3

A Call to Action

Herschel Specter, President
RBR Consultants, Inc.,
United States

1. Introduction

The United States faces enormous challenges as it attempts to move towards a post-petroleum future. Many measures - a continuing significant dependence on imported oil, high greenhouse gas release levels, depletion of national oil reserves faster than new sources can been found, projected increases in demand for energy from a growing population - confirm that the nation has failed to adequately address energy related issues for decades. There is no room to fail again.

There are two energy related pathways that can lead to environmental and human catastrophe. In some ways they seem to be opposites. One threat is the result of insufficient energy and the other threat comes from using energy, specifically from burning fossil fuels which supply about 80% of the energy used today in the United States and a large percentage of world energy use. Insufficient energy can lead to armed conflict while the overuse of fossil fuels can lead to worldwide damage from climate change effects.

Both of these pathways to environmental and human catastrophe must be dealt with; not one at the expense of the other. However, the sequence of actions selected to overcome these twin challenges is crucial. For the United States, reducing petroleum use and therefore oil imports, should initially have the higher priority. There are environmental, economic, and national security reasons that justify assigning a higher initial priority to reducing petroleum use than emphasizing actions that almost exclusively address climate change concerns.

First emphasis should be on reducing oil imports, including establishing goals and timetables for energy security and for eventual energy independence. This is also essential for the protection of the environment from climate change. A three step energy plan is outlined here which could be used to implement these goals within the suggested time lines. Just as climate change is a global threat, so is the challenge of diminishing oil supplies. The phasing out of petroleum presents a world problem and preventing armed conflict requires world solutions. The U.S. has partially recognized this by attempting to deal with climate change. Now these two issues need to be joined, global agreements must be reached, and actions prioritized. This requires actions beyond the United States and, in particular, a new alliance with China if armed conflict is to be avoided.

In the United States there is an unrecognized, and therefore unresolved, conflict between those that project petroleum use for the next several decades and those that have created Congressional legislation that calls for a significant reduction in the release of carbon dioxide. Energy forecasters, such as the Department of Energy (DOE), the Environmental

Protection Agency (EPA), and the National Academy of Sciences (NAS) in its report "America's Energy Future" all predict high levels of oil consumption for the next several decades (see Reference 1). The heart of such forecasts is the assumption that the United States will remain a highly car-oriented, gasoline consuming, society. Even factoring in significant improvements in automobile efficiency, these organizations predict little change in oil consumption in the transportation sector for several decades. Vehicular efficiency gains would be offset by a growing population, the assumption that the U.S. will consume even more energy per person in the future, and the slow turnover rate of several hundred million vehicles.

However burning such enormous amounts of petroleum releases gigatons of greenhouse gases (GHG). Analyses show that burning such large amounts of petroleum would be sufficient, by 2030, to exceed the GHG limits that are central to recent Congressional climate change legislation. This 2030 date, when legislated GHG limits begin to be exceeded by the burning of petroleum, was very conservatively arrived at. It was assumed, unrealistically, that there would be no GHG contribution from burning coal and natural gas. All coal and natural gas electric power plants would, in effect, be shut down along with all other natural gas burning end uses. A slightly more realistic scenario assumed that 20% of the coal and natural gas burned today would be permitted. Burning 20% of today's coal and natural gas, along with burning all the petroleum projected by DOE, EPA, and NAS, would overcome Congressional legislation about five years sooner, by 2025. At a coal and natural gas burning rate equal to just half of today's and with the GHG contribution from burning high levels of petroleum, Congressional climate change legislation limits would be overcome in less than ten years.

Congressional GHG legislation and projected petroleum consumption are incompatible. Such high levels of petroleum consumption are environmentally unacceptable if climate change is to be moderated.

Attention then turned to economic issues and the cost of burning such huge amounts of oil. An analysis was performed which used the unrealistic assumption that all the oil in these forecasts, through 2035, could be purchased by the United States. This is a business-as-usual type of scenario and the total cost of this oil was estimated to be around $14 trillion (2008) dollars, i.e., comparable to the U.S.'s present national debt.

As large as this transfer of national wealth to oil producing countries is, it does not tell the full story. It is very unlikely that the United States would "enjoy" decades of a business-as-usual situation. More likely there will be frequent and prolonged oil shortage initiated deep recessions, similar to the one the United States is experiencing now. A review of history shows that major oil price shocks have disrupted world energy markets five times since 1973 (1973-74, 1979-80,1990-91, 1999-2000 and 2008). According to studies performed at the Oak Ridge National Laboratory "Most of the oil price shocks were followed by an economic recession in the United States". It has been estimated that over the last 30 years oil market upheavals have cost the United States in the vicinity of $7 trillion dollars (1998) dollars. So if the next 25 years, until 2035, is similar to the past 25 years, then the total cost of oil could be in the neighborhood of $14 trillion (2008) dollars plus $7 trillion (1998) dollars. Very little of this money would remain in the United States. With such an enormous transfer of wealth, would enough money be available to also deal with climate change?

Figure 1, produced by the Oak Ridge National Laboratory, shows the very large economic penalties of oil dependence, particularly during times of oil shortages (see Reference 2).

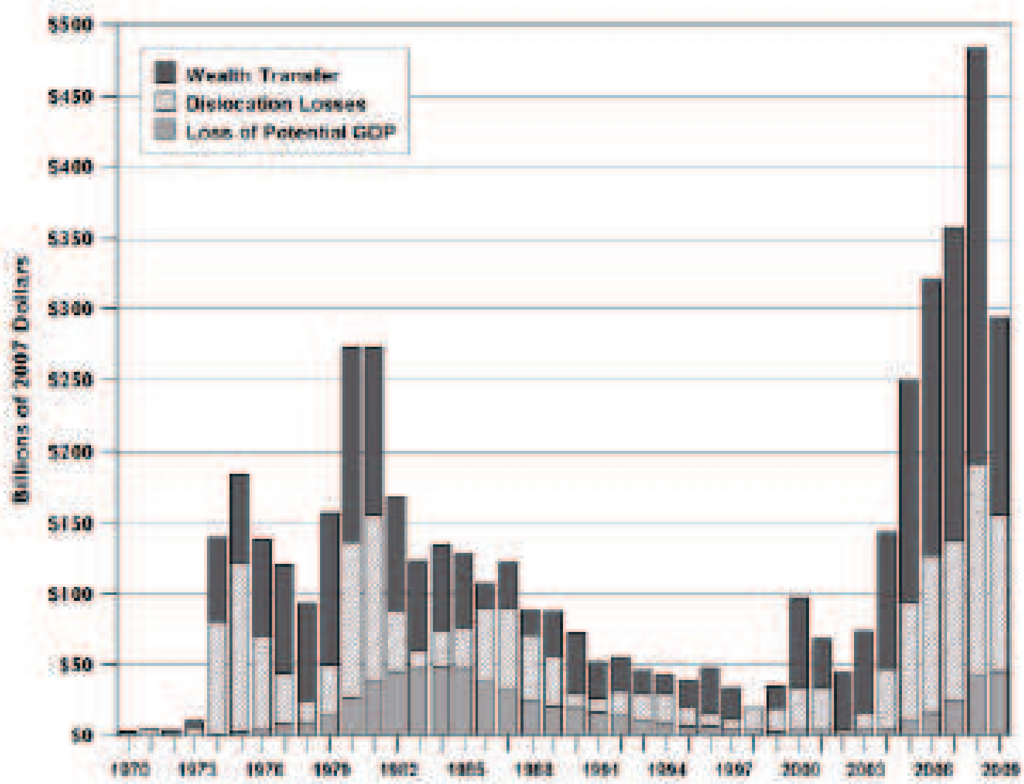

Fig. 1. Costs of Oil Dependence to the U.S. Economy, 1970-2009

Moreover, there are indications that the very nature of oil shocks may be evolving. Reviews of past unbalances between supply and demand, such as the oil embargo in 1973 and the Iranian Revolution in 1979, can be described as politically initiated oil shocks. In the future there could be two causes of oil shortfalls: politically initiated shortfalls, like past oil embargoes, and physically initiated shortfalls whenever demand exceeds supply. There is also the possibility of a political-physical hybrid situation where oil producers favor their best customers with special supply contracts during times when world demand exceeds world supply.

In the past, oil-initiated recessions could end when the political dynamics changed so that full oil flow was again possible, like the end of an oil embargo. In the case of physical shortfalls where demand exceeds supply, it is not clear how they might end. They are materially different from shortfalls initiated by political actions. One can not quickly find new sources of oil and bring that oil to market. Demand can rise far more quickly than creating new supplies. With a limited amount of oil available in the world marketplace, times when demand exceeds supply means that some stronger nations may get less oil than they want while weaker nations will get less oil than they need. Since new sources of oil come on line rather slowly, supply and demand may only come back into a temporary equilibrium when many nations do with less. This new equilibrium would be temporary if demand continues to rise and new supplies can't keep up. Should this occur, back-to-back recessions or even a continuous recession, may happen.

This would be a great hardship for many, but especially for poorer nations, some of whom are already spending more on imported oil than the value of their exports. For example, in Kenya fuel imports exceed their current account balance by 174%. Since food prices correlate closely with energy prices, much higher oil prices, especially during shortfall periods, means that many tens of millions of people will not have enough to eat. Higher oil prices and restricted availability of oil means that they may not be able to buy sufficient fertilizers, herbicides, fuel for their tractors or oil to run their irrigation pumps.

Up to now the more severe oil related recessions have been fairly far apart in time with the more recent ones occurring around 1974, then another in 1980-81 and a third in 2008-10 (or longer). In between oil shocks nations often had time to restore their economies. With both politically initiated and physically initiated shortfalls, the time between recessions may shrink. As stated before, there are fewer mechanisms available to recover from a shortfall of oil supply and therefore recessions initiated by physical shortfalls may last longer. In between recessions there could be periods of high oil prices. In 2008, when demand temporarily exceeded supply, the price of oil hit $147/ barrel. Prior to that historic moment there was a run-up on oil prices which rose steadily from $33.75/barrel in 2003 to $75.14/barrel in 2007 to $97.26 in 2008. Prior to 2003 there was considerable margin between the sum of OPEC spare capacity plus world oil production minus oil consumption. This margin largely eroded between 2003 and momentarily disappeared in 2008 as prices reached $147/barrel. See Figure 2. So a more complete description of the cost of importing oil includes the business-as-usual costs between recessions and the additional costs of recessions.

