuel, but they also cannot operate without food, or the implements of war provided through our industrial base. Workers need fuel to get to work. Factories need fuel to operate. Farmers need fuel to cultivate their fields. Ultimately, a balance must be struck between these competing interests. While rationing schemes can and have been imposed, they come at a high cost both in terms of inefficiency and inconvenience.

Taken together, these factors illustrate the potential of an oil supply disruption to seriously hamper the military's access to the petroleum products it requires to operate. As a result, ensuring a reliable fuel supply in the face of an increasingly competitive and unstable oil market will be a priority.

Ultimately, it is likely that the only way this goal can be achieved will be through the development of secure, domestically-based alternatives that can be employed in the event supplies from overseas are disrupted.

Yet, until such time as alternatives are developed, the increased requirement for petroleum products to fuel the new strategic paradigm will remain. This means that as long as the U.S. is dependent on oil imported from the Middle East, maintaining the flow of petroleum from that region – and the costs associated with that mission will remain a strategic priority.

The question is, what does maintaining the capability to assure the flow of Persian Gulf oil cost America's taxpayers, and what other costs arise from our chronic oil import dependence.

CHAPTER ONE NOTES

1. British Petroleum Statistical Review of World Energy, 2002
2. ibid.
3. Copulos, Milton, Surge Production During Operation Desert Storm, The National Defense Council Foundation, Alexandria, VA May, 1993
4. Source United States Department of Energy, Energy Information Administration chart: Global Oil Supply Disruptions Since 1951
5. ibid.
6. Source: Petroleos de Venezuela.
7. Amsler, Robert, Railroads in the Civil War, Gateway Division, NMRA, Feb 8, 2003; Environmental Systems Research Institute Map Book.
8. Times Illustrated Encyclopedia of the Civil War. Ed. Patricia L. Faust. New York: Harper & Row, 1986.
9. For a discussion of the "Fast Division" see Yergin, Daniel, The Prize, Simon and Schuster, New, York, NY 1991 pp. 155-156
10. Paleontological Research Institute, 1259 Trumansburg Rd, Ithaca, NY
11. Ayers, Col. Leonard P., Chief, Statistics Branch of the General Staff, The War With Germany A Statistical Summary, Second Edition with data revised to August 1, 1919, Government Printing Office, Washington, D.C. 1919
12. Gropman, Alan L. Mobilizing U.S. Industry In World War II: Myth And Reality, Institute for National Strategic Studies, National Defense University, Washington, D.C. August, 1996
13. Ayers op. cit.
14. Gropman op. cit.
15. Goralski, Robert and Freeburg, Russell W. Oil and War, How the Deadly Struggle for Fuel in WWII Meant Victory or Defeat, William Morrow and Company Inc., New, NY 1987
16. Goralski, op. cit.
17. FM-100, The United States Army Statement of Doctrine, United States Department of Defense, Introduction, Washington, D.C. June 2003
18. Conrad, Scott W., Moving the Force: Desert Storm and Beyond, Institute for National Strategic Studies, National Defense University, Washington, D.C. December, 1994
19. ibid.
20. ibid.
21. ibid.
22. ibid.
23. See: Atkinson, Rick, The Fog of War, Washington Post, July 30, 1998
24. Conrad, Scott W., op. cit.
25. ibid.
26. ibid.
27. Pagonis, Lt. Gen. William G., Moving Mountains, Lessons in Leadership and Logistics from the Gulf War, Harvard Business School Press, Boston, MA, 1991
28. Goralski, op. cit.
29. Joint Forces Command, A Concept for Rapid Decisive Operations, Version ROD II, 2002
30. Pagonis, Lt. Gen. William G., Moving Mountains, Lessons in Leadership and Logistics from the Gulf War, Harvard Business School Press, Boston, MA, 1991
31. Scarborough, Rowan, US Forces Outran Water, MREs in Rush to Baghdad, Washington Times, Washington, D.C., April 25, 2003
32. The estimate is based on published reports of troop strength.
33. Thompson, Mark, The Tools of War, Time Magazine, October 21, 2002
34. ibid.
35. ibid.
36. Source: U.S. Department of Defense
37. ibid.
38. ibid.
39. Source: United States Department of Energy
40. ibid.

41. ibid.
42. Source: United States Department of Defense
43. Cordesman, Anthony, Western Military Balance and Defense Efforts, Center for Strategic and International Studies, Washington, D.C., 2002
44. Steward and Stephenson, Contractor, FMTV
45. Source: U.S. Department of Defense
46. U.S. Targets Fuel-Guzzling Trucks, National Defense Magazine, Arlington, VA, January 2000
47. Source: U.S. Department of Defense
48. ibid.
49. U.S. Targets Fuel Guzzling Trucks, op. cit
50. U.S. Army Advances On Hybrids, Automotive News, April 15, 2002
51. On Horizon, Military Sees High Technology Vehicles, New York Times, March 30, 2003
52. ibid.
53. U.S. Advances on Hybrids, op. cit.
54. ibid.
55. United States Army Tank, automotive and Armaments Command (TACOM)
56. Source: United States Department of Energy, Energy Information Administration
57. ibid.
58. ibid.
59. ibid.
60. ibid.
61. ibid.
62. ibid.
63. ibid.
64. ibid.
65. Based on EIA statistics
66. Source: United States Department of Energy, Energy Information Administration
67. ibid.
68. Based on EIA Statistics
69. ibid.

CHAPTER 2: ASSURING THE FLOW:
THE COST OF DEFENDING PERSIAN GULF OIL

Energy is the lifeblood of the American economy. Without it factories could not operate, farms would be reduced to subsistence agriculture, the transportation grid would shut down and our highly mechanized military establishment would be rendered impotent. Clearly, maintaining access to the energy we require is essential to both economic and military security. Nowhere is this objective more a matter of concern than in regard to oil.

Although America is blessed with an abundant energy resource base, for half a century its petroleum resource base has been diminishing. As a result, it has become increasingly necessary to rely on petroleum imports to meet domestic needs. More importantly, despite efforts to diversify sources of supply, almost 20% of U.S. oil imports (1) still come from the Middle East and an even larger proportion is likely to come from that unstable region in the years ahead. Currently, Middle East countries account for around 30% of total world oil production (2) and hold roughly two-thirds of the world's proved oil reserves. (3) The Middle East's disproportionate share of world oil resources means that the region is likely to account for an ever-increasing percentage of the world's oil production. Given these facts, it is unsurprising that the U.S. would dedicate some portion of its defense budget to safeguarding these critical resources. The question is, just how big a price does our import dependence exact?

DEFENSE EXPENDITURES AND OIL: THE ANALYTICAL FRAMEWORK

While several attempts have been made to determine the cost of defending U.S. oil supplies, there has been considerable variation among estimates of that figure. In large degree, these variances result from differing assumptions about what should or should not be included in the analysis.

At the one extreme are estimates that limit themselves to costs that are exclusively and clearly oil-related such as the reflagging of Kuwaiti tankers in the late 1980s, or some portion of the "Southwest Asia Contingencies" budget. Under these minimalist assumptions, the defense-related costs of imported oil are relatively small. At the other extreme are estimates that take virtually all expenditures remotely related to Southwest Asia and attribute them to oil imports. Neither approach withstands rigorous analysis.

Minimalists ignore the need to maintain certain capabilities within the defense establishment so that it will be possible to defend the Middle East's oil fields should the necessity arise. Because the Defense Department does not categorize specific expenditures on a regional basis, much oil-related spending may not be earmarked as such.

At the same time, the simple truth is that the Middle East would have some degree of strategic importance even in the absence of its vast oil resources. The region has long been the crossroads between East and West and contains such strategic assets as the Suez

Canal. Some level of military capability would be maintained to defend these assets whether or not oil was present in the region. Therefore what needs to be determined is what proportion of the U.S. Defense Expenditures can properly be allocated specifically to the protection of oil supplies.

CATEGORIES OF EXPENDITURES

Oil-related defense expenditures can initially be divided into two basic categories: one-time and ongoing expenditures.

Ongoing expenditures represent outlays for permanent military capabilities that are maintained to assure the ability to defend Middle East oil supplies. These can be determined by examining the various line items in the defense budget and then using the mission they are designed to fulfill as a basis for allocating a portion of them to the defense of oil supplies. This process is by nature somewhat subjective because, as noted, the Defense Department has consistently resisted attempts to identify expenditures on a regional basis. Still, the manner in which certain defense elements have been historically employed, as well as their location can provide a reasonable basis on which such subjective judgements can be made.

One-time expenditures are those outlays that are made in response to specific circumstances related to oil supplies. These may vary widely. Also, as with ongoing expenditures, there will be an element of subjectivity in any estimate. For example, the reflagging and escort of 11 Kuwaiti oil tankers during the Iran/Iraq War to defend them from attack by the warring parties was clearly aimed at protecting oil supplies. The establishment of pre-positioned supplies on ships in the region was similarly a direct consequence of the need to defend oil. Other one-time expenditures, however, may be less clear. The cost of Operation Desert Shield/Storm, the first Persian Gulf War, which arguably included the protection of oil supplies, as one of several objectives is an instance where a degree of subjective judgement must be applied.

How then, can a reasonably accurate estimate of defense costs be compiled? The first step is to identify where within the Defense Budget spending related to protecting oil supplies is most likely to be found. These outlays represent the ongoing military expenditures related to protecting oil. To do this, the logical place to begin is with the budget of the U.S. Central Command or CENTCOM in military parlance.

CENTCOM is the military command responsible for defending U.S. interests in the Middle East. Indeed, as a review of CENTCOM's genesis and current mission will demonstrate, the entire rationale for its existence is grounded in concern over threats to the flow of oil from the Persian Gulf.

CENTCOM'S ORGANIZATION AND MISSION

On November 27, 1979, President Jimmy Carter announced his intention to establish a "Rapid Deployment Force" within the Department of Defense. (4) The move was in response to the growing tensions in the Middle East that arose following the Iranian Revolution and Soviet Invasion of Afghanistan. At the time, the mission of the RDF was defined as protecting U.S. interests in the Middle East, with a special emphasis on assuring the free flow of oil from the region. On January 1, 1983, the Rapid Deployment Force was reconstituted as a separate unified military command designated as the United States Central Command (CENTCOM). (5)

CENTCOM includes five subordinate commands (6):

ARCENT (ARMY) HQ Third Army Ft. McPherson, GA.
NAVCENT (Navy) HQ Fifth Fleet Bahrain
AFCENT (Air Force) HQ Ninth Air Force Shaw AFB, SC
MARCENT (Marines) HQ MARFORPAC Camp Smith, HI
SOCCENT (Special Operations) McDill AFB Tampa, Florida

Its area of responsibility, or AOR stretches from the Central Asian States to the Horn of Africa and comprises an area of approximately 6.5 million square miles, holding some 25 countries populated by 522 million people. Of these, eleven are located in the Middle East and eight are on the Persian Gulf, including all of the region's major oil producers. (7) According to CENTCOM's official description of its mission, the focus of its operations is "*primarily on the Middle East*." (8)

Despite CENTCOM's clear responsibility for Middle East security, its physical presence in the region has been minimized due to cultural and political considerations. (9) As a result, only around 25,000 military personnel are stationed in the region during times of peace. (10) Of these, at least half are on board naval vessels on station there. (11) These personnel, along with pre-positioned supplies, however, provide the framework for a rapid build-up of pre-designated forces in times of crisis. These pre-designated forces routinely participate in training and exercises to maintain their readiness to respond on a moment's notice.

Operation Desert Shield/Storm, the 1991 action in Iraq, illustrates just how substantial these forces actually are. Within weeks of the initiation of hostilities, U.S. forces in the region included two entire Army Corps, five Carrier Battle Groups including 514 combat aircraft, an entire Marine Expeditionary Force, the bulk of the 9th Air Force with an additional 518 combat aircraft and various Special Operations units. This rapid deployment was made possible, in part, by the huge stockpiles of materiel and equipment pre-positioned at various positions in the Middle East and on pre-positioning ships at Diego Garcia in the Indian Ocean. (12)

The deployment to Iraq illustrates why the minimalist approach to calculating the cost of defending Persian Gulf oil is flawed. Under minimalist assumptions the only costs taken into account would be, at best, a portion of those associated with forces permanently stationed in the Middle East. Yet the 1991 action in Iraq demonstrates that a substantial contingent of forces was maintained outside the region to make such action possible. Therefore, it is clear that to merely attribute some portion of the forces stationed in the Middle East in times of peace to the cost of defending the region's oil supplies grossly understates the true magnitude of DOD expenditures for that purpose. Outlays for maintaining the capability to rapidly intervene in times of crisis are an element that must be considered as well. The question is how much of CENTCOM's overall capability may be included in this calculus?

CALCULATING THE COST: FACTORS TO CONSIDER

Although it is true that CENTCOM's area of responsibility is not limited to the Middle East, the region is, by the command's own admission, its primary concern. Moreover, CENTCOM's predecessor, the RDF was established *specifically* to respond to threats to the flow of oil. As noted, however, more than just the forces stationed in the region must be considered. This broader view is particularly important when one considers the fundamental change in military doctrine that has occurred since the collapse of the Soviet Union.

Throughout the Cold War, U.S. military planning and doctrine was predicated on the notion that the primary military threat the nation faced would arise from a superpower confrontation in Europe. As a consequence, significant amounts of men and materiel were "forward based" in the region. With the fall of the Berlin Wall, disintegration of the Soviet Empire and advent of the European Union, military doctrine underwent a radical change. The overall size of the U.S. defense establishment was radically reduced and many forward positions eliminated. Most importantly, the new doctrine called for a force prepared to respond to threats ranging from:

> *"… large-scale aggression by regional powers with interests antithetical to ours…"* to *"…the potential for smaller, often internal conflicts based on ethnic, or religious animosities, state sponsored terrorism and the subversion of friendly governments*." (13)

Under this new doctrine, forward basing became much more difficult, because threats could arise anywhere on the globe. As a result, military planners came more and more to develop strategies based on the rapid deployment of forces stationed in the Continental United States to areas of conflict at the time the conflict arose. Nowhere has the implementation of this new doctrine been more evident than in CENTCOM's operations.

THE OIL FACTOR IN CENTCOM OPERATIONS

Recent CENTCOM deployments and missions include (14):

> **Operation Southern Watch**: enforcement of the "no-fly zone in southern Iraq.
> **Operation Desert Fox**: a strike at 100 Iraqi military targets over the course of four nights.
> **Operation Resolute Response**: a recovery, rescue, support and security operation following the bombing of U.S. embassies in Nairobi, Kenya and Dar es Salaam, Tanzania.
> **Operation Desert Thunder**: a deployment 50 U.S. ships and submarines and 200 naval aircraft to the Persian Gulf to pressure Iraq into allowing UN arms inspectors to perform their jobs.
> **Operation Desert Strike**: a combined attack using cruise missiles from U.S. ships and U.S. Air Force B-52 bombers against targets in Iraq.
> **Operation Enduring Freedom**: the counter-terrorism campaign that began with the destruction of the terrorist camps in Afghanistan.
> **Operation Iraqi Freedom**: a U.S. led coalition effort to depose Saddam Hussein.

What is significant about this list is that five of the seven major recent operations were directed at targets in Iraq – one of the most problematical regimes in the Middle East. Moreover, while there are a variety of concerns associated with the Baghdad regime, the security of energy resources within the region is unquestionably a major consideration – especially given Saddam Hussein's repeated attempts to gain control over neighboring oil-rich territory.

For example, when Iraq invaded Iran, its objective was to gain control of the oil rich region surrounding the Iranian side of the Shatt al-Arab river. The invasion of Kuwait was similarly aimed at gaining control over that nation's vast oil resources and possibly those of Saudi Arabia as well. Even Hussein's actions within Iraq itself in repressing Kurds in the north and the Shia in the south were largely intended to assure his control over oil fields located in their areas.

The most recent action against Iraq, Operation Iraqi Freedom confirms the importance assigned to protecting Middle East oil production in CENTCOM's planning process. The task of securing oil wells in both northern and southern Iraq was among the earliest military objectives identified by planners. Moreover, the successful attainment of this objective has been frequently cited at military briefings further confirming its importance in the eyes of CENTCOM's planners.

Having established that protection of Middle East oil resources is a major component of CENTCOM's mission, the next step is to determine what the actual cost of fulfilling this role is.

THE ONGOING COST OF DEFENDING THE GULF

In order to calculate the cost of defending the Persian Gulf, the first step is to determine a baseline that reflects overall Department of Defense outlays for CENTCOM. To do this it is necessary, in turn, to determine outlays required to support each of its five subsidiary commands: ARCOM, AFCOM, NAVCOM, MARCOM and SOCCENT. One way to do this is by examining the line items in the Department of Defense Budget. Another is to use a formula developed by the U.S. Department of State that estimates outlays per member of a nation's Armed Forces.

THE DEFENSE BUDGET-BASED ESTIMATE

The Department of Defense Budget is divided into seven broad categories: Personnel, Operations and Maintenance, Procurement, RDT&E, (Research, Development, Training and Engineering), Revolving and Management Funds, Military Construction and Family Housing. (15) For purposes of computing CENTCOM's baseline estimate, only the Personnel and Operations and Maintenance elements plus certain unique costs including Special Operations, Pre-positioned materiel, Strategic Mobility and allocations for Southwest Asia contingencies were considered.

In FY 2003, the Defense Department has allocated $94.296 billion for Personnel and $150.444 billion for Operations and Maintenance. (16) Taken together, these two budget elements total $244.74 billion. Of this, $243.24 is allocated to conventional forces. In addition, the Special Operations Budget for FY 2003 is $4.5 billion (17), $158 million is assigned to pre-positioned equipment and materiel (18), $360 million to Strategic Mobility (19) and $1.1 billion (20) to Southwest Asia contingencies.

CENTCOM's conventional forces account for roughly $81.08 billion of DOD's $243.24 billion conventional force Personnel and Operation and Maintenance outlays. (21) An additional $4.5 billion is spent on Special Operations (22) for a total of $85.608 billion in personnel and Operations and Maintenance costs. Taken together with pre-positioning and strategic mobility costs and outlays for Southwest Asia contingencies, the total of outlays for CENTCOM comes to almost $87.2 billion annually. This figure is CENTCOM's baseline.

To determine what proportion of the baseline can be properly allocated to protecting the Persian Gulf's oil fields, it is necessary to examine CENTCOM's operations. Slightly more than 70% of recent CENTCOM operations have been directed at the Middle East. All of these, however, have not been of equal magnitude. Moreover, CENTCOM is expected to incur continuing costs for Operation Enduring Freedom, the war on terrorism, some of which will be directed at the Middle East, and some of which will not. As a result, attributing half of CENTCOM's budget to protecting the flow of oil from the Persian Gulf would appear a reasonable assumption.

It should also be noted that several National Security Directives (NSD) including NSD 45 and NSD 54 (23) make specific reference to the importance of protecting the flow of oil from the region. These documents serve to further confirm the validity of this assumption.

In addition to half of all Personnel and Operations and Maintenance outlays, the full cost of pre-positioned equipment and materiel, strategic mobility and Southwest Asia contingencies are also properly assigned to the protection of Persian Gulf oil flows.

Using the calculus outlined above, the total ongoing costs of defending Persian Gulf oil comes to $44.408 billion annually. Spreading this cost over the total volume of crude oil and refined petroleum products currently imported from the region yields a per-barrel cost of $44.55 or approximately $1.06 per gallon – this, it should be noted, is in addition to the pump sale price. (24)

USING THE STATE DEPARTMENT FORMULA TO ESTIMATE COST

A second, and significantly more conservative approach to calculating the price tag of defending Persian Gulf oil supplies is to use a formula developed by the U.S. Department of State that estimates how much is spent for each member of the military – e.g. the cost per soldier. Using this formula the cost of CENTCOM's conventional forces would come to $66.2 billion annually. (25) An additional $2.6 billion is spent on Special Operations personnel for a total of $68.8 billion total per-service member costs. (26) In addition to these outlays, there are additional area-specific expenses for pre-positioned equipment and materiel, strategic mobility and the Southwest Asia contingencies budget that bring the total to $68.8 billion annually. (27) Adding half of CENTCOM's personnel expenses to the area specific outlays yields the cost of defending the Gulf. The total comes to $37.312 billion annually. (28) Spreading this cost over the total amount of oil imported from the region yields a per-barrel defense burden of $37.50, (29) or slightly more than 89 cents per gallon. (30) As with the previous estimate, this figure is over and above the nominal pump price.

HOW TO ALLOCATE THE COST

There are some, however, who argue that these costs should be spread over the total volume of U.S. oil imports rather than just those originating in the Persian Gulf. Their assertion is based in the notion that "oil is just another commodity" bought and sold in a global market. Accepting this view of cost allocation, the burden of defending overseas oil supplies using the Defense Budget approach comes to $10.47 per barrel, or approximately 25 cents per gallon. (31) Using the State Department formula, the figures would be $8.80 and 20 cents per gallon respectively. (32)

Similarly, using the highly restrictive minimalist assumptions that only consider expenditures for forces actually stationed in the region and outlays specifically earmarked as oil related significantly reduces the estimate of defense-related costs. An analysis based on the Defense Budget approach and using the minimalist assumptions yields an estimate of $8.85 per barrel or 21 cents per gallon if only Persian Gulf oil is considered. (33) Using the State Department formula approach, the burden of defending Persian Gulf oil comes to $7.10 per barrel or about 17 cents per gallon. (34) Since the minimalist approach only considers forces actually stationed in the Persian Gulf, it is not applicable to the total volume of oil imports.

While the apparent defense burden of defending Persian Gulf oil is significantly lower under minimalist assumptions, it is still substantial. Indeed, the total derived using the Defense Budget approach is an amount greater than the budget of the Department of Commerce, the Department of the Interior or Environmental Protection Agency. (35) It is also is nearly double the total spent on the Federal Bureau of Investigation and Drug Enforcement Administration. (36) Still, to only take into account forces stationed in the region and a few other limited outlays ignores the realities of the military planning process and of the way contemporary military capabilities are organized.
In addition to the ongoing expenditures required to maintain the flow of Middle Eastern oil, there have also been substantial one-time expenditures that are worthy of note.

ONE-TIME EXPENDITURES: WHAT TO INCLUDE?

In attempting to relate one-time expenditures to the protection of Persian Gulf oil supplies, a number of factors were considered. These include the stated purpose of the expenditure, the context within which it occurred (was it related to a specific event in the Persian Gulf?) and the location of the expenditure (was it in the Gulf region?). In some instances, an expenditure may actually serve several purposes, the protection of oil supplies among them. In such instances, a portion of the expenditure is included as a cost. Where one-time expenditures might represent a recurring periodic cost, they were amortized over the anticipated length of the period. Where they involved equipment, they were amortized over the projected life cycle of the equipment in question.

PRE-POSITIONED EQUIPMENT AND MATERIEL

The first category of one-time expenditure involves the pre-positioning of equipment. Substantial amounts of equipment and materiel have been pre-positioned in anticipation of a need in the Persian Gulf, with additional equipment and materiel scheduled for pre-positioning over the next few years. There are three areas of cost associated with pre-positioning:

1. The cost of the equipment and materiel.
2. The cost of ship acquisition to store and move the equipment.
3. The cost of improvements to land bases where some of the equipment is stored and harbor facilities where it will be received.

Currently, there are three pre-positioned "Brigade Sets" earmarked for use in the Persian Gulf. A Brigade Set includes the vehicles, supplies and other materiel required to outfit an entire Armored Brigade. Each set includes:

88 M1A2 Abrams Tanks
54 Bradley Fighting Vehicles

331 other Tracked vehicles
849 wheeled vehicles

The cost per Brigade Set is $262.6 million (37)

In addition, at Camp Doha there are additional pre-positioned vehicles including:

100 Abrams M1A2 Tanks
30 Bradley Fighting Vehicles
80 Armored Personnel Carriers
12 Paladin 155 MM motorized Howitzers
48 Armored Command Vehicles
30 Bulldozers and Bridge Layers
150 other assorted Trucks and Humvees

The cost of this equipment is $252.3 million. (38)

Taken together, the cost of the three currently pre-positioned Brigade Sets and the additional equipment stored at Camp Doha comes to over $1 billion.

In order to store and deliver this equipment the Department of Defense has spent some $6 billion on pre-positioning and roll-on/roll-off ships.

Some $546 million in improvements have been made at Camp Doha, but are to be reimbursed by the Government of Kuwait. Another $200 million in non-reimbursed outlays have been made to port facilities in Kuwait in order to accommodate military pre-positioning vessels. In addition, at least $150 million has been spent at Diego Garcia to accommodate pre-positioning activities there.

The total of non-reimbursed facilities expenses therefore is $350 million. (39)

Because the pre-positioned equipment and materiel have been called into use in the Iraq conflict, their cost will be amortized over a ten-year period (the time between initiation of the program and deployment of the materiel).

This comes to a total of $739.01 million annually.

In the coming decade, it is expected that the number of pre-positioned Brigade Sets earmarked for the Gulf will increase from three to seven. This means an additional four complete sets will be added. Also, given that there will be some combat losses during the conflict, an additional outlay will be required to bring the original three up to standard. It is estimated that there will be no more than a 5% loss from direct combat and an additional 5% from breakdowns, accidents and so forth.

Therefore, over the next decade, the equivalent of 4.1 Brigade Sets will be acquired. At current prices this will come to approximately $1.1 billion. (40)

Over the next decade there are plans to spend an additional $8 billion on sealift to provide strategic mobility for the pre-positioned equipment. (41)

In addition, improvements to facilities and harbors to accommodate the equipment are anticipated to cost roughly $400 million. (42)

These three elements of pre-positioning will total $9.5 billion. Amortizing the cost over a decade as was done with previous pre-positioning outlays would result in an annual amortized expenditure of $950 million.

In addition to the cost or pre-positioned supplies, another cost that must be taken into account is the oil-related portion of the cost of the Persian Gulf and Iraq Wars.

THE COST OF CONFLICT

Determining the appropriate proportion of war-derived costs to attribute to the protection of oil supplies is, of necessity, largely subjective. Some analysts attribute the full cost to this purpose, others none of the cost. Reasonable people can disagree over the appropriate allocation, but there is some subjective evidence that offers guidance.

First, five of seven recent military actions have been directed at the region. In addition, twelve out of thirty instances in which the United States used its military forces abroad between 1984 and 1993, involved action directed at the Persian Gulf. (43)

Second, both the Iran/Iraq War and, Operation Desert Shield/Storm, the 1990-91 Persian Gulf War, were sparked by a move on the part of Iraq to seize oil rich territories from its neighbors.

Third, in Operation Iraqi Freedom, the 2003 Iraq War, seizure and protection of that nation’s oil fields has been repeatedly cited as a major objective.

Given these facts, it is reasonable to assign a significant proportion of the war-related costs to protection of the flow of oil from the Gulf. For purposes of this analysis, it has been determined that the appropriate allocation is 50%. On this basis, the following costs are calculated.

Operation Desert Shield/Storm, the first Persian Gulf War, cost a total of $61 billion. (44) Of this, various nations contributed a total of $53 billion in both funds and in-kind to help offset the burden. As a result, the net cost to the U.S. Treasury was roughly $6 billion. Therefore, $3 billion of the cost was assigned to the protection of Persian Gulf oil flows. For purposes of this estimate, this cost is amortized over the decade between 1991 and 2001.This amounts to $250 million annually. When added to the $739.01 amortized outlays for other one-time expenditures, the total is $989.01 million per year for the period between 1993 and 2003.

The total cost of Operation Iraqi Freedom, the 2003 Iraq War, remains undetermined, but the initial budget request from the Bush Administration was for $74.4 billion. (45) Assuming that the request accurately reflects the eventual outlays required a 50% share would come to $37.2 billion. Amortized over a ten-year period, this would amount to $3.72 billion per year. It should be noted that the figure quoted does not take into account future spending on restoration of the Iraq economy or other potential costs – much or all of which may be defrayed by Iraqi oil revenues.

To recap, the estimate for the amortized cost of pre-positioning equipment and materiel comes to $950 million per year for the period between 2003 and 2013. The amortized cost of the Iraq War is estimated at $3.72 billion per year. Taken together this yields a total of $4.67 billion annually. When added to the on-going costs, the defense related costs of a barrel of imported oil break down as follows:

DEFENSE-RELATED OIL IMPORT COSTS

1993-2003
(Billions)

ONGOING COSTS	**Budget-Based**	**State Formula**	**Minimalist**
Personnel, O&M	$42.790	$35.700	$5.418
Prepos. & Strategic Mob.	$ .518	$ .518	$ .518
S.W. Asia Contingencies	$ 1.100	$ 1.100	$ 1.100
Total Ongoing	$44.408	$37.318	$ 7.099
One-Time Amortized	$ .989	$ .989	N/A
Total Defense Costs	$49.088	$38.307	

Persian Gulf Only

1993-2002
(Billions)

Per Barrel cost	$45.54	$38.43	$ 7.12
Per Gallon cost	$ 1.08	$ .91	$ .17

All Imports

Per Barrel Cost	$10.71	$ 9.03	N/A
Per Gallon Cost	$ .25	$ .22	

DEFENSE-RELATED OIL IMPORT COSTS

2003-2013
(Billions)

Persian Gulf Only

Per Barrel Cost	$49.24	$42.12	$ 7.12
Per Gallon Cost	$ 1.17	$ 1.00	$ .17

All Imports

Per Barrel Cost	$11.58	$ 9.90	N/A
Per Gallon Cost	$ .28	$ .24	N/A

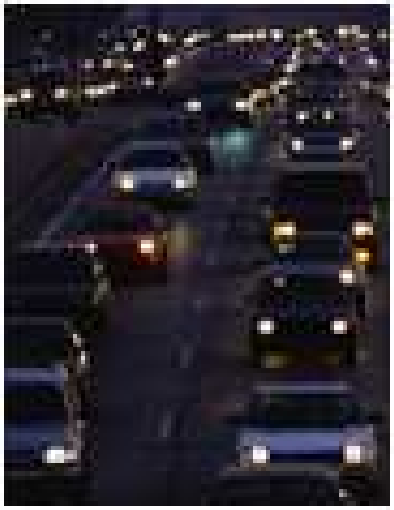
But defense-related costs are not the only penalty our oil import dependence exacts. Other general economic costs result as well.

CHAPTER TWO NOTES

1. American Petroleum Institute, Weekly Petroleum Update April 1, 2003
2. ibid.
3. ibid.
4. Source: United States Central Command, official chronology, 9th U.S. Airforce
5. ibid.
6. Source: United States Central Command, official description Third United States Army
7. ibid.
8. Sokolsy, Richard Ed. The United States and The Persian Gulf, Reshaping Security Strategy for the Post-Containment Era, National Defense University Press, Washington, D.C. 2003
9. Source: United States Central Command, NAVCENT official description
10. ibid.
11. ibid.
12. Source: CENTCOM Order of Battle as of March 3, 2003, Global Security, 300 North Washington Street, Alexandria, VA
13. United States Department of Defense, "Bottom Up Review," Washington, D.C. 1993
14. Source; United States Central Command
15. United States Department of Defense FY 2003 Greenbook
16. ibid.
17. ibid
18. ibid
19. ibid
20. ibid.
21. Source: CENTCOM Order of Battle as of March 3, 2003, Global Security, 300 North Washington Street, Alexandria, VA, op .cit.
22. Source: FY 2003 Special Operations Budget, US Department of Defense, Washington, D.C.
23. Source: Federation of American Scientists Intelligence Resource Program.
24. Based on U.S. Department of Energy annual import figures for 2002 and the Defense Budget based estimate of CENTCOM costs as described.
25. ibid.
26. See United States Department of State, Bureau of Verification and Compliance, World Military Expenditures and Arms Transfers 1999-2000, page 21, Washington, D.C. June, 2002
27. Estimate based on U.S. Department of State formula for per military member cost plus CENTCOM order of Battle op. cit.
28. ibid
29. Based on U.S. Department of Energy annual import figures for 2002 and the State Department Formula based estimate of CENTCOM's costs as described above.
30. ibid.
31. Based on U.S. Department of Energy annual import figures for 2002 and the Defense Budget based estimate of CENTCOM expenditures described above.
32. Based on U.S. Department of Energy annual import figures for 2002 and the State Department Formula based estimate of CENTCOM expenditures described above.
33. See note 24
34. See note 25
35. Source: OMB
36. Source: OMB
37. Based on original acquisition costs of $1.8 million per M1A2 Abrams Tank, $1 million per Bradley Fighting Vehicle, an average cost of $35,000 per other tracked vehicle, and $35,000 per other wheeled vehicle.
38. The cost figures for M1A2 Abrams tanks, Bradley Fighting Vehicles and other wheeled vehicles are the same as above. The unit cost of the Paladin is $1.8 million, for Command Vehicles the cost is $200,000, for bulldozers and bridge layers, the cost s $33,000 and for the trucks and Humvees $37,000.
39. Source: Department of Defense Budget
40. ibid.

