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National Security, Energy Security, and a Low Carbon Fuel Standard

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About the Author

Mr. Jeff Kueter works with scientists to help improve the understanding and awareness of complex scientific topics to the public, the media, and policy makers. Focused on national security and the environment, Mr. Kueter manages the day-to-day operations of the George C. Marshall Institute, authoring its policy papers and analyses and engaging the public and the policy making community.

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Executive Summary

The principal aim of a low carbon fuel standard is improving environmental quality by reducing the carbon content of transportation fuels. However, proponents of this approach also claim the standard will encourage the development and use of new kinds of transportation fuels to displace imported petroleum. Reducing imports is said to improve U.S. national and energy security by decreasing dependence on volatile regions and hostile governments.

A reduction in imports will not produce the national security benefits sought. The interconnectedness of the world's energy marketplace, and indeed, the global economy, prevent the kind of insulation from perturbations in the price of oil desired by advocates of energy independence. The United States will remain vulnerable to oil price and supply shocks regardless of fluctuations in its imports so long as it trades with countries that purchase petroleum off the world market. A sharp rise in prices that undermines the economic health of Europe or China, for example, will negatively impact the U.S. economy. Further, U.S. national interests in the Middle East, whose instability is most commonly cited as justification for reducing oil imports, are more complex than the simple consumption of petroleum. Concerns about terrorism, the security of Israel, the peace process, global and regional power projection, and international leadership all suggest that continued engagement will be the norm for the U.S. for years to come, regardless of oil import patterns.

If the national security rationale for a low carbon fuel standard is dubious, the consequences of its imposition are not. The standard would restrict U.S. use of oil sands from Canada because of their high carbon lifecycle. The Canadian oil sands represent reserves equivalent to nearly one-quarter of projected U.S. transportation fuel needs in 2030. Presently, the U.S. consumes virtually all of Canada's petroleum exports. Under a national low carbon fuel standard, those exports would flow elsewhere with consequences for U.S. energy security as well as harmful environmental outcomes. The standard also would deter further exploitation of the oil shale resources found in the western United States. Oil shale, like the oil sands, has a high carbon lifecycle that would not meet the standards sought by proponents of a low carbon fuel standard. Unlike the oil sands, there has been only sporadic investment in the technical base and related infrastructure needed to productively exploit the oil shale reserves. If a low carbon fuel standard is imposed, little incentive would remain to make further investments in this area. Doing so means that the United States will have elected to eschew the development of deposits estimated to hold enough oil to meet current U.S. import levels for the next 110 years. Enacting a policy that inhibits the use of ample and readily available resources hardly improves energy security, which is commonly judged as improving the reliability of supply through diversification of sources and fuels in an affordable manner. In fact, that policy is rightly judged as weakening energy security.

The likely result of a low carbon fuel standard is an expansion of biofuels. At present, corn-based ethanol is the only alternative fuel ready for the market not requiring major infrastructure development or introduction of new vehicles. More advanced biofuels are decades away from commercial use and face significant scientific, technical, and commercialization obstacles before they will be available for widespread consumption. Bio-based fuels have lower greenhouse gas lifecycle emissions compared to unconventional petroleum products, with debate ongoing about their advantage relative to conventional petroleum. There are other consequences of shifting agricultural commodities into transportation fuel use, notably the effects on water and soil quality and food security, which must be weighed against the perceived advantages of lowering greenhouse emissions and the limited availability to meet projected transportation fuel needs.

The assertion that a low carbon fuel standard will improve U.S. security is not as clear cut as its proponents would lead the American public to believe. Reducing imports of petroleum will not prevent future incidents of international terrorism, reduce U.S. vulnerability to price and supply shocks, or preclude U.S. involvement in the politics of the Middle East. The real consequences of the policy—shifting Canadian exports to other nations and hindering the development of domestic energy supplies—actually reduce security.

Introduction

In approving California's low carbon fuel standard in January 2007, Governor Schwarzenegger justified the decision on the grounds that "being dependent on one source of fuel leaves our economy and our national security vulnerable to price shocks and global events beyond our control."[1] The quest for reduced dependence on imported petroleum is hardly a new one, but seeking reductions of greenhouse gas emissions and petroleum use through a national low carbon fuel standard has implications for U.S. economic and national security unacknowledged by the Governor of California and other proponents. By negatively treating high carbon fuels, effectively retarding their development, and the investment in the underlying technology needed to utilize them at some future date, a low carbon fuel standard raises significant unintended consequences for those concerned about U.S. national security and energy policy. Further, the claims that a low carbon fuel standard will somehow insulate the United States from price shocks or other global events that impact the stability of energy markets are overstated.

In short, the notion that independence from imported petroleum will reduce U.S. vulnerability to events in the Middle East ignores the realities of the energy market and how its changes impact U.S. foreign policy and economic well-being.[2] Furthermore, a low carbon fuel standard enacted in the U.S. may very well erode energy and national security by preventing the exploitation of readily available resources with little positive environmental return. By promoting further expansion of biofuels, a low carbon fuel standard puts additional strain on agricultural ecosystems and complicates the markets for foodstuffs worldwide.

When considering the merits of a low carbon fuel standard, the public should consider the matter broadly and make certain to critically examine the offered benefits with the known and potential consequences.

The Quixotic Quest for Energy Independence

On October 17, 1973, the Organization of Petroleum Exporting Countries' (OPEC) Arab members launched an oil embargo against the United States. The resulting "oil shock" caused President Richard Nixon to call for energy independence "to ensure that by the end of this decade, Americans will not have to rely on any source of energy beyond our own."[3] Nixon's salvo, dubbed Project Independence, was overwhelmingly aimed at displacing foreign oil imports with increased domestic energy production, efficiency, and conservation. Energy independence has been called for by every president since.[4] More recently, President Bush famously said "America was addicted to oil" in his 2006 State of the Union address and set a goal to reduce Middle East oil imports 75 percent by 2025.

The U.S. has never come close to achieving energy independence, yet the desire for independence has powerful political resonance. During the 2008 presidential campaign both the Republican and Democratic presidential candidates, John McCain and Barack Obama, claimed achieving energy independence was a top policy goal.[5] As a candidate, President Obama said he sought the elimination of imports from the Middle East and Venezuela in 10 years, to be achieved in part through the imposition of a national low carbon fuel standard.[6] Organizations on both sides of the political spectrum justify policies to reduce imports on the grounds that buying foreign oil helps fund anti-American terrorist activities and prop up unstable and dictatorial regimes.[7] Over time, the pursuit of these goals is tempered by the fact that the American public's focus on energy policy ebbs and flows with the price of energy they pay. As one commentator said, "For many Americans lower gasoline prices and lower home electric bills are the only energy independence they want or need."[8] Stable, low prices may be all that the American public seeks or demands from its energy policy.

Nevertheless, policy makers continue emphasizing the need to wean the U.S. off imported petroleum. By linking this objective with the environmental goal of combating climate change, proposals for reducing petroleum consumption, including a national low carbon fuel standard, are gaining political strength. The facts of American energy use and trade patterns suggest the challenge of matching actions to the rhetoric will be great. The United States imported roughly 12 million barrels of petroleum products per day (MMbd) during 2007, while consuming close to 20 MMbd.[9] The gap between domestically supplied production and consumption (or demand) for petroleum products has widen appreciably since the mid-1980s as the rate of consumption increased while supplies from domestic production fell. This gap gives rise to the argument that U.S. dependence on imported petroleum is a problem that must be solved. Political leaders, intellectuals, and the media lend credence to the argument when they cite this import statistic without further examination of how the international petroleum market operates and critically evaluating the probable impacts of proposals to reduce imports, including the low carbon fuel standard.

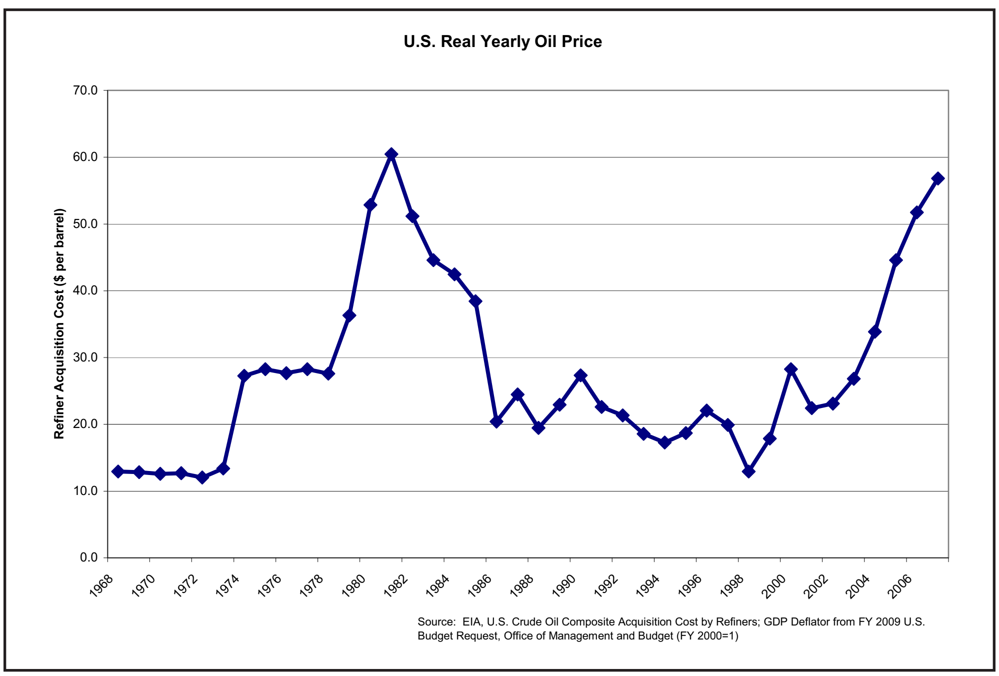
The national security case in favor of a low carbon fuel standard rests on two assumptions. The first claims that imports leave the U.S. vulnerable to supply and price disruption, which may harm the general economy. The second is that U.S. purchases of crude oil may undermine its security by providing financial resources to states that wish to harm to the United States or support groups that do.

Examining Energy Vulnerability

How vulnerable is the United States to price and supply shocks? And, more importantly, would reduction in the demand for imported petroleum lessen that vulnerability or the impact of said shocks were they to occur?

As a critical cog of the global economy and the world's largest consumer of petroleum, the United States feels the consequences of changes in the price for that commodity, positively or negatively. The United States has experienced five large oil price shocks in the past several decades (1973-74, 1979-80, 1990-91, 1999-01, and 2003-07). The most recent presents the most severe case, with prices jumping from $50.77 per barrel (refiner acquisition cost) in January 2007 before peaking at $129.03 per barrel in July 2008.[10] Since reaching that high, prices have slipped to $54.44 in November 2008, which returns the prices to the range they were in before the run-up began. Figure 1 presents price data per barrel of oil paid by U.S. refiners on an annual basis. Data for 2008 is not final, but a preliminary estimate (not shown here) projects a further increase in the trend line.[11] Aside from the large spikes, oil prices have remained remarkably stable. In the nearly 20 years between 1986 and 2003, oil prices floated in a range between $15-30 per barrel.