A closer look at the oil situation around 2008 shows that the margin between world oil production capacity and demand temporarily disappeared, starting the great financial crisis. A margin of about 4 MB/D has since been established since then, largely because as a result of the recession. U.S. oil consumption in 2009 has decreased to 18.5 MB/D, down from 20.7 MB/D in 2007. Figure 2, derived from DOE’s Energy Information Administration, displays oil margins between 2002 and 2010.

Unclear at this time is whether a series of shortfalls or back-to-back prolonged recessions would weaken the U.S. economy to the point that the resources needed to achieve long term energy independence or adequately abate GHG releases will not be available. In other words, an economic tipping point could be reached by prolonged or frequent recessions brought on by oil shortages. Back-to-back prolonged recessions puts the economy under great stress. These stresses become far more acute if there is not sufficient energy to meet a nation’s basic needs, such as an adequate food supply, and this could lead to armed conflict to secure sufficient oil. In a world filled with weapons of mass destruction, global armed conflict would be the end of civilization as we know it. Global armed conflict must be avoided.

Therefore it is logical to ask “How long might it take before the present margin of about 4MB/D would be used up and then what happens?” One energy forecast, predicts a 10 million barrels per day (MB/D) shortfall by 2015 (see Reference 3). Most of the future increase in oil demand will not come from OECD nations or the United States, but from emerging nations like China, India, and Brazil. China is the fastest growing oil market in the world, even though the United States at this time remains the top consumer. The potential demand for oil from China alone is tremendous. Even in the short time since 2007 the oil scene has shifted considerably. Chinese oil consumption has now reached 8.5 MB/D, up from 7.6 MB/D in 2007. By 2011 the number of cars sold in China will be more than double those sold in the U.S. and further demands for oil will come from India with its $2000 car entering its transportation market. The rise in oil demand from China is reshaping the geopolitics of oil, with Saudi Arabia now exporting more oil to China than to the United States. According to the NY Times “The Chinese military is seeking to project naval power well beyond the Chinese coast, from the oil ports of the Middle East to the shipping lanes of the Pacific, where the United States Navy has long reigned as the dominant force, military analysts say." Further evidence of growing energy related friction between China, its neighbors, and the United States recently occurred when the U.S. challenged China on its dispute with its smaller Asian neighbors over a string of islands in the South China Sea. These islands are rich in oil and natural gas deposits.

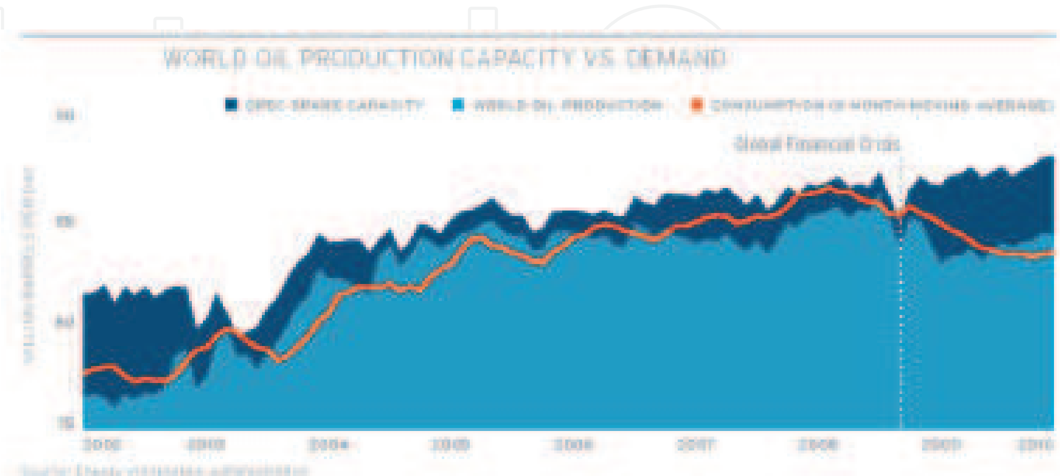

Fig. 2. World Oil Production Capacity vs. Demand

Questions like "How long will it before the world runs out of oil?" and "When will conventional oil production peak?" have spurred debate. Yet these questions may be of secondary importance. Long before the world runs out of oil (conventional plus non-conventional) either a post-petroleum future will be in place or the effects of major climate changes and/or armed conflict over remaining critical resources would have occurred. Nature will not wait for people to cut back their releases of GHG. People and nations will not wait until a critical resource is exhausted before they use force. When or if the world will run out of oil is rather unimportant compared to other oil related issues, like shortfalls.

The precise moment when conventional oil peaks is also rather unimportant. The world has already seen major recessions because of high oil prices. The world has have also seen armed conflict over oil shortages. An oil embargo by the United States on Japan, when the US was a major oil exporter, was a factor in the bombing of Pearl harbor. All of these events have already occurred, well in advance of conventional oil reaching its peak production. Even after the global financial crisis in 2008 world oil production plus OPEC spare capacity continued to gradually increase, demonstrating that peak production has not yet taken place. Conversely, if handled properly through world co-operation, severe consequences might be avoided in a post-peak oil time period.

The time of peak conventional oil production is an interesting moment in history, but other parameters are more important. Perhaps the most important parameter to watch is oil shortfalls with questions like: when might the next shortfall might occur, what is the possible frequency of additional shortfalls, what might be their durations and severity, and which nations would be most affected by them?

The full justification for placing more initial emphasis on imported oil than climate change is therefore:

1. Burning projected amounts of oil releases so much GHG that legislated limits are soon exceeded.

2. Purchasing vast amounts of oil would transfer so much national wealth it is unlikely that sufficient funds would be available to adequately reduce our GHG releases to protect against climate change or to achieve energy independence.
3. There is a possibility that oil shortfalls could lead to armed conflict much sooner than severe effects of climate change would be felt globally.

In response to these energy challenges a three step energy plan for the United States has been assembled. This plan is guided by the following goals and timetables:

1. By 2015 the U.S. should be able to withstand a sudden and enduring decrease of 5 MB/D in imported oil without a loss of any critical function, such as providing adequate food, space heating, and transportation.
2. By 2030, the importation of liquid fuels should be limited to sources from North, South, and Central America, including the Caribbean, and that amount not to exceed 4 MB/D of gasoline equivalent. Some of this imported gasoline equivalent should be in the form of ethanol.
3. By 2030 the release of GHG should be limited to about 3.6 Gt/year of CO_{2e} which would be consistent with the limits legislated in the House of Representatives bill, H.R. 2454, for that date.

Step One of this plan covers the time period from now through 2020, or so.The purposes of Step One are to put into place a capability to withstand a sudden decrease in imported oil supplies and to lay the groundwork for long term energy independence and the protection of the environment from climate change. Step Two is a much larger endeavor and concentrates on petroleum-displacing actions which would also reduce GHG release rates. It would run between now and 2030 or so and would therefore overlap Step One. At the conclusion of Step Two an assessment would be made to determine if the goal of limiting GHG releases to 3.6 Gt/year had been achieved. Simultaneously, using the science of 2030, a determination would be made to see if the 2050 GHG limits in H.R. 2454 need to be adjusted. Based on these two pieces of information a specific set of actions would be identified to be implemented in Step Three from 2030 to 2050.

2. Environmental, economic, and national security issues

2.1 Introduction

This section elaborates on the central energy related issues of the impact of energy use and the impact of insufficient energy on the environment, the economy, and on national security.

2.2 Environmental issues

Reports by the International Panel on Climate Change and many others have lead to a world-wide concern that rising greenhouse gas (GHG) levels will lead to enormous environmental damage. As climate change occurs, as many scientists predict, it could threaten world catastrophe with huge areas of human habitat flooded by rising sea levels, accelerated loss of species, increased frequencies of category five hurricanes, droughts in some areas and excessive rainfall in other areas, food supply challenges, hundreds of millions of displaced persons, and other severe effects (see Reference 4).

In response to the GHG climate change concern the U.S. House of Representatives passed an energy bill, "American Clean Energy and Security Act of 2009", also known as H.R. 2454. H.R.2454 is quite clear about dealing with the issue of climate change: it presents a timetable by which specific GHG reductions must be achieved. The Environmental Protection Agency

(EPA) made an analysis of H.R.2454 by analyzing six energy scenarios. In all six scenarios petroleum consumption remained essentially unchanged out to 2050, primarily because of the assumed continued use of gasoline powered vehicles. The EPA is not alone in predicting a high consumption of petroleum for several decades by the United States. Various studies by the Department of Energy (DOE) and the National Academy of Sciences (NAS) also predict continuing high levels of petroleum use. The NAS has published "America's Energy Future" (AEF). To quote AEF's Figure 2.1, "Combining the projected growth in vehicle fleet size with potential savings results in only slightly higher gas (gasoline) consumption in vehicles in 2020 and 2030 than exists today".

However, GHG releases from such predicted petroleum consumption would, by 2030, defeat the goals of climate change legislation, H.R. 2454, even if the energy efficiency of U.S. vehicles were significantly improved and 100% of the releases of GHG from coal and natural gas were eliminated. A slightly more realistic analysis showed that even if 80% of today's GHG releases from coal and natural gas were eliminated, the limits set by H.R. 2454 would be overcome would be about five years sooner, by 2025. If only 50% of today's GHG releases from coal and gas were eliminated, the limits in H.R. 2454 would be exceeded in less than ten years. Significant expansion of ethanol from biomass in these time frames are estimated to only defer these dates by about one to three years. In effect, the EPA analysis of H.R. 2454 shows that the goals of this climate change energy bill and continued high consumption of petroleum are incompatible. Table 1, below, summarizes the analysis that led to these conclusions, based on projected oil consumption figures from "America's Energy Future"(AEF). Note that the AEF projections already assume significant efficiency improvements for light duty vehicles (LDVs) and heavy duty vehicles (HDVs). It was further assumed that non-transportation uses of petroleum would become less oil consuming and that there would also be a reduction in the release of greenhouse gases that are not based on carbon dioxide molecules.

