WORKING PAPER

Crude Oil Imports and National Security

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USAEE-IAEE WP 11-088

October 2011

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Crude Oil Imports and National Security

The Yale Graduates Energy Study Group*

Abstract

The authors demonstrate that the United States profits handsomely in all circumstances by imposing an embargo on imports of foreign crude oil. The US removes its exposure to foreign oil supply shocks and recovers deadweight lost producers surplus. The embargo plan will lead to greater domestic production of crude oil and alternative fuels without the tax and subsidy schemes heretofore employed.

The widely varying political conflicts that affect energy production in the Middle East, Africa and South America have again caused substantial volatility in the world price of crude oil. The most recent price increases are in direct conflict to market movements during a worldwide recession in which demand has declined. Only the withholding of production by those countries seeking to "manage" the price level in consuming economies of the western world could increase prices in a recession. This state of affairs is not in the national interest of the United States.

What has not occurred, but will happen, is even less in our own interests. The targeted reductions in worldwide supply, for political reasons, in 1973-74 and again in 1980-81, caused exponential increases in the price of crude in this country and elsewhere. These "shocks" have not re-occurred in the last decade because it was not in the self interest of the leading sovereign national producers to cut back, when inventories of alternative supply were at least partially available to replace political cutbacks. But in the new, second decade of this century excess supply capacity is not likely to be extensive, and therefore a run up the world price line cannot be forestalled—"lessons" can be taught by cutting supply resulting in very large spot price increases on every crude oil exchange worldwide.

The threat of new potential "shocks" has caught the attention of policy analysts, and the response that we gain "independence" has been coming on strong. But it is only rhetoric, since there are no plans to meet a large foreign cutback with domestic replacement supplies, or an invasion of the hostile producing nations, or a takedown of the terrorist network capable of destroying a Middle East or European pipeline network.

White House and cabinet level officials are obviously now immersed in issues related to the conservation of energy and its effects on air quality. There are many high-level experts seeking to find ways of developing new products that conserve fuels while reducing carbon emissions of the combustion machines that run the economy. As far as we can determine, however, there is

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no political focus on preventing strategic disruption in crude markets—a producing country shutdown or targeted anti-US cut off that would tear asunder our transportation markets.

It is remarkable how easy it would be to disrupt these domestic markets. Since the law of one price prevails, a spike in the crude price in some remote producing country creates the same spike in the Houston spot market and the New York commodity exchange. There is no way to prevent a sovereign producer or terrorist initiated outage somewhere that determines crude prices in the world market and, therefore, disrupts our energy and consumer markets.[1]

We (graduates of Yale), claim modestly that we have a plan to prevent such targeted price in the interest of national security. We would disconnect the United States from the world crude market (and price) and thus would greatly reduce disruption in our market. Terrorism to work its destructive forces would have to do so by blowing up shipping in Houston or refineries in New Jersey; it would no longer be effective in the United States to destroy shipping in the Straits of Hormuz or oil wells in the Caucasus.

The reason we claim to have a plan, and the President of Denmark does not, is we have generated numerical estimates of cost and benefits that indicate it costs less to cut off imports as a policy than take a surprise "shock" from a foreign supplier. That is, prudent elimination of foreign oil supplies as a Federal policy initiative would be less costly than if the US were to suffer a surprise, "shock," supply interruption. We believe that the facts in current and near future supply and demand conditions support that conclusion, for any one to six month shock.

The plan is simple and straightforward. It calls for phased withdrawal of North America (United States) from the world crude oil market. In a 10-year period, from 2010 to the end of 2020, US imports from all parts of the world except Canada would be reduced each year by a pro rata share of forecast US 2020 demand.[2] This would be achieved by a presidential Executive Order, presumably but not necessarily followed by legislation justified as in the interests of national security.

Our plan would not provide complete protection against a supply disruption over the next ten years, but it would ensure supply and price stability following 2020. Before 2020, due to the law of one price, if the US is importing even one barrel of oil per day, a foreign supply disruption would drive up the domestic price of all sources of supply. Even so, by following this

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[1] Fully 94% of known oil reserves are owned and controlled by sovereign nations. OPEC controls 76%. See US Department of Energy, Energy Information Agency, *Energy in Brief*, "Who are the major players supplying the world oil market?" January 28, 2009

[2] CAPP – Crude Oil: Forecast Markets & Pipeline Expansions June 2009, Page 19. The East to West, West to East ability of Canada to export is limited by its lack of pipeline capacity from producing areas to its coasts. Canada's integration with the US markets was illustrated in 2008 when Canadian supplies to the US were less than $40 per barrel even as WTI and foreign oil prices were in excess of $80 per barrel.

voluntary withdrawal policy, the US would lose less consumers surplus and capture more producers surplus domestically each year of the self imposed embargo, including during any conceived supply disruption before 2020.

This is neither new nor radical. Oil import controls established by Executive Order were in force in the Eisenhower Administration, designed to further the growth of domestic supply of crude, in the face of a glut of foreign oil at two dollars per barrel. This program was ended in good part because of a Nixon Administration Task Force Report critical of the price increases that followed. But we ask a different question. Taking out foreign supplies reduces total US supply, and that increases US price, but is that enough to reduce economic welfare below that from no import control plus terrorists shutdowns? The answer is found by estimating the economywide net loss or gain by comparing (1) the price of continued imports and a spike initiated abroad under business as usual policy, with (2) concurrent higher domestic price, due to year to year reductions of foreign imports under the embargo policy. The losses or gains in our national security in dollar terms are approximated by the consumers surplus lost, net of producers surplus gained.

This seems complex, but it is not. In your mind's eye draw a picture of supply and demand for the United States (or, more easily, go to Figure One below). The day-to-day market clearing price for domestic and foreign imported production takes place at the world price level. This is because the marginal sources of supply are imports trading at the same price in one of the foreign crude exchanges such as at Rotterdam or Riyadh and trading at the same price on CME Group, formerly NYMEX. In addition the negatively sloped domestic demand curve intersects this flat part of the supply curve, which is a horizontal (flat) section at the right end at the spot price in Rotterdam.

Consider the following example. With North America integrated into the world market, spot price for crude is hypothetically 100 dollars per barrel. In a worldwide price spike initiated by the shutdown (again hypothetically) of 10 million barrels per day of middle east production, one-eighth of the world`s production, the new price would be approximately $413 per barrel (given a "shock" price elasticity of -0.04).[3] The volume of imports would scarcely change given such an inelastic demand, and given surprise there would be no increase in domestic supply. In 2015, the

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[3] Again, while widely used, this estimate of short run elasticity is hypothetical but comparable to what was observed during the 1973-74 Arab oil embargo: a 288% increase in price from 1972, pre-Arab oil embargo, to 1974, $3.22 per barrel to $12.52 per barrel. Professor William D. Nordhaus estimates elasticity of demand at -0.015 for the time period of one quarter and -0.047 for a year. See "Who's Afraid of a Big Bad Oil Shock?", William D. Nordhaus, *Brookings Papers on Economic Activity*, 2:2007. For prices, see http://www.eia.doe.gov/emeu/aer/txt/ptb0521.html and http://www.eia.doe.gov/emeu/aer/txt/ptb1107.html; for world crude production, see http://www.eia.doe.gov/aer/txt/ptb1105.html; for the quantity of US oil imports, see http://tonto.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRIMUS1&f=M; and for the stability of the US Dollar, the Federal Reserve Data at http://www.federalreserve.gov/releases/H10/Summary/indexb_m.txt

US would pay $3.1 billion per day for imports, not the $749 million per day forecast by the US Department of Energy ("DOE"), Energy Information Agency's ("EIA") (see Table One).

Now consider that there is a White House embargo being phased in during 2015 on imports. Given the planned reduction in foreign supply, not only would the import bill be reduced but domestic sources would replace part of the spiked supply.[4] Substitutes (liquids from coal or biofuels) being developed would replace imports as would increased domestic crude production.

Each year the spot price will move up the domestic demand curve (as external supply is reduced) in accordance with the long run elasticity of demand (greater than that experienced in a "shock"). Price in a shock increases one-fold, not four-fold. If the attack took a large supplying country out of the market for more than a few months, the total dollars in the spike would be much greater than the total dollars of a sustained price increase from the White House program to exclude foreign supplies. Two or three spikes, taking out production in Iran, Mexico and Brazil, for example, would after the fact make the embargo not only a source that was more secure but also one that is much cheaper in dollars lost in the crude market.

