North American Natural Gas Production and EROI Decline

Posted by Nate Hagens on February 27, 2008 - 9:40pm
Topic: Supply/Production
Tags: canada, canadian natural gas, charles hall, cutler cleveland, energy break even, eroei, eroi, jean laherrère, natural gas, net energy, robert costanza [list all tags]

This is a guest post by TOD reader Jon Friese. Jon is a software engineer living in Minneapolis and a volunteer with the Twin Cities Energy Transition working group, seeking a path to a low carbon future. Under his own initiative Jon tracked down literature on EROI methodology, contacted the Canadian Government and an energy consulting company for data, and came up with the following analysis on declining energy return on Canadian Gas. This draft analysis is provocative (backing into an EROI estimate using $/GJ suggesting possible energy break even for natural gas within a decade). However, in addition to the new info, I was inspired that a smart, engaged citizen chose to volunteer his time on the pressing issue of fossil fuel decline, and then shared it with others in the TOD forum for feedback. Thanks for your initiative here Jon.) ***(Editors Note: Jon is working on an update to this analysis incorporating feedback from the TOD community -please treat the information in this post as a work in progress.)***

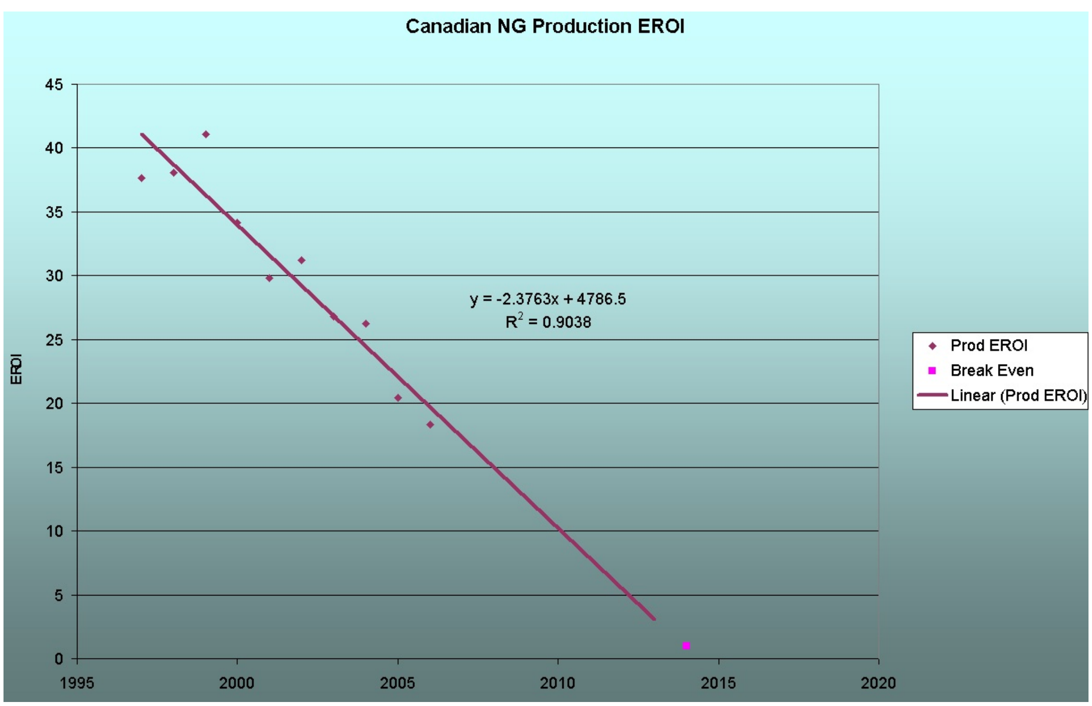


Figure 1 Canadian Natural Gas Energy Return on Investment, actual + trend line (Click to enlarge)

EROI at Theoildrum.com

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. In the coming weeks, Charles Hall (referenced in Johns report below) will be running a series of EROI articles on TOD, starting with "Why EROI is Important". Here are some selected historical posts on the topic:

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

And the following is Johns analysis on:

North American Natural Gas Production & EROI

Abstract

Creating an Energy Transition Plan away from natural gas requires at least a rough forecast of future production. Two very different forecasts for North American natural gas exist. The official “consensus” view published by Natural Resources Canada [NRC 2006] argues that 2,200 Tcf (trillion cubic feet) remain and that less than 50% of the total natural gas has been produced. Jean Laherrere has posted a forecast which shows only 600 Tcf (trillion cubic feet) remaining with about 70% already produced of the total supply of 1900 Tcf.

Energy Return on energy Invested (EROI) was explored as a method for choosing between the two forecasts. Examining a historical study of Louisiana natural gas production shows that EROI declined rapidly post peak production and that peak production occurred at about 70% of URR.

