Report on 'Tar Sand', history, processing and development

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Introduction - by Stuart Agnew

I have commissioned this report on the mining, processing and trade features of Tar Sands as a result of constituent interest and to try and counter a rather hysterical and emotive poster/leaflet campaign, doing the rounds of the European Parliament at the moment, with a factual and objective report.

The report is split into two parts. The first deals with the technical side of the process, but deliberately avoids industry jargon and obscure technical terms in order to inform a wider readership.

The second part of the report deals with the CETA trading agreement between the EU and Canada which is about to be concluded and involves the issue of oil from Tar Sands.

PART 1 – Tar Sands

History

The use of bitumen (also known as asphalt or tar although strictly speaking tar is purely man made), dates back to Palaeolithic times. In Europe, since time immemorial wild boar knew that the best way to get rid of their vermin was to wallow in the oily puddles of the forests of northern Alsace, near Pechelbronn. They were, no doubt, the first users of the oil, followed by man who, for centuries, made use of the oily slick floating on the surface of the Pechelbronn spring to lubricate cart wheels and to cure tooth ache, gout and wounds. Later the deposits were extensively mined and the vapour separation process was in use as early as 1742.

Some 40,000 years ago in sites in Syria bitumen was found adhering to stone tools used by Neanderthals. Later it was used for the construction of buildings and water proofing of reed boats, among other uses. In ancient Egypt, the use of bitumen was important in sealing the bandages of Egyptian mummies.

Bitumen was also found in Mesopotamia and used by the Sumerians and Babylonians, although it was also found in the Levant and Persia. Along the Tigris and Euphrates rivers, the area was littered with hundreds of pure bitumen seepages. The Mesopotamians used the bitumen for waterproofing boats and buildings and they used it to hold heads on arrows and spears and for some structural works.

In North America, the early European fur traders found Canadian First Nations using bitumen from the vast Athabasca oil sands to waterproof their birch bark canoes.

In Canada, Tar Sands first became known publicly in the late 18th century, when fur traders spotted heavy oil seeping from riverbanks.

The widespread use of Tar Sand to oil started with the development of the separation technique in the 1920s by Dr. Karl Clark. In 1936 Max Ball produced diesel oil from it. Commercial production started in 1963 when the Sun oil company (Suncor), started the construction of the first commercial Tar Sand production plant. The first barrel of commercial oil from open pit mining was produced in 1967 but the more complicated in situ techniques only began production in 1985.

Preamble

Tar Sands (also referred to as Oil Sands) are a combination of Kerogen, clay, sand, water, and Bitumen, a heavy black oil in a semi-solid or solid form. They differ from Shale in their origin although both can contain Kerogen. It is a mixture of organic compounds that make up part of the matter in sedimentary rocks that has not yet been turned into lighter oil by geological processes. The soluble component in Kerogen is known as Bitumen and this after mining can be extracted and then refined into oil. With an average composition of 83.3 percent carbon and 10.5 percent hydrogen, Bitumen is too thick in its natural state and cannot be pumped from the ground because its viscosity is so high; its API generally less than 10 and viscosity higher than 10,000 Centipoises, (*As a comparison, conventional crude oil has an API gravity of about 30-40, and a viscosity of 5 Centipoises*). Because of this Tar Sand deposits are both mined and processed afterwards, or the Bitumen is extracted directly by underground heating together with additional upgrading.

Only Canada produces a large quantity of oil from Tar Sand, although a small amount is produced commercially in Venezuela. The main Canadian tar sand deposits and its mining, takes place in and around Alberta. Canada produces more than one million U.S. Barrels of synthetic oil a day from these facilities. Currently, Tar Sand provides about two-fifths of Canada's oil and production is on an upward curve. About one-fifth of U.S. crude oil and products come from Canada; mainly from Tar Sand. The limiting factors to growth in production are likely to be not a shortage of Tar Sand but of the associated hydrogen, water requirements and environmental impacts. It is likely to be a rate limited, rather than a resource limited, process for some time.

Canadian Tar Sand is different from U.S. Tar Sand in that in Canada they are found in the presence of water, while U.S Tar Sands are found with hydrocarbons. As a result of this difference, extraction techniques for the Tar Sand in Utah will be different than those developed in Alberta.

Much of the world's oil (more than two trillion U.S. Barrels) is in the form of Tar Sand, although it is not all recoverable. While Tar Sands are found in many places worldwide, the largest deposits in the world are found in Canada (Alberta) and Venezuela, and much of the rest is found in various countries in the Middle East. More than three-quarters of known Tar Sands (not including Shale deposits) are located deeper than 70-80m below the surface**,** the remainder being found above this level.

