Modern American life is premised on the assumption that inexpensive oil will be available forever to fuel our transportation system. Our vehicles, our jobs, and even the structure of our communities all depend on reliable supplies of affordable oil. Yet growing worldwide demand for oil and tightening supplies strongly suggest that the days of cheap, plentiful oil are over. Because we consume so much oil, which is so highly valued and for which we have virtually no substitutes in the short-term, price volatility in the world oil market inflicts significant economic damage on the United States. Our dependence on oil has been equally damaging beyond our shores, constraining our conduct of foreign policy and placing significant operational demands on our military.

Oil price volatility is a result of highly inelastic short-term demand, geopolitical instability in oil producing nations, inadequate investment in production capacity, and surging demand in emerging market nations. It is exacerbated by a classic market failure—oligopolistic behavior by nations participating in an oil producers’ cartel. Unfortunately, traditional antitrust remedies are not available because the conspirators are sovereign nations. Unable to address the supply side of the problem, we are left to examine the demand side of the equation.

In order to escape the severe economic consequences of oil price volatility, it is necessary to electrify the short-haul transportation system. Electrification offers several advantages over the status quo: using electricity promotes fuel diversity; electricity is generated from a domestic portfolio of fuels; electricity prices are less volatile than oil and gasoline prices; using electricity is more efficient and has a better emissions profile than gasoline; using electricity will facilitate reduction of greenhouse gas emissions; and electricity is a low-cost alternative. We also observe that electricity is superior to other practical alternatives to petroleum to fuel the short-haul transportation system—natural gas, hydrogen, and biofuels—for many reasons, both economic and scientific.

Because of the advantages that they offer, it is likely that we will ultimately transform our short-haul ground transportation fleet to grid-connected vehicles. Though such vehicles are uneconomic in the United States at the present time, they are more competitive in Europe because of the high price of fuel, and are easier to transition to in China, because of the government’s control over the economy and the absence of a car culture in which drivers have expectations that their cars can match the characteristics of internal combustion engine-powered vehicles. Accordingly, the government should implement policies to actively promote the development and deployment of technology to electrify the short-haul transportation system as part of an effort to reduce the economy’s petroleum intensity, thereby enhancing our nation’s national and economic security, and to avoid falling behind our major economic competitors in a transition that is nearly certain to occur.

I. THE AMERICAN OIL ECONOMY

For over a century, plentiful cheap energy has driven American economic growth. In one sense, this does not differentiate our nation from almost any other in modern economic history. Since the early days of the Industrial Revolution, economic growth has been yoked to energy

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1 This paper, edited by Ronald Minsk, is a condensed version of two other papers: 1) “Plugging Cars Into the Grid: Why the Government Should Make a Choice,” published in the December, 2009 Energy Law Journal, coauthored by Ronald E. Minsk, Sam Ori and Sabrina Howell; and, 2) The Electrification Roadmap, published by the Electrification Coalition in November 2009, of which Ronald Minsk was one of several coauthors.
demand growth. As economic activity increases, the need for energy increases as well. After all, at its most basic level, energy is simply the ability to do work. And economic growth does not come without work.

Yet the United States is a special case. The United States is responsible for twenty-three percent of the world’s daily oil consumption, twenty-two percent of daily natural gas consumption and seventeen percent of daily coal consumption. Of every 100 kilowatt hours of electricity generated each day in the world, twenty-three percent are generated in the United States. Our cities, our culture, and our society were built on the assumption that energy—and the fuel to make it—would be practically limitless and indefinitely cheap. And for the most part, we continue to live that way today. This is particularly true in the case of petroleum.

By 1900, U.S. oil production had been ongoing for more than forty years, initially for use as an illuminant. By 1900, annual U.S. oil production was roughly 63.6 million barrels. By 1905, it had more than doubled to 138 million barrels.

The growth of the oil industry laid the groundwork for what would eventually become its most reliable customers—transportation in general, and the internal combustion engine in particular. In the United States, vehicle registration rose from 8,000 in 1900 to 944,000 in 1912. By 1929, there were more than 23 million vehicles and 140,000 gas stations across the nation.

Over time, vehicle ownership soared ever higher as Americans moved away from overcrowded urban environments to enjoy the benefits of cleaner, less dense suburbs. Passage of the G.I. Bill of Rights accelerated the growth of the suburbs and the need for automobiles. Then, the federal government built a national highway system and Americans began to hit the roads en masse every summer. As of 2007, there were 844 vehicles for every 1,000 people in the United States compared to 426 in the United Kingdom, 543 in Japan, and thirty in China. It is not surprising, therefore, that there are few recurring phenomena that influence global petroleum prices more heavily than the so-called “summer driving season” in the United States.

There were bumps along the road as the American oil economy expanded in size and scope. The 1970s ushered in the rise of the Organization of the Petroleum Exporting Countries’ (OPEC) power, the Arab Oil Embargo, and the Iran-Iraq War. These geopolitical disruptions resulted in skyrocketing oil prices, and initial public policy responses in the United States often only exacerbated problems. Gas lines, rationing, stagflation, and “turning down the thermostat” were defining aspects of the 1970s that seemed to significantly—if not permanently—alter views about oil consumption, in government and around the country.

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5. Id.
7. Id. at 191-92.
The Energy Policy and Conservation Act of 1975 mandated an improvement in the efficiency of the American automotive fleet. And the Fuel Use Act of 1978 was primarily responsible for reducing petroleum use in the electric power sector from fifteen percent in 1975 to four percent in 1985. All told, the petroleum intensity of the U.S. economy fell by thirty-five percent between 1973 and 1985. Between 1973 and 1995, the difference was forty-five percent. But only a few years later, it was easy for most Americans to view the events of the 1970s as one-off perturbations. Disagreements among OPEC members led to an oil price collapse by 1985. Crude oil was discovered in Prudhoe Bay and the North Sea, adding a much-needed boost to global oil supplies and placing further downward pressure on prices.

With lower prices and new discoveries, oil market volatility posed a minimal threat in most American’s minds by the end of the 1980s. Efforts to increase efficiency fell by the wayside. And with oil prices at such low levels, most international oil companies scaled back their investments in developing new reserves, believing such efforts to be unprofitable in the short-term. In many ways, the 1990s served to reinforce these beliefs. Despite turmoil in Kuwait and Iraq and the resulting erosion of OPEC spare production capacity for several years, for most of the period between 1993 and 2002 global oil production capacity stayed well above global oil demand, and prices were generally low and stable.

Change, however, was on the horizon. Many of the efficiency gains of the 1980s were reversed with the explosion in popularity in the United States of sport utility vehicles, whose viability was premised, in significant part, on the availability of cheap oil. But the 1990s were perhaps the last decade of “easy oil.” By 2008, almost 100 years to the date after Ford introduced “the car that put America on wheels,” Americans were confronted with the possibility that there was a limit to the seemingly endless flow of oil that had for close to a century supported our mobile lifestyle.

[17] Id.
Today, the U.S. economy is dangerously exposed to a global oil market whose fundamental characteristics will ensure that, at least through the medium-term, it is likely to be increasingly volatile and unstable. Growing demand for oil from the developing world, limited access to the reserves owned by national oil companies, the higher cost of production of those fields that are available to international oil companies, and the inevitable fact that at some point in the future, production of conventional oil will peak and be replaced by more expensive unconventional oil, all suggest that the threat posed to our economy by our dependence on oil will continue to grow over time.

In the five years from 2004 to 2008, U.S. oil consumption averaged 20.46 million barrels per day (mbd). In 2008, total transportation was responsible for sixty-nine percent of oil consumption, with light-duty vehicles (LDVs) representing 8.6 mbd of that demand. The transportation sector as a whole is today ninety-five percent reliant on petroleum products for delivered energy—with no substitutes available at scale. This extraordinary reliance on a single fuel to power an indispensable sector of our economy has exposed the United States to a significant vulnerability, both for our economy and for our national security.

II. THE EFFECTS OF OIL DEPENDENCE

A. A Different Kind of Price Spike

If the oil price spike of 2008 felt different from prior episodes of oil market volatility, it was for good reason. When oil prices reached their inflation adjusted all-time high of more than $147 per barrel, it was not just a bump in the road. A portion of that price was, instead, largely the result of a set of fundamental factors that increasingly appear inherent to the global oil market: rising demand for energy in developing countries, stagnant growth in OPEC oil production capacity, and increasingly complex and costly development outside of OPEC.

Between 2003 and 2008, oil prices climbed steadily higher. Economic growth in developing countries like China and India added a new component to the world oil demand picture. In total, world demand for oil increased by eleven percent between 2000 and 2008, but fully 100 percent of this growth occurred in non-Organisation for Economic Co-Operation and Development (OECD) countries.

At the same time that demand was increasing, new oil supplies struggled to keep pace. Within OPEC, decades of underinvestment left total production capacity in 2008 at 34 mbd, less than its 37 mbd level in 1973, despite the fact that the cartel’s proved reserves more than doubled between 1980 and 2008. Outside of OPEC, oil supplies also struggled to grow, but for

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different reasons. In United States, the United Kingdom, and Norway, new supplies became more geologically difficult and costly to access. In other high-potential regions like the Caspian Sea area, Latin America, and West Africa, geopolitical factors combined to stymie investment. As a result of these factors, the global oil market operated with minimal spare capacity—less than three percent of daily demand—throughout most of the period from 2005 to 2008. In such a tight market, even small events around the world can have dramatic effects on oil prices.

In 2003, real oil prices averaged $33.75 per barrel. It then rose to $75.14 in 2007 and $97.26 in 2008. By July 2008, oil prices reached a level that was simply unsustainable—the point of demand destruction. Demand for oil is highly inelastic, but only to a point. As gasoline prices soared past $4.00 per gallon, household budgets fell apart. Exacerbated by recession, in the third quarter of 2008, oil consumption was down more than 8.5 percent compared to the same period in 2007, the largest annual decline since the first quarter of 1980.