The EROI of Canadian natural gas production was found to be falling quickly. If current drilling rates are maintained, Canada could see energy break even occur as soon as 2014.

The EROI analysis was extended to the US by comparing data on Yield-per-foot drilled and Yield-per-well drilled between the two countries. It was found that the US is rapidly approaching the same low EROI as Canada.

Taken together this evidence supports Laherrere’s position that North America is past peak production and that as little as 30% of our natural gas endowment remains to be produced.

Two Forecasts

Coping with global warming or peak oil requires a reliable forecast for natural gas. Natural gas is a clean burning substitute for coal and oil. Natural gas is essential to ethanol and tar sands production. Much like world oil supply, the official forecast is that natural gas supply will be abundant for nearly a century. This view suffered a serious setback in 2001 when the US production peaked and again in 2003 when Canadian production peaked. The ASPO has put forward a more conservative forecast. These two forecasts are examined in more detail below.

The Official View

The official "consensus" forecast (an average of several government agencies) is that there will be an abundant supply of domestic natural gas at relatively low prices for many years to come. Here is a good summery of the official position:

"The total remaining US natural gas resource base, including proved reserves is 1,620Tcf. At 2004 levels of domestic production, the US has about an 86-year supply of natural gas." [NRC 2006, pg 23]

The reason for this optimistic forecast is clear when looking at the reserves and resources map below. 100+ years of extraction have not even consumed half of the natural gas that is expected to be produced.

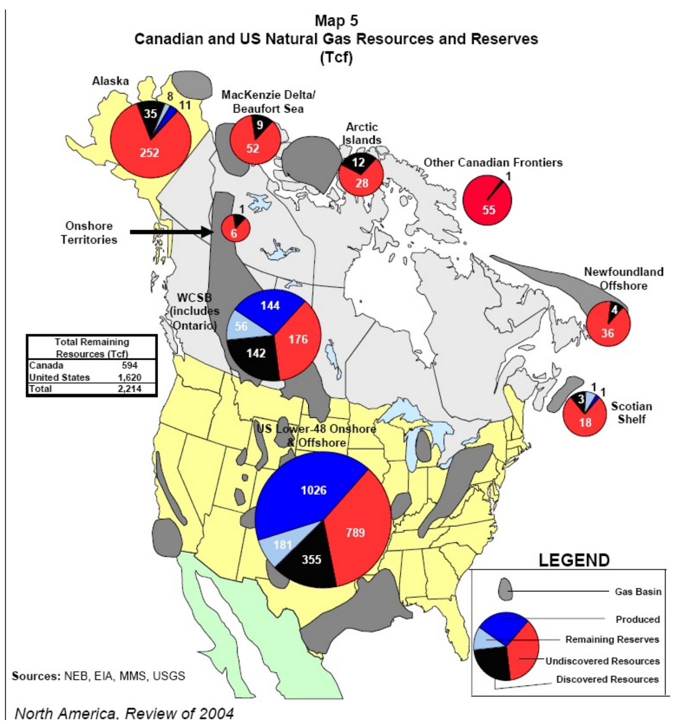


Figure 2 Official "Consensus" Resources and Reserves Forecast [NRC 2006, pg 22] (Click to enlarge)

Yet this position does not explain why natural gas production in both Canada and the US has peaked. Nor does it explain why large scale drilling campaigns have tripled prices while not bringing further production on line. If less than half the natural gas has been produced, then why cannot production rise?

The Alternate View

ASPO member Jean Laherrere is an internationally renowned expert in oil and gas exploration. He was in charge of Total Canada's exploration from 1966 to 1971. He has recently published a forecast for North American Natural Gas production [Laherrere 2007]. Here is his summary graph:

