PETROLEUM COKE: THE COAL HIDING IN THE TAR SANDS

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Cover photo: Fort McMurray, Alberta. 2007. Steam rising from the Syncrude upgrading site, where Tar Sands is converted into synthetic crude oil, and petroleum coke is manufactured. This upgrading site is among the biggest of its kind in the world. ©Jonas Bendiksen/Magnum Photos

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All weights in this report are in pounds and short tons unless otherwise stated.

EXECUTIVE SUMMARY

The Canadian tar sands have been called the "most environmentally destructive project on earth", with good reason. Extracting tar sands bitumen from under the boreal forests of Alberta, Canada requires huge amounts of energy and water. It has cleared vast tracts of forest, left scars on the land that are visible from space and threatened the health and livelihoods of indigenous First Nations communities across the region.

It is a well established fact that full exploitation of the tar sands is a grave threat to the climate. Emissions from tar sands extraction and upgrading are between 3.2 and 4.5 times higher than the equivalent emissions from conventional oil produced in North America. On a lifecycle basis, the average gallon of tar sands bitumen derived fuel has between 14 and 37 percent more greenhouse gas emissions than the average gallon of fuel from conventional oil.

But as bad as these impacts already are, existing analyses of the impacts of tar sands fail to account for a byproduct of the process that is a major source of climate change causing carbon emissions: petroleum coke - known as petcoke. Petcoke is the coal hiding in North America's tar sands oil boom.

Petcoke is like coal, but dirtier. Petcoke looks and acts like coal, but it has even higher carbon emissions than already carbon-intensive coal.

- On a per-unit of energy basis petcoke emits 5 to 10 percent more carbon dioxide than coal.
- A ton of petcoke yields on average 53.6 percent more CO_2 than a ton of coal.
- The proven tar sands reserves of Canada will yield roughly 5 billion tons of petcoke – enough to fully fuel 111 U.S. coal plants to 2050.
- Because it is considered a refinery byproduct, petcoke emissions are not included in most assessments of the climate impact of tar sands or conventional oil production and consumption. Thus the climate impact of oil production is being consistently undercounted.

Petcoke in the tar sands is turning American refineries into coal factories.

- There is 24 percent more CO_2 embedded in a barrel of tar sands bitumen than in a barrel of light oil.
- 15 to 30 percent of a barrel of tar sands bitumen can end up as petcoke, depending on the upgrading and refining process used.
- Of 134 operating U.S. refineries in 2012, 59 are equipped to produce petcoke.
- U.S. refineries produced over 61.5 million tons of petcoke in 2011 - enough to fuel 50 average U.S. coal plants each year.
- In 2011, over 60 percent of U.S petcoke production was exported.

Keystone XL will fuel five coal plants and thus emit 13% more CO_2 than the U.S. State Department has previously considered.

- Nine of the refineries close to the southern terminus of Keystone XL have nearly 30 percent of U.S. petcoke production capacity, over 50,000 tons a day.
- The petcoke produced from the Keystone XL pipeline would fuel 5 coal plants and produce 16.6 million metric tons of CO_2 each year.
- These petcoke emissions have been excluded from State Department emissions estimates for the Keystone XL pipeline. Including these emissions raises the total annual emissions of the pipeline by 13% above the State Department's calculations.

Cheap petcoke helps the coal industry.

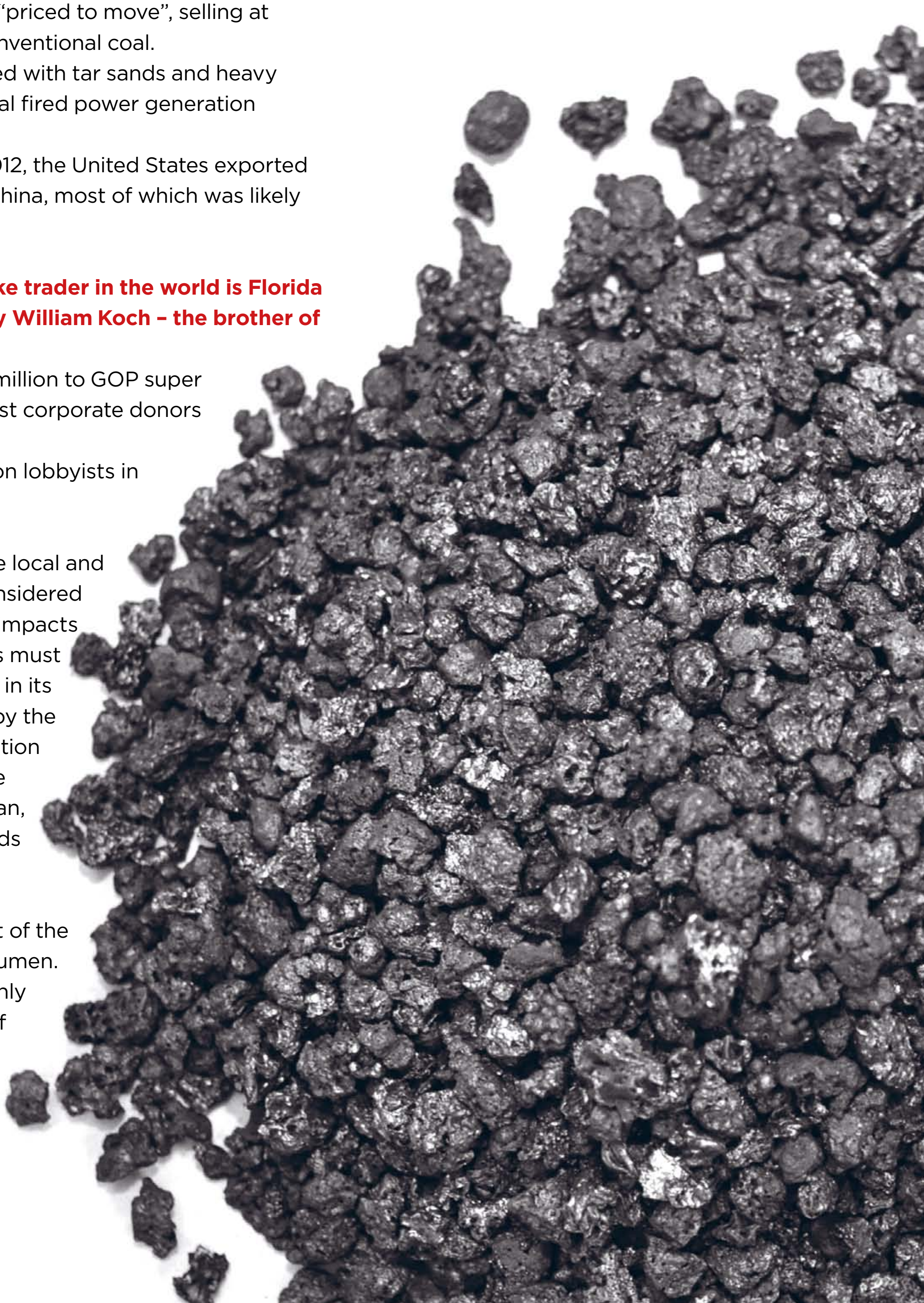
- As a refinery byproduct, petcoke is "priced to move", selling at roughly a 25 percent discount to conventional coal.
- Rising petcoke production associated with tar sands and heavy oil production is helping to make coal fired power generation dirtier and cheaper - globally.
- From January 2011 to September 2012, the United States exported over 8.6 million tons of petcoke to China, most of which was likely burnt in coal-fired power plants.

"PetKoch": The largest global petcoke trader in the world is Florida based Oxbow Corporation, owned by William Koch – the brother of Charles and David Koch.

- Oxbow Carbon has donated $4.25 million to GOP super PACs, making it the one of the largest corporate donors to super PACs.
- Oxbow also spent over $1.3 million on lobbyists in 2012.

To date, the impacts of petcoke on the local and global environment have not been considered by regulatory bodies in assessing the impacts of the tar sands. Petcoke's full impacts must be considered by the European Union in its debate on the Fuel Quality Directive, by the U.S. State Department in its consideration of the climate impacts of the Keystone XL pipeline, and by Canadian, American, and European governments in tar sands policies across the board.

Increasing petcoke use is a clear result of the increasing production of tar sands bitumen. Petcoke is a seldom discussed yet highly important aspect of the full impacts of tar sands production. Factored into the equation, petcoke puts another strong nail in the coffin of any rational argument for the further exploitation of the tar sands.



INTRODUCTION

This report explores one of the inherent risks of exploiting the hydrocarbons within Canada's tar sands. It highlights the fact that what lies below the boreal forests of Alberta is bitumen, a substance that due to its high carbon content resembles coal more than oil.

It is well documented that extracting and processing bitumen involves higher carbon emissions than exploiting conventional oil.[1] Emissions from tar sands extraction and upgrading are between 3.2 to 4.5 times higher per barrel than emissions from conventional oil produced in Canada and the United States.[2] In a world struggling to contain carbon emissions in order to avoid the severest impacts of climate change, this alone justifies a more cautious approach to exploiting the tar sands.

However, this report follows tar sands bitumen through the refining process and finds that its climate impacts reach beyond the additional emissions involved in extracting and processing bitumen. We examine a little known byproduct of tar sands bitumen refining that is making coal-fired power generation cheaper and dirtier.

The Hidden Coal in Canada's Oil Boom

In the intensive process of manufacturing gasoline and diesel from bitumen, between 15 and 30 percent of a barrel of bitumen forms a solid coal-like residual fuel known as petroleum coke (petcoke). Petcoke can be produced from lighter conventional oils but only in very small quantities that are typically consumed within the refinery.

Petcoke is over 90 percent carbon and emits 5 to 10 percent more carbon dioxide (CO_2) than coal on a per-unit of energy basis when it is burned.[3] As petcoke has high energy content, every ton of petcoke emits between 30 and 80 percent more CO_2 than coal, depending on the quality of the coal.

The proliferation of tar sands bitumen and heavy oil processing in the United States is turning American refineries into coal factories. Of 134 operating U.S. refineries in 2012, 59 are equipped to produce petcoke including many of the largest refineries in the country.[4] These refineries produced over 61.5 million tons of petcoke in 2011.[5] That is enough petcoke

1 Adam R. Brandt. *Variability and Uncertainty in Life Cycle Assessment Models for Greenhouse Gas Emissions from Canadian Oil Sands Production*. In *Environmental Science & Technology*. 2012, 46, Pp. 1253-1261.

2 Marc Hout, September 2011. *Oilsands and climate change: How Canada's oilsands are standing in the way of effective climate action*. The Pembina Institute. http://pubs.pembina.org/reports/oilsands-and-climate-fs-201109.pdf

3 The lower value is compared to sub-bituminous coal and the higher figure is compared to bituminous coal. These are the dominant types of coal mined in the United States and traded globally.

4 U.S. Department of Energy Energy Information Administration. (EIA). Refinery Capacity Report, January 1, 2012. http://www.eia.gov/petroleum/refinerycapacity/

5 EIA, U.S. Refinery Net Production of Petroleum Coke. Data is in barrels, there are 5 barrels of petcoke in a short ton. http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mckrx_nus_1&f=a

Syncrude Aurora tar sands mine, Alberta, Canada.

to fuel 50 average U.S. coal plants each year.[6] Over 60 percent of this was exported.[7] In addition, petcoke from tar sands upgraders and refineries in Canada is also increasingly entering the world market.

As a refinery byproduct, petcoke is priced to move and sells at a significant discount to steam coal. As a result, the petcoke produced in U.S. refineries and Canadian upgraders is increasingly being blended with coal in coal-fired power plants in the U.S. and abroad, effectively making coal-fired generation cheaper and dirtier.

Coal-fired electricity generation is the largest source of climate forcing greenhouse gases (GHGs) globally, and petcoke blending only increases these emissions. In the United States, however, the largest source of GHGs is in fact the production, processing and consumption of petroleum, including petcoke.[8]

The large volumes of petcoke produced from tar sands bitumen are the hidden coal in the tar sands. They are the proof positive that tar sands bitumen is a far more carbon intensive energy source than conventional oil.