And yet, despite the current economic environment, the underlying factors that led to record oil prices in 2008 have not substantially altered. Demand growth for oil products—particularly in the industrialized world—has temporarily subsided, to be sure. But this reduction is not the result of any fundamental change in technology, policy, or infrastructure. Rather, it is simply the result of reduced economic activity during the current downturn. As economic activity resumes, demand for all energy—including petroleum—will also increase, particularly in emerging economies that will continue to require high rates of economic growth to accommodate population growth and higher standards of living. Assuming no changes in government policies, by 2030, the International Energy Agency (IEA) expects that world demand for petroleum will increase by 21.2 mb/d, or roughly twenty-five percent compared to 2007 levels. Fully 100 percent of the growth is forecast to occur in the developing world, with sixty-three percent in China and India alone.

On the supply side, the picture is also bleak. In its 2008 World Energy Outlook, the IEA conducted a field-by-field analysis of 798 of the world’s largest oil fields, which collectively account for three-quarters of all initial reserves ever discovered. Of these initial reserves of 1,306 billion barrels, only 697 billion barrels remain. This latter figure, however, makes up seventy-nine percent of remaining conventional oil reserves. Five-hundred and eighty of the 798
fields are post-peak production and declining at a rate of 5.1 percent per year. In total, the IEA estimated that crude oil output from existing fields will decline from roughly 70 mbd in 2007 to just 27 mbd in 2030. In other words, the world’s oil producers will need to add 64 mbd of new capacity (including unconventional fuels, biofuels, and natural gas liquids) between 2007 and 2030 to replace lost reserves and meet incremental demand growth from emerging markets.

All told, the IEA estimated that total upstream investment of at least $5 trillion is required to meet oil demand over the next twenty years, a level of investment that seems challenging for national oil companies, whose governments use production revenue to finance other government programs and for international oil companies, which cannot access the most promising reserves and whose remaining reserves are increasingly costly to produce. Moreover, financing has been difficult to attract through the recent recession. In 2009, the IEA estimated that 6.2 mbd of planned capacity additions had either been cancelled or postponed for more than 18 months.

These circumstances paint a picture in which world demand grows and supplies are constricted, and medium-term and long-term oil prices rise until meaningful substitutes are deployed. More importantly, prices can be expected to retain a substantial level of volatility as uncontrollable events around the world continue to rattle markets. Given U.S. dependence on petroleum, this volatility can be expected to exact a heavy toll on long run economic growth. To understand why, it is useful to examine the economic effects of oil dependence in greater detail.

B. The Characteristics of Oil That Underlie Its Economic Power

The volatility of oil prices is the primary manner in which our dependence on oil threatens our economic and national security. Yet, if the price volatility occurred alone, it would not represent a more significant threat than that that posed by our use of any other commodity. Instead, it is the combination of price volatility with three other characteristics that make our petroleum dependence unique: the volume of oil that we consume, the value of oil that we consume in any given time period, and the inelasticity of short-term demand for oil.

1. Volume of Oil Consumed

The United States consumed 19.5 mbd of oil in 2008, twenty-three percent of global consumption. As seen in Figure 1, for at least the past twenty-five years, the demand for oil has generally risen at a relatively steady rate, although it has fallen on a few occasions in response to sustained periods of high prices and recession. It is possible that this long-term trend may change. The small decline in demand that resulted from the recent recession, followed by stagnant demand as tightened fuel economy standards that were enacted in 2007 begin to affect average fuel economy in 2011, may mean that U.S. oil demand is finally nearing a peak. Nevertheless, we will still consume an enormous volume of oil.

42. According to the IEA, the average size of the fields analyzed was substantially larger than the global average, as the IEA data set includes all super-giant fields and the majority of the giant fields. Because decline rates tend to be lower in larger fields, IEA assumes that the global data set (which would include a much larger share of smaller fields) has a significantly higher average decline rate. IEA calculates this figure to be 6.7 percent. Id. at 43.
43. Id. at 255.
44. Id. at 250, 255.
45. Id. at 323, 324.
48. Id.
2. Value of Oil Consumed

The volume of oil that we consume might not be important in its own right except that oil is relatively expensive. The total value of oil consumed by the United States represents a significant portion of all economic activity in the nation. Even when oil prices are low, the value of our total consumption remains large. As seen in Figure 2, the value of oil and oil products consumed in the United States has ranged from $48 billion to $925 billion over the past three decades, representing between 2.6 and 8.5 percent of the GDP.\(^\text{50}\)

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3. Inelasticity of Short-term Demand

Demand for gasoline is highly inelastic in the short-term. There are few (if any) substitutes for oil, at least and especially in the short-term and most consumers cannot stop using gasoline on short notice in response to rising prices. As damaging as such a price increase might be, the costs of alternatives are generally greater, especially if the price spike is perceived to be transient, a perception that nearly always exists and has, thus far, always proven correct.

Our intuitive understanding that the short-term demand for oil is relatively inelastic is confirmed by economic data. The short-term inelasticity of demand can be seen in Figures 3 and 4. Although demand for oil has responded to changes in price, the response is weak. As depicted in Figure 3, from January 2007 through July 2008, the price of gasoline rose from $2.38 per gallon to $4.17 per gallon. Yet during this time period, gasoline demand actually increased by 1.6 percent. Similarly, as depicted in Figure 4, from mid-February 1999 through September 2000 the price of gasoline rose from $0.96 to $1.58 per gallon. Yet during that time period, gasoline demand remained essentially flat, averaging about 8.5 mbd.

These particular examples are supported by research at the Institute of Transportation Studies, University of California, Davis, which examined the short-term price and income elasticity of gasoline demand between 2001 and 2006. The researchers concluded that short-term demand was highly inelastic between 2001 and 2006, with the price elasticity of gasoline demand ranging from -0.034 to -0.077.

4. Oil Price Volatility

We intuitively know that the price of gasoline, the major component of which is the price of oil, is highly volatile, as we have all seen the price of gasoline move sharply higher and sharply lower many times in recent years. Our intuition is supported by the facts, as demonstrated in Figures 5, 6, and 7 below. Figure 5 shows the percent change in the price of oil over the previous month. Since 1974, the average price of oil has either risen or fallen by more
than ten percent from the previous month fifty-four times,\textsuperscript{57} while over that same time period, the
c consumer price index has never risen or fallen by more than 1.9 percent in a month (and has only
risen or fallen by more than 1.5 percent in a month only once).\textsuperscript{58} Oil prices, then, are highly
volatile relative to the economy overall. Figure 6 describes the percent change in the price of
gasoline from week to week, showing that the price of gasoline has become increasingly volatile
in recent years. That is further demonstrated in Figure 7, which plots the difference between the
high and low price of gasoline over the previous fifty-two weeks.\textsuperscript{59} In fact, one recent study
concluded that crude oil prices are currently more volatile than about sixty-five percent of other
commodities, and more than ninety-five percent of products sold in the U.S. economy.\textsuperscript{60}

\textbf{Figure 5: Percent Change in Oil Prices and CPI-U From Previous Month}

\textbf{Figure 6: Percent Change in Price of Gasoline From Previous Week}

\textsuperscript{57} See United States Dep’t of Labor, Bureau of Labor Statistics, \textit{Consumer Price Index Databases},

\textsuperscript{58} Id. (Authors’ calculation based on data available at United States Department of Labor, Bureau of Labor Statistics,
Consumer Price Index Databases).

\textsuperscript{59} DOE, EIA, \textit{U.S. Gasoline and Diesel Retail Prices}, available at
tonto.eia.doe.gov/dnav/pet/xls/PET_PRI_GND_DCUS_NUS_W.xls.

\textsuperscript{60} Eva Regnier, \textit{Oil and Energy Price Volatility}, 29 Energy Economics 3, 405-427 (2007). See also Amanda Logan &
5. **All Characteristics Are Equal, But Some Are More Equal Than Others**

It is the unique combination of these four characteristics of our use of oil and the world oil market that creates economic vulnerability. If any three characteristics existed without the fourth, then our vulnerability would be significantly reduced or perhaps eliminated. But though our dependence is a function of all four of these characteristics, price volatility is a particularly damaging characteristic because it thwarts the possibility of a sustainable, market-driven effort to use oil more efficiently throughout our economy.

If we could predict future oil prices, and knew that they would simply be higher, we could mitigate much of the damage through planning. In fact, not only can we not predict future oil prices with any degree of accuracy, the one thing that experience has shown in the past is that prices are highly volatile and that at some point after the prices rise sharply, they will fall almost as far as they rose—if not further. Therefore, not only do volatile prices hurt us when prices rise by eroding our purchasing power, but they also harm us when prices fall, by undermining our ability to make investments in efficiency and other alternatives.

Accordingly, a year-long oil price spike is sufficient to do significant economic harm, but is insufficient to induce significant investment in efficiency and alternatives. The lack of such investments then increases the likelihood of further price volatility and its attendant economic harm. In other words, price volatility appears to have, thus far, condemned us to a world in which we are subject to a cycle of oil-driven economic boom and bust.

Moreover, price volatility is, perhaps, oil’s most overlooked characteristic. In fact, changes in price are more harmful than high prices because while one can adjust to a high price, it is hard to adjust to a volatile one. Nevertheless, the combination of these four characteristics, which do not exist anywhere else in the economy, makes oil like nothing else we consume.
C. The Economic Consequences of Our Dependence on Oil

There are at least three mechanisms through which U.S. oil dependence weakens our economy: the economic adjustment costs that result in misallocated resources and reduced GDP, the transfer of wealth to foreigners, and additional means of foregone GDP.61

1. Economic Adjustment Costs and Loss of GDP

Economic adjustment costs are the additional reductions of GDP, beyond that which would occur simply as a result of higher prices, which are caused by the temporary misallocation of resources as the result of sudden price changes. This is perhaps the most noticeable category of costs that our dependence on oil imposes on our economy because these accompany price spikes, whereas the other categories discussed below are more likely to exist, though possibly in less potent form, even in the absence of a price spike.