Figure 1



In each of these cases, the short-term increase in price proved disruptive and burdensome to the economy, with measurable effects on gross domestic product and other economic variables. As an important variable in economic growth, a sharp increase in the price of energy should be expected to have this kind of effect. However, as the energy intensity of the economy has fallen steadily over the past several decades, the ability of energy price shocks to wreak long-standing harm on the economy has waned.[12] Still, because producers cannot easily lower other input prices, an increase in the price of crude oil generally will cause prices to rise and most of that increase is passed on to the consumer.[13] The end result of an oil price shock is the reallocation of resources that often provides advantages to oil producers, but has no real long-run impact on the nation's productive capabilities.

The petroleum market is an international one where the price is affected by a number of variables, only some of which can be controlled or influenced by the United States. Oil sold on that market is fungible and world demand is rising. The International Energy Agency recently concluded that global demand for oil will jump from 85 MMbd in 2007 to 106 MMbd in 2030 and "all the increase in world oil demand comes from non-OECD countries," paced by India and China, who will have growth rates above 3.5 percent per year on average.[14] Chinese consumption is projected to more than double (from 7.5 MMbd in 2007 to 16.6 MMbd in 2030) as will Indian consumption (from 2.9 MMbd in 2007 to 7.1 MMbd in 2030). In total, non-OECD nations are projected to increase their demand for oil by more than 20 MMbd between 2007 and 2030 (from 34.9 MMbd in 2007 to 57.7 MMbd in 2030). OECD consumption is expected to drop approximately 2 MMbd over the same period with Japan accounting for 50 percent of the decline.[15]

Theoretically, then, if the U.S. were to reduce its consumption of imported oil to zero, would the U.S. economy be insulated from a rise in world oil prices? The answer is no. First, the global economy is interconnected, with the U.S. acting as the largest importer of goods. To the degree that energy costs are embedded in any of those goods, whether it be petroleum byproducts in the good itself, petroleum used in the manufacture or production of the good, or its transport from supplier to factory to consumer, those costs will be passed on to the American consumer in the final price of imported goods. Imported goods would be more expensive, reducing the purchasing power of the U.S. consumer.

Second, the global energy market for oil is interlinked. Contrary to popular belief, the U.S. remains a significant producer of oil. The United States produces 5 MMbd and the EIA projects U.S. domestic supplies will increase to approximately 9-10 MMbd by 2030.[16] U.S. oil reserves as of January 2008 stood at 21 billion barrels.[17] North American reserves were judged to be substantially higher, at 211 billion barrels.[18] As the EIA notes, reserve numbers frequently are underestimated because they can not accurately account for production beyond the intended lifespan of a field or technological or other developments that extend the life of a field. For instance, in 1998 the U.S. reportedly had proved reserves of 22.1 billion barrels, which is only 1 billion more than what is reported today despite more than 30 billion barrels having been consumed from U.S. sources in the intervening decade. If world oil prices rose, U.S. oil producers would have every incentive to sell their oil on the international market. This diversion of U.S. supplies from domestic to foreign markets would result in rising domestic costs for petroleum.

Third, in the face of rising projected demand and the limited availability of alternative fuels, the assumption that the U.S. could reduce its demand for imported petroleum significantly is unsupportable. As will be discussed below, projections from both the Energy Information Administration and the International Energy Agency show slight declines in U.S. demand for imported petroleum through 2030, even as total consumption continues to rise. So long as the United States remains a large consumer of imported petroleum, rising oil prices will impact the U.S. economy for years to come, even with increased use of alternative fuels or electric vehicles.

Imports as a National Security Concern

The other question that must be considered when evaluating the energy independence debate is the whether the United State is undermining its own security by purchasing petroleum from nations that sponsor terrorism or by involving the U.S. in the politics of volatile regions in order to maintain the free flow of oil.

Liberal and conservative advocates for a low carbon fuel standard and the move toward energy independence argue that U.S. expenditures on imported oil finances Al Qaeda and other terrorist groups. During the height of the recent oil price spike, then-candidate Obama said: "The nearly $700 million a day we send to unstable or hostile nations also funds both sides of the war on terror, paying for everything from the madrassas that plant the seeds of terror in young minds to the bombs that go off in Baghdad and Kabul."[19]

Frank Gaffney, head of the Center for Security Policy and a leading voice in the call for energy independence, popularized the argument in the wake of the September 11 terrorism attacks. Typical of his argument is a January 2007 statement sent out by Set America Free, a group he founded to pursue energy independence policies. Gaffney said: "some of the hundreds of billions of dollars we transfer each year to various petroleum-exporting nations winds up in the hands of terrorists. This is not simply an addiction. It is a death wish."[20]

It is impossible to prove with any certainty whether proceeds of U.S. oil purchases support terrorists. Nor can it be proven with any certainty whether resource availability is a constraint on terrorist activities, recruitment, or success. The credibility of the moral imperative—we are funding our own enemies—has to be judged against the reality of U.S. import patterns, the operation of the international petroleum marketplace, and likely impact of any policy to reduce imports.

...even if it imported less, the United States remains vulnerable to supply and price shocks so long as it remains connected with the global economy. Fewer imports would not reduce U.S. security interests in the region, would not lead to less involvement in regional affairs, and would not influence the probability of future terrorist attacks. In fact, if import reductions were accompanied by a U.S. withdrawal from the region both politically and militarily, the consequences for U.S. security would almost certainly be negative. Policies in pursuit of improved security through import reductions promise more than they can deliver.

Money is fungible and funds lost or gained from petroleum sales may offset or be offset by assets held or derived elsewhere. Proof for the linkage between petrodollars and terrorist funding is presented as connections between prominent and, most importantly, wealthy individual Saudis and Al Qaeda.[21] Sacrifices made in pursuit of a commitment to a cause or a religious objective can not be judged with the same criteria one would use to rationally examine a financial investment. The personal fortunes of those individual Saudis (or other nationalities) held in other assets, savings, or investments might be liquidated and made available for use by terrorist groups. Wealthy individuals committed to the jihad against the U.S. may be willing to expend their entire fortune in pursuit of that goal. The depth of the individual commitment is unknowable and the likelihood that U.S. policy on oil use will bring about change in those commitments is low.

To the extent that a terrorist group is supported by external sources who derive their resources from the international oil market, profits from future sales on the market would still be available (unless the price of a barrel drops below the price of production—an unlikely occurrence under any circumstance) to support terrorist acts against the United States, provided the sponsor, like the individual, is committed to the cause. Sponsors may elect to prioritize terror financing above other uses of their funds, reducing expenditures in other areas to maintain the same level of support for terrorism. So long as marginal profits remain, U.S. efforts to improve its security by reducing expenditures on imported petroleum may have no tangible impact on the resources available to terrorist groups.

A drop in U.S. imports may not diminish the financial base of terrorist financiers. As noted, global petroleum demand is projected to jump markedly in the next 20-30 years on the strength of expanding use in Asia and throughout the developing world. As U.S. imports decline, the short-term global price for petroleum is expected to drop as well, with the likely result of growing demand around the world as lower prices make consumption more affordable. In the long-term, the surge in consumption in the non-OECD world projected by the IEA will lead to increasing prices. Oil producers can reasonably expect to recoup the revenues lost from the decline in the U.S. market. As the world's economies grow and their populations seek higher standards of living, demand for energy will remain robust and all projections show that petroleum will remain the principal fuel for the world's transportation needs for the next several decades. Policies designed to reduce U.S. imports of petroleum in order to weaken the financial resources available to terrorist groups will have limited impact.

Dependence on Middle Eastern oil is said to enmesh the United States in the political struggles of that volatile region, with the related human and economic costs. If this dependence was reduced or eliminated, the U.S. could reduce its commitments in the region, the argument concludes, as its interests there would be less significant. This argument presumes two important points. One is that the Middle East is a major supplier of U.S. petroleum imports. The other is that oil is the major reason for U.S. engagement in the region.

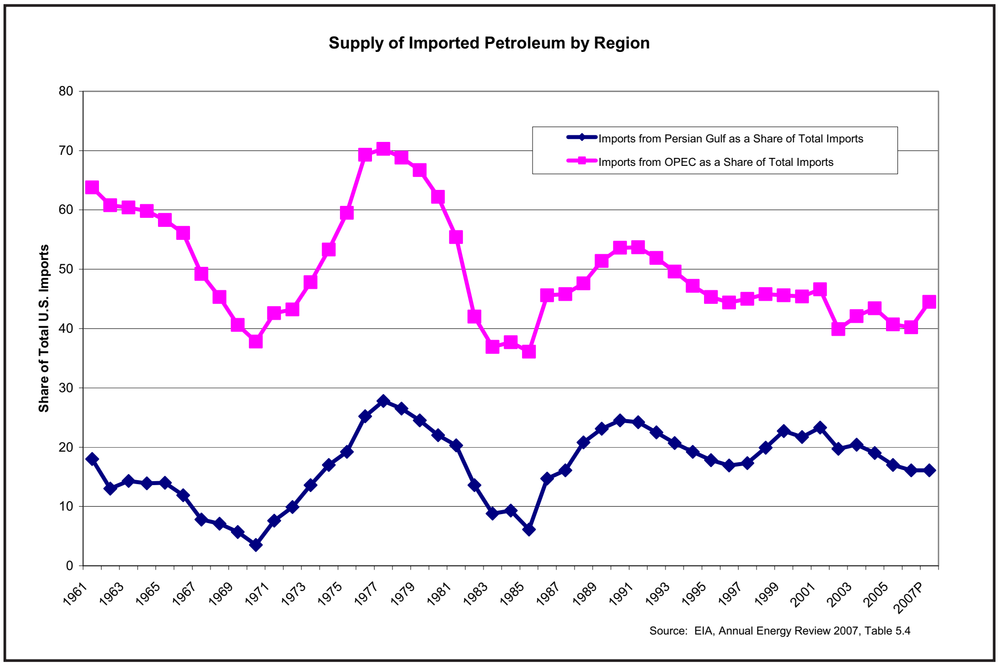
U.S. dependence on Middle Eastern oil is a debatable point. Many countries supply petroleum to the world market. As Table 1 shows, 11 of the top 15 suppliers to the United States are found outside of the Persian Gulf region. Figure 2 illustrates the changing share of the source of U.S. imports by region since the 1960s. The Persian Gulf states currently provide less than 20 percent of U.S. imports and have never accounted for more than 30 percent of imports. In the aggregate, the Department of Energy projects U.S. crude oil imports to decline 1.5 percent between 2007-2030.[22] The International Energy Agency's forecasts for 2030 also project declining import dependence for the United States.[23]

Table 1
Total U.S. Imports of Petroleum by Country (Top 15 Countries)
(Thousand Barrels per Day)

Country	YTD 2008	YTD 2007
Canada	2,437	2,468
Saudi Arabia	1,540	1,451
Mexico	1,296	1,549
Venezuela	1,189	1,356
Nigeria	1,011	1,103
Iraq	652	493
Algeria	541	699
Angola	514	522
Russia	472	419
United Kingdom	240	288
Brazil	258	214
Virgin Islands	322	335
Kuwait	201	186
Ecuador	216	208
Colombia	203	151

Note: The data in the tables above exclude oil imports into the U.S. territories.
Source: EIA, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/company_level_imports/current/import.html

Figure 2



There are strong reasons for continued U.S. engagement in the Persian Gulf regardless of the evolution of its import patterns. Instability in the Middle East would negatively reverberate throughout the global economy. Europe, Japan, and China rely on Persian Gulf supplies for much larger shares of their energy needs than does the United States.[24] Disruption in the supply of oil would harm their economies and, by extension, harm the U.S. economy through rising import prices and reduced resources available for investment in the U.S.

