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 ?

C.J. PETER ASSOCIATES ENGINEERING

May 22, 2012

Chris Peter,
P. Eng., LEED AP O+M

Norm Jacob,
B.A.Sc., B.Sc., M.Sc.

Mechanical engineering consulting firm located in Prince George, B.C.

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.

LEED7 AP and Member of US Green Building Council since 2008.

Energy **R**eturn **O**n Energy **I**nvested is very simple

$$\textbf{EROI} = \frac{\text{Energy Out}}{\text{Energy In}}$$

$$= \frac{\text{Usable Energy Acquired from a Resource}}{\text{The Energy Expended to Acquire that Energy}}$$

$$\text{EROI} = \frac{\text{Energy Out } [E_{out}]}{\text{Energy In } [E_{in}]}$$

Calculation of Energy Out:

Eout = Energy remaining in saleable Product:

DILBIT: A combination of **DIL**uent and **BIT**umen. 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.

$$\textbf{EROI} = \frac{E_{out}}{E_{in1} + E_{in2} + E_{in3} + E_{in4}}$$

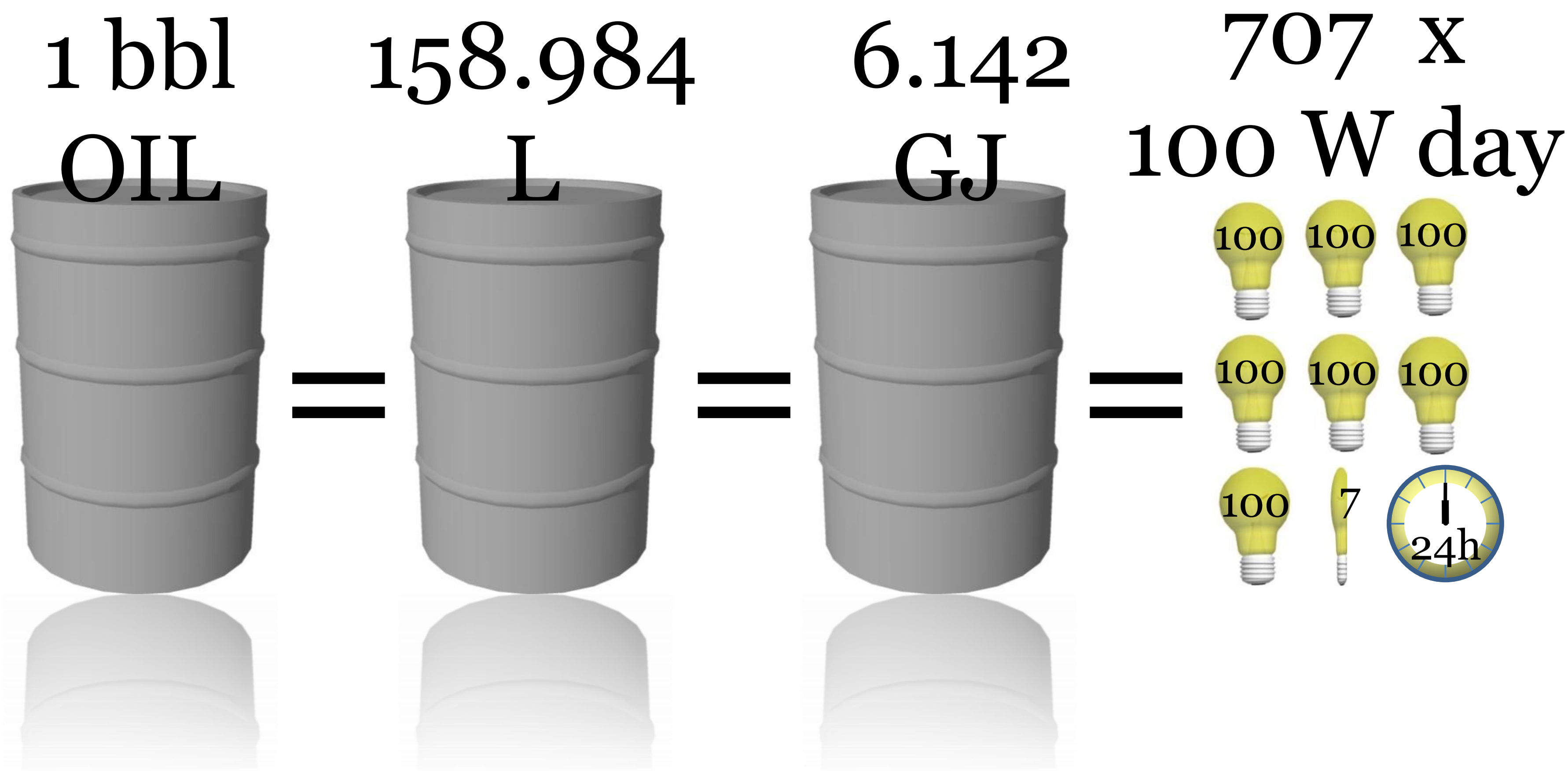
Calculation of Energy In:

