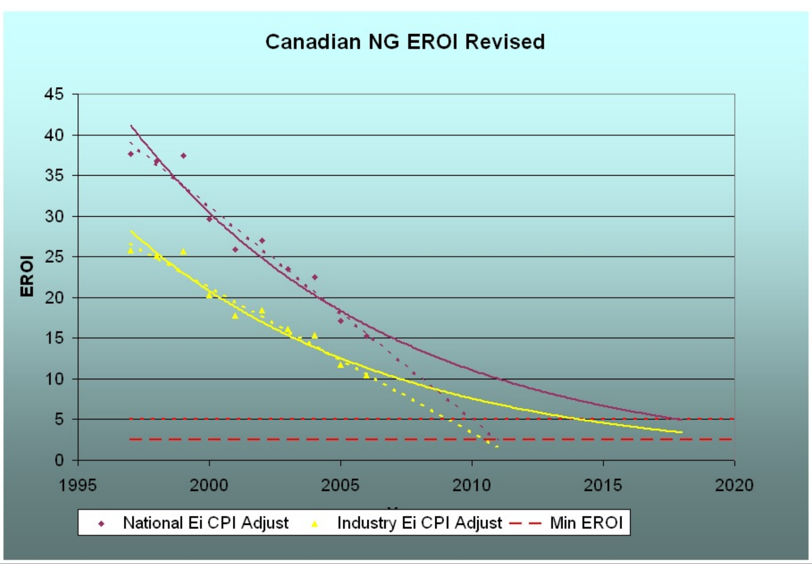
An Update on the Energy Return on Canadian Natural Gas

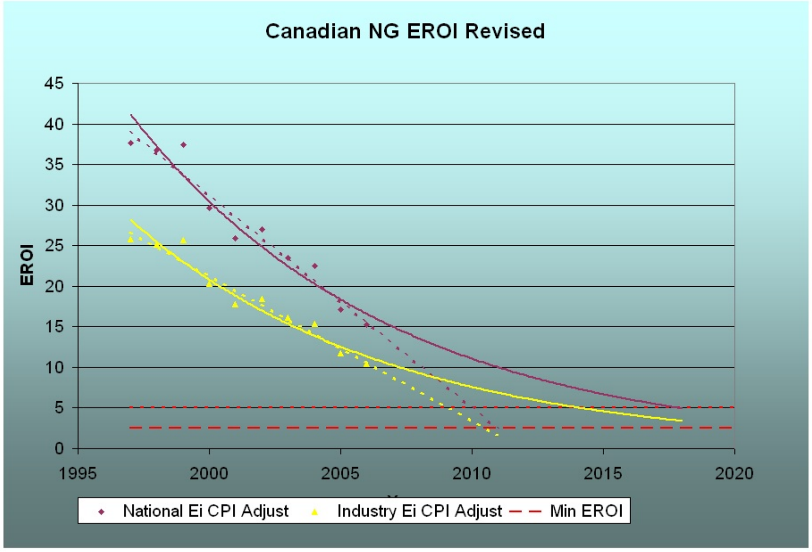
Posted by Nate Hagens on August 4, 2008 - 9:45am
Topic: Supply/Production
Tags: david hughes, depletion, eroei, eroi, jon freise, natural gas, net energy, original, western canada sedimentary basin [list all tags]

This is an updated post on the energy return on energy invested on Canadian natural gas by Jon Freise. Jon's initial draft of this analysis, and related comments, can be found here.

An intermittent but longstanding theme here on theoildrum is that dollars do not sufficiently inform us of the long term details of energy depletion, and that the inexorable race between technology and depletion can be better understood using biophysical methods. Essentially this post suggests that it is requiring more and more energy to procure the same amount of natural gas in Canada, and this trend will likely continue into the future. This update makes the initial analysis too *pessimistic* on the rate of EROI NG decline but also too *conservative* on the absolute level of energy return. It is going to be a very interesting few years as Canada declines, Barnett peaks, and Haynesville and other unconventional plays ramp up. The treadmill spins on.



EROI of Canadian Natural Gas, Revised



Preamble

[Hughes 2007] Interview transcript with David Hughes of the Canadian Geological Survey.

"The assessment of discovered and undiscovered gas is based on statistical methodology. So, we look at what's called pool size distributions - discovered and undiscovered - and we can make an estimate of how many undiscovered pools are left, and the size of those pools. I'm also on the Canadian Gas Potential Committee - a group of senior geoscientists that prepares periodic national assessments of Canada's discovered and undiscovered gas resources - and in our most recent assessment, on the conventional gas side, in the Western Canada Sedimentary Basin, the two-thirds of the gas that we found were contained in 44,000 pools. The one-third of the gas that we haven't discovered, yet, is contained in 500,000 pools. And the last 200,000-300,000 pools on that tail will be far too small to be commercially developed. ***So, roughly 90% of what's left of the undiscovered resources are contained in probably 250,000 pools. It takes us two wells to find each one - that's 500,000 wells to find the last 30% of Canada's gas. To put that in perspective: we've drilled 300,000 wells to find the first 70%, so we can see that's the treadmill, the law of diminishing returns."***

Introduction

This paper uses data collected by the Canadian National Energy Board to estimate the Energy Return on Energy Invested (EROI) of Canadian natural gas production.

EROI is critical because no fossil fuel can remain an energy source with a low EROI. A falling EROI is an indication that technology is losing the race against depleting reserves. (See Ten Fundamental Principals of Net Energy by C. Cleveland)