But what do we actually expect to happen in cost terms in the next decade? Without disruption of the crude oil world market, according to the US Department of Energy March 2009 Reference Case, total conventional world crude production will be in the range of 86 million barrels per day in 2020, of which close to 10 million barrels per day will be American production. This domestic production will not be sufficient to clear the demand in the American crude market; slightly less than 8 million barrels per day would have to come from foreign production sources as well. The choice is between the US does little or nothing to increase security against a shock but in fact a series of disruptions of foreign sources increases our prices up to four-times the forecast level for some period. Alternatively, the US reduces its imports each year by decree, to reduce the effects of foreign disruptions and still takes the hit from a "shock" increasing domestic prices. To illustrate how to resolve the issue as to which costs less, we forecast the effects of the US moving entirely out of foreign supply as a variant on the US Department of Energy ("DOE") no spike, no embargo forecasts, and then, for example, the effect of a six month spike on both scenarios.

The Conceptual Framework

Consider the crude price by 2020 in New York or Houston under a regime in which the President uses his executive authority to take out a pro rata share of crude imports per year. Unless there is a similar percentage reduction in demand, from say intense new conservation efforts, excess

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[4] One source we will not discuss is the US Strategic Petroleum Reserve's maximum drawdown capacity of 4.4 million barrels of oil per day for less than six months of foreign supply http://www.fossil.energy.gov/programs/reserves/spr/spr-facts.html We do not expect the SPR to be deployed to alleviate world oil supply problems or that drawing down the SPR in the face of a supply disruption would reduce prices over an extended disruption.

demand over the reduced supply each year through 2020 will require price increases to clear gasoline or fuel oil markets.

Starting with these markets in equilibrium in 2010, with US domestic plus imports totaling crude supply of 19.4 million barrels per day, including imports of 8.0 million barrels per day, domestic price would be at the world crude price level of $88.80 per barrel. We then consider the embargo plan of the US reducing oil imports through 2020 that will have the effect of raising the domestic crude price each year until imports are eliminated in 2020.[5]

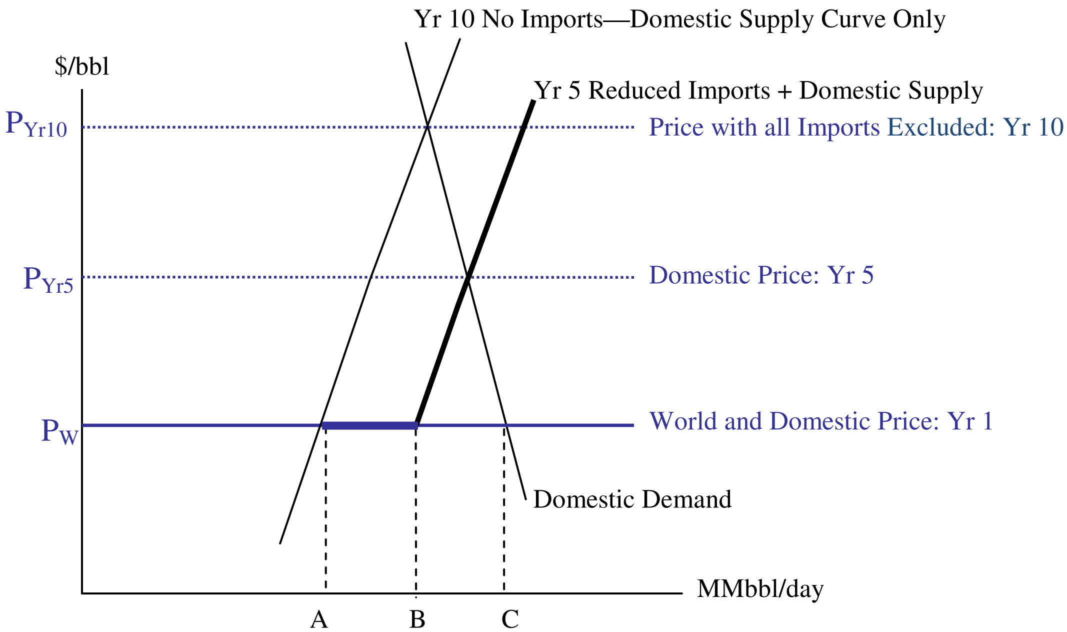
Assume first that there is no domestic response to the rising prices. At this point turn to the supply/demand diagram in Figure One to observe a negatively sloped demand function with a short run arc elasticity between -.1 and -.06.[6] This demand function intersects the supply curve at the world price due to imports in 2010. Import reductions each year shift the supply function to levels that cause only domestic supply to connect with demand (see the darkened supply curve for the example of 2015). At the end of this process price increases to a level that domestic supply clears all demand (at P_{Yr10} in Figure One).

(Figure One on following page)

[5] See Appendix, Page 20, Table 1

[6] Using the Arc elasticity equation (log (q1/q2) / log (p1/p2) = E) and world oil quantity and price data associated with the periods September 2008 to December 2008 and January 2007 to September 2007, -.06 and -.1 demand arc elasticities are derived respectively. World crude production data was taken from EIA website: http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=50&pid=53&aid=1 and Oil Price data was taken from EIA website: http://tonto.eia.doe.gov/dnav/pet/pet_pri_spt_s1_d.htm

Figure One: Evolution of Price from the Restriction of Imports



Notes: A to C is current level of US imports, Yr 1
A to B is reduced level of US imports, Yr 5
In Yr 10 domestic price increases to "Price with all Imports Excluded."

But only domestic crude sustains the process of market clearing. The increasing domestic price eventually would generate incentives for increased domestic volumes of not only higher cost crude oil but also larger volumes of crude substitutes. A decade's forecast annual price increases should provide the basis for producers to plan to increase the supply of crude substitutes. Domestic producers of crude, whether exploration and development companies with drilling rights for shallow wells in Colorado, or major offshore development companies with Federal drilling rights for half billion dollar wells 25,000 feet deeper, should find it profitable to do more of what they do. Companies in new product development of liquid fuels now at the demonstration plant stage can make the case for building commercial plants and putting them into operation as well.

The EIA forecasts that the price of crude will rise from $88.80 per barrel to $182.50 in its March, 2009 High Price Case.[7] We consider this to be a "business as usual" case. We build a

[7] EIA March 2009 High Price Case can be found at the following EIA website: http://www.eia.doe.gov/oiaf/aeo/aeohighprice.html

comparable embargo policy case based on detailed supply elasticity calculations for domestic crude oil and crude substitutes. The two sets of forecasts are show in Table One below.

Table One: The Effects of U.S. Elimination of Crude Oil Imports

Source of Supply (Mbbl/day)		2010	2015	2020
1) EIA Crude Oil Demand/Production Forecast (March High Price Case)				
1a. Domestic Crude Oil Production:		5.62 Mbbl/day	5.87 Mbbl/day	7.16 Mbbl/day
1b. Crude Oil Imports		8.02 Mbbl/day	7.49 Mbbl/day	5.44 Mbbl/day
1c. Crude Oil Substitutes		5.77 Mbbl/day	6.20 Mbbl/day	6.69 Mbbl/day
	Total	**19.41 Mbbl/day**	**19.55 Mbbl/day**	**19.28 Mbbl/day**
2) EIA Crude Oil Price Forecast (2007 $'s - March High Price Case)		$88.8/bbl	$157.7/bbl	$182.5/bbl
3) YGESG Crude Oil Demand/Production Forecast (Elimination of Imports Case)				
1a. Domestic Crude Oil Production:		5.78 Mbbl/day	6.06 Mbbl/day	7.85 Mbbl/day
1b. Crude Oil Imports		7.63 Mbbl/day	5.54 Mbbl/day	-.06 Mbbl/day
1c. Crude Oil Substitutes		5.89 Mbbl/day	7.71 Mbbl/day	10.46 Mbbl/day
	Total	**19.29 Mbbl/day**	**19.31 Mbbl/day**	**18.25 Mbbl/day**
4) YGESG Crude Oil Price Forecast (2007 $'s Elimination of Imports Case)		$100./bbl	$181.3/bbl	$262.5/bbl

EIA estimates (in their 2009 March High Price Reference Case) that based on crude prices rising to $182.50 per barrel over the decade that domestic crude plus imports, gas plant liquids, refinery processing gains, etc. will approximate 19.3 million barrels per day. Imports will decrease over the decade, from 8.0 to 5.4 million barrels of oil per day.

The embargo policy that would eliminate imports over ten years would result in a series of upward shifting domestic supply functions, at the end of the annual truncated foreign horizontal supply curve. The final supply curve would be at the point equal to only domestic production (See Figure One again). Domestic markets would clear in 2020 at this price of $262 per barrel. The price increases would reduce demand (with an arc elasticity of –.125) by approximately one million barrels per day. [8] A price of gasoline in excess of $6.00 per gallon (excluding fuel taxes!) would be the domestic economy cost of energy security. [9]

[8] See appendix page 21 for a detailed overview of the domestic crude demand elasticity and methodology employed to determine the reduction in demand at higher prices

[9] $262.50/bbl, divided by 42 gallons/bbl, without including processing costs, equals $6.25/gallon. $400.00/bbl, divided by 42 gallons/bbl, without including processing costs, equals $9.52/gallon.