E_{in1} = Energy in Extraction of Bitumen (SAGD process) + dilution

E_{in2} = Pipeline transport, dilbit + condensate

E_{in3} = Tanker Transport (4 parts of journey)

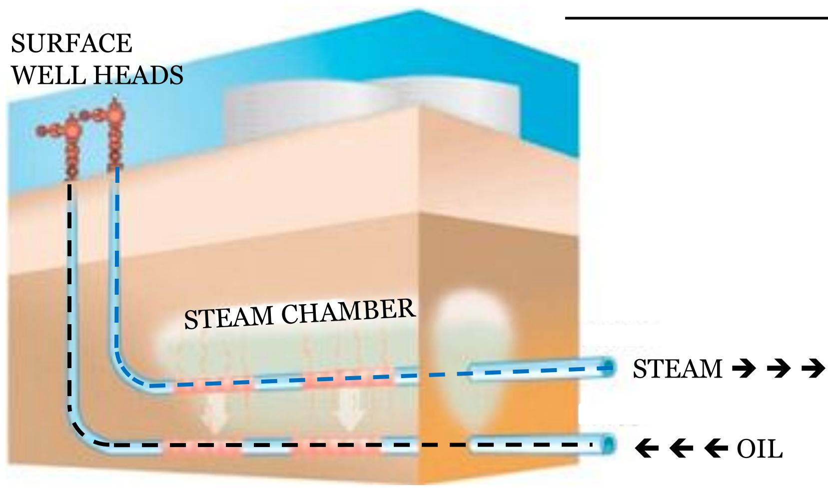
E_{in4} = (Pre)refining, diluent recovery + hydrogen addition to produce crude oil equivalent


1 bbl
OIL
=
158.984
L
=
6.142
GJ
=
707 x
100 W day
100
100
100
100
100
100
100
7
24h

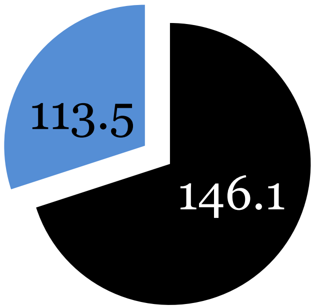
$$\text{EROI} = \frac{\text{Energy Out}}{\text{Energy In}}$$

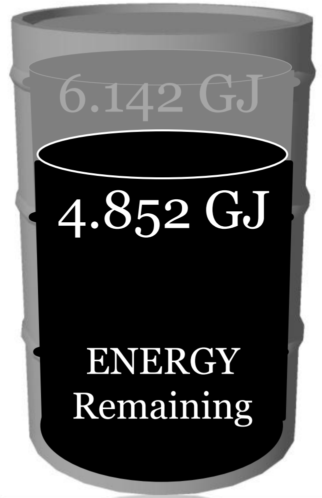
"It takes about 34 cubic metres (1,200 cubic feet) of natural gas to produce one barrel of bitumen from in situ projects" N.E.B. 2010.

Energy to Produce Steam	7,784 kJ/L
Pumping Electrical Energy	70 kJ/L
TOTAL	**7,854 kJ/L**



Steam Assisted Gravity Drainage





DILBIT PUMPING

Waupisoo Dilbit Pipeline / Norlite DiluentPipelines	88.772 kJ/L
Enbridge Northern Gateway Pipeline	119.8887 kJ/L
TOTAL	**208.66 kJ/L**

CONDENSATE PUMPING

Waupisoo Dilbit Pipeline / Norlite DiluentPipelines	160.94 kJ/L
Enbridge Northern Gateway Pipeline	217.36 kJ/L
TOTAL	**378.30 kJ/L**

