BCSEA Webinar:
Alberta to China:
What’s the Energy Return?

How much energy does it take to extract, transport to China, and upgrade a barrel of diluted bitumen from the Athabasca? Is it worth it?

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Providing professional mechanical engineering services since 1994 for office, commercial, institutional, health care and remote facilities.

Principal of the firm, C.J. Peter, P.Eng, has over 25 years experience in building mechanical design, energy modelling and energy conservation engineering.

Design and retrofit of major buildings throughout Nunavut, Northwest Territories, Manitoba, Alberta and B.C., in the last two of which jurisdictions registered professional status is maintained.

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Energy Return On Energy Invested is very simple

\[
\text{EROI} = \frac{\text{Energy Out}}{\text{Energy In}} = \frac{\text{Usable Energy Acquired from a Resource}}{\text{The Energy Expended to Acquire that Energy}}
\]
EROI = \frac{\text{Energy Out } [E_{out}]}{\text{Energy In } [E_{in}]}

**Calculation of Energy Out:**

\[ E_{out} = \text{Energy remaining in saleable Product:} \]

**DILBIT:** A combination of \textbf{DI}Luent and \textbf{BI}Tumen. Blends made from heavy crudes and/or bitumens and a diluent, usually condensate, for the purpose of meeting pipeline viscosity and density specifications. For this analysis a 70:30 ratio of bitumen to condensate was used.

For the purposes of this analysis all energy acquired or expended is expressed as **Kilojoules per Litre of Dilbit transported.**
$$\text{EROI} = \frac{E_{\text{out}}}{E_{\text{in}1} + E_{\text{in}2} + E_{\text{in}3} + E_{\text{in}4}}$$

**Calculation of Energy In:**

- **Ein1** = Energy in Extraction of Bitumen (SAGD process) + dilution
- **Ein2** = Pipeline transport, dilbit + condensate
- **Ein3** = Tanker Transport (4 parts of journey)
- **Ein4** = (Pre)refining, diluent recovery + hydrogen addition to produce crude oil equivalent
1 bbl OIL = 158.984 L = 6.142 GJ = 707 x 100 W day

05/22/2012
"It takes about 34 cubic metres (1,200 cubic feet) of natural gas to produce one barrel of bitumen from in situ projects" N.E.B. 2010.

Energy to Produce Steam 7,784 kJ/L
Pumping Electrical Energy 70 kJ/L

TOTAL 7,854 kJ/L

EROI = Energy Out / Energy In

ENERGY Remaining 6.142 GJ
ENERGY WELL HEADS 4.893 GJ

Steam Assisted Gravity Drainage
DILBIT PUMPING

Waupisoo Dilbit Pipeline / Norlite Diluent Pipelines | 88.772 kJ/L
Enbridge Northern Gateway Pipeline | 119.8887 kJ/L
TOTAL | 208.66 kJ/L

CONDENSATE PUMPING

Waupisoo Dilbit Pipeline / Norlite Diluent Pipelines | 160.94 kJ/L
Enbridge Northern Gateway Pipeline | 217.36 kJ/L
TOTAL | 378.30 kJ/L

PIPELINE TRANSPORT

Condensate Pumping | 378.32 kJ/L x 30 % = 113.5 kJ/L
Dilbit Pumping | 208.66 kJ/L x 70 % = 146.1 kJ/L
“During operations, Northern Gateway expects that between 190 and 250 oil and condensate tankers will call on the Kitimat Terminal each year. On average, this will likely comprise 50 VLCCs, 120 Suezmax tankers and 50 Aframax tankers.”