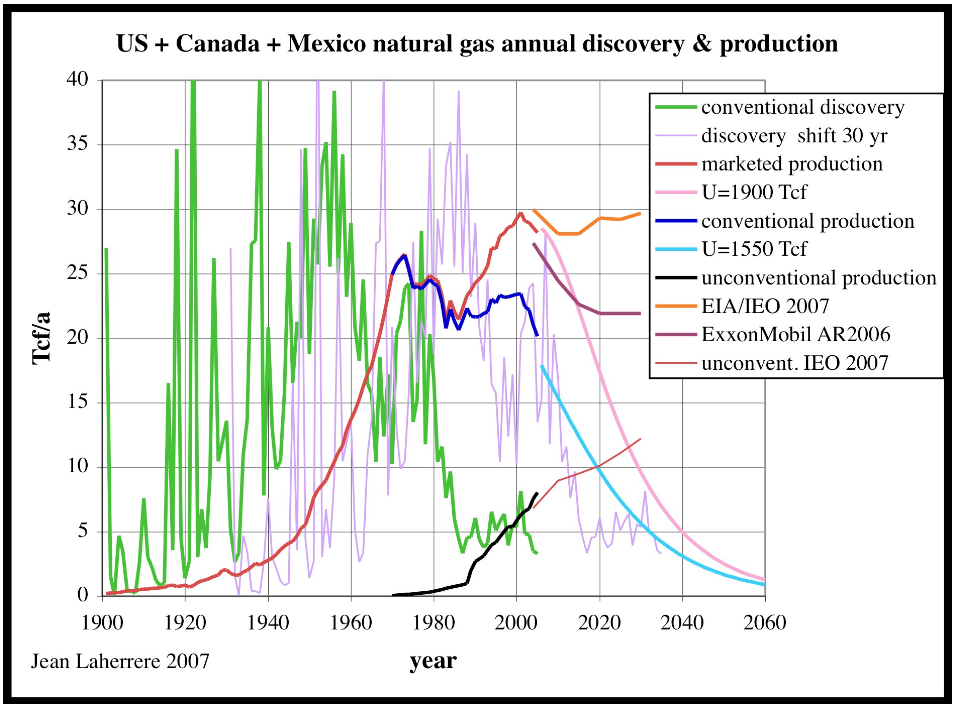


Figure 3 Laherrere's alternate forecast (Click to enlarge)

The first line to look for is the pink line that describes overall natural gas production (U=1900Tcf) and the second line to look for is the pale blue line that describes conventional natural gas production (U=1550). He has no difficulty explaining why production cannot be raised. It cannot be raised because North America has already produced 70% of the total natural gas that will ever be produced. Production has peaked and will now decline during the final 30%. In his forecast there will not be 86 years of production at current rates. Instead, in less than 50 years production will be a tiny fraction of current levels.

One of the many ways he supports his forecast is by plotting backdated discovery data against the number of exploratory wells to form what he calls a "creaming curve".

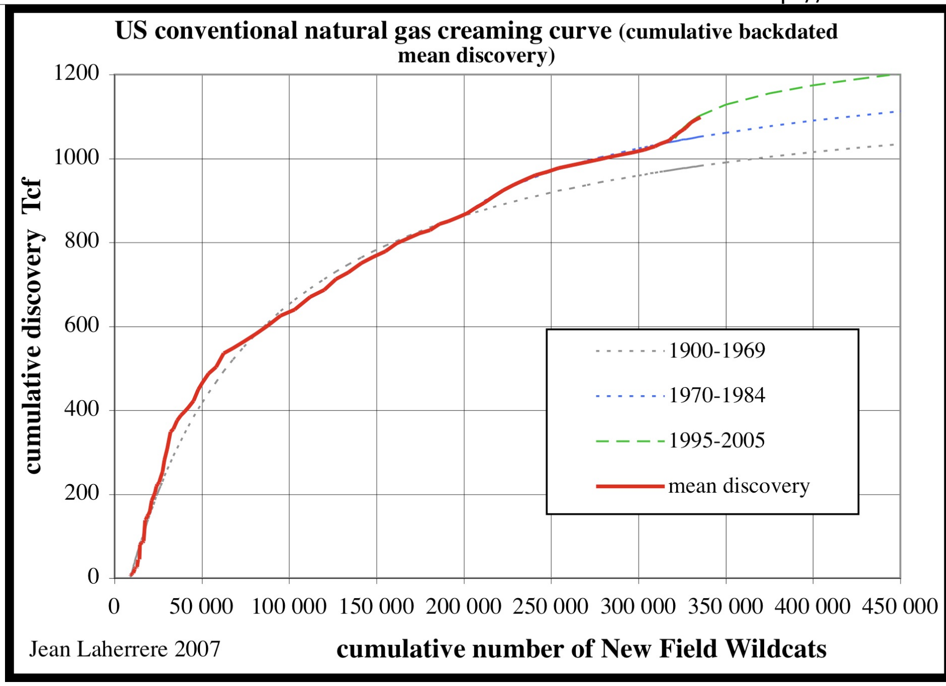


Figure 4 Creaming curve evidence (Source Jean LaHerrere) (Click to enlarge)

In a new region the first few exploration wells discovery a large amount of natural gas resulting in a steep upward curve. As most of the discoveries are made, each new exploration well discovers less gas, bending the curve downward until it points to the Ultimate along the right hand side. Looking at this creaming curve for the US it is hard to imagine that the curve could accommodate another 800 Tcf of new discovery that the official forecast predicts. A huge number of exploratory wells have already been drilled. The curve is already close to flat.

Economic Reserves and Energy Return

How is it possible that two forecasts made with similar data could reach such a different result? One reason hinges on the definition of “Economic Reserve”. There are vast quantities of non-conventional natural gas. But it is expensive to produce. At what drilling and operating cost do you draw the line between reserves that can be produced at a profit and non economic resources that never will be produced? Opinions can and do differ and this leads to very different forecasts. However, fuel sources have a clear boundary between the economic and non economic reserves. A fuel source must be produced with a positive Energy Return on energy Invested (EROI). An economy cannot spend more energy drilling for natural gas than the economy gets from the natural gas itself. At energy break even, fuel production will stop (unless it is subsidized by a lower quality fuel)

Calculating the EROI of current natural gas production would give another line of evidence. If EROI is steady or rising than the official forecast is likely correct and natural gas will be abundant. If the EROI is falling then we can assume that much of the official resources will never be economical and that production will continue to fall.