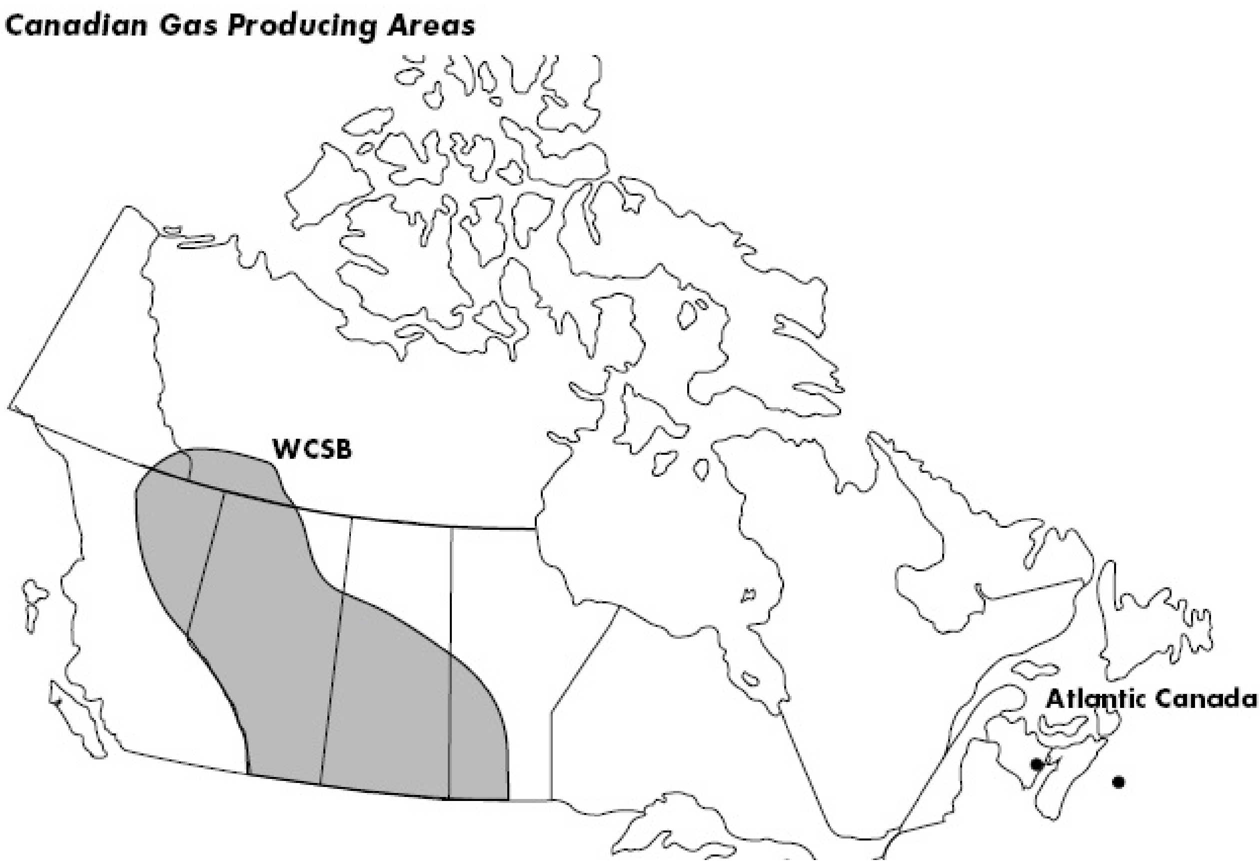
In the prior article on the EROI of Canadian Natural Gas showed that EROI was falling rapidly, and that it could possibly hit unity in less than 10 years. This article refines the prior estimate after helpful suggestions from Nate Hagens, Dr. C. Hall, and Dr. C. Cleveland. Unfortunately, the estimates were revised downward because the natural gas industry is more energy intensive than the national average industry. North American Natural Gas Production and EROI Decline.

This article also focuses in greater detail on the Canadian EROI calculations.

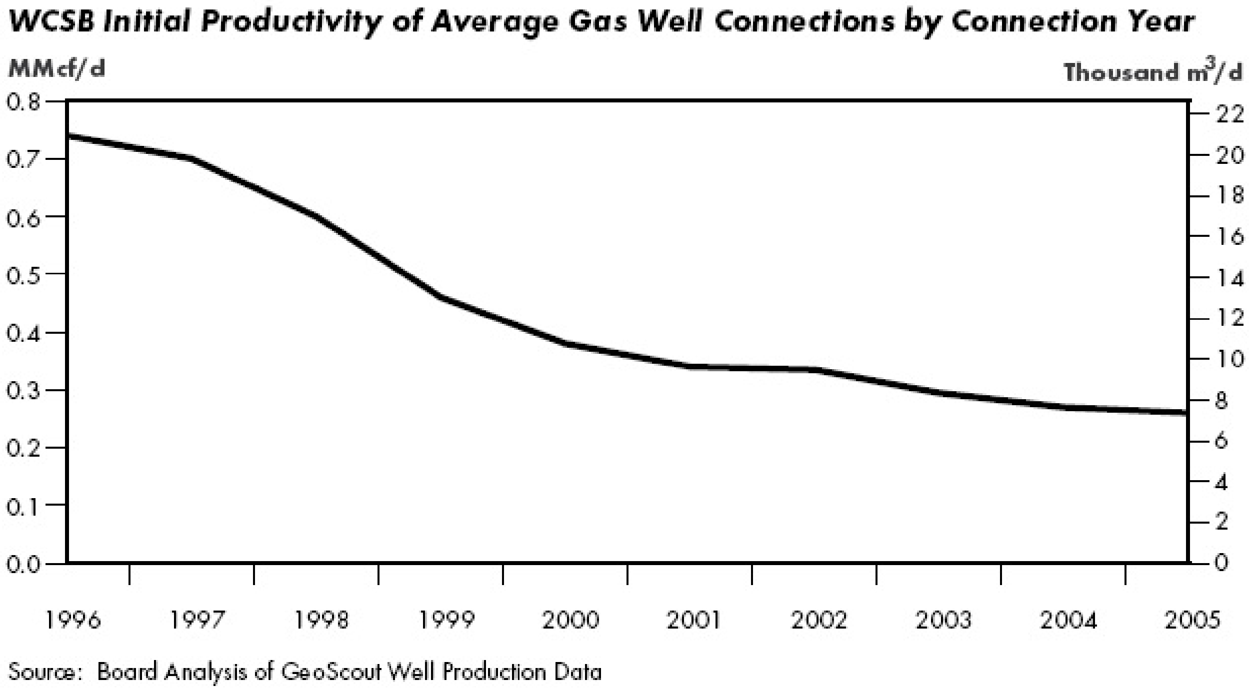
It would be helpful to hear from anyone who has access to drilling and operating cost data so we might form a more complete picture of what is happening with the most recent wells in the United States.

Decline in the WCSB

Canada is a major natural gas producer and supplies about 18% of the natural gas used in the United States. Most of Canada's natural gas is extracted from the Western Canadian Sedimentary Basin, which is located north of Montana and North Dakota.



The WCSB is a mature region and well productivity has been slowly falling.



Falling well productivity means that more wells must be drilled each year to produce the same amount of natural gas.

Natural gas drilling and extraction is very energy intensive and more wells means more fuel must be used, more steel pipe, more drilling rigs, and more labor. Eventually the energy required to drill and operate a well will require more energy than the well produces. At that point natural gas extraction will stop being a fuel source and if continued would only be a fuel upgrade

We examine how to calculate EROI and how to forecast EROI trends below.