One important ramification of this analysis is its effect on the policy debate about carbon taxes versus a cap and trade approach to reducing GHG releases from coal and gas electric power plants. Neither policy option has much value unless petroleum use is sharply reduced. Regardless of which policy option or combination of options the nation chooses, if any, it would be overcome in a few years unless petroleum use is simultaneously reduced. Congressional actions limited to only reducing GHG emissions from fossil fueled electric power plants are doomed to fail to adequately address climate change issues.

2.2.1 Environmental conclusion

Significant reductions in petroleum use are necessary on environmental grounds in order to meet proposed GHG release limits and moderate climate change.

2.3 Economic issues

2.3.1 A business-as-usual scenario

A business-as-usual scenario was examined in which it was assumed that adequate oil is available at market prices, at least through 2035. No oil shocks from gaps between supply and demand are considered nor any armed conflict.

The Energy Information Administration (EIA) Annual Energy Outlook for 2010 predicts a cost of $133/barrel (in 2008 dollars) by 2035. This would be about $224/barrel in nominal dollars. Since we have already briefly experienced a peak price of $147/barrel, the EIA

1. No Coal or Natural Gas GHG Contribution	Year 2007	Year 2020	Year 2035
From petroleum used in LDVs.(2020 and 2035 amounts derived from AEF numbers).	1455	1686	1511
From petroleum for HDVs.(2020 and 2035 amounts derived from AEF numbers).	580	675	605
From petroleum for non-transportation uses. (Based on EIA 2007 petroleum data, with assumed 20% and 25% reductions by 2020 and 2035, respectively).	545	436	409
Non-CO_2 greenhouse gases (Based on EIA 2007 data, with assumed 20% and 25% reductions, by 2020 and 2035, respectively).	1261	1009	946
Total CO_{2e} from petroleum and non-CO_2 GHG.	3841	3806	3471
H.R. 2454 CO_{2e} limit.	N/A	5000	3000
Percent of H.R. 2454 limit, no coal or natural gas GHG contribution.	N/A	0.76	1.16
2. With a coal and natural gas GHG contribution equal to 20% of the 2005 release amount.	Year 2007	Year 2020	Year 2035
20% of 2007's coal and natural gas GHG releases.	N/A	680	680
Total CO_{2e} from petroleum and non-CO_2 gases + 20% of 2007's coal and natural gas GHG releases.	N/A	4486	4151
Percent of H.R. 2454 limit with 20% of coal and natural gas 2007 GHG releases.	N/A	0.90	1.38
3. With a coal and natural gas GHG contribution equal to 50% of the 2005 release amount.	Year 2007	Year 2020	Year 2035
50% of 2007's coal and natural gas GHG releases.	N/A	1700	1700
Total CO_{2e} from petroleum and non-CO_2 gases + 50% of 2007's coal and natural gas GHG releases.	N/A	5506	5171
Percent of H.R. 2454 limit with 50% of coal and natural gas 2007 GHG releases.	N/A	1.10	1.72

Table 1. Millions of Tonnes/year of CO_{2e} Released

projected prices may be low. It was assumed that between 2010 and 2035 the time averaged price of oil, in 2008 dollars, would be $120 (2008 dollars)/barrel. In 2007 the U.S. imported about 10,000,000 barrels of oil/day or about 3,650,000,000 barrels/year. The AEF report projects that the United States would continue to consume oil, through 2035, at a rate similar to that of 2007. If this rate of imports were continued for 25 years at $120/barrel, the total cost would be, approximately, $11 trillion (2008) dollars. This amount is in the range of the present national debt.

There are two other major costs that deserve to be considered. There is the U.S. defense costs related to protecting its oil supplies. At a minimum this cost is about $67.5 to $83 billion (2008) dollars per year not including the costs of actual warfare (see Reference 5). Additionally, estimates have been made by the National Academy of Sciences of the cost of the 2005 health effects caused by our energy system (see Reference 6). These health costs from energy use are estimated to be $120 billion /year of which some $56 billion/year are attributed to transportation, i.e., to the use of petroleum. The total cost of imported oil, the oil related portion of our national defense effort and transportation (petroleum) related health effects for the next 25 years would, conservatively, come to about $14 trillion (2008) dollars for the business-as-usual scenario.

2.3.2 An oil shock scenario

In the business-as usual scenario, there was a sufficient and stable supply of oil. As stated in Section 1, the business-as-usual scenario is very likely to be interrupted by oil shocks which then lead to recessions. Over the last 30 years oil market upheavals have cost the United States in the vicinity of $7 trillion (1998) dollars. So if the next 25 years, until 2035, is similar to the past 25 years, then the total cost of oil could be in the neighborhood of $14 trillion (2008) dollars plus $7 trillion (1998) dollars. This adds up to about an average of a trillion dollars per year to be borne by a weak economy for about 25 years.

2.3.3 Economic conclusion

Dealing effectively with GHG emissions and eventually achieving energy independence may not be possible with such huge transfers of money to oil exporting countries.

2.4 National security issues

Oil dependence represents a grave national security issue for the United States. To illustrate how precarious the United States's position is, two tables are presented below. Table 2 lists the top seven countries in terms of oil consumption in 2007. Table 3 lists the 2007 oil and gas reserves. The contrast between Tables 2 and 3 is stark. The United States is, by far, the world's largest consumer of oil, yet American oil companies, ExxonMobil and Chevron, rank 17th and 21st, respectively, in total reserves of oil equivalents. The U.S. has become the Saudi Arabia of consumption.

Rank	Country	Barrels of oil/day
1	United States	20,680,000
2	China	7,578,000
3	Japan	5,007,000
4	Russia	2,858,000
5	India	2,722,000
6	Germany	2,456,000
7	Brazil	2,372,000

Table 2. 2007 Oil Consumption, Top Seven Countries

Rank by 2007 Oil Equiva-lent Reserves	Company	Liquid Reserves, Millions of Barrels	Natural gas Reserves, Billions of Cubic Feet	Total Reserves (in Oil Equiva-lent), Mil-lions of Barrels
1	Saudi Arabian Oil Company (Saudi Arabia)	259,900	253,800	303,285
2	National Iranian Oil Com-pany (Iran)	138,400	948,200	300,485
3	Qater General Petroleum Corporation (Qatar)	15,207	905,300	169,959
4	Iraq National Oil Company (Iraq)	115,000	119,940	134,135
5	Petroleos de Venezuela, S.A. (Venezuela)	99,377	170,920	128,594
17	ExxonMobil Corpora-tion (United States)	7,744	32,610	13,318
21	Chevron Corporation (United States)	7,087	22,140	10,870

Table 3. 2007 Oil and Gas Reserves

Back-to-back oil shocks may severely and permanently weaken the U.S. economy. If the U.S. is unable to secure sufficient oil through the market place because its economy can not outbid stronger countries and this results in severe food shortages (mostly due to a transportation system that does not have the fuel to deliver sufficient food) or the loss of other critical functions, then this could lead to armed conflict.

2.5 Overall conclusion

Analyses of environmental, economic, and national security issues point to the same conclusion: unless the consumption of petroleum is sharply reduced in the United States on a priority basis, then the goals of limiting the adverse effects of climate change, of achieving energy security or of eventual energy independence, are unlikely to be reached. Achieving these goals largely depends on removing petroleum from our transportation sector. It must also work with other nations, especially China, to co-manage the complicated world transition to a post-petroleum era in a peaceful way.
A three step energy plan directed at addressing the proposed goals in section 1 is presented below.

3. A three step energy plan

3.1 Introduction

The purpose of this section is to provide a first draft of an energy plan that would address national security issues, economic, and climate change issues. This proposed plan is divided into three steps. The purposes of Step One are to put into place a capability to withstand a sudden decrease in imported oil supplies and to lay the groundwork for long term energy independence while protecting of the environment from climate change. Step One would use mature conservation techniques, like home insulation, to reduce GHG releases. This part of Step One is expected to more than pay for itself. With regard to creating an ability to withstand a sudden decrease in imported oil supplies, “no tech” actions, like car pooling, and “low tech” actions, like using more buses and other forms of mass transportation, could be assembled fairly quickly and used to reduce oil consumption and GHG releases. In Step Two other actions both for the near term and for the long term would be initiated. Among such actions would be the creation of different liquid fuel industries based on biomass, coal, and natural gas. The use of energy storage would be greatly expanded. The use of nuclear power would be expanded to first emphasize evolutionary nuclear plants and later the use of high temperature plants for process heat, hydrogen, and electricity. Renewable energy, particularly biomass and windpower, would be encouraged, but a more regional approach would be recommended. Significant investments would be required in this step. Major portions of this investment would come from savings from the U.S. oil import bill.

Step Three is designed to further reduce GHG releases, if shown to be necessary. The time lines of each of these steps are described below.

3.2 Step One, 2010-2020, or so

3.2.1 Non-transportation actions to abate GHG

Step One calls for the implementation of well known energy conservation actions and is expected to produce a net savings in money. These conservation actions can be implemented rather quickly and with little uncertainty about costs or effectiveness.

Those actions that relate to reducing the release of GHG, but not including a modified transportation future, are displayed in Figure 3 (see Reference 7). The quicker that GHG gases can be abated, the greater the GHG reduction over time. Energy conservation has multiple benefits beyond saving money and reducing the release of GHG. Many conservation actions, like home insulation, are long lasting and would not require further use of resources. Further, conservation actions usually depend on different supply chains and infrastructure support than energy producing actions.

As shown in reference 7, about 1.1 gigatons/year (Gt/yr) of greenhouse gases can be abated by 2020 through actions like home insulation, with a net savings in money. It is estimated that for a \$520 billion dollar investment, about \$1.2 trillion dollars in energy costs could be saved, yielding a net surplus of about \$680 billion dollars. To make further reductions in the release of GHG requires investments that would have a net cost. For the purposes of this report the boundary of Step One is the point at which further investments in GHG abatement would require major construction projects and would have a net cost. Many of these additional investments are to be included in Step Two which also starts in 2010, but would continue on to 2030 or so.

Since current climate change legislation calls for GHG abatement well beyond 1.1 Gt/yr, it is obvious that achieving much larger GHG abatement could require trillions of dollars. For example, the National Renewable Energy Laboratory estimates that to supply 20% of the nation’s electricity with wind power by 2024 would cost \$1.1 trillion dollars, not including the cost of new dedicated transmission lines, yet this is but a small piece of what has to be done. The most advantageous way of paying for such large investments is to recycle the savings generated by reducing the cost of importing oil.