In Europe public concern came about in part due to the imminent conclusion (2011) of the negotiations between the European Union and Canada on CETA (Comprehensive Economic and Trade Agreement), which would allow**,** via free trade aspects of the agreement, the export from Canada of crude oil or petroleum products based on Tar Sand, (see Part 2 of this report), and the associated pollution resulting from the extraction processes.

Production general

'Tar Sand' can be extracted in two ways: open-pit mining or strip mining for Tar Sands down to 60 – 70 m below the surface, which is then processed to extract useful oil feedstock, as opposed to 'in situ' techniques to recover Bitumen from Tar Sand whilst still underground. About two U.S. tons of Tar Sand are required to produce one U.S. Barrel of oil (about one-eighth of a U.S. ton), and both mining and in situ operations use between 2 and 4.5 U.S. Barrels of water for the extraction of one U.S. Barrel of Bitumen**.**

The product produced by the mining and processing of Tar Sand is sometimes called Syncrude generically, although that is also the name of a company that produces the product.

Surface mining

There is one operational Canadian mine, which excavates the Tar Sands by opencast mining techniques. After excavating, the extracted material is treated above ground, first in a separation plant and then in an "upgrader" plant. The first step in this treatment cycle is the sizing process, where the biggest pieces are broken into smaller ones by a crusher. Then the Bitumen is separated from the water, sands and clays by a water-based process.

The next phase is either to chemically upgrade the Bitumen to 30^{o} API oil, which has a quality comparable to conventional crude oil, or to dilute it with conventional oil to achieve the same gravity. In both cases**,** the resulting feedstock's can be processed at existing refineries.

Underground mining

The in situ techniques that can currently be used for extracting Tar Sands are:

- Cold Heavy Oil Production on Site (CHOPS)
- Steam Assistance Gravity Drainage (SAGD).
- Cyclic Steam Stimulation (CSS).
- Toe-to-Heel Air Injection (THAI).

The **CHOPS** process does not filter out the sands at the production wells, but instead pumps the sand fraction up along with the Bitumen and water. It is commonly used for extra-heavy oil production.

The **SAGD** technique uses two horizontal wells. Steam is injected in the upper well to heat the Tar Sands and lower the viscosity of the Bitumen, and the lower well is for pumping out the Bitumen. A solvent is included in the steam to assist in the viscosity reduction.

The **CSS** technique uses a horizontal or a vertical drill to inject steam into the Tar Sand. This heats the Bitumen and reduces its viscosity but can take several weeks to do so. The liquidized Bitumen can then be pumped up to the surface.

The **THAI** technique is a combustion process which uses a vertical air injection well and a horizontal production well. A small part of the Bitumen is burned with the inserted air so that the remaining Bitumen will warm up and attain a lower viscosity. The fluidized Bitumen then flows down to a collecting pool and is extracted by the production well.

Future Greener Production Technology

Scientists at Pennsylvania State University have designed an environmentally friendly way of extracting oil from Tar Sand: the method uses ionic liquids to separate heavy, viscous oil from the sand. The new technique uses very little energy and water, instead it uses ionic liquids -- salt in a liquid state -- that can be recycled. The separation takes place at room temperature without the generation of waste process water or use of heat. Most of the Bitumen is recovered in a clean form, without contamination from the ionic liquids because the Bitumen, solvents and sand/clay mixture separate into three distinct phases, which can be removed separately. This technique is not yet in large scale production.

Bitumen Separation

The separation takes place in separation cells. Hot water is added to the sand, and the resulting slurry is piped to the extraction plant where it is agitated. The combination of hot water and agitation releases bitumen from the oil sand, and causes tiny air bubbles to attach to the bitumen droplets, that float to the top of the separation vessel, where the bitumen can be skimmed off.

Further processing removes residual water and solids. The bitumen is then transported by road tanker or by pipeline and eventually upgraded into synthetic crude oil. An issue can be the durability of the tank/pipeline as diluted bitumen has high concentrations of chloride salts which can lead to chloride stress corrosion in high pressure pipelines and sulphur also contributes to corrosion through a process called sulphide stress corrosion cracking. Diluted bitumen can contain more than15 time’s higher acid concentrations than conventional crude oil. Refiners have also found it to contain residual abrasive quartz sand particles and alumina-silicates.

Higher temperatures, such as those found in the high pressure diluted bitumen pipelines increase the speed at which acids and other chemicals corrode the pipeline.

From the above information it can be seen that the life span and maintenance of the transportation systems is a significant feature of Tar Sands production economics and safety.

Bitumen Processing

Upgrading must be done to produce a useable product, which typically consists of two steps. The primary upgrading is based largely on “coking” and “catalytic” processes.

The primary process will crack the heavy Bitumen into lighter products, but the process will leave a significant amount of sulphur and nitrogen compounds in the lighter products and a secondary process is needed.