The Basic Calculation

There are many ways to calculate EROI described in the literature [Hall 1979] (the primary reason there is not ONE way is the lack of available data in parsed energy terms). The method used here is one that could be repeated with the same information needed to calculate the financial ROI.

The basic equation is:

EROI = Eoutput / Einput

The Eoutput is easy to calculate. This is the energy in the sum total of natural gas produced by a well (or group of wells). Natural gas production is often measured in cubic feet and this should be converted to Joules of energy.

The Einput is harder to calculate. Einput includes all fuels used to drill, complete and operate the natural gas well(s). But it must also include all capital equipment, materials, and labor. The energy embodied in these materials often exceeds the energy consumed directly as fuel. (Casing pipe being one major energy cost).

Our society does not track the energy content of every item we use. Instead, our society does accounting using money. This means that we need a mechanism for converting from money into energy.

The equation to do this is simple (in principal):

Einput = Eintensity * (drilling cost + completion cost + operation cost).

Eintensity is the conversion factor from $ to Joules. It is expressed in J per $.

National Energy Intensity

An accurate Eintensity conversion factor is very important. One method is to calculate a national average Eintensity. This is done by taking the GDP of the country and dividing by the total energy used by a country.

Eintensity = Total Energy / GDP

For Canada the GDP was taken from the Statistics Canada and the Total Energy was taken from the BP Statistical review. [Can Stat 2007] [BP 2007]

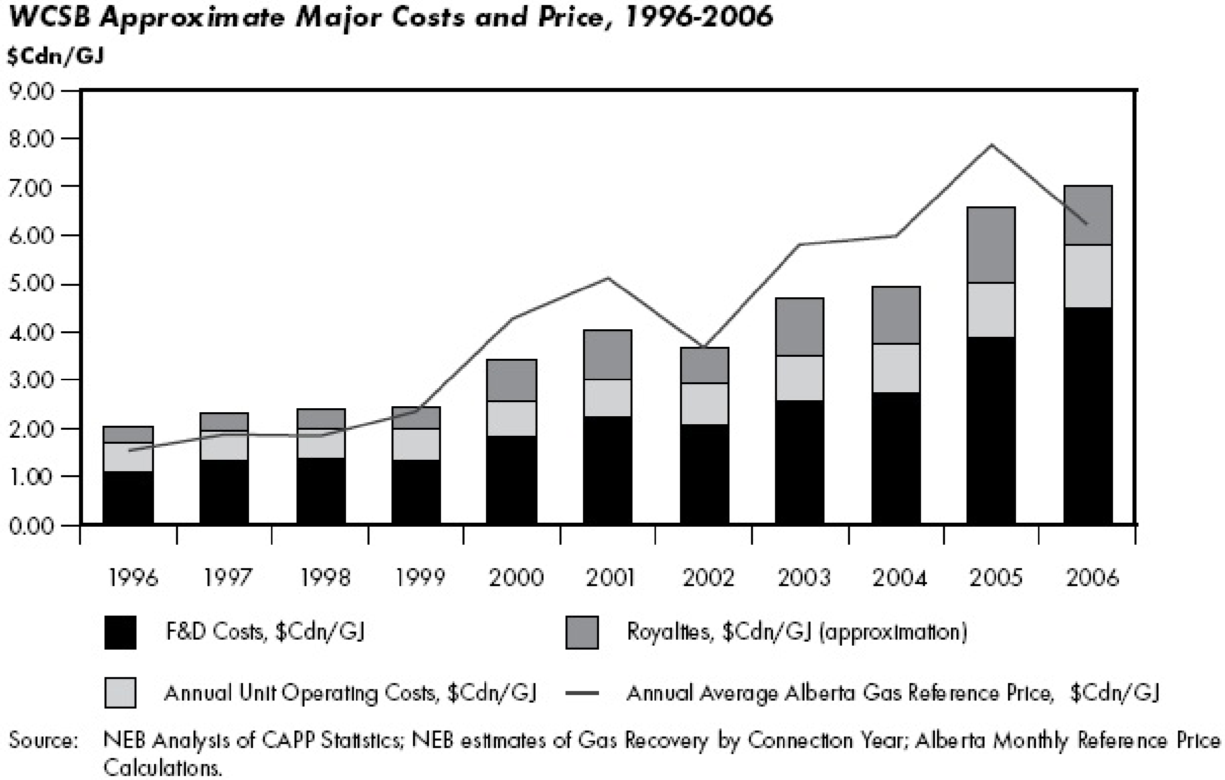
As an example here is 2006:

9.4e6 j/$ = 1.36e19 j / 1.45e12 $

Now we have an (approximate) method of converting $(Can) into energy. The next step is to get the Eoutput and cost input data.

Canadian National Energy Board Data

The Canadian National Energy Board calculates the total natural gas production from each year's newly drilled wells. And they calculate the cost of drilling and operating those wells. The data is summarized in the following table. *Notice how costs have been rising to produce the same 1 Gj of natural gas.*



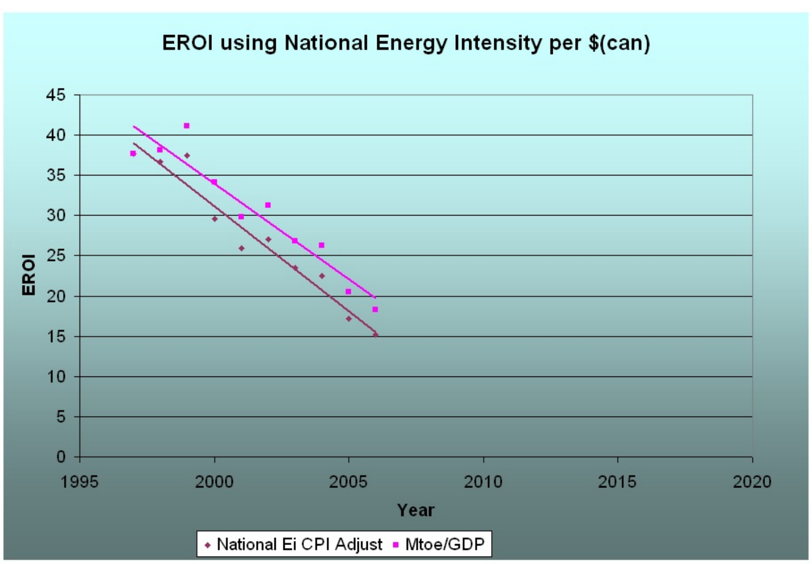
The equation is:

EROI = Eoutput / Einput

Eoutput = 1Gj (because the NEB data is provided this way)

Einput = Eintensity * $Can/Gj (the NEB data for the chart is also in table form)

This is done for every year from 1996 to 2006 and is graphed below:



This method yields a 2006 EROI from 15-18.