3.2.2 No tech and low tech transportation actions to reduce oil consumption

Recently the United States government increased the fuel efficiency standards of new cars to 35.5 miles per gallon, almost 10 miles per gallon more than the average for new cars today.

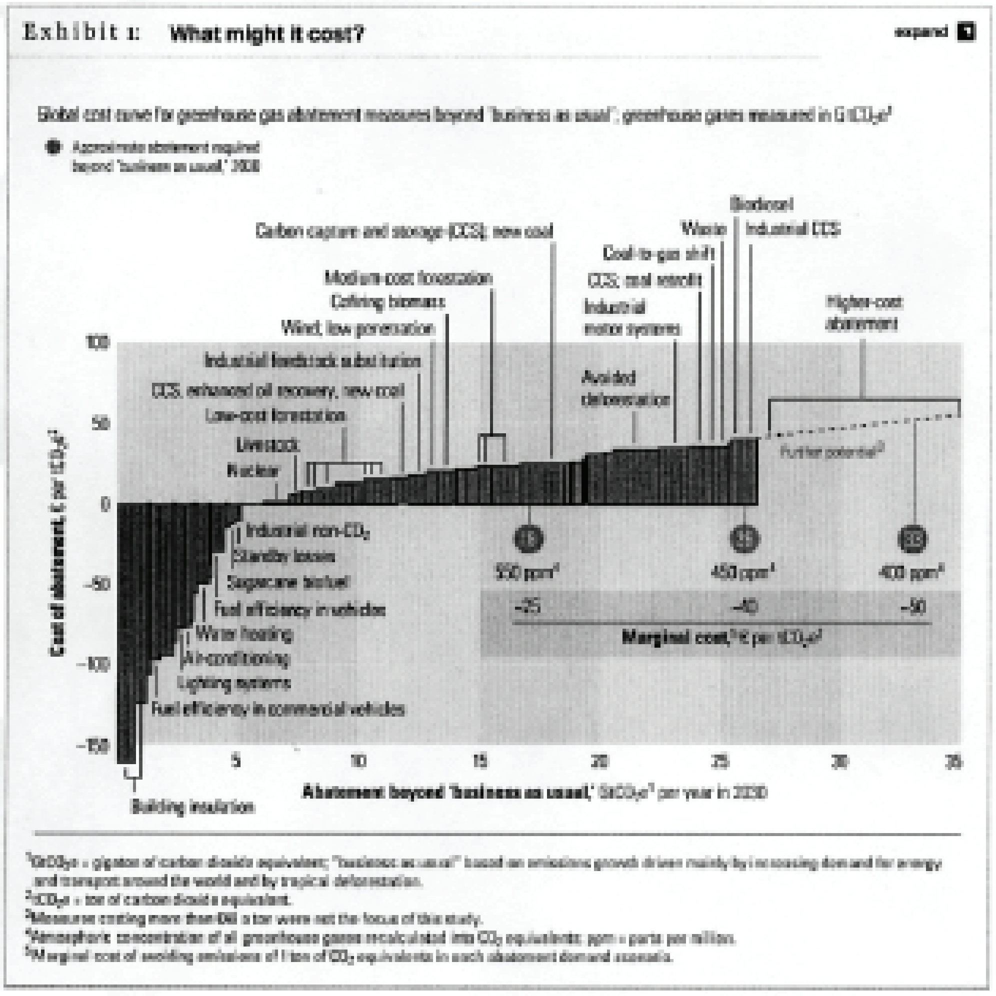

Fig. 3. McKinsey & Company, Exhibit 1

This significant efficiency improvement, about 38%, will take years to fully implement and is only expected to start within the next six years. Nonetheless, it is a move in the right direction. A requirement to make all new vehicles flex-fuel capable should be implemented as well.

It is going to take many years to build up the kind of infrastructure, like more efficient cars and high speed trains, to begin to reduce both GHG releases and oil imports. As discussed above, a comparatively rapid start can be achieved in reducing GHG releases using mature conservation actions in non-transportation applications. It is also possible to supplement these conservation actions in the transportation sector with activities that are well established and could be implemented rather quickly at comparatively low costs. It is possible to implement near term "no tech" and "low tech" solutions that could reduce GHG and simultaneously reduce oil imports, assuming that U.S. political leaders and policies can create sufficient public support for these approaches.

The least cost trip is the one you didn't have to take. In this regard, working at home or in walk-to short term rental offices with teleconferencing (telecommuting) services would be a true energy and GHG saver. In this digital age of instant electronic communications greater use of teleconferencing is an important tool in reducing oil use and GHG releases. Greater government emphasis needs to be placed on true virtual presence high definition bi-directional video. This means greatly increasing the band width to homes. Other countries in the world are further along on this than the U.S.

A major example of a "no tech" improvement is higher ridership in individual vehicles using car pools and in public transportation. Table 4, below, adapted from Table 2.12 of ORNL-6984, sheds light on the relationship between ridership (load factor) and energy use for automobiles, buses, airplanes, and trains.

Vehicle Type	Load factor (persons/vehicle)	Btus per vehicle-mile	Btus per passenger- mile
Automobile	1.57	5,517	3,514
Buses	9.1	39, 408	4, 315
Airplanes	97.2	301,684	3,103
One passenger car in an Amtrak train.	21.7	54,585	2,516

Table 4. U.S. Passenger Travel and Energy Use, 2007

One "no tech" practice that could have a very large effect on energy use and GHG releases would be greater use of car pools. If the average number of persons per vehicle were around 3.0 instead of today's 1.57, oil use in individual vehicles would be cut in about half. This exceeds the benefit of increasing average fuel efficiency by almost 10 m.p.g., as mentioned above, and is equivalent to replacing all of our present fleet of automobiles with plug-ins that would have batteries with a range of 27 miles (See Table 6). Of course car pools and more energy efficient vehicles can be used together to further increase energy savings. Public apathy and resistance to forming car pools is expected and political leadership is needed here. Yet car pools might be implemented rather quickly, especially if fuel prices rise sharply through taxation or if people again began to experience gas stations with "out of gas" signs because of oil shortfalls.

As shown in Table 4 the energy use per passenger-mile was the highest for travel by bus. The problem is not with the buses. This is directly attributable to the very low load factor for buses because of our car-oriented society. Travel by air in 2007 had a very high energy use per vehicle-mile, but because the load factor was also quite high, the Btus per passenger-mile was actually less than those for both cars and buses. If efforts are made to increase bus ridership to an average load factor of, say 70, the Btus per passenger-mile would drop to about 561, or six times better than the efficiency of 2007 internal combustion engine automobiles with its own typically low ridership.

So well before people would be able to use hydrogen based buses or high speed trains, today's ordinary petroleum driven buses could cause a large reduction in gasoline use, provided high ridership is achieved. The U.S. government needs to identify which bus routes would be crucial and create several tens of thousands of new jobs building such a bus system in the United States. All new buses should be flex fuel hybrids with regenerative braking. A steadily increasing tax on imported oil should be levied until gasoline prices resemble those in Europe. Some of the revenues from this import tax should be used to subsidize mass transportation.

Table 4 also shows that increased ridership for Amtrak trains could significantly decrease its energy use per passenger-mile. Mass transportation with high ridership has the potential to reduce oil use far more than all the projected improvements in internal combustion vehicles that are not plug-ins. High speed electric trains would not be part of Step One, but the groundwork for them would fall into Step Two.

Success in Step One is not a matter of finding a breakthrough in battery technology or discovering a way for algae to produce liquid fuels. All the above increases in ridership were observed during previous oil shortages and just faded away as oil became available again and gasoline prices dropped. Similarly, any of the older technologies (streetcars, buses with overhead power lines, etc.) can be used in the United States to cut oil consumption. What is required here is political leadership that the public has confidence in and policies, such as a tax on imported oil, with the proceeds going to reduce the costs of mass transportation. Perhaps the lesson here is that in the transportation sector is that the U.S. should consider "going backward in time" while working on high tech solutions to go "forward in time". Also note that if Steps Two and Three evolve more slowly than what is envisioned here, car pooling and other Step One practices can continue as long as necessary.

3.2.3 Use of natural gas to reduce oil consumption

After many years of decline the reserves of natural gas in the United States has increased dramatically. The reason for this turn around is the ability to extract natural gas from shale using new technologies and the realization that there are vast amounts of shale gas in the country, from Texas to New York.

With regard to transportation, the best use of natural gas is to convert it to methanol which can be distributed through the present petrochemical distribution system, although compressed natural gas can also be used in transportation. The main environmental concerns with regard to shale gas are water management issues and effective disposal of fracture fluids (see Reference 8).

Shale gas offers many important advantages over imported oil. First and foremost it is a domestic energy source. Further, shale gas converted to a liquid fuel produces less GHG than diesel fuel. High fuel use vehicles that use diesel fuel like trash trucks, delivery trucks, buses, etc. are logical candidates to substitute liquid fuels made from shale gas for diesel fuel. With regard to buses, first emphasis on using liquid fuels derived from natural gas should be on those buses that are used for long distance travel, as this is an area not well suited for electric buses or plug-in hybrids and could be implemented well before high speed trains could be put into practice. Further, buses fueled with methanol from natural gas, could travel to any location whereas high speed trains would likely be concentrated in high population density areas. If these buses were also built with a flex fuel platform they could be used in those areas in the country where ethanol from biomass was the dominant oil-displacing liquid fuel and in other areas where methanol was used to displace oil. As indicated in Table 5, the longer average distance traveled in rural areas results in a greater dependence on liquid fuels, such as locally produced ethanol. The shorter average distance traveled and the higher population density of city areas results in greater dependence on electricity in these locations.

Location	Average daily distance driven in U.S., miles
Rural areas	40
Suburban areas	33
Center City areas	30

Table 5. Average Daily Distance that is Driven in the U.S., Miles

The use of natural gas to displace diesel fuel should start in Step One and continue on through Step Two (2010 to 2030). While an improvement over diesel fuel, natural gas is still a fossil fuel and its long term use may be limited by climate change concerns. However, the long term use of natural gas would be an issue for Step Three, which starts around 2030 or so.