The secondary upgrading process is based on hydro processing by one or more hydro processing units; this in simple terms is done by introducing hydrogen into the feedstock before it goes over the catalyst.

These processes are calibrated to reduce the ‘gravity’ to about 30^{o} API. (About 1.16 U.S. Barrels of Bitumen and 28 cubic metres of natural gas are necessary to produce 1 U.S. Barrel of syncrude by this method.). The average production cost of one U.S. Barrel of syncrude from the Tar Sand resources in Canada is approximately 36 USD (2011 figures)**.**

Sulphur and Nitrogen compounds

Sulphur and Nitrogen are natural components in Tar Sands and crude oil. Both Sulphur and nitrogen are removed from oil products by various refinery processes including the Topsше hydro-treating process, (see References)

Sulphur is considered a by product, and is transformed and sold as either elementary sulphur or sulphuric acid in commercial grade Topsше WSA process, (see References). However the market limit seems to have been reached, resulting in large storage requirements for raw Sulphur.

The Ammonia (NH_3) produced is incinerated to produce Nitrogen (N_2) that is released into the atmosphere via a stack.

Environmental/Socio Effects – during production

Both mining and processing of Tar Sand involve a variety of environmental and social impacts, including CO_2 gas emissions, disturbance of mined land; impacts on wildlife, air and water quality together with the use of water and hydrogen. Also an important ecological issue is the degree to which natural gas is required either for process heat or for upgrading the quality and reducing the viscosity of the extracted Bitumen.

In 2002 Canada agreed to reduce their greenhouse gas emissions (GHG) emissions by 6% compared to their 1990 emissions in the Annex I period of the Kyoto protocol (2008 – 2012). By 2004, however, the GHG emissions had already risen by 28% above 1990 levels. In 2006, Canada declared it could not meet their Kyoto targets and even considered removing the policies designed to meet the targets.

The oil sand industry is one of the major GHG emitters in Canada and the entire process approximately doubles to triples the amount of CO_2 released per barrel of petroleum used compared to conventional extraction. The mining process emits about 35 kg CO_2 equivalent/barrel, and the upgrading process 45 kg CO_2 equivalent/barrel, and the SAGD process 55 kg CO_2 equivalent/barrel.

According to the National Energy Board, natural gas use will increase from 0.7 billion cubic feet per day in 2005 to 2.1 billion cubic feet per day in 2015. Although Canada has natural gas resources, this enormous rise in natural gas demand will be difficult to meet. The current capacity of the natural gas infrastructure and production will not be sufficient to keep up with these rises and might present a problem. In addition, the natural gas prices are coupled to the crude oil prices, and so they have risen as well. There is also the issue of where the natural gas will come from. Unless new pipelines are installed there will not be enough natural gas available to match the demand, (One company, Exxon has said that they may not be able to build the necessary pipeline unless they receive significant monetary help from the government).

Both mining and in situ operations use large volumes of water for their extraction process, between 2 and 4.5 volume units of water are used for the extraction of one volume unit bitumen (Canadian National Energy Board 2006). Currently the mining operations are licensed to divert 370 million cubic metres (equivalent to 2.3 million barrels) of fresh water per year from the Athabasca River. The planned mining projects will push the cumulative diversion with 529 million cubic metres (3.3 million barrels) per year (Alberta Environment 2006). Almost all process water ends up in tailing ponds.

Besides the fresh water diversions, the mining operations have a direct effect on the ground water level. Mining pits are excavated up till 70-80m below ground level, which is often below natural ground water levels as well. To prevent water flowing into the mining pit, the groundwater has to be controlled by pumping it up. As a result, the groundwater level of the surrounding area is lowered, and the flows are disturbed.

In Canada the most common in situ technique is SAGD, which uses steam to extract the bitumen. This process requires a large amount of water. Although most in situ projects try to reduce fresh water use by mixing with saline groundwater, and recycling about 90 to 95% of the used water, the amount of diverted fresh water is relatively high. In 2004 the in situ projects used 5 million cubic metres (31.5 million barrels) of fresh water, and this will grow to 13 million cubic metres (81 million barrels) in 2015. (Canadian National Energy Board 2006).

The holes that the mining pits leave behind are so large that they can be seen clearly in satellite pictures from space. The surface areas involved are enormous.

The decline in unemployment, the increase in prosperity, and the independency in liquid energy supply are positive (economical) social effects, although they are also associated with the familiar issues of boom towns associated with alcohol and sometimes family disruptions.

Environmental - in use

Contrary to popular belief**,** fuels derived from Tar Sands can be refined to equal conventional fuels and so create no more pollution than their peers. That is of course up to the refiner's processing techniques.