Inflation Adjustment

One issue with using a conversion from money to energy is that monetary inflation will skew the results. An inflating currency will appear as a dropping EROI. Inflation must be removed from the cost data.

There are two series in the above chart. Each series represents a different technique for removing inflation.

The first method (CPI Adjust) is to adjust all $ values using the Canadian Consumer Price Index. All cost data is inflation corrected to the same base year. Then the Eintensity is calculated for the base year and is applied to all years.

The second method (Mtoe/GDP on the chart) does not use the CPI but instead recalculates the Eintensity every single year. If monetary inflation is happening, that should show up as inflating GDP numbers and should be canceled out. Both methods yield similar results.

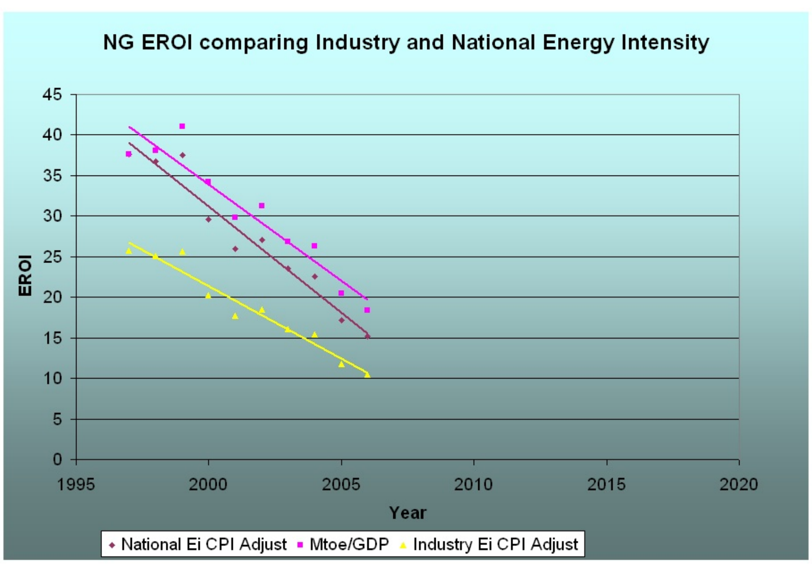
The CPI method is used for the rest of this paper because it works better for the technique explained next.

Industry Energy Intensity

The problem with an Eintensity based on the National Average is that some industries are much more energy intensive than other industries. Specifically energy producing industries can use double the energy per $ that other economic sectors use. And this is the case with natural gas.

Dr. Hall provided an updated estimate of Eintensity for the natural gas industry of 20e6 j per $(2005). This is just about double the national average and means that the prior EROI calculations were twice as optimistic as they should have been.

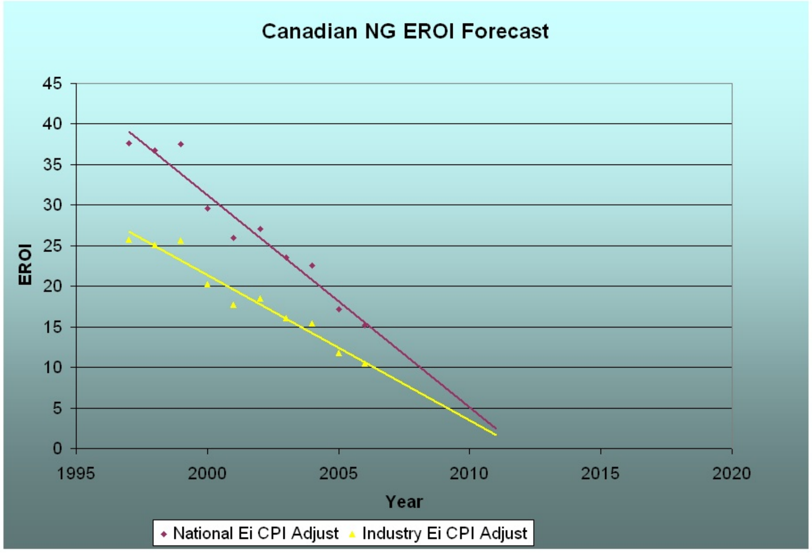
The yellow line in the chart below shows the EROI recalculated using the industry Eintensity.



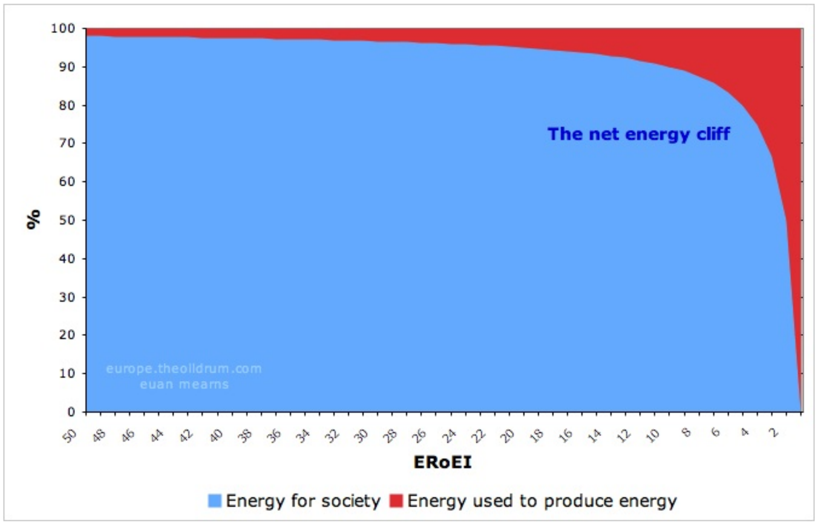
The yellow line is much lower than the prior estimates. This apparent bad news is offset somewhat by a more moderate rate of decline.

Forecasting EROI

In my prior article, future EROI was calculated using a simple linear regression of the EROI data points and extending that line to unity. This resulted in a forecast of EROI hitting unity in just a few years.