The use of liquid fuels from shale gas in buses, preferentially in longer distance intercity travel, would supplement the use of hydrogen/electric buses, described in Step Two, which would be concentrated in urban and suburban locations. As shown in Table 6, below, about 38% of today's passenger car miles are for trips longer than 40 miles, the range of the Chevy Volt, just on batteries. This means that there could be a significant market for liquid fuels of which natural gas derived liquid fuels could be an important contributor.

Trip Length (in miles)	Cumulative Percent of Trips Taken	Cumulative Percent of Miles Travelled
0-0.9	9.7	0.4
1-4.9	49.7	9.5
5-9.9	71.4	23.2
10-19.9	87.6	44.0
20-49.9	97.3	70.9
50-99.9	99.2	82.9
100 +	100.0	100.0

Table 6. Trip Length vs. Cumulative% of Trips Taken and Miles Traveled

It is also possible to generate liquid fuels from biomass and from coal. Having a diversity of liquid fuels is an advantage, especially if the use of shale gas has to eventually be curtailed because of climate change concerns or the need to save shale gas for other applications, such as in residential and commercial space heating and as a chemical feedstock. Ethanol from biomass and methanol derived from coal would be natural supplements to methanol from natural gas, but significant quantities would not be available in Step One.

3.3 Step Two, 2010-2030, or so

3.3.1 Introduction

Step Two has two purposes: to reduce, by 2030, the U.S. release of GHG to 3.7 Gt/yr and to limit U.S. oil imports to North, South, and Central America and the Carib-bean. Step Two describes a possible multi-modal transportation future that relies on electrification to further reduce GHG by burning less oil and simultaneously improving the U.S. national security posture. Step Two also describes the use of ethanol from biomass and methanol from coal and natural gas to replace oil in transportation modes where liquid fuel is necessary.

3.3.2 Reducing oil imports through an electrified transportation future

Three interrelated modes of electrically driven forms of transportation are envisioned. They are individual vehicles, principally plug-in hybrid cars (mode one); mass transportation in the form of electric buses, light rail, streetcars and subways for local travel (mode two); and high speed long distance electric trains (mode three). These three modes would be interconnected, with further ties to airports and other forms of long distance transportation.

3.3.2.1 Mode One: Plug-in Hybrids and EVs for individual transportation

Plug-in hybrids are individual vehicles that have the potential to displace a considerable amount of imported oil. These hybrid vehicles are composed of a battery system that can be charged from the electric grid and from small wind turbines or photovoltaic systems principally in rural areas, and a liquid fuel driven engine which enables hybrids to increase their range well beyond the range of the electric only driving. Plug-in hybrids would also use regenerative braking.

The main purposes for plug-in hybrids are to enable local travel in the electric-only mode and to link up with the other modes of travel that use electrified mass transportation. The batteries in plug-in vehicles would be mainly recharged from the 110 volt electric grid at residential locations at off-peak times when the cost for electricity should be lower. Charging times for today's batteries are long, usually several hours. There is interest in level 11 charging, between 208 and 240 volts, to shorten this recharging time. These level II charging outlets would most likely be located in public places. Level III chargers would be capable of providing high voltage to recharge batteries in minutes, not hours. Such chargers might be located along intercity roads to accommodate longer trips (see Reference 9). Long recharging times encourages the recharging of plug-ins in residential settings at night. Since most plug-ins would be recharged at off-peak times, they represent an important step towards a flatter electricity demand profile.

Israel is taking a different approach by establishing many quick electric charge locations throughout the country. This Israeli technology will also be explored in Denmark and Australia. The recharging stands being used in Israel now could be applied to a transportation hub/plug-in hybrid arrangement that would be more closely tailored to transportation needs in the United States. High voltage recharging stands in parking areas at mass transportation hubs could recharge plug-in batteries during the time the drivers were away at work thereby avoiding the inconvenience of waiting for the recharging periods to be concluded.

Recharging stations at transportation hubs would increase the range of plug-ins, up to twice as long. Commuters could drive to the transportation hubs with batteries charged at night at home and return to home with batteries charged at the transportation hubs while they were away at work. Consider the transportation hub as the center of a circle. By doubling the radius which can be totally served by battery power, this increases the fully electrified travel area by a factor of four. Thus, potentially, many more commuting plug-in drivers would be capable of getting to and from these transportation hubs in the electric-only mode if these transportation hubs had recharging stands. Although purchasing electricity at a transportation hub during the day would be more expensive per kilowatt-hour than off peak purchases at home, the cost of electricity per mile traveled is considerably less than paying for gasoline.

Parking buildings near where people work could similarly be upgraded to provide electricity to recharge plug-in batteries during the work day. Such an arrangement has all the benefits of the transportation hub arrangement and could increase the number of miles driven in the electric-only travel mode. A rough estimate can be made of the potential benefits of the recharging station/plug-in hybrid combination by using Table 6, above. Assume that all plug-ins have a battery system with a 10 mile all-electric range. Based on Table 6 this would be sufficient to travel 23.3% of our miles in the electric-only mode, leaving 76.8% of our miles to be traveled using liquid fuels. If the availability of recharging stations at transportation hubs and business parking lots doubles the range of the electric-only travel mode, then 44% of the plug-in miles could be achieved in this manner, leaving 56% of the plug-in miles to be accomplished by liquid fuels. If half of the trips performed by plug-ins take advantage of recharging stations, then the overall liquid fuel savings would be (0.50) x (76.8%-56.0%) ~10% reduction in national liquid fuel use for the plug-in mode of travel. This simple approximation implies that the cost of building many recharging locations could be offset by a reduced oil import bill.

Additionally, fully charged plug-ins might be available for rent at major mass transportation hubs, again using parking lot recharging stands. Rentals could extend the number of electrically driven miles in a combined electric mass transportation/plug-in hybrid trip. Taxis, which often queue-up waiting for passengers disembarking from trains, could also be plug-in vehicles which are recharged to some degree as they wait for new fares. Level III chargers might be the best match for taxis. Some plug-in hybrid owners, like apartment dwellers, may not have easy access to an electric outlet to gradually recharge their batteries over night. The availability of recharging stands at transportation hubs and at parking areas near work could ease this problem. Apartment dwelling commuters could do the opposite of those commuters that live in private homes and have ready access to an electrical outlet at night. Apartment dwellers might charge their plug-in batteries at a transportation hub or work parking area and then use this stored energy to drive home to their apartments and then back to the transportation hub the following day using their plug-in's electric-only mode.

Federal subsidies for plug-in hybrids might directly be used to reduce the cost of ownership of such vehicles. However, the concept of placing plug-in hybrid recharging stands at transportation hubs and work locations might be a superior way of investing tax dollars.

Plug-in hybrids are also capable of travelling long distances in a liquid fuel mode. The liquid fuel portion of plug-in vehicles should be designed to use a variety of liquid fuels that cover a range of ethanol/methanol/gasoline mixtures, i.e., to be a flex-fuel engine. This capability could be particularly important on longer trips because the type of liquid fuel that might be available could differ from one region of the country to another.

There has been some confusion about the percent of trips that plug-ins can achieve in the electric-only mode and the percent of miles that these trips entail. Table 6, based on light duty vehicle data from the Department of Transportation, can be used to clarify this difference.

Most of our trips are short ranged. A plug-in hybrid with a 20 mile all-electric range would be sufficient for 87.6% of our trips. However, 56% of the miles we drive are on trips that are longer than 20 miles. This means that even if all vehicles in the country were plug-ins with a 20 mile battery range, we would still need 56% of the gasoline, or its energy equivalent, that we consume today, unless we also use other modes of electrified mass transportation to a much greater degree. A plug-in hybrid like the Chevy Volt with its 40 mile range in the electric-only mode would be capable of accomplishing 94.1% of our trips, but 38% of the miles would still remain to be accomplished through liquid fuels for the remaining 5.9% of our trips. To put this into perspective, 38% of the oil the U.S used in 2007 is 7,858,400 barrels per day, of which about two thirds was used for transportation, or about 5.2 million barrels per day. In 2007, France, the UK, and Italy, combined, consumed about 5.4 million barrels of oil per day for all purposes; transportation and otherwise. Even if a 100 mile battery could be developed at an acceptable cost, weight, and size, some 17.1% of the miles to be travelled would need liquid fuels. Unless there are additional modes of electrically driven transportation, e.g., electrically driven mass transportation, completely replacing present internal combustion engine vehicles with plug-ins would still require vast amounts of liquid fuel.

At this time the cost for batteries in plug-in vehicles is high. As reported by the National Research Council the Chevy Volt with its 40 mile battery system will cost about $18,000 more to manufacture than a similar-sized conventionally powered vehicle (see Reference 10). The plug-in version of Toyota's Prius will cost an estimated $6600 dollars more than a conventionally powered car and is expected to have an all-electric range of 13 miles. There have been interesting proposals that might lower these costs. One thought is that people who plan to go on an occasional long trip rent a special small trailer that carries additional batteries to supplement the normal plug-in batteries.

The need to have batteries with higher energy densities and other improvements is clearly recognized. The present U.S. administration has allocated $2.4 billion dollars into developing and subsidizing next generation plug-in hybrids (PHEVs) and fully electric vehicles (EVs).

With recharging stands at transportation hubs plug-in hybrid purchasers might more frequently opt for lower cost plug-ins with the smaller batteries because this transportation hub arrangement would significantly increase their electric-only range when commuting. This in turn would encourage a more rapid market penetration of the lower cost plug-in version. A more rapid market penetration of lower cost plug-ins would serve the national interest by more rapidly reducing the amount of oil that need be imported. Electric Transportation Engineering Corporation was recently awarded a stimulus grant of nearly $100 million to build 12,800 charging stations in five different states.

Although much of the discussion about plug-ins centers around battery technology, it is important to seek high efficiencies in the liquid fuel mode of travel. To very effectively reduce national petroleum consumption, one might combine plug-in hybrids with car pools.

Although plug-ins would not completely solve future transportation needs, it is clear that plug-in vehicles should be part of the U.S. multi-modal transportation future. In this analysis no credit is given to EVs, all electric vehicles. It is assumed that their very high battery costs will limit their impact on reducing petroleum use in the Step Two time frame, i.e., between now and 2030. However, as discussed earlier, some plug-in hybrids used by commuters may, in effect, act like EVs when combined with recharging stations.

