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Energy Security Implications of a National Low Carbon Fuel Standard

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Research Highlights

- We explore energy security implications of a U.S. national low carbon fuel standard (NLCFS).
- A NLCFS encourages oil substitutes, e.g. biofuels, with notable security benefits.
- The mean energy security benefits of NLCFS range from \$5-\$22/BBL in 2035.
- Oil sands compliance costs (mitigation or credit) are well below production profit.
- Diminished Canadian oil sands production is possible but seems unlikely as a result of a NLCFS.

Abstract

This paper discusses the potential energy security implications of a National Low Carbon Fuel Standard (NLCFS). A low carbon fuel standard is designed to reduce greenhouse gas (GHG) emissions by targeting the fuel portion of the fuel-vehicle system. Specifically, a NLCFS would set national targets for the average carbon intensity (CI) of motor fuels, and establish a market for credits that allows fuel producers and importers to respond in a variety of ways to the signal provided by the credit price. An important method for lowering the CI of transportation is to substitute lower-carbon alternative fuels such as advanced biofuels, electricity, CNG, and H2. Despite the focus on GHGs, so long as transportation fuels remain dominated by petroleum, transportation fuel policies like a NLCFS also will be evaluated in terms of their energy security impacts. We examine the fuel substitutions that are projected to be induced by a NLCFS and consider the energy security implications of displacing higher carbon fuels, such as imported Canadian Oil Sands oil or certain imported crude oils, with lower-carbon domestic oil, biofuel, or lower carbon oil imported from other sources.

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Key Words: Energy security; transportation; low carbon fuel

1. Introduction

This paper discusses the potential energy security implications of a National Low Carbon Fuel Standard (NLCFS). A key objection to a NLCFS is the concern that it could reduce energy security. Some argue that in restricting the carbon-content of fuels, a NLCFS would adversely affect energy security by preventing the use of reliable high-carbon unconventional oils (Kueter 2009),(Canes and Murphy 2009),(NPRA 2010), (CNAES 2009). The primary concern is that it could deter the importation and use of Canadian oil sands. There is also mention of the possible impact on domestic production of oil shale,[i] and other unconventional heavy crudes, possibly Venezuelan ultra-heavy crudes. This, it is said, would encourage U.S. reliance on less secure oil imports. It would then either lead to export of those oil sands to other countries resulting in little net reduction in global CO2 (crude "shuffling" CO2 leakage); *or* it would lead to reduced global use of unconventional oils from stable, competitive sources, hence greater global reliance on insecure or cartelized conventional oil.

Some of these arguments are not formally structured and rely on bold claims without supporting analysis. The assertion that the U.S. would rely increasingly on insecure imports omits consideration of the degree to which a NLCFS could reduce total U.S. conventional oil use through the diffusion of alternative-fuel substitutes like biofuels and electricity. The discussion of potential crude shuffling and leakage is not precisely an energy security concern, although it is at times conflated with energy security issues. Indeed, one important point is that full CO2 leakage, in the sense of global shuffling of oil sands and heavy crudes, implies low energy security concerns.[ii] This is because it maintains a consistent level of global production of stably-supplied unconventional liquids. The global nature of the oil market means that U.S. exposure to sustained high oil prices or episodic oil shocks is strongly influenced by net global oil balances, and by the global fraction of oil that is from stable suppliers. These would be unchanged by pure oil shuffling.

While these concerns could each be discussed in turn qualitatively, it is helpful to acknowledge that energy security is well-assessed through a coherent and structured quantitative analytical framework focusing on specific economic costs. Certainly, much energy security concern and rhetoric relates to geopolitical, strategic and foreign policy considerations, the formal analysis of which is problematic. If the *economic* costs of energy dependence and insecurity were diminished, however, it is arguable that the weight of many of these aforementioned concerns could be lightened. The *economic* consequences of energy dependence and insecurity can be quantitatively estimated. The actual level of energy security costs derives from a set of economic conditions related to: fuel demand levels; import levels; the proportion of the global fuel supply that is stable and competitive; the risk of shocks to unstable supplies; the size and use-policy of the Strategic Petroleum Reserve; short and long-run supply-demand flexibility; and the economy's sensitivity to fuel price shocks. Our analysis encompasses the interplay between these key factors.

Many subsidiary issues are raised by critics of a NLCFS, questioning whether it could enhance energy security at all. Some echo the view that energy security itself is an elusive or even counterproductive goal (Keuter 2009:2). Is there any such thing as energy independence, and is it a worthwhile goal? Given our many interdependent interests, e.g. in the Mideast, can we reasonably seek energy independence? Is exposure to shocks unavoidable? Can substitution with domestic supplies like ethanol reduce exposure? What if the substitute fuel is imported (Canes and Murphy 2009:17)? Our perspective is that energy dependence, and exposure to shocks, can be reduced by degrees. Progress can be measured at least partly in terms of avoided economic costs.

Sperling and Yeh (2010) note concern about discouragement of oil sands and the potential risk of increased dependence on lower carbon crudes from the Mideast. They observe that the concern may be real but overstated, noting that Canadian oil sands produce only a small fraction of world supply (1.4% projected to grow to 3.5%). The size of the oil sands contribution does not resolve the issue, however, not only because 3.5% is actually a significant quantity in the global oil market but also because small changes at the margin can be relevant to economic analysis.

Variations in Carbon Intensity by Petroleum Source

A wide range of crudes is used to produce U.S. motor fuels, with lifecycle Carbon Intensity (CI) varying from slightly under 90 to over 110 g/MJ. Across various sources of gasoline or diesel fuel, the most significant differences in CI come from the upstream stages of feedstock (crude) extraction, upgrading, and refining (see Figure 1). Heavy crude processing can be much more energy intensive, and some crudes are associated with greater gas flaring or venting. Crude from oil sands differs from many conventional crudes in having particularly energy-intensive extraction and production processes. Transportation distances for crude oils and finished products also matter, but to a lesser degree. Some crude oils such as those from Saudi Arabia, Algeria, and the majority of U.S. crudes, have significantly lower GHG emissions than heavy crudes including Venezuelan, Californian and Canadian Oil Sands (COS) (Gerdes and Skone 2009). Substantial uncertainty remains concerning the CI of any particular crude type Griffin, W. M., M. Kocoloski, et al. (2012).). The CI of COS also varies, depending on the specific source and production methodology. Consensus estimates are that average well-to-wheel

(WTW) lifecycle CIs for COS are approximately 10% greater, with an approximate range of 5% to 15%, than average CIs for crude oil refined in the U.S. (CERA 2010).

[Figure 1 Here]

The primary concern raised about a NLCFS on energy security grounds is that it discourages fuel supply from some sources that are secure but higher in life-cycle carbon content. This is particularly acute when considering crude oil originating from COS since they are a substantial source of imported oil. The concern is also potentially valid for other high-carbon feedstocks from domestic shale or coal, although those sources figure far less prominently in the supply mix projected by the U.S. (EIA AEO 2010.)

2. Energy Security Accounting Framework

Understanding the impact of a NLCFS on energy security requires applying a measurable definition of energy security to assess the implications of altered fuel-usage patterns under a NLCFS. We define energy security in economic terms, as the protection of the U.S. economy against the risk of significant short-term and long-term increases in energy costs and their attendant macroeconomic consequences. These concerns stem from sustained high oil import costs; the non-competitive (cartelized and government-controlled) supply of oil; the importance of oil to the economy; and the economy's vulnerability to episodic shocks.

We utilize and extend a quantitative characterization of energy security impacts, derived from Leiby (2008). We apply it to the fuel use changes under NLCFS compliance estimated with the Transportation Regulation and Credit Trading (TRACT) model in a companion paper (Rubin and Leiby, 2012). Within this formal energy security framework we are able to generate quantitative estimates of NLCFS security impacts, accounting for fuel substitutions and potential security gains from biofuels. This includes the effects of changed crude sourcing, import levels, and the global mix of liquid fuel supply on oil price levels and the expected costs of shocks to the U.S. economy.

To account for energy security costs that are of societal concern, we apply the energy security "Premium" framework [Bohi and Montgomery 1982, Broadman, Broadman and Hogan 1986, Toman, Leiby et al. 1997, Leiby 2008, Brown and Huntington 2009]. The "Premium" is the portion of marginal cost associated with security and market power that is *not* accounted for by private agents. Some energy security costs, such as the expected economy-wide macroeconomic costs of future oil disruptions, are too diffuse and indirect to be anticipated by oil consumers or reflected in the market price consumers pay for oil. They are therefore part of the premium. Other security costs, such as the expected price change that would be directly experienced in future shocks by a consumer who makes a long-lived decision to use oil now, are likely to be at least partially internalized. However, oil consumers do not account for how their personal consumption can induce changes in expected future price shock costs to *other oil consumers*. The security premium counts only those cost components, or portions thereof, that are not internalized or reflected in the market price.

Early oil import premium work (Plummer 1981, Bohi and Montgomery 1982, Broadman 1986) defined the essential framework and focused on the question of optimal import tariffs. A careful restatement of the issues and methods for estimating the social costs of oil imports was provided in Leiby et al. 1997. Useful reviews of energy security by Toman (2002), Parry and Darmstadter (2004) surveyed some estimates of the oil security premium. An update in Leiby 2008, that applied the method to energy security implications of oil import displacement by the renewable fuels standard (RFS), provides the foundation and description for the method used for NLCFS energy security estimates here. Brown and Huntington (2009) differentiated between the security premium for consumption of oil imports and consumption of domestically produced oil (finding the latter to be about half as big). In this paper we develop premia for multiple fuels, allowing estimates of the marginal security costs of paired fuel substitutions and the security costs for the average fuel mix over time.

The basic approach for calculating the energy security premium (cost) for each fuel stream starts with a simple statement of economic welfare, or net benefits (NB), from fuel consumption, including expected losses from supply shocks:

$$\begin{aligned} NB = {} & \text{Consumption Value} - \text{Supply Cost} - \text{Import Cost} \\ & - \text{Expected(GDP losses + Import Costs)} \end{aligned} \tag{1}$$

The energy security cost premium is derived as the marginal reduction in net economic benefits from using a fuel, that is, the marginal change in total economic costs minus price (see Leiby 2008).[iii]

“Economic costs” include economy-wide impacts but exclude environmental costs and political or foreign policy costs. The key factors driving estimates of oil security cost can be related to its two main components. The first component, long-run dependence costs, counts the effect of marginal demand on the long-term import costs for the energy good, in cases where the global supply of the good is non-competitive or cartelized. This is computed from a simple market model that depends on undisrupted fuel supplies and demands, long-run elasticities of demand and supply in various regions, and prospective behavior and market power of non-competitive suppliers (OPEC). The second component is expected marginal disruption cost. This cost depends on disruption likelihoods and sizes, their price effects (through short-run supply and demand elasticities and emergency stock use), and the sensitivity of the economy to price shocks.