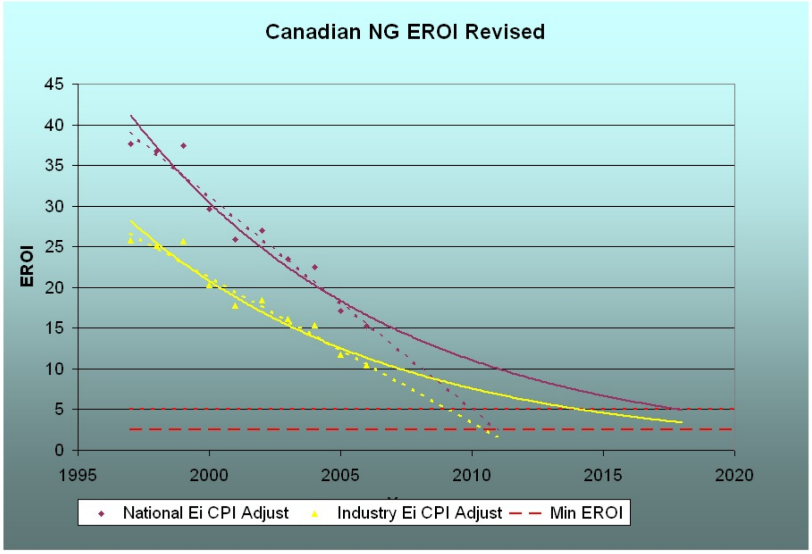


However, EROI does not have a linear behavior at low values. A change in EROI from 100 down to 10 requires only a 10% change in energy input. But a change in EROI from 10 down to 5 takes another 10% increase in energy input. The shift from a slow input change to a fast input change is easiest to see graphically -it resembles a knee or cliff.

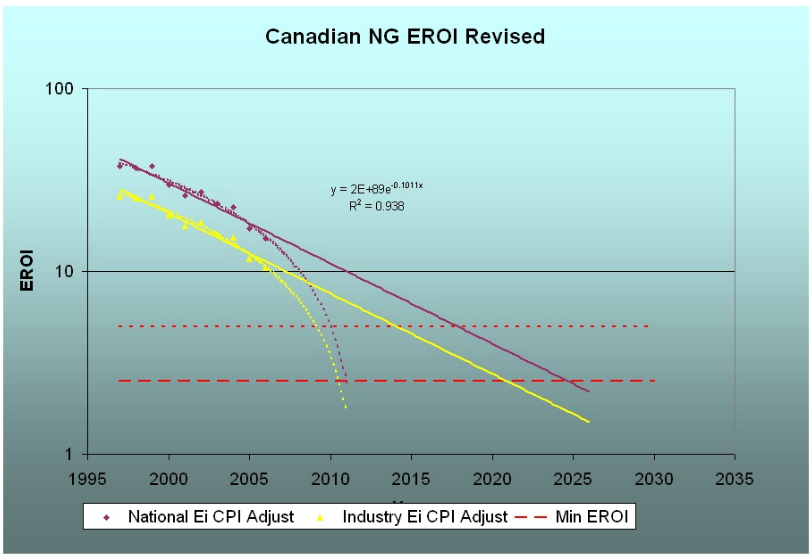


This sudden bend in the chart suggests that we cannot use a linear regression to forecast EROI.

Instead we forecast EROI using an exponential function. While the exponential fit is good, it depends on there being a very large number of future wells, each with smaller and smaller URR. There is evidence to support this position [Hughes 2007]



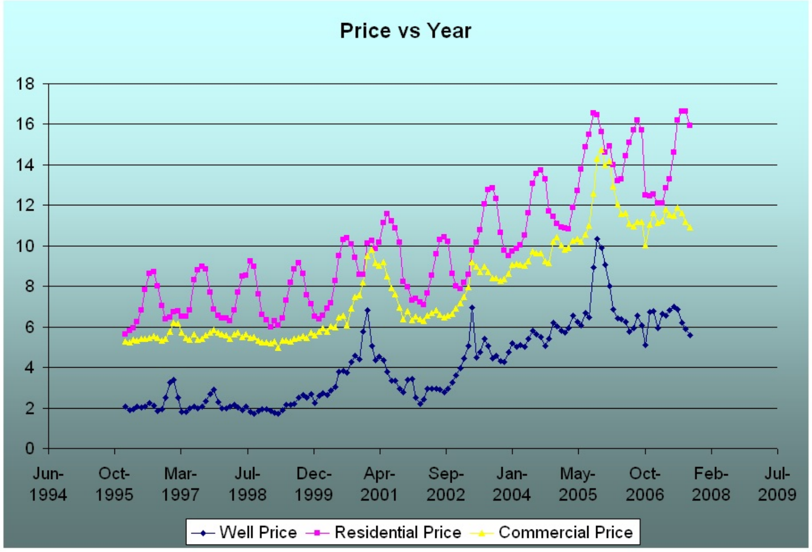
If the graph is changed to a Log Normal plot then the exponential appears as a straight line and the new intercepts can be seen to occur about 2030.



Which brings up the question: How low can EROI drop before we have serious issues with our natural gas supply?

How Low Can EROI Go?

Not down to 1:1. Look at this graph of natural gas prices. The well head price is much lower than the delivered price. Looking at the 1990 numbers, you can see that most of the cost was in distribution. By 2008 that had reversed and the largest cost was at the well head. Natural gas distribution uses significant amounts of natural gas for compression and storage.

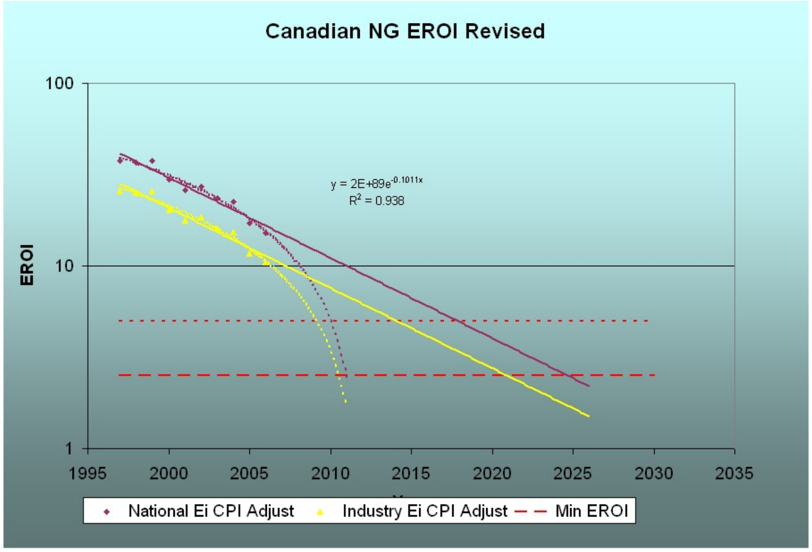


Estimating the EROI at the well head is just the first step in calculating the minimum EROI for a fuel source. For a residential consumer the distribution cost would at least double the energy input needed to get the fuel to the customer. This means a well head EROI of 2:1 sounds like it would be energy positive, but actually all the net energy surplus would be consumed in distribution and the residential customer would receive no heat. (Other types of customers have lower distribution costs).