41. ibid.
42. ibid.
43. Collier, Ellen, Instances of the Use of United States Forces Abroad, 1798-1993, Department of the Navy, Navy Historical Center, Washington, D.C. October 7, 1993
44. Copulos, Surge Production op. cit.
45. President's Supplemental Budget Request to Congress

CHAPTER 3: THE ECONOMIC IMPACT OF IMPORT DEPENDENCE


Typical rush hour traffic in any major city

Ready access to energy has brought enormous benefits to American society. It was central to the rise of industrialization, allowing machines to eliminate the drudgery of pre-industrial life and bringing about a level of economic well being undreamed of in previous eras. It made the generation of electricity a reality, expanding the scope of purposeful human effort to encompass nighttime hours. Nowhere, however, is the impact of energy more evident than in the area of transportation.

The invention of the internal combustion engine and advent of the automobile have given Americans a degree of mobility unprecedented in human history. Distances that once required days or weeks of grueling effort to traverse could now be traveled in minutes or hours in relative comfort. While it was once the norm for an individual to be born, live and die within a radius of a few miles from their birthplace, transcontinental travel is now unremarkable.

But the increased mobility made possible through the automobile has also brought with it costs – primarily associated with the rising tide of oil imports required to meet the nation's transportation needs.

Over the last two decades, a tidal wave of foreign crude has flooded America's shores. Today America depends on imports for almost 55% (1) of its oil needs with 13.6% (2) coming from the Persian Gulf.

Over the past two decades, America has spent nearly $1.1 trillion to satisfy this spiraling addiction to foreign oil (3) – a hemorrhage of capital that has cost millions of jobs reduced federal, state and local tax revenues and undermined domestic economic stability. Disruptions in foreign oil supplies have rocked the U.S. economy and sparked the two most serious recessions of the post World War II period. (4)

Yet, as substantial as these costs are to the U.S. economy, they are not reflected in the price paid at the gasoline pump. As a result, most energy consumers are unaware of the serious impact they have on daily economic activity.

What are these costs and how great is the burden?

ASSESSING THE COST: A FRAMEWORK FOR ANALYSIS

Because energy is such a pervasive commodity, the effects of energy imports are felt on a number of levels. On the most fundamental level, as with any commodity produced in another country, there are direct effects on employment and investment. Put simply, a dollar spent to purchase a commodity from a foreign supplier is a dollar that does not create direct employment of investment in the domestic economy. This is particularly true in times when there is a foreign trade imbalance, because domestic employment and investment losses arising from foreign purchases are not offset by employment or investment gains resulting from the sale of products overseas.

In the case of oil, a trade imbalance not only exists; it has become increasingly large over the last several decades. For the two decades between 1983 and 2002, the cumulative trade deficit in oil is almost $1.1 trillion (5), or an average of roughly $55 billion per year. (6) The average trade deficit, however, does not accurately reflect the enormous growth of net imports in recent times.

Since the millennium, our oil trade deficit has skyrocketed totaling $297.4 billion (7) or an average of over $99 billion annually. (8) The economic consequences of this imbalance may be viewed as the "Current Cost" of imports. The "Current Cost" may be further divided into two categories: "Direct" and " Indirect" effects.

DIRECT AND INDIRECT COSTS

Direct effects are comprised of the loss of domestic employment and domestic investment related to the actual production and delivery of oil imports. These would include such things as oilfield workers, petroleum geologists and engineers, transportation workers, refinery personnel, and all the rest of the people whose daily activities are involved in the production and delivery of the commodity. It would also include investments in drilling, pipeline operation, refinery construction and similar activities. These, however, are only the most obvious and immediate effects.

Indirect effects are comprised of the secondary employment and investment that would result from the economic activity generated by direct effects. For example, when a well is drilled or a pipeline is built, purchases are made of equipment and materials. Also, workers employed in the production and distribution of energy will make purchases in the local economy that in turn create further employment and economic activity. Economists refer to this as the "multiplier" effect. The greater the number of transactions that take place following the initial transaction that constitutes the "direct" cost the higher the multiplier will be. For example, the multiplier for a retail transaction is lower than that for a wholesale transaction. Since oil is a raw material, it carries a relatively high multiplier.

For purposes of this report, however, the direct and indirect effects of oil imports have been examined within two sets of parameters. The first looks at oil imports as a whole, and the other looks only at oil imports from the Persian Gulf.

THE QUESTION OF OPPORTUNITY COST

In addition to the direct and indirect effects that arise from the specific activity of producing and transporting oil, there is another level of impact that must be considered: opportunity cost. In the case of oil imports, the opportunity cost arises from the diversion of capital that would otherwise be available for investment in the domestic economy beyond that required to sustain the specific economic activity in question.

Historically, the oil industry has had a high rate of re-investment of capital – largely in the development of new supplies, but in recent decades in other areas as well. It is also important to understand that the published data on after-tax profit margins within the oil industry – around 7% (9) – do not accurately reflect the amount of capital available for investment. There are a number of special provisions in the tax code that tend to minimize the industry's taxable income.

A second point is that the oil industry tends to be a "cash-flow" business. This is to say that investment decisions are based more on revenue streams than on "accounting" estimates of profitability.

In estimating opportunity costs, therefore, revenue flows, and historic investment patterns provide a more reliable basis for estimation than after-tax profits.

CONSEQUENCES FOR GOVERNMENT REVENUES

When economic activity takes place abroad it is largely immune from federal, state and local taxation. As a result, such activity constitutes a real loss of revenue to these governmental bodies.

SUPPLY DISRUPTIONS

The current costs and opportunity costs that arise from the nation's oil import dependence constitute an ongoing drain on the U.S. economy. These economic penalties, however, are not unique to oil. An excessive trade imbalance in any product or commodity would impose similar burdens. There is, however, another important economic impact associated with the nation's addiction to foreign crude that is unique to that particular product: the economic consequences of oil import supply disruptions.

Unlike most products or commodities, energy, and particularly oil are essential to the operation of the U.S. economy. Without it, the economy simply cannot function. For this reason, even relatively modest disruptions of oil supplies can have an inordinate economic impact.

The most dramatic demonstrations of the economic havoc oil supply disruptions can wreak occurred in 1973 and 1979. In both instances the U.S. economy was thrown into a deep recession with enormous consequences for employment, production, interest rates and inflation. Even more modest supply disruptions, though, such as the one that accompanied the Persian Gulf War can still have a substantial negative effect on economic activity.

MARKET MANIPULATIONS

Another economic cost unique to oil arises from the inordinate ability of certain producing states, particularly Saudi Arabia, to manipulate oil prices. The consequences of price manipulation were most apparent during the period between October of 1985 and April of 1986 when predatory pricing moves by the Saudis nearly destroyed the U.S. domestic independent oil industry.

What then are the economic penalties our oil import dependence has exacted?

CUMULATIVE IMPACT

America first became a net oil importer in 1947. (10) Initially modest, import levels have accelerated with each succeeding year. As the level of imports has grown, so too, has the penalty they impose on the American economy. As noted, the U.S. has spent $1.1 trillion to purchase foreign oil over the past twenty years. (11) Yet, this figure in and of itself tells us little of the real underlying economic cost of our dependence.

Relying on overseas sources for oil has sent an average of 138,036 jobs overseas annually (12) and has cost the U.S. economy another 345,090 jobs from secondary employment that would have been generated by the lost domestic economic activity. (13) The loss of employment, in turn, has robbed the U.S. worker of an average of $20.5 billion in wages annually (14) and has caused the cumulative loss of some $212.3 billion in state, federal and local taxes. Even these average figures, though, do not tell the full story because the level of imports has been rising rapidly over the last several years. The reasons behind this steady increase suggest that the economic consequences of America's oil import dependence can only become more severe.

A DRAMATIC SHIFT

After rising steadily for two decades, (15) foreign crude oil and refined product imports began to fall off in the early 1980s. At that time, a combination of record prices and relaxation of federal regulations served to spark an enormous increase in domestic exploration and production that steadily reduced the need to rely on foreign oil. In addition, alternatives to oil and conservation were gaining ground. By 1985, imports had fallen to 27.2% of domestic supplies (16) a share smaller than anytime since the late 1970s. (17)

Nowhere was the impact of declining imports felt more strongly than in Saudi Arabia. From a peak of exporting 1.356 million barrels of oil to the U.S. daily in 1979, (18) by June of 1985 Saudi oil exports to the U.S. had fallen to a paltry 26,000 per day (19) – a decline of 98%. Alarmed at the loss of revenue, the Saudis instituted a series of price cuts that effectively halved the cost of a barrel of oil by April of 1986. No other producing nation could or would have taken such action, but Saudi production costs are so low -– between 10 cents and $1 per barrel – (20) and their reserves so prolific that price was less of a concern to the desert kingdom than market share. From that point forward, prices were closely monitored to assure their market share would be maintained.

One immediate consequence of the Saudi move was to accelerate the abandonment of so-called "stripper" oil wells. These are oil wells that produce less than 10 barrels of oil per day. They constitute the vast majority of the 534,000 wells producing oil in the U.S. today. (21) Since production costs for these marginal wells are high, they are very sensitive to price movements. When prices decline the number of "stripper" wells that are "abandoned," i.e. shut down and plugged by their operators will increase correspondingly. Conversely, as prices rise, the number abandoned will fall.

In 1984, the year prior to the Saudi price cut, 11,032 "stripper" wells were abandoned by their operators. (22) By 1986 that number had jumped to over 16,000 (23) and by 1987 to over 19,000. (24) Assuming an average production of 2.35 barrels per day, (25) the premature abandonments caused by the price cut reduced U.S. oil production by over 38,305 barrels per day or nearly 14 million barrels annually.

Over the longer term, Saudi price manipulation has not only had an effect on "stripper" well production. More importantly, it also served to restrain investment in domestic oil exploration and development. As a consequence, U.S. domestic oil production has fallen from 10.2 million barrels per day (mm/bd) to slightly over 5.8 mm/bd today. (26) Indeed, since 1994, the U.S. has imported more oil than it produced (27) – a trend that is expected to continue. What, then, are the current costs of our import dependence and what does the future hold?

THE CURRENT COST OF IMPORTS

As noted earlier, the current cost of imports, can be divided into two categories: direct costs and indirect costs. Direct costs are those that arise from the diversion of economic activity associated with producing, refining and delivering crude oil and refined petroleum products to foreign shores. Among the years 2000 and 2002 (inclusive) Americans spent more than $99 billion per year on average for imported crude oil and refined petroleum products. The economic impact of this enormous diversion of resources to foreign economies has been significant.

For the three years encompassing that period, the direct impact of oil imports on employment has been to send almost 250,000 jobs overseas annually. (28) These jobs would have generated almost $10.6 billion in direct wages and over $26.1 billion in indirect economic activity, (29) for a total loss to the economy of $36.7 billion per year. But the direct and indirect current costs are only part of the picture.

The opportunity cost (e.g. direct and indirect economic activity that would have resulted from capital investment arising from the revenue stream associated with oil imports) is even higher. Taking into account historic capital spending patterns within the oil industry as well as secondary capital spending that would occur from indirect economic activity, capital spending losses resulting from America's oil import dependence come to $33 billion annually.

For the same period, the lost capital spending results in direct losses of domestic economic activity totaling $35.2 billion annually (30) and an additional $88 billion in annual indirect costs. (31) This brings the total opportunity cost to $123.2 billion per year. (32) When added to the direct and indirect current costs, the total is some $159.9 billion annually. (33) The employment impact of lost capital spending through opportunity cost is a loss of almost 830,000 jobs. (34)

Local, state and federal governments also incur losses as a consequence of our import dependence. For the federal government the most significant impact is the loss of royalty payments that would otherwise be paid on domestic production. These would total $8.1 billion per year. (35) The federal treasury also suffers a loss of personal and corporate income tax payments of approximately $400 million per year (36) for a total impact of $8.6 billion annually.

At the state level, losses of royalty payments come to $4.3 billion annually. (37) The impact of these losses is particularly significant in states such as Texas and Oklahoma where royalty payments are an important source of funds for education. The loss of tax revenues to the states is approximately $600 million per year for a total impact of $4.9 billion per year. The total impact on state and federal revenues is $13.4 billion.

THE IMPACT OF PERSIAN GULF IMPORTS

While there is no question that America's overall reliance on imported oil and refined petroleum products exacts an enormous penalty from the U.S. economy, imports from the Middle East and particularly the Persian Gulf region pose a special problem. The politically unstable Middle East region has been the source of all 14 disruptions of global oil supplies that have occurred between 1951 and the present. (38) Imports from the Persian Gulf, and particularly from Saudi Arabia have steadily increased since 1995 (39) despite efforts to diversify import sources and are expected to continue to do so in the future. Moreover, all projections of production trends suggest that in the future, Persian Gulf oil will account for an increasing proportion of global oil supplies in the years ahead. (40) The question then, is what is the economic price Americans pay for using Persian Gulf oil?

THE ECONOMIC IMPACT

For the three-year period between 2000 and 2002, inclusive, the U.S. spent an average of $37.7 billion annually on oil imports from the Persian Gulf. (41) Overall Persian Gulf oil accounted for an average of 12.7% of U.S. oil supplies. (42) Over 31,000 jobs were lost to U.S. workers as a consequence of Persian Gulf imports, (43) creating a current direct economic impact of nearly $1.4 billion annually. (44) In addition over $3.3 billion in current indirect impacts are incurred for a total of nearly $4.7 billion annually. (45)

Opportunity costs associated are also substantial. Direct opportunity costs amount to an average of almost $4.5 billion annually. (46) Indirect opportunity costs add nearly $11.2 billion to this figure for a total of almost $15.7 billion annually. (47) The employment effect of these economic losses is to cost American workers more than 105,000 lost jobs per year. (48) The combined total of current economic impacts and opportunity costs associated with Persian Gulf Imports comes to more than $20 billion per year. (49)

Federal, state and local revenues are also adversely affected by the loss of domestic economic activity. For the federal government, the negative effects include a loss of approximately $1 billion per year in royalty payments (50) and $100 million in lost income tax revenues. (51) At the state level, losses of royalty payments come to $520 million annually and $76 million in state income tax revenues. (52) The total drain on governmental revenues comes to approximately $1.7 billion per year.

There is, however, another unique cost specifically associated with Persian Gulf imports of crude oil and refined petroleum products that is not incurred with imports from other regions: the cost of oil supply disruptions.

THE COST OF OIL SHOCKS

Anyone who lived through the oil supply disruptions of the 1970s and early 1980s knows the extent to which our growing appetite for imports posed an imminent threat to national security.

THE 1973 YOM KIPPUR WAR AND THE 1973-74 ARAB OIL EMBARGO

THE YOM KIPPUR WAR

On October 6, 1973, Jews in Israel were observing Yom Kippur, the holiest day of the year, when Arab forces comprised primarily of Egyptian and Syrian troops launched a two-pronged attack.

In the north, Syrian forces that included five divisions, 188 artillery batteries and 1,400 tanks attacked the two brigades and 11 artillery batteries Israel had stationed in the Golan

Heights. In the south, two Egyptian army corps comprising over 80,000 troops attacked across the Suez Canal rapidly advancing 15 kilometers and quickly overcoming the two Israeli "Sinai" divisions.

Within two days, the Israeli Defense Forces had called up their reserves and begun a counterattack with an air raid on Syrian headquarters.

By October 11th, Israeli troops had driven Syrian forces from the Golan Heights and were advancing into Syria. Ultimately they reached a position within 40 kilometers of Damascus, putting the Syrian capitol within the range of their artillery.

On October 15th, an Israeli division was able to breach the line formed by the Egyptian Second and Third armies along the Suez Canal and create a bridgehead. The following night, two Israeli divisions used the breach to cross the Suez Canal and begin harassing Egyptian supply lines. At this point it was clear that the tide of the war had turned.

On October 22, 1973 the United Nations negotiated a cease-fire between Syria and Israel. Four days later on October 26th, a cease-fire was negotiated on the Egyptian front.

Even as the military situation was approaching resolution, however, a new tactic would be attempted: use of the "oil weapon."

In August of 1973, prior to the outbreak of hostilities, Egyptian President Anwar Sadat had traveled to Saudi Arabia to inform King Faisal of plans for the surprise attack and to seek support. Faisal immediately pledged a half billion dollars in financial support, but, more importantly, also promised to use what he termed the "oil weapon."

On October 17, 1973, as Arab forces were reeling from the Israeli counterattack, King Faisal made good on his promise. Spurred on by Saudi Arabia, the OPEC oil ministers agreed to punish the West for its support of Israel.

On October 19th, the Arab members of OPEC announced an embargo on oil exports to the United States, making the threat to punish the West a reality. Over the next few weeks the embargo was extended to include Netherlands, Portugal Rhodesia and South Africa.

To show that they were serious, on November 5, 1973 Arab oil producers announced that they would cut production by 25% and threatened to cut output even lower if the West continued its support of Israel. (53)

Faced with what it believed would be a real loss of oil on the world market, and responding to a flood of constituent mail, Congress enacted the Emergency Petroleum Allocation Act (EPAA) that allowed the President to put controls on the price, production, allocation and marketing of oil.

On November 27th President Nixon signed the EPAA into law and set the stage for imposition of a cumbersome set of regulations that would ultimately make the effects of the embargo far worse than they would have been.

THE IMPACT OF THE EMBARGO

Gasoline lines following the AOPEC Embargo.

In addition to imposing the embargo, the Arab states also initiated a series of dramatic increases in the price of crude oil. On October 16th they raise the price by 70 % to $5.12 per barrel. (54) By February of the following year spot prices had climbed to $9.59 per barrel, (55) and in March leveled off at $12.73 per barrel, (56) more than four times the September 1973 price. The effect of price hikes was enormous.

Over the next sixteen months, the U.S. unemployment rate would more than double rising from 4.2% (57) in October of 1973 to 9.1% (58) in February of 1975. By 1974, the rate of inflation would be 12.3%, (59) more than 3.6 times the 3.4% (60) inflation rate experienced in 1972 – the year before the embargo. The increase in prices would cost U.S. consumers some $139.1 billion. (61) But inflation was the least significant economic impact of the embargo.

The impact of higher oil prices caused an actual 0.6% drop in GDP in 1974, (62) and an actual drop of 0.4% in 1975. (63) This compares with an average increase of 4.43% over the three years prior to the embargo. (64) These declines constituted the first instances of negative economic growth in fifteen years. (65) Together they cost the U.S. economy $540.5 billion.

Interest costs, too, were affected by the embargo. Interest rates rose by between 2% and 3% as a result of the embargo (66) costing Americans between $162.9 and $243.9 billion.

Taking the reduction in GDP and the increases in inflation and interest rates into account, the total economic impact of the 1973 embargo was between $842.5 billion and $923.5 billion. (67)

The first oil shock, of course, was only the beginning.

WAR AND REVOLUTION: IRAN AND OIL SUPPLY DISRUPTIONS

THE FIRST PHASE: REVOLUTION

Mohammad Reza Shah and his wife Farah

By the late 1970s, Iran was on the brink of revolution. The ruling monarch, Shah Muhammad Reza Pahlavi, an authoritarian ruler who was trying to rapidly modernize Iran both socially and economically, was at odds with conservative clerics who objected to both the introduction of modern values and the repressive measures the Shah often employed. The situation was aggravated by the fact that despite newfound oil riches, the gap between rich and poor remained large – a situation made far worse by runaway inflation. Tensions mounted steadily throughout 1978 fueled largely by the exiled Ayatollah Khomeini – a long-time opponent of the Shah and spiritual leader of that nation's conservative clerics. A general strike began slowly and then rapidly spread through the oil fields. Production declined and by Christmas Day 1978, Iran ceased exporting oil altogether, removing about 4.5 million barrels per day (MMBD) from the world market. (68)

Anti-Shah demonstration

Although Saudi Arabia and some other Persian Gulf producers did raise their output following the loss of Iranian crude, there was still around a 2 MMBD shortfall of supplies. Even though the shortfall was modest in terms of the total world market, a number of other factors served to make it much worse than necessary. Perhaps the most important of these was market psychology. Memories of the 1973 Arab Oil Embargo and the gasoline lines and economic havoc that followed in its wake loomed large in the public consciousness. Panic buying put a sharp upward pressure on prices.

A second important factor was the impact the loss of Iranian production had on various contractual relationships – especially those with British Petroleum, or BP as it was called. Britain had a long-standing presence in Iran, and

BP had concessions that allowed it to produce far more crude oil than was required to meet its own refining needs. It wholesaled the excess to other oil companies. Suddenly BP found itself without its major source of crude oil and immediately moved to revoke its agreements to supply crude oil to other companies under so-called "force majeure," or "act of God" provisions contained in its contracts. At the same time, it went into the spot market to purchase oil to meet its own needs. This sparked a bidding war among its former customers who now, also, had to scramble for supplies.

Sensing an opportunity, oil producers took advantage of the market panic to raise prices. The average cost of a barrel of imported oil went from $14.35 in 1978 (69) to $21.45 the following year, (70) and to $33.67 in 1980, an increase of almost 135% in just two years. The economic impact of the sudden price spike was immediate. Real GDP again experienced negative growth for the third time in a decade costing the economy $228.8 billion. The following year it remained sluggish, costing Americans an additional $97 billion. (71) Inflation spiked sharply as well, peaking at 13.3% (72) in 1979 – 48% higher than the preceding year. (73) Unemployment would rise by almost 44% between December of 1979 and July of 1980.

By July of 1980 oil markets were beginning to adjust to the loss of Iranian production and the U.S. economy was set to begin a recovery. It was at this critical moment, though, that the other shoe dropped: the Iran-Iraq war.

THE SECOND PHASE: WAR

Defenders at the Abadan oil refinery

Emboldened by the turmoil that had gripped Iran in the wake of the Shah's demise and subsequent disarray within the Iranian military, Iraqi dictator Saddam Hussein decided to move against Iran in an effort to seize valuable oil regions along the Shatt-al Arab river.

In the early morning hours of September 22, 1980 Iraqi aircraft launched a series of unprovoked attacks on targets across Iran. At the same time, Iraq attacked Iran across a broad front with infantry, armor and artillery.

On September 23, Iraqi aircraft followed up the first wave of bombing with assaults aimed at Iran's huge Abadan oil refinery and key Iranian oil facilities. Iran counterattacked in kind striking at Iraqi oil production. As a result of the attacks, global oil production was reduced by some 4 MMBD. On the global market, spot prices shot to $42 a barrel, (74) the highest level in history and almost three times what they had been just two years earlier.

The U.S. economy, which was just beginning to recover from the 1979 oil supply disruption, experienced negative growth for the fourth time since 1973 costing Americans some $111 billion. (75) Unemployment jumped by more than 20% (76) over the following year. Interest rates, too jumped. For example, the cost of a VA-guaranteed home mortgage rose from 11.5% in May of 1980 (77) to 16.5% by October of 1981. (78) Inflation, too, continued at double-digit rates driven by high oil and interest prices.

REVOLUTION AND WAR: THE COMBINED

Because of their proximity in time and common roots , it is useful to look at the oil supply disruptions that arose from the Iranian revolution and the Iran-Iraq War as a whole. Taken together, these two events exacted an enormous toll on the U.S. economy.

Between 1979 and 1981, they reduced U.S. GDP by $436.9 billion. (79) Inflation spurred by higher oil prices contributed an additional $222.6 billion to the total. (80) Excess interest costs ranged between $296.8 billion and $445.3 billion. (81) The total cost of the oil market turmoil of the 1979-1981 period therefore comes to between $ 956.3 billion and $1,104.8 billion. (82) The oil shock of the 1979-1981 period, however, would not be the last.

THE PERSIAN GULF WAR

Although brief, the Persian Gulf War still had a significant impact on the world oil market and imposed an enormous economic burden on the U.S. economy relative to its duration.

OVERVIEW OF THE WAR

Iraqi tanks entering Kuwait City.

On August 2, 1990 Iraqi forces surged into Kuwait, quickly overcoming local resistance and sparking worldwide outrage. Four days later, Saudi Arabia's King Fahd met with U.S. Defense Secretary Richard Cheney to request military assistance. By August 8th, the first U.S. Air Force fighter squadron had arrived in Saudi Arabia in response to the King's request. As the build-up of U.S. forces continued, the Bush Administration went to the United Nations seeking sanction for military operations to oust the Iraqi invader.

On November 29th, the United Nations passed a resolution authorizing the use of "all necessary means" to remove Iraqi forces from Kuwait. The resolution contained a January 15, 1991 deadline for Iraqi forces to withdraw.

Apache Helicopter on mission in Kuwait

The period between August of 1990 and December 1990 witnessed one of the most rapid deployments of U.S. forces in history. Ultimately, the U.S. would send 540,000 troops, 6 aircraft carriers 4,000 tanks, 1,700 helicopters and 1,800 aircraft to the region. (83) Almost 18,500 air deployment missions would be mounted (84) carrying 504,129 passengers (85) and 594,730 tons of cargo. (86) Allied aircraft would fly more than 116,000 combat missions. (87) These forces would require an average of 450,000 barrels of oil per day to operate.

At 2:38 AM Riyadh time on January 17th 1991, the allied attack began with a series of strikes by Apache helicopters. Over the next 30 days, Iraq was subjected to the most intense air campaign since the Vietnam War. On February 24, 1991 the ground campaign began. After approximately 100 hours of intense combat, Iraqi forces were overwhelmed and a cease-fire was announced at 8 AM on February 28th.

THE IMPACT OF THE CONFLICT

An immediate consequence of the Iraqi invasion of Kuwait was to remove 4.2 MMBD of oil from the world market. (88) The effect on prices was instantaneous and profound. Panic-driven speculation pushed prices rapidly upwards. By October of 1990 – just two months after the invasion – the price of oil on the spot market passed $40 per barrel 2.4 times its pre-invasion cost. (89) The average price of a barrel of oil reached $32.88, almost twice the pre-invasion level. (90)

Saudi Arabia and other Gulf producers agreed to raise production to make up the deficit. However, Saudi Arabia also invoked "force majeure" provisions in its contracts for jet fuel so that it could divert all of its production to the war effort. The problem with this move was that the Saudis were the "swing" producer of this fuel. As a result, it caused a worldwide shortage and prices soared. Airlines, already hit hard by a decline in both domestic and international travel that accompanied the war's onset saw their position erode further. In the case of Eastern Airlines, which was in a precarious financial position even before the war, the fuel price hike was too much. The airline went out of business.

Overall, U.S. consumers paid an extra $39 billion for oil as a result of the war-driven price spike. (91) As with previous disruptions of Persian Gulf oil supplies, the impact of high oil prices served to cause a decline in GDP in both 1990 and 1991 costing the U.S. economy some $407.6 billion. One of the most significant effects of the war was to cause a sharp spike in unemployment. The economy had been somewhat weak going into the war, and it greatly magnified what otherwise would have been a modest downturn. As a result of the oil price-driven recession, unemployment rose by 75% (92) eliminating over 1.1 million jobs. (93) The total economic cost of the war, excluding defense spending came to $446.6 billion. (94)

COMPUTING THE ECONOMIC BURDEN OF OIL SUPPLY DISRUPTIONS

The economic burden oil supply disruptions impose on the U.S. economy cannot be overstated. Indeed, over nearly five decades, the U.S. has experienced an actual decline in real GDP on only four occasions, (95) and each of those has been associated with a disruption of oil supplies. When the three major disruptions of the past thirty years are taken together, they yield a combined economic impact of between $2,245.8 billion (96) and $2,474.9 billion. (97) If averaged on an annual basis that would come to between $74.8 billion (98) and $82.5 billion (99) per year.

THE COMBINED BURDEN

The combined economic burden of external costs arising from America's import dependence is staggering whether viewed in terms of total imports or just in terms of imports from the Persian Gulf.

Looking at the economic in the broader sense – all imports – the burden includes current economic costs of $36.7 billion, opportunity costs of $123.2 billion and state and federal revenue losses of $13.4 billion. (100) In addition, there is also an annualized cost of between $74.8 billion and $82.5 billion for the impact of oil supply disruptions.(101) These components yield a total annual economic burden of from $248.1 billion to $255.8 billion. When added to the costs of defending Persian Gulf oil a total of between $297.1 billion and $304.9 billion results. This is equivalent to between $70.07 and $71.91 per barrel (102) or from $1.67 to $1.72 per gallon (103) if amortized over the total volume of oil imports.

If Persian Gulf imports are considered in isolation, the totals are still enormous. These imports impose current economic costs of almost $4.7 billion annually and opportunity costs of almost $15.7 billion. (104) In addition there is a loss of $1.7 billion in local, state and federal revenues for a total of $22.1 billion. (105) Since all of the significant oil supply disruptions of the post-WWII period have been associated with Persian Gulf imports, it is fair to attribute the full cost of supply disruptions to that region. When these costs are included, the total annual economic impact of Persian Gulf oil ranges between $96.9 billion and $104.6 billion. When defense-related costs are added, the total economic and defense burden comes to from $146 billion to $153.7 billion per year. This is equal to from $146.47 to $154.19 per barrel, (106) or to from $3.49 to $3.67 per gallon. (107)

In addition to the current costs, opportunity costs and defense-related costs associated with oil imports, there is one additional category of external costs that should be considered: environmental and health costs.

CHAPTER THREE NOTES

1) Source: Petroleum Supply Annual, United States Department of Energy, Washington, D.C. June, 2002
2) ibid.
3) Based on import and price data from Petroleum Supply Annual op. cit.
4) The Economic Impact of Import Dependence. Natural Petroleum Council, Washington, D.C. 1991
5) Based on balance of trade data from the United States Department of Commerce
6) ibid.
7) ibid.
8) ibid.
9) Source: The Tax Policy Center, Washington, D.C.
10) Source: Basic Petroleum Data Book, American Petroleum Institute, Washington, D.C.
11) Source: Petroleum Supply Annual op. cit.
12) Job estimate based on standard United States Department of Commerce factor for the number of jobs created per million dollars of investment.
13) Based on U.S. Census Bureau income data.
14) Based on Tax Policy Institute estimates of effective tax rates.
15) Source: Petroleum Supply Annual
16) ibid.
17) ibid.
18) ibid.
19) ibid.
20) Source: U.S. Department of Energy, private communication
21) Source: National Stripper Well Association
22) ibid.
23) ibid.
24) ibid.
25) Based on U.S. Department of Energy estimates of average stripper well production
26) Source: Petroleum Supply Monthly, United States Department of Energy Washington, D.C., April, 2002
27) Petroleum Supply Annual op. cit.
28) Based on BEA jobs/capital ratios
29) Based on U.S. Census Bureau income data.
30) Based on estimates of historic investment rate in the oil and gas industry.
31) Based on standard multiplier
32) Based on figures cited above.
33) ibid.
34) ibid.
35) Based on standard federal royalty payment of one-eighth of the wellhead price.
36) Based on Tax Policy Center estimates of effective tax rates
37) ibid.
38) Source: U.S. Department of Energy
39) Petroleum Supply Annual op. cit.
40) Source: U.S. Department of Energy
41) ibid.
42) ibid.