3.3.2.2 Availability of resources

3.3.2.2.1 Introduction

Two of the most important resources in implementing a post-petroleum transportation future are electricity and non-oil liquid fuels.

3.3.2.2.2 Electricity

Today only about one percent of the U.S. passenger miles is accomplished electrically. If future U.S. transportation had but half of its passenger miles accomplished electrically, that would require a 50 fold increase in this form of travel compared to today; a huge undertaking. How much electricity might be needed to supply the needs of a post-petroleum transportation future? The answer to this question requires that we know how large Mode 2 is. Nonetheless, some initial information is at hand.

The U.S. present electrical system has the potential to produce far more electricity than it does today using the same power plants and transmission grids. This is because this electrical system is designed to handle the large diurnal swings in electricity demand that are experienced between business hours and nighttime and weekends. In addition to the diurnal variations in electricity demand there are seasonal variations and to prevent blackouts or brownouts electrical systems require enough capacity to meet peak demands, like on a hot summer day, with a reserve margin in case a plant unexpectedly drops off the grid. It has been estimated that, on an annual average, this electrical system only produces about 46% of the kilowatt-hours it could produce if it ran 100% of the time, less outages for maintenance. To get a more precise understanding of this unused capacity than taking an annual average, one has to compare supply and demand on an hour-by-hour basis throughout the whole year to determine the time dependent amount of excess capacity. A partial answer to this question can be found in a study by Pacific Northwest National Laboratory (PNNL) which analyzed the impact of plug-in hybrid vehicles on the U.S. power grid (see Reference 11).

PPNL made a stylized load shape for one day during the peak season, as reproduced below in Figure 4. Here the area labeled "valley filling" provides opportunities to extract more electricity from our present electrical system without needing to increase the number of power plants or make nationwide improvements to the trans-mission grid for the purpose of supplying electricity to plug-in hybrids.

The PPNL analysis concluded that about 73% of the nation's 2007 stock of about 235 million light duty vehicles (LDVs) could be replaced by plug-in hybrids without requiring additions to our electricity production capabilities. However, in order to achieve the 73% figure, the plug-ins would have to have access to the grid's underutilized capacity 24 hours a day. Using an assumption that would better match likely plug-in recharging times, from 6:00 P.M. to 6:00 A.M., PPNL calculated that the percentage of present LDVs that could be replaced by plug-ins without expanding our electrical system for that purpose would be 43%. The PPNL analysis is based on plug-ins with a battery system capable of travelling 33 miles in the electric-only travel mode. This percentage would increase if regional energy transfers over an improved grid system made more electricity available in the 12 hour time span listed above. If high voltage recharging stands were placed at transportation hubs and elsewhere, they might be energized during time periods between 6:00 A.M. to 6:00 P.M. With the use of recharging stands, plug-ins could replace somewhere between 43% and 73% of the nation's LDVs during the most limiting day, i.e., during peak demand time periods. Other future energy storage applications would also shift the shape of the valley areas in Figure 4 and these would have to be accounted for in a systematic way. Energy storage, which makes better use of the existing electricity system, might enable an even higher percentage of use by plug-ins than PPNL's 73%.

If 43% of today's LDVs were replaced by plug-ins, this would require about 100 million plug-ins. Even if the cost of batteries decreased significantly, it would take many years before such a large number of plug-ins were on the road. In a recent National Research Council (NRC) study an optimistic plug-in penetration of 40 million plug-ins might be achieved by 2030 out of 300 million vehicles expected at that time. A different NRC scenario, thought to be more realistic, places the plug-in penetration at 13 million by 2030. This means that for quite some time before electrical capacity to operate Mode Two type mass transportation vehicles would be a constraint. Electricity demands from plug-ins, under a range of NRC scenarios, appear to be well within the electrical capacity of our present electrical system. These PPNL data and the NRC study imply that all three modes of electric transportation could expand in parallel without running into electrical capacity limits for many years, particularly if extensive energy storage is used.

However, it is possible that the NRC estimates are too low. As discussed elsewhere in this paper, combinations of plug-ins and "outside" sources of electricity such as charging stations, embedded power strips in roadways, the use of rapid charge capacitors/battery combinations, etc., may make the smaller, 10 mile range, lower cost battery closer to the minimum cost size, using today's technology. This would have the effect of having a more rapid ramp up for plug-ins. Because plug-ins displace oil and, as already shown, the cost to the U.S. for imported oil is staggering, plug-ins and rechargers might justifiably receive a significant subsidy.

The demand for electricity for high speed trains should be based on data from France, Spain, Japan, or China rather than Amtrak data in Table 4. These data are not available at this moment. Although it is expected that most of the demand for electricity for Mode Three travel will occur between 6:00 A.M. and 6:00 P.M., there may be ways of meeting some of this demand through energy storage of electricity made in off peak hours. If more generation capacity needs to be added to the system to meet the daytime demands of Mode Three transportation, this would potentially also increase the supply of electricity during off peak times.

In conclusion, it would take many years before the present electrical capacity was insufficient to meet the demands of Modes Two and Three. As more high speed trains come into service additional electric generation capacity may become necessary. There should be ample time to construct this new capacity. If significant electricity generating capacity is

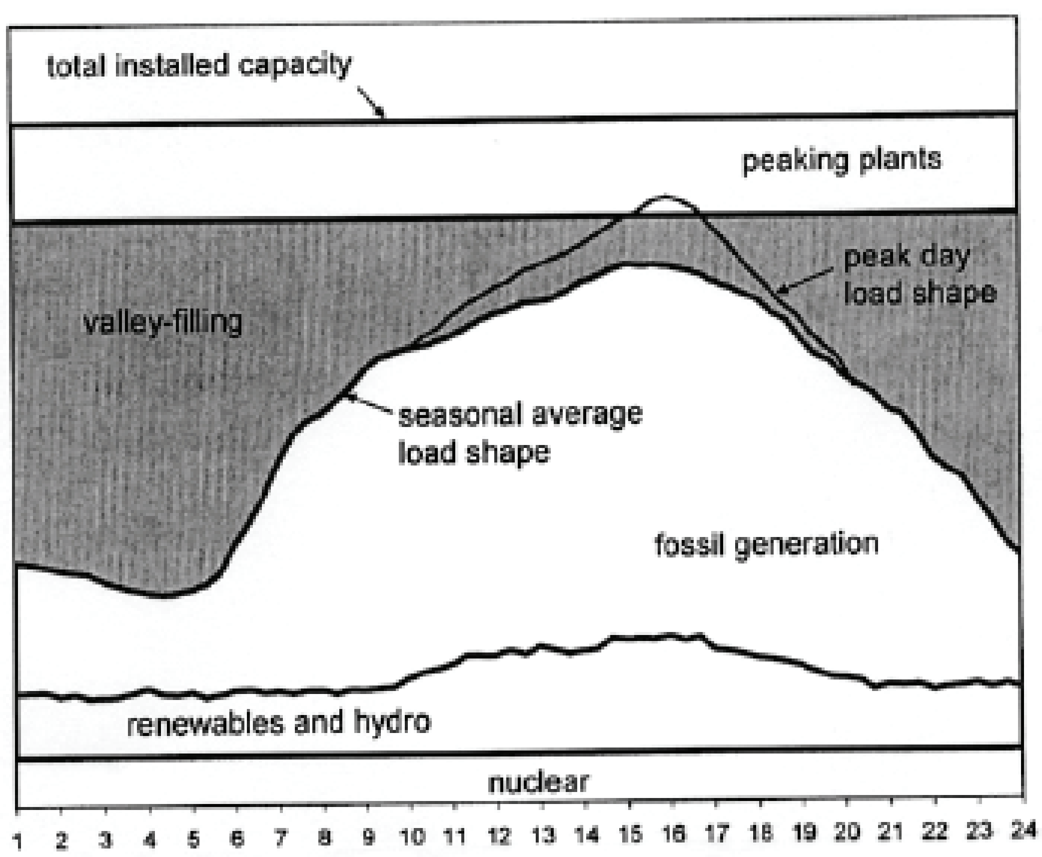

Fig. 4. PNNL - One Day Load Shape During Peak Season

removed by shutting down older coal plants, new low carbon sources of electricity would have to be added. The pace of building this new low carbon electrical capacity would have to be sufficient to replace the shut down coal plants, meet the demands of a growing population, and meet the demands of an increasingly electrified transportation sector. If the pace of adding new electrical capacity is not rapid enough it could slow down the rate at which oil is displaced by electricity in transportation.

In the long term, 2030 to 2050, other major sources of electrical energy may begin to become available such as from breeder nuclear power plants, from fusion, from geothermal energy, and various forms of renewable energy. Any one of these energy sources could supply electrical energy for millennia. This report stresses the use of electrically driven end uses as a means of reducing oil consumption and abating the release of greenhouse gases. However, there is another major benefit of having electrified end uses. As these long term new sources of electricity enter our electrical system, the end use devices they would power would already be in place. This arrangement supports having flexibility built into our energy future.

3.3.2.2.3 Liquid fuels from biomass

The main contributors to the America's Energy Future (AEF) biomass liquid fuels are cellulosic plants, corn stover, and woody biomass. Using the information in AEF's Figure 2.11, a potential supply of 0.5 million barrels of gasoline equivalent per day was forecast for 2020 and 1.7 million barrels by 2035. However it may be possible to significantly exceed these projected production amounts. Perhaps the most promising way to increase the biomass contribution to liquid fuels is a basic rethinking of how land is used. Some 85% of the land used for agriculture in the U.S. does not directly go into making food for humans. Rather, this land is used to make food for animals which are later consumed in our food chain. If however, we could feed cows more digestible grass or crop residues and less grain, the land formerly devoted to feeding them grain can grow grass for biofuels and animal feed. Other means to increase the amount of biomass is to use double cropping. The presence of a double crop would permit the removal of corn stover plus the additional biomass from the double crop. Finally, a larger contribution from biomass would entail increasing the grass yield from pasture land from 3 tons per acre to about 6. Achieving this increase in pasture yield is considered to be plausible based on the fourfold increase in the yield of corn over the past 50 years which was accomplished by better seeds and better agronomic practices. It is estimated that this approach would require about 280 million acres of land and might produce about 100 billion gallons of ethanol per year after accounting for losses in the biorefineries, about half of the energy equivalent of today's gasoline used in transportation in the United States. In addition to growing biomass for liquid fuels in the United States, energy farms might be encouraged in other locations, like Central America.