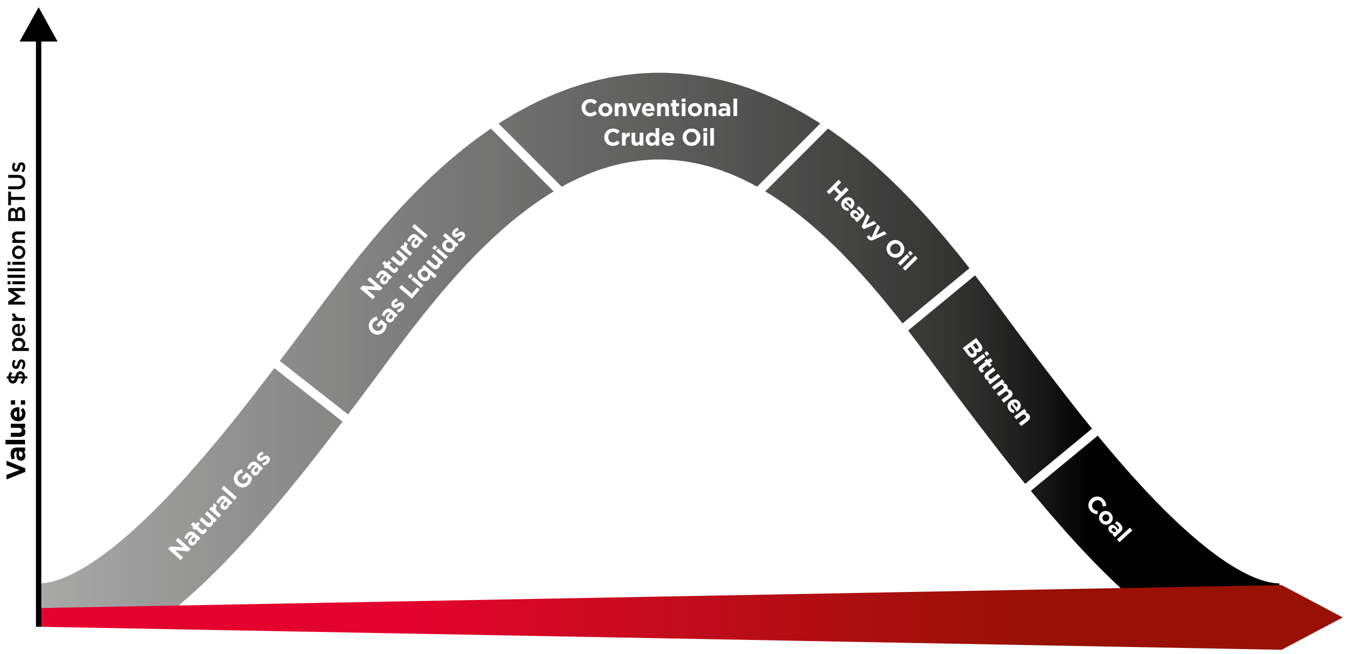
6 Based on a 476MW average maximum summer capacity of U.S. facilities with coal generators in 2011. Data from EIA Form 860 and 7000 tons of petcoke per GW/day.
7 EIA, Exports by Destination, Petroleum Coke. http://www.eia.gov/dnav/pet/pet_move_expc_a_EPPC_EEX_mbbl_a.htm
8 EIA. See Emissions by Major Fuels Compared to their Consumption at: http://www.eia.gov/environment/emissions/carbon/

IT'S BITUMEN, AND BITUMEN IS DIFFERENT

To understand why the tar sands are such a threat to our climate we must first understand that the bitumen in the Canadian tar sands is very different to conventional oil. It is not a liquid. It is semi-solid, owing to the fact that it is comprised of longer and more complex carbon molecules than conventional oil.[9] Tar sands are, in effect, carbon rich and hydrogen poor.

On a spectrum of hydrocarbons that runs from natural gas through oil to coal, bitumen is next to coal based on the balance of carbon and hydrogen that it contains (see Figure 1).

Figure 1: The spectrum of fossil fuels, their carbon content and value.[10]



The higher carbon content in bitumen is a large part of the reason it takes more energy to extract and process. For example, with in situ production, a term that refers to extracting tar sands bitumen with wells and pumps rather than mining it with shovels and trucks, the bitumen needs to be heated with steam for weeks to enable it to flow into a production well. Additionally, the process of transforming the extra-heavy, semi-solid bitumen into a light liquid fuel like gasoline is inherently more intensive than if you begin with relatively light oil in the first place.

The Pembina Institute estimates that extracting and upgrading[11] tar sands bitumen is between 3.2 to 4.5 times more greenhouse gas intensive per

9 Deborah Gordon, May 2012, *Understanding Unconventional Oil*. Carnegie Endowment for International Peace.
10 Adapted from Figure 3 in Deborah Gordon, May 2012.
11 Upgrading is a process of partially refining bitumen into a synthetic crude oil so that it can be refined in less complex refineries that are needed for refining un-upgraded bitumen. See Box on Petcoke Production, page 19.

barrel than producing conventional oil in Canada and the United States.[12] But substantial though these production emissions are, there is far more to the carbon burden of bitumen.

To refine a barrel of bitumen into a light transport fuel requires removing or converting a substantial portion of the embedded carbon. These processes are themselves very energy and input intensive, and therefore carbon-intensive. But the carbon "removed" during that process does not simply disappear. In most cases it remains behind as a byproduct of the refining process. This byproduct is petcoke.

Petcoke can be used just like coal. 15 to 30 percent of a barrel of bitumen can end up as petcoke, depending on the upgrading and refining process used. So a non-trivial proportion of the bitumen extracted results essentially in coal not oil.

Petcoke has higher carbon content than coal. Different quality coals have different carbon content levels and different energy yields. The two most common types of coal are bituminous and sub-bituminous. Using a median figure for these two coal types we find that petcoke emits 53.6 percent more CO_2 per ton than coal and 7.2 percent more CO_2 per unit of energy. So when a coal plant co-fires petcoke it emits more CO_2 than firing coal alone. See Table 1 for estimated values.

The increasing production of tar sands bitumen and other heavy oils is leading to a boom in petcoke production centered in the United States. The petcoke boom is an insidious aspect of tar sands production that is, until now, undocumented. To date, petcoke has been hidden in most discussions about the Greenhouse Gas (GHG) intensity of tar sands.

Tar Sands Bitumen freshly extracted from an in situ well
Source: Southern Pacific Resource Corporation. Corporate Presentation, October 2012.

Table 1: CO_2 and energy values for petcoke and coal.[13]

Fuel	CO_2 per unit of energy (lbs/MMBtu[14])	Energy Content (MMBtu/ton fuel)	CO_2 by weight (ton CO_2/ton fuel)
Bituminous Coal	203.99	24.93	2.54
Sub-Bituminous Coal	211.91	17.25	1.83
Median of Bit./Sub-Bit.	207.95	21.09	2.19
Petcoke	222.88	30.12	3.36
Percentage Increase: Coal median to Petcoke	7.2%	42.8%	53.6%

12 Marc Hout, September 2011. *Oilsands and climate change: How Canada's oilsands are standing in the way of effective climate action.* The Pembina Institute. http://pubs.pembina.org/reports/oilsands-and-climate-fs-201109.pdf

13 Bituminous and Sub-Bituminous coals are the most common types of coal available globally. Together these two coal grades make up about 82% of global reserves. Within these coal grades there is a wide range of energy values and carbon contents. We chose to use a median figure based on the figures given in Environmental Protection Agency, November 2004: *Unit Conversions, Emissions Factors, and other Reference Data.* http://www.epa.gov/cpd/pdf/brochure.pdf in order to give a generalized comparison. It should be noted that an actual comparison in emissions between petcoke and coal can vary depending on the coal quality but in most cases, excepting the use of Anthracite coal, which is less than 1% of world reserves, petcoke has higher emissions. See this link for an explanation of coal grades and reserves. http://www.worldcoal.org/coal/what-is-coal/

14 Million British Thermal Units: a measure of energy content.

In some analyses of the life-cycle emissions of tar sands production it is assumed that the petcoke produced as a byproduct of tar sands refining simply amounts to a one-for-one replacement for coal. The emissions from burning petcoke are therefore considered to be zero and not included in calculations of the GHG footprint of tar sands production in these studies.[15]

But the fact that petcoke has higher CO_2 emissions than coal and is a refinery byproduct that sells at a discount to coal means that petcoke makes coal-fired generation cheaper and dirtier. These realities undermine industry's assertion that emissions from petcoke are negligible.[16] Not including petcoke emissions in estimations of the GHG emissions of tar sands and other crude oils that yield petcoke means the climate impact of oil production is being consistently undercounted.

With more than 300 billion barrels of recoverable tar sands bitumen still in the ground in Alberta and hundreds of billions of barrels of extra-heavy and heavy oils available in reserves around the world, it is time we understood the full impact of exploiting these low quality, high impact hydrocarbons.

WHAT IS PETCOKE AND HOW IS IT USED?

Petcoke is a byproduct of oil refining. It is a concentrated carbon solid residue that is left behind after the refining process has converted the bulk of the oil into valuable liquid fuels such as gasoline and diesel.

Petcoke is a dirty fuel. Besides having very high carbon content (over 90 percent) many of the impurities in tar sands bitumen become concentrated in the petcoke produced from it. Much of the non-volatile sulfur present in the crude oil remains in the petcoke as do the non-volatile inorganics and the heavy metals such as nickel and vanadium.[17] Combusting petcoke in countries that do not regulate and control emissions of sulfur dioxide and do not have adequate procedures for safely disposing of ash laden with heavy metals is a major concern.

Further processing

The petcoke that is produced in a refinery is termed Green Coke. This can be used directly as a fuel and is commonly co-fired with coal in power generation plants and other industrial boilers such as those in cement plants, glass factories and paper mills.

This Green Coke can be processed further to make Calcined Coke. Heating green coke in a kiln to very high temperatures of around 2200-2500°F (1200-1350 °C) removes moisture, reduces volatile matter, and increases the density of the material. The resulting product – Calcined Coke – is almost pure carbon and has very high electrical conductivity. It is generally used as material for anodes in the aluminum smelting industry.

Around 75 percent of petcoke produced today is used as fuel while the rest is generally either calcined for use in the aluminum industry or treated for use as metallurgical coke in steel making. Relatively small amounts are also turned into graphite electrodes and other graphite products.

15 IHS CERA 2012. *Oil Sands, Greenhouse Gases, and US Oil Supply: Getting the Numbers Right – 2012 Update*. http://www.ihs.com/products/cera/energy-industry/download-free-canadian-oil-sands.aspx

16 See 'Measuring the Impact of Petcoke', page 38.

17 Anthony Pavone, 1992, *Converting Petroleum Coke to Electricity*. Available at http://repository.tamu.edu/bitstream/handle/1969.1/92212/ESL-IE-92-04-47.pdf Accessed 03 October 2012.

MORE CARBON IN, MORE CARBON OUT

It is a physical fact that the heavier the hydrocarbon the more carbon embedded in that hydrocarbon. As Figure 1 shows, tar sands bitumen is at the heavy, high-carbon end of the hydrocarbon spectrum, next to coal.

The high carbon loading in tar sands bitumen gives it greater density than liquid oil and renders it semi-solid. The measurement of oil density has been standardized by the American Petroleum Institute and is known as API gravity or Degrees API; the lower the API gravity, the denser the oil. A hydrocarbon with a low API gravity is heavier than one with high API gravity. In other words, a barrel of bitumen literally weighs more than a barrel of light oil, and the additional weight is primarily associated with the bitumen's higher embedded carbon.

Table 2 shows the total carbon dioxide emissions in pounds per barrel associated with the combustion of a barrel of light oil compared to a barrel of bitumen. These emissions are entirely separate to the emissions associated with extracting, transporting and refining the hydrocarbon.

Table 2: The difference in API gravity, density and carbon content between light oil and bitumen.[18]

Oil type	Light Oil	Bitumen
Combustion CO_2 (lbs/bbl)	926	1149
Oil Density (lbs/bbl)	298.6	354.1
API Gravity	34.2	8

There is 24 percent more CO_2 embedded in a barrel of bitumen than in a barrel of light oil. Again, this is entirely separate from the emissions associated with producing and refining these hydrocarbons. This is simply the emissions from combusting the content of the barrel.

18 Based on Table 1 in Deborah Gordon, December 2012. *The Carbon Contained in Global Oils*. Carnegie Endowment for International Peace.

THE CARBON LOGIC

According to the Potsdam Institute, in order to reduce the chance of average global temperatures increasing by over 2 °C (3.6°F), a point beyond which scientists agree dangerous levels of climate change will occur, the global carbon budget for 2000-2050 is 953 billion tons of CO_2 (865 metric tons). Subtracting emissions from the first decade of this century left a budget of 622 billion tons (565 metric tons) for the period 2010-2050. This is an emissions budget which the world is currently failing to adhere to. Staying within the budget has huge implications for the exploitation of the world's fossil fuel reserves.

The International Energy Agency (IEA) uses this emissions budget as part of its model for calculating how much of the world's fossil fuels can be burned to stay within the 2 °C target. The IEA's model also calculates how much of which fossil fuel reserves would likely be exploited under the policies and economics of a 2 °C scenario.[19]

In the IEA's latest annual World Energy Outlook (2012) the agency stated that, "(n)*o more than one-third of proven reserves of fossil fuels can be consumed prior to 2050 if the world is to achieve the 2 °C goal*". The IEA is not the first to highlight this but its public recognition of the issue is highly significant.[20] Other analysts place the figure lower, at just 20 percent of proven reserves.[21]

This 'Carbon Logic'[22] is something the fossil fuel industry refuses to acknowledge because doing so would require facing up to its inevitable demise and discontinuing its relentless drive to replace reserves.[23] The Canadian tar sands industry is a poster child of this tendency to deny climate limits.

