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The Energy Return of Norwegian Oil and Gas Production

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This is a guest post by Leena Grandell, an independent energy analyst from Norway. Her research summarized in this post was carried out in collaboration with Charles Hall from New York State University and Mikael Hook from Uppsala University, and published in the journal Sustainability.

Norway is one of the few petroleum producing countries where data on the production details is abundant and to a large degree public. Even statistical data on energy consumption of the petroleum industry is available on an annual basis – which allows us to take a closer look at the evolution of Energy Return on Energy Invested (EROI) for Norwegian petroleum production. The following text is a short version of our EROI analysis published through Sustainability. Here we assume that the reader is familiar with the EROI concept. More details and theoretical background can be found in the original article, downloadable at http://www.mdpi.com/2071-1050/3/11/2050/.

EROI is a tool used in net energy analysis. EROI is a simple way to examine the quality of an energy resource. What really matters to our economies is the net energy flow (not the gross) provided by our energy sector and this can be estimated through the EROI approach. EROI is calculated from the following simple equation, although the devil is in the details:

$$\text{EROI} = \frac{\text{Energy returned to society}}{\text{Energy required to get that energy}}$$

Energy Outputs

Calculating energy output is easy because of the availability and organization of the data in national database. We calculated the energy output of all petroleum components (oil, gas, condensate, NGL) from all oil and gas fields based on raw data. The data was kindly supplied on a private basis by the Norwegian Petroleum Directorate. Also data on oil and gas field investments was used from the Norwegian Statistics Bureau.

Energy Inputs

In our analysis we have taken into account both direct energy consumption on site as well as indirect energy consumption in form of materials used for the production

On site energy consumption

Normally, energy companies use natural gas as much as possible in the fields since oil is more valuable. We were able to derive energy inputs used on-site (*i.e.*, at the platforms) from two different sources:

1. The first energy input is fuel consumed for all other aspects of petroleum production except drilling. The data covers only the fuel (gas and diesel) consumed for petroleum production (*i.e.*, energy used to pump products or pressurize fields) but not the energy consumed in drilling. The data is compiled and given to us by the Norwegian Petroleum Directorate, NPD.
2. Energy used to drill wells. The NPD data base provides the fuel consumption for petroleum production, but not the energy used to drill wells. Thus we need to know the direct fuel consumption for both exploratory and production drilling activities. For this purpose we use investment data in monetary terms published by Statistics Norway. The data is very detailed, including also direct fuel consumption for drilling purposes, in monetary terms. We divided monetary investments for fuels by average fuel prices paid by Norwegian industry to give fuel consumption for drilling in physical units.

Indirect Energy

The calculation of indirect energy is an attempt to estimate the energy consumption of materials, services *etc*. related to petroleum production by deriving the energy intensity (energy used per dollar or Krone) of an activity for which there is financial data. An estimate (4.01MJ/$) for the energy intensity of the Norwegian economy as a whole was calculated based on the Norwegian GDP and the primary energy consumption of the Norwegian economy.

Estimates for the indirect energy associated with the purchases by the petroleum sector were derived based on comprehensive investment data provided by Statistics Norway. The statistics give detailed information on commodities, services, administrative costs and drilling activities. We excluded the investments needed for fuel (which we had calculated independently). The costs given in current value were inflation-adjusted to 2005 and converted to US dollars (6.445 NOK/US$, average exchange rate for 2005).

The following figure adds all energy components(both direct and indirect also called embodied energy) together.

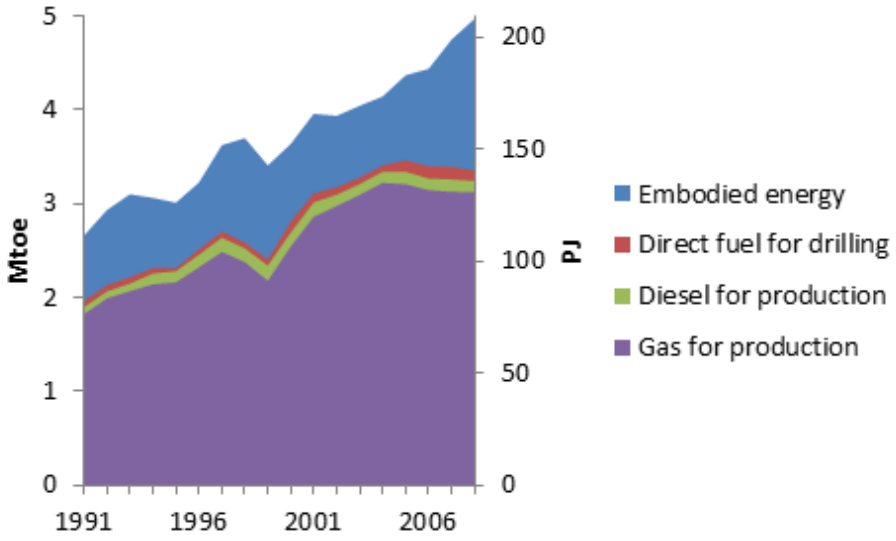

Figure 1: *Energy cost of producing petroleum in Norway.*

Results

We found that the energy return on energy Investment (EROI) for Norwegian petroleum production ranged from 44:1 in the early 1990s to a maximum of 59:1 in 1996, to about 40:1 in

the latter half of last decade. The curve basically follows, and is dependent upon, the pattern of production over time (peak in oil production was in 2000 and peak in total petroleum production was in 2004). Approximately 74% of the energy cost is due to direct fuel consumption in production (*i.e.,* pressurizing fields, lifting oil and so on), 2% is due to direct fuel consumption for drilling (including both exploratory and production drilling). The remaining 24% of energy cost is energy used indirectly in generating the needed infrastructure and services.