Consider what would happen with production rates from the most important other sources as price increases to levels in excess of the EIA forecast level. Data and analysis from government and other substantial research sources project that new undeveloped sources would come into play that could double that increase in production.

The United States Geological Survey (USGS) has demonstrated that domestic crude oil reserves from existing producing fields grow over time (reserve "growth" as it is called).[10] For example, the 1912 vintage Midway-Sunset field in California produced 1.2 billion barrels of oil from 1968 through 1996 while proved reserves increased from 200 million barrels in 1968 to 450 million barrels in 1996. The USGS attributes this reserve growth to revisions of early estimates which underestimated what was in the ground; improvements in recovery methodology; and delineation of adjacent in-place oil ("extensions" and "revisions"). The experience in Midway-Sunset has been replicated throughout domestic onshore fields. As production took place, reserves increased. At the end of 2008, BP estimated that the United States had 30.5 billion barrels of oil reserves with a reserve to production ratio of 12.4. [11] Even if all the reserves were used up at this rate, production would exceed seven million barrels per day for 15 years. Furthermore, the USGS National Assessment of Oil and Gas Resources, 2008 Update, indicates that there are 69 major onshore basins and fields that have extensive proved reserves and unproved but recoverable oil yet to be added to reserves.[12]

The Minerals Management Service ("MMS") has identified 85.9 billion barrels of recoverable oil in the Federal Outer Continental Shelf that can be produced at costs consistent with at a range of prices up to $80 per barrel. [13] Domestic producers could conceivably replace all imports for 17-plus years with incentive prices at $120/barrel. With that said, recent history has shown that large offshore development projects can take more than ten years to develop and occur in sequence (not simultaneously). Far more important is a de facto federal prohibition against further offshore development for a variety of reasons. Therefore, it is likely that the only new source of offshore oil production in the next decade will come from the Gulf of Mexico which is under development currently. At the 95% level of confidence, MMS expects that 41.21 billion barrels is recoverable in the Gulf in addition to approximately 7 billion barrels of proved reserves and 6.9 billion barrels of expected reserves growth.[14] The MMS points out that more than 90%

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[10] United States Geological Survey, "Reserve Growth Effects on Estimates of Oil and Natural Gas Resources", October 2000

[11] BP Statistical Review of World Energy, June 2009, page 6

[12] Undiscovered Petroleum Resources: Resources postulated from geologic information and theory to exist outside of known oil and gas accumulations. From Appendix 2, *Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and the Extent and Nature of Restrictions or Impediments to Their Development*, United States Departments of Interior, Agriculture and Energy, 2006

[13] Outer Continental Shelf includes: Atlantic OCS, Gulf Of Mexico OCS, Pacific OCS, and Alaska OCS

[14] MMS, National Assessment of Outer Continental Shelf, 2006

of Gulf of Mexico's reserves are in waters more than 2,600 feet, and the mean water depth was 3,000 feet for new wells in 2005.[15]

The EIA March 2009 Annual Energy Outlook "High Price Case" forecasts that the United States will produce approximately 7.16 million barrels per day from domestic sources in 2020 of which 3.65 million is from onshore, 2.77 million from offshore, and 749,000 from Alaska.[16] This does not account for additional domestic supply from extensions and revisions, and from currently undeveloped fields that will go into the new reserve category as prices rise.[17]

When ordinary least squares regression analysis is applied to the EIA High Price Case data set from 2006 to 2020, a domestic crude supply price elasticity of 0.22 is estimated. Extending this elasticity to the supply function to $260 per barrel, we estimate 0.7mbbl/day of additional daily production volumes will be realized by 2020.[18]

Additional sources of supply

In 2006, DOE identified a total of 43.3 billion barrels of "stranded" oil in existing onshore oil fields that is recoverable using state of the art enhanced oil recovery ("EOR") technologies. DOE further estimates that next generation CO_2-EOR technology will allow the recovery of an additional 83.7 billion barrels.[19] We have not estimated any increased production from this source.

But we can include Canada as providing more liquid fuels to domestic consumers at the $260 price due to the Canada's tar sand production expansion which is now underway with well integrated pipeline and distribution networks with the US for crude oil, refined products and

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[15] MMS, "Estimate for Oil and Gas Reserves: Gulf of Mexico, December 31, 2005," 2009

[16] For comparison, this would be a 730,000 barrel per day increase from the 2007 level of 5.07 million barrels per day of domestic production: 2.91 million from onshore; 1.44 million from offshore; and 720,000 from Alaska. EIA, An Updated Annual Energy Outlook 2009 High Price Case, Table 14

[17] And likely does not include the Minerals Management Service (MMS) and DOE reports on improved enhanced oil recovery. Minerals Management Service: Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf, February 2006. Undeveloped Domestic Oil Resources: The Foundation for Increasing Oil Production and a Viable Domestic Oil Industry, US Department of Energy, Office of Fossil Energy, Office of Oil and Natural Gas, February 2006, Prepared by Advanced Resources International.

[18] Please see appendix page 22 for a detailed overview of the domestic supply crude elasticity and methodology employed to determine additional supply at higher prices

[19] "Game Changer Improvements could Dramatically Increase Domestic Oil Recovery Efficiency", US Department of Energy, Office of Fossil Energy, Office of Oil and Natural Gas, February 2006; and see "Undeveloped Domestic Oil Resources" cited above.

natural gas.[20] Canadian oil sands, or tar sands, are a type of bitumen deposit naturally occurring mixtures of sand or clay, water and an extremely dense and viscous form of petroleum with known reserves of 178 billion barrels.[21]

The oil sands production process today is fairly evenly split between In Situ (due to the depth required to extract the bitumen) and mining.[22] In 2007 Canada produced approximately 1.2 million barrels per day of oil from oil sands and the Canadian Association of Petroleum Producers ("CAPP") now estimates that by 2020 oil sands production will reach 2.9 million barrels per day (in the growth scenario case, June 2009). When ordinary least squares regression analysis is applied to the data set from 2005 to 2020, a supply price elasticity of 0.749 is estimated. Extending this elasticity to the supply function to $260 per barrel, we estimate that 0.96 million barrels per day of additional daily production volumes.[23] Additional pipeline capacity will be required to handle this new supply; according to CAPP the additional capacity from all currently active pipeline projects would result in total available pipeline capacity in excess of their forecast supply through to the end of the forecast period.[24] Environmentally, the primary issue with oil sands is whether it creates significantly more CO_2 than conventional oil production. CAPP analyses indicate that producing from the oil sands adds only 50 kilograms more CO_2 than Arabian Light Crude on a per barrel basis (full lifecycle). Further reductions in emissions are expected to continue (greenhouse gas intensity reduced by 38% since 1990) through increasing energy efficiency and CO_2 capture and sequestration.

There are multiple sources from new technologies that have some probability of adding more than one million barrels per day of domestic crude substitutes over and above EIA forecasts. These additions would at least partially cancel increases in prices forecast from any annual reductions in imports. That is, as imports decline, the domestic crude price would rise above the breakeven cost of production of these crude substitutes. Three of these sources seem to us to be the most likely given that they have moved in recent years through the demonstration plant stages. They have the financial and technical capacity to grow beyond the one-to-three plant

[20] It is possible but unlikely given the current configuration of the Canadian and US pipeline network that Canada may find it economical to circumvent our plan by purchasing crude from abroad and reselling it to the United States. A prohibition of this behavior would likely be negotiated between the countries.

[21] CAPP – Crude Oil: Forecast Markets & Pipeline Expansions June 2009 Page 2

[22] CAPP – Crude Oil: Forecast Markets & Pipeline Expansions June 2009 Appendix B1 Page 33. Oil sands are mined using trucks and shovels. The oil sands are then crushed and transported to an extraction plant where the bitumen is separated from water and sand. In Situ: In Situ requires technologies like steam assisted gravity drainage (SAGD) and cyclic steam stimulation to bring bitumen to the surface. At the wellhead, the bitumen is blended with a solvent that allows it to flow in a pipeline to an upgrader/refinery

[23] Please see appendix page 23 for a detailed overview of the oil sands supply elasticity and methodology employed to determine additional supply at higher prices

[24] CAPP – Crude Oil: Forecast Markets & Pipeline Expansions June 2009 Page 19.

level to commercial scale of dozens of plants if crude prices can be forecast with some certainty to be steady at levels above $150 per barrel.