Figure 2 provides a schematic of the modeled relationships. The magnitude of the premium is estimated by stochastic simulation of short-run and long-run fuel market outcomes. Uncertainties in the simulation include market shocks, as well as representative probability distributions for the key market model parameters (elasticities, OPEC behavior, and GDP sensitivity to shocks).

[Figure 2 Here]

3. Energy Security and Canadian Oil Sands

The U.S. imports more oil from Canada than from any other country, and also comprises almost all of Canada's export market (Energy Information Administration 2009). The essential story from 1999 to 2009 is one of declining share for Venezuelan crude (from 21% to 12%), rising share for Canadian crude (from 19% to 25%), with new supply from Russia and relatively constant share for the other main sources.

Importantly for GHG emissions and other environmental impacts such as water use and ecosystem disruption, oil sands now (at 1.2 MMBD) make up over half of western Canada's total crude oil production. As discussed earlier, COS production is expected to increase 1 MMBD by 2015, and to reach 3.3 MMBD by 2025. Canadian conventional crude oil production is expected to continue the decline it has been experiencing since the 1990's (Canadian Association of Petroleum Producers 2009).

Economics and GHG Emissions of Oil Sands: Alternative Responses of Oil Sands Producers and Importers to a NLCFS

We consider the implications of a limited number of COS response scenarios under a NLCFS. The scenarios have different implications for costs, energy security and GHG emissions. The principal scenarios identified here are: 1) reduce carbon intensity of oil sands; 2) purchase NLCFS credits and continue to import oil sands to U.S.; 3) export oil sands oil elsewhere (shuffling); and 4) reduce production of COS. The methodology used in this paper is more broadly applicable to other high-carbon oils and other regions as well.

In considering these options, we need to consider the technological options and costs for reducing the CI of oil sands, the transportation costs to alternative destinations , and the economic profitability of oil sands production in the absence of a NLCFS. There are other ancillary policy issues such as how oil sands production and consumption affects the oil refinery and pipeline infrastructure as well as the economies of the US and Canada that are important but not considered in our analysis.

Option 1: Reduce Carbon Intensity of Oil Sands

Producers can reduce the CI of upstream operations, that is, of extraction, upgrading and refining. This can be done by improvements in the energy efficiency of equipment and systems or by carbon capture and sequestration (CCS).There is limited published information on the costs to reduce the CI of COS. Much of the technology and costs are uncertain and not proven at commercial scale. Ordorica-Garcia et al. (2009) estimate the achievable levels and costs of CO_2 emissions mitigation from the COS industry, using a mixed-integer process optimization model. This study considered reductions of between 10% and 40% in the emissions from syncrude oil production between 10% and 40% (this corresponds to WTW reductions of 2% to 8%). Emission reductions can be gained from energy efficiency measures and ultimately from carbon capture. For an initial range, reductions in GHGs are relatively low-cost, but bounded: 0 to 35% reduction in production emissions, 0 - 7% WTW, for almost exactly (\$0.25/BBL)/(%WTW reduction). Beyond 35% (7% WTW), Ordorica-Garcia et al. estimate a big jump in cost, with a maximum reduction of ~40% (~8% of WTW), for a cost of \$9/BBL.

In comparison, Toman et al. (2008) estimate an uncertain range of carbon reduction from COS by CCS, from \$2.8 to \$8.73 per barrel by 2025. Assuming CCS reduces WTW emissions by about ~15% (achieving 100 kg CO2e/bbl), these figures translate into a carbon cost of between \$28 and \$87/MT.[iv]

Option 2: Purchase NLCFS Credits and Import to U.S.

Under a U.S. NLCFS credit trading system there will be an option to continue importing petroleum from COS while offsetting its higher CI with purchased credits. The market price of credits will depend on the stringency of the NLCFS standard and the overall cost of compliance.

To quantitatively examine the implications of a NLCFS and the marginal costs of compliance, we created the Transportation Regulation and Credit Trading (TRACT) Model. With TRACT, we separately model a NLCFS credit trading system among profit-maximizing fuel suppliers. Profits derive from the sales of fuels minus the costs of fuel production, plus net revenues from credit sales. For details and assumptions regarding the calculation of fuel mix and compliance costs, see Rubin and Leiby 2012.

The scope of the TRACT model includes light- and heavy-duty vehicle fuel use in the United States from 2012 - 2030. We model the NLCFS taking into account the current Renewable Fuel Standard (RFS2) program and other existing regulations. The TRACT model has separate standards for the gasoline and diesel fuel categories. In the gasoline sector, fuel suppliers can use blends of petroleum-based gasoline with endogenously determined quantities of biofuels from corn, Brazilian sugarcane, and cellulosic-biomass. For the diesel fuel sector, fuel suppliers can use blends of petroleum-diesel with endogenously determined quantities of biodiesel and Fischer-Tropsch diesel from biomass. In both sectors, transportation services can also be met with plug-in electric, battery-electric, CNG and hydrogen vehicles. The primary data sources used in TRACT are AEO2010 (as captured by Argonne National Laboratory's VISION model) and EPA's estimates of fuel CIs. We also use an alternative set of fuel supply and CI projections from the University of Illinois's BEPAM model, which was used in a separate study of the economic and GHG impacts of the NLCFS (Huang, et al., 2012). Using TRACT we estimate that the price of NLCFS credits ranges widely from \$25 to \$300/MT CO_2e, depending primarily on the assumptions regarding the availability of low CI biofuels (Rubin & Leiby2012).[v] In particular our results show that using estimates from the University of Illinois's BEPAM model for biofuel supply quantities and CI's, credit prices start out at about \$25/MT CO_2e and rise to \$50/MT CO_2e over the 2015-2030 time horizon. If instead the AEO2010-VISION biofuel quantities are correct, but using BEPAM's fuel CIs, then we get credit prices rising from \$140/MT CO_2e to \$220/MT CO_2e. If AEO-VISION quantities of biofuels are correct and we use EPA's estimates of fuel CI, then compliance could be more costly: credit prices start around \$240/MT CO_2e and rise to the posited safety valve price of \$300/MT CO_2e.[vi]

Based on these estimates of NLCFS compliance and credit costs, we can estimate the cost of buying sufficient credits to offset the higher CI of COS.

$$Penalty\ Cost\ COS \left[\frac{\$}{bbl}\right] = Credit\ Price \left[\frac{\$}{MT}\right] \cdot COS\ Average\ CI \left[\frac{MT}{bbl}\right] \cdot 10\% \qquad (2)$$

The marginal penalty cost to bring COS CI down 10% (to the CI of US average crude) at a credit price of \$140 to \$220 is \$7.75/bbl to \$12.19/bbl.[vii]

Option 3: Export Oil Sands Oil Elsewhere (Shuffling)

If petroleum from COS is discouraged from U.S. markets by a NLCFS, it could be transported by pipeline to the coast, either west over the Rockies to the Canadian coast or south transiting the U.S. to the U.S. Gulf coast, and then shipped abroad. The net costs of this depend on the feasibility and cost of additional pipelines, the capacity for refining and utilizing oil sands in new destinations, and the costs to U.S. refiners of substituting alternative crudes.

In general, it is quite difficult to model the actual pattern of commodity trade for highly substitutable commodities like oil. Actual trade patterns between sources and destinations can change dramatically with modest changes in price or transportation costs. This is further complicated by the substantial uncertainty regarding the costs associated with each option for oil sands production and trade.

Currently most COS oil is delivered by pipeline to the U.S. upper Midwest. Even without a NLCFS, multiple proposals are under consideration to deliver COS to the U.S. Gulf Coast or west coast by pipeline. EnSys (2010, p. 6) estimates the cost of transporting COS crude to Asia by pipeline and tanker, see Table 1.

[Table 1 Here]

The study by EnSys estimates the costs of shipping COS oil to China at \$3.77 - \$5.34/BBL (EnSys Energy 2010). This is below the cost required to transport COS to the U.S. Gulf Coast via pipeline. Earlier we showed that the marginal penalty cost per barrel to offset COS CI down 10% with credits, to match the CI of US average crude, is reasonably estimated at $7.75/bbl to $12.19/bbl. Thus, we can conclude that were these credit prices to be realized there would be a strong incentive to shuffle oil to reduce compliance costs. A safety valve price of $80/Mt places a penalty cost on COS (compared to conventional crude oil) of about $4.40/bbl. Thus, if policy makers wish to prevent oil shuffling, they could set the safety valve price at $80/Mt which would approximately equal the costs of shipping oil from COS to China.

In the scenarios of the Barr (2010) report on shuffling, oil sands goes to Asia instead of the U.S., and Middle Eastern crude goes to the U.S. instead of Asia. This results in longer transportation distances and higher emissions from tanker/pipeline transport. There is no assumed change in total crude supply or demand. Barr estimates the emission range is to be 1.3 – 3.9 g CO2e per MJ of oil shuffled or about 1%-4%. The Barr report used pessimistic assumptions that may overstate the emissions from shuffling.

A clear message emerges from the literature: despite the seeming obstacles to widespread trade in oil sands, cost-effective alternative markets for oil sands do exist, primarily in Asia. With additional pipelines to the West coast, access to the Asian market could be greatly increased. Similarly, with the proposed new pipelines to the U.S. Gulf coast like Keystone XL, which is under regulatory review, oil sands supply could be integrated with the global market, encouraging expanded production (e.g. Draitsch 2011).[viii] While there is opposition in British Columbia to new oil sands pipelines (e.g. Cataneo 2012),there is also strong political and economic support for them at the national level. The Canadian political debate is still playing out, but opposition may diminish given environmental safeguards and a more-clear sharing of the benefits with provinces that are transited by pipelines. Given the growing number of alternative proposals and pipeline routes being planned or developed, it seems unlikely that institutional barriers or other costs, beyond the transportation costs above, would strongly limit the movement of oil from COS to non-U.S. markets.