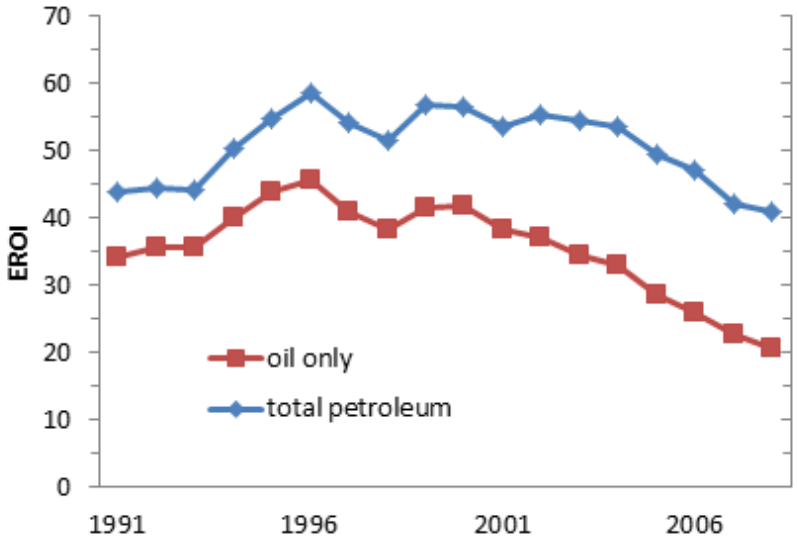

Figure 2. *EROI of the Norwegian petroleum production and of oil production only.*

EROI values for oil alone varied from 46:1 in 1996 to around 20:1 in recent years. In terms of production, these values only take oil into account (they exclude gas, NGL and condensate). On the consumption side, however, it covers the whole energy consumption of the petroleum industry.

Discussion

These EROI values for Norwegian oil and gas reflect the very high quality of the North Sea oil fields, their high profitability, their newness and the impact of the high level of technology and human skills used. There are few oil and gas resources today with such a favorable EROI. Like all petroleum-based wealth, Norway's present high living standard is likely to be a passing phenomenon, unless the country's wealth is prudently invested, financially and physically.

What are the reasons for the decline in the EROI estimates, especially since 1999? Probably the most important factor is that it appears that depletion is a somewhat more powerful force than technological improvement. A second effect is that of drilling intensity presented in figure 3. Previous studies have shown that exploitation efficiency in the petroleum industry declines when exploitation intensity increases. The integrated effects of depletion and variable drilling effort may also explain much of the variability in both the US and the global data. This data shows both a general secular decline over the entire period analyzed and a flattening or even an increase in EROI during periods of reduced drilling effort and a reduction during times of intense drilling.

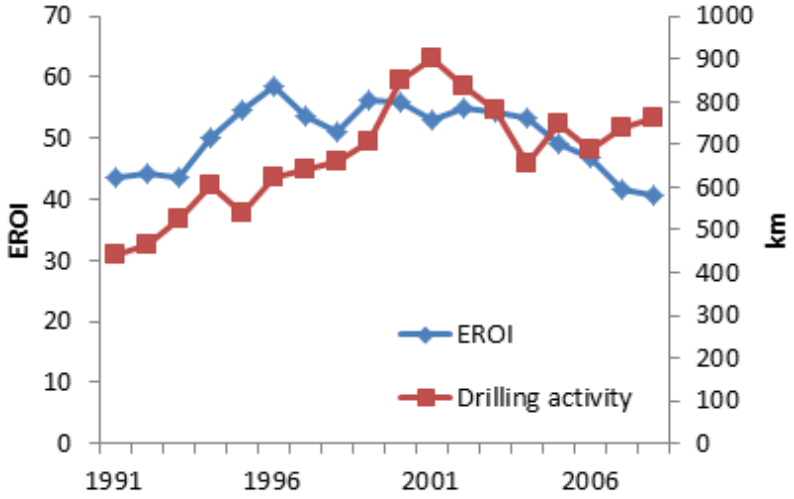

Figure 3: *EROI and drilling intensity.*

When looking closer at the Norwegian data, it seems that changes in EROI are mostly due to field age. However changes in drilling activity could also have a small impact on the calculated EROI values. Linear curves fitted to the data show that, since 2003, years with higher drilling activity lead to a slightly lower value of EROI whereas years with higher drilling activity lead to somewhat lower values of EROI.

The overwhelming share of the energy expenditures in the oil and gas sector is due to production. Drilling activity uses only 2–4% of total direct fuel consumption of the industry. However, 23–54% of investments are caused by drilling activity, which means that a similar share of the indirect energy can be attributed to drilling. This way the share of drilling activity in the total energy cost (both direct and embodied energy) of the sector varies between 7–17%.

Between 1999 and 2001 there was an almost 30% increase in drilling activity and, in the same timeframe, a small decline in EROI. This increased drilling intensity may be the cause of a decline in EROI, and may not result in as much additional net energy delivered to society as would initially seem to be the case. The subsequent decline in drilling activity in 2001 to 2004 may have helped the EROI to increase again. Since 2003, the drilling activity has been oscillating between 700 and 800 km annually whereas EROI declined steadily by 25% from 2003 to 2008. It is most likely that this decline was caused by field depletion and it may continue as the Norwegian oil and gas fields continue to age. A recent announcement by the Norwegian Petroleum Directory to enhance recovery in mature fields could further deteriorate EROI of the Norwegian oil and gas production, since it requires often very energy intensive techniques such as nitrogen or CO_2 injection.