The proven reserves of Canadian tar sands bitumen are more or less already divided among companies and lease holders. These companies have assessed the resources on their leases and drawn up plans for the extraction of bitumen.

The 169 billion barrels of tar sands bitumen that are currently categorized as proven reserves[24] are part of the global proven reserves that the IEA and

19 See the IEA's annual *World Energy Outlook* and *Energy Technology Perspectives* reports.
20 See for example, Carbon Tracker Initiative 2011, *Unburnable Carbon: are the world's financial markets carrying a carbon bubble*? www.carbontracker.org and Greenpeace International 1997. *Fossil Fuels and Climate Protection: The Carbon Logic.* http://archive.greenpeace.org/climate/science/reports/carbon/clfull-Contents.html
21 The difference is due to the IEA using an emissions budget that allows a 50% chance of staying under 2 degrees whereas Carbon Tracker, for example, uses a budget that affords an 80% chance.
22 Greenpeace International 1997. *Fossil Fuels and Climate Protection: The Carbon Logic.* http://archive.greenpeace.org/climate/science/reports/carbon/clfull-Contents.html
23 Lorne Stockman, 2010. *Reserves Replacement Ratio in a Marginal Oil World: Adequate indicator or Subprime Statistic*? Oil Change International, Platform, Greenpeace UK. http://priceofoil.org/educate/resources/reserves-replacement-ratio-in-a-marginal-oil-world/
24 The Canadian government currently uses the term 'Established Reserves' instead of 'Proven Reserves'. The definition of Established Reserves is very similar to that used more widely in the industry for 'Proven Reserves'.

others calculate cannot be fully exploited. Yet government and industry are in the process of building and permitting enough tar sands production capacity to exceed the IEA's estimate of climate limits by around three times.

Figure 2 shows how much tar sands production capacity exists, is under construction and has been approved and proposed. Using the IEA's estimates, the chart shows that to have a 50 percent chance of staying within the 2 degree 'safe limit' only slightly more capacity than is currently under construction would be permissible. In light of the fact that this allows a one in two chance of exceeding the 'safe limit' it would seem that the level of capacity that is today under construction is already risky.

Yet, the Albertan government has already approved over 2 million barrels per day (b/d) of production capacity over this limit, is reviewing some 2.5 million b/d more while companies have announced a further 1.5 million b/d that they would like to build. Figure 2 also shows that the IEA's high demand scenario, which the agency states would lead to catastrophic warming of 6 °C, is already exceeded by currently approved projects.

It is clear that the momentum for production of Canadian tar sands bitumen is out of control from a climate perspective. Neither the industry nor the Canadian or Albertan governments have considered climate limits in their ambition to exploit the bitumen lying under Alberta. In as far as government and industry acknowledge that climate change is a problem, the implicit assumption appears to be that Canada can somehow exploit these resources responsibly and that resources elsewhere should be left in the ground. Yet, if Canada cannot control the exploitation of this lethal resource, how and why should any other nation?

Figure 2: Canadian tar sands projects vs. IEA scenarios.

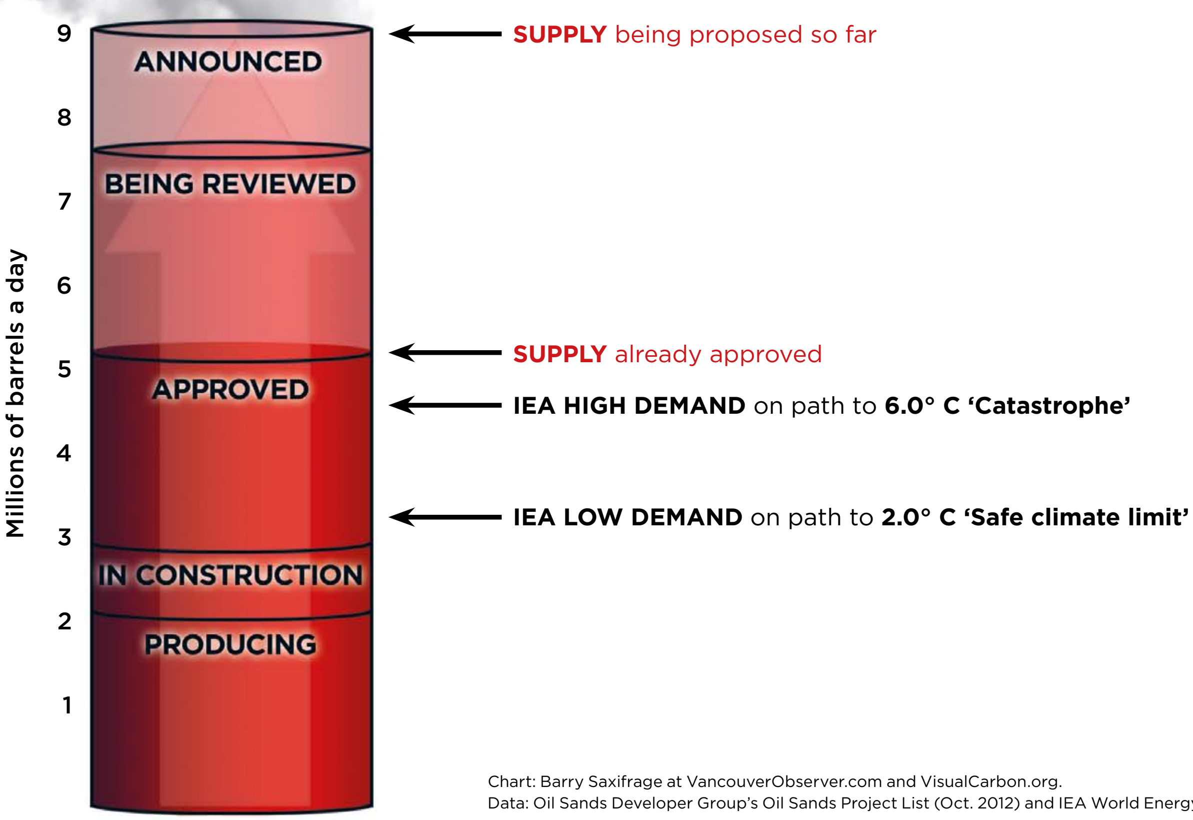


Chart: Barry Saxifrage at VancouverObserver.com and VisualCarbon.org.
Data: Oil Sands Developer Group's Oil Sands Project List (Oct. 2012) and IEA World Energy Outlook 2010.

The Coal Hiding in the Tar Sands

The 169 billion barrels of proven bitumen reserves in Alberta are less than 10 percent of the total bitumen that exists there. The figure is simply an estimate of what is considered to be recoverable with today's technology and with current expectations of oil price.

With higher oil prices and expected technological developments the Albertan government estimates that the 'Ultimate Potential' of tar sands extraction could be almost double at 314 billion barrels. The total amount of bitumen thought to be 'in place' in Alberta is far greater at around 1.8 trillion barrels.[25]

History shows that with time, technological development and rising oil prices, the quantity of hydrocarbons that can be recovered from reservoirs very often exceeds initial expectations.[26] The tar sands are a case in point as despite being a focus of research and pilot projects since the 1930s, the vast majority of the proven bitumen reserve was not considered economic until 2004.[27]

The average global recovery rate for oil is less than 35 percent of the estimated oil in place.[28] So the Albertan government's current estimate of tar sands 'Ultimate Potential', at 17 percent of the estimated oil in place, is well below the global average. It is possible that the continued emphasis on maximizing extraction could lead to increasing estimates of proven and recoverable reserves.

Table 3 details the three main categories of Canadian bitumen resources. We present the embedded carbon in those reserves and the potential petcoke yield based on the 15 percent that most refiners and upgraders obtain. As some projects show, it is possible to get much higher petcoke yields from bitumen, up to 30 percent, so these figures are potentially conservative.[29]

Table 3: Canadian bitumen reserves, embedded CO_2 and petcoke yield.[30]

Canadian Bitumen Reserves	Billion Barrels	Total Combustion[31] CO_2 Billion (short) tons	Petcoke Yield Billion (short) Tons	CO_2 from Petcoke Billion (short) Tons
Proven (Established)	169	97	5	17
Technically Recoverable (Ultimate Potential)	314	180	9	32
In place	1,800	1,034	54	181

25 Alberta ERCB Serial Publications ST-98-2012. *Alberta's Energy Resources 2011 and Supply/Demand Outlook 2012-2021.*
26 For some discussion of this see Leonardo Maugeri, June 2012, *Oil: The Next Revolution*: *The unprecedented upsurge of oil production capacity and what it means for the world.*
27 Marc Humphries, Congressional Research Service, January 17, 2008. *North American Oil Sands: History of Development, Prospects for the Future*. Order Code RL34258.
28 Maugeri, June 2012.
29 See Section *Maximization of petcoke yield, page 30.*
30 Source: Alberta ERCB Serial Publications ST-98-2012. *Alberta's Energy Resources 2011 and Supply/Demand Outlook 2012-2021*'. For CO_2 in Bitumen see Deborah Gordon, Carnegie Endowment for International Peace, December 2012. *The Carbon Contained in Global Oils.* Table 1. Petcoke yields based on our calculations. CO_2 in petcoke based on EPA 2004. 3.36 tons of CO_2 per ton of petcoke.
31 Not including emissions from extracting and processing.

Based on the typical petcoke yield of 15 percent, the proven bitumen reserves of Canada could yield around 5 billion tons of petcoke. That is enough petcoke to fuel 111 U.S. coal plants to 2050. If all the bitumen in Alberta were to be extracted it could yield some 54 billion tons of petcoke. This is about three times the recoverable coal in U.S. coal mines that were producing in 2010.[32]

RESERVES

There are three reserves categories that we use in this report: Proven Reserves, Technically Recoverable Reserves and Oil in Place.

Proven (or proved) Reserves:

Proven reserves are known reserves of oil that are considered to be recoverable in the future under current economic and operating conditions. The Alberta Energy Resources Conservation Board (ERCB) uses the term 'Established Reserves'. The ERCB figures for Established Reserves correspond with the BP Statistical Review of World Energy's and International Energy Agency's figures for Canadian proven reserves. We have therefore assumed they are the same.

Technically Recoverable Reserves:

This category includes all known reserves that are considered producible with today's technology without reference to whether they can be produced economically. These reserves will therefore include proven reserves as well as those reserves that cannot be produced under today's economic conditions but can be produced with today's technology.

The ERCB uses the term 'Ultimate Potential' which we have taken to correspond with Technically Recoverable.

Oil in Place:

Oil in place includes all the oil estimated to be in the reservoir including both recoverable and non-recoverable oil. It is generally impossible to recover all the oil in a reservoir and there is a wide range of recovery rates for different sources of oil. In tar sands mines, where bitumen deposits are very shallow and are extracted with mechanical shovels in surface mines, the recovery rate can be over 90 percent and is among the highest in the world. With in-situ production, where the bitumen is produced by drilling wells and heating the bitumen to enable flow, the recovery rates vary from between 25 and 60 percent.[33] Conventional light oil averages around 30 percent.[34]

Currently 314 billion barrels out of the 1.8 trillion barrels of bitumen in place in Alberta is considered technically recoverable. This is 17.4 percent. This figure could rise with the development of technology and/or an increase in the price of oil.

32 EIA: *Recoverable Coal Reserves at Producing Mines, Estimated Recoverable Reserves, and Demonstrated Reserves Base by Mining Method 2010.*
33 http://www.centreforenergy.com/AboutEnergy/ONG/OilsandsHeavyOil/Overview.asp?page=6
34 Ibid.

The Keystone XL Pipeline: Fueling Five Coal Plants

The Keystone XL pipeline has been the key battleground on which the fight to keep tar sands bitumen in the ground has been fought in the United States over the past two years. If it is built, it has the potential to deliver 830,000 barrels per day of diluted bitumen (dilbit) and syncrude to refineries in Port Arthur, Houston and surrounding areas. The expected ratio of dilbit to syncrude is expected to be 80/20-dilbit/syncrude.[35]

Canadian Natural Resources Limited's SAGD (in situ tar sands) operation, Alberta, Canada

The refineries in Port Arthur and Houston include the biggest petcoke producing refineries in the U.S. and in the world (see Figure 3). When it re-opens in early 2013, the Motiva Port Arthur Refinery, jointly owned by Royal Dutch Shell and Saudi Aramco, will be the biggest refinery in America with the capacity to produce over 8600 tons of petcoke per day. Nine of the refineries closest to the terminus of the proposed pipeline have nearly 30 percent of the petcoke production capacity in America, over 50,000 tons per day.[36]

If the pipeline is built, we calculate that around 15,000 tons of petcoke per day will be produced from the bitumen in the dilbit it will deliver.[37] So the petcoke produced via Keystone XL could fire 4.5 U.S. coal plants.[38] However, petcoke produces 5 to 10 percent more CO_2 emissions than coal for the energy produced.[39] If we use the median figure of 7.2 percent shown in Table 1, the emissions from this amount of petcoke would be the equivalent of 4.8 average U.S. coal plants. That is over 50,000 tons of CO_2

35 The U.S. State Department's Pipeline Temperature Effects Study for Keystone XL states that flows from Canada will be 80/20-dilbit/SCO (page L-2). http://keystonepipeline-xl.state.gov/documents/organization/182235.pdf

36 Includes refineries in Port Arthur and Houston, Texas and Lake Charles, Louisiana.

37 Based on an 80/20 split of Dilbit/Syncrude in the pipeline and a 75/25 split of Bitumen/Diluent in the Dilbit

38 It takes 10,000 tons of coal to run 1 GW (1000 MW) of coal generation for a day. But with the higher energy content of petcoke it would take only 7000 tons a day of petcoke to generate the same amount of power. Therefore, the 15,000 tons of petcoke that could be produced from the dilbit delivered by Keystone XL could run 2.13 GW of typical coal-fired power. The average size of a coal-fired power plant in the U.S. is 476MW. Based on the average summer capability of 2011 coal fired generation sets at facilities recorded in EIA Form 860. Generation sets at individual plants were amalgamated and averaged.