Louisiana Natural Gas

Cutler Cleveland and Robert Costanza did an EROI study of natural gas production in Louisiana [reported in Hall 1992]. That study calculated the EROI from early production, through peak, and into decline.

It is useful to stop and examine this historical production cycle and try to discern some patterns.

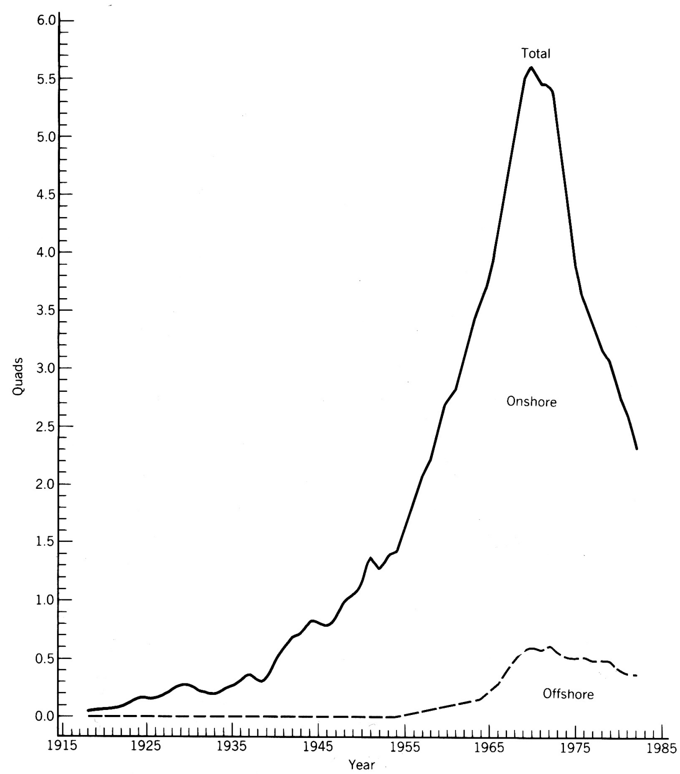


Figure 5 Louisiana Natural Gas production in Quads per year(Click to enlarge)

Cleveland and Costanza calculated the Energy Return on energy Invested (EROI) over the whole production cycle. The year that production fell off "plateau" was 1972 with a cumulative extraction of 150 Quads. 150 Quads corresponds to the first downward EROI point after the sharp rise. The next point over actually has a slight increase in EROI.

[Note: One can imagine an intensive drilling program to try to keep production on the plateau. When drilling finally slowed and yielded to the inevitable, EROI had a small uptick but production dropped. I cannot prove this conjecture because I do not have the well drilling data. But we will see similar bounces later in the current production data.]