The most promising is converting coal into liquid fuels. Coal to liquids ("CTL") is a process or set of processes in commercial operation in South Africa since 1955.[25] Coal is first processed to give off methane, and this gas is then run through the Fisher-Tropsch process, a well-known method of turning coal into diesel and jet fuel taking one-half ton of coal to produce one barrel of liquid fuels at a cost in the range of $45 per barrel (not including environmental costs). To replace conventional diesel fuels in the domestic production mix would require approximately 1.7 million tons per day of additional coal which would bring the total coal use in the United States to 5 million tons per day, or 1.8 billion tons per year. The United States has the world's largest known coal reserves, approximately 263 billion tons, and therefore could operate at these production levels for more than 100 years.

But domestic production of CTL to date has not expanded to the commercial level because the capital costs associated with the process, as well as (alleged) environmental costs, have been in excess of comparable costs for current crude oil production and imports. However, with crude oil prices above $200 per barrel, coal-to-liquids capital costs would not be excessive. But pollution abatement would generate costs that make this process problematical for widespread adoption. If coal liquefaction does not employ either carbon capture and storage, or biomass blending, then adverse environmental effects exceed those from crude oil production and refining. The question at present is that the permitting process in the coal regions takes years which would involve a significant part of the 2010 to 2020 decade even if prompted by a crude oil supply disruption. The EIA March 2009 High Price Case forecasts that by 2020 approximately 115,000 barrels per day of CTL fuels will be produced. When ordinary least squares regression analysis is applied to the data set from 2012 to 2020 (time period when EIA forecasts the USA will produce CTL fuels), a supply price elasticity of 4.2 is estimated. Extending this elasticity to the supply function to $260 per barrel, we estimate that approximately 180,000 barrels per day of additional daily production volumes[26].

Natural gas to liquids ("GTL") has been in commercial use by Sasol since the 1980s and newer commercial facilities are being constructed in Qatar and Nigeria. The Shell Pearl GTL in Qatar is in test runs, now five years after its announcement. The plant will produce 120,000 barrels of liquid fuels per day at today's competitive prices. ExxonMobil has operated a test plant in Louisiana, and both ConocoPhillips and Syntroleum Corporation have operated demonstration facilities in Oklahoma.[27] The discovery of new, very large onshore gas reserves in the Marcellus, Fayetteville, Barnett, Haynesville, Eagle Ford and Mowry shales has provided

[25] Sasol: 50 Years of Innovation, 2000. And, see National Center for Policy Analysis. "Turning Coal into Liquid Fuel". Brief Analysis no. 656 by Nicholas Ducote and H. Sterling Burnett May 1, 2009

[26] Please see appendix page 24 for a detailed overview of the CTL supply elasticity and methodology employed to determine additional supply at higher prices

[27] "Turning Natural Gas to Liquid", *Oilfield Review*, Autumn 2003

projections of supplies that have outstripped the nation's gas pipeline capacity and the ability to get the gas to consumers. Current estimates are that natural gas to liquids is economic at oil prices between $40 per barrel and $115 per barrel.[28] But, we have not included GTL as a crude oil substitute.[29]

We have not included natural gas as a direct substitute for crude oil. The energy equivalent of one barrel of oil is 6 mcf, six thousand cubic feet of gas. In the 1970s, electric utilities switched from crude oil to natural gas, but in the US today, there is no opportunity for natural gas to be substituted for crude oil. Producers and policymakers agree that there is an ample supply of domestic natural gas, but US natural gas policies have stymied the development of supply and delivery of supplies to consumers.[30] At $100/bbl price, the natural gas equivalent price would be $16.67/mcf. At a "shock" price of $400/bbl, the natural gas equivalent price would be $66.67/mcf. The conversion of a gasoline engine to run on natural gas is simple and inexpensive, but the lack of US infrastructure to deliver the natural gas is the problem. Worldwide there are approximately 10 million natural gas fueled vehicles in service—millions alone in Pakistan and Brazil—but less than 120,000 such vehicles in the US.[31]

The EIA March 2009 High Price Case forecasts production by 2020 of approximately 1.92 million barrels per day of natural gas liquids ("NGL"), which include propane, ethane, butane and condensate produced at the wellhead. When ordinary least squares regression analysis is applied to the data set from 2006 to 2020 a supply price elasticity of .063 is estimated. Extending this elasticity to the supply function to $260 per barrel, we estimate that there will be approximately 50,000 barrels per day of additional production volume.[32]

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[28] *OECD/IEA World Energy Outlook 2008*, Oil and Gas Production Prospects, page 218.

[29] Noted as Liquids from Gas in Table 1 in the appendix, page 20.

[30] The problems with US natural gas policy are well documented. See *The Natural Gas Market: Sixty Years of Regulation and Deregulation*, Paul W MacAvoy, Yale University Press: 2001; *The Unsustainable Cost of Partial Deregulation*, Paul W. MacAvoy, Yale University Press: 2007 (also distributed freely by the Social Science Research Network at http://www.ssrn.com); and *Natural Gas Networks Performance After Partial Deregulation: Five Quantitative Studies,* by Paul W. MacAvoy, Vadim Marmer, Nickolay Moshkin, and Dmitry Shapiro. World Scientific Series on Energy and Resource Economics: 2008

[31] See http://www.eia.doe.gov/emeu/aer/txt/stb1005.xls; Estimated Number of Alternative-Fueled Vehicles in Use and Fuel Consumption, 1992-2007; and the International Association of Natural Gas Vehicles, http://www.iangv.org

[32] Noted as Natural Gas Plant Liquids in Table 1 of the appendix, page 20. Please see appendix page 24 for a detailed overview of the NGL fuels supply elasticity and methodology employed to determine additional supply at higher prices. NGLs typically include propane and butane among other streams.

Biofuels could be the most immediately available source of liquid fuel to replace an import gap.[33] EIA forecasts in their High Price Case that 1.89 million barrels per day of liquid fuel will be ethanol, biodiesel and biomass liquids in 2020. The World Biofuels Study by Thomas Alfstad forecasts that North American companies will produce between 20 and 30 billion gallons of ethanol equivalent liquid fuel (inclusive of all biofuels) per year by 2020.[34] Both projections are consistent with volumes required under the 2007 energy bill, which calls for 30 billion gallons (1.96 million barrels per day) by 2020 and 36 billion gallons (2.35 million barrels per day) by 2022.[35] The attendant market-based pricing mechanism enabling producers in certain circumstances to capture a premium for biofuels production increases the likelihood these mandated volumes are actually produced.[36] These would utilize various feedstocks and pay a carbon tax but would involve development of new technology that is far from certain. The production rate, across different scenarios in this study, is on average projected at 1.76 million barrels per day. But a further presentation by Mr. Alfstad projected larger amounts of different biofuels that would be developed as the price of crude increased to $90 per barrel. In total, there would be an increase of 14.6% in supply across all of these technologies in the global liquid fuels markets. If we extrapolate from $70 per barrel to $120 per barrel using Mr. Alfstad's projection, there would be an average increase of 29%. Although the study does not show the impact on supply at crude prices above $120 per barrel, a simple regression analysis indicates a domestic biofuels price elasticity of supply is 0.376.[37] This elasticity applied to $260 per barrel in crude oil prices projects that the quantity of biofuels would generate a net increase of approximately 2.6 million barrels per day. [38]

We have not considered the 1.23 trillion barrels of oil estimated to be locked in oil shale, approximately 70% of which is on federal land in Colorado, Utah and Wyoming. Furthermore,

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[33] Ironically, 95% of United States biodiesel production in 2008, subsidized in the US, was sold to Europe where it gained a further subsidy from EU policies. Subsequently, the EU has imposed a large tariff for US biodiesel and making the sale of US biodiesel in Europe noneconomic.

[34] *World Biofuels Study: Scenario Analysis of Global Biofuels Markets.* Thomas Alfstad, Prepared for the U.S. Department of Energy, Energy Sciences and Technology Department, Brookhaven National Laboratory. BNL-80238-2008

[35] Energy Independence and Security Act of 2007. Signed into law by President Bush on December 19, 2007

[36] *Ibid*. The Renewable Fuels Standard's Renewable Identification Number (RIN) credit trading regime.

[37] "World Biofuels Study", a PowerPoint presentation by Thomas Alfstad given at Transition to a Bio-Economy Conference ,Washington DC, March 30th 2009.

[38] Please see appendix page 26 for a detailed overview of the Bio-Fuels supply elasticity and methodology employed to determine additional supply at higher prices

there are at least 12 billion barrels of crude oil contained in the tar sands of Utah.[39] These deposits are economic to produce at crude oil prices of more than $60 per barrel, but there has been no development to date which provides the basis for a projection of zero addition to supply.[40]

What is the benefit of a voluntary embargo eliminating imports?