43) Based on BEA ratios cited above.
44) Based on BEA ratios and U.S. Census Bureau Income data
45) ibid.
46) ibid.
47) ibid.
48) ibid.
49) Based on figures cited above.
50) Based on standard federal royalty payment.
51) Based on Tax Policy Center effective rate estimates cited above.
52) ibid.
53) See “The Prize” op. cit. for a discussion of the cuts.
54) Source: U.S. Department of Energy
55) ibid.
56) ibid.
57) Source: Bureau of Labor Statistics
58) ibid.
59) ibid.
60) ibid.
61) ibid.
62) Based on Federal Reserve data.
63) ibid.
64) ibid.
65) Based on Bureau of Labor Statistics data
66) ibid.
67) Based on figures cited above.
68) Source: U.S. Department of Energy.
69) ibid.
70) ibid.
71) Based on Federal Reserve data.
72) ibid.
73) Based on Bureau of Labor Statistics data.
74) API Data Book op. cit.
75) Copulos, Milton R. Surge Production During Operation Desert Storm, National Defense Council Foundation, Alexandria, VA, May, 1993
76) Source: Bureau of Labor Statistics
77) Source: Federal Reserve
78) Source: U.S. Census Bureau data.
79) Based on Federal Reserve data.
80) Based on U.S. Census Bureau data.
81) Based on Federal Reserve data.
82) Based on figures cited above.
83) Source: U.S. Department of Defense
84) ibid.
85) ibid.
86) ibid.
87) ibid.
88) Source: U.S. Department of Energy
89) ibid.
90) ibid.
91) Surge Production During Operation Desert Storm op. cit.
92) Source: Bureau of Labor Statistics
93) Based on Bureau of Labor Statistics data.
94) Based on figures cited above.
95) Based on Federal Reserve data on historic GDP.
96) ibid.
97) ibid.

98) Based on figures cited above.
99) ibid.
100) ibid.
101) ibid.
102) Based on Department of Energy statistics.
103) ibid.
104) Based on figures cited above.
105) ibid.
106) Based on Department of Energy statistics.
107) ibid.

CHAPTER 4: ENVIRONMENT AND HEALTH

The relationship of oil imports to domestic economic costs arising from environmental and health effects is not as clear cut as the relationship between oil imports and more general economic and defense related costs. Although there are costs that arise from such things as oil spills, loading and unloading crude oil and petroleum product cargoes at port facilities and other activities directly associated with imports, these are relatively small when considered within the context of the broader economy.

Oil spills from tankers, for example, are often spectacular and can cause major economic damage if the oil reaches shore as was witnessed in the 1989 Exxon Valdez incident. Economic damage from the Exxon Valdez was estimated at $2.8 billion (1) and while the majority of the species damaged by the spill have either recovered or are recovering, several have made no progress. (2)

Even when such large spills occur, however, the damage tends to be localized and often the spills are quickly contained. More important, in the U.S. oil spills have in large degree diminished as an environmental problem over the past dozen years. According to the United States Coast Guard, which has responsibility for overseeing oil spills, in 2000, (the latest year for which figures are available) 96.5% of all oil spills were under 100 gallons. (3) The average spill was just 5 gallons. (4) Additionally, there have been no spills of over 1 million gallons since 1990. (5) Moreover, it could be argued that to the extent imports shift the far more significant health and environmental burdens of oil extraction and refining abroad, imports actually reduce the domestic environmental impact of oil consumption.

At the same time, there is no question that the use of refined petroleum products comes at an enormous environmental and health cost. The link between various mobile source pollutants and a wide range of health effects has been well established. According to EPA, for example:

- Carbon Monoxide (CO) interferes with the absorption of oxygen by hemoglobin in the blood. This impairs both the cardiovascular and nervous systems. It has been linked to fetal growth and tissue development, and can impair learning ability and the ability to perform complex tasks. (6)

- Ozone (O_3) is suspected of contributing to chronic lung disease, lung cancer and an increased susceptibility to upper respiratory infections including bronchitis and pneumonia. It may also interfere with the immune system. (7)

- Sulfur Dioxide (SO_2) constricts bronchial passages and alters the lung's defenses. It can effect breathing and is associated with asthma and other respiratory illness. It also reacts in the atmosphere to contribute to the formation of another pollutant: particulate matter. (8)

- Particulate Matter (PM) may cause a wide range of health problems including chronic cough, lung tissue damage, alteration of the immune system, and respiratory and cardiovascular disease. It is associated with an increased risk of lung cancer. (9)

According to the Centers for Disease Control and Prevention, the overall economic cost of the health-related problems associated with the air pollution range from roughly $65.8 to $71 billion. (10) Of this amount, from $38.2 to almost $47.8 billion are attributable to the air pollution caused by automobile emissions. (11)

Therefore, while the issue of environmental and health effects associated with imported oil warrants serious consideration, it must be addressed within the more general context of oil consumption per se. Once the general parameters of environmental and health effects are established, the portion attributable to imports can be derived. This makes it possible to calculate the reductions in pollutants and associated costs that would occur if that portion of oil accounted for by imports were replaced by some other, non-polluting fuel.

HOW SERIOUS A PROBLEM?

Over the past three decades, the link between air pollution and a variety of adverse health effects has been well established.

Among the most important research investigating the linkage between air pollution and a variety of adverse health effects was the so-called "Harvard Six Cities Study" (12) published in the New England Journal of Medicine in 1993. The study, which as sponsored by the National Institute of Environmental Health Sciences (NIEHS), monitored the air quality and health of some 8,000 adults and 14,000 children living in six cities: Watertown, MA, Steubenville, OH, Harriman, TN, Portage, WI, Topeka, KN and St. Louis, MO over a period of twelve years.

At the time, each of the cities selected was in close proximity to coal-burning power plants and therefore was likely to have substantial particulate matter in their atmosphere. The study's results were dramatic. The researchers found that individuals living in the cities with the most air pollution had a 26% higher mortality rate than those living in the least polluted cities. (13) It also found that on average, their life expectancy was reduced by two years. (14)

One of the more important findings of the Six Cities Study was the effect of air pollution on children. Specifically, the study found that children in high-pollution areas suffered from increased cough, bronchitis and chest illness. (15) As they were followed over the ensuing twelve years, the problems persisted causing the researchers to postulate that the children were potentially at risk for obstructive pulmonary disease later in life. (16)

Since that landmark study, the amount of research that has been conducted confirming the initial findings is impressive. Indeed, the National Library of Medicine's "PubMed" database contains more than 2,000 citations on the subject. Among the most notable is a December, 2000 article by researcher David Diaz-Sanchez confirming the role diesel exhaust particles play in aggravating allergies. (17)

One of the most recent studies was conducted by C. Arden Pope of Brigham Young University in Utah. His research linked some 500,000 deaths annually to air pollution. (18) The study examined mortality data collected by the American Cancer Society in an ongoing study that has tracked approximately 1.2 million adults since 1982. (19) It concluded that fine particulate matter and sulfur oxide-related pollution are linked to both lung cancer and cardiopulmonary disease. (20) Specifically, it found that the risk of lung cancer death increased 8% for every additional 10 micrograms of particulate matter per cubic centimeter of air. (21) In the case of heart disease, the risk of death increased 6% for every additional 10 micrograms of particulate matter. (22) Also, the risk of death from all causes increased 4% per additional 10 micrograms of particulate matter. (23)

AIR POLLUTION AND ASTHMA

One area of special concern in relation to air pollution is the asthma epidemic that has gripped the United States. In 1980, there were 6.8 million diagnosed cases of asthma in the U.S. population. (24) By 1994, the number of diagnosed asthmatics had risen to 13.7 million. (25) In 2001, there were some 31.3 million Americans diagnosed with asthma – many of them children. (26) This represents a 4.6 fold increase. (27) Among children under eighteen, asthma rates may be as high as 6.9 percent. (28) According to the Centers for Disease Control and Prevention, the cost of treating asthma in 2003 is expected to reach $14.1 billion. (29)

A significant factor contributing to the rise may be ozone pollution. In a presentation at the 58th Annual Meeting of the American Academy of Allergy, Asthma and Immunology, Dr. David Penden, Director of the Division of Allergy Immunology and Environmental Medicine at the University of North Carolina outlined his recent research in this area. According to Dr. Penden, asthmatics are more sensitive to ozone than other individuals. (30)

The linkage between ozone and asthma was perhaps most dramatically demonstrated during the 1996 Atlanta Olympic Games. Atlanta employed a number of measures to reduce vehicular traffic. (31) These included such measures as closure of the downtown area to vehicle automobile traffic; increased access to public transportation through additional busses and trains; and encouraging employers to offer such traffic reducing policies as "flex-time," car pooling and telecommuting. (32) The result of these measures was to significantly reduce automobile use during weekday morning rush hours by 22.5 percent. (33) This was considered the most crucial period.

The reduction in traffic resulted in a reduction in the peak daily ozone concentration from 81.3 parts per billion to 58.6 parts per billion – 28 percent. (34)

Viewing the 1996 Atlanta Olympics as a unique opportunity, the CDC dispatched a group of researchers to examine the effect of the traffic reduction measures on pollution-related health effects. The researchers compared the number of emergency room visits for asthma and non-asthma- related conditions during the Olympics to a four-week period before and after the event. (35) The results were dramatic.

Emergency Room visits for acute asthma attacks were measured at four different points: Medicaid claims filed, claims at an HMO, visits to two pediatric emergency rooms and the Georgia Hospital Discharge Base. (36) The researchers found that Medicaid claims fell by 42 percent, (37) the HMO experienced a 44 percent reduction claims. There was an 11 percent reduction in visits to two pediatric emergency rooms (38) and a 19 percent reduction in acute asthma attacks recorded in the Georgia Hospital Discharge Base. (39) But it was not just in relation to asthma that a beneficial effect on health was apparent.

The study also found that the incidence of acute non-asthma events also declined by as much as 3.1 percent during the period. (40) The researchers concluded "Efforts to reduce downtown traffic congestion in Atlanta during the Olympics resulted in decreased automobile use, especially during the critical morning period. This was associated with a prolonged period of low ozone pollution and significantly lower rates of childhood asthma events." (41)

One reason why the focus on ozone pollution is a matter of increasing concern in regard to asthma is the possibility that it is contributing factor in the asthma epidemic the nation is experiencing. According to Dr. John R. Balmes, Professor of Medicine at the University of California, " So far, we've been talking about exacerbation of existing asthmatic responses to ozone, but there are actually some data now suggesting that ozone exposure can lead to the development of asthma." (42)

Dr. Balmes also noted that among college freshmen who had grown up in Southern California, "… decreased flow rates at middle and low lung volume (so-called small airways dysfunction) were found in association with lifetime exposure to ozone and in particular with exposure early in life. (43)

In studies of rhesus monkeys exposed to ozone from birth, "…[you] get striking abnormalities in airway development. There's actually loss of some conducting airways." (44) Moreover, these effects were evident by the time the monkeys reached an age equivalent to three years of age in human children. (45) Also, the monkeys exhibited enhanced allergen responses and asthma-like symptoms. (46)

The potential link between early exposure to high concentrations of ozone and the development of asthma was strongly suggested in a recent study by scientists at the University of California. (47) The study examined 3,535 children with no history of asthma in 12 communities in southern California. Six had high concentrations of ozone, and six had lesser concentrations. (48) The children were followed up for as long as 5 years. (49) Some 265 of the children – 7.9 percent – reported a new case of asthma during the follow-up period. (50) Particular note was taken of their participation in outdoor team sports. (51)

In areas of low ozone concentration, a lack of participation in outdoor activities was found to have no effect on the likelihood of developing asthma. (52) In areas where there was a high ozone concentration, however, the risk of developing asthma for children who participated in outdoor sports was 1.4 times as great as those who did not participate. (53)

Dr. Rob McConnell, one of the lead investigators on the team said, " Our study provides evidence that, contrary to conventional wisdom, ozone is involved in the development of new onset asthma." (54)

AIR POLLUTION AND CANCER

Despite the expenditure of over $50 billion since the National Cancer Act was signed into law in December of 1971. (55) The projected budget for Fiscal Year 2004 alone is almost $6 billion. (56) But research dollars only represent the smallest fraction of the cost cancer exacts on society. According to the American Cancer Society, Americans spent $171.6 billion on doctors, hospitals and drugs to treat cancer in 2002. (57) Yet, progress appears illusive.

The National Cancer Institute (NCI) estimates that by 2050, the cancer incidence will double from 1.3 million to 2.6 million annually. (58) This alone, the American Cancer Society estimates that over 556,500 Americans will die each year from cancer. (59) What is particularly disturbing is that while the five-year survival rate for the fifteen most common forms of cancer decreased by eight-tenths of a percent between 1990 and 1997, (60) the incidence of cancer during the period measured increased by an identical amount. (61) In short, after thirty years, the "War on Cancer" appears stalemated. This raises the question of what can be done to accelerate progress – especially since even the current reports of minimal progress in population-wide cancer deaths may mask the full extent of the problem.

An important fact not immediately apparent from a review of year to year population-wide data is that the longer-term "age-adjusted" data tell a much more alarming story. Among older Americans, cancer rates are skyrocketing. In 1950, the "age-adjusted" rate for cancer was 158 per 100,000. (62) According to the NCI, that figure has risen to 166.9 per 100,000. (63) The change represents an increase of 5.6 percent. (64)

While many factors may contribute to the development of cancer, the American Cancer Society (ACS) notes that "about one-third of the 556,500 cancer deaths expected to occur in 2003 will be related to nutrition, physical inactivity, obesity, and other lifestyle factors that could be prevented. (65) At the top of the list is cigarette smoking, which is viewed as the major cause of lung cancer. (66) The ACS also notes that at least half of all new cancer cases could be detected by early screening. (67) Were such cancers diagnosed early, the ACS estimates the "five-year survival rate" for them could be raised from 82 percent to 95 percent. (68) In addition, from 5 percent to 10 percent of all cancers are hereditary. (69)

The question, then, is what role do automotive exhaust emissions play in causing cancer?

While not on the same scale as cigarette smoking or other major causes, there is a mounting body of evidence that suggests a role for automotive emissions over the long term.

On October 1, 2002, the EPA released the results of a 10-year long risk assessment. While the results hinted that diesel exhaust could be a contributing factor to cancer, the Agency carefully qualified its findings stating:

> *"The assessment concludes that long-term (i.e. chronic) inhalation exposure is likely to pose a lung cancer hazard in humans, as well as damage the lung in other ways depending on exposure. Short-term (i.e. acute) exposures can cause irritation and inflammatory symptoms of a transient nature, these being highly variable across the population. The assessment also indicates that evidence for exacerbation of allergies and asthma symptoms is emerging."* (70)

Still, the EPA cautioned that there were *"… assumptions and uncertainties involved…"* (71) in reaching their conclusions.

The potential risk of cancer from long-term exposure to diesel exhaust is not the only concern arising from automotive emissions. All automobiles also produce what are called "air toxics" in their emissions. Several of these chemicals have been identified as possible or definite carcinogens by the Environmental Protection Agency. Included among those so identified are benzene, formaldehyde, acetaldehyde and 1,3-butadiene. (72) According to EPA, air toxics cause around 1,500 cancers each year. (73)

GREENHOUSE GAS EMISSIONS

There is no doubt that the transportation sector is a major contributor to Greenhouse Gas Emissions. For example according to the Department of Energy's Energy Information Administration, (EIA) the transportation sector is responsible for 33 percent of all U.S. carbon dioxide (CO_2) emissions. (74) But CO_2 is only one component of the air pollution attributable to the transportation sector. Transportation also generates 77.1 percent of all carbon monoxide (CO) pollution, (75) 55.5 percent of nitrogen oxides (NOX), (76) and 47.0 percent of volatile organic compounds. (77)

As with other aspects of mobile source pollution, diesel emissions are a particular concern. They are responsible for 42.3 percent of NOX emissions, (78) 63.7 percent of transportation-related 10-micron particulate (PM10) (79) emissions and 72.5 percent of transportation-related 2.5-micron particulate emissions. (80) Moreover, these pollutants tend to be most heavily dispersed in more densely populated areas of the country (81), greatly magnifying their impact on public health.

The disproportionate contribution of diesel engines to air pollution is apparent when their proportion of the vehicle population is considered. Currently, diesel-powered vehicles account for 5.3 percent of the trucks currently in use, (81) and just 2.8 percent of the overall vehicle fleet. (82) Moreover, they represent a diminishing share of the automotive market. Since the peak year of 1981, when 6.1 percent of all vehicles purchased were equipped with diesel engines (83) in 2001 only 0.18 percent were. (84)

ADDRESSING THE PROBLEM

While billions of dollars have already been invested in improving the environmental performance of automobiles and light trucks, gains made have been largely offset by the increase in the total number of vehicles. Therefore, the most effective method of eliminating mobile source pollution might be to find an alternative means of fueling the transportation sector. Before such a move can be considered, however, it is first necessary to determine what options are available, and which provide the most practical means of accomplishing such a transition.

CHAPTER FOUR NOTES

1. Source, Exxon Valdez Oil Spill Restoration Plan, Update On Injured Resources and Services, Exxon Valdez Oil Spill Trustee Council, Anchorage Alaska, August, 2002
2. ibid.
3. Oil Spills in U.S. Waters, United States Coast Guard Calendar Year 2000, Washington, D.C. 2002
4. ibid.
5. ibid.
6. Our Built and Natural Environments, United States Environmental Protection Agency, Washington, D.C., January, 2001 pp 26-34
7. ibid.
8. ibid.
9. ibid.
10. Source: Centers for Disease Control and Prevention
11. Based on EPA estimates of mobile source pollution and CDC cost estimates.
12. Dockery, DW, Pope, CA 3rd, Xu, X, Spengler, JD, Ware, JH, Fay, ME, Ferris, BG Jr. Speizer, Fe, An Association Between Air Pollution and Mortality in Six U.S. Cities, New England Journal of Medicine, December 9, 1993; 329(24) 1753-9
13. ibid.
14. Ibid.
15. Ware JH, Ferris BG Jr., Dockery DW, Spengler JD, Stram DO, Speizer FE, Effects of Ambient Sulfur Oxides and Suspended Particles on Respiratory Health of Preadolescent Children, American Review of Respiratory Disease, May, 1986, 133(5) 834-42
16. Spengler, JD, Koutraks P, Dockery DW, Raizenne M, Speizer FE, Health Effects of Acid Aerosols on North American Children: Air Pollution Exposures, Environmental Health Perspectives, May, 1996, 104(5) 492-9
17. Diaz-Sanchez D PhD, Penichet-Garcia M MD, Saxon A MD, Diesel Exhaust Particles Directly Induce Activated Mast Cells to Degranulate and Increase Histamine Levels and Symptom Severity, Journal of Allergy and Clinical Immunology, December, 2000, Vol. 106 No. 6
18. Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution, C. Arden Pope III; Richard T. Curnett, PhD.; Michael J. Thun, MD; Eugenia E. Calle, PhD; Daniel Krewski, PhD; Kazuhiko Ito, PhD; George D. Thurston, ScD, Journal of the American Medical Association, Vol. 287, No. 9: 1132-1141, March 6, 2002
19. ibid.
20. ibid.
21. ibid.
22. ibid.
23. ibid.
24. Source: Centers for Disease Control and Prevention
25. ibid.
26. ibid.
27. ibid.
28. ibid.
29. ibid.

30. Penden DB, Diaz-Sanchez D, Balmes JR, Kleeberg SR Air Pollution and Asthma, Presented at the American Academy of Allergy Asthma and Immunology 58th Annual Meeting, March 3, 2002, New York, New York
31. Centers For Disease Control and Prevention Press Release " CDC Study Links Improved Air Quality with Decreased Emergency Room Visits for Asthma" dated February 21, 2001
32. ibid.
33. Friedman MS, Powell KE, Hutwagner L, Graham LE, Teague, WG, The Impact of Changes in Transportation and Commuting Behaviors During the 1996 Summer Olympic Games in Atlanta, Georgia on Air Quality and Childhood Asthma, Journal of the American Medical Association, 285(7) 897-905, February 21, 2001
34. ibid.
35. ibid.
36. ibid.
37. ibid.
38. ibid.
39. ibid.
40. ibid.
41. ibid.
42. Penden DB, Diaz-Sanchez D, Balmes JR, Kleeberg SR Air Pollution and Asthma, Presented at the American Academy of Allergy Asthma and Immunology 58th Annual Meeting, March 3, 2002, New York, New York
43. ibid.
44. ibid.
45. ibid.
46. ibid.
47. McConnell R, Berhane K, Gilliland F, London SJ, Islam T, Gauderman WJ, Avol E, Margolis HG, Peters JM, Asthma in exercising children exposed to ozone: a cohort study. Lancet. 2002 Feb 2;359(9304):386-91.
48. ibid.
49. ibid.
50. ibid.
51. ibid.
52. ibid.
53. ibid.
54. Dr. Rob McConnell quoted in Ozone Link To Asthma, BBC Friday February 1, 2002
55. Based on historic NIH Budget data.
56. Ibid.
57. Cancer Facts 2003, American Cancer Society
58. Brenda K. Edwards, Ph.D. (NCI), Holly L. Howe, Ph.D. (NAACCR), Lynn A.G. Ries, M.S. (NCI), Michael J. Thun, M.D. (ACS), Harry M. Rosenberg, Ph.D. (CDC), Rosemary Yancik, Ph.D. (NIA), Phyllis A. Wingo, Ph.D. (CDC), Ahmedin Jemal, Ph.D. (ACS), and Ellen G. Feigal, M.D. (NCI). Annual Report to the Nation on the Status of Cancer, *Cancer* (Vol. 94, No. 10, pages 2766-2792) May 15, 2002
59. Cancer Facts 2003, American Cancer Society op. cit.
60. National Cancer Institute Surveillance, Epidemiology, and End Results Program (SEER) database data
61. ibid.
62. Cancer Facts and Figures 1999, National Cancer Institute, Washington, D.C. 1999
63. ibid.
64. ibid.
65. ibid.
66. ibid.
67. ibid.
68. ibid.
69. ibid.

70. U.S. Environmental Protection Agency (EPA), 2002, Health Assessment Document For Diesel Engine Exhaust, Prepared for the National Center For Environmental Assessment, Washington, D.C., for the Office of Transportation and Air Quality; EPA/600/8-90/o57F. Available from National Technical Information Service, Springfield, VA; PB2002-107661, and http://www.epa.gov/ncca
71. ibid.
72. Department of Environmental Protection, State of Pennsylvania, Fact Sheet Automobile Emissions: An Overview, Bureau of Air Quality, Harrisburg, PA, April, 1996
73. ibid.
74. United States Department of Energy, Energy Information Administration, Emissions of Greenhouse Gasses in the United States, 2001, Washington, D.C. December, 2002
75. ibid.
76. ibid.
77. ibid.
78. ibid.
79. ibid.
80. ibid.
81. Source: EPA Air Toxics dispersal data.
82. Oak Ridge Transportation Data Book, op. cit
83. Source: Polk and Company
84. ibid.

CHAPTER FIVE FINDING AN ALTERNATIVE

During the four-week period ending June 6. 2003, the United States imported an average of 10.1 million barrels of crude oil and 1.7 million barrels of refined petroleum products daily. (1) Combined, imports for that period equaled 58.7% of all petroleum products supplied (2) These figures illustrate, as nothing else could America's growing import vulnerability and the urgency of stemming the flow of foreign crude.

Recognizing the necessity of reducing petroleum imports, however, is not the same as determining how to accomplish this goal.

OUR DWINDLING OIL RESERVES

At the heart of the issue are two geologic facts. The first is that oil is a finite resource. This is not to say that vast oil resources do not remain. Indeed, the U.S. Geologic Survey (USGS) estimates that the world still has oil reserves amounting to 859 billion barrels – a substantial amount by any measure. (3) Even this estimate, however, may understate the magnitude of the resource, because reserve figures are only part of the picture. Of greater significance over the long term is what geologists call the "resource base." While reserve figures only include potential oil bearing areas that have been identified and assessed, resource base estimates encompass all possible oil deposits. (4) Estimates of the remaining resource base currently place it anywhere between 1,500 billion and 2,000 billion barrels. (5) But, as substantial as these amounts are, they would still only be sufficient to sustain current levels of world oil consumption for from 19.4 to 25.8 years, (6) or assuming that projections of near-term increases in consumption occur, from roughly 12.6 to roughly 16.8 years. (7)

But there is a second geologic fact that must be considered as well: the location of proven and potential oil deposits. Currently, some 65.3% of the World's proved oil reserves – 685.6 billion barrels – are found in the Middle East. (8) In contrast, U.S. proved reserves are just 22.4 billion barrels (9) and account for only 2.9% of the world total. (10) The U.S. resource base for oil is substantially larger, with the Department of Energy estimating that some 105.5 billion barrels of undiscovered oil remain. When extensions of existing fields and other in place reserves are factored in, DOE estimates the total petroleum resource base at 174.82 billion barrels. (11) At current production levels, U.S. proved reserves will be exhausted in roughly 10.7 years – but that assumes a continued dependence on imports for nearly 60% of consumption and no increase in demand. (12) If all requirements were met with domestic crude proved reserves would be exhausted in just over three years – and that assumes no increase in demand! (13) The entire resource base would last just over 23.8 years with the same assumptions. (14)

In order to utilize the full extent of the domestic resource base, however, it will first be necessary to gain access to it. At this time, many of the most promising areas for the discovery of new oil deposits remain off-limits to exploratory drilling, and unless this circumstance changes, domestic production will decline even more rapidly than would otherwise be the case.
It is also important to recognize that the likelihood of identifying vast new undiscovered oil reserves in the United States is relatively slim. The U.S. has been drilled more extensively than any other region of the world. While there are certain areas such as the Arctic Coastal Plain and the Outer Continental Shelf that are likely to hold substantial new reserves, the most promising of these areas have been identified and are already included in current reserve and resource base estimates. Even if these resources are eventually developed they still will not provide sufficient new production to completely eliminate the need for oil imports. Still, their development remains vitally important, because it would help slow the decline of U.S. production. But, it would not reverse the trend.

Clearly, if some substitute for petroleum is not identified, the nation faces an increasing and increasingly perilous dependence on imported oil. Over the long term, the answer lies in developing a practical hydrogen fuel cell vehicle that can ultimately provide a non-polluting means of powering the automobile that relies on an inexhaustible fuel source. In the interim, however, some substitute that can help the U.S. begin to address the immediate danger oil imports pose. The question, then, is how can such a substitute be found and introduced into the U.S. energy economy?

A THREE-PART PROBLEM

The search for a solution to America's energy dilemma is best viewed as a multi-part problem. The element of the problem is determining what can be done immediately to stem the flow of imports. The second element is assuring a supply of conventional petroleum-based fuels for military purposes while the transition to some alternative is taking place. Once these two elements of the problem have been resolved, the third element is to put in place permanent fix. Also, under ideal circumstances, any steps taken to deal with the near-term issue of stemming the flow should serve as a foundation on which a permanent solution can be built. While both near-term steps and a more permanent solution will have many characteristics in common, each will also bring with it a distinct set of requirements.

What, then, would they be?

COMMON CHARACTERISTICS AND DISTINCT REQUIREMENTS

To begin with, it is a given that any proposed alternative – whether designed to address only the immediate needs or to provide a long-term solution – must be domestically based. It would make no sense to substitute America's dependence on imported oil with an identical dependence on some other commodity. A second and obvious requirement is that any alternative must be adaptable to transportation applications. As noted in an earlier section, it is the transportation sector that is most vulnerable to oil supply disruptions. Moreover, increased transportation sector demand is the principal cause of rising oil consumption and imports. Again, whether in the near-term or over the long-term, any viable alternative must also be available from domestic sources in sufficient quantities to replace the entire volume oil and refined product imports. Finally, the substitute must be economically competitive with petroleum.

In addition to these common characteristics, as noted, there are also distinct requirements associated with each element of the problem.

For the near-term, perhaps the most critical factor is how quickly a proposed alternative can be brought into widespread use. For this to happen, one of the first prerequisites is that the alternative does not require a significant technological breakthrough in order to be employed. The need to reduce America's import dependence is simply too pressing to accommodate the delays that would accompany such a need. Preferably, it should employ a relatively mature technology that does not require significant modification of the existing vehicle stock.

A second important factor will be winning public acceptance for the alternative. A substitute is of little use if no one wants it. In order to achieve public acceptance, there should be no characteristics associated with the alternative that would tend to generate public opposition. For example, it should have an environmental profile that is as good as or better than the cleanest petroleum products on the market. Also, bringing it into production should not entail disruptive construction projects in areas of environmental sensitivity, or at a minimum should be accomplished with relatively benign environmental consequences.

A third consideration is its cost. It must be economically competitive with petroleum-based alternatives. If the price is substantially higher than petroleum-based alternatives, the public will reject it.

How then, do America's various energy resources stack up against these criteria?

REVIEWING THE NEAR-TERM ALTERNATIVES

In addition to oil itself, there are three conventional energy resources available that could serve as a substitute to imported oil in the transportation sector: coal, oil shale and natural gas. In addition, there are renewable options including fuel alcohol and the production of petroleum analogs from biomass, such as biodiesel.

Among the various conventional alternatives, coal is clearly the most abundant.

The United States has been called “The Saudi Arabia of Coal.” There is good reason for this characterization. America holds fully 25% of the World’s proved coal reserves. (15) According to the Department of Energy, U.S. Estimated Recoverable Coal Reserves total approximately 275.1 billion tons. (16) This amount is sufficient to sustain current levels of production for more than 200 years. Of course, coal cannot be used in conventional internal combustion engines in its natural state. In order to serve as a source of transportation fuel, coal must be converted into synthetic products that emulate the characteristics of refined petroleum products. This is accomplished through one of two processes: coal gasification or coal liquefaction.

COAL-BASED SYNTHETIC FUELS PROCESSES

Sasol Coal-based synthetic fuels plant in South Africa

The object of both coal gasification and liquefaction is to add hydrogen to coal and thereby transform it into a gaseous or liquid fuel. Of the two processes, gasification is by far the oldest.

Coal gas has been in use for over two centuries. It was first produced in 1798 by James Watt. As early as 1817, a company was formed in Baltimore to manufacture and distribute coal gas, and by the 1920s, about one-fifth of all fuel gas burned in the U.S. was derived from coal. By the advent of World War II, there were at least 20,000 coal gasification units in operation in the United States. However, most gasification processes produce a “medium Btu” gas that has only about half the energy content of methane, conventional natural gas. It must therefore undergo further processing to convert it into “synthesis natural gas” or “syngas” and then upgraded to a liquid fuel through “liquefaction” if it is to be used in a vehicular application. There are two basic methods of accomplishing this transformation: direct liquefaction and indirect liquefaction.

The most widely used method of indirect coal liquefaction employs the Fischer-Tropsch process. Developed in Germany in the late 1920s, it was used to produce over 200 million gallons of liquid fuel during the Second World War. This process employs a reaction of synthesis gas, hydrogen and carbon monoxide in the presence of an iron or cobalt catalyst to produce a synthetic crude oil or “syncrude.” The syncrude is then upgraded through conventional hydrocracking and isomerization refining processes to produce conventional fuel analogs. Today, South Africa uses indirect liquefaction to produce almost 200,000 barrels of synthetic fuels daily. (17)

The second method of producing motor fuels from coal is through direct liquefaction. Direct liquefaction was also used in Germany, with production peaking during World

War II at around 1 million gallons per year. Direct liquefaction is much more difficult than the indirect method. It entails reacting coal and hydrogen in the presence of a solvent at around 400 degrees centigrade, and under pressures of up to 100 atmospheres. Over the past three decades, substantial research has been conducted on new direct liquefaction technologies including H-Coal, Exxon Donor Solvent, SRC-I &II and Catalytic Two-Stage Liquefaction. At present none are in commercial production.