The pace at which liquids from biomass enter the transportation market might not be set by the ability to grow the requisite amount of biomass, but more by the time it takes to build the accompanying infrastructure. Estimates are that it would take decades to build enough biorefineries to convert the biomass into 100 billion gallons of ethanol per year. One estimate is that about 1000 biorefineries might be needed. Even if a new biorefinery became operational every week, it would still take about 20 years to build 1000 refineries. Some other aspects of this infrastructure issue are discussed below.

Transporting biomass can present infrastructure issues. The energy density of many biofuels before processing, like switchgrass, is low. This limits the range over which vehicles, like trucks, can gather up these energy sources. At some point the energy it takes to drive the truck on a round trip will exceed the energy content of the biomass in the truck. This zero net energy point is the maximum distance that the truck should travel from the biorefinery. Because of energy density considerations, steps are taken to densify the biomass near its point of origin, i.e., near the fields themselves. Work is underway to accomplish this localized densification of biomass (see Reference 12).

Unlike methanol, once out of the refinery the resultant ethanol can not be transported in unused petroleum pipelines as presently configured, according to the AEF report: "Ethanol is currently transported by rail or barges and not by pipelines, because it is hygroscopic and can damage seals, gaskets, and other equipment and induce stress-corrosion cracking in high-stress areas". Two suggestions are offered. First, it would be better to use ethanol at locations nearest the point where they are produced/refined, that is in rural areas/farms. Present day farm equipment is sold with flex-fuel engines that could use ethanol blends. Second, it might be worthwhile to investigate methanol/ethanol blends that could be used in flex-fuel vehicles and capable of being transmitted through unused petroleum pipelines. If this were possible, then methanol would be piped into a biorefinery where it would be blended with ethanol and the resultant mix piped out through available petroleum pipelines. Some energy experts take a different view on using pipelines to ship ethanol. Their views are that once the tonnage gets high enough, pipeline companies will come up with ways to avoid ethanol/water interactions and that the pipes themselves would be protected from stress induced cracking conditions. As the tonnage of petroleum shipped by pipeline decreases there is an incentive for the pipeline industry to make this petroleum infrastructure "ethanol friendly". Technical conferences on this very subject have been conducted this year.

There are important insights that support the concept of a more regional approach to using renewable energy, such as biomass. Similar arguments have been presented for wind power, such as emphasizing off shore wind power with its higher average wind speeds and in locations closer to electrical load centers rather than attempting to transmit wind power over great distances and seek permits from multiple states and local jurisdictions.

Table 5 describes the average daily distance driven in the U.S. as a function of location. This simple table supports the idea that electrified transportation is a better fit for higher population density areas. For example, in city and suburban areas a higher percentage of the trips will fall into the range of plug-ins, especially if they are supplemented by strategically placed fast recharging stations. Other forms of electrified mass transportation also make more economical sense in the more densely populated areas. Further, electrified transportation would greatly improve air quality conditions in city and urban areas and the resultant health benefits would save large sums of money each year. In rural areas, many trips would be beyond the range of affordable present batteries and electrified mass transportation is likely to be uneconomical in such low population density areas. Therefore the fraction of the miles that would be driven using liquid fuels is likely to be higher in rural areas than in the more densely populated areas. This suggests that the first priority for liquid fuels from biomass should be to meet the needs of rural areas. The whole pipeline/ethanol issue may not need to be a consideration until after all the liquid fuel needs of rural areas are met.

This regional approach to our transportation future emphasizes the need to require that all new LDVs have a flex-fuel design. The U.S. could take a lesson from Brazil in the use of flex-fuel vehicles. Open Fuel Standard legislation should be supported.
In conclusion, some experts believe that over several decades a large fraction of today's liquid fuels could come from biomass by emphasizing the use of grass fed animals over grain fed and other land use improvements. It seems appropriate to test this important idea by demonstrating that the projected biomass yields can be economically obtained in a sustainable way that does not create water shortages, cause soil degradation, create a net increase in GHG, or reduce the amount of food the nation now produces. Since making liquid fuels from biomass should be able to be accomplished in a way that decreases the release of GHG in transportation, biomass derived liquid fuels could be an important mechanism to meet the long term GHG limits proposed in H.R. 2454. A significant demonstration project of appropriate scale seems to be justified.

3.3.2.2.4 Coal-to-liquid processes

All the various proposed ways to meet long term liquid fuels needs have economic, environmental, and technological uncertainties. This encourages the use of diversity of long term liquid fuel supplies so that there would be a higher assurance that the liquid fuel will be there as needed. The use of natural gas in transportation is already covered in section 3.2.3. Here the use of coal to make liquid fuels is discussed and converting biomass into ethanol as described in section 3.3.2.2.3.
Converting coal into a liquid fuel (CTL) is a long established technology. Coal can be converted to alcohols, ethanol and methanol, through a gasification process. Coal is used to make syngas which, after passing through a catalyst, becomes methanol. This is existing technology and the cost per gallon of methanol is comparatively low. Another advantage of methanol is that it could use petroleum pipelines as part of its distribution system without further modification. Coal supplies in the United States are very large and the cost per barrel of gasoline equivalent from coal is attractive. A shown in AEF's Figure 2.14, CTL would be competitive with gasoline if oil prices remain above $65/barrel (2007 dollars).
One major drawback to CTL is in the GHG it produces. In some CTL processes today coal is used both as a heat source and as a feedstock. GHG are emitted when coal is burned as a heat source and more GHG are emitted when the liquid fuel, such as methanol, is burned in transportation. A number of alternative CTL processes have been suggested that would prevent GHG from entering the environment during the heat addition step. The AEF report identifies two such schemes: Using biomass instead of coal as the heat source and using a carbon capture and storage (CCS) process to capture coal's GHG releases when used as a heat source. The AEF report correctly points out that using biomass as a heat source is not attractive in that this same biomass might be used to make ethanol. This then would leave the CTL process completely dependent on a successfully developed CCS process, which has considerable technical challenges of its own. If CCS is not feasible then the amount of domestic liquid fuels the U.S. would be left with would be limited to ethanol from biomass, methanol from natural gas, plus a minor amount of domestic oil.
An alternative to using coal with CCS as the heat source is to use some non-carbon heat source. Several scientists have written papers on using nuclear power in a CTL process, either as a source of hydrogen or as a high temperature heat source (see References 13,14,15). High temperature nuclear power plants have the additional advantage over the CCS approach in that it would stretch out coal reserves. The AEF report, on page 66,

estimates that to supply 3 million barrels of gasoline equivalent/day would require huge amount of coal, up to 50% of the coal we extract today, assuming coal is both the heat source (with CCS) and the feedstock. Forsberg has studied coupling a nuclear hydrogen plant with a coal liquefaction plant and concludes that this would convert almost all of the carbon in the coal to liquid fuels and eliminate carbon dioxide from the coal liquefaction plant (see Reference 16). Up to three times as much liquid fuel would then be produced per ton of coal. It would be prudent to develop both CCS and high temperature nuclear technology to have greater assurance that liquid fuels will be available when needed.

3.3.2.3 Conclusions on Plug-in Hybrids

A review of plug-in hybrids concludes that there would be ample electricity and liquid fuel from biomass, natural gas, and coal CTL processes to run 100 or more million plug-in vehicles with the present electric power system, depending on the ranges of their batteries. The bulk of the GHG emissions from plug-ins would came from the electric power plants that supply them, and that it is important to build these vehicles to have flex- fuel capabilities and engines with high liquid fuel efficiencies. Battery cost appears to be the major determinant of plug-in market penetration. However, combining plug-ins with charging stations at transportation hubs and in parking garages near work sites, might enable owners to purchase smaller battery designs that could be quite adequate. This, in turn, would lower overall costs and accelerate market penetration of these vehicles. In some cases these recharging stations would enable some drivers who live within a certain range to, in effect, use their plug-ins as EVs, total electric vehicles. Advances in battery technology may lower costs and a new approach to subsidizing technological development, based on its oil-displacing potential, may reduce plug-in purchase costs.

Plug-ins should play a major part in our energy future, but the public will need other means of electrified transportation to supplement the plug-in contribution. This last conclusion places more emphasis on Mode Two and Three electrified mass transportation, particularly those forms that do not rely on huge numbers of lower cost batteries.

3.3.2.4 Mode Two: local electrified mass transportation

Mode Two mass transportation vehicles can be divided into two types: those that follow a fixed route and those that have the capability to alter their route, as necessary. In the latter situation, some form of stored energy within the Mode Two vehicle is necessary to give it the flexibility to alter its route.

There is no question that Mode Two electrified mass transportation can be accomplished. It has been done for many decades using old technology, such as with subways, electric streetcars, and buses which draw electricity from fixed position sources of electricity like overhead electric power lines. Fixed route vehicles generally do not have stored energy on-board. Whereas electrified mass transportation without on-board energy storage is simpler, less costly, and can be accomplished with mature technologies, following a fixed route is a series process: an interruption along the route that can not be by-passed might cause a whole route to be shut down until the cause of the interruption is removed. Further, fixed route Mode Two electrified mass transportation is usually limited to one function: moving people. Mass transportation electric vehicles with on-board stored energy might be put to use in two functions: moving people and moving goods.

In addition to long established Mode Two forms of electrified mass transportation like streetcars, there are modern variations of this. In Seoul, Korea there is now a short distance electric tram system that draws its electricity from power strips imbedded into the road (see Reference 17). In between these power strips this electric tram uses on-board batteries.The use of imbedded power strips reduces the need for on-board batteries by 80%. It is thought that this form of electric vehicle travel might be a model for much wider use in urban areas.

China is experimenting with a different kind of electric bus called a capabus. Instead of using batteries these vehicles store electricity in electrical double layered capacitors (EDLCs). Capacitors have some distinct advantages over batteries. They can be very quickly recharged and discharged. They have a long life and can be put through far more charge/ discharge cycles than ordinary batteries (millions or more compared to 200 to 1000 for most commercially available batteries). These characteristics make capacitors ideally suited for the stop-and-go of city buses and streetcars that use regenerative braking. As a capabus goes from stop-to-stop it can be quickly recharged under what is called an "electric umbrella". In 2006 two commercial bus routes began to use EDLCs, one of which is in Shanghai.