There are at least three categories of economic adjustment costs. First, changes in oil prices alter the budgets of households, businesses and governmental entities, generally resulting in a loss of economic output as the optimal mix of inputs shifts. Second, and closely related to the first category, price spikes can shift consumer demand for products and services, both because consumers may have less disposable income as a result of higher spending on oil and because goods or services may be more expensive if oil (or products derived from oil) was among their inputs. Third, ongoing uncertainty about the future price of oil reduces economic output below what it would be otherwise.

The consumption of gasoline is the primary means through which oil prices filter down to the average American family. American households consume an average of about 1,100 gallons of gasoline each year,62 at an average cost of $3,597 in 2008,63 a level of consumption that is, as described above, inelastic, particularly in the short-term. This represents an important part of the 2007 median household’s income of $50,233.64 Each one dollar increase in the annual average price of a gallon of gasoline reduces average American household discretionary spending by about ten percent,65 effectively acting as a tax increase with the value of the tax accruing to oil producers instead of the U.S. government.66

Between 2001 and 2008, the average retail price of gasoline rose from $1.46 to $3.27,67 increasing the average household’s annual gasoline bill by $1,991. By way of comparison, all changes to the federal tax code during that same period decreased annual federal income and

66. Of the 8.4 million households that used fuel oil, average consumption was 663 gallons per year for space heating and 228 gallons per year for heating water at an average cost of $2,870 in 2008, imposing on them burdens similar to their consumption of gasoline. (Based on authors’ calculations based on data supplied by EIA, 2005 Residential Energy Consumption Survey, at Tbls US2, SH7, WH (Sept. 2008), available at www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html; Annual Energy Review 2008, supra note 18, at 179).
estate taxes by about $1,900 for the median household.\textsuperscript{68} In other words, every penny that the typical household saved due to federal income and estate tax cuts was spent on higher gasoline bills. Businesses that consume oil face similar challenges, as rising prices undermine their budgets as well.

Sustained high gasoline prices, which effectively exist through very high tax rates in much of Europe, might cause U.S. families to reorient their lifestyles around reducing fuel expenditures. This has not yet occurred, however, because persistent opposition to increasing the tax on gasoline keeps taxes low, allowing prices to fall as well as rise, and to fall to levels near which most consumers are not concerned about fuel economy. Moreover, the prospect that prices may fall in the future provides a fig leaf that enables households to make economically irrational decisions to favor perceived quality of life over low energy consumption: even if prices are high now, they may fall in the future.

2. Transfer of Wealth

It is easy to understand how our dependence on oil imports constitutes a significant transfer of wealth from U.S. consumers to foreign producers. The value of that transfer is equal to the product of the volume of oil and refined products that the United States imports from foreign producers and the average cost of imports.\textsuperscript{69} According to the U.S. Department of Energy, the nation imported $450 billion of petroleum in 2008 alone.\textsuperscript{70}

The transfer of wealth abroad directly increases our trade deficit. As oil prices have steadily increased in recent years, petroleum imports have exacted a heavy toll on the nation’s current account balance. In 2008 alone, net trade in petroleum and petroleum products cost the American economy $388 billion.\textsuperscript{71} This staggering total represented fifty-seven percent of our total trade deficit of $681 billion.\textsuperscript{72} Our 2008 petroleum deficit was greater than the deficit with China, NAFTA, or the European Union,\textsuperscript{73} and it exceeded the combined 2008 cost of wars in Iraq and Afghanistan.

This transfer of wealth has the potential to reduce our GDP because money spent abroad on oil and petroleum products may not be recycled to be spent on goods and services in the United States. Moreover, to the extent that we cannot finance our imports with exports, we must finance our imports with foreign borrowing, which imposes a drag on the U.S. economy through significant interest charges. The trend of increased imports should be expected to continue as long as domestic oil production continues to decline and oil consumption remains at least at current levels.\textsuperscript{74}


\textsuperscript{69} While it is true that the United States also exports a small amount of refined product, transfer of wealth is intended simply to measure the amount of capital exchanged for fuel.

\textsuperscript{70} \textit{Annual Energy Review 2008}, supra note 18, at 81.

\textsuperscript{71} Our net trade in petroleum is lower than our gross import of petroleum because although the United States exports little if any crude oil, we do export finished products, largely, but not exclusively, to our Western Hemisphere trading partners.

\textsuperscript{72} \textit{Annual Energy Review 2008}, supra note 18, at 77.


\textsuperscript{74} \textit{Id}. at 46, 47, 48 Tbl 12.


\textsuperscript{76} Whereas we have calculated the magnitude of the transfer of wealth based on our use of oil, Greene et al. have calculated the magnitude of the loss based on the exercise of monopoly power by foreign oil producers. Rather than categorize the value of all imports as imposing a cost on our economy by increasing the trade deficit, Greene has calculated the increase in
3. **Additional Foregone GDP**

The third category of economic losses that results in additional foregone GDP is the decline in consumer and producer surplus which results from the exercise of monopoly power by oil producers, and the lost consumer and producer surplus in other product markets whose prices have been affected by the price of oil.\(^{77}\) This loss occurs whenever prices are higher than they would be in a competitive market (an occurrence that can usually be attributed to OPEC action), whether or not they have recently spiked.

When demand for a product is inelastic, consumer surplus is typically larger than it would be if demand were unit elastic or elastic because consumers are willing to pay more for the product that the seller is charging.\(^{78}\) Oligopolists exploit their power by raising prices to maximize their profits while reducing output, which reduces consumer surplus.\(^{79}\)

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The magnitude of the costs of oil dependence across these three categories clearly varies over time. When oil prices are steady and low, the economic impact of our dependence on oil is also relatively low. When oil prices are high and volatile, the economic costs are generally high and damaging. According to analysis performed at DOE, the costs to the economy, depicted in Figure 8 below, reached $600 billion in 2008.

![Figure 8: Economic Costs of U.S. Oil Dependence](image)

There can be no doubt that the characteristics of our oil consumption and oil markets described above have led to periods in which the loss of GDP was sufficient to throw the economy into recession, with all of its attendant damage. As demonstrated in Figure 9, oil price spikes have either preceded or concurred with every U.S. recession since 1970, including the

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our foreign debt resulting from the exercise of monopoly power by oil exporters. He calculates the value of the transfer as the total value of all crude oil and petroleum product imports, as the volume of imports multiplied by the difference between the price of oil and the estimated price of oil in a competitive market and the price of oil in the actual market. It is his methodology that forms the data used in Figure 8 and the accompanying text.

77. *Id.*
78. *Id.* at 78.
79. *Id.* at 197.
recent one. Although there obviously are numerous factors that contributed to the recession, some recent research has concluded that the oil price spike in 2008 caused the recession to begin six to nine months earlier (in December 2007) than would have occurred otherwise. Although the correlation between oil prices and the onset of recessions does not necessarily imply causation, there is a strong negative correlation between oil price spikes and the strength of the economy.

### Figure 9: U.S. Oil Expenditures and Economic Recessions

![Graph showing U.S. Oil Expenditures and Economic Recessions](image)

Note: Recessionary periods are in light gray

**D. National Security Consequences of Our Dependence on Oil**

While the economic costs of U.S. oil dependence are quantifiable, the national security costs are generally not. There are at least two primary consequences of America’s heavy reliance on petroleum. The first is that U.S. foreign policy is constrained in dealing with a range of foreign policy priorities in oil-producing countries and regions. Second, and closely related, is that the U.S. military is overburdened and overexposed by our need to maintain secure transit routes for global oil supplies.

1. **Foreign Policy**

At a general level, one needs to look no farther than the so-called Carter Doctrine to summarize the impact of U.S. oil dependence on our foreign policy. On January 23, 1980, in his State of the Union address to Congress, President Carter declared,

> [l]et our position be absolutely clear: An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force.

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Of course, the United States may have had a number of reasons for intervening in any invasion of Middle East countries. The Carter Doctrine was largely directed at the Soviet Union in response to its invasion of Afghanistan. Yet, adventurism in the heart of the Persian Gulf had a special significance because of American dependence on a stable global oil market. Our willingness to respond “by any means necessary” might not have held true in many other places.

The statements and policies of successive administrations confirm this notion. President Reagan extended the Carter Doctrine to cover not just external but regional threats to Persian Gulf oil supplies.83 In his corollary to the Carter Doctrine, he stated “there is no way that we could stand by and see [Saudi Arabia] taken over by anyone that would shut off [the] oil.”84 And in 1989, National Security Directive (NSD) 26, issued by President Bush, stated

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\text{[a]ccess to Persian Gulf oil and the security of key friendly states in the area are vital to U.S. national security. The United States remains committed to defend its vital interests in the region, if necessary and appropriate through the use of U.S. military force, against the Soviet Union or any other regional power with interests inimical to our own.}^85
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More recently, the National Defense Strategy issued by Secretary of Defense Robert Gates in June 2008 notes that

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\text{the United States requires freedom of action in the global commons and strategic access to important regions of the world to meet our national security needs. The well-being of the global economy is contingent on ready access to energy resources... The United States will continue to foster access to and flow of energy resources vital to the world economy.}^86
\]

Today, for instance, our interest in stable oil markets constrains our flexibility in dealing with a range of threats posed by Iran. U.S. sanctions may rank among the top factors preventing Iran from maximizing its oil production potential. Yet, the United States’ option set in dealing with Iran’s efforts to develop nuclear weapons, its continued support of Hizb‘allah in Lebanon, and its decidedly unhelpful role in Iraq is likely sharply limited by Iran’s important role in the global oil market. Iran is only one of many examples across the world in which our oil dependence has constrained our conduct of foreign policy. This and many other foreign and military challenges are born at least in part out of our need for a steady global supply of oil.