PIPELINE TRANSPORT

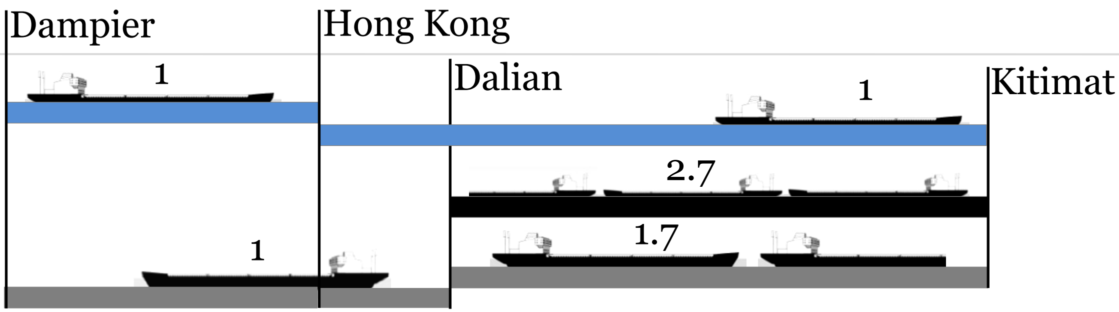
Condensate Pumping	378.32 kJ/L x 30 % =	**113.5 kJ/L**
Dilbit Pumping	208.66 kJ/L x 70 %=	**146.1 kJ/L**

"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

Capacity	[Cubic metres]	157,500.00
Economizing Fuel Efficiency	[met. ton fuel/day]	36.00
Economizing Speed (loaded)	[Knots]	13.00
Economizing Speed (empty)	[Knots]	15.00
Heating Value of fuel	[MJ/kg]	42.00



Energy Expended per Litre Dilbit Delivered:

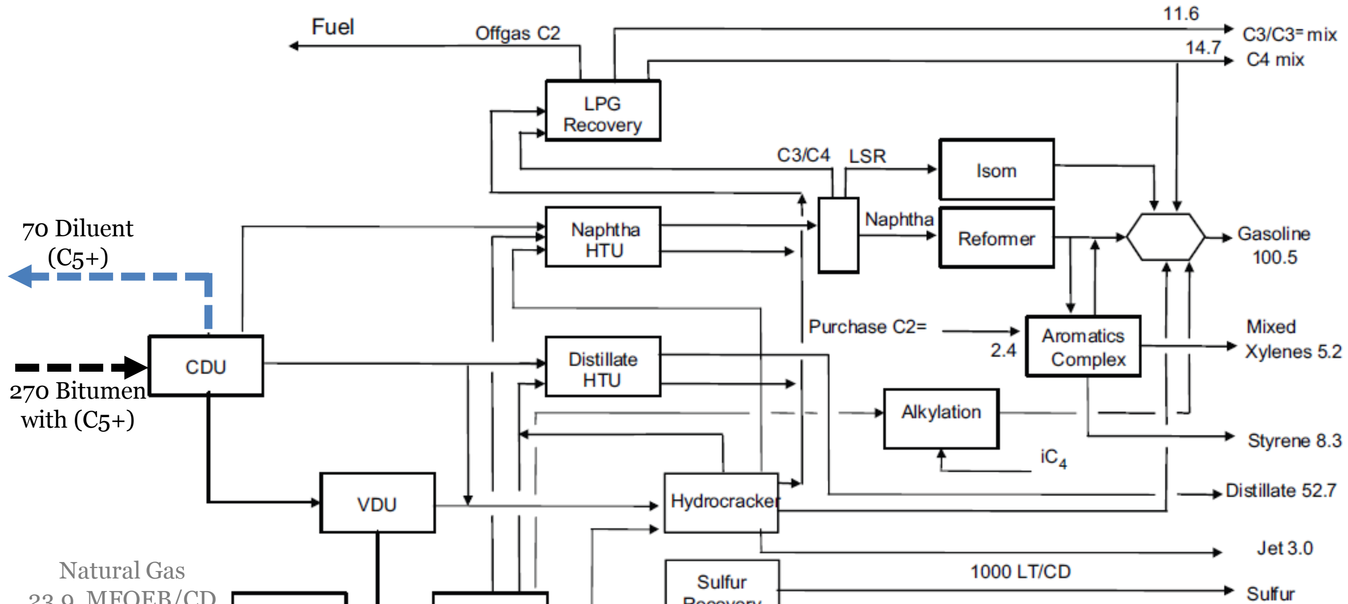
1. 92.00 kJ/L
2. 146.39 kJ/L
3. 68.78 kJ/L
4. 34.35 kJ/L