39 Based on the median figure for lbs CO_2/MMBTU in Table 1.

every day or over 18.3 million tons (16.6 million metric tons) of CO_2 a year. These petcoke emissions have been excluded from State Department emissions estimates for the pipeline. Including these emissions raises the total annual emissions of the pipeline by 13 percent above the State's Department's calculations.[40]

Figure 3: Keystone XL refineries are among the biggest petcoke factories in the world.

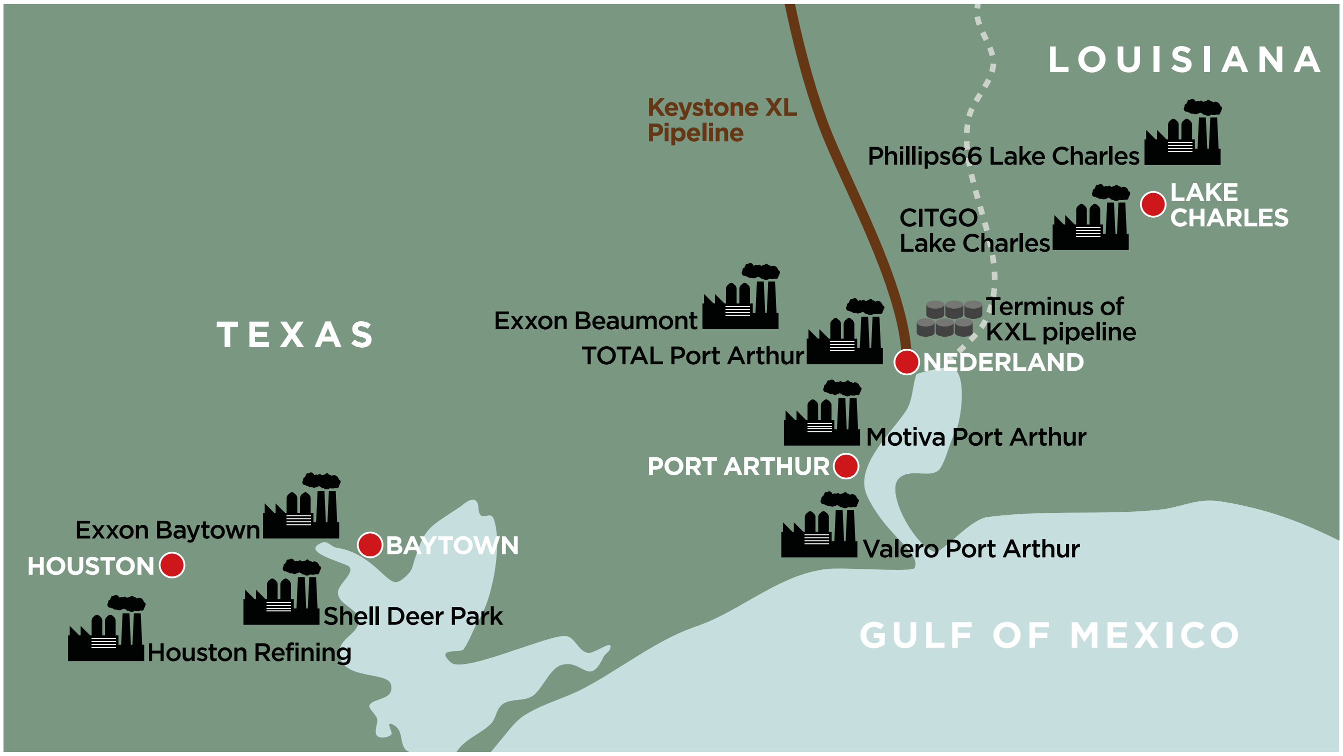


Table 4: Petcoke production capacity at Keystone XL refineries.

Refinery	Petcoke Production Capacity (Tons/Day)
Shell Deer Park	7,740
Exxon Baytown	4,550
Houston Refining	5,850
Exxon Beaumont	3,000
TOTAL Port Arthur	3,660
Motiva Port Arthur	8,625
Valero Port Arthur	6,450
CITGO Lake Charles	6,000
Phillips66 Lake Charles	4,500
Total	50,375

Source: EIA Refinery Capacity Report 2012

40 Based on figures in Table 3.14-3.10 in the State Department's Final Environmental Impact Statement (FEIS) from August 2011, (http://keystonepipeline-xl.state.gov/documents/organization/182069.pdf) we calculated the total annual emissions of the pipeline to be 129 million metric tons. The State Department used NETL 2009 (see the link above) for its estimates, a study which does not include petcoke sold outside of the refinery in its calculations of tar sands life cycle emissions. Therefore the petcoke produced from Keystone XL bitumen is excluded. Including it adds the 16.6 million metric tons that we have estimated. This raises the total annual emissions from Keystone XL to 145.6 million metric tons, a 13 percent increase.

THE RISE OF NORTH AMERICAN COKE

Syncrude Upgrader, Alberta, Canada.

Petcoke has been around since oil refining began, but booming production of tar sands bitumen and other heavy oils has dramatically raised production in recent years, and petcoke now constitutes a major source of both energy and emissions. Critically, the increasing supply has opened new markets for the fuel.

This boom has been concentrated in North America because of the presence of huge reserves of bitumen in the Canadian tar sands as well as the presence of bitumen in Venezuela and heavy oil in other Latin American countries.

Heavy oil sells to refiners at a discount to light oil because it is more difficult to refine. Refiners equipped to process heavier oil are positioned to profit from this price differential because petroleum product prices are generally linked to the price of light oil. As Canadian tar sands production started to emerge as a significant new source of oil in the early years of the twenty-first century, with the prospect of decades of production growth ahead, many U.S. refiners began to plan investments in equipment such as cokers and hydrocrackers to take advantage of the incipient tar sands boom. Many of the largest of these investments have only come on stream in the last few years while others are only just being completed today (see Table 7).

The heavy oil refining capacity in the United States is now the largest in the world and, combined with the tar sands production and upgrading capacity in Canada, has transformed North America into the petcoke production center of the world.

PETCOKE PRODUCTION

The Delayed Coking Process

Refining tar sands bitumen and removing the sulfur, toxins and heavy carbon, requires special equipment and processes. Lighter oils will yield the components of gasoline and diesel at relatively low temperatures in a distillation unit. But the heavier the oil the higher the temperature needed to distil these liquids. With bitumen refining, there is a large proportion of residue left over from the first crude distillation process and this residue is often sent to a delayed coker for further processing in order to obtain more high value light liquids from the residual oil.

In the coking process this residual oil is treated with steam at temperatures around 900 °F (480°C) and held in a coking drum while reactions take place. Further liquid fuels are obtained through this process, but a substantial solid residue is captured in the coke drum, commonly around 30 percent by volume of the material originally entering the delayed coking unit. This solid residue is petcoke. A typical 50,000 barrel-per-day delayed coking unit may produce around 3000 tons of petcoke per day.[41]

Bitumen Upgrading

In Canada, some tar sands producers run special upgraders to process tar sands bitumen into a synthetic crude oil (Syncrude) with similar properties to light crude oil. This can then be refined in standard refineries without the need for coking. These upgraders generally use delayed coking to produce the syncrude and the vast bulk of the petroleum coke that is produced from this portion of Canada's tar sands production is produced at these upgraders. Depending on the properties of the syncrude produced, it will yield little or no petcoke when it is refined.

In recent years, tar sands production has outpaced the capacity of the Canadian upgraders and an increasing proportion of the bitumen produced is being processed in U.S. coking refineries. As upgraders are capital intensive to build, very little new upgrading capacity is currently being planned in Canada. So the future growth of tar sands bitumen is destined for these coking refineries in the United States or possibly those in Asia, should an export pipeline to Canada's west coast ever be built.[42]

Blending

The density of oil varies greatly between different resources and also varies within Canada's bitumen resources. Crude oil that is delivered to a refinery is usually a blend of different oils and these blends are designed to provide refiners with oil of a specific density and sulfur content.

Upgraders in Canada may process pure bitumen, but they do not produce finished fuels. They produce synthetic crude oil which is then refined further in a refinery in Canada or the United States.

As pure bitumen cannot flow in a pipeline to U.S. refineries it is generally diluted with light oil or natural gas liquids. This is known as diluted bitumen or 'dilbit'. Dilbit can be between 70 and 80 percent bitumen and 20 to 30 percent diluent. Based on a 75/25 dilbit the petcoke yield from refining dilbit may be around 11 percent.

The diluent content in dilbit may change over time as it is the aim of the industry to deliver as much bitumen as possible. For example, one tar sands producer is currently planning to deliver all of its production to the U.S. Gulf Coast by rail. One stated advantage of doing so is that much less diluent is needed as the bitumen will not need to flow in a pipeline.[43] So the density of bitumen blends received at U.S. refineries may vary and the higher the bitumen content the higher the petcoke yield is likely to be.

41 See slide 19 in this presentation by Petcoke traders Marsulex: http://www.coking.com/SeminarCanada/PresentationPDFs2010/Marsulex_DonBoonstra_Sulphur&PetroleumCokeMarkets_Coking-SulfurUnitCom_Sep2010.pdf

42 NRDC, Living Oceans Society and The Pembina Institute, November 29, 2011. Pipeline and Tanker Trouble: The Impact to British Columbia's communities, rivers and Pacific coastline from tar sands oil transport. http://www.pembina.org/pub/2289

43 Southern Pacific bitumen rail story

Petcoke in Canada

In Canada, petcoke is primarily produced at tar sands upgraders. These refinery-like plants transform bitumen from the tar sands into a synthetic crude oil known as Syncrude. The Syncrude is then sold to refineries in Canada and the United States to be refined into petroleum products.

The upgraders generally use delayed coking to upgrade the bitumen to a blend of gasoil, naphtha and distillate and further treat the blend to remove sulfur and add hydrogen. This results in a light sweet (low sulfur) oil, which yields little or no heavy residues when it is refined. So the vast proportion of the heavy residue is removed from the bitumen and is left behind at the upgrader site as petcoke.

Canadian petcoke production at upgraders in Alberta and Saskatchewan alone, (excluding petcoke produced at Canadian refineries) was nearly 10 million tons (9 million metric tons) in 2011.

Petcoke emptying into a pit below the delayed coking unit at Total's Port Arthur, Texas Refinery.

Around half of this petcoke production was stockpiled in Alberta due to limited capacity to transport it out of the region. A portion of the petcoke that is not stockpiled is consumed in the upgraders but the bulk of it is sold in Canada and the United States while some has managed to reach Asian markets; mainly China and Japan (see Table 6).

At the end of 2011 nearly 80 million tons (72.3 million metric tons) of petcoke was stockpiled in Alberta.[44] The stockpile is growing at the rate of about 4 million tons (4.4. million metric tons) a year.

Canadian Consumption of Petcoke

Some petcoke is consumed in the power sector in Canada, probably co-fired with coal. Data is only available in megawatt hours of power generated with the fuel and it would appear this has declined from around 3.5 million MWh in 2005 to just over 2 million MWh in 2010, the latest year that figures are available for.[45]

Elsewhere in Canada petcoke is primarily used in refineries and upgraders as fuel as well as in cement and lime kilns. A small amount is used in steel and other metals manufacturing. Since 2000, petcoke used in Canadian manufacturing, including refineries and upgraders, has averaged around 2.2 million tons (2 million metric tons).[46]

Canada also imports significant quantities of petcoke from the United States. Nearly 3.7 million tons were imported from the U.S. from January 2011 to September 2012, making Canada the sixth biggest recipient of U.S. petcoke in that period.[47]

So with petcoke in Canadian power generation in decline and its use in Canadian manufacturing steady for the past 12 years, it would appear that some of the approximately 4 million tons of non-stockpiled petcoke produced at Albertan and Saskatchewan upgraders finds its way to export markets.

Canadian Petcoke Exports are Growing

The governments of both Canada and Alberta state that they do not collect data on petcoke exports.[48] However industry sources show that Canadian petcoke exports are growing. Exports were down in 2011, probably because of an explosion and fire at CNRL's Horizon upgrader in January 2011, which knocked out production there for almost six months.[49] But the data shows that exports in 2012 through July are in line to surpass the 1.3 million tons exported in 2010 (see Table 6).