2. The World’s (Oil) Police

In a world dependent on oil, the United States has periodically endured a unique burden as the guarantor of the world’s oil supplies. At least two large-scale military actions, Operation Desert Storm and Operation Iraqi Freedom, are frequently regarded as having been tied to protecting oil flows. Though some have tried, we believe that it is impossible to quantify the military burden associated with oil dependence.87 In our view, however, it is simply impossible to quantify the American response to the Iraqi invasion of Kuwait based on oil dependence versus other causus belli, such as defense of Kuwaiti sovereignty. It is similarly imprecise to assign the full cost of Operation Iraqi Freedom to oil dependence versus, for example, democracy building. No doubt, oil dependence and oil politics played a strong role in both actions, but assigning a precise monetary cost seems an exercise in futility.

In addition to large scale deployments, other, more routine U.S. military activities occur on an ongoing basis that are also closely associated with energy security and protecting oil flows.

83. KEITH CRANE, ANDREAS GOLDTHAU, ET AL., IMPORTED OIL AND U.S. NATIONAL SECURITY 61 (RAND 2009).
86. Crane, supra note 117, at 62.
For example, U.S. naval assets routinely patrol key shipping chokepoints, including the Straits of Malacca in the Far East, and American forces are currently training security forces to guard critical energy infrastructure in the South Caucasus, West Africa, and the Middle East—almost exclusively at the expense of the U.S. taxpayer. These kinds of routine security functions are often explicitly tied to the preservation of shipping lanes for oil and other goods. More broadly, providing general security training is often aimed at improving the overall security and stability of a region, which is a prerequisite for expanded and secure oil production. Ultimately, the U.S. military helps to provide long-term security—which is a prerequisite for oil production—and oil is a factor in choosing where it should focus on providing that security.

III. OPERATING WITHIN THE EXISTING PROGRAM

U.S. oil dependence overburdens our military while undermining both our economic stability and our foreign policy priorities. So long as we fail to address this vulnerability we will continue to risk the continuance of an oil-driven boom and bust economic cycle. High prices will weaken our economy and initiate economic slowdowns which cost us jobs and undermine our standard of living, while volatility undermines the incentive to engage in efforts to reduce our dependence on oil, thus continuing the cycle. In addition to weakening our economy, it will continue to undermine our foreign policy and impose significant burdens on our military, including the need to put American lives in harm’s way, a cost that is intolerable.

The challenge we face is how best to break this dependence while ensuring that the U.S. economy retains the mobility and flexibility it needs in order to grow.

This is not necessarily a new question. Since the 1970s, Congress has established the Department of Energy and passed a slew of legislation to enhance our energy and economic security. This legislation has provided assistance to a wide range of technologies to fuel vehicles, including synthetic fuels, natural gas, biofuels, hydrogen, and electricity. The range of assistance, however, is not the result of a national energy policy to determine the best and most efficient outcome, but instead is the product of a haphazard, politicized, and inconsistent approach, with policymakers at times unwilling to interfere with industry and at other times mandating or subsidizing various technologies. The former is problematic because it has meant that the market has not been consistently required to incorporate the cost of the externalities of oil dependence. The latter is problematic primarily because support for technology has been highly politicized, with subsidies, mandates, and demonstration projects starting and ending based on factors other than the viability or deployment of the technology.

The fact is that we have had no discernable long-term national energy strategy. It is perhaps ironic that the challenge of transforming our energy sector is compared to the Apollo project. The Apollo project had a clearly defined goal: to send a man to the moon and bring him safely back to earth by the end of the 1960s. Our energy policies, however, are not similarly focused, or even focused at all. We do a little of many things—such as biofuels, natural gas vehicles, hydrogen vehicles, electric vehicles, and more efficient gasoline vehicles—without a clearly focused commitment to achieve any positively stated goal. The result is mixed messaging to the industrial sector, producing little or no progress.

89. See, e.g., ESA80, supra note 156, at §§ 100-95.
Significant oil consumption reduction must come from the transportation sector, which is responsible for more than seventy percent of American oil demand. Moreover, the approach of most policymakers to date—increase domestic supply of oil, reduce demand—while laudable and necessary, will never provide true security for the U.S. economy.

A. Domestic Oil Production

Increasing domestic oil production can improve the U.S. trade deficit, reduce the magnitude of the wealth transfer, and increase reinvestment of oil revenue into the United States. Increased supply cannot, however, meaningfully reduce oil price volatility or the economic damage that volatility wreaks on U.S. households and businesses. If for no other reason, this is true simply because the United States does not possess enough oil to meaningfully alter the global supply-demand balance.

The Department of Energy currently forecasts U.S. crude oil production to be 5.79 mbd in 2020 and 7.14 mbd in 2030.94 This rise of just 1.35 mbd is itself highly questionable given the steady decline in U.S. crude oil output over the past thirty years. Moreover, the entire forecasted increase derives from fields in the lower forty-eight contiguous states, which leads us to believe that DOE has assumed new production from the Atlantic and Pacific offshore regions, which is highly speculative in nature.

Leaving aside domestic production potential, the basic characteristics of the global oil market completely undermine the ability of domestic oil production to insulate the U.S. economy from oil price volatility. Though oil is produced, transported, refined, and consumed at all corners of the globe, there is a single world market for oil. All variations from that price represent adjustments to account for the location of the oil and its quality, international variations in demand between regions, and changes in the balance of demand for different oil products. Professional traders quickly arbitrage out any unsupported price differentials.

Price formation in the global oil market implicitly accounts for all of the oil production and all of the oil consumption in the world. All consumers of oil are dependent on all producers of oil to get their supply to market. Often, isolated variances from this process result in dramatic price swings, particularly in times of low spare capacity. For instance, in late 2002 and early 2003, an oil worker strike in Venezuela resulted in a sharp reduction of oil production.96 The result was not simply higher prices for the United States, which is the main customer for Venezuela’s oil; it was instead a higher global price for oil.97 In other worlds, consuming nations are dependent on every supplier in the world—those from whom they purchase and those from whom they do not—to ensure a stable supply and price of oil. Therefore, increasing domestic oil production will not insulate the United States from oil price volatility.

The only means to address volatility directly through supply would be to build sufficient spare production and refining capacity to serve as buffers that could quickly increase or decrease production in response to exogenous events to maintain price stability. The last time that the United States was able to do this was in the 1960s, when the Texas Railroad Commission could meaningfully manage global supply. Today, however, such an undertaking would be impossible.


95. Indeed, in its online supplemental tables, DOE shows crude oil production from the Atlantic and Pacific increasing from roughly 100,000 b/d today to 700,000 b/d by 2030. DOE, EIA, Annual Outlook 2009 Updated Annual Energy Outlook 2009 Reference Case with ARRA, Apr. 2009, available at www.eia.doe.gov/oiaf/aec/index.html.


97. Id. at 38.
B. Biofuels

Biofuels are largely produced domestically, a fact that is widely perceived to enhance our security relative to the use of imported oil.\footnote{Oxford Analytica, Biofuel Benefits Go Beyond Environment, FORBES, Apr. 10, 2006, available at www.forbes.com/2006/04/07/biofuel-benefit-ethanol-cx_0410oxford.html; DOE, EERE, Alternative Fuels and Advanced Vehicles Data Center (AFAVDC), Ethanol Benefits, July 10, 2009, available at http://www.afdc.energy.gov/afdc/ethanol/benefits.html.} Displacing some portion of petroleum derived fuel with domestic biofuels, however, will not substantially improve our energy and economic security. While the source of biofuels may differ from petroleum products, their use is nearly identical. Thus, a broad expansion of biofuel production, concomitant with the establishment of a policy that all vehicles operate on a wide range of liquid fuels, would essentially convert the domestic gasoline market into a market for liquid motor fuel in which consumers would generally be indifferent to the particular mixture of gasoline and other liquid fuels, so long as price was adjusted to account for the fuel’s actual energy content. Once the markets for the two fuels effectively merge, the problems that plague gasoline would also affect biofuels, as the price of domestically-produced biofuels will be a function of the price of gasoline.

The ultimate result is that, from an energy security perspective, domestic production of biofuels is functionally equivalent to domestic production of oil; it improves the U.S. trade deficit, reduces the magnitude of the wealth transfer, and increases investment into the United States, but does not address price volatility.

C. Fuel Efficiency

One of the few meaningful steps we can take to enhance our energy and economic security while continuing to use oil to power our cars is to increase the fuel efficiency of those vehicles, thereby reducing the petroleum intensity of the economy. As mentioned earlier, the petroleum intensity of the U.S. economy fell by forty-five percent between 1973 and 1995, chiefly due to improved fuel economy of passenger cars, the virtual elimination of oil as a fuel for electric power generation, and a shift to less energy-intensive economic sectors for growth. That improvement has reduced the importance of oil in the economy and mitigated some of the effects of higher and volatile oil prices. Yet much of that improvement was achieved prior to 1990 and due to increased automotive efficiency in response to the establishment of Corporate Average Fuel Economy (CAFÉ) standards in 1975.\footnote{See EPCA § 301, codified at 15 U.S.C. §§ 2001-12 (2006).} However, between 1987 and 2007, however, fuel economy for America’s LDVs remained essentially unchanged.\footnote{See EPCA § 301, codified at 15 U.S.C. §§ 2001-12 (2006).}


While EISA will result in substantial fuel savings, it does not address the underlying problem represented by our transportation network’s nearly complete dependence on oil. Tighter fuel standards can reduce, but not eliminate, the effects of volatility, because new business and
governmental budgets will assume increased efficiency. Nor would they insulate us from price spikes brought on by, for example, a new military conflict in the Middle East, though they can help by reducing the magnitude of the economic effects of price spikes when they do occur. We have seen, however, that merely reducing the fuel intensity of the economy will not eliminate the effects of high and volatile prices, which can in fact, be quite severe.