In the United States, the Fischer-Tropsch indirect coal liquefaction process is currently being examined as a means of producing extremely low sulfur diesel for use in areas with high pollution.

While indirect liquefaction is a mature technology in commercial use in South Africa, there are a number of factors that may serve to limit its use as a substitute for petroleum imports. The most significant of these is cost. In the case of South Africa, the government heavily subsidizes the synthetic fuels industry. In the absence of such subsidies, it would be unable to compete with conventional petroleum products at prevailing prices. When the U.S. considered a major program of synthetic fuels production in the 1980s, it was determined that the fuel would require an oil price of around $45 per barrel in order to be economic. (18) When oil prices collapsed in the mid-1980s, attempts to commercialize synthetic fuels in the U.S. were abandoned.

A second concern regarding synthetic fuels is the impact of their production on the environment. In order to maximize efficiency, most plants would be located near large coal deposits – generally in the Western United States. These areas, however, are ecologically sensitive, and often are protected by various federal environmental rules. In fact, during the 1980s when a major program to build synthetic fuels plants was undertaken, it was anticipated that a special exemption from federal rules would be required to allow the facilities to be built.

A third concern relates to the environmental impact of mining the coal the plants would require. In order to improve the overall economics of the plants, it was anticipated that the coal they used would be stripmined. This problem was further aggravated by the fact that the plants were likely to be located in environmentally sensitive areas where such activity might be particularly damaging.

A fourth concern is the cost of construction. In the early 1980s when the U.S. embarked on an ambitious synthetic fuels program, the estimated cost of building a plant capable of producing 25,000 barrels of synthetic fuels daily was between $3 billion and $4 billion. (19) Given ensuing inflation, this would translate into between $6 billion and $8 billion in current dollars. Therefore, to replace almost 12 million barrels per day would cost around $2.88 trillion. Even if the cost were amortized over the expected 35-year operating life of a synfuels plant, it would still require an investment of almost $83.3 billion annually.

The final, and perhaps most important concern relates to the time horizon for instituting synthetic fuels production on a meaningful scale. Under optimum circumstances, plant construction would take up to four years, exclusive of permitting. When the permitting process is added in, however, the time frame extends to from seven to ten years – and that assumes no problems along the way. A more likely time frame would be similar to that encountered in the construction of large nuclear power plants and coal-fired electrical generating capacity i.e. ten to fifteen years. Given the urgency of America's need to reduce its dependence on imported oil, this factor alone makes synthetic fuels a poor choice as a near-term option.

OIL SHALE

Oil Shale plant, circa 1923.

After coal, oil shale is among America's most prolific energy resources. Oil shale is a type of fine-grained sedimentary rocks that contains relatively large amounts of organic matter—chiefly a substance called kerogen. The organic material can be extracted by heating the shale to high temperatures (500 degrees centigrade). It is estimated that the U.S. may hold as much as 62.5% of the World's oil shale reserves. (20) Reserves found in the Green River formation in Wyoming, Colorado and Utah are estimated to hold up to 130 billion barrels of oil (21) and Eastern Marine Shale reserves may include as much as 400 billion barrels. (22)

Oil shale has been exploited commercially for over two centuries, although principally outside North America. One of the earliest examples is found in the development of an oil shale deposit in Autun, France in 1839. Even as the first commercial oil well was being drilled in the U.S. in 1859, a commercial oil shale industry was beginning in Scotland, with some 20 beds of shale being mined. The industry evolved to the point that between 1881 and 1955, from 1 to 4 million metric tons of oil shale were mined annually. After 1955 production began to decline and ceased in 1962. Oil shale has also been commercially exploited in Estonia, Russia, Brazil and China in the late 19th and 20th centuries, sometimes on a large scale. The largest producer was Estonia whose production peaked at some 20.6 million tons annually around 1980.

In the U.S. interest in oil shale has increased from time to time when oil prices rose for brief periods. Inevitably, however, as oil prices declined, interest in oil shale evaporated. Following the oil supply disruptions of 1973 and 1979, interest in oil shale was renewed, this time with security of supply as well as price as a motive. Still, although a number of major oil companies obtained leases and embarked on efforts to produce economically competitive shale oil, none were successful. The principal reason for the failure was the high cost of extraction.

Like coal, oil shale must be processed in order to extract a usable fuel. There are two basic methods of producing shale oil. In the off-site method, the oil shale is mined through conventional means (drilling and blasting) and then hauled to a processing plant where it is crushed. The crushed shale is then placed in a retort and heated to around 900 degrees Fahrenheit to release the kerogen. The kerogen is separated from the crushed rock for further processing and the remaining debris is then removed and disposed. Following separation, the kerogen must undergo still further processing to add a hydrogen atom supplied from water to convert it into mid-grade petroleum that can be further refined into fuel.

As can be seen from the above description, extracting, processing and refining oil shale through this method is complex and expensive. It also has a number of serious environmental impacts. The most obvious is the impact of mining on the surrounding environment. Unlike the coal mining associated with synthetic fuels production, oil shale generally requires deep mining because the most productive deposits lie deep underground.

The need for water to convert kerogen into mid-grade crude also presents a problem. The areas of Wyoming, Colorado and Utah that hold the most promising oil shale deposits are also areas where water is in short supply, and therefore oil shale production would have to compete with other existing economic interests for this scarce resource. The extensive processing also carries with it a substantial energy requirement.

There is, though, another method: "in situ" extraction.

The in situ method involves heating the shale in place by mining underneath the deposit and excavating a series of compartments to hold shale released through blasting. The shale is then ignited and used to heat the deposit to the requisite 900 degrees Fahrenheit to release the kerogen. The kerogen is then allowed to flow through the rubble into a sump and subsequently removed for the remaining stages of processing.
While the in situ process eliminates the need to transport and crush the unprocessed shale, it still requires that the kerogen go through the expensive two-stage refining process if it is to be used as a crude oil substitute, and would still require large amounts of water for processing.

Because of the requirement for multi-stage processing, the cost of mid-grade crude produced from oil shale could be even higher than that produced through coal liquefaction, largely due to high capital costs. In the late 1970s, the Office of Technology Assessment estimated an oil shale plant producing 50,000 barrels per day would require a capital investment of from $1.4 billion to $2 billion. (23) In current dollars this would equal from $2.8 to $4 billion. (24) In addition, there would be operating costs of from $24 per barrel to $34 per barrel incurred to convert the kerogen to mid-grade crude.

Also, like synthetic fuels, the lead-time for the construction of facilities would be a minimum of six years exclusive of the time required for permitting. When the permitting process is included, the lead-time is easily a decade or more. Further, any project would likely be met with severe environmental opposition due to the environmentally sensitive nature of the areas in which the most potentially productive oil shale deposits are found. Therefore, again, like synthetic fuels, oil shale does not appear to offer the prospect of near-term relief from the need to import foreign oil.

BIOFUELS

As their name would imply, biofuels are produced from biomass – up to now, primarily in the form of agricultural products. The notion of using biomass as a fuel source has enjoyed widespread bipartisan support in Congress and within the environmental community. As a result, no less than fourteen laws beginning with the Energy Security Act of 1978, and continuing to energy legislation currently before Congress, have been proposed or enacted, to encourage the production and use of fuels produced from biomass. There are a number of reasons why biofuels have enjoyed such popularity.

First, because they are produced from agricultural material, biofuels hold forth the prospect of providing a source of "renewable" energy that can be continually replenished. This stands in stark contrast to finite petroleum resources.

Secondly, they provide a new market for domestic farmers hard hit by high production costs, depressed prices and competition from abroad.

Third, they are promoted as being environmentally beneficial – although the extent of environmental benefit is not the same for all biofuels.

The Department of Energy lists five potential forms of biofuel: Ethanol, Methanol, Biodiesel, Biocrude and Methane. Of these, only Ethanol and Biodiesel are in use today, and Ethanol is by far the most prolific.

ETHANOL

Ford's Model T could run on ethanol.

Ethanol is the grandfather of biofuels. When Henry Ford designed the Model T in 1908, he expected it to be fueled by ethanol. (25) In the early 1920s, the Standard Oil Company actually marketed a fuel comprised of a blend of 25% ethanol and 75% gasoline. (26) Ford's commitment to ethanol was so strong that he helped build a fermentation plant at Atchison, Kansas specifically designed to produce ethanol as a motor fuel. (27) During the 1930s, production from this plant and others was marketed at service stations throughout the Midwest billed as "gasohol." (28)

Ford's enthusiasm, however, could not overcome the realities of the marketplace. The discovery of huge, prolific oil fields in the United States during the 1920s and 30s depressed oil prices to the point that ethanol could not compete. By the 1940s, the last remaining fuel ethanol plants closed ending the early experiment with renewable fuels.

Early service station offering ethanol.

With the oil shocks of the 1970s, interest in ethanol as a motor fuel was renewed. Shortages of crude oil caused refiners to look for ways to "extend" motor fuel supplies and viewed ethanol as a prime candidate. A principal reason was that in addition to acting as an "extender," ethanol was also an octane enhancer, adding as much as 2.5 points to a fuel's octane rating. (29) This second attribute became even more important as environmental concerns led to the banning of lead from gasoline. There was, however a significant drawback to ethanol: price.

Even at the high oil prices prevailing in the late 1970s and early 1980s, ethanol was still more expensive than refined petroleum products and, more important, the additives it was used to replace. Part of the reason for this was that prices for competing additives did not reflect their associated external costs. In the late 1970s, Congress addressed this problem through a number of new laws.

In 1977, the Food and Agricultural Act (Public Law 95-113) authorized the U.S. Department of Agriculture (USDA) to provide loan guarantees for four biomass plants and expanded USDA research for renewable fuels.

In 1978, The Energy Tax Act (H.R. 5363) gave a 4-cent per gallon federal excise tax exemption to fuels blended with at least 10% ethanol and granted a 10% energy investment tax credit for biomass to ethanol conversion equipment. This tax credit was in addition to the existing investment tax credit.

In 1980, the Crude Oil Windfall Profits Tax Act (Public Law 96-223) extended the 4-cent per gallon excise tax exemption to December 31, 1992 and the investment tax credit to December 31, 1985. It also created income tax credits for alcohol blenders – 40 cents per gallon for those blending 190 proof alcohol and 30 cents per gallon for those blending 150-190 proof. The Energy Security Act, also passed in 1980, offered insured loans for small ethanol producers covering up to 90% of construction costs and established the DOE Office of Alcohol Fuels.

Over the ensuing years, although the excise tax exemption would be raised peaking at 5.4 cents per gallon in 1990 and currently is 5.2 cents per gallon of blended fuel. It should be noted, however, that gasoline excise taxes increased significantly during this period, and as a result, the actual proportion of excise tax represented by the exemption declined. To illustrate, when ethanol was originally granted a 4 cent excise tax exemption, the total excise tax on gasoline was 4 cents. Therefore, the exemption came to 100% of the applicable tax. Today, the exemption is 5.2 cents, but the federal excise tax on gasoline is 18.1 cents – a reduction of just under 29%.

The blender's income tax credit would also rise to 50 cents per gallon for 190 proof alcohol and 45 cents per gallon for 150-190 proof. The tax credit for the 150-190 proof ethanol was intended for use by farmers who would distill fuel for their equipment locally. However, it has seen little use. In that same year, EPA mandated the use of oxygenated fuels during the winter months in 39 major carbon monoxide non-attainment areas and year-round use in 9 severe ozone non-attainment areas.

With tax subsidies amounting to roughly 5.2 cents per blended gallon and federal mandates requiring the use of oxygenates, it is unsurprising that fuel ethanol has been the most successful biofuel. About 3 billion gallons of fuel ethanol are produced annually, (30) with roughly 12% of U.S. Motor fuel containing ethanol as a fuel additive. (31) There currently are 75 ethanol production facilities either in operation or under construction (32) employing approximately 250,000 people. (33) It is estimated that ethanol production contributes around $6.5 billion to farm income each year. (34) A recently approved move by the House and Senate to establish a Renewable Fuel Standard (RFS) for motor fuels would establish an annual growth rate for ethanol, increasing to 5 billion gallons over the next ten years. (35)

Although ethanol has strong congressional support, and has value as an oxygenate and extender, it is an unlikely candidate to replace oil imports as a primary fuel. To do so would require producing roughly180 billion gallons of fuel alcohol – 120 times as much as is produced today. (36) If the alcohol were produced from corn, it would require processing some 72 billion bushels, (37) or roughly 7.1 times the TOTAL current U.S. corn crop. (38) It would also require approximately the use of 533.3 million acres, (39) or 54% to the total U.S. acreage under currently under cultivation, (40) to produce the required amount of corn. Further complicating the use of corn to produce fuel ethanol on such a massive scale is the additional issue of what that level of production would do to markets for other corn products such as corn oil and high fructose sweeteners used in soft drinks and processed foods. These byproducts are extremely important to the economics of fuel ethanol, and the potential of disrupting their markets complicates the substitution of ethanol for petroleum products impractical.

Ongoing research concerning the use of feedstocks other than corn, especially agricultural, municipal and forestry wastes may open the door to a broader contribution than can be attained through food crops alone.

Even without the development of new feedstocks, however, ethanol will continue to play an important role in the transportation sector as an octane booster and fuel extender. Although the complete substitution of ethanol for refined petroleum products would be impractical, there remains room for significant expansion of its existing role in stretching the existing supply of refined petroleum products and providing an environmentally benign means of improving octane.

BIODIESEL

The notion of using agricultural products as a source of diesel fuels dates from the earliest period of diesel engine development. Biodiesel is manufactured through a process called "transesterification in which natural oil or fat is combined with an alcohol in the presence of a catalyst. This process has been known since the mid-1800's. It was originally used to distill out glycerin to make soap. In 1898, when Rudolph Diesel demonstrated his engine at the World's Exhibition in Paris he reportedly used peanut oil as a fuel. Although the advent of cheap petroleum prevented biodiesel from gaining a foothold in the market, it was used to power heavy-duty vehicles in South Africa prior to World War II. In the post-war period, however, South Africa developed an ambitious program to manufacture synthetic fuels from coal, and biodiesel was largely forgotten. In the United States, it is only in the last decade that interest in biodiesel arose.

Like ethanol, biodiesel has significant support in Congress and the farm and environmental communities. Also, like ethanol it has been primarily as an additive rather than as an undiluted or "neat" fuel. In 2001, the most recent year for which figures are available, approximately 25.4 million gallons of biodiesel were used in the United States. (41) Most of this was used in blended fuels comprised of 20% biodiesel and 80% conventional diesel primarily to reduce cost. The cost of biodiesel is in part dependent on the feedstock used to produce it. As a result it can cost anywhere from $1 to $1.70 per gallon before taxes are added. (42) With the additional 50 cents per gallon in state and federal excise taxes, the retail price of the fuel is between $1.50 and $2.20 per gallon. (43) This compares with an average wholesale price of 95 cents for diesel fuel, or $1.45 when excise taxes are added in. (44)

Current installed capacity to produce biodiesel is around 50 million gallons per year. (45) This comes to roughly 3,261 barrels per day. In contrast, in 2001, the U.S. used over 2.34 million barrels of #2 diesel in on-road and off-road applications daily. (46). Advocates of biodiesel claim that up to 2 billion gallons could be produced annually, or roughly 130,463 barrels per day. (47) Even this figure, however, would amount to only a little less than 5.6% of U.S. diesel fuel consumption. (48) Since a bushel of soybeans yield enough oil to produce 1.5 gallons of biodiesel, this means that over 1.3 billion bushes would be required to meet this target. This would equal almost 46% to the total U.S. soybean crop. (49) To replace all petroleum-derived diesel with biodiesel produced from soybeans would consume just over 23.9 billion bushels, (50) or approximately 8.2 times the current crop. (51) At current maximum crop yields, growing 23.9 billion bushels of soybeans would require approximately 598 million acres, (52) or approximately 60.5% of U.S. farmland. (53)

There is no doubt that, like fuel alcohol, biodiesel can make a contribution to the nation's transportation energy mix as a fuel additive. It does represent a practical means of replacing limited volumes of refined petroleum products.

NATURAL GAS

SUPPLY


Natural Gas Processing Plant

After coal, natural gas is America's most prolific energy resource. Currently, proved reserves stand at over 183 Trillion Cubic Feet (TCF) (54). The total domestic resource base is estimated at 1, 614 TCF, (55) the equivalent of over 257.7 billion barrels of oil. (56) Today, natural gas accounts for around one-fifth of all energy used in the United States, (57) a remarkable figure given that it was once considered a waste byproduct of oil drilling.

Despite the substantial size of U.S. proved and potential natural gas reserves, concern has been expressed recently about near-term shortages. The reason some fear a shortfall is that for the past decade, the U.S. has been depleting the so-called natural gas "bubble" that had evolved in the 1980s.

The "bubble" was actually created by accident. During the 80s high oil prices led to a spike in exploratory drilling as wildcatters swarmed over the oilfields to take advantage of the new economic realities. While some new oil was discovered, far more of the exploratory wells found gas. As a result, natural gas was cheap and abundant. It was at this stage that normal market forces took over. The surplus of supply coupled with low prices reduced the cash flow wildcatters had available to finance new wells. The problem was greatly exacerbated in the mid-1980s when, as mentioned earlier, Saudi Arabia instituted a series of steep price discounts that undercut the price of oil and made drilling in the United States even less attractive. This led to record-low rig counts, and a corresponding decline in new discoveries.

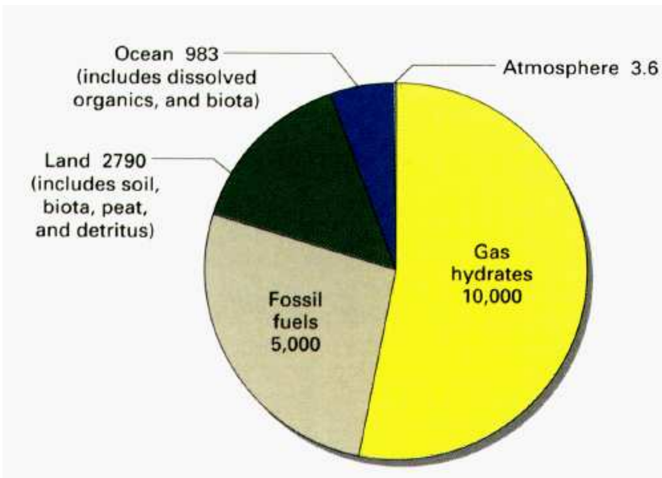
Still, the size of the "bubble" was such that most consumers were unaffected. At the same time, a move by the electric utility industry to utilize more natural gas for power generation due to their inability to gain approval for new coal or nuclear plants further increased demand. This combination of growing demand and declining exploration led to a rapid consumption of the surplus and advent of the current market tightness.

Fortunately, the problem is self-correcting.

It is important to recognize that the issue is not one of resources. Domestic natural gas supplies remain abundant, and substantial additional reserves are available from Canada and Mexico. At current consumption rates, the domestic natural gas resource base is sufficient to meet all needs for more than 73 years. (58) If consumption increases by 50% as some analysts project, supplies are still adequate to last up to roughly 49 years. (59)

What is necessary to solve the problem is to drill more wells, and the higher prices that have accompanied the decline in the gas "bubble" are creating an incentive to do just that. But even if conventional supplies are exhausted, a new and virtually unlimited source may be on the horizon: methane hydrates.

METHANE HYDRATES



Distribution of organic carbon in Earth reservoirs (excluding dispersed carbon in rocks and sediments, which equals nearly 1,000 times this total amount). Numbers in gigatons (10^{15} tons) of carbon.

Source: U.S. Geological Survey

In the mid-1960s scientists made a remarkable discovery: ice-like substances lying deep in the ocean that contained trapped methane and other gasses within a lattice-like arrangement. Called methane hydrates, these formations are found primarily in ocean-bottom sediments at water depths exceeding 450 meters and in permafrost. EIA estimates that hydrates may contain as much as half of the world's carbon. (60) In terms of natural gas, the agency estimates that Oceanic Natural Gas Hydrates comprise a resource of from 30,000 TCF to 49,100,000 TCF. (61) Continental deposits (primarily in permafrost) add from 5,000 TCF to 12,000 TCF to this total. (62)

For the United States, EIA estimates that methane hydrate resources in place contain 320,222 TCF. This is equal to over 51.1 trillion barrels of oil, (63) almost 25 times the total remaining world oil supply. (64) Onshore methane hydrate deposits in Alaska alone comprise some 519 TCF. (65) This is the equivalent of approximately 82.9 billion barrels of oil. (66) What remains, though, is to determine how to produce them.

Methane Hydrate core sample

In at least one instance, it appears that natural gas is being produced from methane hydrates, although not by intent.

Russia's West Siberian Basin holds the Messoyakah Natural Gas Field. The Messoyakah field produced natural gas on a continuing basis from 1970 to 1978, and has continued production intermittently since. As is normal in oil and gas

Test well for Methane Hydrates in Canada.

production, over time, as the resource was consumed, field pressure began to decline. It did not, however, decline as rapidly as expected. Puzzled, the phenomena was investigated and researchers discovered that there was a layer of naturally occurring methane hydrates about 100 meters thick located at a depth 700 meters below the surface. The researchers postulated that as the conventional gas was withdrawn from the field, the reduction in pressure caused the methane hydrate layer to begin to decompose and release its trapped gas to the formation above. The result was that the methane released from the hydrates partially replaced the gas that had been extracted and helped maintain pressure at a higher level than would otherwise have been the case. Today, the Russians believe that as much as half of the Messoyakha field's production is derived from decomposing methane hydrates.

While the Messoyakha field is the only deposit that may be producing natural gas for the commercial market – if indeed decomposing hydrates are responsible for the higher than expected field pressure – there is hope that this new source may provide a limitless supply of the most environmentally benign fossil fuel. There remain, however, significant technical and economic hurdles to overcome before the promise can become a reality. But they are not insurmountable. Indeed, from its earliest history, the use of natural gas hinged on technological advance.

HISTORY

Perhaps the earliest mention of natural gas is found in the writings of Plutarch, who, around 100-125 AD described the ancient, "eternal fires" that could be found in certain areas of present-day Iraq. These were most likely gas seeps (gas leaking through cracks in the ground) that had been ignited by lightening strikes.

In 1609, John Baptise van Helmont of Brussels experimented with natural gas, but could not find a means of confining it so that it could be harnessed.

It was not until the 19th century that gas came into commercial use – primarily for street and residential lighting. Indeed the period was called the "gaslight era." By the 1890s, however, many cities began to convert their streetlights to electricity and the market for gas dwindled. In 1885 the German physicist and chemist, Robert von Bunsen provided the industry's salvation. His "Bunsen burner" showed how mixing gas with air made it practical to use the fuel for cooking and heating buildings. But, the use of gas was still limited by the lack of a means to get it to widespread markets.

Although a few relatively long gas pipelines were built as early as 1890, it was not until the end of the Second World War that pipeline construction began in earnest. The reason was that military research during the war developed improvements in metals, welding techniques and pipe that made the construction of large pipelines more feasible. Throughout the 1950s and 1960s pipeline construction proceeded at a rapid pace, to the point that today, the U.S. natural gas pipeline network, if laid end to end, would stretch to the moon and back twice.

NATURAL GAS AS A VEHICLE FUEL

Ford F-150 Natural Gas-powered truck.

Natural gas has been used as a vehicle fuel since the 1930s. Until the 1970s, though, the availability of cheap, petroleum-derived fuels largely precluded the use of natural gas in the transportation sector. With the oil shocks of the 1970s, many countries began to look more seriously at natural gas as an alternative to conventional gasoline and diesel fuels. Over the ensuing three decades, the number of natural gas vehicles (NGVs) in service has steadily grown. Today, there are over 2.8 million NGVs on the road. (67) Argentina has both the highest number – 926,352 (68) – and the highest proportion of NGVs – 15% (69) – of any nation. Brazil has the second highest number – some 550,000 (70) with Italy's 434,000 third. (71) According to the latest DOE statistics, the United States has 126,341 natural gas vehicles in operation. (72)

Although the initial impetus for switching to natural gas as a vehicle fuel came from the fear of oil supply disruptions, the continued growth has been motivated as much or more by environmental considerations. Natural gas is the cleanest burning fossil fuel and as such is being utilized in many areas around the world as a means of reducing urban air pollution. This point was made eloquently at an October 4, 2002 meeting of California's South Coast Air Quality Management District Board that stated in the Agenda for the proceeding:

"Natural gas vehicles (NGVs) represent one of the cleanest combustion powered vehicles on the market. For example, the 1999 Honda Civic GX NGV has been certified by CARB for sale in California at 1/10 of ultra-low emission vehicle standards for all three criteria pollutants. Catalyst conversion efficiency is up to 99% with cold starts included.

Compared to a similar gasoline vehicle, toxic emissions are reduced by 97% and carbon monoxide emissions by 25% as tested by DOE." (73)

Despite the superior environmental performance associated with natural gas vehicles, they have been slow to gain market penetration in the United States. Up to the present, natural gas has been principally employed in conjunction with fleet vehicles in the United States. Two factors have contributed to this circumstance. First has been the lack of a fueling infrastructure for personal vehicles. Although the U.S. does have 1,250 natural gas fueling stations (74), most of these were built to fuel specific fleets. As a result, many are not accessible to the general public. In contrast, there are 176,000 conventional gasoline service stations in the United States. (75)

As the South Coast Air Quality Management District Board noted:

> *"One of the key barriers to consumer acceptance of NGVs as personal cars is the limited publicly accessible refueling infrastructure. Fleet operators can financially justify the installation of their own refueling station due to the cumulative fuel throughput and local concentration of fleet vehicles. Fuel retailers are just beginning to make the transition to offering natural gas refueling, as the number of NGVs on the road increases."* (76)

Put simply, it is unlikely that consumers would purchase a vehicle if they were not sure they would be able to obtain fuel to operate it.

A second issue underlying the slow market penetration of natural gas as a vehicle fuel has been range. Because natural gas is not as dense as liquid fuels, it must be compressed and stored in tanks designed for that purpose. As a result, the storage space required for an amount of natural gas equivalent to a gallon of gasoline is greater than space storing a gallon of the liquid fuel would require. In order to preserve trunk capacity, this has often led NGV manufacturers to reduce the volume of compressed natural gas stored on a vehicle. Unfortunately, along with the reduction of on-board fuel came an accompanying loss of range – sometimes reducing it to 150 miles or less. Since the gasoline-powered vehicles Americans are accustomed to have a range of from 350 to 450 miles, (77)

Recent technological advances, though, provide solutions to the problems of fueling and range.

The issue of refueling has been resolved by the development of what is termed the "Vehicle Refueling Appliance," or VRA. A VRA is a natural gas fueling device designed for use in homes with natural gas service. Currently around 55% of all U.S. households have access to natural gas, (78) and approximately 200,000 more are adding gas service every year. (79) Therefore, the opportunities for home refueling are significant. Moreover, new versions of VRAs have been developed that sell for under $1,000. This low cost places them within the financial reach of most homeowners.

The second issue, range, has a technological fix as well: the hybrid electric vehicle. Through June 30, 2002, some 39,179 hybrid electric vehicles had been sold in the United States. (80) By using a small conventional internal combustion in combination with a small electric motor hybrids are able to achieve substantial improvements in mileage – as much as double their conventional counterparts. A hybrid could therefore carry enough natural gas on board to provide the range the American consumer expects.

Moreover, using natural gas-powered hybrids would provide a means of accomplishing many of the steps necessary to make the eventual move to the hydrogen fuel cell while making important progress in reducing oil imports and enhancing environmental quality in the near-term.

Natural gas also offers the most environmentally benign solution to providing military fuels in the event supplies are disrupted in time of war. Natural gas can be used as a feedstock for the Fischer-Tropsch process to manufacture synthetic diesel and jet fuel. This eliminates the need to incur the expense and environmental impact of mining and processing coal while still providing a non-petroleum source for these critical wartime commodities.

MAKING THE RIGHT FUEL CHOICE

In reviewing the various alternatives to imported oil, it becomes clear that the optimum choice is natural gas.

In the case of coal, although supplies are plentiful, extensive processing with significant environmental impacts are required before it can be used as a motor fuel. While the technology for producing synthetic fuels is well proven, implementing it on a large scale would entail enormous economic costs and lengthy delays for both construction and permitting. Even when the plants are in place, they would only be profitable at oil prices above $35 per barrel – a fact well known to the oil producing nations. It is likely that were a synthetic fuels program undertaken, oil producers would engage in the same sorts of price cutting practices that they used to render this option uneconomic in the past.

In regard to oil shale, it, too, is plentiful, but like synthetic fuels produced from coal, environmental and economic concerns make it an unlikely candidate. Of particular concern is the amount of water that producing shale oil would require given the arid nature of the regions where the most promising oil shale deposits are found.

Biomass does not bring with it the same environmental concerns that accompany synthetic fuels from coal and oil shale. While cost is an issue, the principal drawback with this option is the inability to produce biofuels in sufficient quantities to meet national requirements. The simple fact is that we could not produce enough biomass material to replace a substantial proportion of imported oil. Further, diverting corn or soybean production to serve, as a feedstock for motor fuels would severely disrupt the markets for co-products that are essential to making biofuels even marginally economic.

Biomass may, however, continue to play a role as a substitute for oil in other applications – especially in the production of lubricants and plastics.

What remains is natural gas. In the immediate-term, as has been demonstrated by the more than 126,000 NGVs on the road today, it can provide a viable, environmentally superior option both through use in fleets and by individuals when combined with the use of VRAs. In the near-term, natural gas can serve as a means to substantially reduce oil imports through its use in hybrid electric vehicles. Moreover, natural gas-powered hybrid electric vehicles can provide a transition medium to the hydrogen fuel cell.

But can natural gas play a similar role in meeting the near-term need for fuels to power the military's tactical vehicles?

NEAR TERM OPTIONS TO ENHANCE SUPPLY: REQUIREMENTS

There are several characteristics that any alternative under consideration as a near term means of assuring adequate fuel supplies for military needs must possess. First among them is that it must be domestically based. It would be pointless to exchange a dependence on one type of imports for another. Secondly, it must be available in adequate volumes to meet projected needs. In particular it should have the ability to "surge" should the tempo of military operations suddenly increase. A third characteristic is that it should not depend on an unrealized technological breakthrough to be implemented. The need for options is immediate and therefore any alternative considered should be technologically mature.

A final consideration is cost. The alternative selected should the lowest cost consistent with meeting the other requirements for providing the Armed Forces with a petroleum substitute. It is important to note that determining an acceptable cost level for military fuel differs from performing the same task in regard to civilian use. In the civilian sector, fuel choice is primarily a matter of economics. Achieving the lowest possible cost is therefore the focus of decision makers in regard to energy.

Conversely, in military operations fuel is more than just a commodity. It is an essential element of achieving tactical and strategic objectives. A lack of fuel can paralyze an army in the field and even lead to its destruction. Therefore, while cost is a consideration, availability is the primary concern of military logisticians.

The task, then, is to determine what options are available to provide fuel for tactical vehicles that meet the necessary criteria.