The net cost of the embargo is the difference between lost consumers surplus and gained producers surplus. The lost consumers surplus is the reduced consumption due to higher price. Eliminating imports allows US producers of crude and crude substitutes to capture the producers surplus heretofore exported. Both are noted in Table Two, below.[41]

[39] United States Department of Interior, Bureau of Land Management, http://www.blm.gov/wo/st/en/prog/energy/oilshale_2.html; and http://ostseis.anl.gov/documents/docs/OSTS_Overview_slides.pdf

[40] *Ibid., and the OECD/IEA World Energy Outlook 2008,* page 218

[41] OPEC's reaction to a US embargo may be to flood the world market with oil in order to drive the world price well below the YGESG Price to punish the US and thereby raise the perceived cost to consumers of the embargo policy.

Table Two: Gain from the Embargo Policy

Estimated Cost of YGESG Embargo--	YGESG Price	EIA High Price Case	Embargo Domestic Demand mmbopd	EIA High Domestic Demand mmbopd	**Lost Consumers Surplus* (billion)**	EIA High Import mmbopd	Embargo Case Imports mmbopd	Decrease in Imports mmbopd	**Gained Producers Surplus** billion**	**Gains From Embargo*** billion**
2010	$100.00	$88.80	19.29	19.41	**($0.24)**	8.02	7.63	0.39	**$0.80**	**$0.56**
2011	$116.30	$102.80	19.55	19.70	**($0.37)**	8.20	7.54	0.66	**$1.64**	**$1.27**
2012	$132.50	$117.30	19.69	19.83	**($0.39)**	8.07	7.24	0.83	**$2.30**	**$1.91**
2013	$148.80	$130.90	19.61	19.77	**($0.53)**	7.96	6.77	1.19	**$3.89**	**$3.36**
2014	$165.00	$145.20	19.52	19.68	**($0.59)**	7.83	6.23	1.61	**$5.80**	**$5.21**
2015	$181.30	$157.70	19.31	19.55	**($1.03)**	7.49	5.54	1.95	**$8.39**	**$7.36**
2016	$197.50	$166.70	19.14	19.48	**($1.90)**	7.10	4.67	2.43	**$13.68**	**$11.78**
2017	$213.80	$174.30	18.92	19.38	**($3.30)**	6.61	3.64	2.96	**$21.35**	**$18.05**
2018	$230.00	$178.20	18.70	19.36	**($6.23)**	6.18	2.50	3.68	**$34.76**	**$28.53**
2019	$246.30	$180.40	18.49	19.34	**($10.23)**	5.81	1.23	4.58	**$55.08**	**$44.85**
2020	$262.50	$182.50	18.25	19.28	**($15.08)**	5.44	0.00	5.44	**$79.37**	**$64.28**
				Totals	**($39.89)**				**$227.06**	**$187.16**

*Lost Consumers Surplus = [(YGESG P – EIA High P) X (Q embargo - Q eia) X # of days]/2

**Gained Producers Surplus Gained = [(YGESG P – EIA High P) X (Decrease in imports) X # of Days]/2

*** Gain From Embargo = Lost Consumers Surplus + Gained Producers Surplus

In sum, the embargo alone provides a net gain of $187.2 billion for entire decade if there are no shocks.[42]

But the U.S. has suffered policy related and technical disruptions with some frequency since 1974. While we have not estimated the risk of a supply disruption, a RAND monograph on oil and national security discusses various scenarios and sets out high probabilities of significant supply disruptions.[43]

A supply cut of 10 million barrels of oil per day in the world market would lead to a spike price estimated to be in excess of $400 per barrel for the domestic market. Table Three, below, is a simple static equilibrium analysis of the deadweight loss to the US economy of a shock under Business As Usual **(Table 3A)** versus the Embargo case **(Table 3B)** for a period of six months.

Table Three 3A: The Cost of a Shock to the US Economy under Business as Usual

		Lost Consumers Surplus		Gained Producers Surplus		**Deadweight**
	EIA High Price Case	EIA High Domestic Consumption Mmbopd	**6 month shock cost (billion)**	EIA High Domestic Production mmbopd	**6 month shock gain (billion)**	**Cost of Shock (billion)**
2010	$88.80	19.41	**($566.3)**	11.39	**$332.2**	**($234.1)**
2011	$102.80	19.70	**($549.9)**	11.50	**$321.0**	**($228.9)**
2012	$117.30	19.83	**($527.7)**	11.76	**$312.8**	**($214.9)**
2013	$130.90	19.77	**($502.0)**	11.82	**$300.0**	**($202.0)**
2014	$145.20	19.68	**($474.4)**	11.85	**$285.6**	**($188.8)**
2015	$157.70	19.55	**($449.2)**	12.06	**$277.1**	**($172.0)**
2016	$166.70	19.48	**($431.8)**	12.38	**$274.4**	**($157.4)**
2017	$174.30	19.38	**($416.3)**	12.77	**$274.4**	**($141.9)**
2018	$178.20	19.36	**($409.1)**	13.18	**$278.5**	**($130.5)**
2019	$180.40	19.34	**($404.9)**	13.53	**$283.3**	**($121.6)**
2020	$182.50	19.28	**($400.0)**	13.85	**$287.3**	**($112.8)**

[42] In effect, the embargo policy will redistribute income from domestic consumers to domestic producers. This redistribution will, of course, result in producers paying more in taxes as incomes rise, but the redistribution will also support the development of crude oil substitutes.

[43] The RAND study an eight percent (8%) probability of a one to six month supply disruption of at least 10 million barrels per day; an almost fifty percent (50%) probability of a one to six month supply disruption of at least five million barrels per day which would be more than the U.S. Strategic Petroleum Reserve could replace. The probability of a longer disruption of six to 18 months is thirty-five percent (35%), and the probability is fifteen percent (15%) for a disruption of more than 18 months. "Imported Oil and US National Security," by Keith Crane, Andreas Goldthau, Michael Toman, Thomas Light, Stuart E. Johnson, Alireza Nader, Angel Rabasa, and Harun Dogo, RAND Corporation, 2009, page 17

Table Three 3B: The Cost of a Shock to the US Economy under the Embargo Case

		Lost Consumers Surplus		Gained Producers Surplus		**Deadweight**
	YGESG Price	Embargo Domestic Consumption Mmbopd	**6 month shock cost (billion)**	Embargo Domestic Prod. mmbopd	**6 month shock gain (billion)**	**Cost of Shock (billion)**
2010	$100.00	19.29	**($543.4)**	11.66	**$328.5**	**($214.9)**
2011	$116.30	19.55	**($522.0)**	12.02	**$320.9**	**($201.1)**
2012	$132.50	19.69	**($497.1)**	12.44	**$314.1**	**($183.0)**
2013	$148.80	19.61	**($466.3)**	12.85	**$305.5**	**($160.8)**
2014	$165.00	19.52	**($435.7)**	13.29	**$296.6**	**($139.1)**
2015	$181.30	19.31	**($402.7)**	13.77	**$287.2**	**($115.5)**
2016	$197.50	19.14	**($371.2)**	14.48	**$280.8**	**($90.4)**
2017	$213.80	18.92	**($339.2)**	15.28	**$273.9**	**($65.3)**
2018	$230.00	18.70	**($308.0)**	16.20	**$266.8**	**($41.2)**
2019	$246.30	18.49	**($277.4)**	17.26	**$258.9**	**($18.5)**
2020	$262.50	18.25	**$0.0**	18.31	**$0.0**	**$0.0**

Lost Consumers Surplus = (((Shock Price* - EIA High Price or YGESG Price)*Total Daily Consumption)*# of Days)/2

Gained Producers Surplus = (((Shock Price - EIA High Price or YGESG Price)* Total Daily Domestic Production)*# of Days)/2

Note: Triangle geometry is used to calculate both lost consumer surplus and gained producer surplus because we do not expect that the Shock Price will endure for the entire 6 months but will decline back to the pre-Shock price.

Deadweight Cost of Shock = Lost Consumers Surplus + Gained Producers Surplus, or simply Total Imports* (Change in Price)

*Shock Price ($/bbl) **$413** **# of Days** **180**

Does the embargo policy in a shock reduce the costs?

There are three answers that follow from our estimates. If there were a 2010 shock of six months duration, the impact on US consumers would be $543.4 billion under the embargo down from $566.3 billion under business as usual. The deadweight loss to the US under the embargo policy is $214.9 billion versus $234.1 billion under business as usual. The embargo reduces shock costs by $19.2 billion to which must be added the net gain of $0.56 billion (Table Two) for a net gain of $19.8 billion. If there were a 2015 shock, the deadweight loss from the shock is $115.5 billion under the embargo policy, rather than $172.0 billion, plus the cumulative net gain of $19.7 billion (Table Two), for a total savings of $76.2 billion. But in 2020, the deadweight loss from the shock is zero under the embargo policy, saving the deadweight loss of $112.8 billion under business as usual plus the cumulative gain of $187.2 billion throughout the decade.[44] We come out $300.0 billion ahead if the shock is in 2020, and of course, we have assumed that consumers would not be confronted by a lack of foreign supply at any price in the future. These gains increase if there are two or three shocks in this period. For example, if there are three shocks in the years shown, then the gains total $375.7 billion.