341.52kJ/L

EXTRACTION ENERGY	7,854 kJ/L
PIPELINE TRANSPORT	
Condensate Pumping (30%)	113.5 kJ/L
Dilbit Pumping (70%)	146.1 kJ/L
TANKER TRANSPORT	
Condensate Full	92.0 kJ/L
Dilbit Full	146.4 kJ/L
Dilbit Empty	68.8 kJ/L
Condensate Empty	34.4 kJ/L
TOTAL	**8,455.2 kJ/L**

TYPICAL DILUTED BITUMEN REFINING PROCESS

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



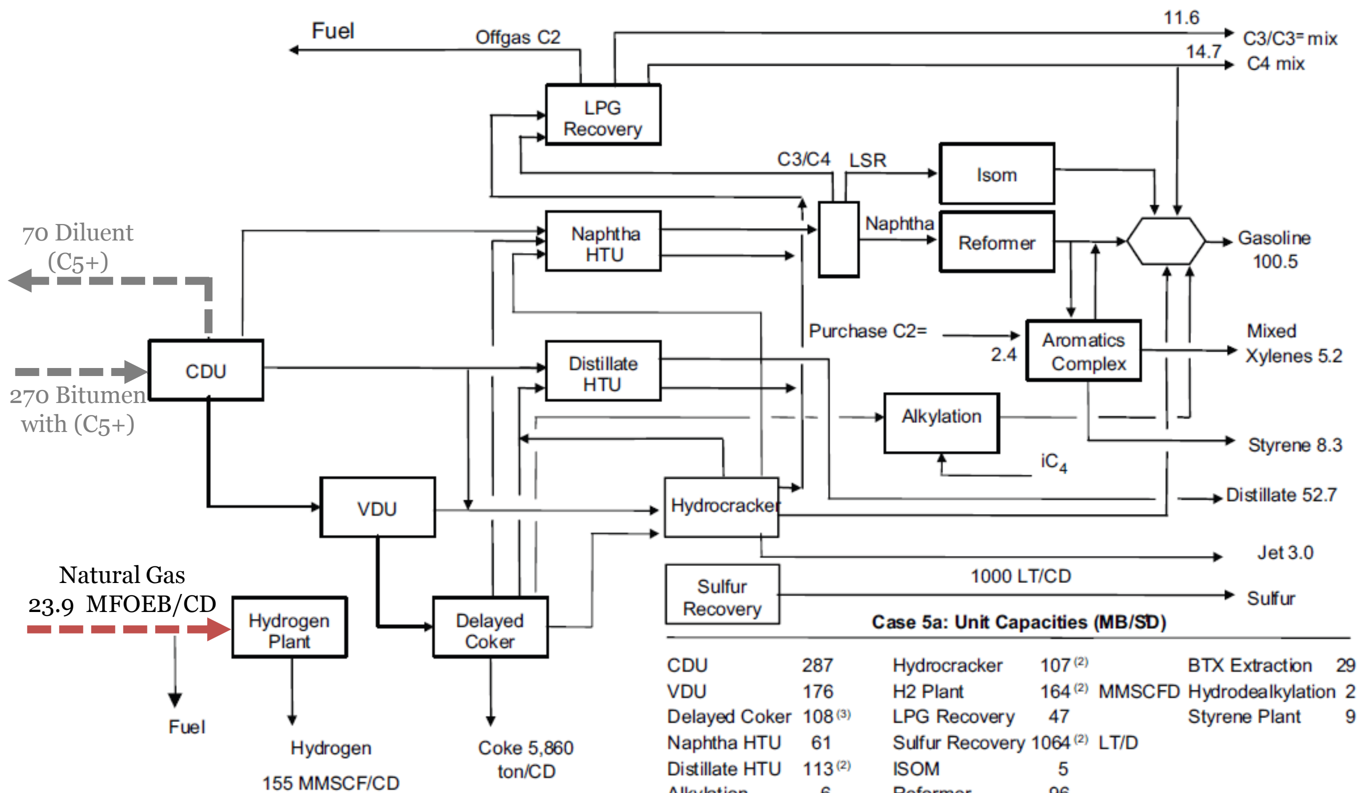
Case 5a: Unit Capacities (MB/SD)

CDU	287	Hydrocracker	107 (2)	BTX Extraction	29
VDU	176	H2 Plant	164 (2) MMSCFD	Hydrodealkylation	2
Delayed Coker	108 (3)	LPG Recovery	47	Styrene Plant	9
Naphtha HTU	61	Sulfur Recovery	1064 (2) LT/D		
Distillate HTU	113 (2)	ISOM	5		
Alkylation	6	Reformer	96		

