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EROI Update: Preliminary Results using Toe-to-Heel Air Injection

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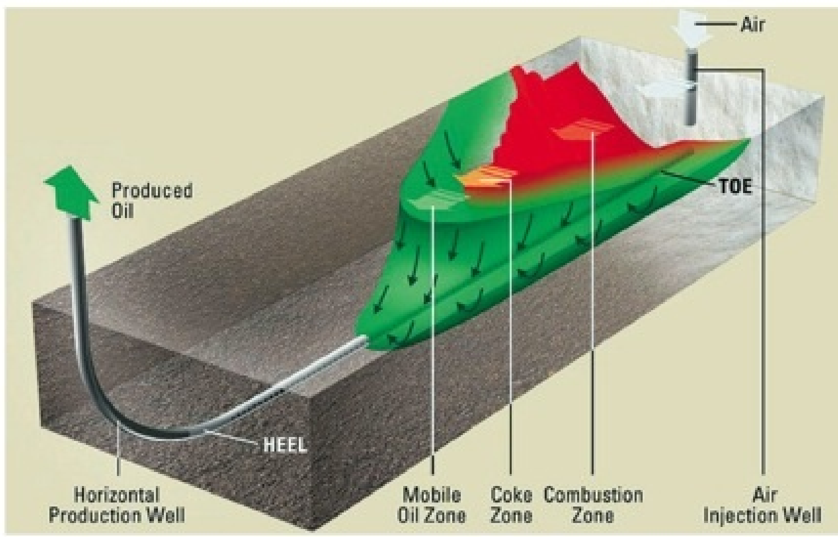

In August 2007, a post titled Extracting Heavy Oil: Using Toe to Heel Air Injection (THAI) introduced readers of The Oil Drum to a technology for producing an upgraded extra-heavy oil from Alberta Tar Sands without the environmentally messy and energy-intensive surface mining procedures that currently dominate extraction. The post provided a first-look at producing and partially upgrading Alberta bitumen in situ. In this post we make preliminary estimates of the Energy Return on Investment (EROI) of the THAI process.

The Alberta Tar Sands continued to garner interest through the first half of 2008 because of declining conventional oil production in Canada, the apparent success of the Steam Assisted Gravity Drainage (SAGD) process and the increasing price of crude oil. Today they are still of interest as the countries of North America (and around the world) desire cheap, abundant crude oil from politically stable regions (See Unconventional Oil: Tar Sands and Shale Oil - EROI on the Web, Part 3 of 6). However the subsequent financial collapse during the second half of 2008 has caused many tar sand projects to be deferred. In fact, Canada's oil-sands industry has hit the skids, spreading a deepening gloom over Alberta's economy, and to some degree, across the country. Some expansion projects that were under way in the Fort McMurray region have been put on the shelf, as oil companies slash their budgets to reflect the new economic environment in which they operate – that is – a world of lower oil demand and, at least compared to the summer of 2008, low oil prices.

The environmental benefits that the THAI process appears to offer include lower water and natural gas requirements, and a smaller surface footprint when compared to similar extraction technologies used in the Tar Sands, e.g. SAGD. However, in August of 2007 when the first post on The Oil Drum was written, there had been only about one year of pilot operating experience, and the news from the Whitesands Project cited problems with sand contamination in the extracted bitumen.

Can the Alberta Tar Sands Help this Situation?

In December 2008, with over two years of pilot operating experience from the Whitesands Project, the operator Petrobank filed an application with the Alberta Energy Conservation Resources Board (ECRB) and Alberta Environmental for the construction and operation of a 10,000 barrels per day (bpd) THAI commercial facility, called the "May River Project Phase l" (see here and type in permit application number 1600065 – warning: large files). This is of particular importance from an EROI perspective because the documentation accompanying the permit provides the opportunity for an energy performance review of a proposed commercial THAI facility based on actual operating data from the Whitesands Project. Our attempts to acquire more detailed information directly from Petrobank were denied.

In this post a retired oil refinery engineer and TOD member "daveinmarinca" and EROI Guy review the project facilities design and energy performance with the goal of establishing a preliminary EROI for the THAI process in Alberta. Daveinmarinca is an arms-length investor in Petrobank Energy and Resources Ltd., the company that patented THAI™, and otherwise has no ties with the company. We intend for this post to be an objective and academic analysis.