The bulk of Canada's petcoke exports travel by rail to the Ridley Terminals near Prince Rupert, British Columbia, where petcoke is loaded onto ships

44 See ERCB ST-39 2011: http://www.ercb.ca/data-and-publications/statistical-reports/st39
45 Statistics Canada. CANSIM table 127-0006.
46 Statistics Canada. CANSIM Table 128-0005
47 EIA Exports by Destination. Petroleum Coke. http://www.eia.gov/dnav/pet/pet_move_expc_a_EPPC_EEX_mbbl_m.htm
48 Personal communication with author. Emails from NEB and ERCB
49 http://www.pem-mag.com/News/cnrl-resumes-oil-production-after-horizon-fires-source-found-repairs-made.html

mostly bound for Asia. Some makes its way to the United States probably directly by rail. Over 900,000 tons of petcoke left Prince Rupert from January through August 2012, a nearly 60 percent increase on the same period in 2011.[50]

Table 5: **Canadian petcoke production from upgraders – short tons.**

	2010	2011
Production	9,664,375	9,239,986
Consumed or Marketed	5,151,794	4,887,323
Total Stockpile (at end of year)	75,404,700	79,774,423

Source: Alberta ERCB

Table 6: **Canadian petcoke exports – short tons.**

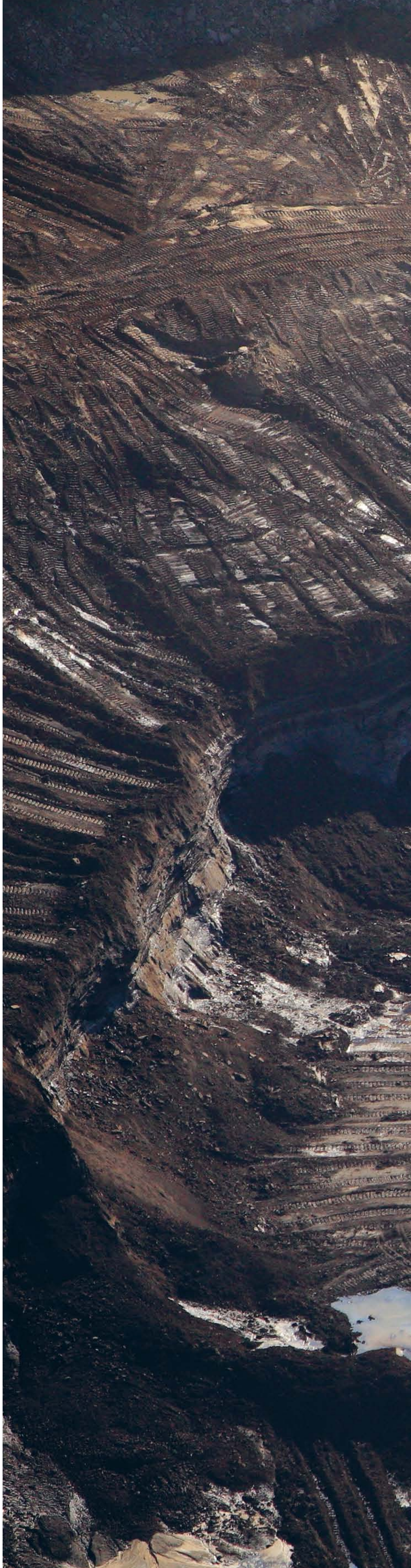
	2010	2011	2012 (Jan-Jul)
Total	1,337,873	892,436	1,171,355
China	654,920	387,853	563,195
Japan	449,160	205,089	187,758
USA	174,112	299,416	367,406

Source: Energy Publishing, LLC's Domestic and International Petcoke Report

The production of around 10 million tons a year of petcoke in Canadian tar sands upgraders is a significant source of petcoke. While the industry has talked about using this fuel to generate electricity by gasifying it and sequestering the carbon,[51] no gasification project is currently sequestering any carbon. Meanwhile a significant portion is finding its way onto the market and is being fired in industrial plants and power generators in Canada and abroad.

The growth of petcoke production in Canada depends on whether more upgraders will be built there. Only one new upgrader is currently under construction and it is unclear when other proposed upgraders will be built. In the meantime, tar sands bitumen that is not upgraded in Canada is exported to the United States in the form of diluted bitumen (dilbit) or other heavy oil blends, where refineries with cokers and other secondary processing units upgrade and refine the bitumen into petroleum products. All the petcoke produced in the United States is finding its way onto the market.

50 Energy Publishing, LLC's Domestic and International Petcoke Report, September 2012. *Ridley exports up significantly.*
51 http://www.greenfuelsfactory.ca/coal/petroleum-coke




Mining bitumen at the Suncor Millennium tar sands mine. Alberta, Canada.

PETCOKE IN THE UNITED STATES

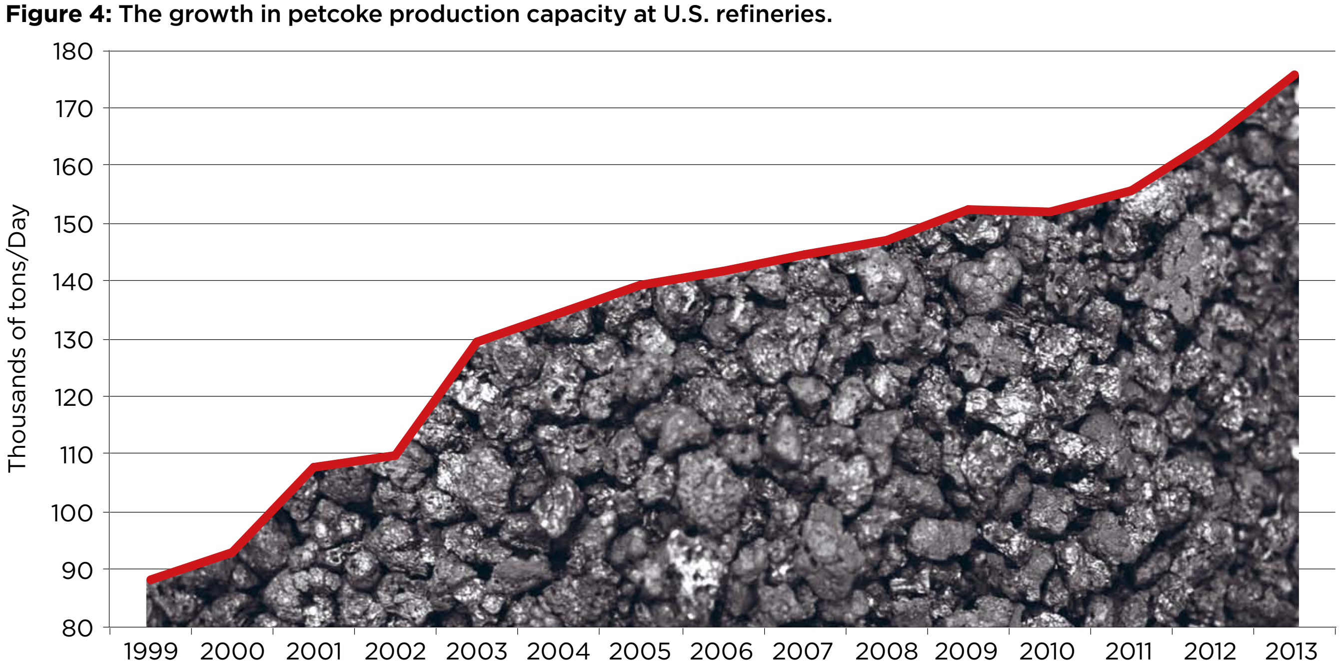
The rise in U.S. petcoke production has positioned the United States as the biggest producer of petcoke in the world, with over 40 percent of the global market.

The capacity to produce petcoke in U.S. refineries has doubled since 1999 (Figure 4). The increase in U.S. petcoke production closely follows the ongoing boom in Canadian tar sands production, which has been gathering pace since the beginning of the current century.

At the beginning of 2012, capacity was 165,000 tons per day. This will rise to over 176,000 tons per day by mid-2013 after three major refinery projects complete their construction of cokers and other new equipment (Table 7).[52]

U.S. refineries produced over 61.5 million tons of petcoke in 2011. This is enough to fuel 50 average U.S. coal plants.[53] Around 60 percent of U.S. petcoke production was exported in 2011, amounting to over 36 million tons.[54] Petcoke exports have grown by over 100 percent since 1999 (See Figure 6).

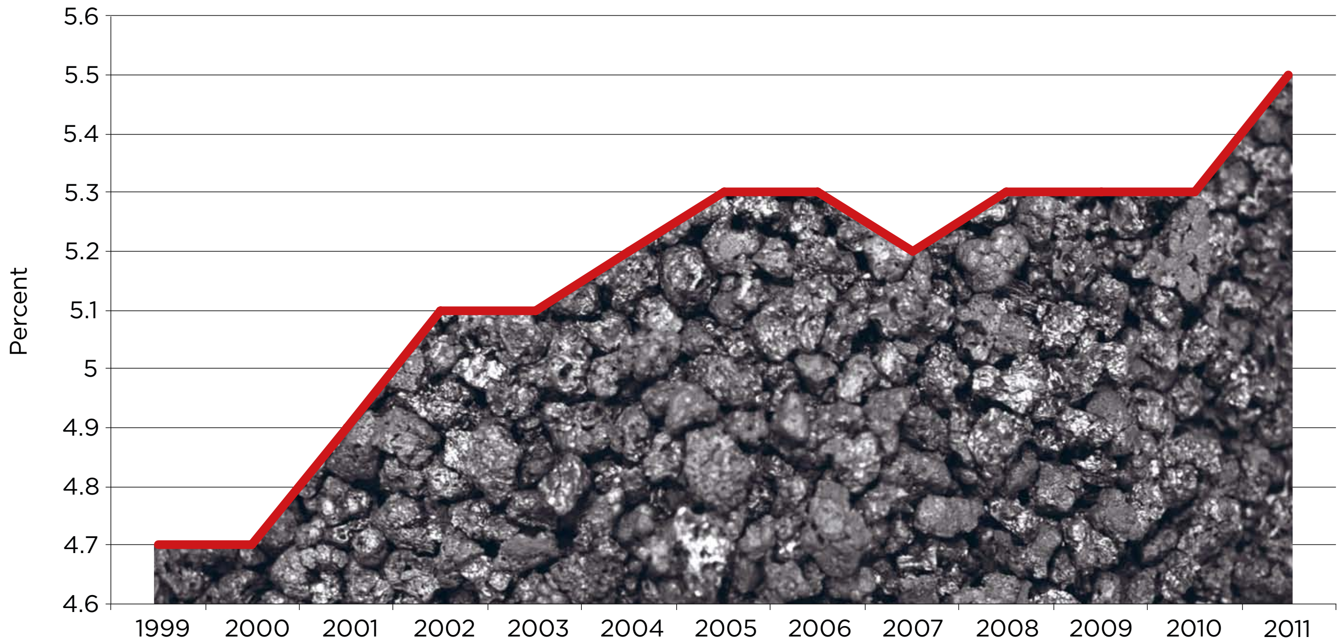
Figure 4: **The growth in petcoke production capacity at U.S. refineries.**



Source: EIA

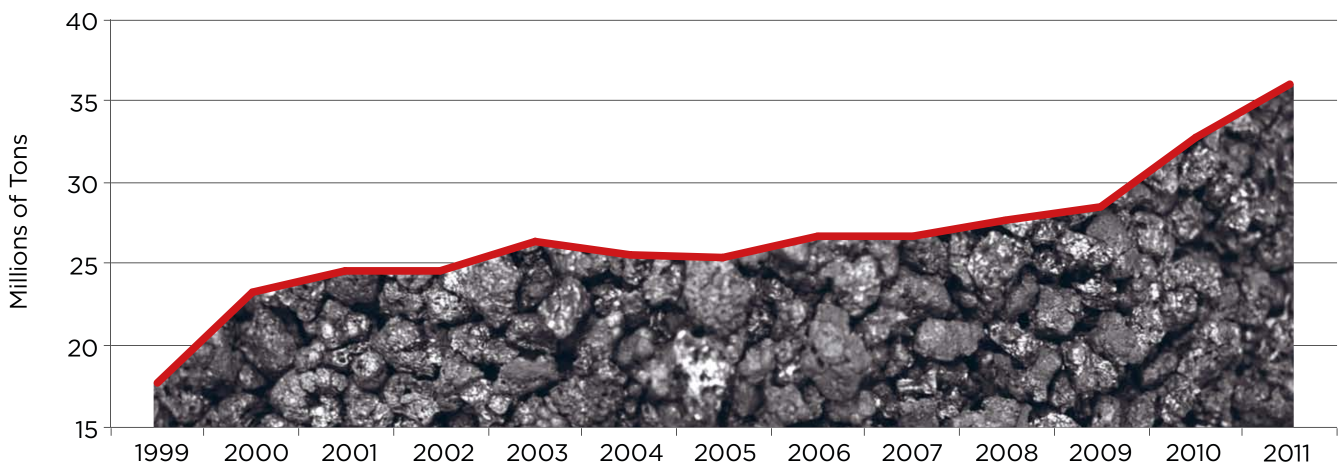
52 Motiva Port Arthur started up in June 2012 but was shut down within weeks due to leaks. It is scheduled to be back on line in early 2013. The others are BP Whiting, which is scheduled to come on line in mid-2013 and Marathon Detroit, which came on line in November 2012.
53 Based on a 476MW average maximum summer capacity of U.S. facilities with coal generators in 2011. Data from EIA Form 860.
54 EIA, Exports by Destination, Petroleum Coke. http://www.eia.gov/dnav/pet/pet_move_expc_a_EPPC_EEX_mbbl_a.htm

Figure 5: Growth in the percentage of petcoke production capacity in U.S. refinery yield.