IV. TRANSFORMATIONAL CHANGE FOR THE LONG-TERM: ELECTRIFICATION

Working within the traditional paradigms, though helpful, cannot offer the transformative change required to end our nation’s dependence on petroleum. What is required is a new model: electrification of our nation’s short-haul ground transportation system.

GEVs offer the potential to address the two primary problems that electric vehicles (EVs) have faced in the past. The viability of EVs has long been limited by their range and the time needed to recharge their batteries. By combining an electric motor and gasoline engine into a single drive-train in a hybrid-electric vehicle (HEV), automakers were able to significantly improve gasoline mileage. Now that it is clear that an HEV can be modified to operate as a plug-in hybrid electric vehicle (PHEV), a vehicle that operates in part (or exclusively) as an electric car until its battery reaches its discharge limit, and then as a traditional hybrid until it can be recharged, the possibility of an ultra-efficient car is more attainable than ever before. Because the majority of vehicles travel fewer that forty miles a day, such a vehicle offers the opportunity for much of the oil savings possible from EVs without their restriction on range. The deployment of PHEVs, therefore, represents an opportunity to radically improve the fuel efficiency of the short haul transportation fleet, even prior to the deployment of EVs, reducing the petroleum intensity of the U.S. economy in the short-run. In doing so, they can offer a step towards the deployment of battery EVs, while improving our economic and national security.

Given our relatively recent discovery of the new opportunities provided by GEVs, one can reasonably ask why we should deliberately choose the path of electrification. Given that we have emphasized different approaches to our energy security at different times, including interest in hydrogen, biofuels and the electrification in just the past decade alone, why should we focus our effort, energy and investments in one particular technology that itself remains unproven? Does it not seem likely that five years from now we will believe that some other technology holds more promise than electrification, and that this too was just a phase?

A. Why the Government Should Intervene

Government intervention in the marketplace should generally be limited to those instances in which there is a market failure. There is a clear market failure in the world oil market. OPEC members engage in oligopolistic behavior by withholding oil supplies from the market. OPEC members, as a matter of practice, withhold production from the market despite the fact that their marginal cost of production was far below the market price of oil. Since the short-term demand curve is so inelastic, the revenue they lose by withholding volume may be made up for with higher prices.


104. See, e.g., James L. Williams, Oil Price History and Analysis, WTRG Economics, www.wtrg.com/prices.htm (last visited Sept. 15, 1009); See also, Martin Seiff, OPEC Oil Price Push May Threaten World Recovery, UPI, May 28, 2009, available at www.upi.com/news/issueoftheday/2009/05/28/OPEC-oil-price-push-may-threaten-world-recovery/UPI-7358124354589/ (For most non-OPEC producers, although the fixed costs of oil production may be very high, the cash costs are quite low, meaning that they always have an incentive to produce at or near maximum capacity. They cannot, therefore, counteract OPEC production cuts. OPEC members have therefore had the ability to exercise oligopoly power over the market even though they controlled less than half of all production).
If OPEC-like behavior were to occur within our borders, the government would intervene. Colluding with competitors to withhold product from the market is a clear violation of U.S. antitrust laws. Those laws, however, do not and cannot apply to sovereign nations. Geopolitical factors, violence, and instability represent additional factors within the global oil market over which the United States has no practical control, but that directly threaten our economy. In the alternative, if we were willing to internalize some of the external costs of oil use through a tax, such as security costs or carbon emissions, consumers might increase their use without additional government intervention. But political leaders are unwilling to support substantial fuel taxes to internalize such costs.

Unable to address supply, the government is left with no option but to address the demand side of the equation. The policy question is whether the government should take unprecedented measures to address this market failure. We believe that it must for all of the reasons above. Oil’s role in the economy is both unique and enormous, and the anticompetitive behavior undertaken by OPEC members significantly damages our national security, our foreign policy, and our economy. A policy that would penalize the oligopolistic behavior might seem the best policy, but even if it were available it would fail to address either the myriad of supply side problems outside of OPEC or the climate change problems associated with petroleum. Moreover, policies undertaken over the past thirty-five years to this point have largely failed. Our conclusion is that the government should adopt a policy to affirmatively promote electrification of the short-haul transportation sector of the economy not because we generally support government intervention in the market, but because, to paraphrase Winston Churchill, doing so may be the worst policy choice available, except for every other one.105

B. Balancing Energy, Economic and National Security

Electrification represents the best opportunity in the foreseeable future to enhance our energy, economic, and national security while reducing our nation’s dependence on oil. EVs, which are powered by batteries that are charged by connecting them to the electrical grid either at home, work, or elsewhere, operate without using oil. However, the viability of EVs has been constrained by the high cost of batteries, vehicle range and recharging time.

While we await the development of affordable electric vehicles, the combination of high oil costs, concerns about oil security and availability, and air quality issues related to vehicle emissions are driving interest in “plug-in” PHEVs. PHEVs feature a larger battery and a plug-in charger that allows the driver to charge the battery by connecting it directly to the power grid. When the battery is sufficiently charged, the vehicle may operate in a battery-depleting all-electric or blended mode. Once the battery is depleted to the point that it can no longer power the vehicle, the vehicle may then operate as a traditional HEV, powered by its gasoline-fueled engine and its electric motor, a mode of operation during which it would still generally achieve far greater fuel economy than a gasoline-powered vehicle. Therefore, PHEVs may derive a substantial fraction of their miles from grid-derived electricity, but without the range restrictions of pure battery EVs.

The average LDV’s trip is less than ten miles, and average households log less than thirty-five miles per day.106 According to data assembled by the U.S. Department of Transportation, vehicles driven forty or fewer miles per day log an estimated seventy percent of all vehicle miles traveled on weekdays and eighty percent of all vehicle miles traveled on

106. Oak Ridge Nat’l Lab, supra note 26, at Figs 8.3, 8.5.
Because the majority of Americans drive only relatively short distances each day, electric cars should be able to satisfy most driving needs even if they need to recharge more often than gasoline-powered vehicles need to be refueled.

In 2006, the Bush administration announced the U.S. Advanced Energy Initiative, which sought to develop a PHEV capable of traveling up to forty miles on a single electric charge (a PHEV-40). Such a vehicle could cut many drivers’ gasoline consumption in half if charged only at home, and as much as 80 percent if the driver had the capability to charge at work and elsewhere. Deployed at scale, this technology would provide significant oil savings, reducing the petroleum intensity of the economy and enhancing our economic and national security. Therefore, while EVs might represent complete freedom from petroleum, PHEVs can constitute a first step towards that goal, a step that will support the development of common infrastructure and technology, and which can, even as an interim step, significantly reduce the petroleum dependence of the U.S. economy. As of early 2010, production of PHEVs is essentially limited to demonstration vehicles and prototypes. But their initial deployment is on the horizon.

A path towards electrification is also supported by the fact that a substantial portion of the LDV fleet could be recharged using the existing electric infrastructure with important, but practical, upgrades. While the grid is generally capable of recharging the first PHEVs to hit the consumer market, as their numbers grow over time, it will be necessary to upgrade the infrastructure. But that investment is both manageable in cost and sound in policy. Most of the upgrades to the grid are either in the last few feet of wire (connecting existing wires to charging devices), or related to technological upgrades to transform the existing grid into a “smart grid,” upgrades that will likely occur whether or not GEVs are deployed. Moreover, the transformation will take place over time, creating an opportunity to explore the best way to fund any necessary upgrades, based, at least in part, on the business models that develop to support GEVs.

For the reasons stated above, we believe that the development of PHEVs represents a transformative event that signals the first step towards the wider deployment of a range of GEVs that will have radical implications for energy security. For those drivers who want the benefits of an electric vehicle without restricted range, a PHEV should meet their needs, almost immediately. In doing so, they can represent a cornerstone of our transportation future, one which will strengthen our economy and national security while enhancing our environment.

C. Why Electrification is the Best Approach

Electrifying the light-duty fleet is the best approach to reducing our dependence on oil for five reasons: using electricity promotes fuel diversity; electricity is generated from a domestic portfolio of fuels; electricity prices are less volatile than oil and gasoline prices; using electricity

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107. Id.
112. Id.
is more efficient than gasoline; and using electricity will facilitate reduction of greenhouse gas emissions. When it comes to powering the LDV fleet, electricity is superior to all other alternative fuels.

1. **Using Electricity Promotes Fuel Diversity**

   America’s vehicles currently are powered almost exclusively by fuel derived from crude oil. Electricity, in contrast, is generated by a diverse set of fuels. An electrically-powered transportation system, therefore, is one in which an interruption of the supply of one fuel can be made up for by others, even in the short-term, at least to the extent that there is spare capacity in generators fueled by other fuels, which is generally the case. Similarly, price volatility for one fuel is dampened by price stability in others. Lastly, the ability to use different fuels as a source of power increases the flexibility of an electrified light duty vehicle fleet. As our national goals and resources change over time, we can shift transportation fuels without overhauling our transportation infrastructure. In short, an electrified transport system would offer much greater control over the fuels we use to support the transportation sector of our economy.

2. **Domestic Fuels Generate Electricity**

   While oil supplies are subject to a wide range of geopolitical risks, the fuels that we use to generate electricity are generally sourced domestically. All renewable energy is generated using domestic resources. We are a net exporter of coal, from which we generate about half our electricity. Although we currently import approximately sixteen percent of the natural gas we consume, over ninety percent of those imports were from North America in 2008. More importantly, perhaps, is that we do not rely, yet, on a global natural gas market, which could expose us to the same types of vulnerabilities with respect to our natural gas supplies that we currently face with our oil supplies.