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

TYPICAL DILUTED BITUMEN REFINING PROCESS

Hydrogen Addition $\frac{23.9 \times 6{,}142{,}000 \text{ kJ Barrel}}{200 \times 159 \text{ L Barrel}}$ = **4,616.2 kJ/L**



Case 5a: Unit Capacities (MB/SD)

CDU	287	Hydrocracker	107 (2)	BTX Extraction	29
VDU	176	H2 Plant	164 (2) MMSCFD	Hydrodealkylation	2
Delayed Coker	108 (3)	LPG Recovery	47	Styrene Plant	9
Naphtha HTU	61	Sulfur Recovery	1064 (2) LT/D		
Distillate HTU	113 (2)	ISOM	5		
Alkylation	6	Reformer	96		

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

$$\textbf{EROI} = \frac{\text{Energy Out}}{\text{Energy In}}$$

? :

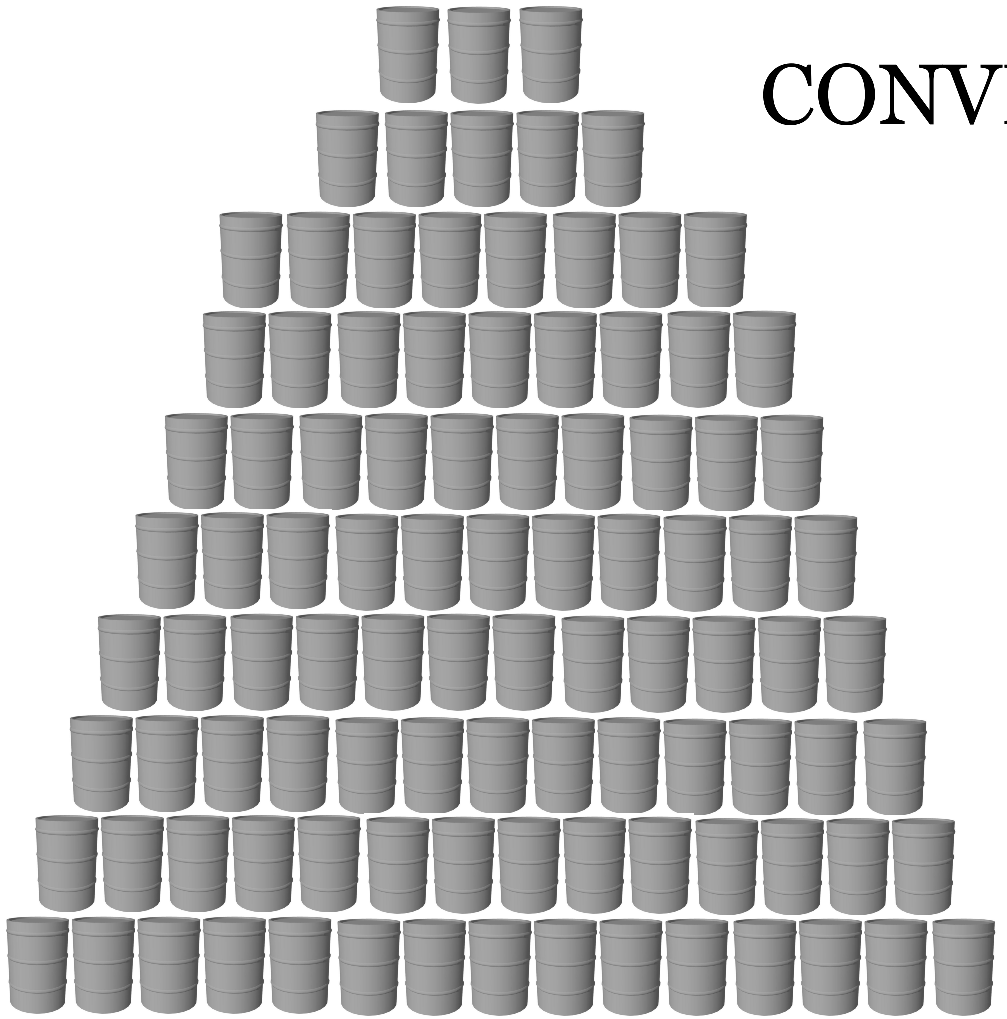
ENERGY EXPENDED PER LITRE EQUIVALENT OF CONVENTIONAL CRUDE

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:

$$\frac{(6{,}142.0)\ \text{MJ}\ \ \text{Barrel}\ \ \text{L}\ \ (1{,}000)\ \text{kJ}}{(159)\ \text{L}\ \ \text{Barrel}\ \ (16{,}042.1)\ \ \text{kJ}\ \ \text{MJ}} = \underline{\mathbf{2.41}}$$