Source: EIA

Figure 6: U.S. petcoke exports.



Source: EIA

Tar Sands Growth Drives U.S. Coker Build

While heavy oil has been a focus of some refineries in California and the Gulf Coast for some time, the prospect of growth in the tar sands has been driving an increase in coker units in the U.S. for much of the last decade, particularly in the Mid-West and Gulf Coast regions.

The expectation of Canadian heavy crude reaching the Gulf Coast was a stated aim of many recent coker and hydrocracker projects in the region.[55] The delay in construction of the Keystone XL pipeline has not slowed petcoke production at Gulf Coast refineries, as refineries that invested in cokers in order to process tar sands bitumen from that pipeline have instead run heavy crudes from Latin America and elsewhere. But it seems doubtful that so much coking capacity would have been built on the Gulf Coast if it had not been for the expectation of a steady supply of dilbit from Canada.

Cokers completed since 2008 along with those currently under construction account for a petcoke production capacity expansion of nearly 23,000 tons per day. 11,200 tons of this is currently in the final stage of construction and will come on stream by mid-2013 (see Table 7). The steep increase in capacity expected over the coming year is anticipated to lower petcoke prices significantly next year.

Table 7: U.S. coker expansions 2008-2013.

Refinery	Location	Completion date	Petcoke capacity before expansion (tons/day)	Petcoke capacity after expansion (tons/day)
Cenex Laurel	Laurel, MT.	2008	0	800
Marathon Garyville	Garyville, LA.	2009	2,900	5,800
Total Port Arthur	Port Arthur, TX	2011	0	3,660
Phillips66/Cenovus Wood River	Wood River, Il.	2011	1,300	5,700
Marathon Detroit	Detroit, MI	2012	0	1,720
Motiva Port Arthur	Port Arthur, TX	2013	3,125	8,625
BP Whiting	Whiting, IN.	2013	2,000	6,000
Total			9,325	32,305
Increase			22,980	

55 For example see http://www.total.com/MEDIAS/MEDIAS_INFOS/4841/FR/Total-2011-financial-analyst-canada-l-paszkiewicz.pdf for Total Port Arthur, and see http://www.albertaoilmagazine.com/2011/12/american-refineries-are-benefiting-from-low-cost-canadian-crude-oil/ for discussion of Valero's ambition to get Canadian heavy crude to its Port Arthur refinery.

PETKOCH

The largest petcoke trader in the world is Florida based Oxbow Corporation, a private company owned by William I. Koch. William is the brother of David and Charles Koch, who own Koch Industries, which in turn owns the Flint Hills refinery in Minnesota that is one of the biggest refiners of tar sands bitumen in America.

Oxbow ships about 11 million tons of petcoke annually around the world primarily from the Gulf Coast to Asian, Latin American and European markets. Is also one of the world's biggest producers of calcined petcoke (See What is Petcoke and How is it Used?, page 10). Oxbow has four plants in the U.S. producing calcined petcoke and one in Argentina. These plants can produce up to 2.6 million tons of year of this material for the aluminum and metallurgical industries. Oxbow's biggest facility and primary laboratory and testing facility are located in Port Arthur, Texas, where the Keystone XL pipeline would terminate and where some of the biggest petcoke producing refineries in the world are located.

Oxbow Corporation was the one of the largest corporate donors to Republican Super PACs in the 2012 election, spending $4.25 million dollars.[56] It also has its own PAC which raised nearly $165,000 in the 2012 cycle.[57] Oxbow also spent over $1.3 million on lobbyists in 2012.[58]

William Koch is known for his staunch opposition to the Cape Wind offshore wind farm in Massachusetts where he owns a holiday home, and is said to have donated millions of dollars to the Alliance to Protect Nantucket Sound, a group set up to oppose the project.[59] Koch described the project as "somewhat of an irritant".[60]

The Coker: How Petcoke is Formed in a Refinery

The density of the oil going into a refinery is an indicator of the different intermediary petroleum products that come out. These intermediary products are then processed further to make the petroleum products we are familiar with, such as gasoline and diesel.

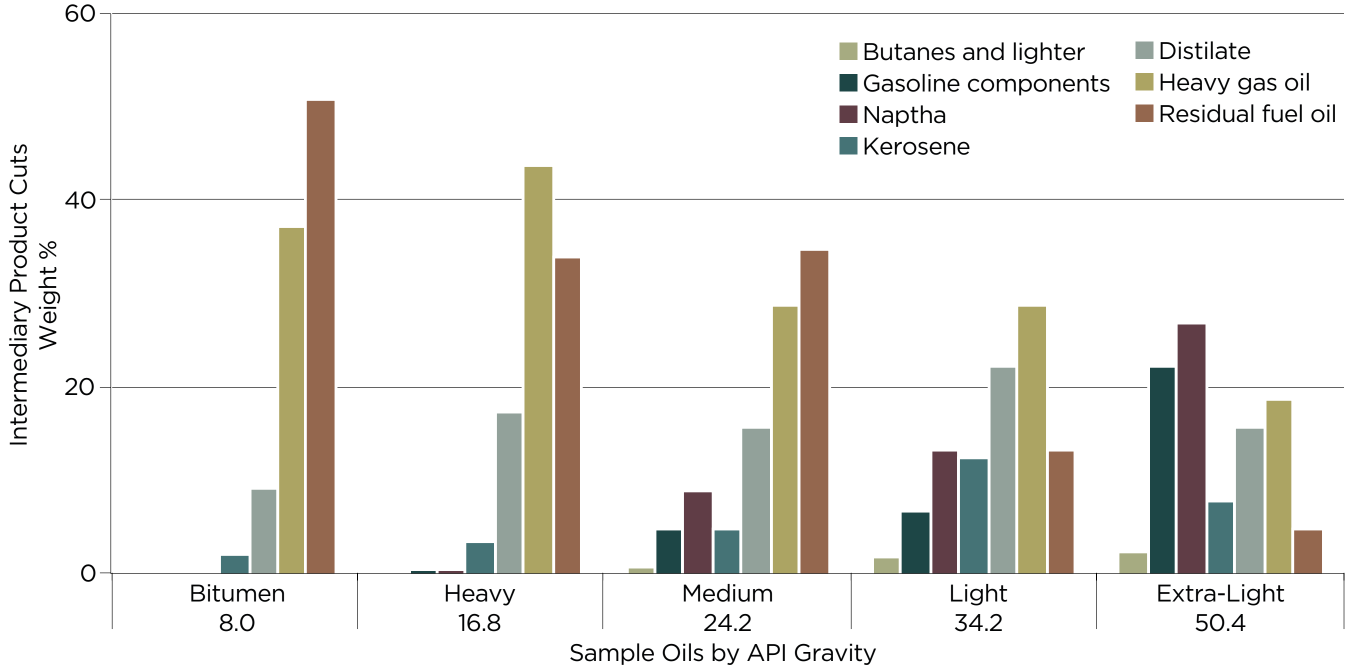
Figure 7 shows how these intermediary product yields differ markedly between oils, from extra-light oil to bitumen.

Light oils yield a more even balance across the spectrum of intermediary products. They contain a higher proportion of light petroleum inputs such as naphtha and gasoline components, with smaller amounts of residual oil. Heavier oils contain far more residual oil and heavy gas oil, and hardly any gasoline components or naphtha. Bitumen is the heaviest in the range and contains very high proportions of residual fuel oil and heavy gas oil.[61] The typical yield of residual fuel oil from a barrel of pure bitumen is 51 percent of the barrel.

Residual fuel oil is not useful to most refiners. It is generally used in shipping and power generation and commonly sells at a discount to crude

56 OpenSecrets Blog, November 5, 2012, *Mystery Firm is Election's Top Corporate Donor at $5.3 Million.* http://www.opensecrets.org/news/2012/11/mystery-firm-is-elections-top-corpo.html
57 http://www.opensecrets.org/pacs/lookup2.php?cycle=2012&strID=C00436550
58 http://www.opensecrets.org/lobby/clientsum.php?id=D000000600&year=2012
59 Patrick Cassidy, Cape Cod Times, November 01, 2012. *Politics shape Cape Wind debate.*
60 Ibid.
61 Deborah Gordon, December 2012.

Figure 7: Typical intermediary product yields from different density oils.[62]



oil and therefore does not yield profit. The refiner's aim is to convert as much as possible of that portion of the barrel into the more profitable petroleum products, gasoline, diesel and jet fuel. This can be done through intensive secondary and tertiary refining processes. Petcoke is a typical result of such extensive processing.

Tweaking the Yields:The Path to Petcoke

While the quality of oil going into the refining process does heavily influence the ratio of different products that come out, refiners can tweak yields to get more of the high value products they desire. One of the most common technologies for processing residues from heavy oils is delayed coking.

The delayed coking unit's job is to convert residues from earlier stages of the refining process into lighter liquids and petcoke. In the initial refining process – atmospheric distillation – about one-half of the original bitumen will be converted to residual fuel oil. This is usually further distilled in a vacuum distillation unit and then transferred to a delayed coking unit.

In the coking process the heavy residue is heated to 900 degree (F) and held in a drum for a period to allow reactions to take place. More light liquid intermediary products are obtained while about 30 percent by volume is deposited on the walls of the coking drum as petcoke. Typically, around 15 percent of the original bitumen ends up as petcoke.[63] Some of America's biggest refineries produce 5000-8000 tons of petcoke every day through delayed coking (see Table 7).

62 From Deborah Gordon,. December 2012, *The Carbon Contained in Global Oils.* Carnegie Endowment for International Peace. These calculations have been drawn from High Temperature Simulated Distillation (HTSD) models, a method that extends the boiling range distribution of hydrocarbons, providing a more accurate assessment of oils that contain high carbon residues.

63 A precise figure depends on the quality and constituents of the original barrel. In the case of blended or diluted bitumen it will be less as the bitumen content in the barrel is less than 100 percent. See Box on Petcoke Production, page 19.

The sustained high temperatures required for coking make it an energy intensive process. But this is not the final stage of processing. The liquids obtained from the coking process require further processing to make the final products we are familiar with.

Further along in the process hydrogen is added for desulfurization and hydrogenation. Hydrogen production is also highly energy intensive requiring temperatures between 1,300 and 1,800 degrees (F). So in order to convert the high proportion of heavy, low quality residues in a barrel of bitumen into high value liquid fuels, vast amounts of energy are expended in a complex, multistage process. Even so, 15 percent of the barrel commonly remains as this solid high carbon byproduct, petcoke.

The delayed coking unit at Total's Port Arthur, Texas refinery. The drums are emptied of petcoke daily into the pit below.

Delayed coking is the most common way to optimize the yield of high value, light liquids for transport fuels. However, it is possible to both maximize and eliminate petcoke yield, although elimination carries with it significant energy and emissions costs.

Maximization of Petcoke Yield

One project in Canada currently gets double the yield of petcoke from its tar sands bitumen compared to the average coking operation. The 30 percent petcoke yield reported for the Nexen-CNOOC (formerly Opti-Nexen) Long Lake Integrated Oilsands Project gives an indication of how much petcoke is potentially embedded in the tar sands.[64]

The project maximizes its petcoke yield in order to use the petcoke as a fuel to run the project's extraction and processing of tar sands bitumen. It does this by gasifying the petcoke and using the resulting synthetic gas as fuel and the associated hydrogen for hydrogenation of the rest of the bitumen.[65] The upgrader produces a synthetic crude that can be readily refined into gasoline and diesel in simple refineries. Gasification splits petcoke into hydrocarbon fuel and CO_2, which offers the opportunity to capture CO_2 and sequester it away from the atmosphere. But to date this is not happening at Long Lake. It is therefore a highly CO_2 intensive operation.[66]

Eliminating the Petcoke Yield

The Long Lake project shows that if it is desired, the yield of petcoke from bitumen processing can be much higher – 30 percent – than the common delayed coking yield, 15 percent.