Other important national security and foreign policy goals are at stake in the Middle East. Instability in the Middle East may give rise to the increased incidence of terrorism. So long as Islamic terrorists work toward the destruction of the United States, the U.S. will seek to combat terrorism at its source. Instability in the Middle East may lead to aggressive actions against Israel. U.S. support for Israel long predates its large scale importation of Middle Eastern oil and persists for reasons unrelated to those imports. Instability in the Middle East encourages nuclear proliferation and the spread of weapons of mass destruction, along with the means to deliver those weapons. The emergence of a nuclear-armed Iran, complete with long-range ballistic missile capabilities, presents an extraordinarily difficult problem for the United States and our allies.

Alone each of these reasons provides ample justification for the continued involvement of the U.S. in the region and together they are a compelling rationale. Unless the United States elects to withdraw from its position as a world leader, its engagement and leadership in Persian Gulf affairs is needed and expected.

Despite suggestions to the contrary, the invasions of Afghanistan and Iraq are not linked to desires to expand or secure access to oil supplies. The Afghanistan operation began in clear response to the September 11, 2001 terrorism attacks and is rooted in the pursuit of Al Qaeda's base of operations. The Iraq wars were related to concerns about the character of Hussein regime, its invasion of Kuwait, and its failure to comply with United Nations and International Atomic Energy Agency (IAEA) limits on its weapons of mass destruction programs. Evidence suggesting that the U.S. has gained unique concessions or greater access to oil supplies by virtue of its military presence in the Gulf is limited.

Furthermore, the U.S. military has long had a presence in the Middle East. A persistent U.S. naval presence in the eastern Mediterranean dates to 1946. Bahrain, Qatar, the United Arab Emirates, and Kuwait, among others, all house significant U.S. military facilities and place considerable value on the U.S. presence. These bases contribute to the U.S.'s ability to rapidly project power and influence throughout the world. They are staging areas for military and humanitarian operations and serve as active symbols of U.S. global leadership. Falling imports will not alter the fundamental value of those bases to the U.S. or its friends or the need to have military forces deployed there.

A final argument advanced in favor of reduced dependence on imported petroleum is that dependence "causes political realignments that constrain the ability of the United States to form partnerships to achieve common objectives."[25] For example, China pursues alliances in the Middle East and elsewhere with the objective of securing supplies at the expense of other interests or potential cooperation with the U.S. U.S. leverage is diminished, the argument goes, as competition for supplies increases and the influence of suppliers grows as demand for their products increases. It is unclear how reduced U.S. consumption of imported petroleum alleviates these concerns. China's demand for energy will continue at an accelerating pace regardless of U.S. actions and the Chinese should be fully expected to prioritize energy supply concerns in their foreign policy. As was previously shown, forecasts show that demand in the developing world outpaces the rest of the world. That such a shift in global patterns of trade leads to new geopolitical dynamics as new political and economic relationships are forged is neither surprising nor unexpected.

At its core, energy independence is a quixotic quest for autarky. If the United States could pull itself back from the world and supply its own fuel, it would not need to bear the risks and costs of leadership. Fewer imports imply less interest in events abroad and less reason to be involved. As has been shown, even if it imported less, the United States remains vulnerable to supply and price shocks so long as it remains connected with the global economy. Fewer imports would not reduce U.S. security interests in the region, would not lead to less involvement in regional affairs, and would not influence the probability of future terrorist attacks. In fact, if import reductions were accompanied by a U.S. withdrawal from the region both politically and militarily, the consequences for U.S. security would almost certainly be negative. Policies in pursuit of improved security through import reductions promise more than they can deliver.

Diversifying Energy Supply to Achieve Greater Energy Security

If the goal of energy independence is illusory, how can the United States achieve greater energy security? Views on how to improve energy security abound, but each shares a common theme—diversification of the supply of energy. The National Petroleum Council recent considered the question and said ". . . "U.S. energy security can be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global trade and investment. There can be no U.S. energy security without global energy security."[26] A Council on Foreign Relations panel defined energy security as "the reliable and affordable supply of energy."[27] A 2003 Strategic Plan released by the Department of Energy established achieving greater energy security as a goal for the nation. It claimed energy security could improve by "developing technologies that foster a diverse supply and delivery of reliable, affordable, and environmentally sound energy by providing for reliable delivery of energy, guarding against energy emergencies, exploring advanced technologies that make a fundamental improvement in our mix of energy options, and improving energy efficiency."[28] Energy expert Daniel Yergin argues that the usual definition of energy security, which is "the availability of sufficient supplies at affordable prices," remains valid, but is subject to interpretation depending on the circumstances of the country.[29] Finding stable markets is the goal of energy exporters, some suppliers seek to consolidate state control over their domestic supplies to maximize profits for the state, those who were formerly self-sufficient seek reliable access to new sources, and those countries who depend on imports seek stable supplies through diversification.

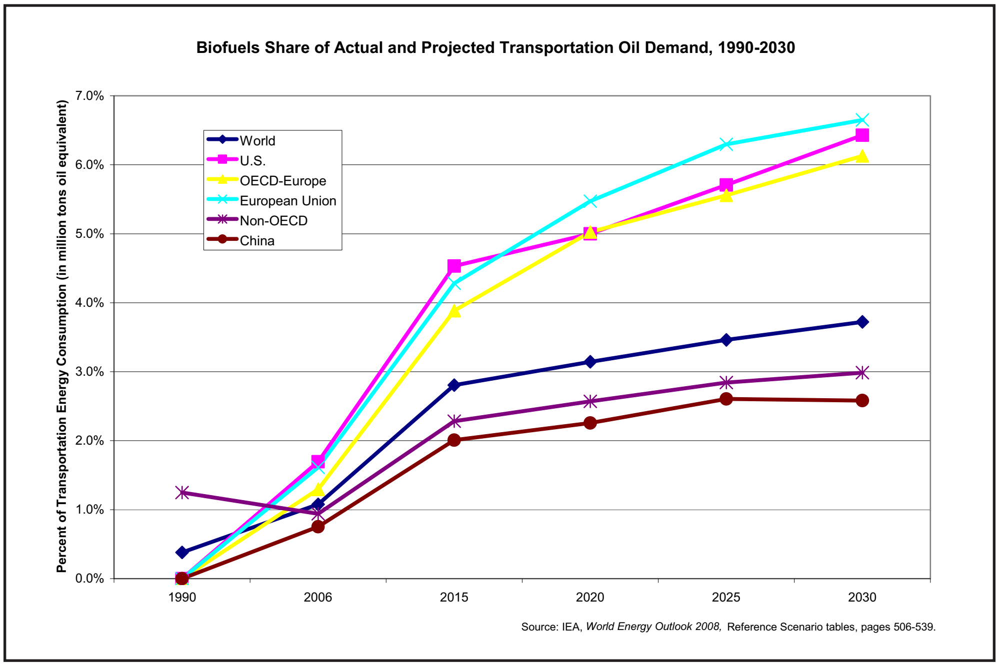
As a country that imports a considerable amount of petroleum, the U.S. should be expected to pursue supply diversification and place a premium on those supplies that are reliable and affordable. Diversifying the sources of domestically available energy is an important initial element of most plans for achieving greater energy security. For instance, the 2008 presidential campaign focused for a time on whether to expand drilling in coastal waters. Complementing the discussion of drilling in recent years is the growing interest in alternative transportation fuels. President Bush supported major expansion in the use of biofuels and the U.S. Congress mandated that biofuels provide a greatly expanded the share of the U.S. gasoline supply. The Obama administration is said to be preparing policies that require automakers to produce only flexible fuel vehicles and which would impose a national low carbon fuel standard requiring fuel suppliers to reduce the carbon content of gasoline by 5 percent within 5 years and 10 percent within 10 years, beginning in 2010.[30] The Obama plan does not specify how to reduce the carbon content, but the same section of the energy plan specifically references increased biofuels production and use of undefined advanced low carbon fuels. Presidents Bush and Obama, the Congress, and others advocate policies to expand alternatives to gasoline in an effort to diversify supply, but security is not derived from the mere fact that supplies are diverse. The other elements of the definition, that this supply be affordable and reliable, prove to be more difficult standards for alternatives to meet, particularly when the burdens of meeting environmental goals are added. Canes and Murphy evaluated the limitations associated with low carbon fuel alternatives and showed that their costs are likely to be high and their environmental benefits low.[31]

As demand for transportation fuel more than doubles in the non-OECD world (from 744 million tons of oil equivalent (Mtoe) in 2006 to 1540 Mtoe in 2030), the IEA believes that demand will be filled almost entirely by petroleum.

The first consideration then is determining how much non-petroleum alternatives can reasonably contribute to meeting the forecasted increase in demand. In other words, how much supply diversification can they provide? Corn-based ethanol, the most available current alternative fuel, has posted remarkable rates of growth in consumption, jumping to 6.5 billion gallons in 2007, up from less than 5 billion the year before.[32] This growth is supported by favorable public policies which have created a market for its use and which protect that market from international competition by imposing a tariff on imported ethanol. Putting that growth in context reveals the limits of ethanol as a contributor to diversifying the supply of gasoline. Americans will consume over 140 billion gallons of gasoline this year. That volume is projected by the Energy Information Administration to increase to 163 billion in 2015 and 191 billion by 2030.[33] This year's ethanol production of about 7 billion gallons represents only 4 percent of current gasoline consumption. Even with the proposed congressional mandate of 36 billion gallons by 2020, ethanol would only replace 21 percent of the projected gasoline supply. However, ethanol only has about 60 percent of the energy of petroleum-based gasoline. On an equivalent energy basis, it would replace only 12 percent. And, the subsidies, which today total almost $4 billion, will have grown to over $15 billion.