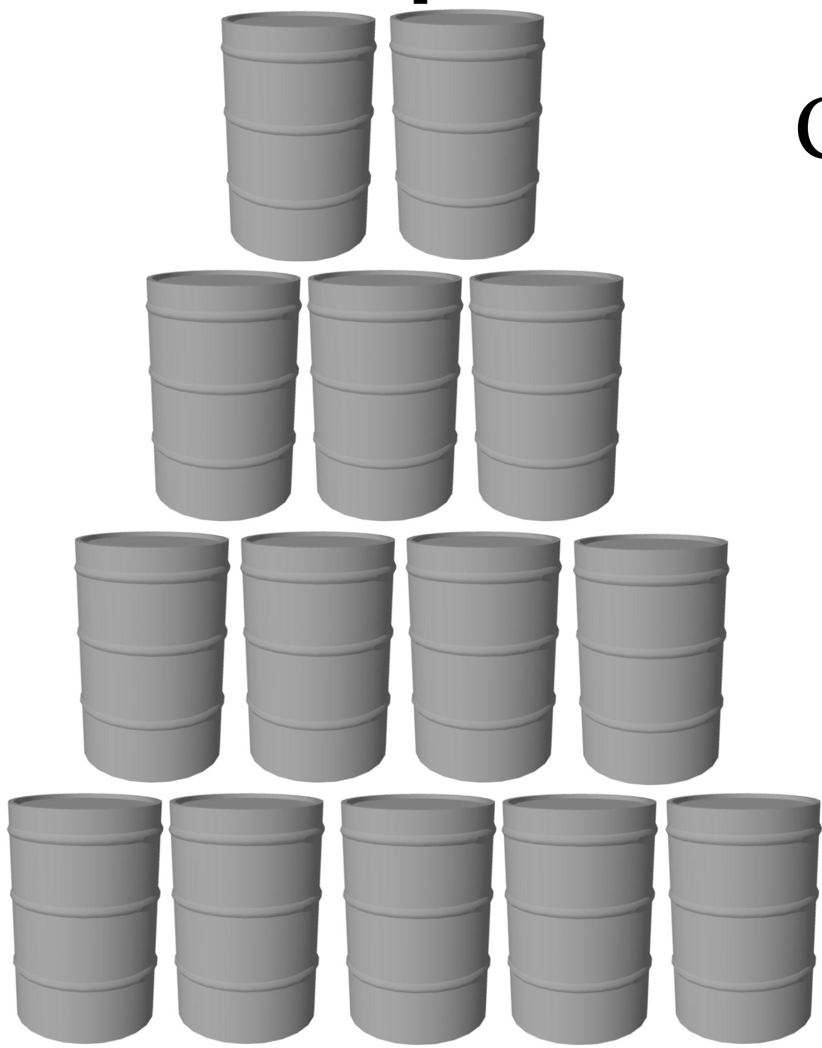
100



1930
CONVENTIONAL OIL
EROI = 100

1

14



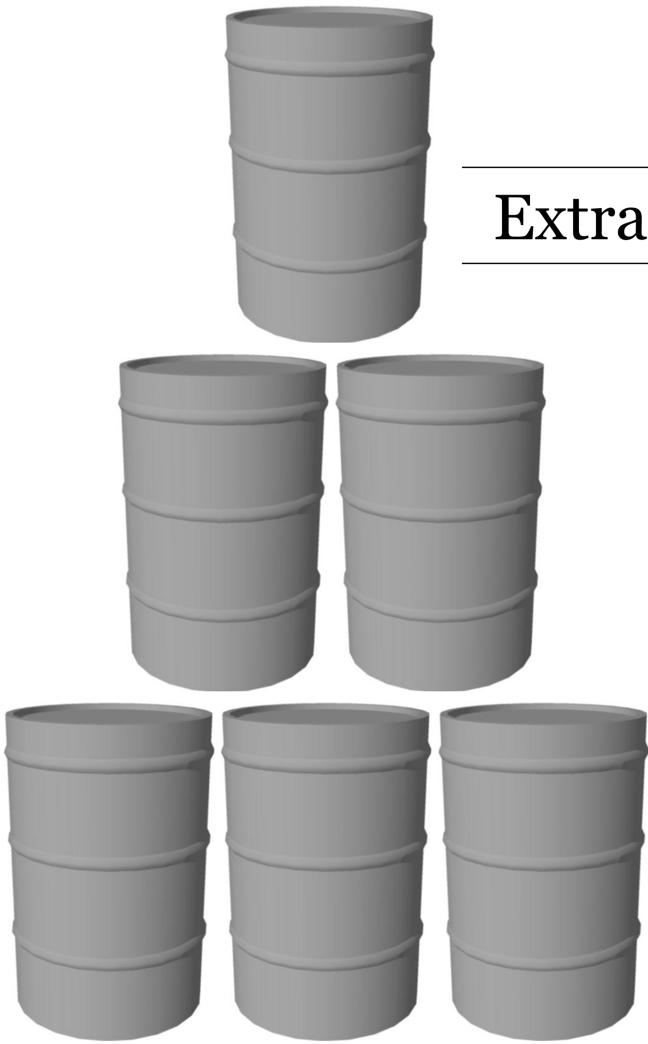
2011

CONVENTIONAL OIL

EROI = 14

1

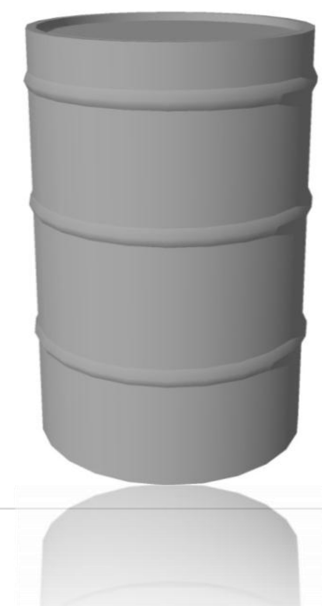
6



	Surface Extraction	SAGD Extraction
Extraction only	**7.2 : 1**	**5 : 1**

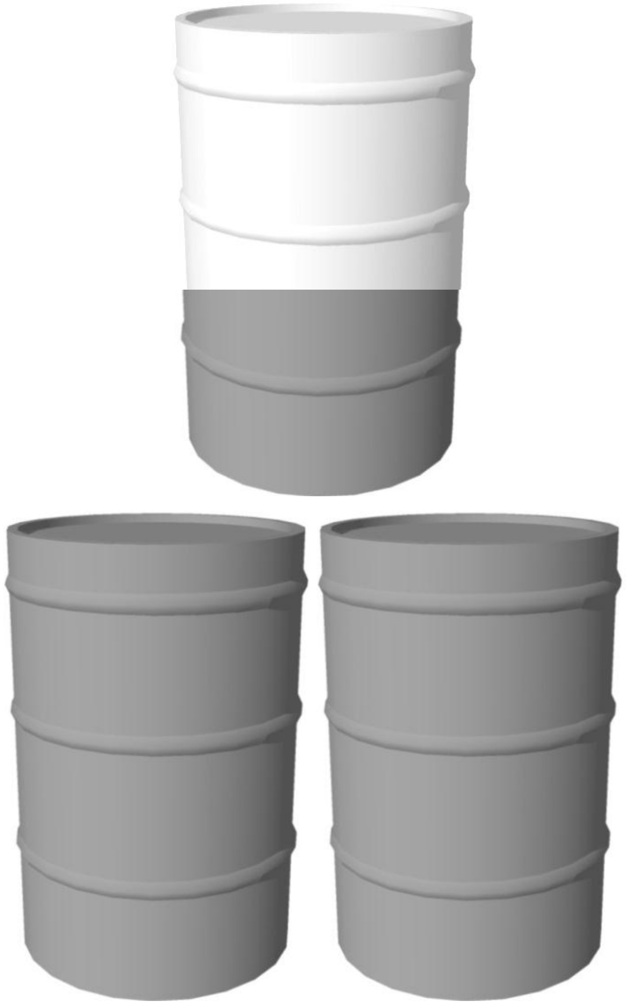
OIL SANDS
EXTRACTION
[AVERAGE]

1



ENBRIDGE NORTHERN GATEWAY PROJECT

2.41



EROI = 2.41

1

$$\textbf{EROI} = \frac{E_{out}}{E_{in1} + E_{in2} + E_{in3} + E_{in4}}$$

Calculation of Energy In:

E_{in1} =	Energy in Extraction of Bitumen (SAGD process) + dilution [49%]
E_{in2} =	Pipeline transport, dilbit + condensate [1.6%]
E_{in3} =	Tanker Transport (4 parts of journey) [2.1%]
E_{in4} =	(Pre)refining, diluent recovery + hydrogen addition to produce crude oil equivalent [47.3%].

$$\textbf{EROI} = \frac{E_{out}}{E_{in1} + E_{in2} + E_{in3} + E_{in4} + E_{in\ other}}$$

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)

EROI Equation:

$$(1)\ EROI = Eout / Ein$$

Net Energy is the difference between the energy put into a process and the usable energy we obtain from that process.