PART 2 – Canada-European Union: Comprehensive Economic and Trade Agreement (CETA)

Preamble

There is a certain amount of public concern over the possibility of the EU buying syncrude from Canada using the free trade aspects enshrined within CETA: in other words without tariff. The perception is that by using oil from tar sands the EU would be 'buying into' the pollution issues surrounding tar sands production and processing. There is an element of truth in this concern in that one of the 'sticking points' of the negotiation is the issue of pollution improvement protocol.

Currently the EU represents Canada's second largest trading partner in goods and services and according to 'Statistics Canada', the EU is also the second largest source of foreign direct investment (FDI) in Canada, with the stock of FDI amounting to $163.7 billion at the end of 2009. In 2009, the stock of Canada's direct investment in the EU totalled $148.9 billion, and the EU is the destination of 25.1% of Canadian direct investment abroad. According to Eurostat, the EU identified Canada as its third largest destination and its fourth largest source of FDI in 2008.

CETA Status

Canada and the EU have completed the sixth round of negotiations toward a *Comprehensive Economic and Trade Agreement (CETA).* Two further rounds of negotiations have been scheduled for April and July 2011, in Ottawa and Brussels respectively.

CETA negotiation history

On October 16th 2008, Canada and the EU publicly released a *Joint Study on Assessing the Costs and Benefits of a Closer EU-Canada Economic Partnership*. The study shows there are important benefits for both sides to pursuing a closer economic partnership in many commercial sectors. The study also shows potential for enhancing the relationship in areas such as investment, labour mobility, regulatory cooperation, environment, and science and technology.

On March 5th 2009, Canada and the EU publicly released the *Canada-European Union Joint Report: towards a Comprehensive Economic Agreement*. The Joint Report outlines a broad and ambitious negotiating agenda, which includes: trade in goods and services; investment; government procurement; regulatory cooperation; intellectual property; temporary entry of business persons; competition policy and other related matters; labour; and environment.

At the Canada-EU Summit on May 6th 2009, in Prague, Czech Republic, Leaders announced the launch of negotiations toward a Comprehensive Economic and Trade Agreement (CETA). Leaders asked negotiators to conclude the negotiations within two years. Canada and the EU are maintaining fast track negotiations.

Objections to CETA

There are objectors in Europe and in Canada to this agreement. The Europeans believing that Canada's environmental controls are insufficient and the Canadian's believing that CETA is about pushing the interest of private enterprise above that of national governance.

There are valid concerns from in both parties': but the negotiations keep on, largely 'behind closed doors!'

CONCLUSION

The use of Tar Sands to produce fuel grade oils is economically viable, although hardly an ideal approach to maintaining liquid fuel supplies. The most significant problem is the local and global environmental impact of the extraction processes**.**

Tar Sands are unlikely to make a large impact on the overall supply of liquid fuels in Canada because their supply is likely to be rate, rather than resource limited. If the maximum rate could grow to about 2 billion U.S. Barrels a year this would approximately meet Canada's demand but would leave relatively little for export.

About half of the increased production is necessary to compensate for the decline of existing conventional wells. The growth required may not be achieved if ecological constraints cannot be accommodated by technological development in the Tar Sand processing phase.

The developments at 'Penn State' may prove critical if the process licensing requirements are not too draconian.

In perspective the local ecological issues are manageable if correctly controlled by contract and license. The emission of CO_2 is another matter and the significance of its release is still open to debate scientifically, based on temperature and CO_2 curve comparisons going back several centuries. Even the most ardent of 'anthropomorphic global warming' believers has to admit that the big unknowns are water vapour and its relationship to CO_2 release. So should Canada or any other country for that matter, base its critical future decisions on un-proven science? Perhaps not until there is a genuine consensus throughout the scientific community and the carbon moguls are recognised for what they are – traders not scientists.

References

http://www.lloydminsterheavyoil.com/upgraddecoke.htm

http://en.wikipedia.org/wiki/Oil_sands

http://www.theoildrum.com/node/3839

http://ostseis.anl.gov/guide/tarsands/index.cfm

http://ostseis.anl.gov/guide/tarsands/index.cfm

www.hubbertpeak.com/laherrere/OilShaleReview200509.pdf

http://pubs.acs.org/doi/pdf/10.1021/ef9009586

http://www.environment.alberta.ca/documents/Oil_Sands_Opportunity_Balance.pdf

http://archaeology.about.com/od/bcthroughbl/qt/bitumen.htm

http://www.musee-du-petrole.com/page14.htm - select English version

http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyvrvw/cndnnrgyvrvw2007/cndnnrgyvrvw2007-eng.html#s4_2

http://www.topsoe.com/business_areas/refining/Hydrotreating.aspx.
http://www.topsoe.com/business_areas/sulphuric_acid/Wet_gas.aspx

http://www.international.gc.ca/trade-agreements-accords-commerciaux/agr-acc/eu-ue/can-eu.aspx