Option 4: Reduced Production of Canadian Oil Sands

The fourth possible response to a NLCFS is that COS producers would reduce output. This would be the worst-case outcome for U.S. energy security *if* the U.S. must also import more crude oil from elsewhere. In that case the global supply of oil is likely to be more volatile, as stable COS is replaced by less-stable non-U.S. sources. Reduced COS production would impose an opportunity cost on COS suppliers equal to the difference between the crude oil price and the marginal cost of COS production. The estimated production costs of COS is not completely known or uniform, but multiple available estimates (Canada NEB 2006, Shell 2009, OilSandsReview 2010) are between $36 to $50/BBL, for the full cost of production and upgrading to syncrude oil in 2010. These costs can rise with the price of energy, since energy comprises 20-25% of cost. Under EIA AEO midcase oil price projections ($80-$120/BBL), and most other expectations about the future oil market, syncrude production from COS can yield substantial profit, ranging from $30 to $70 per barrel. If there is reduced COS production there will be economic losses to both Canadian and U.S. firms that operate in the oil sands, or provide supplies and services to companies that do. These potentially large losses mean that there will be strong economic pressure to produce COS. Given the costs of the alternatives reviewed above, reduced COS production seems the least likely response to a NLCFS. Furthermore, if the U.S. market is reduced by a NLCFS, the potential non-

U.S. market demand for COS seems to be large, based on growing international investments in the resource and pipeline development.[ix]

4. Energy Security Premium Estimation Results

Given these four possible outcomes from a NLCFS, we now estimate energy security premia for alternative time-paths and alternative combinations of domestic and imported fuel consumption combining the outcomes of the TRACT model and the energy security approach used in Leiby (2008). We benchmark a model of base fuel market conditions and marginal responses to AEO2010, and then probabilistically simulate the effect of changed fuel demands with randomized parameter variations and hypothetical supply shocks for each year from 2012 to 2035. The simulation gathers the marginal cost components associated with increased consumption of domestic or imported fuels, for both oil and substitute fuels.[x] This allows the reconstruction of total marginal security cost for individual fuels. That marginal cost for each fuel is also interpreted as the marginal security gain in cases of a reduction in that fuel's use. The effect of a substitution between two fuels can be estimated by the difference between their respective consumption premia.

We can then consider various patterns of marginal change in supply, demand and imports that re-balance fuel markets, with oil sands production either unchanged, reduced or going overseas. The various offsetting options are shown in Table 2.

[Table 2 Here}

The NLCFS energy security impacts depend on which outcomes in Table 2 apply, i.e. they depend on the fuel-mix changes estimated by TRACT, and on which oil sources are used to produce the petroleum fuels (domestic, imported conventional oil, or COS). Alternative fuel mixes under the NLCFS are taken from results of the TRACT model in the companion paper (see Rubin and Leiby 2012), which is benchmarked closely to AEO2010 in its base (no NLCFS) solution. Figure 3 shows this Base petroleum demand over time, and three alternative cases under NLCFS.

[Figure 3 Here]

We can estimate the average energy security impact of the NLCFS under various conditions: different NLCFS scenarios (Base, 10% CI reduction by 2030, 10% by 2030 with no COS, 10% by 2030 with trading); and different assumptions about the oil sources displaced when U.S. petroleum demand is reduced (either domestic crude, imported crude, or COS oil).

Figure 4 shows the time path for the energy security gains per barrel of petroleum use displaced by the NLCFS (Case: 10% NLCFS by 2030, AEO2010/EPA data). These estimates account for the mix of alterative motor fuels displacing petroleum. They differ based on which petroleum source is reduced. The energy security analysis accounts for global rebound effects in demand and supply, following U.S. petroleum demand displacement.

[Figure 4 Here]

The most salient concern that has been raised about the energy security implications of a NLCFS is the possibility of discouraging the U.S. use of COS, a secure North American fuel. We conclude that this is an energy security concern only when all three of the following conditions hold:

i. The NLCFS creates compliance cost and credit cost barriers that are so large that it is not cost-effective to import COS; and

ii. The reduced COS imports are replaced with imported crude (increasing the U.S. demand for unstable, cartelized oil) rather than with U.S. petroleum or alternative fuels supply, or demand reduction; and

iii. The displaced COS imports are no longer produced at all, decreasing the world supply of stable oil.

Consider the relevance of each of these conditions in turn. If the first condition does not hold, then the COS will still be imported to the U.S. within the rules of the NLCFS system and the COS energy security concern is unfounded. If the second condition does not hold, then displaced COS imports are replaced by domestic fuels or, to a limited extent, by imported biofuels. These fuels have similar energy security characteristics to COS in that their supply is competitive, and relatively stable.[xi] In this case the energy security impacts of domestic fuels are at least modestly beneficial (see Figure 5), and substantially beneficial if COS oil sands production continues and is exported to other markets, since the overall world supply of stable transportation fuels increases. The recent rapid growth of U.S. production of tight oil from shale formations, like the Bakken formation, strengthen confidence that domestic fuel replacements for COS could be found, if necessary.

Finally, if the first two conditions hold (COS imports to U.S. are displaced and replaced by other oil imports) but the COS is still produced and exported to non-U.S. markets, then this is a case of global COS “shuffling.” Such fuel shuffling will diminish the effectiveness of the NLCFS in reducing GHGs. But it has very little impact on U.S. energy security. This is because the world oil market is highly integrated. Price changes spread quickly through the world, and price differences cause oil shipments to adjust until prices equilibrate globally. Under most anticipated conditions, U.S. energy security depends little on the identity of its specific suppliers, and more on its level of oil consumption and imports. The risk and cost of U.S. oil use depends on the global levels of demand for oil from unstable and cartelized sources, versus stable competitive ones.[xii] These factors are unaffected by global oil shuffling.

[Figure 5 Here]

Stated differently, so long as COS production is unaltered, the behavior of the world oil market as “one great pool” means that pure shuffling is not a significant security concern. [xiii] This implies that rather than regional markets operating independently, supplies and demands balance globally to equilibrate prices, and supply shocks are ultimately felt by all oil consumers. A corollary is that added stable supply anywhere improves U.S. security to some extent. Thus shuffling or reallocation of COS to other destinations is not necessarily an energy security problem for the U.S. What matters is the total demand for scarce and cartelized oil supply and the extent to which global fuel supplies derive from stable sources.

In contrast to the oil shuffling outcome, a principle conclusion of this study is that by displacing petroleum fuels with more stably supplied fuels, mostly domestic biofuels, a NLCFS can improve energy security. Although this outcome is dependent on specific assumptions for the availability and costs of biofuels, such a displacement of petroleum is estimated in most NLCFS scenarios examined. Figure 3 shows the reduction in total U.S. petroleum fuel use under a NLCFS as estimated by the TRACT model’s central case using AEO2010 and EPA data.

Under a NLCFS, we find that excluding COS does not lead to significantly less alternative fuel use and more oil consumption, or oil imports. As a test of what might occur in the *credit market* if oil sands are excluded from the U.S. fuel mix (either due to shuffling elsewhere, or reduced COS production), we considered

NLCFS Credit market scenarios corresponding to a “No Oil Sands” case. In this case, the average CI of crude consumption in the U.S. was reduced to the average reference path value *excluding* COS. In the resulting credit market scenario (using the TRACT model) the lower average crude CI reduced the cost of attaining a 10% reduction from base CI level. But despite lower average crude CI, that least cost NLCFS solution did *not lead to a substantially greater use of petroleum rather than biofuels* compared to the same NLCFS case with COS in the U.S. fuel supply. One reason for this small impact of COS disposition on fuel mix under a NLCFS is that even completely eliminating COS can only reduce U.S. average fuel CI by 0.8% to 1.5%.[xiv] The trend toward the use of increasingly carbon-intense oil in the U.S. and globally means that over time in the analysis there is narrowing CI gap between COS and "conventional crude." Thus over time the reduction in average CI achievable from even completely eliminating COS is increasingly modest. This narrowing CI gap also means that the differential cost burden for continued U.S. use of COS under a NLCFS is declining.

Figure 6 shows the average energy security premium for all fuels used in the Base case. The premium, or marginal energy security cost, for each fuel is weighted by its share of fuel supply. There is substantial uncertainty about the level of this premium, given our uncertainty about oil market conditions, market supply and demand elasticities, macroeconomic sensitivity to energy shocks, and OPEC behavior. The premium changes over time, reflecting changing Base Case market conditions such as U.S. import levels, world price levels, and the oil-intensity of the U.S. economy.

[Figure 6 Here]

The average premium shown above is only of interest for comparison, since we are examining a policy that will substitute among fuels but not reduce each in proportion to its base market share. We can consider the effects of different paired fuel substitutions on energy security cost. Figure 7 shows the estimated marginal effect of substituting either domestic oil supply, domestic biofuels, or conservation for oil imports. This plot shows only the *disruption* portion of the premium, i.e., does not account for the long-term price effect of reduced imported oil demand, leading to a reduction of total import costs to the U.S.. That is, it omits the terms of trade effect. Figure 7 shows that the maximum gain in disruption-related energy security is obtained by conservation, eliminating the fuel use entirely.

[Figure 7 Here]

However, there are significant gains from substituting domestic biofuel, which is expected to be less subject to supply disruptions and price increases than oil.. Additionally, since said fuels are of domestic origin, much of the economic cost of biofuel shocks is a transfer within the U.S. economy. Less effective in reducing disruption cost is displacing domestic oil supply with somewhat more stable domestic biofuels. Replacing domestic oil supply with either efficiency or biofuels has much less expected gain during disruptions than replacing imported oil, because importing oil both creates greater export costs during disruption and marginally increases the global reliance on less stable oil supplies.