– Vol. 1 Overview and General Information, Section 2.5.5
E.N.G.P. Application

### Suezmax Tanker properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Cubic metres</td>
<td>157,500.00</td>
</tr>
<tr>
<td>Economizing Fuel Efficiency</td>
<td>met. ton fuel/day</td>
<td>36.00</td>
</tr>
<tr>
<td>Economizing Speed (loaded)</td>
<td>Knots</td>
<td>13.00</td>
</tr>
<tr>
<td>Economizing Speed (empty)</td>
<td>Knots</td>
<td>15.00</td>
</tr>
<tr>
<td>Heating Value of fuel</td>
<td>MJ/kg</td>
<td>42.00</td>
</tr>
</tbody>
</table>
Energy Expended per Litre Dilbit Delivered:

1. 92.00 kJ/L
2. 146.39 kJ/L
3. 68.78 kJ/L
4. 34.35 kJ/L

\[ \text{TOTAL} = 341.52 \text{kJ/L} \]
## Extraction / Distribution Summary

### Extraction Energy

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy (kJ/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>7,854</td>
</tr>
</tbody>
</table>

### Pipeline Transport

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy (kJ/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensate Pumping (30%)</td>
<td>113.5</td>
</tr>
<tr>
<td>Dilbit Pumping (70%)</td>
<td>146.1</td>
</tr>
</tbody>
</table>

### Tanker Transport

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy (kJ/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensate Full</td>
<td>92.0</td>
</tr>
<tr>
<td>Dilbit Full</td>
<td>146.4</td>
</tr>
<tr>
<td>Dilbit Empty</td>
<td>68.8</td>
</tr>
<tr>
<td>Condensate Empty</td>
<td>34.4</td>
</tr>
</tbody>
</table>

### Total

<table>
<thead>
<tr>
<th>Description</th>
<th>Energy (kJ/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>8,455.2</td>
</tr>
</tbody>
</table>
Diluent Recovery: \[
\frac{8,455.2 \text{ kJ/L} - 8,455.2 \text{ kJ/L}}{0.74} = 2,970.7 \text{ kJ/L}
\]

**TYPICAL DILUTED BITUMEN REFINING PROCESS**

- **Diluent Recovery**: \[
\frac{8,455.2 \text{ kJ/L} - 8,455.2 \text{ kJ/L}}{0.74} = 2,970.7 \text{ kJ/L}
\]

**ENERGY Remaining**

- **4.325 GJ**
- **6.142 GJ**

**Fuel**

- **Natural Gas**
- **23.9 MFOEB/CD**

**Case 5a: Unit Capacities (MB/SD)**

<table>
<thead>
<tr>
<th>Process</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDU</td>
<td>287</td>
</tr>
<tr>
<td>VDU</td>
<td>176</td>
</tr>
<tr>
<td>Hydrocracker</td>
<td>107(2)</td>
</tr>
<tr>
<td>Delayed Coker</td>
<td>108(1)</td>
</tr>
<tr>
<td>Naphtha HTU</td>
<td>61</td>
</tr>
<tr>
<td>Distillate HTU</td>
<td>113(2)</td>
</tr>
<tr>
<td>Sulfur Recovery</td>
<td>1064(2)</td>
</tr>
<tr>
<td>Hydrogen Plant</td>
<td>155 MMSCF/CD</td>
</tr>
<tr>
<td>Coke, 5,860 Ton/Cycle</td>
<td>47</td>
</tr>
<tr>
<td>BTX Extraction</td>
<td>29</td>
</tr>
<tr>
<td>H2 Plant</td>
<td>184(2)</td>
</tr>
<tr>
<td>MMSCFD</td>
<td>47</td>
</tr>
<tr>
<td>Hydrocrack</td>
<td>5</td>
</tr>
<tr>
<td>Refiner</td>
<td>96</td>
</tr>
</tbody>
</table>

(1) Assumes 94% onstream factor
(2) 2 Trains
(3) 6 Drums

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TYPICAL DILUTED BITUMEN REFINING PROCESS

Hydrogen Addition

\[
\text{23.9} \times 6,142,000 \text{ kJ Barrel} = 4,616.2 \text{ kJ/L}
\]