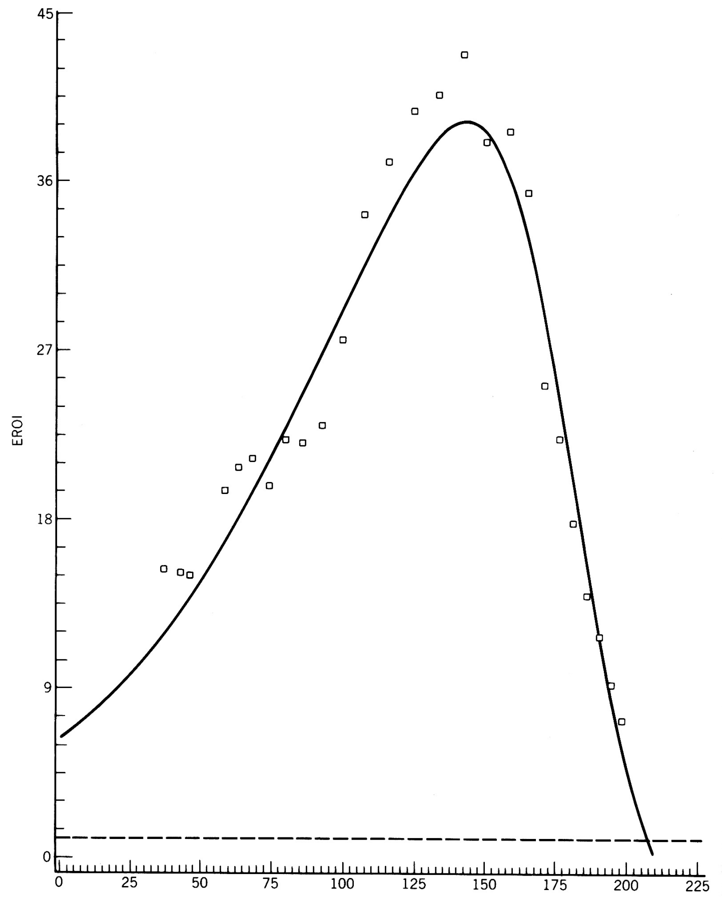


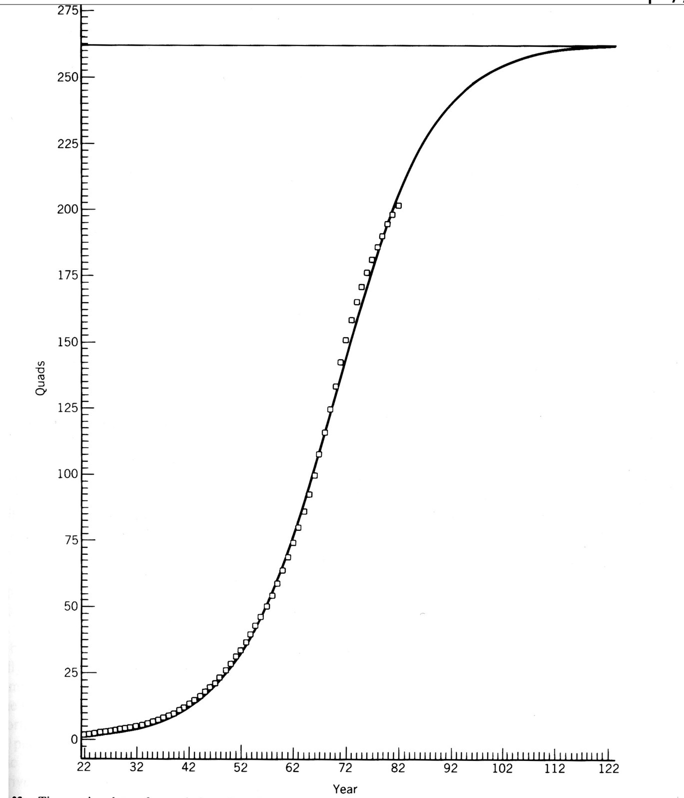
Figure 7.22. EROI for oil and gas extraction in Louisiana. The points are computed values for EROI. The curve represents curve to the data, extrapolated to the energy break even points (----). (From C. Cleveland and R. Costanza, 1983).

Figure 6 Louisiana Natural Gas EROI(Click to enlarge)

Please note the following: First is that the maximum EROI is in the 40 to 1 range (which will be important later).

Second is that the EROI decline rate is quite steep and it is very linear. The EROI plunges from maximum to minimum in only 25% of the quads extracted.

Third is that energy break even (where EROI = 1:1) happens far before a 300 quad URR. It is normally assumed that peak happens at 50% URR, but in this case, the energy return would end up skewing the graph so that peak appeared at 150/210 = 70%. (Sound familiar?)



.23. Time-series data of cumulative oil and gas extraction in Louisiana fitted to the logistic growth equation. (From a and C. Cleveland, 1983. Final Report to Center for Energy Studies, Louisiana State University, CES 85-01-20, under U ent of Energy Grant No. DEFG 058 OER 10197.)

Figure 7 Cumulative quads versus year(Click to enlarge)

This final graph plots cumulative quads against years. It follows the classic Logistic shape. The logistic is pointing to a URR of ~260, but the EROI graph is saying there will not be a positive energy return past ~210. This graph can be used to convert from years to quads for matching up data points on the two prior graphs.

Summarizing this historical example:

1. EROI peaked around 40:1

2. Production peaks at about 70% of total extraction.

3. EROI declines sharply past peak.

4. The steep EROI decline indicates extraction is in the final 25%.

Canadian Natural Gas EROI

There are several techniques for calculating Energy Return on energy Invested when you only have cost data in dollars. Charles Hall describes one technique [Hall 1979] where the energy content of each dollar is calculated in the following manner:

Energy content per $ = National Energy Use / GDP.

The EROI of natural gas production can then be calculated by

EROI = Energy output of total NG / ($ cost of NG production * Energy *associated with spending* *of a $*)

The Canadian National Energy Board (NEB) publishes the “Short-term Canadian Natural Gas Deliverability” report. In the 2007-2009 edition they provide data on how many Canadian $ are required to produce 1 Giga Joule of natural gas. [NEB 2007] The Canadian NEB calculated $/Gj in a special way that only includes new gas produced. What they did was use decline models of each type of well in each region. And then they totaled up the number of new wells in a year of each type. They used the decline model to predict exactly how much gas would be produced from those new wells (long term).