Figure 8 shows the impact of the same five marginal fuel substitutions as Figure 7, but this time reporting the full cost to the U.S. including the effect of oil import demand on the undisrupted world oil price and the total cost of oil imports to the U.S. This component, called the “terms of trade” effect, or “monopsony” effect, has commonly been included in estimates of the oil import premium. There is strong argument for accounting for this component along with the disruption component, because it represents the degree to which the U.S. can retain a portion of the substantial wealth losses it routinely bears due to the non-competitive nature of the world supply of oil. Because the projected Base price of oil is quite high relative to historical levels, and because the oil market is expected to be increasingly facing stronger global demands and contracting supply curves, the level of U.S. demand for imports is likely to influence the world price of oil. The marginal effect of U.S. oil imports' demand on world oil price implied by the assumptions of this analysis (ranging from $0.50/BBL to $1.80/BBL for every million barrel per day change in imports demand) is not unusually large compared to many other estimates. However, when applied to the large total U.S. import quantity the effect on total import costs is significant. The terms-of-trade component for imported oil reduction is substantial, about as large as the disruption component of the premium. Note: following much of the literature, we only count the terms-of-trade for imported oil, because that market is historically subject to substantial non-competitive influences. For normal competitive markets, the demand-effect and resulting terms-of-trade component can be excluded as a normal consequence of trade.

[Figure 8 Here]

Early in this paper we identified four effects that the NLCFS could have on oil sands: continued importation with CI reduction; importation with NLCFS credits; reallocation or shuffling to new destinations; or production decline. A pivotal issue is whether the NLCFS could cause the production of oil sands to decline, and what this implies for U.S. energy security. Figure 5 shows that *if* the NLCFS causes a decline in oil sands production, the energy security result depends strongly on the source of the replacement fuel supply. .

The right two bars in Figure 5 do confirm that in a polar case where oil sands production declines and the U.S. replaces oil sands imports with an average mix of conventional crude oil, there can be a substantial security cost premium. The higher demand for conventional crude oil would increase prices, and the higher global reliance on oil from unstable sources would increase expected disruption size. All of these are potentially small effects at the margin, but the nature of the premium approach is to recognize that such small changes sometimes apply to a large level of consumption and imports, and can be significant on a per barrel basis. The mean value of security cost per barrel (in 2020) would be about $3.8 for disruption incremental costs and $12.1 in long-run terms-of-trade costs.

On the other hand, we find that even if both oil sands imports *and production* were to decline and that source was replaced by increased domestic oil or biofuel production then the U.S. would expect a slight increase in energy security. For replacement by U.S. domestic oil there is a small gain even if we recognize that oil sands supply is stable, so consuming oil sands does not drive up global supply risk. The same is true for U.S. oil supply. The small gain from substituting domestic oil for oil sands is simply the avoidance of direct risk of high payments to another country *for that unit of fuel itself* if there is a global shock.[xv]

There is also an expected security gain, slightly larger, even if oil sands production declines *providing* it is replaced by domestic biofuel (or by another even more stable alternative fuel like electricity). In this case the gains are from the uncorrelated and lower supply shock risk of biofuels compared to the oil market.

The Energy Security Implications of Potential Oil Sands Shuffling

Note that pure shuffling, the one-to-one exchange of U.S. COS imports with imported crude oil (using an average non-U.S. crude mix) would have a comparatively small energy security penalty. If oil sands flow to other world regions instead of the U.S. they can free up the same volume of conventional oil supply there as would then be demanded by the U.S. There is no increase in total world oil demand, and no change in the amounts supplied by each region. So world price would be little-changed. Similarly, the share of world liquid petroleum fuels production from stable sources is unchanged, so disruption frequency and size should also be unchanged. These conclusions follow from recognizing that the world oil market generally behaves as “one great pool.” Historically, supply shocks anywhere have been felt globally even during large disruptions, so long as oil trade continues and markets function.

5. Limitations

In this research we do not evaluate the full net economic benefits of the NLCFS, or make a claim regarding its overall economic, or full environmental, benefits. Rather, we focus on addressing its energy security implications, resulting from possible fuel market responses to the costs of carbon intensity. The only environmental measure considered is a fuel's carbon intensity, while some alternative fuels or biofuels types may have adverse effects on water quality or water demands. We have not addressed macroeconomic impacts of shuffling of COS – what this might mean for balance of payments and recycling of revenues from oil sand production. Additionally, we have not considered if the NLCFS will have any impacts on the imports or exports of the product market. That is, will the NLCFS encourage more imports of gasoline and diesel, and does this matter? Finally, we have held the final demand for motor fuel fixed such that any demand reductions and conservation measures from price impacts in response to NLCFS are not considered. This is appropriate since the NLCFS, as a carbon intensity standard, primarily encourages fuel substitutions rather than reduction.

6. Summary Conclusions

A NLCFS based on the average CI of all fuels sold in the gasoline and diesel markets will generate a disincentive for the use of higher CI petroleum feedstocks, notably Canadian Oil Sands. As a stable and competitively-supplied North American resource, COS production enhances U.S. and global energy security. We compare cost ranges for four possible responses of COS suppliers and importers to a NLCFS. First, COS imports could continue with CI reduction to levels comparable with other crudes. A review finds that the lifecycle CI of oil sands can be reduced to a level within 2%, of average conventional crude for an estimated cost of \$7 to \$10 per BBL.

Second, COS imports could continue with the purchase of NLCFS credit offsets. Based on our parallel TRACT modeling analysis of a NLCFS reducing average fuel CI by 10%, credits can be purchased to offset COS carbon to levels comparable to average crude at \$2-\$14/BBL of COS. Third, COS could be shuffled out of the U.S. to other markets. Shuffling costs are in the range of \$3.8 to \$5.3/BBL. The relatively low cost of transport and expected growing non-U.S. market for COS *regardless of a NLCFS* suggests that shuffling COS to foreign destinations could be part of the least-cost response to a NLCFS. Finally, COS production could decline as a result of the NLCFS. The current and projected profitability of COS production (\$30-\$70 per barrel) so far exceed the costs of the other three responses such that this seems economically unlikely. However, we consider its energy security implications since this is the worst-case outcome.

The first two responses to the NLCFS have no energy security implications: COS production and shipment to the U.S. is essentially unchanged. Shuffling would diminish the carbon-reduction achieved by a NLCFS. But we argue that except for catastrophic world events where global trade radically breaks down, energy security would be little-affected by shuffling of the origins and destinations of COS and other particular crudes.

The worst-case outcome for energy security would occur if both U.S. COS imports and COS production decline together, only to be replaced by greater U.S. imports of crude oil from other sources. This would impose a security cost of about \$17/BBL for each barrel so eliminated (mean in 2035) reducing the benefits just reported. We note that the credit market simulations done with TRACT do not assume that this happens in order to achieve compliance, and they suggest that if it did it would not dramatically reduce the compliance cost or change the fuel mix in the solution. More significantly, our review of oil sands economics estimates in the literature reveals that such a worst case outcome would be unlikely: COS producers would forgo profits that are *much* larger than the estimated costs of alternative solutions, including reduction of oil sands carbon intensity, the purchase of NLCFS credits necessary for continued sale to the U.S., or shuffling the COS oil to non-U.S. destinations. A much lower cost outcome, the pure shuffling outcome, in which COS barrels are shipped overseas and crude imports headed for those destinations are redirected to the U.S., has very little incremental effect on U.S. energy security.

Given uncertainty regarding costs of each of the COS responses, and the overlapping uncertainty ranges, it is difficult to determine which response will dominate. We expect COS production to continue with little effect from a U.S. NLCFS. Given the comparatively low cost of *partial* reduction of COS CI through energy efficiency in production an upgrading, the most likely response to a binding NLCFS is a combination of low-cost partial CI reduction of COS, some importation of this lower CI COS with credits, and some shuffling of the higher CI COS.

Apart from any effect on oil sands use, simulations by Rubin and Leiby 2012 and Önal et al. 2011 indicate a NLCFS is expected to decrease petroleum consumption by substituting lower-carbon alternative fuels such as advanced biofuels, electricity, CNG, and H2. This paper shows that to the extent that it does this, energy security is improved. The mean security benefits in 2035 range from $5/BBL if domestic alternative fuels substitute for COS consumption, to $12/BBL if all sources in the base U.S. mix of petroleum are decreased proportionally, to $22/BBL if imported crude oil demand is decreased. There are fairly wide uncertainty ranges around these means.

Table and Figure Legends

Figure 1: Lifecycle CI for production of diesel fuel. Source: NETL 2009, Table 3.1.

Figure 2: Schematic of modeled relationships, yielding two main security cost components. Marginal changes in these components, beyond those costs internalized in the market, constitute the security premium.

Figure 3: Time path of U.S. petroleum use by highway vehicles, with and without the NLCFS.

Figure 4: Time paths for energy security premia, various cases.

Figure 5: The energy security cost (benefit) of substituting different fuel sources for imported crude oil sands, assuming that COS are no longer produced (mean and 90% confidence intervals from simulations).

Figure 6: Average energy security premium for U.S. transportation fuels, averaged across the fuel mix.

Figure 7: Change in energy security cost per barrel of fuel substituted, for various pairs. Includes disruption component of premium only. (Year 2020 conditions, 2005$)

Figure 8: Change in full energy security cost per barrel of fuel substituted, for various pairs. Includes disruption component and long-run terms of trade costs from the impact of increased oil imports on the world oil market. (Year 2020 conditions, 2005$)

Table 1: Oil Sands Crude Transportation Costs ($/BBL)

Table 2: Possible Patterns of Offsetting Supplies, Imports, and Demands

References

Adelman, M.A. (1984). "International Oil Agreements." The Energy Journal 5(3): 1-9.

Bohi, Douglas R. And W. David Montgomery 1982. *Oil Prices, Energy Security, and Import Policy* (Washington, D.C.: Resources for the Future, Johns Hopkins University Press).

Broadman, H. G. 1986. “The Social Cost of Imported Oil,” *Energy Policy* June: 242-252.

Broadman H.G. and W.W. Hogan, 1986. “Oil Tariff Policy in an Uncertain Market.” Harvard, Energy and Environmental Policy Center, Discussion paper E-86-11.

Environmental Policy Center, Discussion paper E-86-11.Brown, Stephen P A, and Hillard G Huntington. “Reassessing the Oil Security Premium” (2009).

BARR (2010) Low Carbon Fuel Standard “Crude Shuffle” Greenhouse Gas Impacts Analysis.

Birn, K. and P. Khanna (2010) A Discussion Paper on the Oil Sands: Challenges and Opportunities, Natural Resources Canada.