A Brief Review of- and Updates to- the THAI process

We review here the THAI process; for a more detailed review please visit the original post by Gail. The THAI process utilizes well pairs consisting of a vertical air injection well and a 700 meter horizontal collection well (Figure 1 at the top of this post). First, the vertical air injection well is preheated with steam. Next, compressed air is injected and oxidation (i.e. combustion) is initiated to create the "mobile oil zone". In effect some of the bitumen is burned to give heat and mobility to adjacent bitumen. As the hot bitumen drifts downward and down slope it transfers heat to other bitumen, causing that to be fluid too. As oxidation and oil production proceeds, a broader combustion zone is established until the well reaches its production capacity. Each well-pair at the Whitesands Project had a thermal-hydraulic limit of 555 bpd per well.

Table 1 (below) lists the physical properties of the virgin bitumen and the THAI oil analysis at the well-head. According to Petrobank, the thermal cracking in the reservoir, which is an inherent feature of the THAI process, reduces the viscosity, sulphur content and asphaltenes while increasing the API gravity and lighter hydrocarbon elements. This results in a lighter, higher quality product that is easier to refine than the in situ bitumen and requires less diluent for shipping.

Based on the results from the operating Pilot, bitumen produced using the THAI™ process has an API gravity between 10 and 15 degrees, and a much reduced viscosity than typical values for Athabasca bitumen. An analysis of the partially upgraded bitumen from the Pilot is presented in Table 2.3-3.

Table 2.3-3: Pilot THAI™ Oil Analysis

Parameter	Athabasca Bitumen	THAI™ Oil
Viscosity at 20°C (cp)	555,000	1,550
Sulphur Content (weight %)	3.2	2.6
API Gravity (degree)	7.9	12.3
SARA Analysis at 11° API (weight %)		
– Volatile Organics at 20°C	21.1	25.6
– Saturates	12.7	23.5
– Aromatics	30.3	22.6
– Resins	19.0	17.2
– Asphaltenes	16.9	11.1

In June 2008, Petrobank completed a replacement THAI™ well at the Pilot which included a new incremental catalytic upgrading process called CAPRI™. Based on laboratory experiments, bitumen generated from the THAI™/CAPRI™ (controlled atmospheric pressure resin infusion) process is expected to be up to 6 degrees higher API gravity and have lower viscosity than the bitumen produced using the THAI™ process alone. An annular sheath of solid catalyst surrounds the horizontal THAI™ producer well in the bottom of the reservoir. Thermally cracked oil produced by THAI™ drains into the horizontal producer well, passing through the layer of catalyst achieving significant upgrading without the cost of surface upgrading. If the CAPRI™ technology is proven effective in the field, it will be incorporated in the Project design.