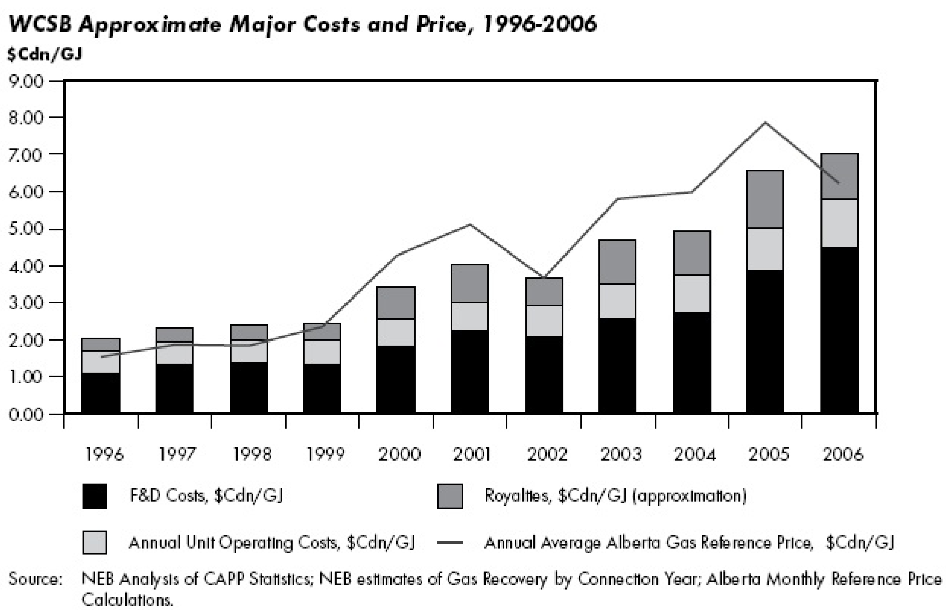


Figure 8 National Energy Board cost per Gigajoule (Click to enlarge)

There are several features of this graph worth noticing. The first is that drilling costs have overshot prices, despite a 3x increase in price. The second is that Finding and Discovery (F&D) costs show the largest increase. It is getting harder and harder to find natural gas. These are both certain signs of falling EROI. Royalties are not counted in the following EROI calculations.

Using the NEB data simplifies our EROI formula:

EROI = 1 Gj / ($ drilling cost * Gj/dollar)

As the NRB data provides the “$ drilling cost” term, the next step is to calculate the energy value of each Canadian $. That value is estimated by taking the Canadian GDP for each year and dividing by the total energy used by Canada in that year. The GDP data was taken from the Canadian Government web site Statistics Canada. The data for GDP Expenditures in Current $ was selected (mostly because I know of no reason to prefer one data series to another for this type of calculation). [Can Stats 2007] The total energy use data was taken from the 2007 BP Statistical Review of World Energy [BP 2007]. The review provides a “Primary Energy per annum” that sums all energy sources. The resulting sum is in Mtoe (Millions of tons of oil equivalent).

Here are the values from 2006 to help understand the calculation:

GDP = $1.44e12
Primary Energy = 322e6 Mtoe
Gj/$ = 9.4e-3

EROI = 1 Gj/(5.79*9.4e-3) = 18

EROI Results

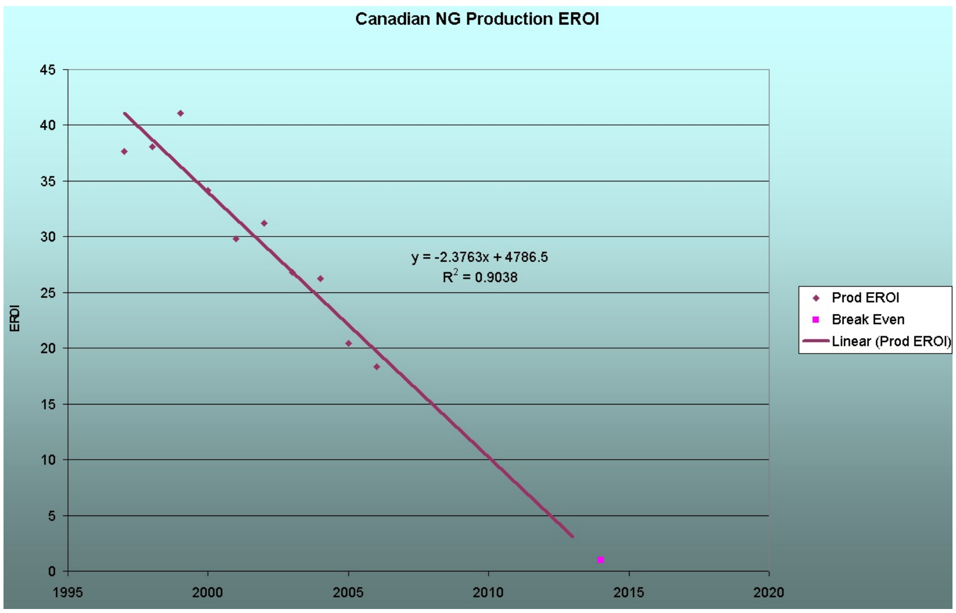


Figure 9 Canadian Natural Gas EROI 1996-2006(Click to enlarge)

The results are quite dramatic. EROI is dropping very quickly. If high drilling rates are maintained, costs will rocket upwards and EROI could hit break even by 2014. If drilling rates fall, then production will fall. Either way Canadian production will come off plateau and go into decline.