After distribution, the energy cost of the furnaces or heating equipment must be added because it is vital to turn the natural gas into usable heat for the consumer. Again, this ratchets upwards the minimum EROI threshold.

There are many other uncounted energy drains in the natural gas production chain. A truly wide boundary analysis would include more of these indirect costs. Universities and colleges are needed to train the technical staff that oversee the whole production and distribution system. The road and transport system is vital to transport and maintain the natural gas infrastructure. If society stops paying any of these hidden energy costs, it would be impossible to maintain the natural gas production and distribution system. So a holistic analysis must set aside extra energy to account for these necessary expenses.

Thus we can place a very approximate lower bound for EROI somewhere between the absolute minimum of 2.5:1 up to possibly as high as 5:1.



This approximate lower bound leaves us with a serious natural gas net energy issue somewhere between 2013 and 2020.

Results and Discussion

Using this method, the EROI of Canadian natural gas production has dropped by nearly 50% in the last 10 years and is trending strongly downwards. The WCSB is clearly showing signs of depletion. A heroic effort by natural gas producers has held production relatively flat, but at a tremendous energy cost.

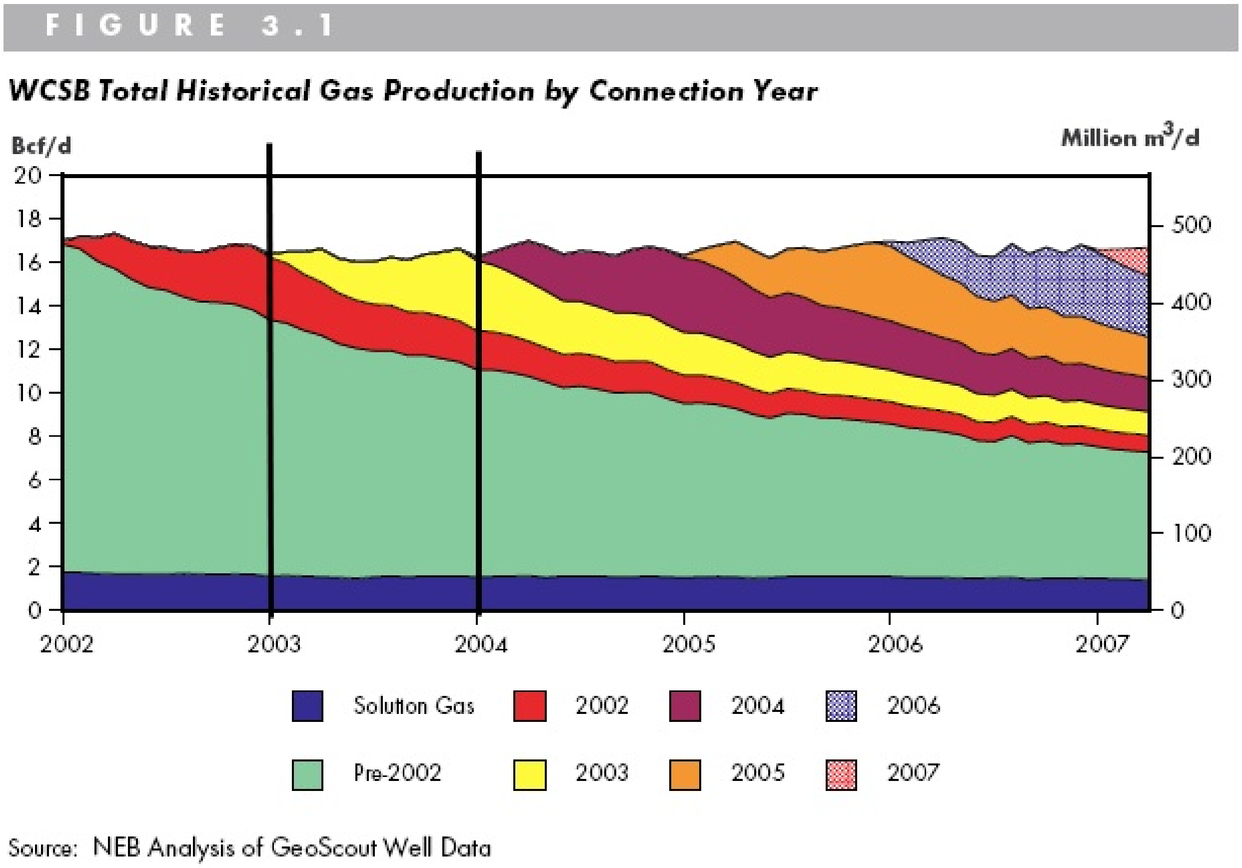
Depletion is fast outpacing drilling technology. It is possible that within the next 10 years Canada will no longer be a supplier of energy positive natural gas. (Again, they might still produce natural gas, but only by utilizing abundant lower quality energy inputs, if available.

Forecasts that show flat natural gas prices and flat or rising production are likely in error (Such as the EIA's AEO 2008). Either prices must rise to cover the rising production energy cost, or production must fall. And most probably, prices will rise at the same time production falls.

Appendix A. Estimating Natural Gas Production per Well

This section discusses a few details on how the Gj/$ dollar values were calculated by the NEB. The full details are in [NEB 2007] Appendix A & B.

This graph shows the problem with trying to calculate EROI for a given years drilling and producing activity. Take a look at year 2003 (Yellow). You can see that most of the gas production in the year 2003 was actually from prior years drilling (red and green and blue on the bottom). That means that the EROI calculation is going to be skewed by prior years drilling.