[44] We are assuming that the US would not be an exporter of crude and crude substitutes. If that is not the case and the US is open to the world market during such a shock, the lost consumer surplus would still be offset by the gain in producer surplus.

Conclusion

US energy policy has been counterproductive or remarkably ineffective apart from military campaigns (expensive) over the past 40 years. The DOE was founded in part to promote energy independence, and this was a fool's errand because it was founded while pre-existing crude oil and natural gas price controls were allowed to continue for years. DOE was handicapped from the start as the US lost domestic production and dramatically increased imports.

The ineffectiveness of policy is well illustrated by *The National Academies Summit on America's Energy Future* which lists the various starts and stops of energy policy initiatives[45]—

Nuclear Technology
- Clinch River Breeder Reactor (1970-1983)
- Advanced Liquid Metal Reactor Program (1989-1994)
- Global Nuclear Energy Partnership (2006)

Vehicle Technology
- Virtually pollution-free car (Nixon 1970)
- Reinventing the Car (Carter 1977-1980)
- Partnership for a New Generation of Vehicles (Clinton 1993-2000)
- Freedom Car (Bush 2003)

Biofuels
- Alcohol fuels (Energy Security Act 1980)
- Oxygenated Fuels (Clean Air Act Amendments 1990)
- Biofuels (EPAct 2005; EISA 2007)

Coal Utilization
- US Synthetic Fuels Corporation (1979-1985)
- Clean Coal Technology Program (1987)
- Clean Coal Power Initiative (2001)
- FutureGen (2003)

To which we add:

Mandatory Crude Oil Import Quota (1959 -1974)
Crude Oil Price Controls (pre-1972 and post-1972; 1973-1979)
Strategic Petroleum Reserve (1973-now)

As well-intended as they were, not one of these initiatives accomplished "energy independence." Many of the programs were not sustainable. Tax incentives and subsidies are not effective solutions. Not one of the current proposals addresses the most fundamental problem, the nation's dependence on foreign sources of crude oil in a market that is subject to manipulation by suppliers and by terrorists. Our policy does.

If we do nothing? The costs of lethargy and despair are billions of dollars more. A shock in 2020 under the business as usual, do nothing scenario costs consumers $400 billion with a deadweight loss to the US economy of $112.8 billion while the embargo policy provides a gain of $187.2 billion.

Under our proposed embargo policy, the US would not be spending additional billions to protect shipping lanes and to defend "friendly" oil producing nations. The gains to the US Current Account, US employment, and tax receipts will be a bonus.

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[45] *The National Academies Summit on America's Energy Future: Summary of a Meeting*, National Academies Press, 2008. Page 134

We offer an alternative to business as usual, a scenario that continues to leave the U.S. with the unnecessary risk of world supply disruptions in the oil markets. Nothing we have proposed is novel. The U.S. has restricted oil imports as a matter of national interest before, and the U.S. has restricted imports for many other commodities and products as a matter of national interest.

Table 1 - Detail: The Effects of U.S. Elimination of Crude Oil Imports	Yrly Price Inc:	$16.25	$100/bbl	$116/bbl	$133/bbl	$149/bbl	$165/bbl	$181/bbl	$198/bbl	$214/bbl	$230/bbl	$246/bbl	$263/bbl
	EIA Forecast		USA Domestic Supply Forecast at Embargo Pricing (M bbl/day)										
	2010	2020	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crude Oil													
Domestic Crude Production	5.62	7.16	5.78	5.79	5.89	5.95	5.98	6.06	6.27	6.58	6.98	7.43	7.85
Alaska	0.69	0.74											
Lower 48 States	4.93	6.42											
Net Imports	8.02	5.44											
Gross Imports	8.05	5.47											
Exports	0.03	0.04											
Other Crude Supply	0.00	0.00											
Total Crude Supply:	**13.64**	**12.59**	**5.78**	**5.79**	**5.89**	**5.95**	**5.98**	**6.06**	**6.27**	**6.58**	**6.98**	**7.43**	**7.85**
Other Supply													
Natural Gas Plant Liquids	1.90	1.92	1.92	1.93	1.94	1.93	1.90	1.91	1.91	1.93	1.95	1.98	1.97
Net Product Imports	1.63	1.28											
Gross Refined Product Imports	1.62	1.46											
Unfinished Oil Imports	0.57	0.44											
Blending Component Imports	0.62	0.71											
Exports	1.17	1.33											
Refinery Processing Gain	0.98	0.88											
Other Inputs	1.25	2.60											
Ethanol	0.84	1.66	2.28	2.48	2.68	2.88	3.09	3.29	3.49	3.69	3.90	4.10	4.30
Domestic Production	0.84	1.56											
Net Imports	0.00	0.10											
Biodiesel	0.07	0.13											
Domestic Production	0.07	0.13											
Net Imports	0.00	0.00											
Liquids from Gas	0.00	0.09											
Liquids from Coal	0.00	0.11			0.016	0.031	0.060	0.074	0.097	0.127	0.170	0.226	0.293
Liquids from Biomass	0.00	0.10											
Oil Sands from Canada			1.69	1.83	1.91	2.06	2.26	2.44	2.72	2.95	3.20	3.53	3.90
Other	0.34	0.51											
Total Supply	**19.41**	**19.28**	**11.66**	**12.02**	**12.44**	**12.85**	**13.29**	**13.77**	**14.48**	**15.28**	**16.20**	**17.26**	**18.31**
Total Consumption/Demand From EIA Table 11:			**19.60**	**19.88**	**20.01**	**19.95**	**19.86**	**19.68**	**19.59**	**19.47**	**19.41**	**19.37**	**19.31**
Reduction in Demand From Embargo Pricing			**-0.31**	**-0.32**	**-0.32**	**-0.34**	**-0.34**	**-0.37**	**-0.45**	**-0.55**	**-0.70**	**-0.88**	**-1.06**
Demand with Embargo Pricing			**19.29**	**19.55**	**19.69**	**19.61**	**19.52**	**19.31**	**19.14**	**18.92**	**18.70**	**18.49**	**18.25**
Imports:			**7.63**	**7.54**	**7.24**	**6.77**	**6.23**	**5.54**	**4.67**	**3.64**	**2.50**	**1.23**	**-0.06**
Yearly Import Reduction:				-0.09	-0.29	-0.48	-0.54	-0.69	-0.87	-1.02	-1.14	-1.27	-1.29

Elasticity Estimates:	
Domestic Crude Oil Supply:	0.22
Domestic Bio-Fuels Supply:	0.38
Domestic Natural Gas Liquids Supp	0.06
Domestic Coal to Liquids Supply:	4.19
Canadian Oil Sands Supply:	0.75
Domestic Crude Oil Demand:	-0.12

SUMMARY OUTPUT 2006 to 2020 - Demand Elasticity March High Case	USA Liquid Fuels Demand	Real Price
2006	20.65	$ 61.8
2007	20.65	$ 65.7
2008	19.54	$ 97.9
2009	19.25	$ 58.2
2010	19.60	$ 88.8
2011	19.88	$ 102.8
2012	20.01	$ 117.3
2013	19.95	$ 130.9
2014	19.86	$ 145.2
2015	19.68	$ 157.7
2016	19.59	$ 166.7
2017	19.47	$ 174.3
2018	19.41	$ 178.2
2019	19.37	$ 180.4
2020	19.31	$ 182.5

Period	Date	Price	Quantity
2008q4 to 2009q1 Data	Jan 30, 2009	$42.7/bbl	20,306
2008q4 to 2009q1 Data	Oct 03, 2008	$96.6/bbl	18,341

2008q4 to 2009q1 Data Stigler ARC Elasticity	-0.125
Arc Elasticity Equation: log (q1/q2) / log (p1/p2) = E	
Demand Price Elasticity	-0.125

Date	Cushing, OK Spot Price	U.S. Weekly Petroleum Prod' Supplied
Jan 30, 2009	$ 42.7	20,306
Dec 26, 2008	$ 33.0	20,211
Dec 12, 2008	$ 44.6	20,192
Dec 19, 2008	$ 39.7	20,191
Jan 23, 2009	$ 42.2	20,151
Jan 02, 2009	$ 42.4	19,836
Feb 13, 2009	$ 36.9	19,690
Feb 06, 2009	$ 40.8	19,662
Nov 28, 2008	$ 53.3	19,606
Feb 27, 2009	$ 41.1	19,577
Nov 21, 2008	$ 52.3	19,482
Feb 20, 2009	$ 37.2	19,233
Oct 31, 2008	$ 65.2	19,216
Oct 17, 2008	$ 75.2	19,193
Mar 20, 2009	$ 49.5	19,191
Dec 05, 2008	$ 45.6	19,149
Oct 24, 2008	$ 68.6	19,113
Jan 16, 2009	$ 36.7	19,097
Nov 07, 2008	$ 64.3	19,004
Nov 14, 2008	$ 58.6	18,972
Mar 06, 2009	$ 43.2	18,892
Oct 10, 2008	$ 86.2	18,865
Mar 13, 2009	$ 45.7	18,787
Jan 09, 2009	$ 44.5	18,640
Mar 27, 2009	$ 53.0	18,591
Oct 03, 2008	$96.6/bbl	18,341