Internationally, the trends are not much different. The IEA forecasts that biofuels will account for only 3.7 percent of global transportation-related petroleum consumption in 2030.[34] As Figure 3 illustrates, no region of the world is projected to have biofuels provide more than 7 percent of its energy needs for transportation by 2030. The figure also shows a remarkable difference in the distribution of global demand for biofuels. The U.S. and the European Union will consume nearly one half of the globe's supply of biofuels in 2030, continuing the well-established trend. As demand for transportation fuel more than doubles in the non-OECD world (from 744 million tons of oil equivalent (Mtoe) in 2006 to 1540 Mtoe in 2030), the IEA believes that demand will be filled almost entirely by petroleum.[35]

Figure 3



Reasonable expectations suggest that biofuels will provide only minimal diversification to global transportation fuel demand. Those expectations are based on optimistic assumptions about the size of harvests, continued increase in crop yields, and the absence of droughts, blights, or other calamities that are known to befall agricultural enterprises. Nevertheless, supporters of biofuels counter these facts with the argument that demand for the fuel would increase if more supply were available and the introduction of advanced biofuels will ameliorate the harmful effects of corn-based ethanol. Typical of this view is a Department of Energy and Agriculture report which concluded that production of cellulosic ethanol from biomass could perhaps replace one-third of the gasoline pool by mid-century. The report caveats that assessment by noting the obvious, which is that it is true only if a host of technological, market, and cost barriers are overcome.[36] Those hurdles will be difficult to overcome within the span of a couple of decades.[37]

The promise of cellulosic ethanol, coupled with recently high petroleum prices and favorable public policies, generated a flood of private investment into the sector. Still, U.S. cellulosic fuel production costs are estimated at more than $2.50 per gallon, compared with $1.65 per gallon for corn ethanol.[38] According to William Coyle, a USDA analyst, other costs of the exploitation of cellulosic ethanol have yet "to be fully assessed." Specifically, he mentions:

> "… the impacts of harvesting grasses, trees, and crop residues on the erodibility and fertility of land resources. There are also questions regarding the upstream logistical and environmental costs of harvesting, transporting, and storing large volumes of bulky feedstock used in processing."[39]

If the policy goal is to displace more than 12 percent of gasoline consumption through biofuels, the only remaining alternative is to import it. Filling the gap between the expected demand for transportation fuel and the supply of ethanol would require massive imports. Action that might replace dependence on imported petroleum could create different dependence on imported alcohol.

When examined against the characteristics necessary to improve energy security—that the fuel be reliable, available, and affordable—biofuels fail to meet the criteria. Even with extensive government subsidization and protection, available supplies of ethanol will only displace at most 12 percent of the projected gasoline supply. The cost of that subsidization and protection is a large net loss to the U.S. taxpayer. Great hope is placed in the emergence of advanced biofuels—cellulosic fuels or biomass derived from algae, for example—but these alternatives are not available today and will not be in the next decade or more. Public policies to support their technical maturation may be justified, but these advanced biofuels can not be considered a viable contributor to energy security until they are available on the market. In the short term, ethanol displaces some petroleum use in the transportation at a high cost, but those concerned about energy security must look elsewhere for viable alternatives.

Unintended Consequences of a Low Carbon Fuel Standard

Proponents of a low carbon fuel standard contend it will spur the exploitation of domestic alternatives to imported petroleum, which have the added advantage of reducing greenhouse gas emissions from transportation fuel use. Canes and Murphy question the economic viability of the standard as well as its likely environmental contribution. A low carbon fuel standard also will retard the exploitation of other domestic and international alternatives to petroleum with significant implications for U.S. energy security as well as other unintended consequences.

Weakening Energy Security

A national LCFS will discourage the importation of petroleum from the Canadian oil sands and most likely prevent industry from exploiting America's vast oil shale resources. Although producers have lowered aggregate carbon dioxide emissions per barrel by around 50 percent since 1990, oil sands and shale release more carbon dioxide than regular petroleum. The low carbon fuel standard proposed by President Obama would establish strong disincentives for further investment in or use of either source of energy. Refiners would face great difficulties in meeting the proposed standard if they elected to use high carbon content fuels, thereby subjecting themselves to penalties and other civil actions.[40] If energy security is achieved by providing additional supplies at affordable prices, is a national LCFS good public policy?

U.S. Oil Sands Resources

U.S. oil sands resources are estimated to be about 54 billion barrels, of which 11 billion barrels are thought to be recoverable. The majority (32 billion barrels) are located in Utah, Alaska holds 18 billion barrels, and the rest are found in Alabama, Texas, California, and Kentucky.

According to the Department of Energy's Task Force on Strategic Unconventional Fuels, U.S. oil sands are "found in sandstone" and are "hydrocarbon-wet," which makes traditional extraction techniques "infeasible." New extraction technologies and techniques will be required to successfully utilize U.S. oil sands.

Source: Task Force on Strategic Unconventional Fuels, Development of America's Strategic Unconventional Fuels Resources: Initial Report to the President and Congress of the United States, September 2006

Canada possesses the world's second largest proven oil reserves. Canada has 179 billion barrels (bbl) of oil reserves, 95 percent of which are located in Alberta province; only Saudi Arabia contains more proven reserves.[41] Approximately 174 billion bbl or 97 percent of Canada's total reserves are the heavy, viscous so-called "bitumen oil" that an LCFS would probably keep from entering the United States. Oil sands or tar sands are a naturally occurring mixture of clay, water, sand, and bitumen. Bitumen petroleum accounted for nearly half of Canada's daily 3.36 million bbl of production in 2007.[42] Almost every drop (99 percent) of Canada's approximately 1.85 million bbl daily exports went to the United States.[43] The 2001 National Energy Policy (NEP) deemed the Canadian oil sands a pillar of sustained North American energy and economic security.[44]

Petroleum is extracted from oil sands in two ways: open-pit mining or in-situ techniques. Open pit mining techniques remove oil located close to the Earth's surface. Chemical treatments separate the oil sludge from the residual sediment. The tar-like bitumen product is either refined into a lighter Synthetic Crude Oil (SCO) or shipped to the U.S. as heavy crude for the additional refining. However, open-pit mining can only recover 20 percent of the total reserves.[45] The rest must be separated from deeply buried rock and coaxed to the surface using in-situ methods. One commonly deployed in-situ technology is Steam-Assisted Gravity Drainage (SAGD), in which heated water is pumped underground and the resulting steam removes the bitumen oil from sediment, pushing it upwards until it can be sucked out. In-situ operations continue to expand in scope and efficiency. The Canadian National Energy Board (NEB) reported *in-situ* bitumen production expanded by 20 percent from 2006 to 2007.[46]

> *A national LCFS will discourage the importation of petroleum from the Canadian oil sands and most likely prevent industry from exploiting America's vast oil shale resources.*

The relative importance of Canada's oil resources for U.S. national and energy security is illustrated by the large future production estimates, the reliability and integration of U.S.-Canadian energy markets, and the possibility that strategic competitors may benefit from consuming the reserves America refuses to import.

Currently, Canada is the top supplier of crude oil to the United States, providing around 18 percent of America's crude oil and petroleum-based products in 2007. This amount exceeds imports from Mexico (11.4 percent), Saudi Arabia (11 percent), Venezuela (10 percent), and Nigeria (8.5 percent), America's next largest suppliers.[47] The Canadian NEB projects that the oil sands industry will produce 3-4.5 million bbl/d of bitumen oil by 2015[48] and, if current trade patterns hold true, all of this production can be expected to come to the United States.

The increasing output from Canada's oil sands could become a crucial component of fulfilling America's long-term energy needs. U.S. total consumption of liquid fuels is predicted to grow at an average annual rate of 0.4 percent, from 20.7 million barrels per day in 2006 to 22.8 million barrels per day in 2030. Transportation usage will be responsible for the majority of this growth, as it is projected to account for 73 percent of total liquid fuel demand by 2030.[49] Absent government regulation, the oil sands will play an increasingly important role in satisfying American demand.

Other advantages accrue to the U.S. from its energy relationship with Canada. Presently, Canada and the United States form the most integrated and efficient energy market in the world. A recent examination highlights the unique nature of the market:

> Canada and the United States benefit from a broadly integrated energy market. While most oil and natural gas in the world is owned, mined, and exported by state-controlled companies, the market shared by Canada and the United States is almost entirely private. The enormous demand for both oil and natural gas on the part of American customers has led to considerable investment, exploration, and exports of Canadian natural gas and oil resources. This demand-and-supply relationship between the two nations has been streamlined and made highly efficient when both countries beginning in the late 1980s dropped most nationalistic policies such as price controls, export limits, and restrictions on foreign ownership. Unencumbered by nationalistic or protectionist laws and regulations, and guided by a world price for oil and regional price for natural gas, the flow of energy products closely mirrors market demand and supply.[50]

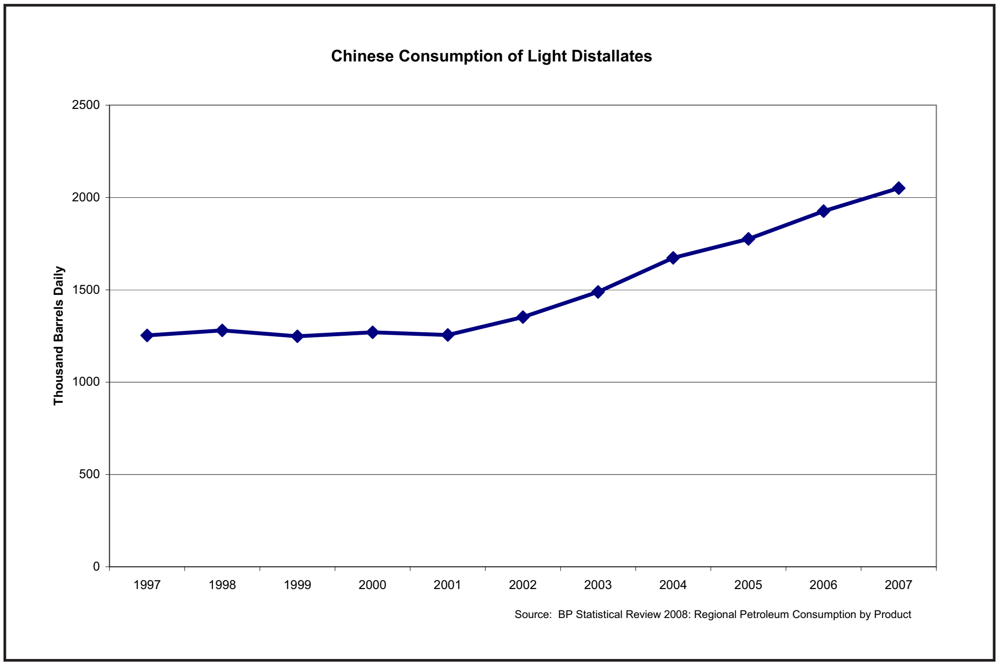
David Wilkins, the U.S. Ambassador to Canada, did not to understate the importance of the topic when he said that decisions regarding the use of the oil sands will define the relationship the U.S.-Canada relationship for at least the next decade.[51] A national low carbon fuel standard would arrest the export of one-half of Canada's petroleum output. Canadian producers will seek other customers and the U.S. will be forced to purchase alternative fuels or petroleum from other sources.