However, an additional alternative to coking is to hydrogenate more of the residual fuel oil from the first stage of the process and reduce or eliminate the formation of petcoke. This intensive hydrogenation is carried out at Shell's Scotford Upgrader in Edmonton, Alberta, where Shell upgrades the bitumen from its massive tar sands mines into synthetic crude oil.[67] It is the only upgrader in Alberta that does not produce petcoke.

The hydrogen addition process is not a solution to the carbon burden of bitumen. It simply shifts emissions from the combustion of petcoke to the conversion of heavy residues into lighter liquid hydrocarbons.

64 Data from Alberta Energy Resources Conservation Board (ERCB)Serial Publications ST-39 Alberta Mineable Oil Sands Plant Statistics. 2011. http://www.ercb.ca/data-and-publications/statistical-reports/st39
65 See http://www.nexeninc.com/en/Operations/OilSands/HowLongLakeWorks.aspx
66 See Brandt 2012, page 1257 for a brief discussion of the carbon intensity of this process.
67 http://www.shell.ca/home/content/can-en/aboutshell/our_business_tpkg/business_in_canada/upstream/oil_sands/scotford_upgrader/

A life-cycle analysis of hydrogen production using natural gas, the most common fuel source used by refiners to make hydrogen, found that nearly 12 kilograms (26.4 pounds) of CO_2-eq is emitted for every kilogram of hydrogen produced.[68] The analysis also found that for every megajoule (MJ) of natural gas consumed, 0.66 MJ of hydrogen is produced. In other words, there is a net energy loss incurred by converting natural gas into hydrogen.[69]

It is clear that there is a high energy and emissions penalty associated with the intensive hydrogenation at Shell's Scotford upgrader. It is therefore no surprise that Shell is receiving a CAD$865 million subsidy from the Albertan and Canadian federal governments to build a carbon capture and storage (CCS) project at the plant.[70] This aims to sequester 1 million tons of CO_2 per year, just 35 percent of the plant's emissions.[71] If successful it will also enjoy a double credit offered by the Albertan government on the CAD$15 per ton carbon price in the province, thus adding a potential CAD$30 million a year to the subsidy.[72]

The success of the CCS project remains to be seen but given the level of subsidy, it is clearly not an economically viable option under current market conditions.

The Bitumen Refining Subsidy

The high energy penalty incurred by these complex processes of converting a semi-solid hydrocarbon into light liquids – through delayed coking, hydrogenation and other tertiary processes – is typically subsidized by other means.

In the United States today, the financial cost of the intensive inputs into this process are eased by low natural gas prices and the discounted price of low quality tar sands bitumen from Canada. Additionally, there simply is no cost currently associated with the high level of CO_2 emissions resulting from these additional refining processes.

There is a CAD$15 carbon price in Alberta but it is only levied on excess emissions above a company's target. The Pembina Institute calculated that this is worth 18 cents on a barrel of oil produced in Alberta.[73] This level of pricing is too insignificant to have any material effect on any tar sands producer's strategy.

It is clear that by not adequately paying for the CO_2 emitted in this process, bitumen and heavy oil refiners are receiving a substantial subsidy. This is a subsidy that is increasingly being paid by the millions of Americans, and people all over the world, whose lives are impacted by climate change.

68 Pamela L. Spath and Margaret K. Mann, U.S. Department of Energy, National Renewable Energy Laboratory. February 2001. *Life Cycle Assessment of Hydrogen Production via Natural Gas Steam Reforming.*
69 Ibid.
70 Petroleum Economist, 12 July, 2011. *Shell Quest CCS advances with government investment.*
71 Clifford Kraus, New York Times, September 5, 2012. *Shell to Test Capturing Carbon in Canada.*
72 21st Century Tech. *Energy Update: Carbon Sequestration and the Oil Sands.* http://www.21stcentech.com/energy-update-carbon-sequestration-oil-sands/
73 The Pembina Institute, May 6, 2010. *False claims highlight Alberta's inadequate GHG regulations.* http://www.pembina.org/media-release/2014

USING PETCOKE AS FUEL

The use of petcoke as fuel has historically been concentrated in the cement and lime industries. Cement production requires high temperatures and the high energy content and cheap price of petcoke is attractive to this highly energy intensive industry.

However, as the processing of bitumen and heavy oil has increased in recent years, particularly in U.S. refineries, the availability of petcoke has exceeded the demand from these industries. The availability of petcoke to the power generation sector and other energy intensive industries emerged as a significant market trend only within the last decade. This trend is placing onto the market an alternative fuel that emits more CO_2 than any fuel on the market, and in a sector that has low carbon choices available.

A fundamental question is whether the increasing role of petcoke co-firing[74] in coal-fired electricity plants significantly improves the economics of coal-fired generation in the markets that have access to it. A related question is whether by making coal-fired generation cheaper, will increasing quantities of petcoke in the market help keep struggling coal plants open when they would otherwise shut? If petcoke co-firing makes coal-fired generation more viable and more carbon intensive, then the GHG footprint of tar sands is even greater than current estimates indicate.

Petcoke as Fuel: Many Disadvantages – One Overwhelming Advantage

There are a number of disadvantages associated with using petcoke as a fuel. In particular it is low in volatile compounds, which makes it challenging to ignite. It is therefore often blended with coal so that the burning coal ignites the petcoke and keeps it burning.

Another disadvantage is its hardness. Like coal, petcoke needs to be ground in to small particles before it is burned. However, petcoke is much harder than coal, and therefore difficult to grind. Grinding petcoke can decrease the life of grinding equipment and may require specialized equipment.

As well as significantly higher CO_2 emissions, petcoke has high sulfur and metals content. This raises the already high toxic emissions associated with burning coal.

But set against these disadvantages is one major advantage for plant operators: price. As a byproduct of refining, petcoke is "*priced to move*".[75] Refiners cannot store vast quantities of this bulky refinery waste and

74 The burning of petcoke and coal together.
75 "*Decisions about production levels are not made based on the markets for petroleum coke, as it is a waste product it is "priced to move" rather than store.*" From PR Newswire, August 16, 2012 http://s.tt/1l0Lu

therefore have an incentive to sell it cheap. The vast majority of the profits from refining oil are derived from the main liquid transport fuels such as gasoline, diesel and jet fuel.

Petcoke sells at a discount to coal although the price varies greatly according to sulfur content and hardness. An industry analyst told us that, "*the utilities determine their fuel choice, such as the competition between coal and petcoke, on a per-million-Btu basis. Petcoke pricing usually tracks behind coal, often rising when coal rises.*"[76]

So while petcoke prices might be higher than some coal grades on a per-ton basis, the higher energy value means that there are significant savings to be made for customers. An executive from French cement giant LaFarge told a conference in May 2012 that, "*Coal is capping petcoke, which is discounted on average 25 percent below coal price.*"[77]

New U.S. petcoke capacity scheduled to come on-stream in the coming months is expected to lower petcoke prices significantly and is being greatly anticipated by some buyers. The giant Motiva refinery in Port Arthur, Texas recently completed a 5-year, $10 billion dollar project to expand capacity to 600,000 barrels per day (b/d) and become America's biggest refinery. In the process it added over 90,000 b/d of delayed coking capacity raising its petcoke production from 3000 tons per day to over 8,600. The new equipment was started up in May this year but was shut down in early June following a vapor leak that destroyed the new crude distillation unit.[78] Restart is expected at the end of 2012 or in early 2013.

A petcoke buyer interviewed for the industry journal *Petcoke Report* was clearly keen for Motiva to get back online believing that the refinery's production will place significant downward pressure on petcoke prices.

"*If (Motiva Port Arthur) comes on in December, great. The sooner the better. I hope it comes online and starts flooding the market with a lot of petcoke to drive the prices down more. (...) Motiva will have an impact on pricing in the Gulf because you will have 2.5 million tons of added production coming out of there on top of their 700,000 tons. It will definitely have an impact. When that happens, petcoke will become very attractive. You could see a $10 drop by April. They will be making about 266,000 tons of petcoke a month. That's got to go somewhere, and it has to go ratably somewhere.*"[79]

As Table 7 shows, two refineries in the Midwest are also poised to bring on substantial new petcoke capacity in the coming months indicating that petcoke pricing is about to get significantly more attractive to buyers than it already is. In all, 11,220 tons per day of new petcoke capacity is to be added in the U.S. by mid-2013. That is over 4 million tons a year.

76 Personal communication
77 Argus Media, May 16, 2012. *Asia-Pacific demand to boost global petcoke production.*
78 Lorne Stockman, Oil Change International, August 09, 2012, *A big mess at Motiva and why Gulf Coast refiners are making a killing.* http://priceofoil.org/?p=11871
79 Energy Publishing, LLC's Domestic and International Petcoke Report, October 2012. *Port Arthur output might hit market in December.* Subscription Only.

Cheap Petcoke Means Big Savings for Coal Plants

Petcoke pricing creates significant advantages for coal plants that are able to co-fire the fuel to supplement their coal supply. A typical blend is 20-30 percent petcoke to 70-80 percent coal.

A power plant co-firing petcoke with coal can cut its fuel costs by over 35 percent compared to firing coal alone. In one example, presented by analysts at Roskill Consulting (see Table 8), a typical 1000 MW coal plant using a petcoke/coal blend saves around US$120 million a year in fuel costs.

Table 8: The economics of blending petcoke with coal.

	Existing Plant	Petcoke/coal blend refueled plant
Fuel type	**Coal**	**Petcoke blended with coal**
Gross Power Output	1,000 MW	1,000 MW
Fuel price (US$/GJ)	US$6.33	US$3.69
Fuel cost (US$mill./yr)	US$376 million/year	US$236 million/year
Total cost of power	US$152/MWh	US$133/MWh
Savings	-	US$120 million/year

Source: Roskill Consulting. Using 2011 US$ prices Note: Actual economics are plant dependent.

New Petcoke Supply in the Midwest Could Help Sustain Struggling Coal Plants

The decline of coal-fired generation is an emerging trend in U.S. energy. The abundance of natural gas afforded by the shale gas boom has resulted in natural gas prices declining from over $9 per million Btu in 2008 to around $3 in recent months.[80] It is generally considered that continued slow economic growth and an ongoing surplus of natural gas will keep prices low for some time to come.[81]

As a result, coal-fired generation in the U.S. has declined from 49 percent of generation in 2007 to 32 percent in April 2012; although it bounced back to 39 percent in August.[82] Around 41GW of U.S. coal-fired generating capacity has been scheduled for retirement in the coming years, nearly 4 percent of total U.S. generation in 2009.[83] These plants are some of America's oldest and dirtiest.

The Union of Concerned Scientists (UCS) recently calculated that another 59GW of coal-fired capacity could be retired using economic criteria that suggests that the plants will be uncompetitive with cleaner and more

80 See 'Electric Power Price' at EIA Natural Gas Prices. http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm annual data and http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm for monthly data.
81 See EIA forecast data here: http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2011&subject=0-AEO2011&table=78-AEO2011&region=0-0&cases=ref2011-d020911a
82 http://www.eia.gov/todayinenergy/detail.cfm?id=8450
83 Union of Concerned Scientists, November 2012. *Ripe for Retirement: The Case for Closing America's Costliest Coal Plants.*

Mining bitumen at the Syncrude Aurora tar sands mine, Alberta, Canada.

affordable energy sources.[84] But could rising production of cheap petcoke help to keep some of these struggling coal plants alive, prolonging the life of some of America's dirtiest power plants?

Some of the plants on the UCS retirement list are already co-firing petcoke.[85] But the addition of over 2 million tons per year of petcoke capacity in the Midwest on top of recent additions (see Table 7) is driving a lot of speculation as to where the fuel may go and who will benefit.

Marathon's Detroit refinery began production in November 2012 following a major refit specifically designed to process Canadian tar sands bitumen. The 1,720 tons of petcoke per day (600,000 tons per year) it is expected to yield is being eyed by one of the Midwest's biggest coal plants, Detroit Edison's 3.2GW Monroe Plant in Michigan. Tests are currently underway to see how much petcoke can be blended at the plant.[86]

However, it is the prospect of over 2 million tons of petcoke per year from the BP Whiting refinery in Indiana that is really causing a stir. By mid-2013 this refinery will become one the country's biggest petcoke suppliers when it finishes constructing the second largest coker in the world along with other equipment that is part of its four billion dollar refit designed specifically to process tar sands bitumen.[87]

According to industry sources, the quality of the petcoke that will be produced by the new equipment at Whiting will be very different to that which it has produced to date.[88] The current production is less hard, has lower sulfur content and has primarily been marketed to the steel industry. The new production, being primarily derived from high sulfur tar sands bitumen, will be both harder and higher sulfur and will not suit steel making. There is speculation that the product from Whiting will also be too hard for the cement industry and therefore will likely all be marketed as fuel for coal-fired power plants. NIPSCO (Northern Indiana Public Service Company) has been mentioned as a likely bidder.[89] NIPSCO has one coal plant scheduled for retirement and one on the UCS 'Ripe for Retirement list'.[90]

Co-firing a blend of just 20 to 30 percent petcoke can bring substantial cost savings to struggling coal plants (see Table 8). In the Midwest, petcoke production capacity will grow from 10.1 million tons per year prior to November 2012 to 12.9 million tons by mid-2013, a 28 percent increase.[91] While it is currently unclear where all the new petcoke that will be produced in the Midwest will go, it seems unlikely that some of the region's struggling coal-fired power plants will not take advantage of the cheap dirty fuel that is increasingly available to them.