Per Year $/BBL Increase **$16.25**

Embargo Case	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EIA Demand (Mbbl/day)	19.60	19.88	20.01	19.95	19.86	19.68	19.59	19.47	19.41	19.37	19.31
EIA Price ($/bbl)	$ 88.8	$ 102.8	$ 117.3	$ 130.9	$ 145.2	$ 157.7	$ 166.7	$ 174.3	$ 178.2	$ 180.4	$ 182.5
Price: Embargo ($/bbl)	$ 100.0	$ 116.3	$ 132.5	$ 148.8	$ 165.0	$ 181.3	$ 197.5	$ 213.8	$ 230.0	$ 246.3	$ 262.5
% Change in Price	12.6%	13.1%	12.9%	13.7%	13.6%	14.9%	18.5%	22.7%	29.1%	36.5%	43.8%
Elasticity Multiplier	-1.6%	-1.6%	-1.6%	-1.7%	-1.7%	-1.9%	-2.3%	-2.8%	-3.6%	-4.6%	-5.5%
Reduction in Demand from Embargo (Mbbl/day)	(0.31)	(0.32)	(0.32)	(0.34)	(0.34)	(0.37)	(0.45)	(0.55)	(0.70)	(0.88)	(1.06)
Total Demand - Embargo	**19.29**	**19.55**	**19.69**	**19.61**	**19.52**	**19.31**	**19.14**	**18.92**	**18.70**	**18.49**	**18.25**

* Elasticity multiplier is equal to % change in price multiplied by the elasticity
** Reduction in Demand from embargo is calculated by multiplying the elasticity multiplier times the EIA demand for that year

SUMMARY OUTPUT 2006 to 2020 - EIA March High Price Case - Domestic Oil Supply Curve

	US Domestic Crude Supply (Mbbl/day)	LN US Dom Crude Supply (Mbbl/day)	Real Price ($/bbl)	LN Real Price ($/bbl)
2006	5.10	1.63	$ 61.80	$ 4.12
2007	5.07	1.62	$ 65.70	$ 4.19
2008	4.95	1.60	$ 97.87	$ 4.58
2009	5.38	1.68	$ 58.20	$ 4.06
2010	5.62	1.73	$ 88.80	$ 4.49
2011	5.62	1.73	$ 102.82	$ 4.63
2012	5.72	1.74	$ 117.34	$ 4.77
2013	5.77	1.75	$ 130.88	$ 4.87
2014	5.81	1.76	$ 145.20	$ 4.98
2015	5.87	1.77	$ 157.71	$ 5.06
2016	6.02	1.80	$ 166.71	$ 5.12
2017	6.27	1.84	$ 174.26	$ 5.16
2018	6.56	1.88	$ 178.16	$ 5.18
2019	6.87	1.93	$ 180.35	$ 5.19
2020	7.16	1.97	$ 182.49	$ 5.21

Regression Statistics	
Multiple R	0.838
R Square	0.703
Adjusted R Square	0.680
Standard Error	0.061
Observations	15.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	0.115	0.115	30.772	0.000
Residual	13.000	0.048	0.004		
Total	14.000	0.163			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.706	0.191	3.701	0.003	0.294	1.119	0.294	1.119
High Case - Real Price	0.221	0.040	5.547	0.000	0.135	0.307	0.135	0.307

Per Year $/BBL Increase	**$16.25**										
Embargo Case	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EIA Demand (Mbbl/day)	5.62	5.62	5.72	5.77	5.81	5.87	6.02	6.27	6.56	6.87	7.16
EIA Price ($/bbl)	$ 88.8	$ 102.8	$ 117.3	$ 130.9	$ 145.2	$ 157.7	$ 166.7	$ 174.3	$ 178.2	$ 180.4	$ 182.5
Price: Embargo ($/bbl)	$ 100.0	$ 116.3	$ 132.5	$ 148.8	$ 165.0	$ 181.3	$ 197.5	$ 213.8	$ 230.0	$ 246.3	$ 262.5
% Change in Price	12.6%	13.1%	12.9%	13.7%	13.6%	14.9%	18.5%	22.7%	29.1%	36.5%	43.8%
Elasticity Multiplier*	2.8%	2.9%	2.9%	3.0%	3.0%	3.3%	4.1%	5.0%	6.4%	8.1%	9.7%
Additional Supply from Embargo (Mbbl/day)**	0.16	0.16	0.16	0.17	0.18	0.19	0.25	0.31	0.42	0.56	0.69
Total Supply - Embargo (Mbbl/day)	**5.78**	**5.79**	**5.89**	**5.95**	**5.98**	**6.06**	**6.27**	**6.58**	**6.98**	**7.43**	**7.85**

* Elasticity multiplier is equal to % change in price multiplied by the elasticity

** Additional supply from embargo is calculated by multiplying the elasticity multiplier times the EIA demand for that year

SUMMARY OUTPUT 2005 to 2020 - June 2009
CAPP Growth Case - Canadian Oil Sands
Supply Curve

	Oil Sands Production (Mbbl/day)	LN Production (Mbbl/day)	Real Price ($/bbl)	LN Price ($/bbl)
2005	0.99	(0.01)	$54.0/bbl	$4.0/bbl
2006	1.11	0.11	$61.8/bbl	$4.1/bbl
2007	1.20	0.18	$65.7/bbl	$4.2/bbl
2008	1.21	0.19	$97.9/bbl	$4.6/bbl
2009	1.39	0.33	$58.2/bbl	$4.1/bbl
2010	1.55	0.44	$88.8/bbl	$4.5/bbl
2011	1.67	0.51	$102.8/bbl	$4.6/bbl
2012	1.74	0.56	$117.3/bbl	$4.8/bbl
2013	1.87	0.62	$130.9/bbl	$4.9/bbl
2014	2.05	0.72	$145.2/bbl	$5.0/bbl
2015	2.20	0.79	$157.7/bbl	$5.1/bbl
2016	2.39	0.87	$166.7/bbl	$5.1/bbl
2017	2.52	0.92	$174.3/bbl	$5.2/bbl
2018	2.63	0.97	$178.2/bbl	$5.2/bbl
2019	2.77	1.02	$180.4/bbl	$5.2/bbl
2020	2.93	1.08	$182.5/bbl	$5.2/bbl

Source: CAPP - Curde Oil - Forecast, Markets & Piepline Expansions June 2009. Real prices taken from EIA March 2009 Forecast (2007 US Wellhead price)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.949
R Square	0.900
Adjusted R Square	0.893
Standard Error	0.114
Observations	16.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	1.641	1.641	125.779	0.000
Residual	14.000	0.183	0.013		
Total	15.000	1.823			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2.960	0.317	-9.339	0.000	-3.640	-2.280	-3.640	-2.280
LN Price	0.749	0.067	11.215	0.000	0.606	0.892	0.606	0.892

Per Year $/BBL Increase	**$16.25**										
Embargo Case	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CAPP Quantity (Mbbl/day)	1.55	1.67	1.74	1.87	2.05	2.20	2.39	2.52	2.63	2.77	2.93
EIA Price ($/bbl)	$ 88.8	$ 102.8	$ 117.3	$ 130.9	$ 145.2	$ 157.7	$ 166.7	$ 174.3	$ 178.2	$ 180.4	$ 182.5
Price: Embargo ($/bbl)	$ 100.0	$ 116.3	$ 132.5	$ 148.8	$ 165.0	$ 181.3	$ 197.5	$ 213.8	$ 230.0	$ 246.3	$ 262.5
% Change in Price	12.6%	13.1%	12.9%	13.7%	13.6%	14.9%	18.5%	22.7%	29.1%	36.5%	43.8%
Elasticity Multiplier*	9.4%	9.8%	9.7%	10.2%	10.2%	11.2%	13.8%	17.0%	21.8%	27.4%	32.8%
Additional Supply from Embargo (Mbbl/day)**	0.15	0.16	0.17	0.19	0.21	0.25	0.33	0.43	0.57	0.76	0.96
Total Supply - Embargo	**1.69**	**1.83**	**1.91**	**2.06**	**2.26**	**2.44**	**2.72**	**2.95**	**3.20**	**3.53**	**3.90**