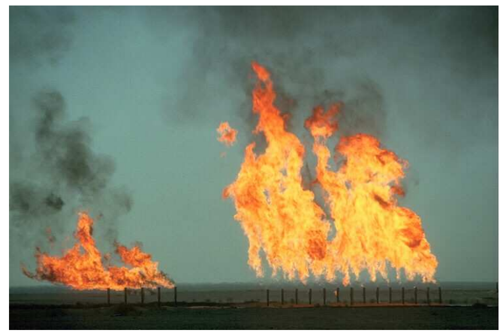
SETTING THE STAGE

Perhaps the first question to be addressed in designing a program to meet military fuel needs in the event of a supply disruption is just how much fuel will be required? This, of course is a function of the size and composition of the force fielded. There are some logical assumptions, though, that can help narrow the range.

First, it is reasonable to assume that a supply disruption would occur as a consequence of either a major conflict, or a significant political upheaval in a major oil producing nation.

Second, it is reasonable to assume that the needs of brief, relatively small-scale military operations can be met from market sources, even in times of supply disruption. This in fact was what occurred during both the Arab Oil Boycott and the Iranian Oil Embargo.

Third, fuel supplies only become a significant issue if there is an active conflict that requires the deployment of U.S. forces. Otherwise, there would be time to develop alternatives or to simply wait for normal market conditions to return.



Saddam Hussein set fire to Kuwait's oil wells to prevent their use by the Allies.

Therefore, what emerges is a scenario in which it is necessary to field a significant force in a relatively contemporary time frame in response to a major conflict. It is also reasonable to assume that the conflict will be abroad, as the likelihood of an aggressor reaching U.S. shores with a substantial force is at best highly remote.

Recent experience can also help to narrow the range.

Over the past twelve years, there have been two military operations that approximate the conditions in the scenario described above: Operation Desert Storm and Operation Iraqi Freedom. What makes these operations even more instructive is that they demonstrate the evolution of U.S. military doctrine as reflected in the concept of "Rapid Decisive Operations."

In the case of Operation Desert Storm, when peak deployment was reached, Allied Forces required roughly 450,000 barrels per day of refined petroleum products, with a heavy emphasis on JP4 and JP8. On a per capita basis, this amounted to roughly 35.5 (81) gallons of fuel per soldier, per day.

During Operation Iraqi Freedom, some 300 million gallons of fuel were purchased to provide for the first 30 days of operations for an Allied force of approximately 238,000. (82) This amounted to a per capita fuel requirement of roughly 41.7 gallons of refined petroleum products per day – an increase of approaching 17.5% over Operation Desert Storm. (83) Given the emphasis on mobility warfare in current doctrine and the increasing reliance on CONUS-based forces, (both active duty and mobilized National Guard and Reserve) per capita fuel requirements may grow even higher in the future.

Given the experience in the two most recent major conflicts, then, it is reasonable to postulate that the per capita fuel requirement for deployed forces in future conflicts will be at least 42 gallons, or one barrel of refined petroleum products per day. It is also reasonable to postulate that the range of troop strength that would be deployed would range somewhere between 250,000 and 500,000 during peak combat operations. This translates into the need for a minimum production capability of 250,000 barrels per day, and a maximum of 500,000 barrels per day.

What then, would be needed to provide this level of assured fuel supplies?

MEETING THE NEED

During the early 1980s when the notion of using coal-derived synthetic fuels processes to meet some portion of U.S. petroleum needs was first considered, the notion was eventually rejected due to cost and environmental concerns.

On the financial front, there were a number of factors that adversely impacted cost. First of all, interest rates were at or near record highs, making financing of capital-intensive projects extremely expensive. Secondly, all of the projects considered used coal as a feedstock. Moreover, virtually all projects contemplated also envisioned locating the plants adjacent to coal mines excavated for the express purpose of providing feedstocks for synfuels. Developing these mines would, of course, further increase the overall capital requirements.

On the environmental front, there were serious issues concerning water use, given the likely location of the facilities in the Western United States where water was already in short supply. In addition, many of these areas were near national parks and other protected regions where environmental rules were stringent. Finally, there was the simple fact that the processes did have substantial environmental impacts, both from mining operations and from the processing of coal into syngas. Providing for these environmental concerns entailed significant pollution control and remediation expenditures further raising costs.

When all of the factors were considered, it was estimated that the cost of building a plant capable of producing 25,000 barrels of synthetic fuels daily would be from $3 to $6 billion. (84) This would mean that it would require an investment of from $60 to $120 billion to provide the capacity necessary to meet military needs in the event of a supply disruption. These enormous costs would make any attempt to provide a “safety net” for military needs prohibitively expensive. Fortunately, they no longer reflect current conditions.

A number of major energy firms including ExxonMobil, Sasol Chevron, Shell, BP and Syntroleum are actively developing Gas to Liquid or “GTL” synthetic fuels plants. (85) In fact, Shell already has a 12,500 barrel per day plant operating in Bintulu, Malaysia that produces specialty products. (86) It has plans, however, for a 140,000 barrel per day plant in Qatar that will produce diesel fuels for the commercial market. (87) Also, Sasol Chevron is scheduled to begin construction on a 34,000 barrel per day plant in Qatar later this year. (88)

Unlike the coal-based synthetic fuels plants of the 1980s whose construction ranged between $120,000 per daily barrel to $240,000 per daily barrel of capacity, GTL technology construction costs are expected to range between $20,000 per daily barrel to $25,000 per daily barrel. (89) Although significantly lower than two decades ago, the $144 billion to $288 billion investment that would be required to replace all imports remains prohibitively expensive. Providing assured supplies for military purposes, though, is a less daunting prospect.

Syntroleum Natural Gas to Liquids Plant

Based on contemporary estimates of the capital investment required for each daily barrel, building the capacity to provide 250,000 barrels of synthetic fuels using GTL technology would cost between $5 billion and $6.25 billion – roughly the cost of one Nimitz Class aircraft carrier. Building enough capacity to provide 500,000 barrels per day would cost between $10 billion and $12.5 billion.

At present, assuming a natural gas price of $4.42 per million Btu, (the Henry Hub spot price for October 1, 2003) (90) the unit production cost of GTL synthetic fuels would average $39.75 per barrel. (91) This is roughly 11.7% more than the current (October 1, 2003) landed spot price for Kerosene-Type jet fuel in New York. (92) It should be noted that these prices include a provision for capital recovery and taxes. It would appear, therefore, that while slightly higher than petroleum-derived fuel, GTL alternatives are within reasonable economic parameters. But cost is not the only consideration.

The fact that the GTL process uses natural gas as a feedstock represents a major advantage in that it is domestically based. As a result, if oil supplies are disrupted, the production of military fuel from these facilities would remain unaffected. Moreover, it would also eliminate the need to divert whatever petroleum supplies that remained available from civilian to military use.

Another major advantage of using the GTL process is that many of the environmental concerns associated with coal-based synthetic fuels processes would be eliminated. The fuel itself has a very low sulfur content, a distinct advantage over petroleum-derived alternatives. Also, with almost 1.3 million miles of natural gas pipeline, (93) methane can easily be delivered from existing or new fields to processing facilities minimizing the environmental impact of obtaining and delivering the feedstock. Also, the extensive pipeline network makes it possible to locate the synfuels production facilities in areas where water is abundant, eliminating another key concern associated with coal-based processes and environmental impacts on sensitive ecologies. In fact, it would make it possible to locate the facilities on existing military reservations enhancing security.

Locating the facilities on existing military reservations would also permit the use of existing fuel depots and terminals for storage and loading. Therefore the existing mechanisms for transporting fuel to the theater of operations can be used.

FINANCING THE PROJECT

Even though the investment required to provide a guaranteed fuel supply for military operations using GTL technology would be significantly lower than coal-derived synthetic fuels options, it is still substantial. In a time of budgetary constraints, a logical question would be how to provide the financing for construction and maintenance of the facilities. One option would be to establish a public-private partnership through which private firms would build, operate and maintain the plants in exchange for purchase guarantees at a fixed price that contained a premium equal to the difference between the market price for petroleum-derived fuels and their GTL analogs. The premium would remain in effect until the capital costs had been recovered, after which time the fuel would be priced at prevailing market levels.

Since the Department of Defense would be purchasing fuel whether or not the plants were built, the only real additional cost would be the premium over prevailing prices – around 9.9 cents per gallon. Moreover, in times of supply disruption when prices would certainly increase substantially, the fixed price arrangement could actually result in significant savings to the Department.

Employing a purchase guarantee, of course, will be viewed by some as an unwarranted intervention in the marketplace. Yet, there has been a long history of government involvement in the development of new technologies – particularly for purposes of national defense that has reaped enormous benefits for the American public. Therefore, not only are there precedents for such a move, but in fact a long tradition of federal involvement in fostering innovation.

Clearly, natural gas would appear to present the promise of an alternative that could not only meet near-term military needs but that could provide broader import relief within the broader economy. This transformation, though, could not be accomplished without a major role for government. Before discussing how this could be accomplished, it is first necessary to determine just what the role of government should be in helping free America of its oil import dependence.

CHAPTER FIVE NOTES

1. Weekly Petroleum Status Report, Energy Information Administration, United States Department of Energy, June 6, 2003
2. ibid.
3. World Petroleum Assessment, Table AR-1 United States Geological Survey, 2000
4. ibid.
5. Sources: P.J. McCabe, "Energy Resources – Cornucopia or Empty Barrel" American Association of Petroleum Geologists Bulletin, vol. 198 p.p. 2110-34; U.S. Geological Survey, World Petroleum Assessment 2000; Oil and Gas Journal annual estimates of world oil production.
6. Estimate based on United States Department of Energy, Energy Information Administration estimates of world oil consumption.
7. Estimate based on United States Department of Energy, Energy Information Administration projection of 119 MBD world oil consumption by 2025
8. Source: BP Statistical Review, BP, p.l.c, Britannic House, 1 Finsbury Circus London, UK, June, 2002
9. U.S. Crude Oil, Natural Gas and Natural Gas Liquids Reserves, 2001 Annual Report, United States Department of Energy, Energy Information Administration, Washington, D.C. November, 2002.
10. BP Statistical Review, op. cit.
11. U.S. Crude Oil, Natural Gas and Natural Gas Liquids Reserves, op .cit.
12. Based on current crude oil production of 5.7 mmbd as reported by the U.S. Department of Energy.
13. Based on 20.1 mmbd of consumption as reported by the U.S. Department of Energy.
14. ibid.
15. Source: United States Department of Energy, Energy Information Administration
16. ibid.
17. ibid.
18. Based on internal price evaluation prepared for the United States Synthetic Fuels Corporation by the author.
19. Schell, Joseph M., "The Bottom Line: Can We Finance Major Synfuels Construction In the 80s?" presented at the Eighth Annual International Conference on Coal Gasification, Liquefaction and Conversion to Electricity, University of Pittsburgh 1982
20. Source: U.S. Geological Survey
21. ibid.
22. ibid.
23. Source: Office of Technology Assessment
24. Based on Bureau of Labor Statistics inflation index
25. History of Biofuels, United States Department of Energy, Office of Energy Efficiency and Renewable Fuels, June, 2003
26. ibid.
27. ibid.
28. ibid.
29. Biofuels and Agriculture, United States Department of Energy, Oak Ridge National Laboratory, September, 2001
30. Source: Clean Fuels Development Coalition
31. ibid.
32. ibid.

33. ibid.
34. ibid..
35. ibid.
36. Based on data from Weekly Petroleum Status Report, op. cit.
37. Based on crop yield data reported in Biofuels and Agriculture, op. cit.
38. Based on USDA estimate of 2003 corn crop at 10.104 billion bushels.
39. Based on USDA estimates of average yield of 135 bushels of corn per acre.
40. Based on USDA estimate of 987 million total acres under cultivation in the U.S.
41. Source: United States Department of Energy, Energy Information Administration.
42. ibid.
43. ibid.
44. ibid.
45. ibid.
46. ibid.
47. ibid.
48. ibid.
49. Source: U.S. Department of Agriculture.
50. See: U.S. Department of Energy, Biofuels and Agriculture op. cit. for data on biodiesel yields from soybeans.
51. Source: U.S. Department of Agriculture data on crop yields per acre.
52. Source: USDA data on acreage in production.
53. ibid.
54. Source: U.S. Crude Oil, Natural Gas and Natural Gas Liquids Reserves, Energy Information Administration, U.S. Department of Energy, Washington, D.C. November, 2002, op. cit
55. ibid.
56. Based on DOE estimates of an average energy content of 926.2 Btus for 1 cubic foot of natural gas and an average energy content of 5,800, 000 Btus for a barrel of crude oil.
57. Source: Energy Information Administration.
58. ibid.
59. ibid.
60. Natural Gas 1998, Issues and Trends U.S. Department of Energy, Energy Information Administration, Washington, D.C. April, 1998
61. ibid.
62. ibid.
63. Based on EIA data
64. Based on DOE estimates of world oil resources.
65. ibid.
66. ibid.
67. Source: International Natural Gas Vehicle Association
68. ibid.
69. ibid.
70. ibid.
71. ibid.
72. Source: Energy Information Administration
73. South Coast Air Quality Management District, Board Meeting Agenda, October 4, 2002
74. Source International Natural Gas Vehicle Association
75. Source: Energy Information Administration
76. South Coast Air Quality Management District Board Agenda, op. cit.
77. Based on a survey of all manufacturers surveys for major name plates sold in the United States for the current model year.
78. Source: Energy Information Administration.
79. ibid.
80. Source: United States Department of Energy, Office of Transportation Technologies.
81. Pagonis, Lt. Gen. William G., Moving Mountains, Lessons in Leadership and Logistics from the Gulf War, Harvard Business School Press, Boston, MA, 1991
82. Based on published reports issued by the Department of Defense

83. The estimate is based on published reports of troop strength and Defense Logistics Agency fuel purchases.
84. Based on internal price evaluation prepared for the United States Synthetic Fuels Corporation by the author.
85. Tullo, Alexander H., Catalyzing GTL, Chemical and Engineering News, Vol. 81, No. 29, pp. 18-19, July 21, 2003
86. ibid.
87. ibid.
88. ibid.
89. ibid.
90. Source: Energy Information Administration
91. ibid.
92. ibid.
93. Source: The American Gas Association

CHAPTER 6: PRIMING THE PUMP:
THE HISTORY OF GOVERNMENT AID

Government intervention in the marketplace to address externalities or to assure national security is not a new phenomenon. Since the founding of the republic, the federal government has found it necessary to provide incentives or to intercede in other ways both in times of peace and war. Two of the most frequent areas of such intervention have been the construction of infrastructure and the promotion of technological development. Nowhere has this practice been more evident than in regard to transportation and communications.

TRANSPORTATION INFRASTRUCTURE

The "Golden Spike" completes the Transcontinental Railroad May 10, 1869

Among the earliest, and perhaps most important examples of the use of government incentives to provide infrastructure is the construction of the intercontinental railway system.

In the mid-1840s, as the nation expanded westward, interest in a transcontinental railroad grew. As early as 1845, Asa Whitney presented a plan to Congress for the federal government to subsidize the construction of a railroad from the Mississippi River to the Pacific Ocean. The impetus for such a line was reinforced by settlement of the long-standing Oregon boundary dispute with Great Britain in 1846 and the addition of vast new western territories from Mexico in 1848 under the terms of the Treaty of Guadalupe-Hidalgo. For the first time, America's borders stretched from shore to shore, and if it were to make full use of and be able to protect its new frontier, a better transportation infrastructure was essential.

In 1853 Congress appropriated funds to survey various routes, but introduction of the Kansas-Nebraska Act in 1854 gave rise to sectional rivalries over the route the proposed line would take that delayed action. With the outbreak of the Civil War and subsequent Republican control of Congress, the way was open to establishing a route.

On July 1, 1862 Congress enacted legislation providing for the construction of a transcontinental railroad along a northern route. The law provided that two companies would build the railroad, each receiving federal grants of ten alternate sections of land – equaling ten square miles – per mile on both sides of the line. In 1864, this amount was doubled. They also were given a 30-year government loan for each mile of track constructed. In 1863, the Union Pacific RR began construction from Omaha, Neb and the Central Pacific broke ground in Sacramento, CA. The two lines met at Promontory Point, Utah on May 10, 1869 when a golden spike was driven into the track to join the two railways. The two companies had built a total of 1,774 miles of rail line (1) at a cost of $50 million, (2) an enormous undertaking for that time. (3) Over the next two decades, the transcontinental system would be further expanded by the addition of the Northern Pacific Railroad from Lake Superior to Portland, Or, the Santa Fe Railroad from Atchison, KS to Los Angeles, and the Southern Pacific from Los Angeles to New Orleans, LA. Each of these companies received extensive land grants, but did not get federal loans. Ultimately it would comprise 3,500 miles of track. (4)

It would be difficult to overstate the impact building the transcontinental railroad had on the United States. Prior to its construction, an overland trip across the continent took from five to six months by stagecoach and cost around $1,000. The only alternative was a perilous sea voyage entailing either an 18,000-mile trip around South America, or a dangerous crossing of the Isthmus of Panama. By rail, the trip took only five days, and the cost of a first-class sleeper compartment was $150. As a result, the vast natural resources and agricultural potential of the American West was made available to the industrialized east. Millions of acres of land became available for settlement by the waves of new immigrants reaching our shores. With the addition of, the Northern Pacific from Lake Superior to Portland OR, the Santa Fe from Atchison, KS to Los Angeles, and the Southern Pacific from Los Angeles to New Orleans a template for future growth was put in place. By the 1880s, over 40,000 miles of feeder lines had been added to the nations railroads (5) facilitating America's transition from a pioneer society to a modern industrialized state.

But underwriting the Transcontinental Railroad would not be the last time Congress acted to spur a life-altering addition to the nation's transportation infrastructure. The development of the Interstate Highway System had perhaps an even more profound impact on daily life.

THE INTERSTATE HIGHWAY SYSTEM

THE CUMBERLAND ROAD

Although road construction in the United States was primarily a state and local matter through most of the 19th and 20th centuries, the federal role in road construction actually dates from the earliest days of the Republic. Although during the early 19th century, water transport was the preferred mode of travel, some areas lacked navigable rivers and waterways to make it possible. Among these was the area that now comprises Ohio, which lacked a water route east. It became evident that some way of connecting the Ohio

River with the headwaters of the Potomac was necessary. As a result, in 1803, Congress enacted legislation allocating a little over $6.8 million from the sale of lands in Ohio for construction of the Cumberland Road, or National Pike as it is also called. This road was the first federally financed highway. Originally designed to stretch from Cumberland, Maryland to Wheeling in what is now West Virginia, the road was eventually extended to Springfield, Ohio and was 800 miles in length. Still, the Cumberland Road remained an exception during the 19th century. Indeed, it would not be until the middle of the 20th century that the federal government would play a major role in road construction.

Although a serious effort to build an interstate highway system would not take place until the mid-1950s, its genesis could be found an event that took place three decades earlier.

THE COMING OF THE AUTOMOBILE

Armored Car used by General Pershing's forces in pursuit of Pancho Villa.

In 1900 there were only 8,000 automobiles in the United States. (6) By 1916, there were 3.5 million. (7) By 1919, the figure had mushroomed to 7.5 million. (8) But the spectacular growth of individual automobile ownership was not the only impact this new invention had on society. It had also become an important military asset in the just concluded First World War. Because of its novelty, many questions remained in the minds of senior military commanders about what its real capabilities were and how they could best be employed. Indeed, the U.S. Army's first use of motor transport in combat operations only dated from 1916 when General "Black Jack" Pershing led an expeditionary into Mexico in pursuit of Pancho Villa.

Eisenhower's 1919 "Motor Truck Train."

As a result, the U.S. War Department decided to conduct an experiment in 1919 to determine the feasibility of using motor transport to move an army across the continent. It sent what it termed a "Motor Truck Train" from a starting point on the Ellipse in Washington, D.C. to San Francisco, California. Because the convoy would include a Renault tank, it wanted to send a tank officer along as a staff observer.

A 29 year-old Lt. Col. named Dwight D. Eisenhower who had only joined the newly formed Tank Corps in 1918 eagerly volunteered for the job "partly as a lark, and partly to learn." (9) The "Motor Truck Train" would travel 3,251 miles at an average speed of 6 miles per hour. (10) Its progress was a little more than 58 miles per day. (11) As a result, it would take the convoy 62 days from the time it left Washington, D.C. on July 7, 1919 to reach its endpoint at San Francisco on September 6, 1919. (12)

MAJs. Eisenhower and Sereno at beginning of trip.

Since the major objectives of the expeditions were to test various military vehicles, and to determine, by actual experience, the feasibility of using them to transport troops in war, the General Staff wanted to make the test as realistic as possible. (13) To do this, the "Motor Truck Train" operated under wartime conditions. The Army had largely demobilized following the First World War, and was limited to a maximum strength of 130,000 soldiers. Therefore, the 24 expeditionary officers, 13 other War Department staff observers and 258 enlisted men in the convoy made it a major undertaking for the time. (14)

Lt. Col. Eisenhower and Major Sereno Brett joined the convoy the first night out of Washington at Frederick, MD. Their experience would leave a lasting impression on the young officer. Along the way, they experienced no less than 230 accidents and breakdowns. (15) At times, vehicles sunk up to their axles in mud and had to be pulled out by hand. Sometimes the vehicles crashed through wooden bridges not capable of carrying their weight. (16) Near North Platte, Nebraska 25 trucks skidded into a ditch due to icy conditions.

Motor Truck Train arrives in San Francisco

Eisenhower's experience on the "Motor Truck Train" would stay with him for the rest of his life, but it would be his experience in Germany during World War II that clarified his vision of what the nation's transportation system needed.

On August 6, 1932, Germany dedicated the first section of its new high-speed roadway system dubbed the "autobahn." When Adolph Hitler assumed power as Chancellor of Germany a few months later in January of 1933, he embraced the program, recognizing its military potential. Over the next eight years, 2,400 miles of autobahn would be completed and construction initiated on another 1,550 miles when the advent of war brought the program to a halt.

In the early stages of World War II, the autobahns proved invaluable to the "Blitzkrieg" tactics that were central to German military strategy. After the Allied invasion of Normandy, however, the high-speed roads eventually proved a double-edged sword. Once the Allies crossed the Rhine, they could take full advantage of the mobility the autobahns made possible. They were used to devastating effect. After the war, Eisenhower said:

Gen. Eisenhower in Europe

"The old convoy had started me thinking about good, two-lane highways, but Germany made me see the wisdom of broader ribbons across the land." (17)

It would be another decade before Eisenhower was able to act on what he had learned.

The need for a national highway system both to facilitate commerce and to provide for defense requirements was recognized in the late 1930s. In 1938, Congress passed the Federal-Aid Highway Act that directed the chief of the Bureau of Public Roads to study the feasibility of a six-route toll road network. On April 27, 1939, President Roosevelt transmitted the report to Congress recommending it consider taking action on:

> *"[A] special system of direct interregional highways, with all necessary connections through and around cities, designed to meet the requirements of the national defense and the needs of a growing peacetime traffic of longer range."* (18)

Initially work on building the system proceeded slowly. By January of 1953, when President Eisenhower took office, only a little more than 6,400, or about 15% of the eventual 42, 700-mile system had been completed. (19) Still, some $955 million had been invested in their construction. This, however, was a mere fraction of what would ultimately be required.

One reason for the slow pace was the lack of a substantial commitment of federal funds. The Federal-Aid Highway Act of 1952 authorized funds on a 50/50 state/federal matching level. These were the first funds dedicated to the cause, but the amount, $25 million was woefully inadequate. The election of Eisenhower though would quickly change that and add a sense urgency to completion of the roadways.

On June 29, 1956 President Eisenhower signed the Federal Aid-Highway Act of 1956 which authorized the interstate highway system. The name of the system was later formally changed to the Dwight D. Eisenhower System of Interstate and Defense Highways. The act authorized 41,000 miles of high quality highways. (20) It was later amended to encompass 42,500 miles. (21) There are now actually 42,796 miles of interstate highway planned for the system, with all by 30 miles complete as of December 31, 1995. (22)

When state highways are included there are a total of 50,000 miles of superhighway in the United States. Interstate highways carry 45% of the nation's motor freight. (23)

The Federal Highway System cost $329 billion through 1995 in 1996 dollars. (24)

Today, the U.S. has ten times the superhighway mileage of the Former West Germany, (25) 12 times the amount in France, (26) 20 times the amount in Japan, (27) 30 times the amount in the UK. (28) In fact seven U.S. states (California, Florida, Illinois, New York, Pennsylvania and Texas) (29) have as much mileage as the entire United Kingdom.

Even adjusted for population and geographic size the U.S. far outstrips other nations in superhighway mileage. Adjusted, it has 2.4 times the amount of the former West Germany, (30) 2.9 times the mileage of France, (31) 6.5 times the mileage of the UK, (32) and 9.7 times the mileage of Japan. (33)

But it is not just projects like the transcontinental railroad and interstate highway system that have sparked government intervention. The federal government has acted on more than one occasion to assure the availability of critical commodities and assist in the development of new technologies – especially in times of war or international crisis.

WARTIME MEASURES

During times of war, there is a long history of government involvement in commercial markets to assure the availability of critical commodities.

During the First World War, a War Industries Board was established to help allocate materials and manage the war effort, and a Food Administration and Fuel Administration were established to regulate the sale and shipment of these commodities. Congress also enacted a number of laws to regulate economic activity, including one establishing the depletion allowance for oil producers to encourage domestic production of this vital commodity. (34)

During the Second World War government intervention reached unprecedented levels to meet the needs of Allied Forces. In January of 1941, President Franklin Roosevelt established an Office of Production Management (OPM) headed by William Knudsen, then Chairman of General Motors. Like its First World War counterpart, the OPM had limited authority, but unlike its predecessor, met with only limited success. As a result, in January of 1942, the War Production Board (WPB) was established with vast powers to mobilize the national economy.

By 1944, the war production effort would consumer 44% of U.S. GNP and by the war's end, the federal government would invest over $12.7 billion (35) – the equivalent of $125 billion today (36) – in direct financing to build 1,600 plants, and another $6 billion (37) – the equivalent of $59 billion today (38) – in indirect subsidies to build hundreds more. (39) Together these subsidies would total $184 billion current dollars. (40)

The results of this investment were stunning. By the war's end, U.S. factories had cranked out over 98,700 fighter aircraft, 55,000 medium bombers, 34,400 heavy bombers, 64,546 landing ships, 86,333 tanks and 41,585,000 rounds of ammunition. (41)

The Second World War would also mark an unprecedented government investment in science and technology that would give birth to radar, sonar, antibiotics, computers and nuclear energy. (42)

Despite all these accomplishments, the mobilization was not untroubled. In a 1963 letter to Senator Clifford Case, former President and Allied Supreme Commander Dwight D. Eisenhower described his experiences with materials shortages during both the Second World War and Korean Conflict:

> *"… our lack of an adequate stockpile of strategic and critical materials gravely impeded our military operations. We were therefore forced into costly and disruptive expansion programs. The nation was compelled to divert, at the most critical time, scarce equipment, and machinery to obtain the necessary materials…*
>
> *But even after the experience we had not fully learned our lesson. After World War II, stockpiling was confined too much to mere talk, it neglected implementation. After we became involved in hostilities in Korea, we went through experiences almost identical to those of World War II."* (43)

The experience of the Korean Conflict is particularly instructive in regard to the cost of government's failure to act prudently in relation to critical materials. During the period prior to the Korean Conflict, Congress failed to appropriate $2.6 billion needed to acquire defense critical materials. (44) As a result, when war broke out, it became necessary to spend $8.4 billion under the Defense Production Act to produce the materials it had failed to stockpile. (45) This would be the equivalent of spending nearly $74.5 billion today. (46)

But it is not just in times of war that the government intervenes in the marketplace for defense-related purposes, nor is such intervention limited to commodities.

THE AVIATION INDUSTRY

One of the most revealing examples of government intervention in a nascent industry lies in its relationship with aviation. Today, the U.S. aviation industry is the world's leader. This might not have been the case, however, were it not for a strong and continuing federal role that has nurtured and promoted aviation virtually since its inception. A central motivating factor behind this ongoing interest was the early recognition of the importance to national defense of maintaining supremacy in aviation technology.

The notion of air warfare long predated the advent of the airplane. As early as 1670, the Italian Jesuit Francesco de Lana Terzi wrote of the possibility of using balloons in military operations. (47) Indeed, balloons were used by the French Army in 1794 to direct fire against Austrian Forces and by the Army of the Potomac in 1862 and 1863 to observe movements of Confederate troops. (48) A balloon was also used in the Battle of San Juan to direct artillery fire. (49) Balloons, however had limited mobility and were highly vulnerable to ground fire. As a result, they were only sporadically employed prior to the turn of the century.

With the Wright Brothers flight at Kitty Hawk, N.C. on December 17, 1903, the military potential of flight was altered dramatically. On August 2, 1909, the U.S. Army Signal Corps purchased its first airplane from the Wright Brothers and the face of the battlefield was changed for all time. (50)

Prior to the First World War, the future direction of aviation remained uncertain. Although regular air passenger service was established, it used dirigibles rather than airplanes. In the U.S., the first authorized airmail service took place at an air meet on Long Island with mail carried five miles from Nassau Boulevard to Mineola for one week. The first scheduled U.S. passenger service was established in 1914. (51)

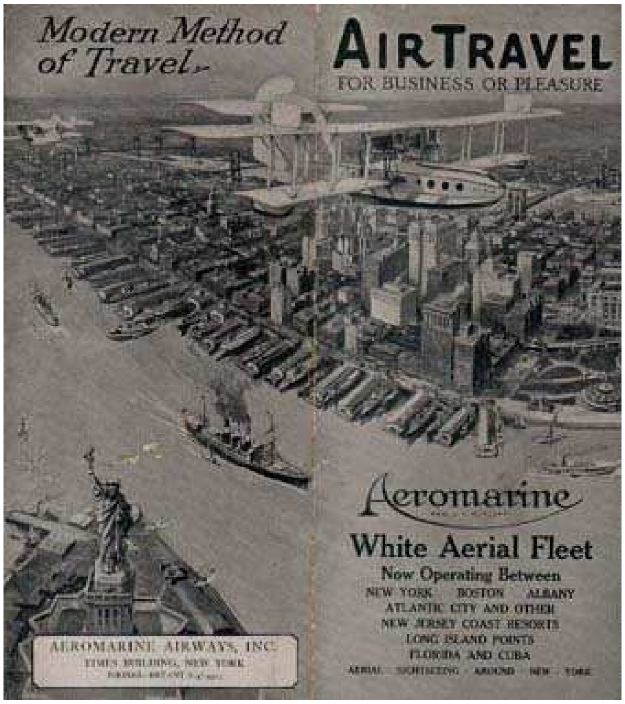
With the advent of the First World War, advances in aviation accelerated enormously to meet wartime requirements. In addition, the dominant role of the airplane as opposed to competing technologies such as the dirigible was established once and for all. The need for heavy bombers led to the development of multi-engine designs that would pave the way for passenger and cargo carriers. Of greater importance, during the four years of the war, more aircraft would be built and pilots trained than during the entire thirteen years that ensured between the Wright brothers' first flight and the outbreak of hostilities. (52) At the war's conclusion these pilots and planes would provide a ready foundation for the evolution of a commercial industry.

This wartime progress set the stage for a peacetime government program that would ensure the future of commercial aviation in the United States.

THE KELLY AIR MAIL ACT OF 1925

Perhaps the single most important government initiative directed at aviation was the Kelly Air Mail Act of 1925. The Post Office had purchased a fleet of aircraft to establish airmail service in 1918 with the initial route carrying mail between Washington, D.C. and New York City using military pilots. The following year, transcontinental airmail service was established between Washington, D.C. and San Francisco, California. But this slow progress was inadequate for congressional flight enthusiasts who were anxious to foster a domestic aviation industry, and viewed the airmail program as a means of accomplishing this goal. They recognized that some assistance was needed if flight was to gain a foothold in America.