Canadian Association of Petroleum Producers (CAPP). (2009). "Crude Oil: Forecast, Markets & Pipeline Expansions." Canadian Association of Petroleum Producers, CAPP (report type: (accessed 18 May 2010), June 2009, 40pp. <http://www.capp.ca/GetDoc.aspx?DocId=152951>.

Canadian Association of Petroleum Producers (CAPP) (2010) Crude Oil: Forecast, Markets & Pipelines.

Canes, M. and E. Murphy (2009) "Economics of a National Low Carbon Fuel Standard."

Cattaneo, Claudia 2012. "Resistance fierce as oil sands battle shifts to British Columbia," *Financial Post*, Apr 25, 2012 (http://business.financialpost.com/2012/04/25/resistance-fierce-as-oil-sands-battle-shifts-to-british-columbia/)

CERA (2009) Growth in the Canadian Oil Sands: Finding the New Balance, *Executive Summary*, and *Main Report*.

CERA (2010) *The Role of Canadian Oil Sands in US Oil Supply*.

Canes, M., and E. Murphy. “Economics of a National Low Carbon Fuel Standard.” Marshall Institute (2009). http://www.wpmca.com/pages/downloads/public_affairs/LCFS Economics.pdf.

CNAES Center for North American Energy Security. “NESCAUM Public Meeting Comments on Low-Carbon Fuel Standard”, 2009. www.nescaum.org/.../center-for-north-american-energy-security-lcfs-comments-nov-10-2009.pdf.

Chester, L. “Conceptualising energy security and making explicit its polysemic nature.” Energy Policy 38, no. 2 (2010): 887-895.

Draitsch, D. (2011). “The link between Keystone XL and Canadian Oil Sands production,” Backgrounder, The Pembina Institute, April. (http://pubs.pembina.org/reports/kxl-production-backgrounder-pembina.pdf)

Energy Information Administration (2009). Canada Energy Data, Statistics and Analysis - Oil, Gas, Electricity, Coal. Country Analysis Briefs: Canada, Energy Information Administration: 14.

Energy Information Administration (2009). U.S. Imports by Country of Origin. PET_MOVE_IMPCUS_A2_NUS_EP00_IM0_MBBL_A.xls. Washington, DC, Energy Information Administration: Annual Data.

Energy Security Leadership Council. Recommendations to the Nation on Reducing U.S. Oil Dependence, 2006.

Ensys Energy (2010). Keystone XL Assessment, Final Report, Dec.

EPRINC. A Primer on Canadian Oil Sands, An EPRINC Briefing Memorandum, 2010. http://www.eprinc.org/pdf/oilsandsprimer.pdf.

Gerdes K.J. and T.J. Skone (2009). "An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact on Life Cycle Greenhouse Gas Emissions, DOE/NETL-2009/1362

Greene, David L. and Paul N. Leiby 2007. "Oil Independence: Realistic Goal or Empty Slogan?" Oak Ridge National Laboratory, March, 2007.

Greene, D L, and P N Leiby 2006. "The Oil Security Metrics Model: A Tool for Evaluating the Prospective Oil Security Benefits of DOE's Energy Efficiency and Renewable Energy R&D Programs. ORNL/TM-2006/505", 2006. http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2006_505.pdf.

Greene, D. L., Leiby, P. N., Patterson, P. D., Plotkin, S. E., and Singh, M. K. (2008). "Oil Independence: Achievable National Goal or Empty Slogan?" Transportation Research Record: Journal of the Transportation Research Board,2017, doi: 10.3141/2017-07; pp.47-53.

Griffin, W Michael, Matthew Kocoloski, Kimberley A Mullins, and Aranya Venkatesh. 2012. "Addressing uncertainty in life-cycle carbon intensity in a national low carbon fuel standard." Energy Policy: submitted.

Haggett, S. (2009). "UPDATE 4-PetroChina takes C$1.9 bln stake in Canadian oil sands." Reuters. Published on 31 August 2009 (accessed 17 May 2010) <http://www.forbes.com/feeds/afx/2009/08/31/afx6834032.html>.

Huang, Haixiao, Madhu Khanna, Hayri Onal, and Xiaoguang Chen. 2012. "Stacking low carbon policies on the renewable fuels standard: economic and greenhouse gas implications." *Energy Policy*: accepted.

Huntington, Hillard G. "The Oil Security Problem, EMP OP-62." Energy Modeling Forum, Stanford University, no. February (2008).

Keuter, Jeff. "National Security, Energy Security, and a Low Carbon Fuel Standard", 2009. http://www.marshall.org/pdf/materials/643.pdf.

Kruyt, B, D P van Vuuren, H J M de Vries, and H Groenenberg. "Indicators for energy security." Energy Policy 37, no. 6 (2009): 2166-2181.

Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, 1997. *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1.

Leiby, Paul N. 2008. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports, " Oak Ridge National Laboratory, ORNL/TM-2007/028, March 14.

Montgomery et al (2010) Economic and Energy Impacts Resulting from a National Low Carbon Fuel Standard, Charles River Associates.

National Energy Board. (2006). "Canada's Oil Sands Opportunities and Challenges to 2015: An Update." Cat. No. NE23-116/2006E, ISBN 0-662-43353-X, National Energy Board, National Energy Board (report type: Report) (accessed 5 March 2010), June 2006, 71pp.

NPRA 2008. "NPRAs December 16 2008 Comments on the Draft California LCFS," Dec 16.

NPRA 2009. “NPRAs February 25 2009 Comments on the Draft California LCFS,” Feb. 25.

OilVoice (2010). "China Buys Into Canadian Oil Sands." OilVoice. <http://www.oilvoice.com/n/China_Buys_Into_Canadian_Oil_Sands/7d689186d.aspx> (accessed 29 April), last updated 03 January 2010.

Önal, H., M. Khanna, et al. (2011). Impacts of Alternative Designs of a Low Carbon Fuel Standard on US Agricultural Markets, Land Use and Feedstock Supply. National Low Carbon Fuel Study. Urbana-Champaign, University of Illinois.

Ordorica-Garcia, G., A. Elkamel, P. L. Douglas, E. Croiset, and M. Gupta. “Energy Optimization Model with CO 2 -Emission Constraints for the Canadian Oil Sands Industry.” Energy & Fuels 22, no. March (2008): 2660-2670.

Ordorica-Garcia, G., A. Elkamel, et al. (2009). "Optimizing energy production with integrated CCS technology for CO2 emissions mitigation in the Canadian oil sands industry." Energy Procedia 1(1): 3985-3992.

Parry, Ian W H, and Joel Darmstadter. “The Costs of U.S. Oil Dependency.” RFF Discussion Paper 03-59, no. December (2003).

Plummer, James L. 1981. “Methods for Measuring the Oil Import Reduction Premium and the Oil Stockpile Premium,” *Energy Journal* 2(2):1-18.

Ripple, Ronald D. and Peter R. Wilamoski, 1995. "Is the world oil market ‘one great pool?’: revisited," OPEC Review, 19(4):283–292.

Rubin, J. and P. Leiby (2012). "Tradable Credits System Design and Cost Savings for a National Low Carbon Fuel Standard for Road Transport." Energy Policy, Available online 11 June 2012, In Press, http://dx.doi.org/10.1016/j.enpol.2012.05.031.

Sauer, Ronald D. (1994), “Measuring Economic Markets for Imported Crude Oil.” The Energy Journal 15(2):107-123.

Sperling, D, and S Yeh. “Low carbon fuel standards.” Issues in Science and Technology 25, no. 2 (2009): 57-66. http://www.ef.org/documents/LowCarbonFuelStandards.pdf.

Tar Sands Watch (2009). "China's oil sands push." Tar Sands Watch, Polaris Institute's Energy Program. <http://www.tarsandswatch.org/chinas-oil-sands-push> (accessed 12 May), last updated 2 October 2009.

Toman, M A. “International Oil Security Problems and Policies.” Brookings Review 20, no. 2 (2002): 20-23.

Toman, Michael A. 1993. “The Economics of Energy Security: Theory, Evidence, Policy,” *Handbook of Natural Resource and Energy Economics*, vol. III, edited by A.V. Kneese and J.L. Sweeney, Chapter 25. (New York: Elsevier Science Publishers B.V.).

Toman et al. 2008. Unconventional Fossil-Based Fuels Economic and Environmental Trade-Offs, Rand Corporation.

U.S. Energy Information Administration (EIA). (2009). "Canada Energy Data, Statistics and Analysis - Oil, Gas, Electricity, Coal." Energy Information Administration, E. I. Administration (report type: Canada Energy Data, Statistics and Analysis - Oil, Gas, Electricity, Coal) (accessed 4 May 2010), 27 July 2009, 14pp. <http://www.eia.doe.gov/emeu/cabs/Canada/Background.html or http://www.eia.doe.gov/emeu/cabs/Canada/Full.html>.

Weiner, R.J. (1991). "Is the World Oil Market 'One Great Pool?'" The Energy Journal 12(3): 95-107.

Wilamoski Peter R. and Ronald D. Ripple 1998. "Is The World Oil Market ‘One Great Pool’?: Revisited, Again"

Yeh, Sonia, and Daniel Sperling. “Role of Low Carbon Fuel Standard in Reducing U.S. Transportation Emissions.” In On, Climate and Transportation Solutions: Findings from the 2009 Asilomar Conference Transportation and Energy Policy, Daniel Sperling and James S. Cannon, Eds., 53-54, 2010.

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[i] By “oil shale” here we mean kerogen shale and not the recently prominent production of tight oil from hydrofracture of shale deposits. Production of oil from kerogen shale is a very energy intensive process. The carbon intensity of tight oil from shale is still being investigated.

[ii] Of course leakage diminishes the carbon reduction from a NLCFS. This point, that under full-shuffling of oil sands the global oil market and global shock risk would be little-changed, is acknowledged by Canes & Murphy 2009:35).

[iii] Assuming there are no significant external or social benefits from consumption, the marginal consumption value is its market price, P_f. While there are anticipated social benefits from the use of alternative fuels like biofuels, we omit them along with any non-security related social costs including environmental and other sustainability issues. Food security is also left as a separate issue, outside this analysis.

[iv] Note: 1 bbl has ~6100 MJ, and therefore roughly 670kg CO2e for oil sands at 100 g/MJ.. So 100 kg is ~15% of oil sands lifecycle emissions.