   Though we import a substantial portion of the uranium we use for civilian nuclear power reactors, forty-two percent of those imports, are from Canada and Australia. Moreover, although we rely more on imported uranium than other fuels in the electric power sector, over half of uranium purchases are pursuant to medium-term or long-term contracts that contain fixed price or base-escalated pricing provisions, which limit the effects of uranium price volatility. Further, the cost of fuel represents a much smaller portion of overall costs at nuclear plants than at other non-renewable energy power generating stations. Therefore, even when uranium prices are volatile, that volatility is not reflected in the price of power generated at nuclear plants.

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116. Id. at 102.
123. Id.
3. Electricity Prices Are Less Volatile Than Oil and Gasoline Prices

Electricity prices are significantly less volatile than oil or gasoline prices. As depicted in Figure 11, over the past twenty-five years, electricity prices have risen steadily but slowly. Since 1983, the average retail price of electricity delivered in the United States has risen by an average of less than two percent per year.\(^\text{125}\) Moreover, prices have risen by more than five percent per year only three times in that same time period.\(^\text{126}\) This price stability exists for at least two reasons.

First, the retail price of electricity reflects a wide range of costs, only a small portion of which is the underlying cost of the fuel. The remaining costs are largely fixed.\(^\text{127}\) In most instances, the cost of power plant fuel represents a smaller percentage of the overall cost of delivered electricity than the cost of crude oil represents as a percentage of the overall cost of retail gasoline.\(^\text{128}\) This cost structure promotes price stability with respect to the final retail price of electricity.

Second, although real-time electricity prices are volatile, sometimes highly volatile on an hour-to-hour or day-to-day basis,\(^\text{129}\) power prices are relatively stable over the medium-term and long-term. Therefore, in setting retail rates, utilities or power marketers use formulas that will allow them to recover their costs, including the occasionally high real-time prices for electricity, but which effectively isolate the retail consumer from the hour-to-hour and day-to-day volatility of the real-time power markets.\(^\text{130}\) By isolating the consumer from the price volatility of the underlying fuel costs, electric utilities would be providing to drivers of GEVs the very stability that oil companies cannot provide to consumers of gasoline.

\(^\text{125}\) *Annual Energy Review 2008*, supra note 18, at 261.
\(^\text{126}\) *Id.*
\(^\text{130}\) *Energy Brief*, supra note 229.
4. Use of Grid-Enabled Vehicles Reduces Carbon Emissions and Energy Consumption

Using GEVs reduces carbon emissions as compared to petroleum-fueled vehicles. While emission reductions are greater if the GEV is recharged using electricity generated from a renewable resource, several well-to-wheels analyses conclude that even vehicles powered by the current mix of fuel sources in the United States will produce substantially lower carbon emissions than conventional vehicles.

Well-to-wheels analyses examine emissions attributable to the use of a fuel from the time an energy source is extracted until it is consumed by a vehicle. In 2007, the Natural Resources Defense Council (NDRC) and the Electric Power Research Institute (EPRI) published a well-to-wheels analysis of several different automotive technologies fueled by a range of fuels commonly used to generate power. Its analysis concluded that using a PHEV would reduce carbon emissions as compared to a petroleum-fueled vehicle, even if all of the exogenous electricity used to recharge the PHEV was generated at an old (relatively dirty) coal power plant. Whereas a conventional gasoline vehicle would be responsible for emissions, on average, of 450 grams of CO₂ per mile, a PHEV that was recharged with power generated at an old coal plant would be responsible for emissions of about 325 grams of CO₂ per mile, a reduction of about twenty-five percent. Emissions attributable to the vehicle could be reduced to as low as 150 grams of CO₂ per mile if the exogenous power was generated at a plant without carbon emissions and ranged between 200 and 300 grams of CO₂ per mile if the power used were generated using any other fossil fuels and generation technologies. Therefore, the NRDC study demonstrated that no matter how the exogenous power consumed by a PHEV was generated, the overall level of emissions attributable to its operation would be lower compared to a conventional vehicle.

The results of the NRDC/EPRI study were consistent with an MIT study that examined the same issue. That study included an integrated well-to-wheels analysis of the different vehicle technologies to determine their relative level of carbon emissions and energy usage. The study concluded that PHEV-10s, PHEV-30s, PHEV-60s, and EVs use less energy on a well-to-wheels basis than petroleum-fueled conventional vehicles. While a conventional vehicle consumes 3.35 MJ/km of energy, the various types of PHEVs and the EV consume 1.16, 1.24, 1.32, and 1.79 MJ/km respectively. Their increased efficiency is reflected in their reduced level of carbon emissions, with the PHEVs and EVs emitting 84.3, 86.2, 89.8, and 115.6 grams of CO₂/km as compared to a conventional vehicle’s emission of 251.7 grams of CO₂/km. These two studies are consistent with the results of numerous other analyses that have examined this issue and found that the emissions profile of PHEVs and EVs is always superior to an ICE-powered vehicle. Accordingly, even if one powers a PHEV or EV with electricity generated...
at an old coal plant, overall carbon emissions will be lower than emissions from a traditional internal combustion engine. And to the extent that the electricity used to power the vehicle is generated at a power plant with fewer carbon emissions than an old coal plant, the carbon emissions profile of the PHEV or EV will improve as well.

5. Using Electricity Will Further Facilitate Reduction of Greenhouse Gas Emissions

The light-duty fleet is responsible for about 17.5 percent of U.S. greenhouse gas emissions. Running cars on electricity offers advantages in dealing with greenhouse gas emissions both at the demand (vehicle) level and at the supply (generation) level. In the absence of greenhouse gas emission regulation, the extent to which the use of GEVs reduces greenhouse gas emissions will be a function of the marginal generation fuel used by the utility generating the electricity. But as just explained in Section IV.C.4 above, no matter what fuel is used to generate the power consumed by GEVs, the vehicle is responsible for lower carbon emissions even if the power it uses is generated from coal.

But perhaps of greater importance is that once GEVs are in place, their emissions profile will continue to improve without any additional changes to the vehicle, as the emissions profile of our power generating plants improve. At the moment, there are over 250 million LDVs on the road, each burning fuel and emitting carbon dioxide. To achieve improvements in their cumulative emissions profile, improvements must be made in the emissions profile of each vehicle, one at a time. An electric-powered vehicle fleet, however, would circumscribe the challenge of reducing those carbon emissions to roughly 6,900 coal and natural gas generation plants that comprise over eighty percent of the nation’s power generating capacity. It is far simpler to sequester carbon or employ renewable energy at the power plant than the tailpipe. Indeed, analyses of the cost of greenhouse gas emission reductions routinely find that it is more expensive to reduce emissions from vehicles than from power plants. Therefore, proportionately more emission reductions will come from power plants that from vehicles. By shifting the emissions stream created by vehicles from their tailpipes to central power stations, we will both facilitate and lower the costs of combating climate change.

V. Evaluating the Competition

The perils of relying on fuel derived from crude oil are well known. Yet, there are only a limited number of possible alternatives to gasoline or diesel, including alternative liquid fuels, hydrogen, natural gas, and electricity. In addition to the reasons stated above, the nation should pursue a path of electrification because every other alternative fails to meet several critical objectives. The shortcomings of biofuels are addressed above. Neither of the two other potential alternatives, natural gas and hydrogen, is a compelling alternative to electrification.

A. Natural Gas

A growing chorus of analysts and observers point to natural gas as a potential game-changer in transportation because of its ability to satisfy multiple constraints, such as

sustainability, affordability, and security. While natural gas has a critical role to play in the United States’ energy future, it should not be as an alternative to petroleum in short-haul transport vehicles. Instead, for several reasons, natural gas makes the most sense in the electric power sector and, perhaps, in fleet vehicles with central refueling stations.

First, consuming natural gas emits about thirty percent less CO₂ than oil and forty percent less CO₂ than coal on an energy equivalent basis, a calculation that does not take into account the platform in which the fuel is consumed. On average, internal combustion engines currently achieve an efficiency rating of just twenty to thirty percent. Meanwhile, the fleet of U.S. coal power plants currently rates at thirty percent. The current gas fleet reaches roughly forty-three percent, and has been improving substantially as combined cycle gas plants are deployed in greater numbers. Current generation combined cycle plants reach efficiency levels of sixty percent, which, when combined with the lower carbon profile of gas, results in an emissions reduction of about seventy percent per unit of electricity generated versus the coal fleet.

Second, natural gas is currently a largely domestic fuel. In 2008, dry domestic natural gas production equated to eighty-nine percent of total natural gas consumed in the United States. In addition, ninety percent of U.S. gross natural gas imports came from Canada. Only a small fraction—about 1.5 percent—of U.S. gas supplies came from the global liquefied natural gas (LNG) market in 2008. This was just below the all-time high in 2007 of about three percent. It is important to note, however, that domestic natural gas prices have historically tracked international oil prices, which raises concerns about price volatility. During the summer of 2008, U.S. natural gas futures prices spiked as high as $13.58 per million Btu on the New York Mercantile Exchange (NYMEX). Figure 11 plots NYMEX oil prices versus natural gas prices on a Btu equivalent basis since 1994.

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151. Authors’ calculations assuming natural gas contains 45% less carbon than coal and comparing a combined cycle gas turbine (60% efficiency) to the existing coal fleet (32% efficiency).
153. Id. at 191.
156. DOE, EIA, Natural Gas Navigator: Daily Natural Gas Futures: Contract 1, tonto.eia.doe.gov/dnaw/ng/hist/rngc1d.htm (last visited, Sept. 11, 2009) [hereinafter, Natural Gas Navigator].
Finally, mounting evidence suggests that the United States may have an abundance of domestic natural gas. Just a few years ago, most analysts had concluded that U.S. gas production was in an irrevocable free-fall.\(^{158}\) By early 2008, however, U.S. gas markets were being completely reshaped by advances in the recovery of gas resources from unconventional reservoirs like shale gas, coal bed methane, and tight gas. The estimates vary widely, but consensus seems to be settling on undiscovered technical recoverable reserves well in excess of 1,000 tcf. In June of 2009, the Potential Gas Committee at the University of Colorado estimated that total U.S. reserves—proved, probable, possible, and speculative—were in excess of 2,000 trillion cubic feet.\(^{159}\) By way of comparison, BP reports that current U.S. proved gas reserves are just over 200 tcf.\(^{160}\) One look at Figure 12 tells the story.