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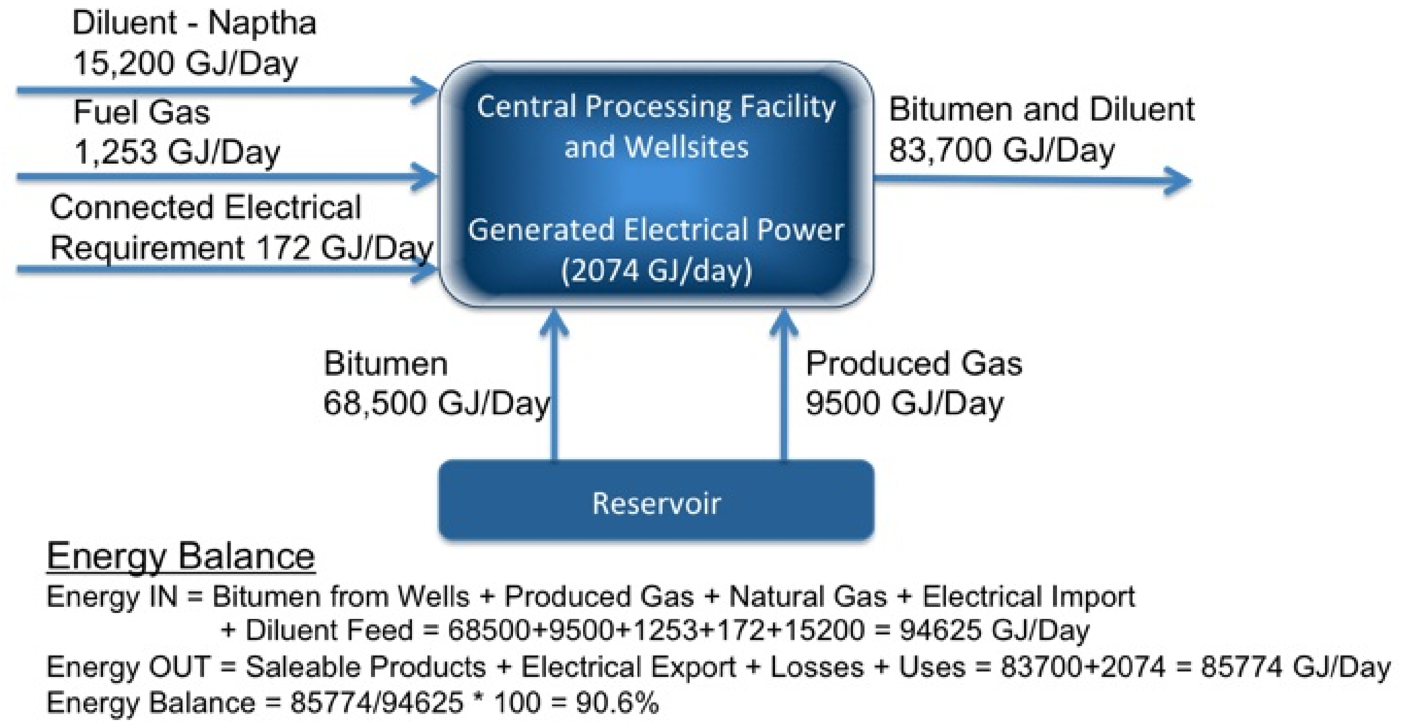
Preliminary Estimates of the Energy Return on Investment for the production of bitumen using THAI

The permit application includes an energy balance from which we can make coarse estimates of a range of EROI values that we might expect from the THAI process (Note: 1. All the permit performance numbers and the EROI analysis are based on Whitesands THAI performance without CAPRI™ as provided in the project permit documents – CAPRI is not discussed in this post. 2. The diagram below was re-created from the files submitted by Petrobrank in order to increase clarity. For the original diagram please see the permit application linked above).



The “energy balance” as calculated by Petrobank is 90.6% implying we think that for every ten units of energy taken from the reservoir 1 unit is used up in the process. This is not an EROI calculation, rather it is an assessment of the efficiency of the Central Processing Facilities and Wellsites. In other words they calculate that 94,625 GJ/day flow into these facilities and they produce 85,774 GJ/day of products, for a conversion efficiency of 90.6%.

We calculate somewhat different numbers, and our preliminary EROI for the THAI process is between 3.3:1 and 56:1 (Table 2 - below), depending on the input energy allocated for naptha (diluent which is generated from outside the immediate system, usually during the fractional distillation of oil) and the amount of input energy allocated to the bitumen burned in situ. The estimate of 3.3 includes as an energy cost 100% of the energy content of the naptha and 100% of the energy content of the bitumen burned in situ. The estimate of 8.9 excludes the entire energy cost of naptha, assuming that it is recycled, and the estimate of 56 excludes both the cost of naptha and the cost of the energy burned in situ.

Table 2. Various preliminary estimations of the EROI for the THAI production process.

	Energy (GJ/Day)
Energy Inputs	
naptha	15200
Fuel Gas	1253
Electricity	172
Energy Burned in situ	7,611
Total Energy In w/ naptha	24,236
Total Energy In w/out naptha	9036
Total Energy IN w/out naptha and w/out energy burned in situ	1425
Energy Outputs	
Bitumen	68,500
Produced Gas	9,500
Electricity (to grid)	2074
Total Energy Out	80,074
EROI with naptha	3.3
EROI without naptha	8.9
EROI without naptha and without energy burned in situ	56

Asssumptions:

One major assumption in the EROI calculation is that the input energy allocated to the bitumen burned in situ (combustion zone) is only 10% of the original oil in place. This amount is as close of an estimate as we can make from the reports filed by Petrobank. If this 10% is correct, then the total amount of recoverable oil in the system under study is 76,111 GJ/day (68,500 / 0.9), which would mean that the energy burned in situ is 7,611 GJ/day (76,111 - 68,500).