The Louisiana historical example offers some guidance. The EROI peaks are roughly the same 40:1. The decline in EROI is rapid and linear. It is safe to conclude that Canadian production is in the final 25%. This lends support to Laherrere's forecast.

Extending the Analysis to the US

The same analysis cannot be done for the US because the EIA does not provide an estimate of the underlying decline rate or the $ per GJ production cost. It is possible to make a rough approximation but this part of the post is more speculative. *(Editors note - I am attempting to get some of this type of data form the API (American Petroleum Institute) - I am told it is quite expensive but am still trying - such data may be able to replicate and advance Johns Canadian analysis)*

Production per Well Foot Drilled

Most of the production cost is drilling related and there are drilling statistics for both countries [EIA Foot][Capp 2007]. Figure 10 shows the yearly production divided by the number of feet drilled that year. This is only a rough approximation of Yield per Effort because production is mostly from prior years drilling. A clear trend down is visible in both the US and Canada. More and more drilling is yielding less and less production. This is a sure sign of dropping EROI.

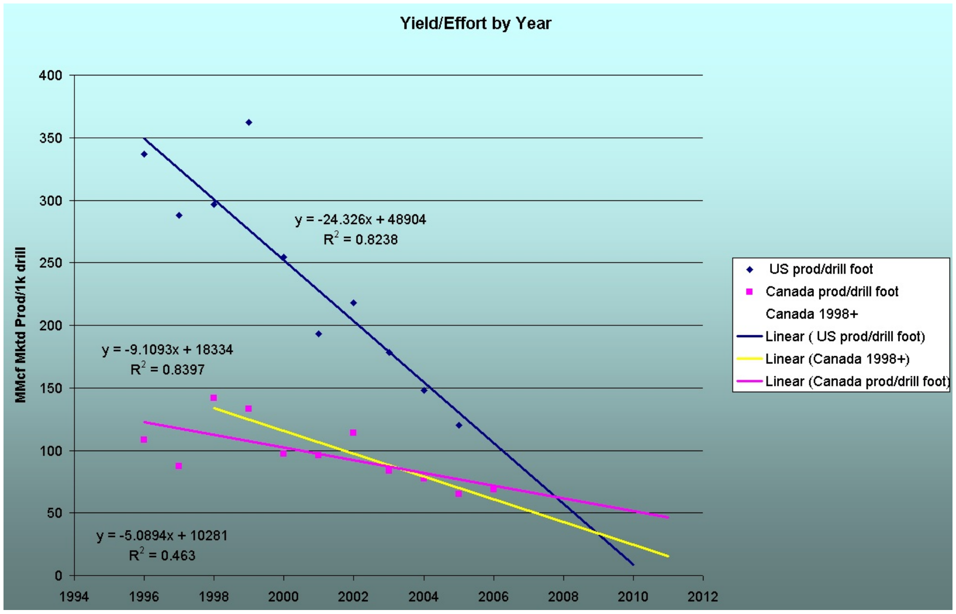


Figure 10 US & Canadian Production per well foot drilled (Click to enlarge)

Canadian Yield-per-foot drilled is lower than the US. However in the last few years the US has fallen into the Canadian area and the slope is very steep. That steep slope will soon cross the Canadian trend lines. It is safe to assume the US EROI values are falling as fast or close behind the Canadian EROI. There are two regressions for the Canadian data. The yellow regression discards the first two years as outliers to get a better fit. The yellow regression shows a steeper slope that would cross the zero point at approximately the same location as the Canadian EROI graph hits break even.

Production per Well Drilled

Another way to look at Yield per Effort is to examine Yield-per-well instead of Yield-per-foot drilled [EIA Well][Capp 2007]. In Figure 11 Canadian production is divided by the number of wells drilled. The trend is downward as expected, but the fit is poor. The trend line begins to approach zero production per well around 2016.