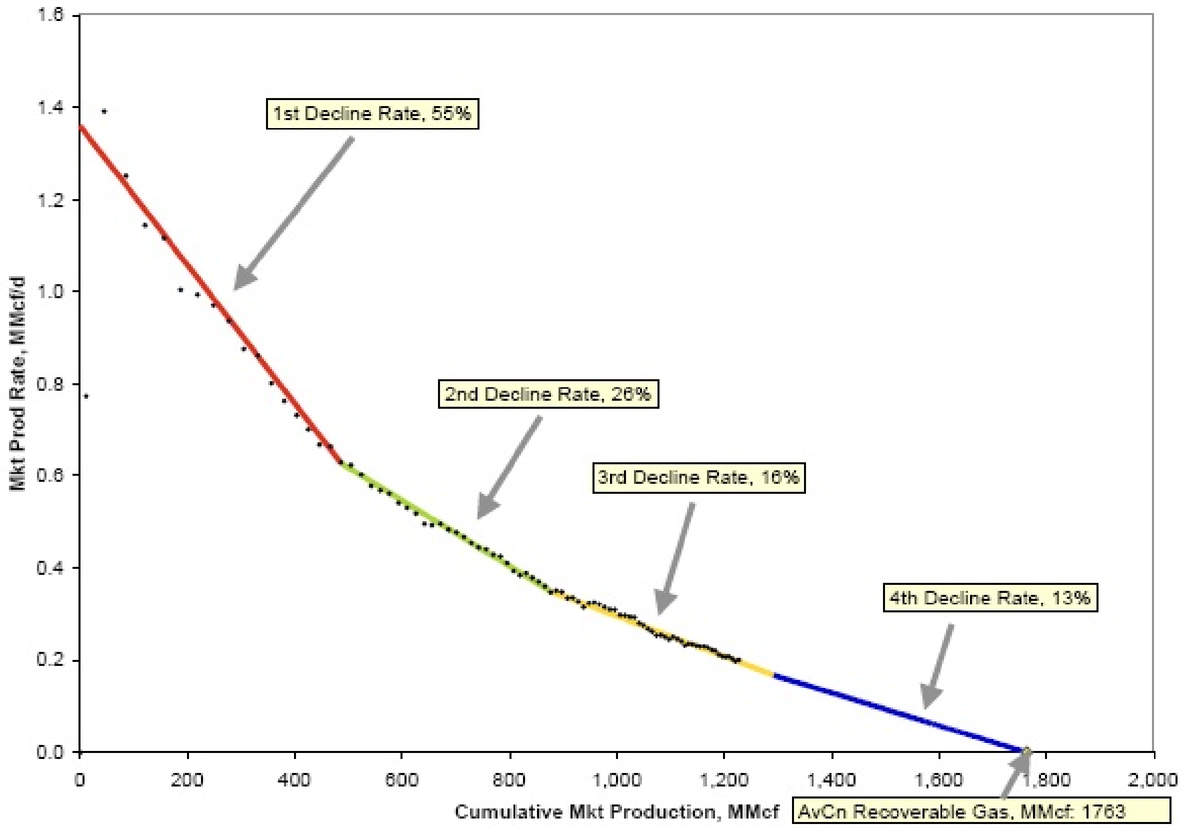
There are two ways to deal with this problem. The first is to just accept the error if there is no way to separate out new gas from old gas.

The second method is to separate out the production of each year (as the graph above does) and then estimate the future production of each years wells. Then calculate the EROI for each year using only the gas produced that year. (So take only the production costs for 2006 and only the natural gas produced from year 2006 vintage wells).

The future estimate of each year's production is done with a decline model. This next graph shows what a decline model looks like.

FIGURE B.1.2

Example of Average Connection Production Decline Analysis Plot, Conventional Gas Connections, Alberta Foothills Front, 1999 Connection Year



Source: NEB analysis of GeoScout well production data

There are several downward slopes and eventually production hits zero cubic feet of gas per day. The amount of gas produced is totaled up and the energy value of that gas is calculated. Then energy output is divided by the cost to drill the well and you get Gj/$.

Or would if there was data for every single well. In reality, lots of wells are averaged together (read the report for further details).

The NEB uses this decline model strategy to calculate Gj/$. And that is why we can see the EROI decline very quickly. It is not getting "muddied" by prior year's gas production.

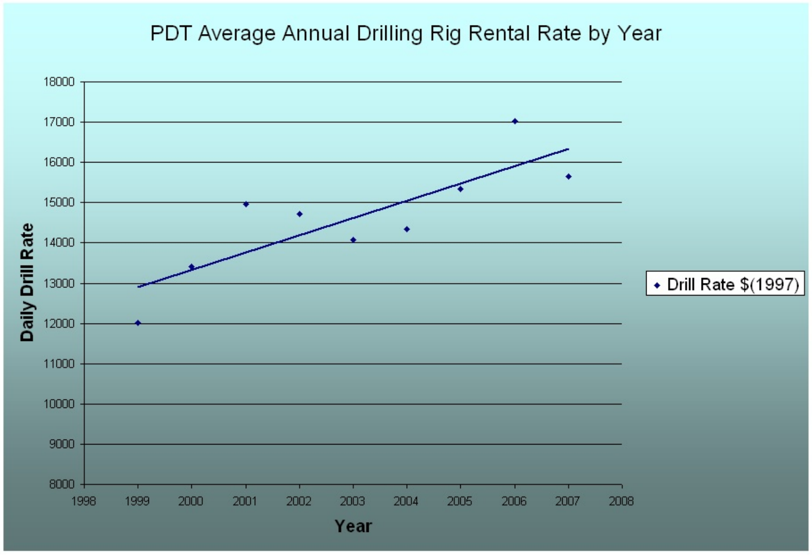
Appendix B. Real Demand Inflation

Inflation can cause drilling costs to rise and can look like falling EROI. That was corrected by using the CPI. However, during a period of high demand for drilling rigs, it is possible that companies bidding against each other (real demand) pushes prices up faster than the CPI.

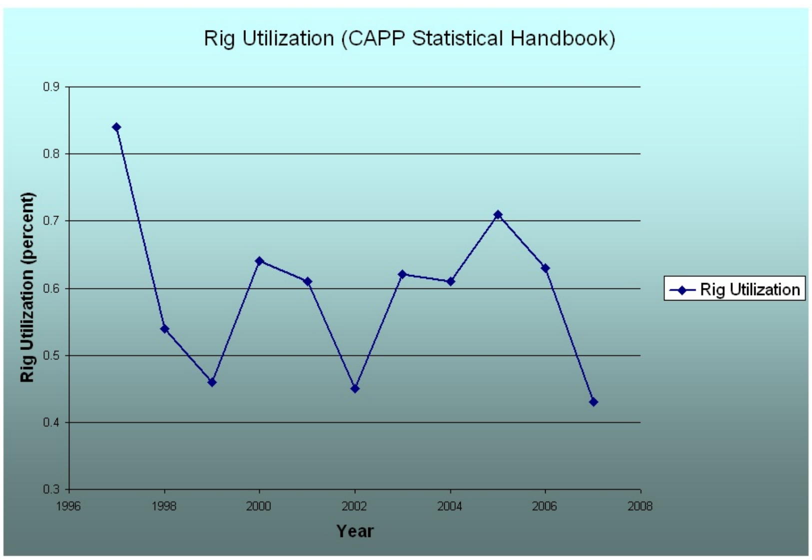
This brings up the question: Is Canadian EROI falling because energy inputs are rising or because demand for rigs and equipment is pushing up prices and it just looks like EROI is falling?