Brazil uses "Bus Rapid Transit" or a BRT system that appears to be very cost effective. Capital and infrastructure costs are extremely low compared to rail and subway systems and utilization has been high. BRT systems use "transit stations" in place of bus stops. These are elevated platforms where passengers pay to enter the transit station or use passes to enter, thereby eliminating any waiting for fare collection. These buses have wide doors to speed up passenger entry and exit times. Because the BRT system uses supercapacitors, these buses can be quickly recharged at the transit stations. Similar BRTs have also been used in the United States and in Europe, however the user-friendly transit stations seem to be predominantly in South America.

There may be some Mode Two designs that would be particularly attractive to the United States because it would build upon two existing infrastructures: the electric power system and the petroleum distribution system. This U.S. design would use supercapacitors and could operate under both a fixed route and variable route conditions and would be pollution free at the point of use.

One design would use solid oxide fuel cells (SOFCs).These fuel cells are considered impractical for cars and light trucks because they only operate at high temperatures. However, SOFCs might be useful in heavy trucks and in buses. With good insulation these SOFCs could be kept hot continuously. The fuel could be hydrogen from renewable energy sources or nuclear power or it can be natural gas or volatile hydrocarbons; it could even be de-mineralized coal or wood charcoal feeding an on-board gasifier. Such fuel cells would be combined with supercapacitors, regenerative braking and possibly some energy storage in batteries for prolonged power on uphill grades or prolonged braking on downhill grades.

Use might be made of present gasoline stations, as they would take on a somewhat different role in the future. These stations are ubiquitous, have or could have 220 volt electrical service or higher and already have underground storage tanks used to hold gasoline or diesel fuel. In the future many of these gas stations could be transformed to serve future vehicles. A portion of the underground storage at these stations would hold liquid fuels, such as methanol, ethanol, or any petroleum-like product that comes from biomass, coal, or natural gas. This liquid fuel would be for vehicles, like plug-in hybrids and buses, that need liquid fuel for longer distance trips. The remaining underground storage would be for hydrogen where large pressurized tanks would replace former gasoline storage tanks. Since this underground hydrogen storage tank would be stationary, its heavy weight would not be a problem. The technology for storing and handling hydrogen seems to be well advanced in Germany. There the Linde Group has opened a hydrogen filling station for zero emissions fuel cell passenger ships (see Reference 18). The hydrogen in this former gasoline station system would be generated by electrolysis of water using lower cost off-peak electricity. Such highly dispersed hydrogen storage depots could be used to put electricity back on the grid during peak demand periods to avoid blackouts or to supply energy to emergency vehicles. Since these energy depots would be decentralized energy storage systems, but located close to end use devices they service, their stored energy would be less vulnerable to terrorist acts. Such hydrogen energy storage depots could be shared by all sources of electricity, including nuclear and wind power.

3.3.2.5 Mode Three: long distance electrified transportation

Because of its great emphasis on individual automobiles the United States has fallen far behind Europe and other countries in the use of high speed trains. China recently became the world leader in manufacturing high speed electric trains. China has 42 high-speed trains recently opened or set to open by 2012 with an average speed of 215 miles per hour. The State of California which plans to build its own high speed rail system. This has gained widespread interest in that China, Japan, Germany, South Korea, Spain, France, and Italy have approached California to build this train system. Of particular interest is China's offer. China is not just offering to build a railroad in California, but to help finance its construction. "We are the most advanced in many fields, and we are willing to share with the United States" said Zheng Jian, the chief planner and director at China's railway ministry (see Reference 19). Such an arrangement would be beneficial to both countries. Much like what the auto industry has done, foreign countries can create large industries in the U.S. employing many American workers. As China helps to reduce U.S. petroleum consumption through advanced technology and creative financing, it helps to moderate world oil prices and sustain a margin between supply and demand. With China's increasing appetite for petroleum, actions that help to moderate world oil prices saves China vast sums of money.

If the nation were to build a substantial high speed rail system it should look for routes that might have the greatest impact on reducing gasoline usage as rapidly as possible. For example, a high speed route between Richmond, Virginia and Portland, Maine could well be a top choice because of the high population density in this important area.

Significant liquid fuel savings, as well as reductions in GHG emissions, may be achieved by modifying our ground freight shipments. Liquid fuel consumption in the ground freight transport system could be reduced by 80% by the combination of electrification of railroads, as in Europe, and large scale intermodal rail truck systems. Most of the long distance truck transport would be replaced by containerized freight that travels long distances by rail, with local delivery by truck. Modifying ground freight transport by using electrified trains is estimated to reduce America's petroleum demand by 5%. To accomplish this Forsberg estimates that 50,000 megawatts-electrical would be required or about 30-35 large nuclear power plants (see Reference 20).

Forsberg also points out "In the 1970s, the French Government decided to build an electrified high-speed super train system to connect major metropolitan areas and to reduce consumption of liquid fuels. The system has demonstrated that high-speed trains can replace air travel for distances up to 500 miles because of lower costs, higher point-to-point speeds and greater comfort. Simultaneously, rail stations have been built at major airports to provide point-to-point transport."

Greater use of such trains have secondary benefits, as well. Almost half of the aircraft flight delays in the country were directly or indirectly a result of the three New York and two Washington, D.C. airports. If one wants to fix the U.S. airline system, including long taxi lines that burn jet fuel, high speed rail is a requirement for the east coast corridor to unload those airports. This would reduce the release of GHG, lower air pollution, reduce the use of oil, and increase customer satisfaction.

3.4 Step Three, 2030-2050, or so

The purpose of Step Three is to assess what additional efforts, if any, need be taken to further reduce the release of GHG and to establish a plan to implement such efforts. Step Three would start around 2030. By that time many GHG reducing efforts should have already become operational. Further, the science of climate change should have advanced with more data and more sophisticated computer models.

One area that might receive closer attention is the 2050 GHG release limit as presently spelled out in H.R. 2454 which is very low at about 1 Gt/yr. Since many of the easier GHG actions would presumably been taken by around 2030, implementing this final reduction could be quite difficult. The science available at 2030 should be better able to inform us of the environmental consequences if the world's carbon sinks come into equilibrium with GHG releases at a level that is higher than 1 Gt/yr. The higher the acceptable point of GHG equilibrium, the more likely that it can be achieved. If it turns out that a 1 Gt/yr release rate is appropriate, the implementation of Steps One and Two would match the release rate called for in H.R. 2454 so no time would have been lost in addressing climate change.

4. References

[1] "America's Energy Future", National Academy of Sciences, 2009.
[2] "Transportation Energy Data Book: Edition 28-2009", pg 1-9,ORNL-6984.
[3] Joint Operating Environment, United States Joint Forces Command, pg 28, February 18, 2010.
[4] "Storms of My Grandchildren", Dr. James Hansen, 2009.
[5] "Imported Oil and National Security" Rand Corporation, 2009, page 71.
[6] "Hidden Costs of Energy-Unpriced Consequences of Energy Production and Use", National Academy of Sciences, 2009.
[7] "Reducing Greenhouse Gases-How Much at What Cost?", McKinsey & Company, 2007.
[8] "The Future of Natural Gas, An Interdisciplinary MIT Study", 2010.
[9] "Electrification Roadmap", pg.15, Electrification Coalition, November, 2009.
[10] "Transitions to Alternative Transportation Technologies-Plug-in Hybrid Electric Vehicles", National Research Council, Prepublication Copy, March, 2010.
[11] "Impact Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids, Part:1 Technical Analysis", Michael Kintner-Meyer, et al, Journal of EUEC, Volume 1, 2007.
[12] "Technical and Financial Feasibility Analysis of Distributed Bioprocessing Using Regional Biomass Pre-Processing Centers", J.Coralan, S. Joshi, and B. Dale, Journal of Agricultural & Food Industrial Organization, Volume 5, Article 10, 2007.

[13] "Meeting U.S. Liquid Transportation Needs With a Nuclear Hydrogen Biomass System", Forsberg, C.W., American Institute of Chemical Engineers, Manuscript Number 85370, September 7, 2007.
[14] "Sustainable Fuel for the Transportation Sector", R. Agarwal, et al, Proceedings of the National Academy of Sciences, Vol.104, March 20, 2007.
[15] "Producing Transport Fuels with Less Work", D. Hildebrandt, et al, Science,vol.323, March, 2009.
[16] "Nuclear Energy For a Low-Carbon-Dioxide Emission Transportation System with Liquid Fuels", C.W. Forsberg, Nuclear Technology, Vol.164, December, 2008).
[17] "In Seoul, Green Transit is Mayor's Pet Project", Choe Sang-Hun, NY Times, March 27, 2010.
[18] "The Linde Group Opens First Hydrogen Filling Station for Fuel Cell Passenger Ships", Marketwatch, August 29, 2008.
[19] "China Again Hopes to Drive U.S. Rail Construction", Kenneth Bradsher, NY Times, April 7, 2010).
[20] Personal communication, Professor Charles Forsberg, MIT, April 6, 2010.

Paths to Sustainable Energy
Edited by Dr Artie Ng

ISBN 978-953-307-401-6
Hard cover, 664 pages
Publisher InTech
Published online 30, November, 2010
Published in print edition November, 2010

The world's reliance on existing sources of energy and their associated detrimental impacts on the environment- whether related to poor air or water quality or scarcity, impacts on sensitive ecosystems and forests and land use - have been well documented and articulated over the last three decades. What is needed by the world is a set of credible energy solutions that would lead us to a balance between economic growth and a sustainable environment. This book provides an open platform to establish and share knowledge developed by scholars, scientists and engineers from all over the world about various viable paths to a future of sustainable energy. It has collected a number of intellectually stimulating articles that address issues ranging from public policy formulation to technological innovations for enhancing the development of sustainable energy systems. It will appeal to stakeholders seeking guidance to pursue the paths to sustainable energy.

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

Herschel Specter (2010). A Call to Action, Paths to Sustainable Energy, Dr Artie Ng (Ed.), ISBN: 978-953-307-401-6, InTech, Available from: http://www.intechopen.com/books/paths-to-sustainable-energy/a-call-to-action-

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821