[v] The $300 upper limit is our safety valve price for NLCFS credits.

[vi] We find that the credit price for the no COS case is about $60/MT lower until it too hits the safety valve price in later years. This $60/MT is the *average* cost across all credit sales and purchase.

[vii] This assumes US average crude oil at 100 g/MJ and COS have a 10% greater CI and US average crude oil has 5539 MJ/bbl. Offsetting 10% would then requires 55.4 kg, or 0.055 MT CO2e worth of credits. However, There is substantial uncertainty in establishing the carbon intensities of fuels, both petroleum and alternative.

[viii] The EnSys report on Keystone XL, which focused on the potential for global transportation and refinement of West Canadian Sedimentary Basin (WCSB) oil sands and other crudes, did not conclude that the KXL pipeline in particular would increase oil sands production or reduce U.S. imports from outside North America. Rather it concluded that those trends were supported by many logistical developments, of which KXL is only one.

[ix] Anticipated market demand for Canadian oil sands is reflected in recent direct foreign investments in the region. PetroChina International Company Limited has a memorandum of understanding with Enbridge Inc. to develop a pipeline that can supply crude oil from Canada to China (National Energy Board 2006; Oilvoice 2010). The Chinese National Petroleum company also has exploration rights in Alberta (Energy Information Administration 2009). PetroChina has a 60% investment in two COS projects. (2009; Haggett 2009). The bitumen from these oil sands had been slated to go to the U.S., although other export routes are considered. Korea National Oil Corporation bought a bitumen deposit in COS, and is developing the site for crude production (Energy Information Administration 2009). There are pipeline proposals to expand and/or extend into different U.S. markets (IL, OK, WA, CA, and the U.S. Gulf Coast), with the west coast pipelines possibly being used to ship to Asia (National Energy Board 2006; Energy Information Administration 2009).

[x] The premium cost components measured in the simulation capture direct and indirect marginal effects. They are:

- Long-run changes in import costs (“terms of trade” or monopsony)
  - this results from increased import demand driving up the world price, and is counted only for non-competitively supplied fuels.
- Expected change in GDP losses from shocks
  - due to any marginal changes in disruption size
  - due to any changes in short-run price responsiveness
  - due to altered sensitivity of GDP to price shocks (working through changing value shares (energy intensity) in the economy)
- Expected price increase for imports due to shocks
  - a direct effect, counting only the fraction assumed not internalized
- Expected change in total oil import costs during shocks
  - due to any marginal change in average disruption size (depends on whether reliance on unstable supplies rises or falls)
  - due to marginal change in price slope.

[xi] While biomass and biofuel supply is not completely stable, historically it has been less volatile than crude oil, and at least the shocks to biofuel supply have been uncorrelated with crude shocks. There are some security costs associated with imported biofuel, but our estimates are that they are not markedly different from imported COS.

[xii] Shock costs and the costs of market power also depend on the short-run and long-run elasticity of supply and demand, but that does not change the essential point here.

[xiii] The term originates with Adelman (1984). It refers to the high degree of oil market integration globally, and the ability of inter-regional arbitrage rebalance markets and to prevent price differentials. Weiner (1991) showed some evidence of regionalization, but subsequent empirical work (e.g. Sauer 1994, Ripple and Wilamoski 1995, Wilamoski and Ripple 1998) has been largely supportive of the original hypothesis.

[xiv] COS only amount to 7.9% of reference U.S. oil supply in 2020, rising to 10.0% in 2030 (AEO 2010 and CAPP 2010). If COS are on average 10% to 15% higher CI than other crudes used in the U.S., then eliminating COS use would only decrease U.S. weighted-average petroleum CI by 0.8% to 1.5%.

[xv] There may be a case for omitting that gain as well, under the assumption that the U.S. and Canadian economies are so closely integrated that such wealth transfers pose zero costs to the U.S. We do not make this argument.

Table 1

Route / Year	2010	2020	2030
Pipeline to British Columbia Coast	$1.93	$2.26	$2.48
Tanker from British Columbia to China	$1.84	$2.44	$2.86
Total Transportation Costs to China	$3.77	$4.70	$5.34
Pipeline to U.S. Gulf Coast	$6.41	$7.52	$8.23
Source: EnSys 2010, p. 49 Note: Costs are escalated over time due to increases in fuel costs for the various modes			

Table 2

		U.S. Demand Substitution				Supply Changes				U.S. and Other Imports			
Replacement fuel for Oil Sands	Oil sands destination	Demand US, oil sands	Demand US, dom oil	Demand US, biofuel	Dem US, imp oil	Supply Canada oil sands	Supply US, dom oil	Supply. US, Bio fuel	Supp world, crude	Imports, US, , oil sands	Imports, US, biofuels	Imports, US, crude oil	Imports, World, oil sands
Domestic Oil	Not Produced	-1	1			-1	1			-1			
Domestic Biofuel	Not Produced	-1		1		-1		1		-1			
Imported Oil	Not Produced	-1			1	-1			1	-1		1	
Domestic Oil	OS go Overseas	-1	1			0	1		-1	-1			1
Domestic Biofuel	OS go Overseas	-1		1		0		1	-1	-1			1
Imported Oil	OS go Overseas	-1			1	0			0	-1		1	1

Figure 1

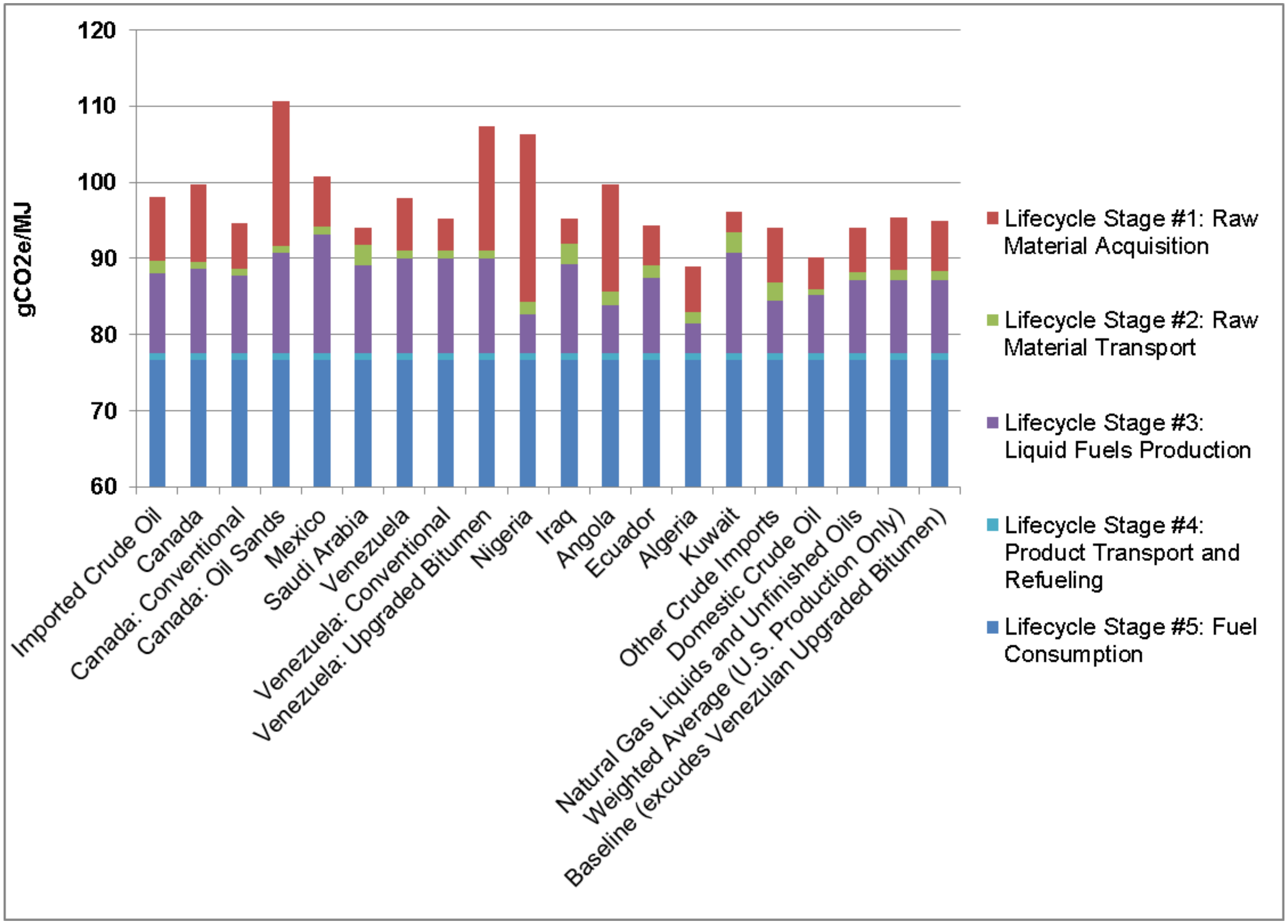
gCO2e/MJ
120
110
100
90
80
70
60
Imported Crude Oil
Canada
Canada: Conventional
Canada: Oil Sands
Mexico
Saudi Arabia
Venezuela
Venezuela: Conventional
Venezuela: Upgraded Bitumen
Nigeria
Iraq
Angola
Ecuador
Algeria
Kuwait
Other Crude Imports
Domestic Crude Oil
Natural Gas Liquids and Unfinished Oils
Weighted Average (U.S. Production Only)
Baseline (excudes Venezulan Upgraded Bitumen)
Lifecycle Stage #1: Raw Material Acquisition
Lifecycle Stage #2: Raw Material Transport
Lifecycle Stage #3: Liquid Fuels Production
Lifecycle Stage #4: Product Transport and Refueling
Lifecycle Stage #5: Fuel Consumption