The Canadian oil industry is a $9.2 billion per-year business and remains a massive source of wealth, high-paying jobs, government revenues from royalties, and international power. Statistics Canada valued the oil sands at $282.9 billion in 2007.[52] The recent analysis by Sharpe *et al* contends that Statistics Canada was too conservative in its estimate and places the value more 4 times higher—at $1.2 trillion.[53] In his first major foreign policy address, Prime Minister Steven Harper said international investors have "recognized Canada's emergence as a global energy powerhouse—the emerging 'energy superpower' our government intends to build."[54] Harper reiterated his "energy superpower" vision in several other high-profile speeches.[55] The opposition Liberals and New Democratic Party (NDP) socialists are more concerned than Harper's Conservatives with the environmental implications of expanded production. But every ruling party must face "an oil and gas industry owned exclusively by the private sector, entrenched provincial jurisdiction leaving no space for federal interference, and trade with the United States tightly regulated,"[56] suggesting that the vested interests in using the oil sands will remain strong for the foreseeable future.

The Canadians are investing in and expanding the industry; if they stop selling oil to the U.S., it will be because of changes in American environmental policy. In June 2008, the annual conference of American mayors adopted a resolution urging a ban on filling municipal vehicles with oil sands petroleum. In reaction, John Baird, Canada's environment minister, responded: "If American mayors want to send their money to unstable, undemocratic countries in the Middle East instead of to Canada, that will be their call. If they want to pay a premium for Iranian, Saudi, Iraqi oil that will be their call."[57]

Perhaps anticipating a change in attitudes by the United States, the Canadian NEB's 2006 market assessment for the oil sands notes the role that Asian markets, specifically China, could play in purchasing Canadian products in the decades ahead.[58] According to the IEA, China is the world's second largest consumer of oil and the third largest importer; its booming economy will require 10 million bbl/d by 2025.[59] China's consumption of light distillates used for gasoline jumped 6.5 percent between 2006-2007 and has grown dramatically in recent years as more and more Chinese come to own and operate automobiles. Recognizing that energy security requires diversity of supply, China is pursuing inroads into the Canadian energy sector.

Figure 4



Chinese companies purchased equity stakes in some oil sands projects; Chinese Sinopec collaborated with Canadian Synenco to develop the Northern Lights sands, which will begin producing 100,000 bbl/d by 2010. The Chinese National Petroleum Company (CNPC) won exploration rights to a 260-acre Albertan tract last year and China's National Offshore Oil Company (CNOOC) bought a stake in MEG Energy's Christina Lake project. Another Sino-Canadian partnership is a proposed pipeline from Fort McMurray in Alberta to a Pacific port in British Columbia province. Enbridge and PetroChina signed a "Memorandum of Understanding" to construct the pipeline in 2004, which could ship 200,000 to 400,000 bbl/d once it is fully online.[60]

Should the U.S. market close, Canadian suppliers will turn to other markets, with China as a leading candidate. Instead of being shipped through pipelines to refineries in the United States, the oil sands petroleum would be loaded onto ships and sailed across the Pacific to ports in China (or elsewhere in the world). Inserting this additional transportation element raises several noteworthy risks. First, the petroleum will be refined in China, not the U.S. with economic and environmental implications. Economically, U.S. refineries would be expected to process less petroleum as non-petroleum alternatives assume larger shares of the market, implying fewer jobs and revenues in that sector. Chinese refineries are already on a strong growth path and the projected increase in demand for transportation fuel indicates that path will continue. Reliable indicators about the environmental effects of China's refining industry are difficult to obtain, but the regulatory system governing the environmental externalities of China's energy sector is relatively weaker than the U.S.[61] In contrast, U.S. refineries operate under an extensive regulatory regime sensitive to limiting negative environment effects. While a precise assessment of the environmental effects of the shift from U.S. refineries to Chinese refineries is not available, reasonably one can conclude that the results will be negative.

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In regards to the reduction of greenhouse gas emissions, the diversion of shipments through the pipeline to a trans-Pacific tanker voyage raises important concerns. A rough estimate of the greenhouse gas emissions of one oil tanker traveling from western Canada to a port in China is possible to construct. Such a journey might begin in Vancouver and end in Shanghai. According to Canada's National Energy Board, the oil company Enbridge is building a pipeline to deliver crude to the west coast of British Columbia in order to tap into Asian markets.[62] As the world's largest port by tonnage received, Shanghai is a good example of where a Canadian ship might offload its oil cargo.

A ship traveling from the port of Vancouver to the port of Shanghai must sail 4984 miles (mi) or 8020 kilometers (km).[63] The ship would be a Very Large Crude Carrier (VLCC) vessel such as the Malaccamax oil tanker. Mitsui Engineering & Shipbuilding Co. builds a Malaccamax with a 300,000 deadweight tonne (DWT) carrying capacity able to travel 16.55 knots (kt).[64]

It takes one liter of bunker fuel to move one tonne of the Malaccamax's crude oil cargo 2800 km.[65] Shipping 300,000 DWT approximately 8000 km from Vancouver to Shanghai requires 226,433 gallons or 838 tonnes of bunker fuel.[66] If the Malaccamax sailed at 16.55 kt non-stop without wasting any time or fuel during on-loading, docking, and offloading procedures, then it would complete the voyage in about 11 days. Around 76 tonnes of bunker fuel would be burned each day.[67] The National Technical University of Athens recently estimated ship emissions and calculated that CO_2 emissions (in tonnes per day) can be computed by multiplying daily fuel consumption by a factor of 3.17. This means our notional oil tanker would emit 241 tonnes of CO_2 per day and 2,656 tonnes total on its trip from Canada to China,[68] without even factoring in the emissions from sailing back to Vancouver.

Over one year's time, diverting oil sands petroleum to China would emit large amounts of CO_2. In 2007, Canada produced 3.36 MMbd of crude oil, with oil sands accounting for approximately one-half of total production.[69] It exported 2.4 MMbd to the United States.[70] Therefore, roughly 1.2 MMbd of oil sands petroleum is imported into the United States or 438 million barrels per year (b/yr), if we assume an even conventional/oil sands mix. The average VLCC can carry 2 million barrels of crude;[71] thus, it would require approximately 219 voyages from Vancouver to Shanghai every year to export Canada's current oil sands product to China. If a single, one-way, fully loaded shipment emits 2,656 tonnes of CO_2, then shipping the entire production would release 581,644 tonnes every year.[72] Of course, this figure would be higher if the additional emissions caused by sailing back to Vancouver and during on-loading, docking, and offloading procedures were added. In addition, the number of shipments required would drastically increase in the long-term; at least 95 percent of Canada's total reserves are in oil sands fields.[73]

So long as the Canadians remain committed to producing and selling the oil sands and there is demand for it on the world market, the greenhouse gas contributions associated with its production will continue regardless of U.S. policy. By enacting barriers to its use in the United States, additional emissions are accrued with the trans-Pacific shipments. Furthermore, those transoceanic voyages might also increase the risks of accidents or spills that are not present when the oil sands petroleum is piped into the U.S.

Some worry about the high costs of producing bitumen crude, which relies heavily on natural gas, itself subject to price fluctuations, will inhibit further exploitation of these reserves. In some cases, per-barrel production costs are seven times greater than the expenses associated with generating one Saudi Arabian barrel.[74] The NEB concludes that oil sands petroleum will remain competitive if standard light sweet crude market price maintains a floor of $30-35 per bbl.[75] In November 2007, the NEB forecast production out to 2030, modeling three scenarios reflecting differences in economic growth rates, world oil and natural gas prices, domestic environmental policies, and geopolitical stability. The resulting estimates range from 2.62 to 4.74 million bbl/d in 2030; if current economic and energy price trends continue, Canada should produce 4.15 million bbl/d in 2030.[76] A recent analysis of the valuation of the Canadian oil sands notes further that the NEB's projections do not rely on the recent spike in crude oil prices. "These projects were announced and planned well before 2008, and do not depend on the recent rise on oil prices to be profitable."[77] Indeed, production trends through 2008 appear to bear this point out. Even with a large swing in crude oil prices, production from the oil sands remained stable.[78] The recent downturn in global financial markets, however, is having noticeable effects on long-term projects. The Oil Sands Development Group said more than $39 billion in projects have been postponed in late 2008 and early 2009.[79]

Statistics Canada places the cost per barrel of extracting the oil sands at approximately $18 per barrel. Extraction costs have risen in recent years due to rising prices of natural gas and steel as well as labor shortages in western Canada.[80] Toman *et al* forecast costs of production, which they determine to be "well under $50/bbl"[81] and compare them with conventional petroleum fuels, concluding that:

> Basic production costs for SCO [synthetic crude oil] are likely to be cost-competitive with conventional petroleum. Production of SCO already is a relatively mature technology, though new processes are being developed to make use of deeper formations. Taking into account both uncertainties that may lead to higher costs than estimated and cost improvements due to learning, and leaving aside for the moment the potential cost of CO_2 emissions, we find that SCO is cost competitive with conventional petroleum unless future oil prices are well below EIA's 2007 reference case scenario for 2025.[82]

Considering the merits of a low carbon fuel standard, the cost comparison is not between the oil sands and conventional oil, but between the oil sands and the alternatives to petroleum. Canes and Murphy explored this question in greater detail.[83]

In summary, a low carbon fuel standard hampering importation of Canadian crude and oil sands will not improve U.S. energy security. Canada's petroleum represents an available, ample, and relatively inexpensive source of energy for the United States. The existing efficiency of the U.S.-Canadian energy marketplace further enhances the value of this supply to the United States. The Council on Foreign Relations noted the importance of the oil sands in their recommendations for improving energy security when they called for increasing the supply of oil from sources outside the Persian Gulf. Specifically, they said:

> The supply increases need not be from conventional oil sources. Drawing from the substantial U.S. reserves of unconventional oil and gas—such as tar sands and oil shale —could have the same impacts on world oil price and on U.S. imports. Similarly, Canadian development of its unconventional sources, particularly the tar sands, could help limit world oil price increases.[84]

If the United States undermines this relationship by inserting barriers to the trade of unconventional petroleum products, China or other competitor nations will capitalize on the opportunity and begin purchasing large amounts of Canada's production. The U.S. will no longer reap the benefits of the integrated, efficient market and no longer be assured of an ample, reliable supply of energy.