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158. See e.g., ROBERT L. HIRSCH, PEAKING OF WORLD OIL PRODUCTION: IMPACTS, MITIGATION, AND RISK MANAGEMENT 33-36 (National Energy Tech. Lab. 2005).


With conventional production in rapid decline, shales, coal bed methane, and tight gas are expected to keep lower forty-eight onshore production steady for the next two decades. Yet, at least two significant questions exist regarding the future of unconventional gas remain.

To extract unconventional natural gas, producers must over-pressurize the source rock, creating multiple fractures in which gas supplies can accumulate. The fracturing process is typically achieved using fluids like water under high pressure along with viscosity-enhancing chemical agents. In addition, producers typically inject a proppant, or propping agent, into the well in order to keep the fractures from closing when pressure is reduced.161

As unconventional gas production grows more common, some externalities of hydraulic fracturing may be coming into focus. Concerns about the impact on water wells spurred debate in Congress in 2009, and there is a growing call for EPA to start regulating hydraulic fracturing to protect drinking water. Further, the broader issue of freshwater access is likely to emerge as a challenge for the industry, particularly in the Western United States. A typical shale well using hydraulic fracturing consumes 3.4 million gallons of fresh water.162 Water treatment options certainly exist, but recycling is not currently the norm.163

The second question mark for unconventional gas is the cost of production—or perhaps more importantly, the price of natural gas required to support ongoing capital expenses in unconventional production. Natural gas production wells have steep decline rates. According to published company reports, the first year decline rate for a typical well in the Haynesville shale play is eighty-one percent; the second year rate is thirty-four percent and the third year rate is twenty-two percent.164 Bernstein Research report recently estimated that Haynesville operators needed a natural gas price of nearly $8 per million Btu to earn a nine percent return on average capital employed.165 Throughout 2009, natural gas prices have been far below this, and the pressure on shale operators to postpone new drilling has been immense.

Setting aside these challenges, the real dilemma seems to be how best to use natural gas. It seems illogical to take natural gas out of combined cycle gas plants and burn it in internal combustion engines. A comparative energy efficiency analysis of the “tank to wheels” conversion of a

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given amount of natural gas to vehicle miles with competing technologies—such as PHEVs—demonstrates this shortcoming. A current generation CNG vehicle gets approximately 28 miles per gallon of gas equivalent (GGE)—the mileage of the Honda Civic GX. There are 127 cubic feet (CF) of natural gas per GGE. One thousand cubic feet (mcf) of natural gas will, therefore, provide about 220 miles of vehicle range when burned in a CNG internal combustion engine. Comparatively, the same one thousand cubic feet of natural gas will provide 457 miles of vehicle range, or 0.46 miles per cubic foot of natural gas, when it is burned in a state-of-the-art combined cycle natural gas plant that provides electricity to a plug-in hybrid electric vehicle. In other words, a PHEV powered by electricity generated in an efficient natural gas generator is about twice as fuel efficient as the NGV. While this is a simplification, this basic efficiency question is one that should be key to determining whether NGVs or electric vehicles are more likely to form the basis of a post-petroleum transportation sector.

There are also substantial drawbacks in distribution of natural gas for NGVs and in the demand side—vehicles—as well. Use of natural gas for surface transportation would require the development of significant new infrastructure that is difficult to justify. While both NGVs and GEVs will require new infrastructure for refueling or recharging, they face different barriers when it comes to refueling. The electric grid already reaches nearly every building in the United States. Although some grid upgrades and the provision of public charging infrastructure would be necessary, the underlying infrastructure is already in place, and a substantial portion of grid improvements will be made in any event as part of the evolution of the smart grid. In contrast, creating a refueling infrastructure for natural gas powered cars would be a significant undertaking, especially in those regions of the United States that do not already have networks for delivery of natural gas to residences and businesses.

Furthermore, refueling stations might be needed more than gas stations for a similar number of vehicles (NGVs tend to have a shorter range than gasoline or diesel fueled vehicles because at ambient temperature, methane is not a dense fuel). Vehicle range, therefore, will always be a challenge for natural gas, which is much better suited to combustion in stationary power plants.

Finally, using natural gas means investing significant resources while remaining reliant on a single fuel. Setting aside all other propositions, this simple fact disadvantages NGVs to electrification. Investing in a technology that allows for the diversification of fuels instead of the concentration of risk in another fuel is a better way to enhance our energy and economic security.

B. Hydrogen

In the early part of this decade, there was a sense that hydrogen-fueled vehicles would provide the answer to our energy security problems. There was significant public discussion and excitement about the development of a hydrogen economy. Yet, over time, much of that excitement abated as attention turned first to biofuels and then to electricity.

Because hydrogen-powered vehicles use electric drive-trains, they share many components with GEVs. In fact, as fuel cell technology progresses and the cost of fuel cells fall, hydrogen vehicles may be a successor or supplement to battery-powered electric vehicles. Yet, at the present time, however, electrification is a more viable and cost-effective proposition.

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166 Christine & Scott Gable, Fuel Energy Comparisons: Gasoline Gallon Equivalents (GGE), for About.com
167 1,000 cubic feet of natural gas equals 7.87 GGE. If the Civic gets 28 miles per GGE, the vehicle range is about 220 miles.
168 Assumes a natural gas plant heat rate of 7000 Btu per kWh, which generates about 142 kWh of electricity, 20 percent line loss and PHEV efficiency of four miles per kWh. (1,000,000 BTU/7,000 BTU per kWh)*0.80*4 miles per kWh).
169 Annual Energy Outlook 2009, supra note 3, at 43.
Commercialization of hydrogen-fueled vehicles faces several challenges that are greater obstacles than those facing battery-powered, grid-connected vehicles. First, there is no clear ability to manufacture sufficient quantities of hydrogen to fuel the automotive fleet. The United States currently manufactures about 9 million metric tons of hydrogen per year for industrial use. That volume is the energy equivalent of about 190 million barrels of oil, less than a ten day supply for the nation. To replace just the portion of oil that is used for short-haul transportation, the nation would have to increase its production of hydrogen by over thirty times. Moreover, most of the hydrogen produced in the United States is produced from natural gas, and we believe that rather than diverting a substantial portion of the nation’s natural gas to produce hydrogen for vehicles, the gas resources should dedicated to power generation, which is a more efficient use of the fuel. While hydrogen can be produced by electrolyzing water, that process is particularly expensive, and the faster you make the hydrogen, the more energy the process consumes. In fact, to produce enough hydrogen to replace the gasoline we consume today would take more electricity than is currently generated in the entire nation.

Second, reliance on hydrogen would require the construction of an entirely new infrastructure to distribute it to consumers. Third, the use of hydrogen raises several safety issues. Hydrogen is highly flammable and easily ignitable. Also, because hydrogen molecules are so small, they leak easily. Moreover, the gas is clear and burns invisibly, making it difficult to tell if it has leaked or is on fire. Fourth, hydrogen fuel cells are significantly more expensive than petroleum or GEVs. While batteries currently make GEVs more expensive than conventional gasoline-powered ones, fuel cells are more expensive, though how much so is unclear because having never been produced at scale it is difficult to estimate manufacturing costs. Nevertheless, most experts agree that hydrogen fuel cells seem to be much further away from commercialization than batteries.

Finally, perhaps the largest obstacle to the development of a hydrogen-fueled light-duty fleet is the fact that hydrogen itself is much more expensive than electricity, and likely always will be. Hydrogen is not a source of new energy, but a carrier of energy processed from either natural gas or with the use of electricity. The process of producing hydrogen, preparing it for transport, distributing it, and converting it back into electricity is itself energy intensive and can consume as much as seventy-five percent of the initially available energy. In contrast, transmission losses from the distribution of electricity, the same electricity that can be used to either make hydrogen or power cars directly, have averaged just below ten percent in recent years. While it is difficult to predict the nature of future technological developments, it may prove to be very difficult for hydrogen to overcome this price disparity.

173. Worldwide, approximately 48% of hydrogen is produced from natural gas, 30% from oil, 18% from coal and the remainder from electrolysis. Romm, supra note 309, at 72.
174. Id., at 75.
175. Id. at 76.
176. Id. at 105.
177. Id. at 105.
178. Id. at 106.
180. Id.
VI. THE PATH FORWARD

Given the immense costs that oil dependence imposes on our economy, and the shortcomings of biofuels, natural gas and hydrogen as workable alternatives to petroleum as a fuel for the light-duty fleet, electrification is the best opportunity to address the nation’s oil dependence. Because of the diverse interests of many participants in the electric and automotive industries, however, it will be difficult for all of the relevant parties to come together to develop an efficient strategy for the wide scale deployment of GEVs. Given the great importance of this issue to the nation, we believe that the government must help facilitate this process.

A. Deployment Challenges

While deployment of GEVs will be a complex process with a myriad of challenges, there are four main challenges that must be addressed to facilitate GEV deployment:

• Battery performance must improve and costs must be reduced;
• Charging infrastructure must be deployed;
• Utilities must upgrade systems to accommodate GEVs; and,
• Consumers must accept vehicles whose ownership and operation is different than existing vehicles.

First, battery technology must be improved to reduce the cost, improve the energy density, and extend the life of existing batteries. Congress and President Obama took significant steps forward in this regard with the American Recovery and Reinvestment Act of 2009. Yet this one time expenditure is enough. Reducing the cost of batteries to consumers is the most critical step to make the total cost of ownership of a GEV competitive with a traditional internal combustion engine powered vehicle. It will be necessary to dedicate more funds to this effort.