By 1920 the first private airlines had been established and two were already carrying international mail. One route was operated by Edward Hubbard carrying mail between Vancouver, British Columbia and Seattle, Washington in a Boeing 700 biplane equipped with pontoons. (53) The other international mail route was operated by Aeromarine Airways, the brainchild of Florida entrepreneur Inglis Uppercru. His airline was also the first airline to offer significant regularly scheduled passenger service. Aeromarine had a fleet of 15 "Flying Boats" that initially offered passenger service between Key West,



Aeromarine Brochure

Florida and Havana, Cuba. His clientele consisted primarily of well to do individuals who wanted to get around Prohibition by going to the West Indies where alcohol was legal. (54) He soon added routes between Miami, Florida and the Bahamas, and between New York and Havana. The success, though, was short lived. (55)

Aeromarine's wooden-hulled Flying Boats were expensive to operate, and were rapidly aging. By 1923 the airline was already having financial problems. Although the company began manufacturing an all-metal hulled Flying Boat its cost was too great to recoup from passenger traffic. Then, in 1924, one of Aeromarine's planes lost an engine off the Florida coast, and four passengers died in the crash that followed. The ensuing publicity was the last nail in Aeromarine's coffin and the airline went out of business.

Just as it appeared that there was little hope for commercial aviation in the United States, Congress came to the rescue. By the mid-1920s, airmail service had gained a large following with more than 14 million airmail letters sent annually. But it was also operating at a huge deficit. (56) In an attempt to improve efficiency and at the same time provide an incentive for the growth of a domestic aviation industry, Representative Clyde Kelly of Pennsylvania sponsored the Contract Air Mail Act of 1925, commonly known as the Kelly Air Mail Act. (57) This legislation would provide the foundation for commercial aviation in the U.S., and early mail contract holders would evolve into the U.S. airline industry.

The New York to Boston route was awarded to Juan Trippe, who founded Pan American Airlines. (58)

The Chicago to St. Louis route went to Robertson Aviation whose chief pilot was war hero Charles Lindbergh. Robertson would become American Airlines. (59)

The Chicago to Dallas route went to National Air Transport, and would eventually evolve into National Airlines. (60)

The Elko, Nevada to Pasco, Washington route was won by Walter T. Varney and would evolve into United Airlines. (61)

Indeed, within a year following the Kelly Air Mail Act's passage, no less than 14 domestic airlines had been established. Initially, the mail contracts awarded to these carriers were the factor that permitted them to operate profitably, because it was not yet possible to make a profit exclusively from flying passengers. An outpouring of investment quickly addressed this problem.

Within a few years, a joint research program funded by American Airlines and McDonnell-Douglas resulted in design of the DC-3, the first aircraft capable of carrying passengers at a profit without a mail subsidy. The DC-3 could carry 21 passengers at 190 mph and became the prototype for commercial passenger aircraft. In fact, the DC-3 was so well designed that it still remains in service today. (62)

In a relatively short time, the mail subsidies permitted the fledgling U.S. airline industry to flourish. By 1940, Pan American Airlines, for example, had grown to service some 47 nations over 82,000 route miles. But even this rapid expansion would soon be overshadowed as wartime exigencies fueled an explosive growth in both the size of the airline industry and its technology.

In 1940 some 193,000 workers were employed by the U.S. domestic aviation industry. In that year, 2,357,000 passengers traveled on domestic carriers. By 1941, aviation industry employment surged to 450,000, the passenger load grew to 3,375,000 and cargo loads increased by 30%. (63)

But this was just the start. As the need for combat aircraft increased, existing factories were converted to military production and new factories were built at an unprecedented rate. Intensive research and development programs produced innovations in design such as pressurized cabins and navigation such as radar. By the peak year of wartime production, 1944, these factories were churning out 14.3 times as many aircraft as they did in 1940. (64) Further, because it became necessary to heavily arm bombers for self-protection, design efforts focused on larger, multi-engine planes providing a technological base suitable for transfer to civilian passenger applications in the post-war years.

As the U.S. economy began its transition to civilian production in 1945, the aviation industry was perfectly positioned to take advantage of the new demand for civilian air transport that was one of the Second World War's lasting legacies. In that year, more than 40,000 civilian aircraft were produced as compared with 6,844 in 1940. (65)

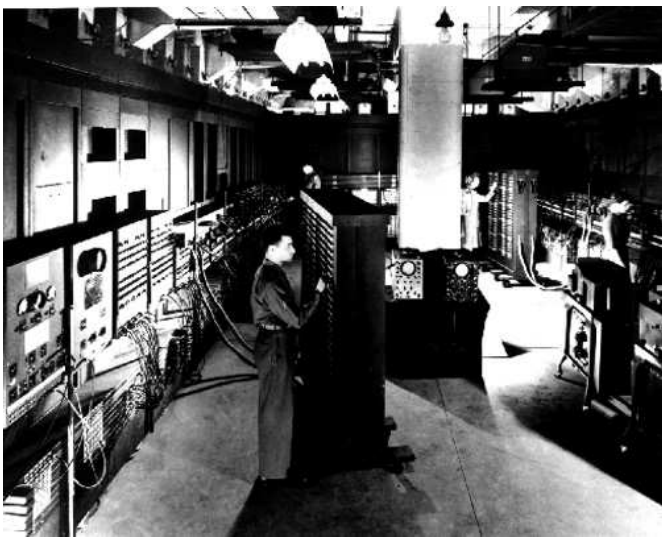
In the years that followed, air transport would replace railroads as the preferred mode of long-distance travel carrying almost 552 million passengers in 2002. (66) According to a survey by the Air Transport Association by 1993, 77% of all Americans had flown at least once in their lifetimes. (67) A survey conducted in 2002 found that 39% of Americans had flown at least once during that year. (68)

In 2002, the aviation industry employed 712,000 people (69) and generated some $148 billion in sales. (70) It also had a positive balance of trade amounting to over $30.6 billion.

(71) These figures suggest that the mail subsidies that permitted the infant aerospace industry to develop and flourish, while a direct intervention in the marketplace, were an intervention that was also well justified.

The aviation industry, though is not the only instance in which military subsidies of and investment in technology resulted in the evolution of an industry that changed the face of society. Perhaps an even more profound example is the evolution of the computer and Internet.

THE FEDERAL ROLE IN THE EVOLUTION OF COMPUTERS



ENIAC computer

Few examples of federally sponsored research have had the impact on society that has accompanied the development of the computer. The world's first electronic digital computer, ENIAC was developed by the Army Ordnance Ballistic Research Laboratories at Aberdeen, MD to assist in calculating ballistic firing tables during the Second World War. (72) Scientists working on the Manhattan Project, the World War II program to develop the Atomic Bomb used ENIAC to assist in their calculations. (73) Through the early 1970s, a significant proportion of computer research and development was conducted with federal assistance, and the federal government was and remains one of the largest consumers of computer hardware. Further, the personal computers that are now present in over half of all U.S. households (74) have their technological roots in the integrated circuit and in small processors, both originally developed for use in guided missiles and the space program. In 2000, U.S. sales of personal computers amounted to fully $108.8 billion. (75)

As with aviation, the government's interest in computers was driven by defense considerations. As noted, one of the earliest uses of computers was in the Manhattan Project, where scientists needed to perform huge volumes of calculations. Government support of computer research continued throughout the 1950s and 1960s. What was particularly important about the government support, though, was that the technologies under development were not classified. As a result, they were available for exploitation by the private as well as the public sector.

This defense-based research has given rise to wide range of computer-related technologies including advanced storage mediums, lasers and micro-miniaturization. None, however, may prove as far reaching as development of DOD's ARPANET, which became the basis of the Internet. From the time it was first made available to the public in 1991, the Internet has grown into an essential element of the economy. Today, some 94 million Americans use the Internet (76) and 41.5% of all families have access to the Internet at home. (77) Nearly 90% of all school-age children use the Internet either at home or in school. (78) With over half of all households now equipped with computers (79) and the number growing every day, the Internet may soon become as ubiquitous as the telephone. Yet, were it not for federal assistance, this powerful economic asset would not exist.

The decision by DOD to permit access to technologies such as microprocessors, as well as to support their development through purchases of hardware were critical to the evolution of a civilian market for the computer and related innovations. Indeed, the practice was so successful that by the early 1970s, the civilian market had matured to the point that the federal government was able to begin purchasing "off the shelf" rather than having to underwrite technological development. Therefore, not only did the practice help spawn an industry, but in the long run greatly lowered the cost of purchasing computer hardware and software for military use.

This model remains as valid in regard to other critical areas of technology as it was in regard to computers and earlier to aviation. Indeed, it can serve as a model for resolving the nation's oil import dilemma. One place where it might be employed is with the Department of Defense administrative fleet.

THE ADMINISTRATIVE FLEET

The Department of Defense leases a fleet of almost 97,000 non-tactical vehicles from the General Services Administration. (80) More than half of the non-tactical fleet, comprising some 51,690 vehicles is leased by the Army. (81) The Army fleet includes 15,420 passenger vehicles and 30,657 light trucks. (82) Unlike tactical vehicles these cars and light trucks are conventional models and are used almost exclusively in the United States.

As noted, the Army's Tank, automotive and Armaments Command (TACOM) is already participating in activities such as the Improved Materials Powertrain Architectures for 21st Century Trucks or IMPACT program and the Commercially Based Tactical Truck, or "COMBATT" program aimed at developing transportation technologies with both civilian and military applications. TACOM's National Automotive Center has made important contributions in areas such as hybrid electric vehicle technology and advanced materials development.

In keeping with the notion of reciprocal technology transfer, it would make sense to build on this existing technological base to accelerate the introduction of new vehicle technologies in both the public and private sectors. This could be accomplished by establishing a program to demonstrate the feasibility of existing and developing technologies on a significant scale and then have the Department of Defense act as a "forward market" by acquiring vehicles using these technologies in substantial numbers for the administrative fleet.

The program would entail the creation of a series of demonstration centers at military facilities around the country. The demonstration centers would also serve as means of familiarizing military personnel with new technologies and helping train the workforce that will be necessary to service and maintain them. The National Automotive Center could act as a coordinating agency and assist in the selection of technologies and the design of demonstration projects. The demonstrations would in turn serve as a basis for the selection of technologies that would be acquired Department-wide.

DOD purchases would help to establish the markets for new technologies that in turn would encourage the development of a manufacturing base. In addition, by demonstrating the feasibility of new vehicle technologies in applications similar to those encountered in the civilian sector, the program would encourage the adoption of such technologies by the private sector. As in examples from aviation to the Internet, this process of in essence “priming the pump” could serve to hasten the day when these new technologies gain substantial penetration of civilian markets.

CHAPTER SIX NOTES

1. Source: Historic American Engineering Record [HAER No. Ca-196] Central Pacific Transcontinental Railroad, National Park Service, Western Region, Department of the Interior San Francisco, CA August 25, 2002
2. ibid.
3. ibid.
4. ibid.
5. Behrman, Daniel, Chapter 12, The Man Who Loved Bicycles, Harper and Roe, 1973
6. ibid.
7. Source, U.S. Bureau of Public Roads, Motor Vehicle Registrations statistics
8. ibid.
9. Weingroff, Richard, F. The Man Who Changed America, Part I, Public Roads, March/April 2003, Vol. 66 No. 5, United States Department of Transportation, Washington, D.C.
10. Ibid.
11. Ibid.
12. Ibid.
13. Ibid.
14. Steadman, Kenneth A. LTC The Evolution of the Tank in the U.S. Army, U.S. Army Command and General Staff College , 21 April, 1982
15. Public Roads, op. cit.
16. ibid.
17. Eisenhower, Gen. Dwight, David, At Ease, Stories I Tell to My Friends, pp. 166-67 Doubleday, Garden City, NY 1967
18. Source: Department of Transportation
19. ibid.
20. ibid.
21. ibid.
22. ibid.
23. ibid.
24. ibid.
25. ibid.
26. ibid.
27. ibid.
28. ibid.
29. ibid.
30. ibid.
31. ibid.
32. ibid.
33. A History of The American People, McGraw Hill, NY, 1971
34. Executive Office of the President, National Critical Materials Council, Draft Critical Materials Report, Washington, D.C. 1987
35. ibid.
36. Based on Bureau of Labor Statistics price inflator.
37. Critical Materials Report, op. cit.
38. Based on Bureau of Labor Statistics price inflator.
39. Draft Critical Materials Report, op. cit
40. Based on Bureau of Labor Statistics price inflator.
41. Goralski, Robert, Oil and War, op. cit.
42. A history of the American People, op. cit.
43. Personal communication from former President Eisenhower to Senator Clifford Case cited in Draft Critical Materials report, op. cit.
44. Source: Draft Critical Materials Report op. cit
45. ibid.
46. Based on Bureau of Labor Statistics price inflator.
47. Funk and Wagnalls New Encyclopedia, Vols. I & II, 1994

48. ibid.
49. ibid.
50. ibid.
51. ibid.
52. Source: U.S. Postal System History of Airmail
53. Lindley, John M. Wings Over The Ocean, Naval Aviation News, February , 1978, Department of Defense, United States Navy, Washington, D.C.
54. ibid.
55. A Forgotten Aviation Pioneer Returns, General Aviation News, Lakeland, WA 2002
56. Source: United States Commission on the Centennial of Flight, Washington, D.C.
57. ibid.
58. ibid.
59. ibid.
60. ibid.
61. ibid.
62. Funk and Wagnalls Encyclopedia, op. cit.
63. ibid.
64. ibid.
65. ibid.
66. Source: Bureau of Labor Statistics
67. Source: Air Transport Association
68. Source: Bureau of Labor Statistics
69. Source: Aerospace Industries Association
70. ibid.
71. Source: Bureau of Labor Statistics
72. Weik, Martin H. The ENIAC Story, ORDNANCE, the Journal of the American Ordnance Association, Washington, D.C., January-February, 1961
73. Manhattan Project History, Los Alamos National Laboratory, contract No. w-7405-ENG-36, University of California, 1998
74. Source: Bureau of Labor Statistics
75. ibid.
76. ibid.
77. ibid.
78. ibid.
79. ibid.
80. Source: General Services Administration
81. ibid.
82. ibid.

CHAPTER 7: GETTING THERE: A ROADMAP FOR THE FUTURE
THE RATIONALE FOR MARKET INTERVENTION

In 1995, the National Defense Council said in its report on transportation and energy security:

> *"Oil imports will account for more than half of domestic consumption in 1995 and, worse, only can be expected to rise in the years ahead. The political situation in the Middle East is becoming increasingly unstable, and the threat of another need to intervene in the Persian Gulf is looming large on the horizon."* (1)

Eight years later, these fears have been realized. At this writing, imports of crude oil and refined petroleum products account for 58.5% of U.S. consumption (2) and are expected to rise even further in the future. The United States and its allies have just concluded a major land war in Iraq and currently some 146,000 U.S. troops remain stationed there for occupation duties. (3) Meanwhile, American consumers continue to shoulder the economic burden of from $146 billion to $305 billion in "hidden" costs for the imported oil they use. (4) This burden deprives the nation of millions of jobs and billions of dollars of investment. (5) More important, it leaves the U.S. economy hostage to the whims of nations hostile to its interests.

The dangers arising from America's excessive dependence on imported oil and refined petroleum products are well understood, yet, no consensus has developed on what to do to resolve the problem. It is true that various programs have been instituted to promote specific alternative fuels. However, as the rising tide of imports demonstrates all too clearly, steps taken to date have done little to stem the flow.

CURRENT PROGRAMS

ALCOHOL FUELS AND RENEWABLE ENERGY

Alcohol fuels were among the earliest targets of congressional action and has been one of the most widely adopted alternatives. This success, though, has been largely a product of federal subsidies and mandates. As early as 1978, incentives for alcohol fuels had been provided through the Energy Tax Act of 1978, or ETA. The tax provided the first excise tax exemption for motor fuels with at least 10% alcohol content – 4 cents per gallon, which was the full value of the excise tax at that time. Over the years, Congress has increased the exemption and expanded its scope to encompass other renewable and alternative fuels. In addition to the excise exemption, a number of other incentives have been enacted into law, including a tax credit for blenders. In addition, bans on various octane-enhancing additives have expanded the market opportunities for the use of fuel alcohol in this role.

As a consequence of these incentives, approximately 1.5 billion gallons of fuel alcohol are produced annually (6) and almost 12% of all gasoline sold in the U.S. is an alcohol blend. (7) While these figures appear impressive at first glance, when taken within the context of the total petroleum market, they are less so. At current consumption levels of around 20.1 million barrels per day, (8) the contribution of fuel ethanol to the total supply of motor fuel is less than one-half of one percent. (9)

This is not to minimize the contribution that alcohol fuels have made to the transportation sector. They have provided an environmentally preferable means of enhancing the octane of gasoline and helped to reduce air pollution as oxygenates. They have also helped create a new market for the nation's battered farm economy. What they have not done, though, is substantially reduce the nation's oil import dependence.

THE CLEAN AIR ACT AMENDMENTS OF 1990

Originally, the Clean Air Act Amendments of 1990 mandated the operation of clean fuel vehicles in 22 urban regions. Currently these provisions are being implemented by the Environmental Protection Agency through initiatives such as the Clean Fuel Fleet Program, or CFFP. The Clean Fuel Fleet Program is a voluntary option for cities that had a population of at least 250,000 at the time of the 1980 census and have serious non-attainment problems in regard to ozone or carbon monoxide. If they do not wish to adopt the CFFP, the affected cities may instead adopt a substitute program that achieves equal or better emission reductions.

The CFFP mandates inclusion of clean-fuel vehicles in fleets operating in cities with substantial air pollution. The mandate extends to federal, state, municipal, fuel provider and private fleets indicated in the Clean Air Act Amendments. These include fleets that own, operate, lease or control at least ten light-duty trucks or heavy-duty vehicles, which are centrally fueled or capable of being centrally fueled 100% of the time at a station owned, operated or controlled by the fleet owner. Participants may employ a variety of fuels including natural gas, methanol, oxygenated fuels and reformulated gasoline to meet the emission reduction goals.

Originally scheduled to go into effect in 1998, the start-date was delayed for one year to 1999. At present, five metropolitan areas have opted-in to the program. Moreover, because the Clean Fuel Fleet Program includes reformulated gasoline in the list of "Clean Fuels," its value in reducing petroleum imports may be limited.

THE ENERGY POLICY ACT OF 1992

The Energy Policy Act of 1992 (EPAct) was enacted with the specific goal of accelerating the use of alternative fuels. The stated goal was to replace 10% of petroleum-based fuels with alternatives by the year 2000 and 30% by the year 2010. (10) Under EPAct, Federal, State, and fuel provider fleets are affected. Covered fleets are those that own, operate, lease or control at least 50 light-duty vehicles in the United States. Of these, at least 20 must be operating within certain areas affected by the Act. They must also be either centrally fueled or have the capability of being centrally fueled. The covered regions are essentially areas with populations of 250,000 or more. Law enforcement and emergency vehicle fleets as well as non-road vehicles are exempt from the mandate.

Under the law, 75% of all federal vehicle, state vehicle purchases must now be powered by alternative fuels. (11) For alternative fuel providers the mandate is 90% of all vehicle purchases, (12) and for municipal and private fleets the target is 20% beginning this year. (13)

Compliance with these requirements has been less than satisfactory, especially in regard to federal fleets. Only 12.1% of federal fleet vehicles are capable of using alternative fuels. (14) But even this figure does not tell the full story. Because most federal acquisitions have been either dual-fuel or "flexible" fuel vehicles, they often are run on conventional petroleum-derived rather than alternatives. As a result, the total federal use of alternative fuels in FY 2000, the most recent year for which data are available, amounted to only a little more than 89 barrels per day of oil equivalent. (15) This compares with the federal government's total petroleum fuel consumption of 513, 828 barrels per day (16) or total domestic oil consumption of 20.1 million barrels per day. (17) The problem is illustrated by the example of the U.S. Army. Although the Army nominally owns over 4,400 alternative fuel vehicles, only 5% of its fuel consumption was accounted for by alternative fuels in FY 2000. (18)

CHARTING A COURSE

There can be no doubt that addressing the nation's import vulnerability is a matter of the greatest urgency. There can also be no doubt that the actions taken to date have failed to produce much in the way of results. Three decades have passed since the Arab Oil Embargo first sounded the warning about imported oil, yet today we are more dependent on imports of crude oil and refined petroleum products than at any time in our history. In order to reverse the trend dramatic steps are needed, and are needed now.

The question is what should be done?

A TWO-TIERED APPROACH

It is useful to view the nation's oil import dependency as two problems. The first is the near-term need to halt, and ultimately reverse the trend towards ever-more oil imports as quickly as possible. The second is the longer-term concern: how to accomplish a transition from traditional fossil fuels to inexhaustible, environmentally benign alternatives. Ideally, any option selected to address near-term considerations should help to create a foundation for a long-term permanent solution. Therefore it should incorporate technologies that might logically evolve over time to accommodate a permanent fix. In order to meet the need for urgent action, the option should also be technologically mature in its own right. There should be no need for significant new breakthroughs before it can be implemented. As mentioned previously, it should also rely on a domestically based resource. In order to determine the optimum near-term solution, however, it is first necessary to determine the appropriate option for a permanent fix. So doing will provide a "target" towards which the near-term can build.

HYDROGEN FUEL CELL VEHICLES: THE LONG-TERM GOAL

In the years ahead, a shift of the transportation sector from vehicles powered by internal combustion engines to hydrogen fuel cells promises to free America from its oil import burden and bring about dramatic improvements as well. What is this miraculous energy source and how does it work

DEVELOPMENT OF THE FUEL CELL

The principle on which fuel cells are based has actually been known for more than a century. In 1839, a British scientist, Sir William Grove produced his "gas voltaic battery," the first fuel cell. Grove had observed that passing an electric current through water split it into hydrogen and oxygen. He reasoned that it might be possible to reverse the process and combine hydrogen and oxygen to get electricity and water. This was the first fuel cell, although the term was not coined until 1889 when Charles Langer and Ludwig Mond used it to describe a practical fuel cell that they were trying to develop. Langer and Mond's fuel cell used an expensive platinum catalyst to react coal gas and air. Unfortunately, the expense of the platinum catalyst made it uneconomic. The problem of fuel cell economics was compounded with the arrival of the internal combustion engine around the turn of the century. As a result of this innovation research into fuel cells was abandoned for a time.

It was not until 1932 that Francis Bacon developed the first successful fuel cell. It replaced the platinum catalyst with nickel and replaced the sulfuric acid medium used previously with alkali potassium hydroxide. His was the earliest alkali fuel cell. But it took until 1959, another twenty-seven years, before Bacon was able to demonstrate a practical version of his device, a 5-kilowatt unit capable of powering a welding machine. In that same year, Harry Karl Ihrig of the Allis-Chambers Company demonstrated a 20-horsepower fuel cell-powered tractor. What was particularly important about Ihrig's design was that it used a stack of 1008 fuel cells to generate 15 kilowatts of electricity. The notion of stacking the cells to provide substantial amounts of electric power provided one of the key innovations necessary to open the door to commercialization.

It was at this point that NASA entered the picture. Looking for a lightweight power source for their space vehicles, NASA invested heavily in fuel cell development. The Gemini program used a fuel cell developed by General Electric that employed a novel Proton Exchange Membrane, or PEM. NASA decided, however, that it needed a longer-lasting fuel cell design. It turned to Pratt and Whitney, which had acquired a license for Bacon's alkali version. NASA first used the Pratt and Whitney fuel cell in the Apollo program and has continued to do so on most other space flights, including those of the Space Shuttle. In addition to longer life, the alkali fuel cell also had the advantage of producing drinkable water as a byproduct.

THE STATUS OF FUEL CELL VEHICLES

Although substantial investments were made in fuel cell research throughout the 1970s and 1980s, it was not until the 1990s that there was sufficient progress to open the door to a fuel cell-powered vehicle. In 1994, DaimlerChrysler unveiled the NECAR 1, which the company describes as "a laboratory on wheels." (19) Powered by a 50 kW hydrogen fuel cell, (20) it had a maximum speed of 55 mph (21) and a range of just 81 miles. (22) It did, however, demonstrate the practical application of fuel cell technology to power an automobile.

Over the next five years, three successive generations of NECAR would be built. NECAR 4, unveiled in 1999 had a larger hydrogen fuel cell with a 70 kW capacity, (23) a top speed of 90 mph (24) and a range of 281 miles. (25)

In addition to passenger vehicles, DaimlerChrysler was also developing a fuel cell-powered bus. In 1997, the first NEBUS was built, powered by a 250 kW hydrogen fuel cell. (26) The NEBUS had a top speed of 50 mph (27) and a range of 156 miles. (28) Between 1998 and 1999, a trial was conducted employing six "P3" buses powered by 250 kW hydrogen fuel cells. The buses had a top speed of 55 mph (29) and a range of 190 miles. (30)

One of the most intriguing concepts for employing fuel cell technology in vehicles is being developed by General Motors Corporation. GM has developed what it calls its "skateboard" chassis. The "skateboard is a flat, six-inch thick platform that does indeed resemble a huge skateboard. The platform contains all of the components of the vehicle's drive train and fuel system. Individual lightweight electric motors are integrated into each of the "skateboard's" wheels eliminating the need for a transmission or driveshaft.

A major advantage of the "skateboard" concept is that it permits a single chassis to serve as a platform for a wide variety of body styles and interiors. Currently, General Motors produces 88 different chassis (31) for its vehicles. The "skateboard" power system would eliminate the wasteful duplication and enormous cost maintaining such a wide variety of platforms entails. GM plans to have its hydrogen fuel-cell vehicle in production within a decade.

CHALLENGES TO HYDROGEN FUEL CELL DEVELOPMENT

While there is a high degree of optimism regarding hydrogen fuel cells in the automotive industry, a number of hurdles need to be overcome before they enter the market in large numbers.

First, the cost of the fuel cell must be reduced to the point that it is comparable to its gasoline counterpart. Currently an average new automobile engine sells for around $3000. (32) Even assuming that a hydrogen fuel cell vehicle is powered by a relatively small 50 kW fuel cell, the cost of the device cannot exceed $60 per kW and remain competitive. The trouble is that the fuel cells on the market today sell for around $4,500 per kW, (33) or roughly $225,000 for a 50 kW unit. In order to meet the competitive requirements, the price would have to be reduced by a factor of 75.

Obviously, mass production will dramatically lower fuel cell prices, but by themselves these savings still might not be enough. The core problem at present is the cost of the catalysts and certain ceramic components used in most contemporary designs. Most are extremely expensive and are a primary reason why prices are so high. Still, there is some hope on this front. Fuel cell designs currently on the drawing board may lower the cost to $1,200 per kW. (34) While still 20 times higher than a cost that would be competitive with internal combustion engines, it still represents a major improvement in fuel cell economics. An even more promising design is under development at the Berkeley Laboratory.

Scientists at Berkeley Lab have developed a solid oxide fuel cell, or SOFC, that replaces expensive ceramic and zirconia components with stainless steel. (35) As a result, the cost of the raw materials per kilowatt is reduced to around $37. (36) While still in the early stages of development, the researchers hope that the SOFC can bring the price per kW below $130. (37) When savings from mass production are factored in, this may bring the total cost of the device to a point that might be competitive with conventional internal combustion engines.

Hydrogen fuel production and delivery also remain major obstacles. At present, there is no infrastructure for mass-producing hydrogen in the quantities that would be required to meet automotive needs. One option that has been considered as an interim step is so-called "on-board reforming." This entails equipping the vehicle with a small "reformer" that manufactures hydrogen from a feedstock. The only problem is that taking this approach would greatly increase the complexity and expense of the vehicle. A more likely interim approach would be to equip fueling stations with small reformers that manufacture the hydrogen in small quantities from natural gas. The hydrogen would be stored on board the vehicle as a compressed gas.

The use of on-site reformers producing hydrogen from natural gas also helps to address another significant problem: transporting the hydrogen. Until major advances are made in materials technology, the storage and transportation of large volumes of hydrogen will remain infeasible. A 1.3 million-mile network of natural gas pipelines, however, already serves much of the continental United States. Areas not serviced by pipelines can readily be provided with fuel supplies by tanker trucks using well-established technology.

Cold-weather operation can also present a problem for hydrogen fuel cell-powered vehicles. One reason is that they always contain water, both as a byproduct and as a humidifying agent. In extreme weather, the water can freeze. Also, the fuel cells must be able to attain certain temperatures for optimum performance.

Safety is also a major issue. Hydrogen is a highly volatile substance and is difficult to contain. Therefore specialized safety protocols will have to be developed to protect against accidents.

A final challenge will lie in the need to win public acceptance. The public has along been accustomed to using liquid fuels in its vehicles. Making the transition to a gaseous fuel will require a psychological as well as a technological shift.

In addition to the technical issues, it will also be necessary to develop an infrastructure to produce hydrogen fuel cell vehicles. Although they will have some components – primarily in the body and interior – in common with conventional gasoline-powered vehicles, many new components will have to be manufactured. These include everything from the electric motors that will drive the wheels to fuel dispensing and monitoring units.

The question is how can these challenges best be met? The answer lies in creating a bridge to the future by combining two established technologies: natural gas and hybrid electric vehicles.

HYBRID ELECTRIC VEHICLES

Ford Escape Hybrid Electric Vehicle

The concept of hybrid vehicles is not new. It has long been employed by railroads, most of which use diesel-electric locomotives that can either use electric current from overhead wires or on-board diesel engines when electricity is not available. In some cities, buses are similarly configured. Submarines and some other naval vessels also operate on this principle. Indeed, it is not even necessary to have the combination of an internal combustion engine and an electric motor to be a hybrid. Consider the motorized pedal bike, or Mo-Ped that combines the muscle energy of its rider on pedals with a small gasoline engine. Because it utilizes two distinct power sources it is also a hybrid.

There are two different designs for hybrid automobiles. The first of these is called a "parallel" hybrid. In the parallel design, both the internal combustion engine and an electric motor can help turn the transmission that then provides motive force to the wheels.

The second type is a "series" hybrid. In a series hybrid, the internal combustion engine operates as a generator for electric motors that turn the wheels. It never provides direct power to the transmission.

The hybrid concept evolved from recognition of a basic fact: most of the time automobile engines use only a fraction of their power. Indeed, it only requires about 20 horsepower to maintain an automobile on a freeway at around 60 mph. (38) The only time the balance of the power is required is to accelerate, overcome inertia from a dead stop or climb a hill. A parallel hybrid uses the added power of its electric motors to provide an assist when these or similar tasks must be accomplished. As a result, a much smaller internal combustion may be used.

Dodge Durango Hybrid

Unlike a pure electric vehicle, a hybrid does not require an outside power source to charge its batteries. The internal combustion engine acts as a primary generator when in operation. If the electricity it produces is not being used, it is stored in on-board batteries for later use. Hybrids also recover energy in other ways. For example, they employ "regenerative braking" to take some of the energy that is being depleted when you use the brakes and storing it for later use. As a result, the fuel efficiency of hybrids can be anywhere from 15% better to more than twice that of conventional gasoline-powered vehicles. (39)

WHY A HYBRID NGV MAKES SENSE

Since the twin goals of producing automobiles with hybrid power systems are reducing petroleum consumption and automotive emissions, it makes sense to select a fuel that maximizes performance in these areas. Even if petroleum-derived fuels were used, of course, substantial improvements in both mileage and emissions would occur for two reasons. First, because the vehicles would burn far less fuel per mile traveled there would be a corresponding reduction in emissions. Secondly, because the internal combustion engines in hybrid vehicles operate at a much higher efficiency than those used in conventional vehicles they would be inherently less polluting. Obviously, if the engines get higher mileage, they would by definition reduce the consumption of petroleum-derived fuels. The real question, however, is whether using gasoline optimizes the potential of hybrids. The answer is no. Natural gas presents a far superior alternative.