Another unintended consequence of a prospective national low carbon fuel standard is the failure to exploit the U.S.'s unconventional oil resources, particularly oil shale. Oil shale refers to sedimentary rock containing a solid bituminous substance which can be extracted as kerogen, a petroleum-like liquid, and combustible gas when the rock is heated.[85] Its energy potential has been understood for centuries; the U.S. Naval Oil Shale Reserve was established in 1912 and since that time millions of barrels of shale oil have been produced.[86]

A few American companies experimented with oil shale production in the late 1970s and early 1980s. In the mid-1980s, high research & development and production costs and declining world crude prices ended the brief flirtation with oil shale. The recent run-up in oil prices prompted an effort to end the existing moratorium on leasing federally-owned shale lands. The Energy Policy Act of 2005 directed the Department of the Interior to issue leasing and production regulations, but in 2007, a moratorium was enacted, overruling the law's directive. In late February 2009, Interior Secretary Salazar terminated leases for oil shale development on federal lands.[87]

Estimates place U.S. oil shale resources at more than 2 trillion barrels. The highest quality shales are located in the Green River Formation in Colorado, Utah, and Wyoming, totaling about 1.5 trillion barrels.[88] Bartis *et al* exhaustively document total Green River resource estimates published by geologists since the late 1970s[89] and conclude that 1.5 to 1.8 trillion bbl of oil are in the Green River Formation. In western Colorado's Piceance Basin, there is potentially 1 trillion bbl, meaning this area holds as much oil as the world's total proven reserves.[90]

However, the numbers represent resources-in-place; not all shale can be reasonably accessed, extracted, recovered, and converted into useful fuel. Estimates suggest about 75 percent of the accessible resource is extractable and convertible to useful fuels.[91] Some of the shale's output-to-mining ratio is too low to warrant recovering. Generally, the oil industry prefers shale producing at least 25 gallons of fuel per ton of mined shale (25 gallons/ton). Recognizing regulatory and production constraints, Bartis *et al* estimates the Green River Formation can ultimately produce between 500 billion and 1 trillion bbl of oil.[92] The federal government owns 72 percent of the Green River Basin, including the most attractive and rich portions; thus, oil shale's future lies mostly in government's hands.

Official government estimates project 800 billion barrels are recoverable. A recent statement from the Bureau of Land Management (BLM) puts that number in perspective meaningful to consideration of oil shale's value to U.S. energy security. "…We estimate deposits hold the equivalent of 800 billion barrels of oil—enough to meet U.S. demand for imported oil at current levels for 110 years," BLM Director Jim Caswell said in 2008.[93]

Capital requirements and costs are major challenges affecting large-scale oil shale projects. A moderately sized 50,000 bbl/d plant requires between $5 and 7 billion in capital investments and a world crude price of at least $75 (in 2005 dollars).[94] Aside from government regulation, cost appears to be the only barrier to wider exploitation of U.S. shale resources. As early as 1978, the federal government concluded: "the development of a domestic oil shale industry was technically feasible and was ready for the next steps toward aggressive commercialization."[95]

China, Estonia, Australia, Canada, and Brazil, which have significant deposits, currently have research, demonstration, or processing underway. Estonia has been producing crude oil from oil shale since the 1920s and mined 31 million tons of shale at its peak production in 1980.[96] Bartis *et al* conclude that R&D completed in the 1970s and 1980s, combined with technological advances made domestically and abroad "supports the judgment that mining and surface retorting is a technically viable approach for producing strategically significant amounts of oil."[97]

Johnson *et al* contend that creation of the complicated web of infrastructure necessary to support large-scale mining is possible. Natural gas (heavily used in ore extraction) is indigenous to most of the Green River Formation area and existing electrical power generation is adequate. The Colorado River Basin System combined with a favorable water rights regime can provide the huge quantities of water needed in many aspects of development. Finally, a pre-existing network of roads and pipelines can be upgraded to serve the industry's future needs.[98]

American shale reserves are abundant and reliable in the sense that they are under the complete control of the U.S., much in the same way domestic biofuels are reliable, but not nearly as abundant. Shale fails the affordability test for energy security under present conditions. The moratorium has deterred investment in the technologies needed to productively exploit it, although that situation is changing. By removing the market for the fuel's use, the imposition of a low carbon fuel standard would further deter investment in the underlying technical base needed to competitively extract the resources as well as account for the known side effects.

The principal argument against the use of unconventional petroleum supplies is that they are environmentally objectionable, particularly on greenhouse gas emission grounds. The environmental objection cuts to the heart of the justification for a low carbon fuel standard. The oil sands are estimated to release three to five times as many full-cycle greenhouse gas emissions as conventional oil,[99] while oil shale production releases 21 to 47 percent more GHG emissions than conventional oil.[100] The extraction processes for both are energy intensive, utilizing considerable amounts of natural gas or other electrical inputs, which contributes to the high estimated life cycle carbon emissions. The Bureau of Land Management estimates that one in-situ project would require 2.4 gigawatts of power for commercial production of 200,000 barrels of shale oil per day, so the production of a million barrels per day could require construction of up to ten new power plants. If these were coal-fired plants, as is likely, they would emit up to 121 million tons of CO_2 per year. This CO_2 could be captured for use in oil recovery or sequestered.[101] The use of nuclear energy would avoid the emissions generated from burning coal (though not those from retorting the shale), but that is unlikely at present. A new in-situ conversion technology developed by Shell Oil is considered promising, but its full fuel cycle emissions are still higher than from conventionally produced petroleum fuels.[102] This process is at least fifteen years from commercial application, which allows time for improvements in carbon capture and storage technology.[103]

The life-cycle carbon emissions from use of the oil sands are higher than low-sulfur, light crude oil. Toman *et al* determined that carbon intensity (ton of carbon dioxide equivalents per billion barrels of oil sands) ranges from 0.094 to 0.13.[104] A 3-million bbl/d oil sand industry in Canada, therefore, would be expected to emit 70-95 million tons of CO_2 per year. Separately, a recent report from MIT's Laboratory for Energy and the Environment concluded that a 10 percent oil sands component in U.S. petroleum fuels would increase greenhouse emissions in the transportation sector.[105]

These estimates for both oil shale and the oil sands assume that no action is taken to mitigate or lessen the life cycle emissions. But important efforts are underway. Canadian industry has reduced the carbon intensity of their oil sands facilities by significant margins, through efficiency improvements and introduction of new techniques.[106] The Canadian government,[107] as well as the provincial government in Alberta,[108] has established emission reduction goals of oil sands producers.

Carbon capture and storage is a preferred option addressing emissions resulting from the production of unconventional fuels. Canada's *Turning the Corner* climate plan states that: "All oil sands upgraders and in-situ plants that come into operation in 2012 or after will be required to meet a stringent target based on the use of carbon capture and storage by 2018."[109] Alberta estimates it has enough storage space for 100 million tons of CO_2 annually for more than 300 years, more than sufficient geological storage capacity for the amount of activity projected.[110]

The provincial government is taking the challenge seriously. In March 2008, the Alberta government announced the Alberta Carbon Capture and Storage (CCS) Development Council. A partnership between governments, industry and scientific researchers, the council is tasked with devising a work plan for implementing carbon capture and storage in Alberta, complete with timing and expectations.[111] In July 2008, the provincial government announced the creation of a $2-billion fund that "will advance carbon capture and storage projects, equivalent to taking one million cars per year off the road."[112] The technologies for geological CCS are proven and there are a few large-scale CCS projects in operation today in Norway, Canada, and Algeria. The costs of capturing and storing carbon are expected to remain high until questions about the effectiveness and efficiency of capturing, transporting, and permanently storing CO_2 are resolved.[113]

Carbon capture and storage, also called sequestration, is a process whereby carbon dioxide is injected into underground geological formations for permanent storage. To prevent leakage, these formations must be relatively impermeable; the formations in which natural gas and petroleum are found are being investigated, as are others, such as unminable coal seams and sandstone formations. Most investigations into CCS technologies have focused on the CO_2 emitted by burning coal, the main fossil fuel used in energy generation; most of these technologies should be equally applicable to CO_2 from other sources, such as oil shale and bitumen sands. A recent effort to create a CCS technology specific to oil shale is the partnership of Lawrence Livermore National Laboratory and American Shale Oil, LLC, to study how to store CO_2 generated in the oil shale extraction process in the depleted underground oil shale retorts.[114] The shale remaining in the ground after oil is extracted could also be used to sequester CO_2 created in the extraction process, as are shale formations in other areas.[115]

The Department of Energy partnered with FutureGen Alliance, a consortium of thirteen power companies, and announced in December 2007 that they would build a clean coal technology demonstration plant in Mattoon, Ill., but in 2008 the Department of Energy backed out of the program due to rising costs. President Obama has previously pledged support for carbon-capture technology[116] and Senator Dick Durbin of Illinois suggests that Energy Secretary Chu is open to re-funding clean coal technologies, including FutureGen, in spite of his reservations about their viability.[117]

By design, the lifecycle assessment of greenhouse gas emissions for oil sands, oil shale, or lower carbon alternatives to petroleum must account for the range of factors affecting the production, shipment, and use of those products. Too often oil sands and oil shale are set aside in discussions of future fuel options because of the relatively high amount of emissions produced during their production. But, as has been shown, the emission consequences of closing the U.S. market to Canadian oil sands are very large and completely avoidable. Other assessments of the lifecycle emissions of biofuels have shown there is little net benefit gained from use of those fuels once the broader perspective is taken.[118] Pursuing a low carbon fuel standard may do little to provide reductions in greenhouse gas emissions, but clearly will undermine the pursuit of greater energy security.

To meet the consensus standards established for improving energy security, an energy option must be affordable, reliable, and diversify the mix of energy supplies. Exploitation of unconventional petroleum supplies meets these standards. Relative to recent trends in the price of crude oil on the world market, further investment in the exploitation of the oil sands and oil shale resources of North America can be profitable for private investment. If governments are truly concerned about improving their energy security, profitability is less of a concern. Government may elect to underwrite the further development of these assured supplies of energy in order to gain the perceived or real advantages that greater security provides. Oil sands and shale are reliable. Ownership of the resources lies within the boundaries of the United States and its chief trading partner, Canada. In some cases, the resources are directly owned by the public and in all cases there is ample opportunity for government oversight of the maturation of the resources. Finally, the projections of extractable resources show conclusively that oil sands and shale will undoubtedly diversify the existing mix of energy supplies.