To try to answer this question, the daily rental cost for drilling rigs was taken from the annual reports of the Precision Drilling Trust (PDT). PDT operates a very large number of the rigs in Canada. It is assumed the costs they charge are a good proxy for all rig costs.

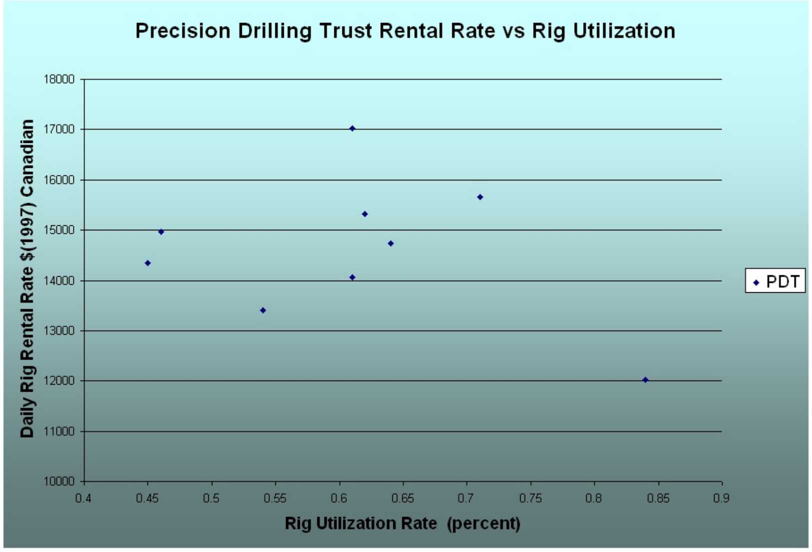
Charting the data from multiple annual reports and inflation correcting the prices shows that the cost of renting drilling rigs is trending upwards.



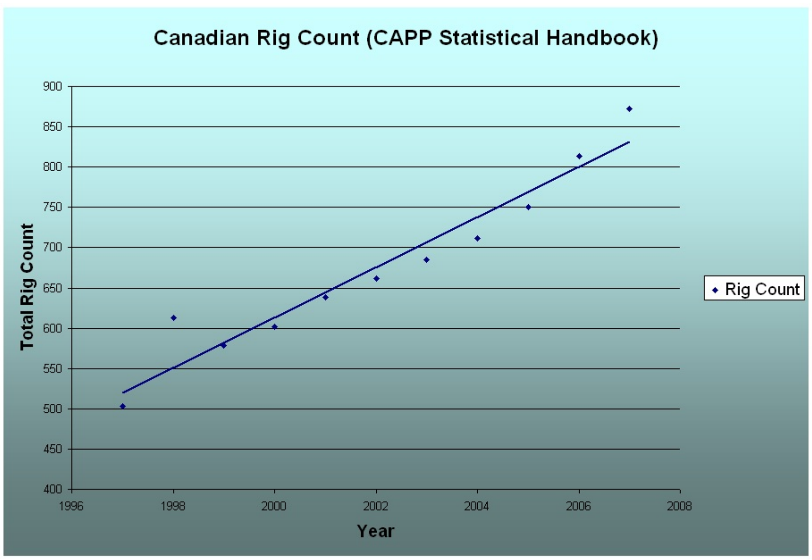
Rig utilization data shows that some years have a high demand and in other years the demand drops quite a bit.



We would expect that on years with high demand we would see much higher prices. And on years with low demand we would get much lower prices. However, this is not what we see. When rig rental rates are plotted against rig utilization, we see no correlation (we expected a line running from lower left to upper right). Instead we get data points scattered all around. Statistical analysis finds no correlation (regression p = 0.51).



If competition is not driving up the cost of rigs, then what might be the cause? One possible answer is that the number of rigs is increasing quickly and the cost of these new rigs must be paid for in drilling rental rates.



Increased capital expenses must be included in the EROI. Increased costs to pay for new drilling rigs are a valid inclusion.

The EROI drop does not appear to be caused by rig demand in Canada. However, further study should examine rig demand in the US. And further study should also examine other major inputs to drilling, such as steel and casing pipe. Another approach might be to look at the profits of major companies that supply drilling services. High profits are more indicative of real demand inflation.

TheOilDrum References

Biophysical analysis is important in a world of finite resources. We write often about net energy and EROI on this site, as it gives insights that might not be immediately seen by conventional dollar analysis.

Here are some selected historical posts on the topic:

Why EROI Matters (Part 1 of 6)
EROI on the Web part 2 of 6, (Provisional Results Summary, Imported Oil, Natural Gas)
At $100 Oil, What Can the Scientist Say to the Investor?
The Energy Return on Time
Peak Oil - Why Smart Folks Disagree - Part II
Ten Fundamental Truths about Net Energy
The North American Red Queen - Our Natural Gas Treadmill
Energy From Wind - A Discussion of the EROI Research
A Net Energy Parable - Why is EROI Important?
Natural Gas and Complacency

Other References

[NRC 2006] Canadian Natural Gas; Review of 2004 & Outlook to 2020", Natural Resources Canada, January 2006. pg 22.

[Hall 1979] C. Hall, M. Lavine, "Efficiency of Energy Delivery Systems:1. An Economic and Energy Analysis", Environmental Management, vol 3, no 6, pp 493-504, 1979 (First part of a 3 part article).

[Hall 1992] "Energy and Resource Quality: The ecology of the economic process", C. Hall, C Cleveland, R. Kaufmann, 1992, University Press of Colorado, pg 184-188.

[NEB 2006] Short-term Canadian Natural Gas Deliverability 2006-2008 National Energy Board, 2006,

[NEB 2007] Short-term Canadian Natural Gas Deliverability 2007-2009 National Energy Board, 2007, pg 8-9.

[Can Stat 2007] Statistics Canada

[BP 2007] BP Statistical Review of World Energy 2007

[EIA Feet] Energy Information Agency. Feet drilled in natural gas wells.

[EIA Wells] Energy Information Agency. Natural gas wells drilled.

[Capp 2007] Canadian Association of Petroleum Producers. Wells and Meters Drilled in Canada 1981-2006

[Capp Rigs 2007] Canadian Association of Petroleum Producers. Western Canada Rigs Drilling, Available Utilization Rate Annual Average 1977-2007

Author Note

This is a guest post by TOD reader Jon Freise. Jon is a software engineer living in Minneapolis, Minnesota USA and is a volunteer with the Twin Cities Energy Transition working group, seeking a path to a low carbon future. Jon can be reached at gmail [dot] com under the name grandpa [dot] trout.