Natural gas has by far the best environmental profile of all fossil and alternative fuels that can be used in internal combustion engines. A simple comparison of the emissions of the principal alternatives as compared to reformulated gasoline makes this abundantly clear. These are Biodiesel used either as B-100, a "neat" fuel (100% Biodiesel content), as B-2 (a blend of 20% biodiesel and 80% standard diesel), E85 (an 85% ethanol blend), and natural gas. The reductions achieved by using each in the three principal “criteria” pollutants, Hydrocarbons (HC), Carbon Monoxide (CO), and Oxides of Nitrogen (NOx) as defined by EPA are (40):

	B100	**B-20**	**E85**	**NATURAL GAS**
HC	67%	20%	25%	89%
CO	47%	12%	20%	70%
NOx	+12%	+ 2%	20%	87%

Although natural gas clearly has the superior emissions profile among the alternatives, even these figures do not fully reveal the emissions reduction potential of natural gas, because they are based on using the fuel in an engine designed to burn gasoline. Natural gas, however, has a much higher octane rating than gasoline. If an engine is specifically designed for natural gas, it can take full advantage of this fact with a resultant improvement in efficiency of up to 20%. If such an engine were used in a hybrid, emissions could be reduced by an even greater percentage. When compared to the average emissions for U.S. automobiles, the following reductions result, depending on whether the engine was a standard design or had been specifically designed to burn natural gas (41):

EMISSION REDUCTIONS
COMPARED TO AVERAGE U.S. PERFORMANCE

	STANDARD ENGINE	**NATURAL GAS SPECIFIC**
HC	94.5%	95.6%
CO	85.0%	88.0%
NOx	93.5%	94.7%

In addition, natural gas-powered vehicles emit virtually no particulate matter, for all practical purposes eliminating this pollutant entirely.

In many areas of the country, reformulated gasoline (RFG) is currently required. The use of natural gas in hybrid vehicles in areas where RFG is mandated would yield the following reductions in emissions. (42)

EMISSION REDUCTIONS
COMPARED TO REFORMULATED GASOLINE

	STANDARD ENGINE	**NATURAL GAS SPECIFIC**
HC	92.5%	94.0%
CO	81.5%	85.2%
NOx	93.3%	94.5%

Improvements in emission performance and reductions in petroleum use are not the only reasons benefits of using natural gas in hybrid vehicles is a preferred option. Even more important is the role natural gas can play in building a bridge to the hydrogen fuel cell vehicle.

WHY NATURAL GAS IS AN IDEAL BRIDGE FUEL

The shift to a hydrogen economy in the transportation sector will constitute one of the most significant undertakings in American History. It will have consequences that profoundly affect vast sections of the U.S. and world economies, requiring the restructuring whole industries and the creation of new ones. It will entail the transformation of trillions of dollars of capital stock to accommodate the production and distribution of a new energy source. It will make necessary the development of a new workforce capable of maintaining new, technologically advanced vehicles. Finally, it will require a shift in public perceptions and engrained habits regarding vehicular fuels. Clearly, accomplishing these tasks will take time as well as a strategy that will allow the profound changes required to take place over time. Using natural gas provides a means of achieving this objective. There are a number of reasons why this is the case.

To begin with, natural gas is both abundant and available from domestic sources. Although there is currently concern over the adequacy of near-term supplies, these concerns do not arise from a lack of resources. Rather they are the product of market forces that acted to constrain the development of new supplies due to a persistent surplus that evolved during the 1980s. With the advent of higher prices, the problem should be self-correcting, provided artificial barriers to the development of domestic supplies do not hinder their discovery and exploitation. At 1,614 TCF, (43) the domestic natural gas resource base is more than adequate to meet projected needs. All that is necessary is to permit its development.

The use of natural gas as a vehicular fuel also has the advantage of being a mature technology. It has been in worldwide use for over seven decades, and currently there are more than 2.8 million NGVs on the road. (44) In the United States, there are nearly 270,000 NGVs on the road (45) and more than 1,200 fueling stations in operation. (46) There is already a trained workforce in place familiar with servicing and maintaining these vehicles than can provide a cadre to train others. As this workforce evolves, because it will already be familiar with gaseous fuels, it can readily be cross-trained to perform servicing and maintenance for hydrogen fueled vehicles.

As noted earlier, there is in place a 1.3 million-mile network of pipelines for distributing natural gas that reaches the majority of the nation. It would be much easier to extend the system to areas currently lacking service than to create a distribution system for some other fuel from scratch. This network of natural gas pipelines can serve as the backbone for an eventual pipeline system to distribute hydrogen. Alternatively, if, as appears likely, natural gas is used as the principal source for vehicular hydrogen, the pipeline system can serve to distribute natural gas to reforming sites around the nation.

Although the current network of natural gas fueling stations is largely limited to fleet use the evolution of "vehicle refueling appliances" or VFRs makes home-based fueling a practical alternative. There currently versions of VFRs designed for home use on the market that cost under $1,000. Moreover, NGV manufacturers are offering incentives for their purchase that will defray the bulk of the cost. This means that any home with natural gas service can also have the capability for refueling an NGV. The advent of home fueling overcomes a major obstacle to the growth of the NGV vehicle stock. It also provides a potential model for an eventual transition to hydrogen, where it might be possible to employ a similar approach in the early stages of its introduction into the vehicle fleet.

Over time, as the number of natural gas vehicles in the overall fleet increased, there would be an incentive for conventional filling stations to add a natural gas refueling pump. This process would likely be similar to that experienced with diesel fuel. Prior to the 1973 Arab Oil Embargo, diesel fuel was generally only available at truck stops. With the proliferation of diesel automobiles that followed in the embargo's wake, however, more and more conventional filling stations installed a diesel fuel pump in addition to their gasoline pumps. Today, they are relatively common. The same would occur with natural gas.

The installation of natural gas fueling facilities at conventional service stations is a key element in the eventual shift to hydrogen, because they will provide an infrastructure for the eventual installation of hydrogen reformers and fueling facilities. Indeed, this concept is a central element of the Department of Energy's strategy for moving to hydrogen fuel cells. It was noted by Assistant Secretary of Energy for Energy Efficiency and Renewable Energy David K. Garman who said:

> *"We also expect that much of the hydrogen produced during the early years of hydrogen vehicle use will come from natural gas that is distributed to fueling stations using established infrastructure, and reformed into hydrogen at the station."* (47)

The other previous drawback to natural gas vehicles, range, is easily overcome through the use of hybrid electric vehicles. Currently, the range of gasoline-powered hybrids ranges from 678 miles for the Honda Insight to 571 miles (48) for the Toyota Prius. (49) Although natural gas has a lower energy density than gasoline, the corresponding range figures for a natural gas-powered version of these vehicles would still be between 342 miles and 407 miles, (50) more than adequate to meet the requirements of U.S. automobile consumers. The expansion of the number of natural gas-powered hybrids within the vehicle fleet will have a number of important consequences for the eventual development of an infrastructure to produce hydrogen fuel cell vehicles.

A substantial proportion of the technology that must be developed to make the hydrogen fuel cell vehicle a reality is also required to produce natural gas-powered hybrid vehicles. These include such things as the refinement of the electric motors to drive the wheels, the delivery systems for gaseous fuels, and the development of lightweight materials that will be required. Initially, the natural gas hybrids can provide a test bed for these technologies. Once they are fully developed and the number of hybrids begins to increase, they will help create the industrial and manufacturing infrastructure that hydrogen fuel cell vehicles will eventually need.

The introduction of natural gas as a vehicle fuel on a widespread basis will also help to spur public acceptance of the concept of using a gaseous fuel in their automobiles. Up to the present, all vehicle fuels have been liquid. This has created ingrained habits and attitudes among automobile owners that must be overcome if hydrogen fuel cell vehicles are to become a practical reality. Once consumers are familiar with natural gas, however, the sift to hydrogen will meet with far less psychological resistance.

Even before the transition to a hydrogen economy in the transportation sector is achieved, the nation will reap substantial economic benefits from shifting to natural gas-powered hybrid vehicles. These include:

- The development of new export markets for NGV hybrid technology,
- The expansion of employment in the United States to manufacture components,
- A reduction in the economic toll our continued dependence on oil imports exacts;
- And an enhancement of the nation’s security as the vulnerability to oil import supply disruption is eliminated.

What then is necessary to expand the number of natural gas hybrid vehicles in the U.S. fleet?

INCENTIVES FOR EXPANDING THE PRESENCE OF HYBRID NGVS

Congress has already enacted a variety of incentives to promote the development of alternative fuels and fuel-efficient vehicles. Currently it is considering legislation that will provide additional incentives, including specific provisions to encourage public acquisition of both fuel cell-powered vehicles and hybrids. The legislation known as the Clean Efficient Automobiles Resulting from Advanced Car Technologies, or CLEAR ACT, has a number of unique characteristics.

PROVISIONS OF THE CLEAR ACT

The CLEAR ACT provides tax incentive for new technology directly to the consumer rather than a manufacturer or fuel provider. Secondly, the Act includes provisions that provide performance incentives tied to a base credit. The incentives for fuel cell-powered vehicles include a $4,000 base credit along with an additional credit of up to $4,000 depending on fuel economy. The credit will be available for the next decade.

There is also a $1,000 tax credit for hybrid electric vehicles that is dependent on the amount of electric drive power that the vehicle employs. Hybrids are also eligible for a credit of as much as $3,000 depending on fuel efficiency. This credit will be available for the next six years, and in order to qualify, a vehicle must equal or beat the average emission level for light duty vehicles.

Dedicated alternative fuel vehicles – those solely capable of running on alternative fuels that promote energy diversity and significant emission reductions are eligible for a base credit of up to $2,500 depending on performance. There is an additional $1,500 credit for "Ultra Low Emission" vehicles. "Flex fuel" vehicles that can run on either an alternative or gasoline are not eligible for the credit. Vehicles that run on E85 are also excluded because they entail no incremental cost.

There is a base credit of $4,000 for electric vehicles that run on batteries and are not dependent on petroleum fuels. An additional $2,000 credit is available to electric vehicles with extended ranges or payload capabilities.

Incentives are also provided for medium-duty and heavy-duty vehicles. As with passenger vehicles, the incentives are tied to fuel efficiency, diversity and emissions reductions. The incentives vary according to weight. The heaviest vehicles (over 26,000 pounds) receive a $40,000 credit for using fuel cells or batteries, $32,000 for using an alternative fuel, and $24,000 for using hybrid energy applications.

The CLEAR ACT also includes provisions that provide a credit of up to 50 cents per gallon for retail distributors of alternative fuels such as natural gas, liquefied natural gas, liquid propane gas, hydrogen B-100 Biodiesel, and methanol. Ethanol is not included in the provisions because it already qualifies for a credit of 82 cents per gallon under other legislation.

The Act also provides a ten-year extension of the existing tax deduction of up to $100,000 for the installation of alternative fuel dispensing sites that are available to the public and also adds a credit of up to $30,000 for actual costs incurred.

The CLEAR ACT represents an important step towards making the vision of an energy-independent nation a reality. It stands as clear evidence that Congress understands the scope of the threat oil imports represent. Yet, it there still may be some actions that government can take to provide even greater impetus to the transition to secure fuels.

OTHER ACTIONS

There are a number of things that the government can do to further accelerate the move to secure domestic fuels with superior environmental attributes. One of the most important would be to make individual tax credits for alternative and advanced technology vehicles refundable for vehicles built in the United States.

Under the most recent changes in the tax code, a family of four making $40,000 per year would pay no federal income taxes. Even families with incomes substantially higher might be unable to take full advantage of the tax incentives the CLEAR ACT provides for individual consumers. Making the tax credit refundable would ensure that the actual purchase price to the consumer would be effectively reduced by its total value. This would make energy efficient, environmentally superior vehicles available to a much broader segment of the population. By applying limiting the eligibility of the refundable credit, it would serve to create American jobs and accelerate the development of the domestic industrial infrastructure for both alternative fuel vehicles, and eventually hybrids. Also, by spurring early sales, it would also hasten the day when economies of scale would reduce their costs to the point that subsidies would no longer be needed.

A second action the government could take would be to provide a refundable tax credit for half of the cost of vehicle refueling appliances. Fuel providers and vehicle manufacturers could be encouraged to provide assistance through either low-cost financing or direct subsidies to cover the balance of the cost. This would greatly accelerate the availability of such devices to consumers and further encourage the purchase of natural gas fueled vehicles.

A third action would be to ensure that the federal government improves its performance in meeting mandated alternative fuel vehicle purchases, and, more important actually run the vehicles on alternative fuels.

As noted, under the EPAct, the federal government is under a mandate to make 75% of new vehicle purchases from models capable of using alternative fuels. Performance among various agencies varies, but it is significant that as of fiscal year 2000 only six federal agencies were in compliance with the EPAct requirements. (51) Worse, in fiscal year 2001, out of 58,000 vehicles purchased by the General Services Administration, only 7,819 alternative fuel vehicles. (52) This amounts to a little more than 13.5% of new vehicle purchases rather than the 75% the law requires. But that is not the only problem with federal AFV use. More often than not, the vehicles are capable of using either alternative fuels or gasoline, and in most instances opt for the latter. To illustrate, according to the latest figures, the federal government used around 1.8 million gallons of alternative fuels in 2001. (53) This equals roughly 117 barrels of oil per day out of a total of more than half a million barrels per day.

Enforcing not only the EPAct and Executive Order 13149 provisions that mandate the acquisition of alternative fuel vehicles, but enforcing the provision that they actually use alternative fuels would go a long way towards improving the performance of federal agencies in this regard.

Another action the government could take is to change General Services Administration rules concerning the purchase of alternative fuel vehicles. Currently, if an alternative fuel vehicles is sold at a higher price than its conventional alternative, the agency seeking to purchase it must pay the full difference at the time of acquisition and may then amortize the balance of the cost over time as it would with a conventional vehicle. This purchasing rule makes the acquisition of such vehicles needlessly costly, and makes no economic sense. If anything, alternative fuel vehicles should be given preferential treatment, not disadvantageous treatment.

The federal government can also help by making its fueling facilities available to the public until such time as a commercial infrastructure is in place. While there may be a need to make exceptions for security reasons, such exceptions should be the given only under extraordinary circumstances. It would be a simple matter to install equipment for private consumers to use credit cards to make their purchases, and in fact, profits from such purchases might help to defray the cost of installing the fueling stations.

TIME FRAME FOR IMPLEMENTATION

Determining the time frame for implementing a program to shift automobile owners first to natural gas hybrid vehicles and eventually to hydrogen fuel cell vehicles is best tailored to normal market operations within the economy's transportation sector. To determine what the pace might be, it is necessary to understand the normal turnover of the U.S. vehicle stock.

Currently, the average passenger vehicle in the United States is around 9 years old. (54) The average light truck is 8 years old. The median life of domestic passenger cars is 16.9 years, and the median life of trucks 15.5 years. (55) Of the cars purchased in model year 1990, one-half will last sixteen years or more, (56) one-third twenty years or more (57) and one-fifth twenty-four years or more. (58) Americans purchase between 16.5 million and 17 million cars annually at present (59), but this figure is likely to rise in the years ahead. (60) This means that the potential market for alternative fuel vehicles is between 16.5 million and 17 million at present.

Of course, only a fraction of vehicles sold for some time to come will use alternative fuels. Both the availability of the vehicles and the creation of a refueling infrastructure will act as constraints in the near term. With the provision of proper incentives and a vigorous program to promote their use, however, the number added annually to the vehicle stock can rapidly increase. What then, are realistic goals and what would the result of achieving those goals be?

THE FEDERAL FLEET AND THE "FORWARD MARKET"

One traditional role for the federal government in the development of new technologies is to act as a "forward market." By this it is meant to say that the federal government can help "prime the pump" for emerging industries and technologies by making the crucial initial sales that permit them to become established. This approach has been used in everything from aviation to computers with great success.

Indeed, it is this concept that underlies Executive Order 13149 mandating federal alternative fuel vehicle acquisition. A good starting point would be for GSA and other federal agencies to comply with the requirements of this Executive Order. Had GSA done so in fiscal year, 2001, for example, it would have purchased 43,500 alternative fuel vehicles, almost 5.6 times the 7,819 AFVs that it actually bought. Had GSA met the mandated target it would have increased the total size of the U.S. alternative fuel vehicle fleet by 9.5%. (61)

In the long run, though, the principal market that alternative fuel vehicles must penetrate is among private owners. It is here that incentives such as the refundable tax credit for vehicles and VRAs can help. Also, as AFVs become more common among individual owners, the increased familiarity should bring with it increased sales: people are much more likely to purchase a known commodity.

Over the past three years new car sales have averaged 16.8 million units. (62) A reasonable approach would be to set goals for AFVs to capture an increasing proportion of sales over time. Since over 80% of the vehicles purchased in any given model year will have been scrapped at the end of 25 years, it would be reasonable to use this timeframe to phase in the use of alternative fuels on a large scale. It would also provide sufficient time to establish the industrial and fueling infrastructure necessary to make the transition.

The pace of the shift should also acknowledge the need to build over time. As the industrial infrastructure grows, so, too, will its ability to fulfill orders. Therefore in the earlier periods of the transition, the targets should be lower than in the later years. Moreover, as production levels increase, economies of scale will lower costs, making alternative fueled vehicles more accessible to a broad range of the general public.

What then would a reasonable schedule be?

Ideally, the targets would follow a curve, beginning at around 1% of new car sales in the first year and increasing by one percentage point through the fifth year. This provides enough time for dealers to acquire a trained work force to service and maintain the vehicles, the beginnings of a national fueling infrastructure to be established, and for the public to begin to become accustomed to the notion of a new fuel. Therefore in the fifth year following their introduction, 5% of new car sales would be AFVs.

Over the next five years, the sales targets can become somewhat more ambitious due to the expanded infrastructure and public familiarity. In this phase, the targets would begin at 12% of new car sales, rising by 2% per year so that by the tenth year 20% of new car sales are AFVs. By year ten, it would also be possible to phase out the refundable tax credit for VRAs, as a relatively extensive commercial fueling infrastructure should be in place.

In year eleven, the proportion of new car sales should begin to increase by three percentage points annually, beginning at 33% of new car sales and rising to 45% by year fifteen. At this point, it would no longer be necessary to provide a refundable tax credit for vehicle purchases, since they will account for close to half of all new car sales and would therefore be supported by a substantial industrial infrastructure.

After year fifteen, the sales target should increase by four percentage points annually for a decade. This would end with AFVs accounting for 100% of new car sales.

AFV PROPORTION OF NEW CAR SALES

PHASE	YEARS	START	END
ONE	1-5	1%	5%
TWO	6-10	12%	20%
THREE	11-15	33%	45%
FOUR	16-25	64%	100%

It should also be noted that in both the earliest and latter stages of the process, not all vehicle purchases are likely to be natural gas hybrids. Initially, as has been the case with gasoline-powered hybrid electric vehicles, the variety of models offered will be limited. As a result, to accommodate their specific needs, some consumers may elect to purchase conventional natural gas vehicles. During the later stages of the process, as hydrogen fuel cell vehicles become available, they will also account for some proportion of new car sales. Indeed, the introduction of hydrogen fuel cell vehicles will likely follow a pattern of market penetration similar to that of natural gas powered hybrid electric vehicles. The development of a fueling infrastructure will also follow a similar pattern, with VRAs and single pump installations dominating the early stages, and multi-pump commercial stations eventually fulfilling this role.

Clearly, the transition to alternative fuels will have far-reaching implications for the economy and national security. Understanding the consequences of this shift underscores the importance of making it a reality.

CHAPTER SEVEN NOTES

1. Copulos, Milton R. Natural Gas Vehicles, Helping Ensure America's Energy Security, National Defense Council Foundation, Washington, D.C. October, 1995

2. Source: Weekly Petroleum Status Update, Energy Information Administration, United States Department of Energy, Washington, D.C. June 10, 2003

3. Source: General Richard B. Myers, Chairman Joint Chiefs of Staff, quoted in "Progress Made in Iraq, but Deaths Hammer Home," American Forces Information Service, United States Department of Defense, June 24, 2003

4. See Chapter 3, The Economic Impact of Imported Oil
5. ibid.
6. Biofuels and Agriculture, United States Department of Energy, Oak Ridge National Laboratory, September, 2001
7. ibid.
8. Source: Weekly Petroleum Status Update, op. cit.
9. Based on DOE statistics
10. Energy Policy Act Fact Sheet, United States Department of Energy, National Alternative Fuels Hotline, September, 1998
11. ibid.
12. ibid.
13. ibid.
14. Alternatives to Traditional Transportation Fuels, 2000, Table 9. United States Department of Energy, Washington, D.C. September 2002
15. Federal Alternative Fuel Consumption, FY 2000 United States Department of Energy, Washington, D.C. 2001
16. Annual Energy Review, Table 1-11, United States Department of Energy, Washington, D.C., June, 2002.
17. Weekly Petroleum Status Update, op. cit
18. Source: U.S. Department of Energy report "Federal Fleet Compliance with Executive Order 11349", Washington, D.C. 2001
19. Source: DaimlerChrysler presentation, May 21, 2002.
20. ibid.
21. ibid.
22. ibid.
23. ibid.
24. ibid.
25. ibid.
26. ibid.
27. ibid.
28. ibid.
29. ibid.
30. ibid.
31. Source: Interview of General Motors CEO on 60 Minutes II
32. Hydrogen Fuel Cell Newsletter, April, 1999
33. Source: United States Department of Energy Office of Fossil Fuels
34. ibid.
35. Krotz, Dan, "Almost There: A Commercially Viable Fuel Cell", Science Beat, Berkeley Lab, Berkeley, CA November 15, 2002
36. ibid.
37. ibid.
38. How Hybrid Cars Work on How Stuff Works @ http://www.howstuffworks.com/hybrid-car.htm
39. Based on fuel efficiency data for hybrid models reported by General Motors, Toyota and Honda.
40. Source: United States Department of Energy Clean Cities Program

41. Based on figures presented in Table 4-38, National Highway Statistics, Bureau of Transportation Statistics United States Department of Transportation, Washington, D.C. July, 2002
42. ibid.
43. Source: U.S. Department of Energy
44. Source: International Natural Gas Vehicle Association
45. Source: United States Department of Energy Alternatives to Traditional Transportation Fuels, 2000 op. cit.
46. Source Transportation Energy Databook, Oak Ridge National Laboratories, September, 2000, Oak Ridge, TN
47. Garman, David K., Clean Cities and the Hydrogen Future, Alternative Fuel News, Alternative Fuels Data Center, United States Department of Energy, Washington, D.C., May, 2003
48. Source: Honda
49. Source: Toyota
50. Based on an assumed capacity equal to 60% of the gasoline normally carried in the vehicle's fuel tank.
51. Federal Fleet Compliance with Executive Order 13149, Fiscal Year 2001, United States Department of Energy, Washington, D.C.
52. Source: United States Department of Energy Clean Cities Program presentation on GSA alternative fuel vehicle purchases, 2002
53. Federal Fleet Compliance with Executive Order 13149, Fiscal Year 2001, United States Department of Energy op .cit
54. Source: Transportation Energy Databook, op. cit.
55. ibid.
56. ibid.
57. ibid.
58. ibid.
59. 2003 NADA Databook, National Association of Automobile Dealers, Maclean, VA., 2003
60. ibid.
61. Source: Transportation Energy Databook, Clean Cities Program presentation

CHAPTER 8: CONCLUSION
THE ECONOMIC BENEFITS OF AN AFV PROGRAM

The economic benefits of instituting an aggressive effort to shift the U.S. transportation sector to alternative fuel carries with it both important enhancements of national security and enormous economic benefits. Broadly speaking, the economic benefits can be divided into two categories: avoided costs and positive economic outcomes.

AVOIDED COSTS

As outlined in previous sections of this report, America's rising dependence on imported crude oil and refined petroleum products exacts an enormous economic toll on many levels. It diverts precious financial resources abroad costing domestic jobs and investment; it deprives federal, state and local governments of revenues from taxes and royalty payments. It promotes instability in financial markets by creating uncertainty over energy prices. It leaves America to severe economic repercussions arising from periodic oil supply disruptions. On an annualized basis these costs total between $297.2 billion and $304.9 billion (1) – the equivalent of from $70.07 to $71.91 per barrel of imported oil if amortized over the total volume of imports, (2) or $146.0 billion to $153.7 billion if amortized over imports from the Persian Gulf. (3) This is equal to from $1.67 to $1.72 when amortized over the total import volume (4) and from $3.49 to $3.67 when amortized over Persian Gulf imports. (5)

But it is not just a financial cost that imports exact. There is a human cost as well, in terms of increased unemployment and reduced economic opportunities. When both the direct loss of employment resulting from economic activity taking place abroad rather than on our shores is combined with the jobs lost through the loss of economic activity and investment related to our import dependence, the total comes to almost 1.1 million. (6)

Although avoiding these substantial costs would, in and of itself justify the move to alternative transportation fuels, there is another reason to do so: the positive economic consequences of accomplishing the shift.

ECONOMIC BENEFITS OF A SHIFT IN TRANSPORTATION FUELS

A number of tasks must be accomplished in order to achieve a successful transition to alternative vehicle fuels. First, a new manufacturing infrastructure must be created. Second, a workforce must be trained to service and maintain the vehicles. Third, a new fueling and distribution system must be established to deliver it to consumers. Finally, public attitudes and perceptions regarding vehicular fuels must be changed so that they accept the new way of powering their automobiles. As a result, the proportion of AFVs entering the national motor vehicle stock will grow at a gradually accelerating rate over an extended period of time. It will take 15 years for the proportion of annual sales represented by AFVs to rise from 1% to 22.8%, but only five years for it to rise to 51.2% Five years afterwards, AFVs will comprise 100% of new car purchases.

FLEET REPLACEMENT*

FIVE YEARS	**1.0%**
TEN YEARS	**7.5%**
FIFTEEN YEARS	**22.8%**
TWENTY YEARS	**51.2%**
TWENTY-FIVE YEARS	**100.0%**

*Based on National Association of Automobile Dealers Sales Data and Bureau of Labor Statistics Market Projections

The question is will this pace justify the expenditures for incentives necessary to overcome market barriers to the entry of AFVs into the automotive sector?

The principal incentive would take the form of a refundable tax credit that would expire after ten years, for individual consumer purchases of AFVs. During the first five years of its life, the tax credit would cost $10.1 billion. During the second five years of its life, the credit would cost $53.8 billion due to increasing numbers of vehicle purchases. While this does represent a substantial outlay, it pales in comparison with the benefits of enhanced economic activity and government revenues it would generate.

In the first five-year period, new AFV sales and secondary economic activity would total $163.8 billion. Federal income tax revenues on wages and profits generated by this activity would equal $11.9 billion (7), a $1.8 billion gain over the outlay for incentives. State income tax revenues would increase by $6.1 billion. (8) This yields a total gain of $7.9 billion when state taxes are taken into account. Establishing the industrial and fueling infrastructure would require an annual investment of $1.267 billion for a five-year total of $6.335 billion. The portion of this investment comprised of new plants or buildings would also result in additional state property tax revenues.

In the second five-year period, new AFV sales and secondary economic activity would generate a total of $1,037.4 billion. Federal income tax revenues on wages and profits generated by this economic activity would equal $75.4 billion (9) a gain of 21.6 billion over outlays for incentives. State income tax revenues for the period would increase by $38.6 billion (10) as a result of the expanded economic activity. This would result in a combined gain of $60.2 billion in income tax revenues when state receipts are taken into account. Because of an increased requirement for fueling stations, an annual investment of $4.272 billion will be required to expand the infrastructure for manufacturing and fueling totaling $21.360 billion for the five-year period. As with the previous investment, additions of manufacturing plants and other buildings will expand the state property tax base.

Over the ten years of its life, the refundable tax credit will cost $63.9 billion. For that same period, however, it will generate $87.3 billion in federal income taxes (11) and $44.7 billion in state income taxes. (12) This yields a surplus of $23.4 billion at the federal level alone and a surplus of $68.1 billion when state taxes are taken into account. It will also generate a total of $27.965 billion in new direct investment and $1,201.2 in overall economic activity for the ten-year period, an average of over $120 billion per year.

ECONOMIC IMPACT OF REFUNDABLE TAX CREDITS*
(BILLIONS)

	COST PERIOD	ECONOMIC ACTIVITY	REVENUES STATE	REVENUES FEDERAL	SURPLUS
YEAR FIVE	$10.1	$ 163.8	$ 6.1	$11.9	$ 7.9
YEAR TEN	$53.8	$1,037.4	$38.6	$75.4	$60.2
CUMULATIVE	$63.9	$1,201.2	$44.7	$87.3	$68.1

*Based on BEA standard multipliers and NADA projections of the U.S. automobile market

By the time the refundable tax credits expire, AFVs should have achieved sufficient market penetration to continue to expand their market share even without the added incentives. More important, a fueling infrastructure – perhaps the single most important barrier to market penetration will have been established.

A parallel may be found in the history of diesel engine penetration into the consumer market. In the years immediately following the Arab Oil Boycott, many consumers purchased diesel engines to take advantage of their higher mileage. Further, they did so despite the lack of a fueling infrastructure. The rapid growth of diesel automobiles, however, created an incentive for service station owners to install diesel pumps to take advantage of the new demand. Today, most commercial gasoline stations have at least one diesel pump.

In addition to the development of a fueling infrastructure, there is another reason to expect the market penetration of AFVs to increase. World oil demand is expected to continue to grow in the decades ahead, especially in the developing world. (13) As this growth takes place, limitations on supply will inevitably cause the price of oil to rise, and create incentives for more efficient vehicles. This continuing growth in demand for fuel-efficient vehicles will in turn require a continuing investment in infrastructure and refueling to accommodate market needs. Since the investment will be driven by vehicle sales, it will take place at a gradually accelerating rate.

As noted above, during the first ten years, cumulative investment requirements will total approximately $27.965 billion. (14) At the end of this period, the level of annual investment can be expected to rise to $8.085 billion (15) for the next five years to accommodate more rapid expansion of the fueling systems and infrastructure. Cumulative investment during this five-year period will total $40.435 billion. (16) At the end of fifteen years, the level of investment will peak at 13.544 billion annually (17) and continue at that level for a five-year period. Again, the reason for the increase will be to accommodate expanding infrastructure and fueling capability. During this period, a portion of the investment in refueling is likely to be directed towards hydrogen for a growing number of hydrogen fuel cell hybrids that are likely to begin entering the market. Total investment for the period between fifteen and twenty years following initiation of the program will total $67.720 billion, the largest amount of the total 25-year investment cycle. (18)

For the final five years of the investment cycle, annual requirements will drop to $7.168 billion (19) as fueling infrastructure becomes substantially complete and the need for additions to manufacturing infrastructure moderates. During this final portion of the investment cycle, the total investment required will be $35.840 billion. (20) For the entire 25-year period the transition to AFVs is expected to require, the total investment that may be expected for the development of manufacturing infrastructure, a fuel delivery system and other related capabilities the total investment that will take place should equal $166.950 billion. (21)

It should be noted that no attempt has been made to estimate the additional investment that may be required to meet export demand for components. As both advanced natural gas-powered hybrid electric vehicles and later hydrogen fuel cell-powered vehicles begin to enter the domestic market in earnest, it is likely that an export market for components and vehicles will evolve as well. Providing the manufacturing infrastructure to meet this demand could constitute a significant additional expenditure of capital that cannot be reliably estimated at this time.