200 x 159 L Barrel

- 70 Diluent (C5+)
- 270 Bitumen with (C5+)
- Natural Gas 23.9 MFOEB/CD
- 6.142 GJ
- 3.591 GJ Remaining

ENERGY

6.142 GJ

3.591 GJ

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EROI = \frac{\text{Energy Out}}{\text{Energy In}}
ENERGY EXPENDED PER LITRE EQUIVALENT OF CONVENTIONAL CRUDE

EXTRACTION DELIVERY 8,445.2 kJ/L
DILUENT RECOVERY 2,970.7 kJ/L
HYDROGEN ADDITION 4,616.2 kJ/L

TOTAL 16,042.1 kJ/L

ENERGY RETURN ON INVESTMENT:

\[
\frac{(6,142.0) \text{ MJ Barrel}}{(1,000) \text{ kJ}} \times \frac{(159) \text{ L Barrel}}{(16,042.1) \text{ kJ MJ}} = 2.41
\]
1930 CONVENTIONAL OIL

EROI = 100

1
2011
CONVENTIONAL OIL
EROI = 14
## OIL SANDS EXTRACTION [AVERAGE]

<table>
<thead>
<tr>
<th>Extraction Type</th>
<th>Surface Extraction</th>
<th>SAGD Extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction only</td>
<td>7.2 : 1</td>
<td>5 : 1</td>
</tr>
</tbody>
</table>
EROI = 2.41

ENBRIDGE NORTHERN GATEWAY PROJECT

EROI = 2.41
**EROI** = \[ \frac{E_{\text{out}}}{E_{\text{in}1} + E_{\text{in}2} + E_{\text{in}3} + E_{\text{in}4}} \]

**Calculation of Energy In:**

- **E_{\text{in}1}** = Energy in Extraction of Bitumen (SAGD process) + dilution [49%]
- **E_{\text{in}2}** = Pipeline transport, dilbit + condensate [1.6%]
- **E_{\text{in}3}** = Tanker Transport (4 parts of journey) [2.1%]
- **E_{\text{in}4}** = (Pre)refining, diluent recovery + hydrogen addition to produce crude oil equivalent [47.3%].
**EROI** – Including other Energy expenditures

\[
\text{EROI} = \frac{E_{\text{out}}}{E_{\text{in}1} + E_{\text{in}2} + E_{\text{in}3} + E_{\text{in}4} + E_{\text{in \ other}}}
\]

**Other Energy expenditures:**

- Pre-extraction (including exploration)
- Refining of end use fuel products (e.g., gasoline, diesel, jet fuel)
- Delivery to points of use (e.g., delivery to service stations)
- Infrastructure (e.g., pipelines, fuel delivery trucks)
- Land reclamation (e.g., cleanup of tailing ponds, pipeline spills)
Net Energy is the difference between the energy put into a process and the usable energy we obtain from that process.

Net Energy Equation:

\[ (2) \quad \text{Net Energy} = E_{out} - E_{in} \]

If we solve the EROI equation (1) for \( E_{in} \), and substitute it into the Net Energy Equation (2), we get:

\[ (3) \quad \text{Net Energy} = E_{out} \times \left( \frac{EROI - 1}{EROI} \right) \]

From this equation (3), E. Mearns created the “Net Energy Cliff” graph.
"Net Energy Cliff" graph (E. Mearns 2008)

- 2011 Conventional Oil: 14.0:1
- Northern Gateway: 2.41:1
- Corn Ethanol: 1.4:1

EROI Threshold:

Energy Out [%]

Energy used to procure energy

Net Energy for Society
International Energy Agency (IEA)

“[An] Energy Subsidy is any Government action that concerns primarily the Energy Sector that lowers the cost of Energy Production, raises the price received by Energy Producers or lowers the price paid by Energy Consumers.”

Alternate Definition of Energy Subsidy based on our Understanding of Energy Return on Energy Invested

“An Energy Subsidy is an action that raises the value of the EROI of an Energy product by the omission of one or other Inputs to the calculation of EROI.”