Figure 2 color

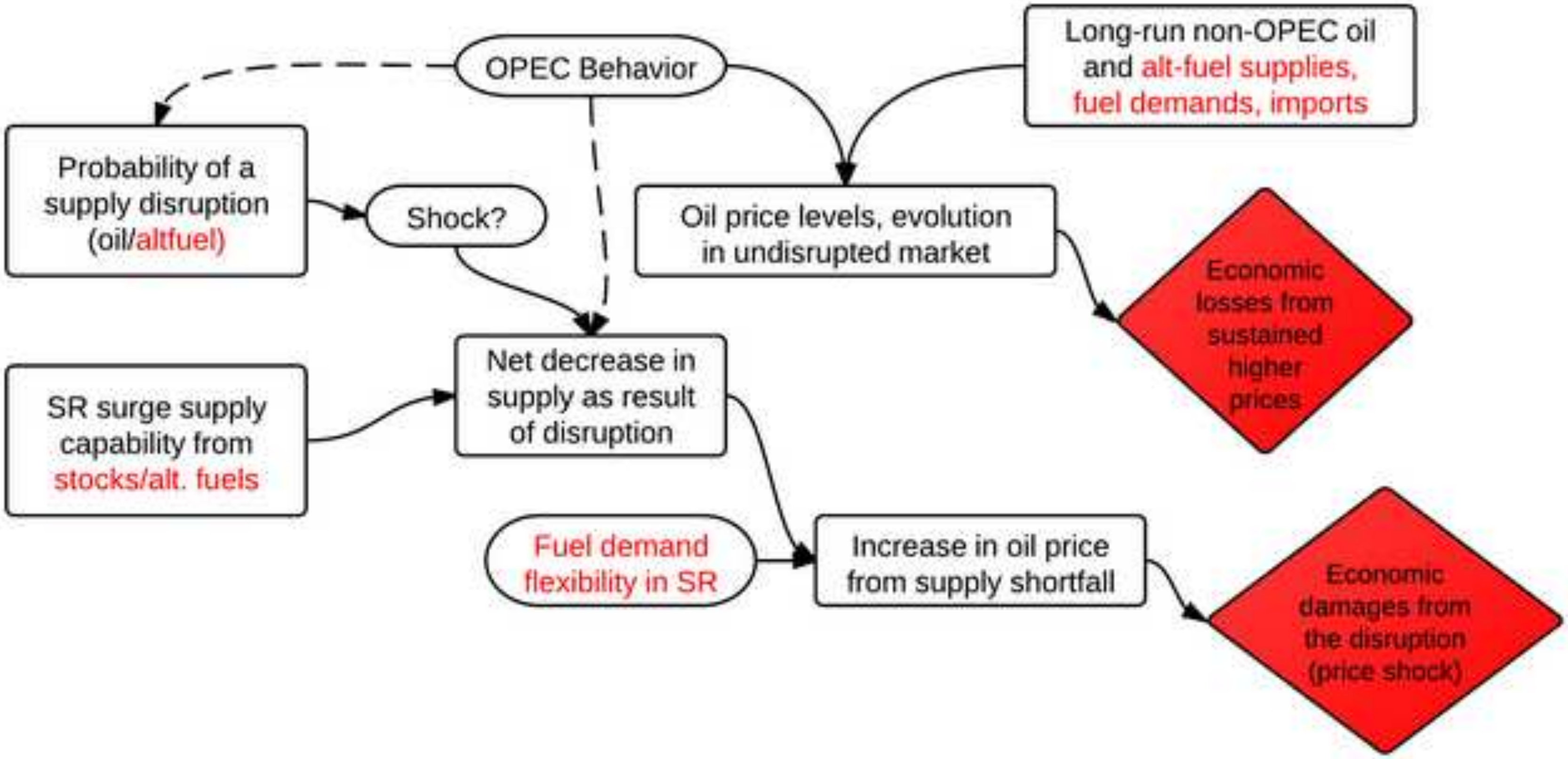

Figure 3 color

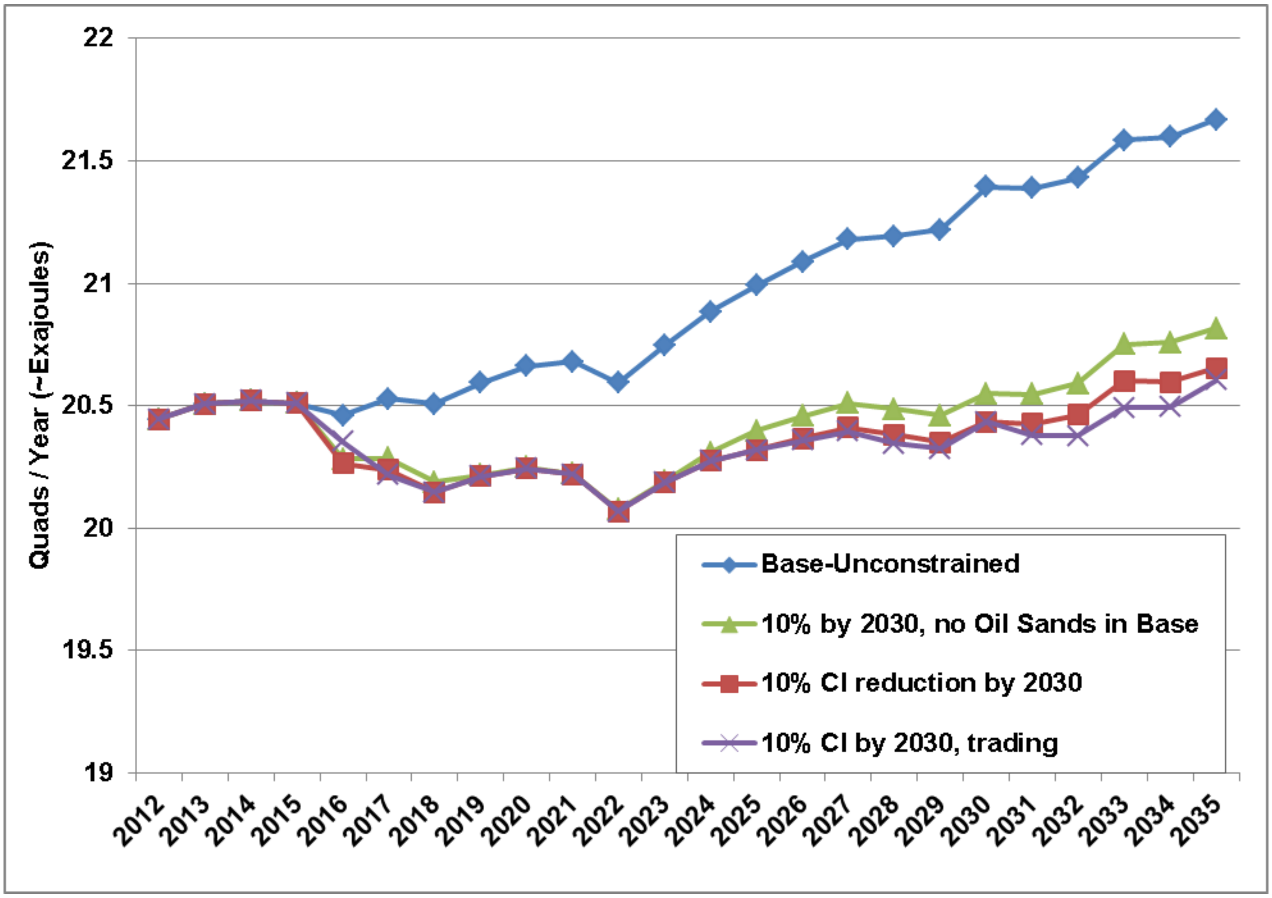

Figure 4 color

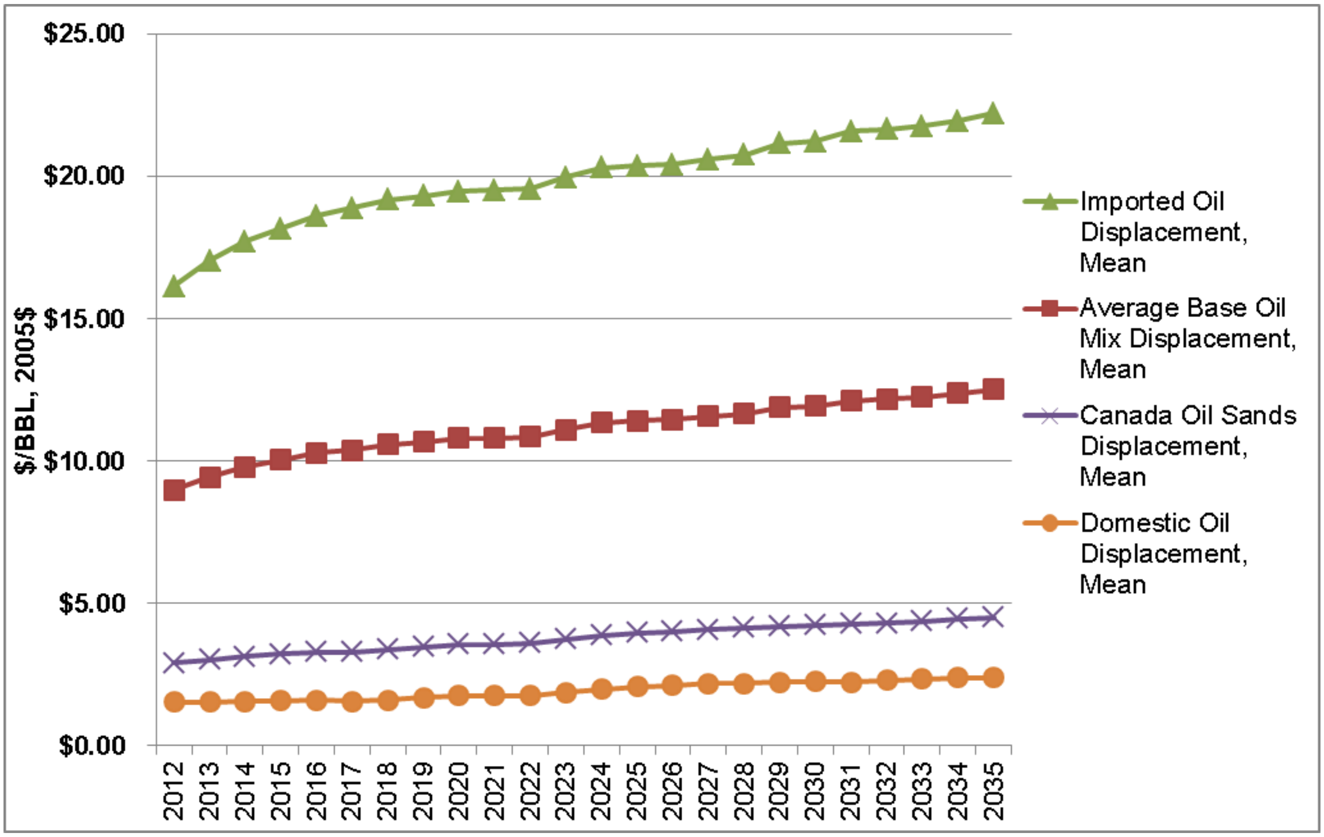