Second, recharging infrastructure must be deployed. While home charging will be important for achieving high rates of GEV deployment, public charging is arguably more important for moving past the very early stages of GEV adoption. Drivers are accustomed to being able to fill up using the ubiquitous gasoline infrastructure developed over the last 100 years. Inability to do so will generate significant hesitancy—range anxiety—for many drivers, and may reduce overall efficiency of PHEVs. Especially early on, a readily available network of Level II public charging facilities may assist in minimizing range anxiety. It should be supplemented by public Level III chargers capable of providing a high voltage “fast charge” that can charge vehicle batteries in minutes rather than hours. Level III facilities will allow a fast charge for a driver who forgot to or was unable to charge overnight, or who is travelling beyond the range of the vehicle without the time to stop and wait for a slower charge.

GEV advocates have suggested that private firms should install public charging infrastructure. However, a profitable business model for public charging infrastructure has not been demonstrated. The only way for consumers to recover the cost of an expensive battery is to defray it over time with comparatively cheap electricity. This upper bound on the price consumers are willing to pay to charge their vehicles, and the availability of home charging, limits what consumers will be willing to pay for public charging. Moreover, at the moment, the payback period on public chargers seems to far exceed the life of the equipment. Unless this challenge is addressed, it is difficult to see how public charging infrastructure will be deployed at scale.

Third, GEVs represent an enormous opportunity for the nation’s electric utilities and electricity market retailers in both regulated and competitive electricity markets. Light-duty vehicles today are the largest energy consumers in the transportation sector, which is the most significant sector of the economy that relies on some form of energy other than electricity. The nation currently consumes about 4.1 trillion kWh of electric power each year. If 150 million light-duty GEVs each consume 8 kWh of power a day, that would represent an additional 440 billion kWh of power consumed each year.

Depending on the manner in which that power is consumed, there will be relatively little need for additional generating capacity at first; much of the vehicle charging can take place during off-peak hours when significant generating capacity is typically idle. Moreover, by flattening the load curve and increasing the utilization rates of existing power generating plants, utilities should be able to spread their fixed costs over a greater volume of power and reduce maintenance costs, perhaps lowering costs for all of their customers.

While adding millions of GEVs as customers is a great opportunity for utilities, it will require them to address several issues. Some utilities will have to upgrade distribution level transformers to ensure reliable service to homes and other charging locations. Along with investments in smart meters and smart charging software, utilities will need to invest in IT infrastructure to support a range of smart grid applications including GEVs. Further, both utilities and electricity market retailers will need new rate plans to reliably serve GEVs.

Fourth, new innovations often require many years to become widely adopted in the marketplace. Making a successful entrance into a competitive automobile market established a century ago is no easy task. Traditional gasoline-electric hybrid vehicles have so far failed to overcome the hurdles, accounting for approximately 3 percent of new vehicle sales in 2008. To a degree, hybrids have demonstrated their potential among early adopters and with automobile manufacturers. However, without a change in consumer attitude, widespread consumer acceptance of electrification remains a difficult proposition. The market for these technologies will only reach a “take-off” point if they can offer a compelling alternative to conventional IC engines on either cost or performance grounds.

B. Deployment Policies

1. Electrification Deployment Clusters (Ecosystems)

To achieve wide-scale deployment of grid-enabled vehicles, the government should undertake a program to establish electrification ecosystems in a number of American cities. In the GEV context, an electrification ecosystem is a community in which each of the elements necessary for the successful deployment of grid-enabled vehicles is deployed nearly simultaneously in high concentrations. By ensuring that vehicles, infrastructure, and the full network of support services and technologies arrive in well-defined markets together, ecosystems will provide an invaluable demonstration of the benefits of integrated electrification architecture. Electrification ecosystems will:

- Demonstrate Proof of Concept: By demonstrating the benefits of grid-enabled vehicles in a real world environment, ecosystems will make consumers aware of the tremendous potential of electrification.
- Drive Economies of Scale: Electrification ecosystems will allow market participants to take advantage of economies of scale, particularly with regard to charging infrastructure. They will also drive demand for grid-enabled vehicles at a rate that is likely to be far in excess of the rate if the vehicles are simply purchased by early adopters scattered around the United States.
Facilitate Learning by Doing: Electrification ecosystems will play a feedback role in the GEV innovation process. Data aggregation and concentration of efforts will be informative to new innovation.

Ecosystem cities should be chosen by the Department of Energy on a competitive basis similar to the Department of Education’s recent “Race to the Top” program. Successful bids would ideally be submitted by a coalition of entities in a community reflecting wide support for GEV deployment. Such coalitions should reflect the support of: state and local government, the applicable Public Utility Commission, local utilities, large local employers, and others.

A phased process will maximize the effectiveness of the electrification ecosystem concept. Phase one ecosystems should each reach stock penetration rates of 50,000 to 100,000 vehicles within four to five years. Massing that many vehicles in a limited number of communities will prove that GEVs can work at scale and allow researchers to generate a large enough data set to evaluate GEV usage patterns.

Phase one of the ecosystem deployment strategy is intended primarily as a proof of concept and data collection exercise. The goal is primarily to take advantage of economies of scale in a handful of cities to deploy relatively large numbers of GEVs in order to build consumer confidence and accelerate the learning process. The lessons learned in those communities will help other cities determine how much charging infrastructure is necessary and where it should go, when drivers will charge their vehicles, how much they are willing to pay to charge their vehicles, to what extent their charging patterns will be affected by the price of electricity, and what business models might be most successful.

Phase two of the deployment strategy would expand deployment to between 20 and 25 additional cities. At the same time, as the GEV concept is proved, battery costs decline, and infrastructure deployment becomes more efficient, government support for ecosystems also should decline.

The government should offer a package of benefits to communities that are selected as ecosystems. Purchasers of GEVs registered in ecosystems should be eligible for tax credits sufficient to cover nearly the entire incremental cost of the vehicles over similarly equipped internal combustion engine vehicles. This will help direct sales of GEVs to the ecosystems. Utilities should be eligible for tax credits to upgrade their systems to support GEVs and entities deploying public charging infrastructure should be eligible for large subsidies.

2. Other Policies

Developing ecosystems alone will be insufficient to facilitate GEV deployment. Other policies will be required, including, but not limited to programs to help bring battery costs down and to transform the necessary manufacturing infrastructure. To help drive scale and promote the manufacture of automotive grade lithium-ion batteries, Congress should establish a tax credit for the purchase of automotive grade batteries for stationary uses. Lithium-ion batteries are suitable for use in stationary applications, but too expensive. Incremental demand from utilities and for other stationary applications could help expand battery supply chains across a number of inputs and could help develop the scale of production needed to reduce the cost of GEVs.

To reach the goals put forward in this report, GEVs will need to become an increasingly significant portion of new U.S. vehicle sales over the next 10 years. Even as battery technology advances, infrastructure is deployed, and consumer attitudes shift, the demands on automotive original equipment manufacturers (OEMs) to retool facilities will be daunting. Currently, the
cost to retool an automotive assembly line with an annual capacity of 100,000 vehicles is estimated at approximately $500,000,000. These are non-trivial costs, especially in a time of economic instability. To enable the industry to reach the scale required to deploy electric vehicles in large numbers, additional federal assistance for retooling and other capital outlays will be necessary. Any automotive OEM with U.S. facilities should be eligible.

Finally, as automotive batteries reach the end of their useful life in a GEV, substantial opportunities exist for secondary applications. Enabling consumers to capture the residual value of automotive battery purchases could significantly offset the higher upfront cost of purchasing a grid-enabled vehicle. Unfortunately, the value of automotive batteries for secondary applications is highly uncertain today. This is a sequencing problem: markets for the first generation of used batteries have not developed because there is not a meaningful supply of used batteries, and cannot be until the first generation of batteries used reach the end of their useful life in GEVs. As the first generation of GEV batteries enters the secondary use market, a value will surely be derived. If nothing else, the recycling of battery raw materials alone will generate a notional return on investment for consumers. More likely, battery values will be well in excess of the recycling value as their use in the electric power sector and secondary vehicle markets drive demand. In the meantime, however, markets are likely to undervalue lithium-ion batteries due to their inability to assess the risk of an unknown technology.

Therefore, Congress should authorize the DOE to establish a program to guarantee residual value for large format automotive batteries. Compared to the uncertainty of battery research and development, establishing a minimum residual value would effectively buy down the cost of batteries immediately. Moreover, while the ultimate cost of such a program is dependent on the actual residual value of batteries, may not impose any meaningful costs on the government, if the actual residual value is higher than the minimum guarantee.

VII. CONCLUSION

Transportation electrification offers the most promising pathway to a more secure energy future, but there should be no mistaking the magnitude of this undertaking. The existing oil infrastructure spans the globe, was created over the course of a century, and is worth trillions of dollars. Replacing it with an alternate infrastructure that delivers similar functionality will take decades, which should not be surprising given that new cars routinely last for fifteen years and new power plants are built to operate for fifty years or more.

Without committing to electrify at least parts of our transportation system, the burdens of oil dependence on our economy and our national security are only likely to grow. In the past, we have failed to commit to a particular technology path, whether because of uncertainty as to the correct path or discomfort about the government making such critical decisions instead of the marketplace. That approach has not worked.

A careful examination of the relative merits and pitfalls of each technology has demonstrated not only that electrification offers numerous advantages over oil, and that it has many advantages over the other most promising alternatives, but that none of the other alternatives even offers the promise of a viable solution. We have chosen electrification of the vehicle fleet because we believe that it will work and because we are certain that the alternatives, including maintaining the status quo, will not.

Once this is understood, the nation can commit itself to solving those challenges that must be addressed for electrification to work and to ultimately connecting the nation’s light-duty fleet to the electrical power grid. In our estimation only this can close the chapter of U.S. dependence on foreign oil.