Of further concern when evaluating the security implications of the oil sands and shale are the costs of failing to develop or use them. Should the U.S. begin to preferentially treat energy supplies by their carbon content, further development of the oil shale base in the United States will cease. Private corporations, investors, and innovators will have no incentive or rationale for investing resources, time, or creativity in devising ways to utilize this immense resource. Chilling that investment guarantees that the concerns about the costs of using oil shale resources (namely, its environmental externalities) will never be overcome. The end result is that the U.S. will have elected to forgo use of "enough to meet U.S. demand for imported oil at current levels for 110 years." If energy security is the policy objective, this is an unwise course of action.

Similarly, regulating energy supplies by their carbon content in the United States closes the door to a productive trade relationship with Canada. Denying Canada's oil industry access to its largest trading partner forces them to look elsewhere for consumers of their product; a product in which they have invested billions of dollars and on which a significant portion of the country's wealth relies. Anticipating such a possibility, Canadian planners have begun courting China and other East Asian nations to become future customers. The United States will have given up an immense, assured, reliable supply of energy and handed it to its chief economic and geopolitical rival.

Food and Land Use Impacts

In April 2008, Texas Governor Rick Perry petitioned the Environmental Protection Agency to waive the application of the renewable portfolio standard which required 7.76 percent of the gasoline supply be derived from ethanol. Perry argued that the requirement "has had the unintentional consequence of harming segments of our agriculture industry and contributing to higher food prices."[119] Food prices jumped 5.5 percent in 2008 according to the Department of Agriculture and corn prices were up more than 100 percent.[120] Many agreed with Perry's claim, arguing that the rapidly growing demand for corn supplies for gasoline production put upward pressure on corn prices which trickled easily into general food price inflation. The 2008 case proves more complicated after a closer examination, but the broader concerns about the use of agricultural commodities and resources for transportation fuel remain an important test for a low carbon fuel standard.

Ethanol supporters deny the linkage between rising food prices and the diversion of the nation's corn supply for transportation fuel. A widely publicized analysis by Informa Economics found weak statistical relationships between corn prices and consumer food prices, and identified other factors as more influential in the long-term movement of food price inflation.[121] Ethanol producers and corn growers point to rising corn yields and an increase in the amount of corn planted, which results in more corn produced overall, as sufficient to meet the rising demand. They also claim that the corn grown to meet ethanol needs is not suitable for human consumption.[122]

For the particular circumstances of 2008, the dramatic short-term jump in food prices is attributable to both rising crude oil prices and growing demand for ethanol. Transportation costs of moving the commodities from farm to producer to consumer coupled with increases in farm input costs associated with petroleum, such as fertilizer and machinery fuel, are said to account for the majority of the observed increase. Nevertheless, many analysts believe the diversion of crops for fuel contributed significantly to the sharp increase in food prices.[123] The question of greatest concern to policy makers considering public policies to promote biofuels, the most readily available low carbon fuel option, is whether the long-run impacts of a fundamental realignment of the demand for corn and other agricultural products will encourage a rise in the price of food.

The Department of Agriculture's (USDA) long-run projections show that growing the ethanol industry will have significant effects on agriculture markets, including structural shifts in commodity prices, changed demand and supply for inputs, altering of global patterns of trade, and shifting land use patterns.[124] The U.S. produced 12 billion bushels of corn in 2008, harvesting over 153 bushels per acre.[125] To meet the forecasted demand of 14.7 billion bushels of corn in 2018, USDA estimates that an additional 13.7 million acres will need to be planted with corn and yields per acre will need to increase by more than 24 bushels, compared to 2006.[126] The USDA projects that corn used for ethanol would consume more than 30 percent of the nation's total use of corn in 2018, up from 19 percent in 2006.[127] Those projections were derived prior to the approval of the 2007 energy bill, which increased the renewable fuel standard for corn-based ethanol to 15 billion gallons in 2015 and holds that amount level. Adjusting the projection to account for the increased demand for corn-based ethanol reveals that an additional 805 million bushels will be needed to meet the new demand in 2015.[128] At a projected yield of 167.3 bushels per acre in 2015, an additional 4.8 million acres of corn for ethanol will be required, representing 6 percent of the total projected harvested acres of corn. The USDA projections hold the amount of land planted for agricultural crops steady at approximately 244 million acres. If that is a correct assumption, expanding the use of corn for ethanol will result in fewer acres being available for other crops or increased imports. A low carbon fuel standard would further exacerbate these trade-offs by increasing demand for ethanol.[129]

The U.S. is expected to remain the world's leading corn exporter, but the USDA believes growing domestic consumption for fuel will limit the growth of those exports.[130] The OECD forecasts that other major corn producers will see noticeable changes in the share of their corn crops devoted to biofuels use. Thirty-five percent of the Canadian corn crop, for instance, is expected to be used for biofuels in 2016.[131] The rising price of corn also is affecting future planting decisions. According to forecasts from the OECD:

> Growth in grain-based ethanol industries, in particular in North America and Europe, as well as rising feed requirements for flourishing livestock sectors, look set to further pressure the already critically low global grain stocks-to-use ratio over the course of the Outlook. Owing to currently low stocks and high prices there will be an incentive to plant more land for grain production. In addition to a foreseen sustained recovery in production in drought-stricken Australia, the area under cereals is projected to rise for a number of reasons. There will in particular be some reallocation of land from other crops in the main OECD producers such as Canada, the U.S. or the EU. In addition, land is taken out of set-aside in the EU for 2008. Finally, new land will be taken into cultivation, particularly in South and Latin America, Sub-Saharan Africa and the Commonwealth of Independent States (CIS). However, overall there will be constraints in expanding new arable areas in many countries and competition for land and resources among grain and oilseed crops is set to intensify with those crops offering the highest returns gaining the most ground.[132]

Global constraints on expanding acres available for agriculture will create upward pressures on prices when demand for agricultural commodities is high, even under conditions of rising yields. Demand forecasts for coarse grain consumption increases by 129,497 kt between 2008-2017, with 61 percent of this growth in the developing world.[133] Rising world populations and increasing standards of living will result in sustained growth in per capita food consumption. Unless there are dramatic improvements in yields, increased demand in the face of constrained supplies will produce rising prices for commodities, feeds for livestock, inputs into other commercial products (such as corn syrup), and food products. University of Minnesota professors C. Ford Runge and Benjamin Senauer summarize the point:

> With the price of raw materials at such highs, the biofuel craze would place significant stress on other parts of the agricultural sector. In fact, it already does. In the United States, the growth of the biofuel industry has triggered increases not only in the prices of corn, oilseeds, and other grains but also in the prices of seemingly unrelated crops and products. The use of land to grow corn to feed the ethanol maw is reducing the acreage devoted to other crops. Food processors who use crops such as peas and sweet corn have been forced to pay higher prices to keep their supplies secure—costs that will eventually be passed on to consumers. Rising feed prices are also hitting the livestock and poultry industries.[134]

Malnutrition, vitamin deficiencies, and starvation breed instability and insecurity. When these consequences are felt in already unstable parts of the world, the conditions for political instability intensify. The moral dimension of knowingly worsening the health and welfare of vulnerable populations is just as alarming.

Mark Rosegrant of the International Food Policy Research Institute (IFPRI) has shown that recent growth in the demand for biofuels accounts for 30 percent of the observed increase in grain prices.[135] Under conditions of continued high oil prices, Rosegrant shows that increasing global biofuel production will push global corn prices up by 41 percent by 2020, oilseeds, including soybeans, rapeseeds, and sunflower seeds, are projected to rise by 76 percent by 2020, and wheat prices by 30 percent by 2020. A World Bank review claims biofuels may account for as much as a 75 percent increase in the price of food.[136] Stefan Tangermann of the OECD's Trade and Agricultural Directorate concludes that the shift toward increased use of biofuels will negatively affect food security in the developing world by producing rising prices, with disproportionate impacts the poor.[137] Another IFPRI scholar puts these trends into context:

> … the increase in crop prices resulting from expanded biofuels production is also accompanied by a net decrease in availability and access to food. Calorie consumption is estimated to decrease across regions under all scenarios compared to baseline levels. Food-calorie consumption will fall the most in

Sub-Saharan Africa, where calorie consumption is projected to decrease by more than 8 percent if biofuels expand drastically.[138]

Malnutrition, vitamin deficiencies, and starvation breed instability and insecurity. When these consequences are felt in already unstable parts of the world, the conditions for political instability intensify. The moral dimension of knowingly worsening the health and welfare of vulnerable populations is just as alarming.

Another consequence of the expanded use of agricultural products, whether it is corn, sugar, soybeans, or cellulose, is its effects on the land. Increasing the amount of corn produced to meet the projections outlined by the OECD and others will require both increased yields and increased acreage devoted to corn production. Farmers typically employ an annual corn-soybean rotation to maintain soil quality. Interrupting that rotation in order to devote more acreage to corn has been shown to reduce yields and increase the risks of diseases and pests.[139] Increasing the use of farmland by converting previously unused acreage to cropland negatively impacts local biodiversity. Cropland can support only a limited number of species and displaces complex ecosystems. Crop monoculture will necessitate increased use of fertilizer to overcome soil degradation and pesticides. The quantitative impact of these effects is difficult to ascertain, but they are known environmental consequences.

Of further concern is the risk to water quality. As more land is brought into production, and the land already under cultivation is farmed more intensively to meet corn demand, water quality is expected to be affected significantly. If soil erosion increases, more soil will be washed into rivers, increasing the amount of sedimentation. The biggest water quality problem of corn-based ethanol production is associated with the increased fertilizer use required to sustain crop yields. The link between hypoxia (oxygen depletion in water) and fertilizer use is well documented. Nitrogen and phosphorous nutrients are washed into water courses, enhancing the growth of phytoplankton and causing an algal bloom. Oxygen is consumed when the phytoplankton die and decompose, causing the dissolved oxygen content to fall to below that able to sustain most aquatic life.

The hypoxic 'dead zone' in the Gulf of Mexico is the second largest in the world, covering 20,000 km^2.[140] Although some hypoxia may have existed naturally before the second half of the twentieth century, the hypoxia has increased in intensity since then and evidence indicates nitrogen loading in the Mississippi River drainage basin, due largely to increased fertilizer application, is the primary cause.

With more intensive corn production, increased nitrogen and phosphorous run-off is likely to increase the hypoxia problem around the United States. Scientists at Virginia Tech recently forecast that over the next five years up to 1 million acres of land will be newly planted with corn within the Chesapeake watershed. This will require more fertilizer than traditional crops such as soybeans and hay, leading to increased nitrogen and phosphorus run-off, and consequently increased hypoxia.[141]

Soil erosion is another concern. A change in land use to increase corn production is likely to increase the soil erosion rate, as land under conventional corn production sees 40 times the soil erosion of permanent pasture.[142] Erosion results in less productive soil and declining yields. If crop yields decline, increased agro-chemical use will be necessary to produce the same amount of corn, making the process less economically viable and more environmentally damaging.