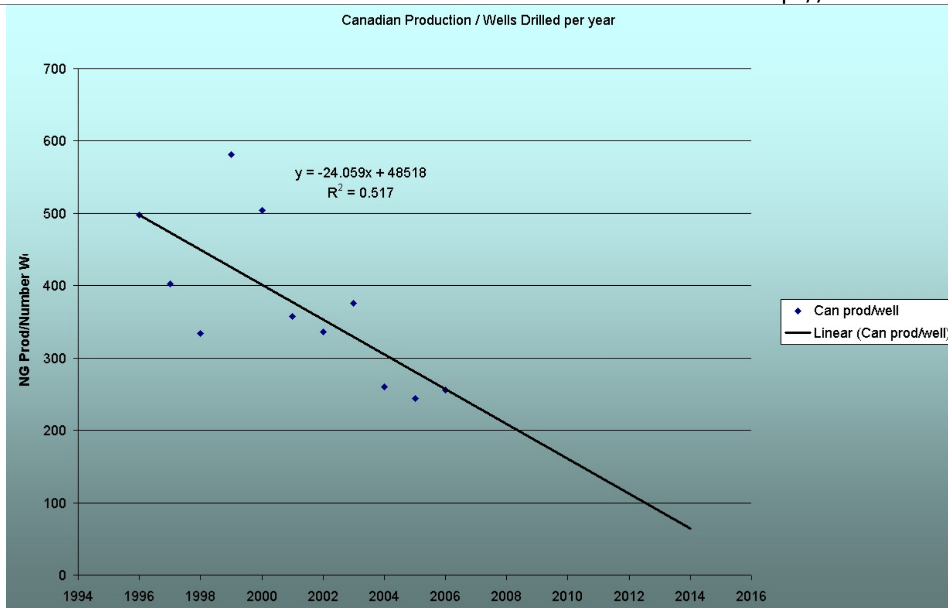


Figure 11 Canadian Production per well (Click to enlarge)

Figure 12 shows that US production per well begins much higher (which is why the data is plotted separately). The trend is downward and at a steeper rate than the Canadian trend. The US data in 2006 is just entering the region where the Canadian production was in the late 1990's.

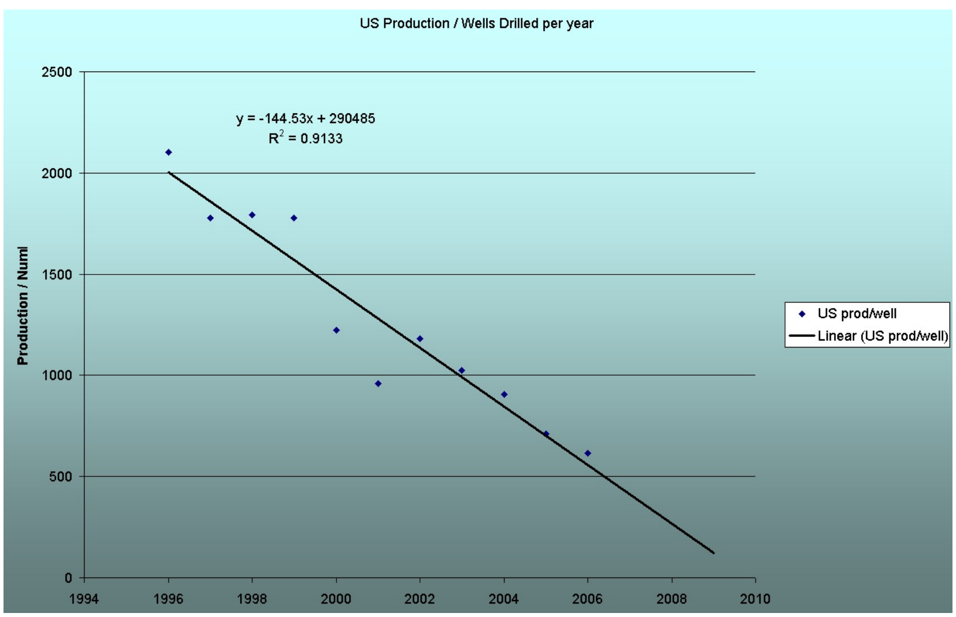


Figure 12 US Production per well(Click to enlarge)

US Notes

Overall the US seems to be entering the same steep EROI decline Canada is facing. The US seems to be slightly behind Canada in EROI decline, however the US has a huge number of producing wells and this may be skewing the productivity results. We do know that the US peaked prior to

Canada.

Conclusion

The natural gas industry has clearly been mounting a heroic effort to keep natural gas production on plateau in North America. This effort has raised costs dramatically. The EROI of Canadian production shows a rapid decline. Drilling statistics suggest a similar EROI decline is happening in the US. The falling EROI makes it impossible for natural gas production to maintain both low costs and current levels of production. It is clear that most of the reserves in the official forecast will never be developed. Jean Laherrere's predictions are more likely to be correct. And if EROI continues to fall at the current rapid rate, he will be remembered as an optimist.

References

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[NEB] Link to Appendix of National Energy Board Calculations and Methodology used in this analysis
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[BP 2007] BP Statistical Review of World Energy 2007
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[Capp 2007] Canadian Association of Petroleum Producers. "Wells and Meters Drilled in Canada 1981-2006"
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