Another potential issue involves the air injected into the combustion zone. After the first post on THAI we learned that in order to maintain combustion below ground the concentration of oxygen in the injected gas must be increased. We have read nothing on the permit application indicating that this is the case at Whitesands, so we assume implicitly that these costs either don't exist or have been incorporated into the costs associated with the central processing facilities and well sites.

Discussion of EROI estimates

There are three complicating factors that become immediately obvious when calculating the EROI for the THAI process.

First, the energy content of the naptha is quite large, yet this GJ amount is not burned or used in any way aside from decreasing the viscosity of the bitumen so that it may be shipped via pipeline. Clearly there is an energy cost associated with both the physical mixing at the processing facility and subsequent separation at the refiner, but this, presumably, will be less than the energy content of the naptha itself. Consequently, if we assume that the cost of the physical mixing of bitumen and naptha is included in the costs of the process facility, and exclude the separation costs at the refiner since the boundary of this analysis is the central processing facility, then the appropriate EROI estimation for the THAI process is 8.9:1.

Second, and perhaps an issue that is more contentious, is the energy value assigned to the bitumen burned within the "combustion zone" of the THAI process. The THAI process according to Petrobank uses the heat energy released from the oxidation of a portion of the original bitumen in place to thermally crack the remaining bitumen, lowering the viscosity and, it seems, increasing the quality (API) of the bitumen that is extracted. Since this bitumen is already in the ground and cannot otherwise be used, and there is no additional financial or energy cost to attain it – it is essentially "free".

There are three reasons, however, as to why the energy cost of the bitumen burned in situ should be included in the EROI calculation. A) There is an "opportunity cost" of the bitumen burned in situ. By burning this bitumen in the combustion zone the opportunity to develop it at a later time by some future technology is lost. B) The THAI process does not work without the heat energy provided by the exothermic combustion of bitumen. So even though this bitumen comes at no additional "cost" to the firm, it still acts as an energy input to developing the bitumen. C) There are various environmental costs that occur, such as the carbon dioxide produced during combustion. As a result, we include the energy of the bitumen burned in situ as part of the energy input to the THAI process in our base case. However, we have no unequivocal position on including or not this energy input.

Third, the bitumen shipped to the refinery is still far from "light, sweet" crude oil and needs significant refining if products other than asphalt are desired – i.e. gasoline. About 10% of the energy content of a barrel of "standard" oil is used in the refining process (Szklo and Schaeffer, 2007), and we would not be surprised if that number were higher, maybe much higher, for the bitumen produced at Whitesands. Furthermore, if the system boundaries in this analysis were extended to include the refinery and all costs until the end-user (i.e. the person at the gas station filling up their gas tank), the EROI would decrease substantially. For example, Hall, Balogh and Murphy (2009) calculated that the EROI for oil extraction in the U.S. decreased by about two-thirds of the original EROI once they included the downstream energy costs, including: refinery costs, non-fuel products, transportation costs, and use infrastructure. Therefore it is reasonable to say that the EROI for the THAI process might decrease by about two-thirds if gasoline is the desired product.

An additional cost we were not able to consider is the infrastructural cost for the air supply (e.g. vertical wells) or extraction systems (e.g. horizontal wells). We assume that all significant operating energies are covered in the above table.

We conclude, based on this preliminary analysis that the THAI process appears to represent a somewhat better process to recover "oil" from tar sands than other above ground methods, as previous estimates of the EROI from surface extraction of Tar Sands have been around 5:1. The highest estimate of the EROI of the production process using THAI is 56:1, while the lowest estimate is 3.3:1. This is clearly a large range, but it is up to the reader to decide which number is most appropriate. We believe that even though the oil burned in situ is "free" in the financial sense, it is a required energy input to the THAI process and, from this perspective, this energy should be included in the estimation of EROI from THAI – resulting in an EROI of 8.9:1, which is an improvement over other tar sand extraction processes, such as SAGD. We welcome additional data and contrarian or other comments.

Author's Note: We would also like to mention that EROI analysis is just one of many important analytical tools or "lenses" through which we can view energy resources and technologies. As is the case with all quantitative and qualitative analyses, there are limitations to EROI analyses, and we at TOD: Net Energy are planning to discuss at length the limitations of EROI in the coming weeks.