* Elasticity multiplier is equal to % change in price multiplied by the elasticity
** Additional supply from embargo is calculated by multiplying the elasticity multiplier times the EIA demand for that year

SUMMARY OUTPUT 2012 to 2020 - EIA March High Price Case - CTL Supply Curve

	Coal to Liquids	LN Coal to Liquids	Real Price	LN Real Price
2012	15.0 Kbbl/day	2.7 Klbbl/day	$117.34/bbl	$4.77/bbl
2013	26.1 Kbbl/day	3.3 Klbbl/day	$130.88/bbl	$4.87/bbl
2014	49.5 Kbbl/day	3.9 Klbbl/day	$145.20/bbl	$4.98/bbl
2015	57.5 Kbbl/day	4.1 Klbbl/day	$157.71/bbl	$5.06/bbl
2016	66.6 Kbbl/day	4.2 Klbbl/day	$166.71/bbl	$5.12/bbl
2017	76.9 Kbbl/day	4.3 Klbbl/day	$174.26/bbl	$5.16/bbl
2018	88.3 Kbbl/day	4.5 Klbbl/day	$178.16/bbl	$5.18/bbl
2019	100.9 Kbbl/day	4.6 Klbbl/day	$180.35/bbl	$5.19/bbl
2020	114.7 Kbbl/day	4.7 Klbbl/day	$182.49/bbl	$5.21/bbl

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.988
R Square	0.976
Adjusted R Square	0.973
Standard Error	0.110
Observations	9.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	3.446	3.446	285.742	0.000
Residual	7.000	0.084	0.012		
Total	8.000	3.530			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-17.170	1.255	-13.682	0.000	-20.137	-14.202	-20.137	-14.202
LN Real Price	4.190	0.248	16.904	0.000	3.604	4.777	3.604	4.777

Per Year $/BBL Increase **$16.25**

Embargo Case	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EIA Demand	.02 Mbbl/day	.03 Mbbl/day	.05 Mbbl/day	.06 Mbbl/day	.07 Mbbl/day	.08 Mbbl/day	.09 Mbbl/day	.10 Mbbl/day	.11 Mbbl/day
EIA Price	$117.34/bbl	$130.88/bbl	$145.20/bbl	$157.71/bbl	$166.71/bbl	$174.26/bbl	$178.16/bbl	$180.35/bbl	$182.49/bbl
Price: Embargo	$120/bbl	$136/bbl	$153/bbl	$169/bbl	$185/bbl	$201/bbl	$218/bbl	$234/bbl	$250/bbl
% Change in Price	2.3%	4.1%	5.0%	7.0%	11.0%	15.5%	22.1%	29.6%	37.0%
Elasticity Multiplier*	9.5%	17.2%	21.1%	29.3%	46.0%	64.9%	92.5%	124.1%	155.0%
Additional Supply from Embargo**	.00 Mbbl/day	.00 Mbbl/day	.01 Mbbl/day	.02 Mbbl/day	.03 Mbbl/day	.05 Mbbl/day	.08 Mbbl/day	.13 Mbbl/day	.18 Mbbl/day
Total Supply - Embargo	**.02 Mbbl/day**	**.03 Mbbl/day**	**.06 Mbbl/day**	**.07 Mbbl/day**	**.10 Mbbl/day**	**.13 Mbbl/day**	**.17 Mbbl/day**	**.23 Mbbl/day**	**.29 Mbbl/day**

* Elasticity multiplier is equal to % change in price multiplied by the elasticity

** Additional supply from embargo is calculated by multiplying the elasticity multiplier times the EIA demand for that year

SUMMARY OUTPUT 2006 to 2020 - EIA March High Price Case - NGL Supply Curve

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.800
R Square	0.640
Adjusted R Square	0.613
Standard Error	0.020
Observations	15.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	0.009	0.009	23.147	0.000
Residual	13.000	0.005	0.000		
Total	14.000	0.014			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.330	0.062	5.284	0.000	0.195	0.465	0.195	0.465
LN Real Price	0.063	0.013	4.811	0.000	0.035	0.091	0.035	0.091

	NGL (Mbbl/day)	LN NGL (Mbbl/day)	Real Price ($/bbl)	LN Price ($/bbl)
2006	1.74	0.55	$ 61.80	$ 4.12
2007	1.78	0.58	$ 65.70	$ 4.19
2008	1.82	0.60	$ 97.87	$ 4.58
2009	1.81	0.59	$ 58.20	$ 4.06
2010	1.90	0.64	$ 88.80	$ 4.49
2011	1.91	0.65	$ 102.82	$ 4.63
2012	1.93	0.66	$ 117.34	$ 4.77
2013	1.91	0.65	$ 130.88	$ 4.87
2014	1.89	0.63	$ 145.20	$ 4.98
2015	1.89	0.64	$ 157.71	$ 5.06
2016	1.89	0.63	$ 166.71	$ 5.12
2017	1.90	0.64	$ 174.26	$ 5.16
2018	1.92	0.65	$ 178.16	$ 5.18
2019	1.94	0.66	$ 180.35	$ 5.19
2020	1.92	0.65	$ 182.49	$ 5.21

Per Year $/BBL Increase **$16**

Embargo Case	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EIA Demand (Mbbl/day)	1.90	1.91	1.93	1.91	1.89	1.89	1.89	1.90	1.92	1.94	1.92
EIA Price ($/bbl)	$ 88.80	$ 102.82	$ 117.34	$ 130.88	$ 145.20	$ 157.71	$ 166.71	$ 174.26	$ 178.16	$ 180.35	$ 182.49
Price: Embargo ($/bbl)	$ 100.00	$ 116.25	$ 132.50	$ 148.75	$ 165.00	$ 181.25	$ 197.50	$ 213.75	$ 230.00	$ 246.25	$ 262.50
% Change in Price	12.6%	13.1%	12.9%	13.7%	13.6%	14.9%	18.5%	22.7%	29.1%	36.5%	43.8%
Elasticity Multiplier*	0.8%	0.8%	0.8%	0.9%	0.9%	0.9%	1.2%	1.4%	1.8%	2.3%	2.7%
Additional Supply from Embargo (Mbbl/day)**	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.05
Total Supply - Embargo	**1.92**	**1.93**	**1.94**	**1.93**	**1.90**	**1.91**	**1.91**	**1.93**	**1.95**	**1.98**	**1.97**

* Elasticity multiplier is equal to % change in price multiplied by the elasticity

** Additional supply from embargo is calculated by multiplying the elasticity multiplier times the EIA demand for that year

Bio-Fuels Supply Curve

Price ($/bbl)	LN Price ($/bbl)	Global Quantity (Bgal/yr)	U.S. Quantity (Bgal/yr)	LN Quantity (Bgal/yr)
$ 50	$ 3.9	77.0	25.4	3.2
$ 70	$ 4.2	82.0	27.0	3.3
$ 90	$ 4.5	94.0	31.0	3.4
$ 120	$ 4.8	106.0	34.9	3.6

Source: The World Biofuels Study: Scenario Analysis of Global Biofuel Markets - Alfstad - PPT
* Pg 23 Figure 10 The World Biofuels Study: Scenario analysis of Global Biofuel Markets - Alfstad - Report BNL-80238-2008

North American Portion of Total Quantity*: 33%

Regression Statistics	
Multiple R	0.981
R Square	0.961
Adjusted R Square	0.942
Standard Error	0.034
Observations	4.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.000	0.059	0.059	49.915	0.019
Residual	2.000	0.002	0.001		
Total	3.000	0.061			

	Coefficients	*Standard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.736	0.233	7.450	0.018	0.734	2.739	0.734	2.739
LN Price	0.376	0.053	7.065	0.019	0.147	0.606	0.147	0.606

Per Year $/BBL Increase $16.25

Embargo Case	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Alfstad Base Quantity	25.4 Bgal/yr										
Alfstad Base Price	$ 50.0										
Price: Embargo ($/bbl)	$ 100.0	$ 116.3	$ 132.5	$ 148.8	$ 165.0	$ 181.3	$ 197.5	$ 213.8	$ 230.0	$ 246.3	$ 262.5
% Change in Price	100.0%	132.5%	165.0%	197.5%	230.0%	262.5%	295.0%	327.5%	360.0%	392.5%	425.0%
Elasticity Multiplier	37.65%	49.88%	62.12%	74.35%	86.58%	98.82%	111.05%	123.29%	135.52%	147.76%	159.99%
Additional Supply from Embargo (Mbbl/day)	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6
Total Supply - Embargo	**2.3**	**2.5**	**2.7**	**2.9**	**3.1**	**3.3**	**3.5**	**3.7**	**3.9**	**4.1**	**4.3**