Figure 5 color

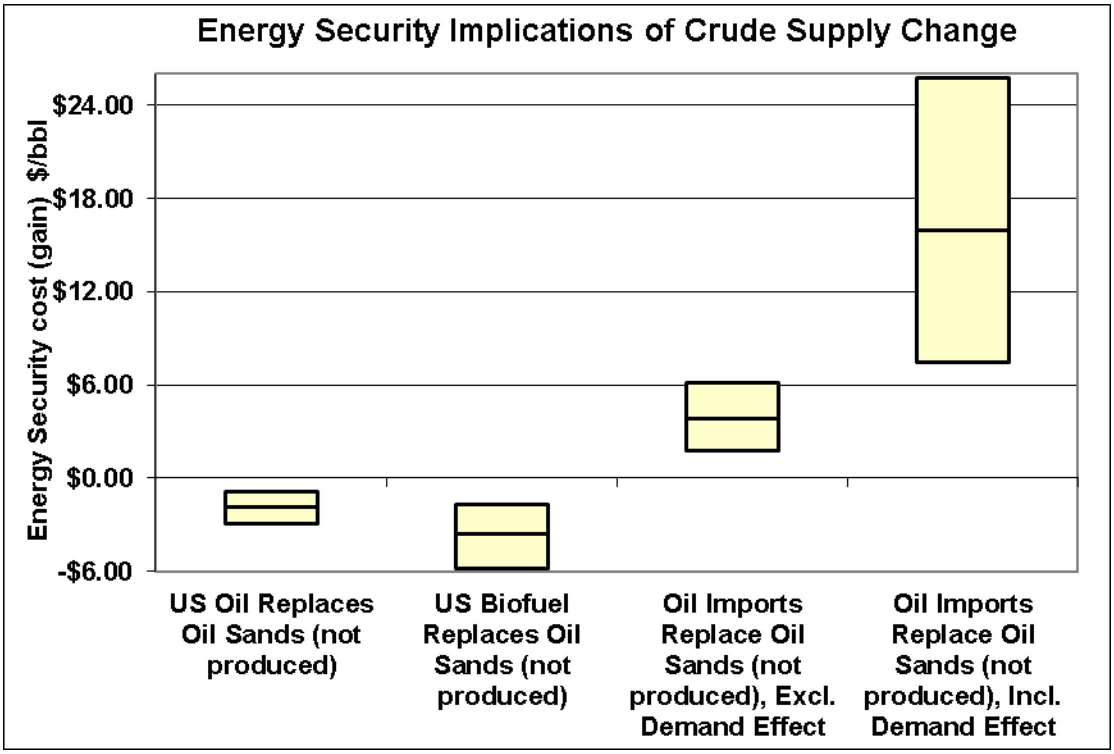

Figure 6 color

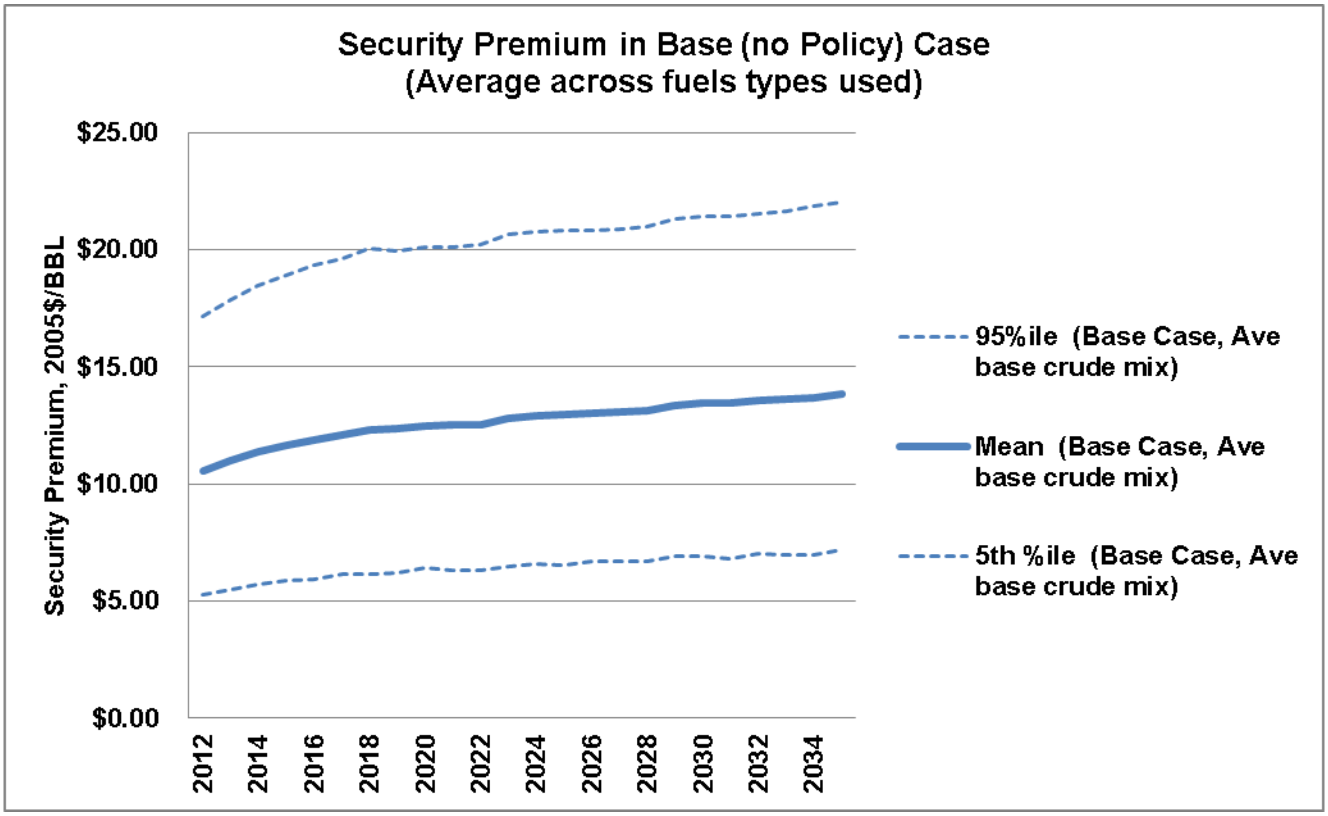

Figure 7 color

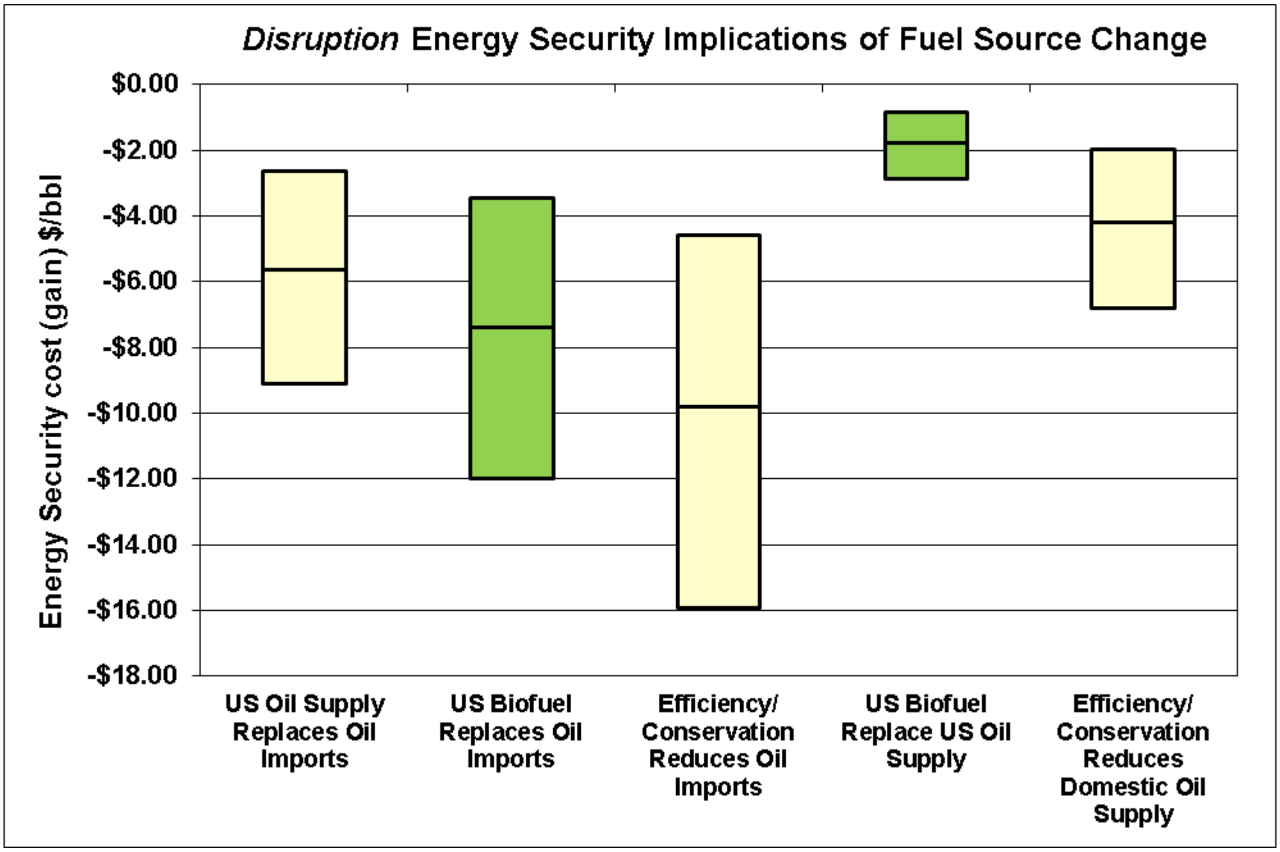

Figure 8 color