84 Ibid.
85 According to EIA Form 860 data for 2011. 3 plants on the UCS list in Michigan, Wisconsin and Florida co-fired petcoke in 2011.
86 Energy Publishing, LLC's Domestic and International Petcoke Report, November 2012. *New petcoke output from Motiva expected to hit market soon.* Subscription Only.
87 Reuters, July 31, 2012. *Update 1-BP Whiting crude unit to come offline as part of upgrade.* http://www.reuters.com/article/2012/07/31/refinery-operations-bp-idUSL2E8IVG8H20120731
88 Energy Publishing, LLC's Domestic and International Petcoke Report, November 2012. *New petcoke output from Motiva expected to hit market soon.* Subscription Only.
89 Ibid.
90 See Appendix E in Union of Concerned Scientists, November 2012. NIPSCO is listed under its parent company name NiSource Inc.
91 Includes all refineries in 15 Midwestern states classified by the EIA as PADD 2.

New Petcoke Power Plants: The Las Brisas (Petcoke) Energy Center

The anticipated increase in U.S. petcoke production and the expectation of a stable and cheap supply of this high carbon fuel has also led to proposals to build power generation plants in the U.S. specifically designed to burn petcoke. These efforts, however, have been met with some challenges. One such plant in Corpus Christi, Texas, The Las Brisas Energy Center, has met with substantial community opposition and recently had its air permit rescinded by a district court judge who found that the Texas Commission on Environmental Quality failed to require the company to perform an analysis of the proposed plant's toxic air emissions.[92]

It would appear that the company trying to build the plant, Chase Power Development LLC, together with its political supporters, was calculating that the relative obscurity of petcoke as a power generation fuel may exempt it from regulations faced by coal generators. Four Texan House Republicans, hoping to take advantage of this obscurity, wrote to the EPA challenging the inclusion of petcoke-fired utilities in the agency's new greenhouse gas rule for power plants.[93]

The GOP representatives, Ralph Hall, Lamar Smith, Randy Neugebauer and Michael McCaul, have between them taken over $2 million in campaign contributions from the fossil fuel industry.[94] They argue that because petcoke is produced as a byproduct of the refining process its emissions are "minimal" on a life-cycle basis.

This is a remarkable claim given that petcoke produces more GHGs per unit of energy produced than coal and, although a byproduct is still linked to high impact tar sands extraction. Further, as there have apparently not yet been any studies of the life-cycle impact of petcoke, it is unclear how the representatives have come to the conclusion that the environmental impacts of petcoke are minimal.

Petcoke, though a byproduct, generates tens of millions of dollars in annual profits for the refineries that produce it, so it represents a significant part of the economic incentive for investing in delayed cokers and processing tar sands bitumen.[95] As the bitumen produced from the tar sands can only be refined in specially equipped refineries, it is refinery demand that drives tar sands extraction, rather than direct consumer demand. If profits from petcoke sales form a part of the economic calculus that leads a refinery to invest in cokers and seek tar sands bitumen feedstock, then petcoke cannot be entirely free of association with the impacts of tar sands production. Not to mention the impact its cheaper price may have on the viability coal-fired power generation.

92 Argus Petroleum Coke August 2012. Also see: http://sierraclub.typepad.com/compass/2012/07/las-brisis.html
93 Clean Air Report. 30 August, 2012. *Texas GOP Lawmakers Query EPA Plan To Include Petcoke In Climate NSPS* Vol. 23, No. 18.
94 See: http://dirtyenergymoney.org/
95 See slide 19 in this presentation by Petcoke traders Marsulex: http://www.coking.com/SeminarCanada/PresentationPDFs2010/Marsulex_DonBoonstra_Sulphur&PetroleumCokeMarkets_Coking-SulfurUnitCom_Sep2010.pdf

MEASURING THE IMPACT OF PETCOKE

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Suncor Millennium tar sands mine and tailings pond, Alberta, Canada.

If proponents of the Las Brisas Energy Center argue that even though petcoke emits more CO_2 than coal and is heavily laden with sulfur and heavy metals its emissions are "minimal", there is clearly a need to shine a spotlight on the petcoke trade.

The claim seems to be based on two main ideas. Firstly, that as petcoke is a byproduct of the production of other dirty fuels, i.e. gasoline and diesel, its production emissions are zero. Secondly, it is often assumed that petcoke simply replaces coal that would otherwise be consumed so the emissions from burning it are also assumed to be zero.

We have discussed how the cheaper price of petcoke can save coal-fired power generators millions of dollars annually. This may prolong the operating life of some coal plants. We have also discussed how petcoke emits 5 to 10 percent more CO_2 than coal per unit of energy produced, which on its own should suggest that petcoke substitution for coal is not a one-for-one exchange from a climate perspective.

It is also clear from the reserves figures presented in Table 3 that the available bitumen resource is very large and that producing and consuming it, including the petcoke that would be produced from it, would be catastrophic for the climate.

There is an urgent need to understand the full impacts of producing and consuming tar sands bitumen as to date, despite significant research and analysis, we still do not have the full picture. This is especially so when the industry appears on the brink of major expansions in production (See Figure 2).

Life-cycle Analysis

Stanford energy economist Adam Brandt has been studying the GHG emissions of tar sands production for many years and has published numerous papers examining the Life Cycle emissions of fossil fuels.[96] Life-Cycle Analysis or Assessment (LCA) studies the environmental impacts of a product from raw material extraction through processing and manufacture to consumption and waste disposal. With tar sands it has been common to examine a unit of gasoline or diesel produced from tar sands bitumen and compare it to the same fuel derived from other sources of oil. This analysis includes the emissions from burning the fuel in an engine and is often known as a well-to-wheels analysis.

The increase in well-to-wheel GHG emissions between fuel produced from tar sands bitumen and conventional oil varies widely between studies within a range of about 14 percent to 37 percent.[97]

Brandt's most recent paper on the issue, discusses the wide variability of results in numerous studies of the life-cycle impacts of tar sands.[98] The variability is partly due to the variety of processes used to extract and process tar sands. But it is also due to the differing models used in the studies.

Some of these models tend to differ according to the desired result. For example, a study commissioned by the Albertan government from industry consultants only studied specific projects rather than attempting to assess an average for the sector, and the projects studied were those that were most efficient and thus had lower emissions.[99]

Another major difference between studies is where the system boundaries were placed in the model. For example, some studies attempt to factor in emissions from land use changes while others do not. Some include the production emissions associated with the natural gas used to fuel tar sands extraction while others do not.

Brandt points out that none of the studies adequately address the question of byproducts, or "coproduction".

Numerous coproduction issues arise that are not incorporated consistently in current studies. For example, the treatment of coproduced coke is a complex issue. (...) If bitumen is shipped to refineries as dilbit, this will result in coke generation near existing fuels markets, which could result in more coke being consumed, offsetting some coal consumption. Calculating

96 See Brandt's publications going back to 2006 here: https://pangea.stanford.edu/researchgroups/eao/publications
97 Natural Resources Defense Council, May 2010. *GHG Emissions Factors for High Carbon Intensity Crude Oils*.
98 Adam R. Brandt, 2011. *Variability and Uncertainty in Life Cycle Assessment Models for Greenhouse Gas Emissions from Canadian Oil Sands Production*. In *Environmental Science & Technology* 2012, 46, 1253-1261.
99 See the discussion of TIAX results in Brandt 2011.

the magnitude of credit or debit associated with such coproduction and displacement is nontrivial and requires understanding of the markets for solid fuels.[100]

He points out that the supply of petcoke entering the market will clearly lead to more petcoke consumption than would otherwise take place but notes that this could offset some coal consumption. However, he also notes that it is far from clear that this is a one-to-one displacement. He goes on to note that, "(t)*he interaction of markets in LCA (as addressed in "consequential LCA") is not studied in detail in any of the above models.*"[101]

Conducting a 'consequential life-cycle analysis' of tar sands production that includes all the impacts and market effects of bringing this huge resource to market has never been done, but if it were it would require a careful study of the impact on coal markets of the associated production of petcoke.

The most recent study to be published on tar sands GHG emissions states that net emissions associated with petcoke are "negligible", "(b)*ecause the coke is simply displacing coal that would otherwise have been burned in power generation*".[102]

This is an assumption that must be challenged by examining the impact of increasing petcoke production on coal markets in far more detail than it has to date. The emissions from petcoke are not zero but are in fact substantial. They must be counted when counting the emissions from combusting bitumen or crude oils that yield petcoke. Dismissing petcoke emissions as zero means that the emissions from oil production and consumption are being consistently undercounted.

More Supply, Lower Prices, More Consumption

While the petcoke trade is relatively small compared to coal, the issue that needs to be carefully studied is what effect the discounted price of petcoke has on the price of coal and whether the large savings associated with co-firing petcoke enable coal-fired generation to remain competitive against low carbon fuels that are gaining a foothold in the market.

From January 2011 to September 2012, the United States exported over 8.6 million tons of petcoke to China,[103] most of which was likely burnt in coal-fired power plants. Petcoke sells at a significant discount to coal, which is the primary reason Chinese coal plant operators are increasingly using it.[104] So what affect might this have on Chinese coal consumption and its related emissions? Is the cheap petcoke really just replacing coal that would anyway have been consumed in those plants?

100 Brandt 2011, page 1259.
101 Brandt 2011, Op. Cit. page 1260.
102 IHS CERA 2012. *Oil Sands, Greenhouse Gases, and US Oil Supply. Getting the Numbers right – 2012 Update*.
103 EIA, U.S. Exports to China of Petroleum Coke. http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCKEXCH1&f=M Divide barrels by 5 to get short tons.
104 See 'Using Petcoke as a Fuel' section.

A recent White Paper by resource economist Thomas Power studied the likely impact of proposed coal exports to China from the U.S. Northwest.[105] The paper cites studies that show that China's coal consumption is highly sensitive to price and that a 10 percent reduction in coal cost results in a 12 percent increase in coal consumption.

He also noted that, "*lower coal prices reduce the incentives to retire older, inefficient, coal-using production processes and discourage additional investments in the energy efficiency of new and existing coal-using enterprises*."

Lower prices can also lead to further investment in coal burning facilities which locks in coal demand for decades to come.

And finally, he points out that Chinese government policy has been very responsive to rising energy prices. Therefore, cheaper coal or petcoke is likely to undermine efficiency drives in the country.

While an in depth consequential life-cycle analysis of tar sands production may enable us to make more precise estimations of the greenhouse gas impact of opening up this vast resource, it seems clear the impact is subject to the basic laws of economics. More supply lowers prices, increases demand and competes with cleaner alternatives that are fighting to achieve the economics of scale.

In addition, we must not forget that even if petcoke did replace coal consumption one-to-one and did not represent an increase in coal demand, which seems unlikely, its emissions are five to ten percent higher on a unit of energy basis. Petcoke is making coal-fired power generation more carbon intensive and cheaper at exactly the time that we urgently need low carbon solutions to energy production.

The United States produced over 60 million tons of petcoke in 2011 and production is set to rise as more cokers come on stream in the coming months. The global petcoke trade is forecast to grow by 4 percent per annum to 2016, reaching 192 million tons (175 million metric tons) per annum in that year.[106]

Petcoke derived from tar sands bitumen is clearly a significant new source of high-carbon fuel entering a market that is already over supplied from a climate limits perspective. Its impact on climate change cannot be dismissed and must surely be included in any climate impact analysis of the tar sands.

105 Dr. Thomas M. Power 2011. *The Greenhouse Gas Impact of Exporting Coal from the West Coast: An Economic Analysis*.
106 Roskill Consulting. http://www.roskill.com/reports/industrial-minerals/petroleum-coke

CONCLUSION

Increasing petcoke consumption is an inevitable result of the increasing production of tar sands bitumen. But petcoke is a little discussed yet highly important aspect of the full impacts of tar sands production. Petcoke emissions are significant and cheap petcoke dumped on the market could constitute a crutch for a declining coal-fired power industry.

Without greater recognition of the role of petcoke in the global energy mix, we risk underestimating the impacts of the emerging transition to heavier oil and tar sands bitumen in the oil market.

Assessments of the impacts of tar sands production, including those of tar sands transportation infrastructure such as pipelines, should include an assessment of petcoke production and consumption.

Additionally, there is an urgent need to consider not only the greenhouse gas intensity of tar sands production in terms of the production processes, but the cumulative emissions of producing, processing and consuming all the products derived from exploiting this vast resource.

Considering tar sands emissions in their entirety must surely lead to the conclusion that we cannot possibly exploit all the recoverable tar sands bitumen. This in turn should highlight the urgent need for society to grapple with one of the most crucial and challenging questions of our time: Which fossil fuels should we leave in the ground and how do we manage the process?


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