If the crop residues are removed to serve as a feedstock for ethanol production, there may be additional soil-related impacts. Crop residues play a crucial role in reducing erosion; erosion increases exponentially as the residue is removed, meaning that rates of erosion on U.S. cropland soils from which the residues have been removed are often much higher. As the residues decompose into the soil, they increase the soil organic carbon level, an important contributor to soil fertility. The wheel traffic associated with the collection of corn stover compacts the soil, reducing its quality. This is not to suggest that no crop residue can be harvested, but that in order to sustain crop production, removal rates may have to be set according to specific local conditions.[143]

Shifting to new biomass-derived fuels lessens some of these impacts, but the most promising alternatives are far from commercially viable. Because of its higher energy content, exploitation of cellulosic materials to create ethanol would require less land use and could be grown in more sustainable ways.[144] Estimates of the biomass resources that could be sustainably harvested are large, leading many to suggest tremendous opportunities for displacing petroleum-based fuels with low carbon alternatives.[145] The potential is there and, in an era of high oil prices and a political climate supportive of non-petroleum fuels, investment capital flowed into the area. But progress has been slow. Fundamental scientific and technological issues remain unresolved,[146] no commercial-scale refineries have been built,[147] significant distribution and infrastructure issues have yet to be fully considered,[148] and the collapse of financial markets is limiting capital availability leading many biofuels operations to close down or significantly scale back.[149] The Department of Energy estimates that at least 15 years of work addressing the scientific and technical questions, deployment of new technologies and capabilities, and integrating those new capabilities into commercially viable systems is needed.[150]

Higher carbon fuels, such as the oil sands and oil shale, certainly have land use implications. The possible environmental impacts of shale oil mining and processing are understood. They include disturbance of the mined lands and ecosystem displacement, diversion of water resources, and groundwater, surface water and air pollution. Neither alternative biofuels nor unconventional petroleum are environmentally benign. Canada plans to continue exploiting its oil sands regardless of U.S. policies, which means that the environmental impacts associated with their use are inevitable. U.S. policy can prevent the development of U.S. shale reserves and thereby avoid those local environmental effects. Replacing the needed transportation fuel demand with biofuels increases the risk of soil erosion, reduction in water quality, increased incidence of pest, and greater use of agro-chemicals. Each of those outcomes has local and regional environmental effects that are otherwise avoidable without the expanded use of biofuels. Which environmental effects are worse is a matter for debate. A final factor for consideration is that, unlike biofuels, unconventional petroleum reserves do not have the distorting impact on global food prices or the availability of foodstuffs.

National Security Demand for Energy

Section 526 of the 2007 *Energy Independence and Security Act* imposed the first national low carbon fuel standard by prohibiting federal agencies from purchasing alternative fuels unless the lifecycle greenhouse gas emissions of those fuels (and their methods of production) were "less than or equal to such emissions from the equivalent conventional fuel produced from conventional petroleum sources."[151] The provision ensures that "federal agencies are not spending taxpayer dollars to promote new fuel sources that will exacerbate global warming."[152] The provision was prompted by the U.S. Air Force's investment in the development of coal-to-liquids technologies as a potential supply of jet fuel. As a prohibition on contracts, Section 526 would prohibit the use of federal funds to purchase alternative fuels if they failed to meet the greenhouse gas intensity measure established by the statute.[153] Given that many advanced technologies are brought into commercial viability through federal subsidy (as is the case with ethanol) or through federal purchases (as was the case with semiconductors),[154] such a prohibition is damaging to the prospects of the nascent alternative fuel sector.

Defense Department (DOD) concerns about its fuel supplies are well founded. The DOD purchased 136 million barrels of oil products in FY 2006, making it the single largest consumer in the U.S. and one which is enormously affected by changes in price. Further examination shows that almost 75 percent of that total was used to power fixed and rotary wing aircraft.[155] Burdened by escalating petroleum prices that rise even higher when considered in the context of transporting fuel to the soldiers, equipment, and facilities, numerous studies and assessments have been undertaken in recent years in support of lowering the total fuel cost to the military and providing more efficient and effective use of the available fuel.

Expanding and diversifying the supply of energy available for defense purposes is a critical element of any future DOD energy strategy.[156] Section 526 attempts to shape the character of the supply options available for defense by adding to the criteria that must be met before a fuel can be used for defense purposes. It goes further than the goals established by the DOD's energy strategy, which acknowledge the concern for environmental effects of alternative fuels, but do not necessarily allow those concerns to dictate whether a fuel is used. Instead, as one would expect, the standard employed is more focused on the military utility of the proposed fuel option. Of further interest is the establishment of secure supplies. Disruptions in the availability of fuel, brought about by natural disasters such as Hurricane Katrina, which temporarily dislocated the supply of refined products, or shortages derived from intentional acts, such as an embargo, are a concern to military planners. The availability of alternative fuels reduces the risks associated with the vulnerability to a supply disruption.

Research on alternative fuels is underway within the Defense Department. For instance, the Defense Advanced Research Projects Agency (DARPA) is supporting efforts to ascertain whether biofuels can power military aircraft, with a specific focus on algae as the biomass source.[157] Controversially, the Air Force is pushing technical development of coal-to-liquids as a possible supplier of aviation fuel.[158]

Whether the U.S. military can exploit oil sands imported from Canada or oil shale reserves developed in the western U.S. remains unclear. The current interpretation of Section 526 suggests these fuels can be consumed if they are in the "generally available fuel supply."[159] An Energy Department official claimed the U.S. government has "made no decisions that would affect the use of oil sands feedstocks" in reference to a question about Section 526 and recent efforts to amend it.[160] Nevertheless, the Section's restrictions will have an impact either as the oil sands become a larger share of the available gasoline supply or if the military decides it desires long-term contracts to ensure supplies of fuel at a given price. The potential prohibitions of Section 526 or a national low carbon fuel standard will cause the military to look elsewhere for fuel supplies. Doing so will result in costs, costs associated with the financial costs of the alternatives as well as the costs of forgoing the exploitation of a readily available resources.

In their assessment of the U.S. oil shale resource, Johnson *et al* conclude:

> America's domestic oil shale resources are more than adequate to assure military fuel requirements. Shale oil development can play a vital strategic role by providing the military with long-term, secure access to domestic fuels that are not vulnerable to interruption. This could provide an important advantage to preparedness planning and execution.[161]

How best to diversify the energy supply available to the U.S. military raises a number of issues of which the greenhouse gas effects should be a relatively minor consideration. The quality of the fuel in performance of the military mission is the foremost concern. The cost of the fuel to purchase and transport is another. Defense planners also will place importance on the reliability of the supply of the fuel. It would seem that the environmental effects of a fuel would be considered only after those factors are weighed. The advanced research on the military applications of biofuels may produce dividends at some point, but they remain sufficiently risky to reasonably base future fuel supply assumptions on them alone. Applying a low carbon standard on military fuel, though, may retard further development of reliable supplies of military quality fuel. Such a decision seems contrary to national security needs.

Conclusion

Champions of alternative fuel sources that remain economically uncompetitive with fossil fuels without government support have long argued that the externalities of petroleum fuels were very large and so negative that a full accounting would result in a positive assessment in favor of alternatives. When considering where the United States will find its transportation fuels for the future, the current policy environment has crafted a system to preferentially support biofuels via subsidies, market share floors, and vehicle standards.

A national low carbon fuel standard is another instrument under consideration. By regulating fuel based on its carbon content to achieve an environmental objective, reducing greenhouse gas emissions by the United States, the standard preferentially treats biofuels or other low carbon options.

Today, corn-based ethanol is the only commercially viable alternative and it is likely to remain so for the foreseeable future. Advanced biofuels are under development, but are not commercially available and face important technical and market barriers before they will be widely used. As shown, increased use of corn for energy stresses the agriculture system to provide the amounts required to meet demand, with risks to environmental quality and food security.

Designed with the intent of improving U.S. security by reducing imported petroleum, the low carbon fuel standard actually may undermine energy security by foreclosing access to and development of readily available and reliable unconventional petroleum options. Concerns about the security implications of imports are overstated and the benefits gained from reducing imports are not large. If greater energy security is the goal, then the low carbon fuel standard undermines the objective. Canada's vast oil sands would be exported to Asia and the U.S. oil shale reserves would remain untapped because their carbon contents would be too high to meet the standard. Biofuels can not replace much of the imported demand for petroleum nor the supply potentially provided by unconventional petroleum reserves. No projection shows biofuels or non-petroleum options accounting for significant shares of transportation fuel demand over the next few decades.

In summary, the national low carbon fuel standard will not result in significant improvements for U.S. national security, preferentially supports fuels that have significant costs, limitations, and environmental consequences of their own, and precludes the use of readily available fuels.

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66. 1 L moves 1 tonne 2800 km.
    2.857 L moves 1 tonne 8000 km.
    857143 L moves 300,000 tonnes 8000 km.
    857143 L = 226,433 gallons = 838 tonnes of oil equivalent
67. 1 kt = 1.852 km/hr, so 16.55 kt = 30.65 km/hr
    8000 km/ 30.65 km/hr = 261 hr = ~11 days to complete the trip
    838 tonnes of oil fuel/ 11 days = 76.18 tonnes/day
68. 76.18 tonnes per day of bunker consumption * 3.17 = 241 t/d CO_2 emissions
    241 t/d * 11 d = ~ 2656 t in total
69. EIA (2008d): 2.
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72. 1.2 m b/d * 365 d = 438 b/yr
    438 b/yr/ 2 m (VLCC carrying capacity) = 219 total one-way trips
    219 trips * 2656 tonnes emitted per trip (Vancouver to Shanghai) = 581,644 t/yr
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128. Using a corn-to-ethanol conversion rate of 2.7 gallons per bushel, meeting a 15 billion gallon RFS requires 5,555 bushels of corn. USDA projected ethanol use of 4,750 bushels for 2015, leaving a demand gap of 805 million bushels. There is some debate about the exact conversion rate. Researchers at the USDA's Economic Research Service estimated it at 2.7 in 2006 (see http://www.ers.usda.gov/AmberWaves/April06/Features/Ethanol.htm), but researchers at Iowa State University put it at 2.75 (see http://www.card.iastate.edu/iowa_ag_review/winter_07/article4.aspx) and ethanol marketers put it at 2.8 (see http://www.ethanolmarket.com/corngrains.html). The conversion rate assumption is significant. Altering it from 2.7 to 2.8 is a difference of approximately 200 million bushels (805 v. 607).

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