Net Energy Equation:

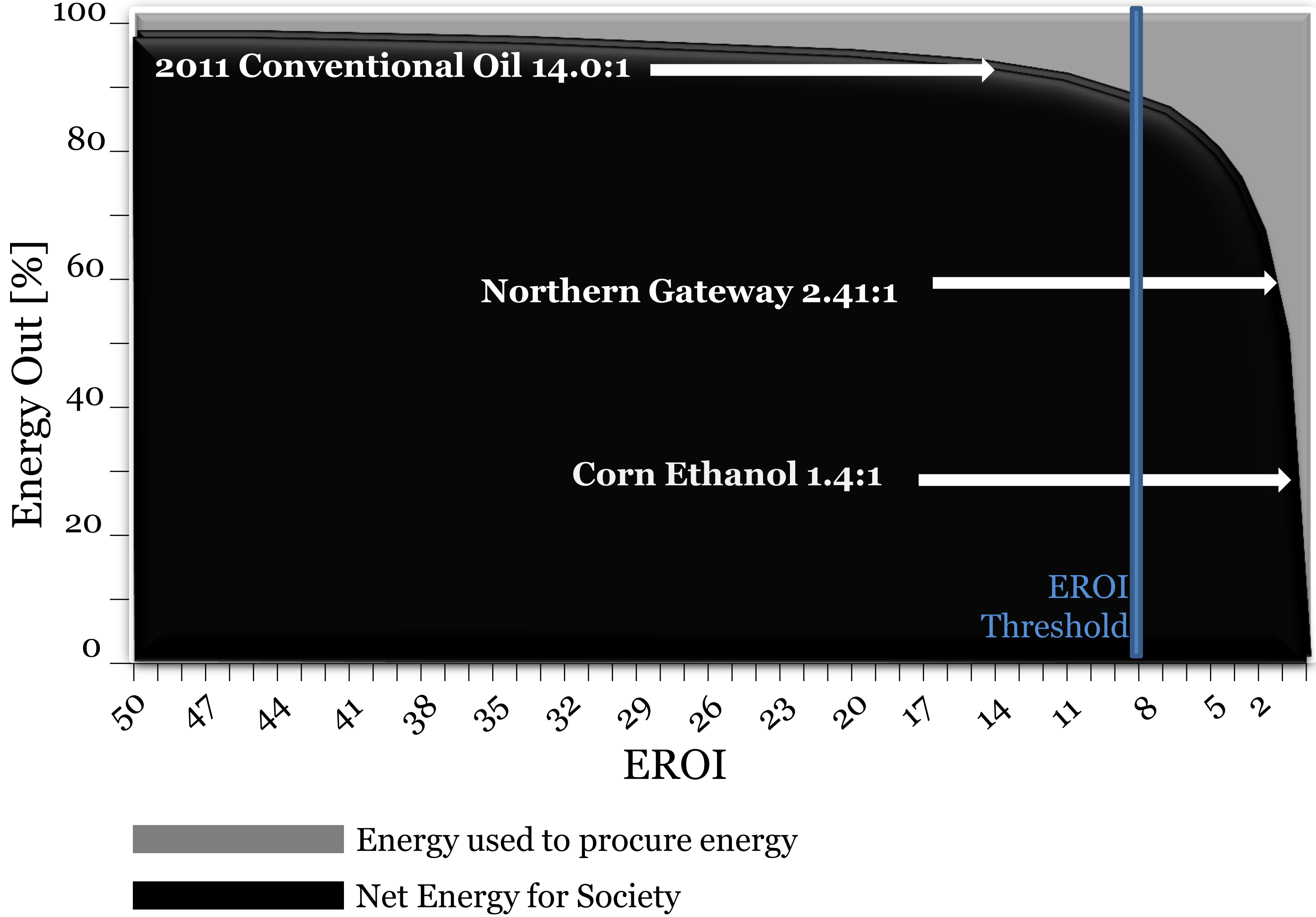
$$(2)\ Net\ Energy = Eout - Ein$$

If we solve the EROI equation (1) for *Ein*, and substitute it into the Net Energy Equation (2), we get:

$$(3)\ Net\ Energy = Eout * \frac{(EROI - 1)}{EROI}$$

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

"Net Energy Cliff" graph (E. Mearns 2008)



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."