INVESTMENT IN INFRASTRUCTURE, FUELING AND DELIVERY* (BILLIONS)

	INVEST	PERIOD	CUM.
FIVE YEARS	$1.267	$ 6.335	$ 6.335
TEN YEARS	$4.272	$21.360	$27.965
FIFTEEN YEARS	$8.085	$40.425	$68.390
TWENTY YEARS	$13.544	$67.720	$131.110
TWENTY-FIVE YEARS	$ 7.168	$35.840	$166.950

*Based on BEA, Census Bureau and Manufacturer data

One of the most important consequences of the investment private sector firms will make in new manufacturing infrastructure, the construction of fuel delivery systems and associated activities is the effect on employment. Over the past two decades, there has been growing concern over the loss of manufacturing jobs to overseas competitors. The transition to AFVs can help to significantly reverse that trend.

As with other economic aspects of the shift to alternative fuels, the addition of new manufacturing jobs will occur at a gradually accelerating rate, with almost 1.4 million new positions created in the first five years. (22) During the second five years of the transition, almost 5.5 million new jobs will be created. (23) By the end of the twenty-five year transition cycle, over 27.4 million Americans will be employed either directly or indirectly in activities related to Alternative Fuel Vehicles. (24) More important, the nature of jobs in the industry is such that they will by and large pay above average wages. (25)

JOB CREATION FROM AVF-RELATED ACTIVITIES*

FIVE YEARS	1,392,353
TEN YEARS	5,490,590
FIFTEEN YEARS	12,472,265
TWENTY YEARS	21,472,860
TWENTY-FIVE YEARS	27,426,700

*Based on BEA jobs/capital ratios

Another way in which the move to alternative fuel vehicles powered by natural gas or hydrogen will benefit the U.S. economy is through a reduction in outlays for health related to environmental pollution. The Centers for Disease Control and Prevention estimate that the cost of illnesses related to mobile source pollution ranges between $28.4 billion and $35.5 billion annually. (26)

As the number of AFVs increases, the pollutants responsible for causing those illnesses will be correspondingly reduced. By the end of the first five years of the transition cycle, AFVs will be responsible for reducing emissions of three important mobile source pollutants: Hydrocarbons (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NOx) by more than 643,000 tons each year. (27) By the tenth year, that figure will rise to over 4 million tons, and by the fifteenth year, the total reduction of these three pollutants will be more than 12.4 million tons annually. (28)

When the transition is complete, the use of natural gas and hydrogen alternative fuel vehicles will reduce vehicular emissions of HC, CO and NOx by almost 47.6 million tons.(29) In addition, because fuels such as natural gas and hydrogen emit virtually no particulate matter, illnesses associated with this form of pollution – especially asthma – will be reduced as well.

REDUCTION IN POLLUTANTS THROUGH AFV USE*
(SHORT TONS)

	5YR	10YR	15YR	20YR	25YR
HC	59,056	374,019	1,141,741	2,559,075	4,370,113
CO	512,567	3,246,259	9,909,632	22,211,245	37,929,972
NOx	71,422	452,337	1,380,819	3,094,940	5,285,204
TOTAL	643,045	4,072,615	12,432,192	27,865,260	47,585,289

*Based on data from Oak Ridge National Laboratory Transportation Databook

In the first five years of the transition to alternative fuels, it can be expected that pollution-related health care costs will be reduced by from $328 million to 478 million annually. (30) At the ten-year mark, that figure will have increased to between $2.46 billion and $3.585 billion. (31) By the time the transition cycle is completed at the twenty-five year mark, the total savings in pollution-related health care costs will range between $32.8 billion and 47.8 billion. (32)

REDUCTION IN POLLUTION-RELATED HEALTH COSTS*

FIVE YEARS	328	TO 478
TEN YEARS	2,460	TO 3,585
FIFTEEN YEARS	7,478	TO 10,898
TWENTY YEARS	16,794	TO 24,474
TWENTY-FIVE YEARS	32,800	TO 47,800

*Based on CDC data concerning health care costs and EPA data concerning emission reductions associated with natural gas and hydrogen.

Health care costs are not the only area in which the reduction in pollution will realize savings. A number of different entities have estimated the cost of eliminating a ton of pollution through various means. Depending upon the method, the cost can range as high as $61,000 per ton. (33) Using natural gas and hydrogen in alternative vehicles is by far the lowest cost option, saving $2,550 per ton over the next least expensive option. The savings realized by taking this approach in comparison to other options is substantial. In the first five years of the transition cycle, using a gaseous-fuel AFV approach will save over $1.6 billion compared to the closest cost alternative. (34) In the tenth year, these savings will total $10.4 billion. (35) By the end of the transition period, the total savings realized annually by using gaseous-fueled AFVs would total $109.4 billion per year.

SAVINGS IN ANNUAL POLLUTION REDUCTION COSTS*
(BILLIONS)

5YR	10YR	15YR	20YR	25YR
$1.6	$10.4	$31.7	$71.1	$121.3

*Based on estimate of removal cost from Association of State and Territorial Pollution Control Administrators

THE BOTTOM LINE: DOING WHAT MAKES SENSE

In the final analysis, implementing a strategy that employs natural gas and hybrid electric vehicles as a bridge to the transition to a hydrogen fuel cell energy economy simply makes sense. In the short to intermediate term, the use of natural gas both in conventional NGVs and hybrid electric vehicles will yield immediate benefits in terms of energy security, economic stimulus and environmental enhancement. Over the long term, it provides the opportunity to develop the manufacturing capabilities, technological innovations, fueling infrastructure and trained workforce necessary to make hydrogen fuel cell vehicles a reality. Moreover, it provides a hedge against unforeseen delays in fuel cell or hydrogen technology development.

When complete, this intermediate phase in the process of weaning the American economy from its addiction to imported oil will have created over 27 million new jobs and fostered over $166 billion in new investment. It will have saved over $121 billion in outlays to reduce mobile source emissions and reduced pollution related health care outlays by as much as $47.8 billion. It would also dramatically reduce the need to spend over $49 billion a year defending Persian Gulf oil, and the loss of between $248.1 billion and $255.8 billion in domestic activity from the diversion of investment abroad. In short, it would serve not only to enhance domestic security, but to revitalize the American economy as well. Given these benefits, it is the only path to energy security that makes sense.

CHAPTER EIGHT NOTES

1. See Chapter 3
2. ibid.
3. ibid.
4. ibid.
5. ibid.
6. Based on BEA capital/jobs ratio factors
7. Based on Tax Policy Center estimates of tax rates for individuals and corporations
8. ibid.
9. ibid.
10. ibid.
11. ibid.
12. ibid.
13. International Energy Outlook 2003, Energy Information Administration, United States Department of Energy, Washington, D.C. May, 2003
14. NDCF estimate based on BEA standard multipliers, Bureau of Labor Statistics data on manufacturing investment and manufacturer's data on fuel delivery system cost.
15. ibid.
16. ibid.
17. ibid.
18. ibid.
19. ibid.
20. ibid.
21. ibid.
22. Based on Bureau of Labor Statistics capital/jobs ratios.
23. ibid.
24. ibid.
25. Based on Bureau of Labor Statistics employment and income data.
26. Source: Centers for Disease Control and Prevention
27. Based on EPA GREET Model projection of grams per mile and DOT estimate of Average Vehicle Miles Traveled and total fleet data.
28. ibid.
29. ibid.
30. ibid.
31. Based on CDC data.
32. ibid.
33. Based on EPA data
34. ibid.
35. ibid.

BIBLIOGRAPHY

GOVERNMENT DOCUMENTS

GENERAL ENERGY

Annual Energy Review 2001, U.S. Department of Energy, Energy Information Administration, Washington, D.C. November 18, 2002

Petroleum Supply Annual, United States Department of Energy, Energy Information Administration, Washington, D.C. June, 2002

U.S. Crude Oil, Natural Gas and Natural Gas Liquids Reserves, 2001 Annual Report, United States Department of Energy, Energy Information Administration, Washington, D.C. November, 2002.

International Energy Outlook 2003, United States Department of Energy, Energy Information Administration, Washington, D.C. May, 2003

Emissions of Greenhouse Gasses in the United States, 2001 ,United States Department of Energy, Energy Information Administration, Washington, D.C. December, 2002

Natural Gas 1998, Issues and Trends United States Department of Energy, Energy Information Administration, Washington, D.C. April, 1998

Petroleum Supply Monthly, United States Department of Energy Washington, Energy Information Administration, D.C., April, 2002

Monthly Energy Review, United States Department of Energy, Energy Information Administration, Washington, D.C. March, 2002

Weekly Petroleum Status Report, United States Department of Energy, Energy Information Administration, Washington, D.C., June 6, 2003

Weekly Petroleum Status Update, United States Department of Energy, Energy Information Administration, Washington, D.C. June 10, 2003

Presentation by EIA Administrator Jay E. Hayes, September 3, 1998

TRANSPORTATION AND ALTERNATIVE FUELS

Transportation Energy Data Book, Edition 22 Oak Ridge National Laboratories, Oak Ridge TN September 2002

Highway Statistics 2000, Federal Highway Administration, Washington, D.C. October, 2002

National Highway Statistics, Bureau of Transportation Statistics United States Department of Transportation, Washington, D.C. July, 2002

Automotive Fuel Economy Program, Annual Update Calendar Year 2001, Department of Transportation, National Highway Transportation Safety Administration, Washington D.C. September, 2002

Historic American Engineering Record [HAER No. Ca-196] Central Pacific Transcontinental Railroad, National Park Service, Western Region, Department of the Interior San Francisco, CA August 25, 2002

Weingroff, Richard, F. *The Man Who Changed America, Part I*, Public Roads, March/April 2003, Vol. 66 No. 5, United States Department of Transportation, Washington, D.C.

Alternatives to Traditional Transportation Fuels, United States Department of Energy, Energy Information Administration, Washington, D.C. 2000

History of Biofuels, United States Department of Energy, Office of Energy Efficiency and Renewable Fuels, June, 2003

Biofuels and Agriculture, United States Department of Energy, Oak Ridge National Laboratory, September, 2001

Energy Policy Act Fact Sheet, United States Department of Energy, National Alternative Fuels Hotline, September, 1998

Alternatives to Traditional Transportation Fuels, 2000, United States Department of Energy, Washington, D.C. September 2002

Federal Alternative Fuel Consumption, FY 2000 United States Department of Energy, Washington, D.C. 2001

Federal Fleet Compliance with Executive Order 13149, Fiscal Year 2001, United States Department of Energy, Washington, D.C., 2001

Bamberger, Robert, *Automobile and Light Truck Fuel Economy: Is CAFÉ Up to Standards*, Issue Brief, Library of Congress, Congressional Research Service Washington, D.C. August 9, 1999

Describing Current and Potential Markets for Alternative Fuel Vehicles, United States Department of Energy, Energy Information Administration, Washington D.C. March, 1996

Ahmed, S., Kopasz, J.P., Russel, B. J., and Tomlinson, H.L., *Gas to Liquids for use in Fuel Cells: Reformability, Energy Density and Infrastructure Compatibility*, United States Department of Energy, Washington, D.C. December, 1999

TRANSPORTATION AND THE ENVIRONMENT

Sitilgoe, John, Roads, *Highways and Ecosystems*, National Humanities Center 2003

U.S. Environmental Protection Agency (EPA), *2002, Health Assessment Document For Diesel Engine Exhaust, Prepared for the National Center For Environmental Assessment, Washington, D.C., for the Office of Transportation and Air Quality*; EPA/600/8-90/o57F. Available from National Technical Information Service, Springfield, VA; PB2002-107661,

Automobile Emissions: An Overview, Department of Environmental Protection, Fact Sheet, State of Pennsylvania, Bureau of Air Quality, Harrisburg, PA, April, 1996

Centers for Disease Control and Prevention Press *Release "CDC Study Links Improved Air Quality with Decreased Emergency Room Visits for Asthma"* dated February 21, 2001

Exxon Valdez Oil Spill Restoration Plan, Update On Injured Resources and Services, Exxon Valdez Oil Spill Trustee Council, Anchorage Alaska, August, 2002

Oil Spills in U.S. Waters, United States Coast Guard Calendar Year 2000, Washington, D.C. 2002

Our Built and Natural Environments, United States Environmental Protection Agency, Washington, D.C., January, 2001

Sheet Pressures on Coastal Environments, U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Washington D.C. 2001

National Cancer Institute *Surveillance, Epidemiology, and End Results Program* (SEER) database data

Cancer Facts and Figures 1999, National Cancer Institute, Washington, D.C. 1999

South Coast Air Quality Management District, *Board Meeting Agenda*, October 4, 2002

Measuring the Productivity Impact of Pollution Abatement, U.S. Bureau of the Census Statistical Brief, November, 1993

Greenhouse Gas Emission Reductions and Natural Gas Vehicles: A Resource Guide On Technology Options and Project Development, National Energy Technology Laboratory, Pittsburg, PA, September, 2002

DEPARTMENT OF DEFENSE AND MILITARY

FM-100 United States Army Statement of Doctrine, Department of the Army, Washington, D.C. June, 1993

Defense Almanac, United States Department of Defense, Washington, D.C. 2003

Ayers, Col. Leonard P., Chief, Statistics Branch of the General Staff, *The War With Germany A Statistical Summary, Second Edition with data revised to August 1, 1919*, Government Printing Office, Washington, D.C. 1919

Gropman, Alan L. Mobilizing *U.S. Industry In World War II: Myth And Reality*, Institute for National Strategic Studies, National Defense University, Washington, D.C. August, 1996

Conrad, Scott W., *Moving the Force: Desert Storm and Beyond*, Institute for National Strategic Studies, National Defense University, Washington, D.C. December, 1994

Sokolsy, Richard Ed. *The United States and The Persian Gulf, Reshaping Security Strategy for the Post-Containment Era*, National Defense University Press, Washington, D.C. 2003

General Richard B. Myers, Chairman Joint Chiefs of Staff, quoted in "*Progress Made in Iraq, but Deaths Hammer Home*," American Forces Information Service, United States Department of Defense, June 24, 2003

Joint Forces Command, A *Concept for Rapid Decisive Operations, Version ROD II*, U.S. Department of Defense, Washington, D.C. 2002

United States Central Command, *Official Chronology, 9th U.S. Airforce*, United States Department of Defense, Washington, D.C.

United States Central Command, *Official Description Third United States Army*, United States Department of Defense, Washington, D.C.

United States Central Command, *NAVCENT Official Description*, United States Department of Defense, Washington, D.C.

United States Department of Defense, "*Bottom Up Review*," Washington, D.C. 1993

United States Department of Defense FY 2003 Budget Request, "Greenbook," United States Department of Defense, Washington, D.C.

FY 2003 Special Operations Budget, US Department of Defense, Washington, D.C.

Department of the Air force, Fiscal Year 2004-2005 Biennial Budget Estimates, Department of the Airforce, Washington, D.C., February, 2003

Department of the Army, Fiscal Year 2004-2005 Biennial Budget Estimates, Department of the Army, Washington, D.C., February, 2003

Department of the Navy, Fiscal Year 2004-2005 Biennial Budget Estimates, Department of the Navy, Washington, D.C., February, 2003

President's Supplemental Budget Request to Congress, Washington, D.C. 2002

United States Department of State, Bureau of Verification and Compliance, *World Military Expenditures and Arms Transfers 1999-2000*, Washington, D.C. June, 2002

Collier, Ellen, *Instances of the Use of United States Forces Abroad, 1798-1993*, Department of the Navy, Navy Historical Center, Washington, D.C. October 7, 1993

Miller Michael, et. Al, *The Costs of Operation Desert Shield*, Congressional Budget Office, January, 1991

Conduct of the Persian Gulf War, Final Report to Congress, Volumes I-VIII, United States Department of Defense, April, 1992

Conduct of the Persian Gulf War, Final Report to Congress, Appendices A-S, United States Department of Defense, April, 1992

Bolstering Defense Industrial Competitiveness, Under Secretary of Defense, Acquisitions, U.S. Department of Defense, July, 1988

Contingency Plans to Deal With Disruptions of Persian Gulf Crude Oil Supplies, A Joint Report Of The U.S. Department of Energy and U.S. Department of Defense, March, 1988

Defense Conversion, Redirecting R & D, U.S. Office of Technology Assessment, Washington, D.C. May, 1990

Effects of Alternative Defense Budgets on Employment, Congressional Budget Office, Washington, D.C. April, 1993

Steadman, Kenneth A. LTC *The Evolution of the Tank in the U.S. Army*, U.S. Army Command and General Staff College, 21 April, 1982

Lindley, John M. *Wings Over The Ocean*, Naval Aviation News, February, 1978, Department of Defense, United States Navy, Washington, D.C.

Andrus, Lt. Col. James G. *Petroleum Allocation Among Major Competing Needs During Total Mobilization,* The Industrial College of the Armed Forces, April, 1982

Hu Patricia S. *Estimates of 1996 U.S. Military Expenditures on Defending Oil Supplies from the Middle East: A Literature Review*, Oak Ridge National Laboratory, Oak Ridge, TN August, 1997

OTHER

Weik, Martin H. *The ENIAC Story*, ORDNANCE, the Journal of the American Ordnance Association, Washington, D.C., January-February, 1961

Manhattan Project History, Los Alamos National Laboratory, contract No. w-7405-ENG-36, University of California, 1998

U.S. Postal System *History of Airmail*, Washington, D.C. 2003

Garman, David K., *Clean Cities and the Hydrogen Future*, Alternative Fuel News, Alternative Fuels Data Center, United States Department of Energy, Washington, D.C., May, 2003

Current Population Survey, Income Surveys Branch, U.S. Census Bureau, Washington, D.C.

Factors Affecting U.S. Oil and Gas Outlook, National Petroleum Council, Washington, D.C. February, 1987

The Economic Impact of Import Dependence. Natural Petroleum Council, Washington, D.C. 1991

Executive Office of the President, National Critical Materials Council, *Draft Critical Materials Report*, Washington, D.C. 1987

Handbook of International Statistics, United States Central Intelligence Agency, Langley, Virginia, February, 1999

Thorpe, George C. *Pure Logistics*, United States Department of Defense, National Defense University, Washington, D.C. 1986

INDUSTRY PUBLICATIONS

American Petroleum Institute *Basic Petroleum Databook* Washington., D.C., 2002

American Petroleum Institute, *Weekly Petroleum Update* April 1, 2003

BP Statistical Review, BP, p.l.c, Britannic House, 1 Finsbury Circus London, UK, June, 2002

Schell, Joseph M., *“The Bottom Line: Can We Finance Major Synfuels Construction In The 80s?”* presented at the Eighth Annual International Conference on Coal Gasification, Liquefaction and Conversion to Electricity, University of Pittsburgh 1982

SP.J. McCabe, *“Energy Resources – Cornucopia or Empty Barrel”* American Association of Petroleum Geologists Bulletin, vol. 198 p.p. 2110-34

2003 NADA Databook, National Association of Automobile Dealers, Maclean, VA., 2003

BOOKS

A History of The American People, McGraw Hill, NY, 1971

Behrman, Daniel, *The Man Who Loved Bicycles*, Harper and Roe, 1973

Eisenhower, Gen. Dwight, David, *At Ease, Stories I Tell to My Friends*, pp. 166-67 Doubleday, Garden City, NY 1967

Funk and Wagnalls New Encyclopedia, Vols. I & II, 1994

Goralski, Robert, *Oil and War*, William Morrow & Co. 1987

Lansdale, Edward, MG, *In the Midst of Wars*, Harper & Row Publishers, New York, 1972

Pagonis, Lt. Gen. William G., *Moving Mountains, Lessons in Military Leadership and Logistics*, Harvard Business School Press, Cambridge, MA, 1991

Schwarzkoph, Norman H. Gen., *It Doesn’t Take A Hero*, Bantam, New York, 1992

Summers, Harry G., *A Critical Analysis of the Gulf War*, Dell Publishing, New York, February, 1992

Times Illustrated Encyclopedia of the Civil War, Ed. Patricia L. Faust. New York: Harper & Row, 1986.

Yergin, Daniel, *The Prize*, Simon and Shuster, New York, 1991

ACADEMIC INSTITUTIONS

Amsler, Robert, *Railroads in the Civil War*, Gateway Division, NMRA, Feb 8, 2003

Burke, Andrew F. and Miller, Marshall, *Assessment of the Greenhouse Gas Emission Reduction Potential of Ultra-Clean Hybrid Electric Vehicles*, Institute of Transportation Studies, University of California, Davis, December, 1997

Burke, Andrew F., *Hybrid Electric Vehicle Technology, (1990-2000)* Institute of Transportation Studies, University of California, Davis, August, 1999

CENTCOM Order of Battle as of March 3, 2003, Global Security, 300 North Washington Street, Alexandria, VA

Copulos, Milton R., *Surge Production During Operation Desert Storm*, The National Defense Council Foundation, Alexandria, VA May, 1993

Copulos, Milton R., *The Desert Storm Fact Sheet*, National Defense Council Foundation, Alexandria, VA, February, 1993

Copulos, Milton R., *The Lesson of Desert Storm*, National Defense Council Foundation, Alexandria, VA, March, 1993

Copulos, Milton R., *The Hidden Threat of Imports: Military and Economic Implications of Dependence,* National Defense Council Foundation, Alexandria, VA, April, 1990

Copulos, Milton R. *Truck Procurement: Bridging The Gap To Tomorrow*, The National Defense Council Foundation, Alexandria, VA March, 1992

Copulos, Milton R. *Natural Gas Vehicles, Helping Ensure America's Energy Security*, National Defense Council Foundation, Washington, D.C. October, 1995

Cordesman, Anthony, *Western Military Balance and Defense Efforts*, Center for Strategic and International Studies, Washington, D.C., 2002

Cordesman, Anthony H., *The U.S. as a "Superpower" : Comparative National Military Forces and Defense Spending Efforts*, Center for Strategic and International Studies, Washington, D.C. April , 1998

Cordesman, Anthony H., *Geopolitics and Energy in the Middle East*, Center for Strategic and International Studies, Washington, D.C. September 15, 1999

Delucci, Mark, *Summary of the Nonmonetary Externalities of Motor Vehicle Use*, Institute of Transportation Studies, University of California, Davis, September, 1998

Delucci, Mark, et. al. *Emissions of Criteria Pollutants, Toxic Air Pollutants, And Greenhouse Gasses From The Use Of Alternative Transportation Modes And Fuels*, Institute of Transportation Studies, University of California, Davis, 1996

Delucci, Mark and McCubbin, Donald R., *The Social Cost of the Health Effects of Motor Vehicle Air Pollution*, Institute of Transportation Studies, University of California, Davis, August, 1996

Greenberg, Maurice (Chair) *Terrorist Financing, Report of the Task Force Sponsored by the Council on Foreign Relations*, Council on Foreign Relations, New York, November, 2002

Military Almanac, Center For Defense Information, Washington, D.C. 2002

Population Reference Bureau *2000 World Population Data*

ARTICLES

A Forgotten Aviation Pioneer Returns, General Aviation News, Lakeland, WA 2002

Atkinson, Rick, *The Fog of War*, Washington Post, July 30, 1998

Brenda K. Edwards, Ph.D. (NCI), Holly L. Howe, Ph.D. (NAACCR), Lynn A.G. Ries, M.S. (NCI), Michael J. Thun, M.D. (ACS), Harry M. Rosenberg, Ph.D. (CDC), Rosemary Yancik, Ph.D. (NIA), Phyllis A. Wingo, Ph.D. (CDC), Ahmedin Jemal, Ph.D. (ACS), and Ellen G. Feigal, M.D. (NCI). *Annual Report to the Nation on the Status of Cancer*, Cance*r* (Vol. 94, No. 10, pages 2766-2792) May 15, 2002

Diaz-Sanchez D PhD, Penichet-Garcia M MD, Saxon A MD, *Diesel Exhaust Particles Directly Induce Activated Mast Cells to Degranulate and Increase Histamine Levels and Symptom Severity*, Journal of Allergy and Clinical Immunology, December, 2000, Vol. 106 No. 6

Dockery, DW, Pope, CA 3rd, Xu, X, Spengler, JD, Ware, JH, Fay, ME, Ferris, BG Jr. Speizer, Fe, *An Association Between Air Pollution and Mortality in Six U.S. Cities*, New England Journal of Medicine, December 9, 1993; 329(24) 1753-9

Friedman MS, Powell KE, Hutwagner L, Graham LE, Teague, WG, *The Impact of Changes in Transportation and Commuting Behaviors During the 1996 Summer Olympic Games in Atlanta, Georgia on Air Quality and Childhood Asthma*, Journal of the American Medical Association, 285(7) 897-905, February 21, 2001

Hydrogen Fuel Cell Newsletter, April, 1999

Krotz, Dan, "*Almost There: A Commercially Viable Fuel Cell*", Science Beat, Berkeley Lab, Berkeley, CA November 15, 2002

Lung Cancer*, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution*, C. Arden Pope III; Richard T. Curnett, PhD.; Michael J. Thun, MD; Eugenia E. Calle, PhD; Daniel Krewski, PhD; Kazuhiko Ito, PhD; George D. Thurston, ScD, Journal of the American Medical Association, Vol. 287, No. 9: 1132-1141, March 6, 2002

McConnell R, Berhane K, Gilliland F, London SJ, Islam T, Gauderman WJ, Avol E, Margolis HG, Peters JM, *Asthma in exercising children exposed to ozone: a cohort study*. Lancet. 2002 Feb 2;359(9304):386-91.

On Horizon, Military Sees High Technology Vehicles, New York Times, March 30, 2003

Penden DB, Diaz-Sanchez D, Balmes JR, Kleeberg SR *Air Pollution and Asthma*, Presented at the American Academy of Allergy Asthma and Immunology 58th Annual Meeting, March 3, 2002, New York, New York

R.L. Polk & Co. *press release* dated January 6, 2002

Scarborough, Rowan, *US Forces Outran Water, MREs in Rush to Baghdad*, Washington Times, Washington, D.C., April 25, 2003

Spengler, JD, Koutraks P, Dockery DW, Raizenne M, Speizer FE, *Health Effects of Acid Aerosols on North American Children*: *Air Pollution Exposures*, Environmental Health Perspectives, May, 1996, 104(5) 492-9

Thompson, Mark, *The Tools of War*, Time Magazine, October 21, 2002

Tullo, Alexander H., *Catalyzing GTL*, Chemical and Engineering News, Vol. 81, No. 29, pp. 18-19, July 21, 2003

U.S. Targets Fuel-Guzzling Trucks, National Defense Magazine, Arlington, VA, January 2000

U.S. Army Advances On Hybrids, Automotive News, April 15, 2002

Ware JH, Ferris BG Jr., Dockery DW, Spengler JD, Stram DO, Speizer *FE, Effects of Ambient Sulfur Oxides and Suspended Particles on Respiratory Health of Preadolescent Children*, American Review of Respiratory Disease, May, 1986, 133(5) 834-42

ABOUT THE NATIONAL DEFENSE COUNCIL FOUNDATION

For a quarter-century, the National Defense Council Foundation (NDCF) has occupied a unique position within the public policy community. Through an emphasis on field research and on-site observation, NDCF has established itself as singularly authoritative in the subject areas it addresses. More important, by combining both academic and direct-action programs, NDCF is able to turn its policy objectives into tangible accomplishments that now span more than two decades. A few examples illustrate this point:

When high transportation costs jeopardized the provision of vital humanitarian aid to conflict-ridden Central America in the early 1980s, NDCF helped draft and then lobbied through the "*Denton Amendment*." This law permitted the transport of such aid in military aircraft on a space-available basis. This enabled NDCF to deliver more than 183 tons of vital medical supplies to the war-torn region.

When a powerful Congressional Committee Chairman attempted to saddle the Department of Defense with a $1.2 billion boondoggle to line the pockets of favored businesses in his District, NDCF took him on. Our report on the issue gained the attention of the New York Times and forced a repeal of the measure.

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When earthquakes ravaged El Salvador, NDCF was the first NGO on the scene delivering over $100,000 worth of antibiotics and other vital medical supplies directly to the hardest hit areas. In the first few months after the disaster, NDCF accounted for fully 10% of all humanitarian aid delivered to that nation.

When narco-guerillas threatened to topple the fragile democracy in Colombia, NDCF took the lead in lobbying through legislation to provide desperately needed helicopters and other equipment to the National Narcotics Police. Recognizing NDCF's key role in obtaining the assistance, it presented our Executive Director, MAJ F. Andy Messing Jr. with its highest civilian award.

In some 45 countries on five continents, NDCF has been on the scene, obtaining vital "*unfiltered*" information for decision-makers, bringing millions of dollars in vital medical aid to the victims of conflict and working to encourage democratic, pro-western policies. Moreover, it has done so with a remarkable degree of efficiency.

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In short, NDCF has been where the action is – not just as academic observers, but as direct participants in the process. In the weeks and months ahead, NDCF will continue to employ its unique approach of academic and direct-action programs to promote peace, freedom and national security.

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For more than three decades, Milton R. Copulos has been a prominent figure in national political circles. He served as a Cabinet-level advisor in the Bush and Reagan Administrations, working closely with the Secretaries of Defense, Energy, Interior and Commerce, as well as the Director of Central Intelligence. While working for the Reagan White House, Copulos authored a number of important studies including the *National Critical Minerals Report* and *Advanced Materials Program Plan*, the Department of Energy's assessment of the Soviet natural resource base as well as a number of classified documents. He was also a participant in the *Defense Industrial Base Initiative* and the principal consultant to the Department of Defense on the *Defense Environment Initiative*.

As a prominent expert on natural resources, national defense and international politics, Copulos is frequently called upon to lecture at universities and other academic institutions around the nation. He has been a visiting lecturer at the Massachusetts Institute of Technology, the University of Maryland Graduate School of Nuclear Engineering and the University of Dallas Graduate School of Management. He was also selected as faculty for the prestigious *Salzburg Seminar* in American Studies sponsored by Harvard University in Salzburg, Austria. He is also the only individual to be asked to deliver the prestigious "*Management Classics*" lecture at the University of Dallas.

A prolific author, Copulos has published more than 700 articles, books and monographs. His writing has appeared in such prominent national news media as the *Washington Post*, *The Los Angeles Times* and *The Chicago Tribune*. He is also a frequent contributor to periodicals such as *Insight Magazine*, *VFW Magazine* and *Regulation Magazine*. His book "*Energy Perspectives*" was a Washington Post best seller, and for four years he wrote a nationally syndicated column distributed by the *Heritage Features Syndicate*. He also has appeared on nationally broadcast news and information programs including such programs as FOX News Network's "*FOX and Friends*", CNN's "*Crossfire*", and "*War Room with Wolf Blitzer*" as well as local broadcasts for major network affiliates. He has also acted as an on-air military analyst for MSNBC.

Because of his internationally recognized expertise in foreign affairs, Copulos has often been asked to meet with foreign leaders. Included among them are individuals such as President Fidel Ramos of the Republic of the Philippines and President Rauf Dentkash of the Turkish Republic of Northern Cyprus.

A veteran of two tours of duty in Vietnam, Copulos was awarded the Bronze Star and Army Commendation Medals, as well as five battle stars. He is a graduate of The American University in Washington, D.C. and lives in Crofton, Maryland.

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Gil Sperling, Attorney, Former Congressional Staff Member

Carol Werner, Executive Director Energy and Environmental Study Institute

ACKNOWLEDGEMENTS

The National Defense Council Foundation wants to express its appreciation for the generous support of the following organizations that made this report possible.

United States Army Tank-automotive and Armaments Command

The Lynde and Harry Bradley Foundation

The Nobel Foundation

The Milliken Foundation

The William H. Donner Foundation

We would also like to thank *INFORM Inc*. and *The Durst Organization* for their support of the section on the defense costs of imported oil.

We would also like to thank the following NDCF Research Assistants for their participation in this project:

Ms. Heidi Bonnett

Mr. Chris DesBarres

Mr. James Copulos