The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The financial return on energy invested

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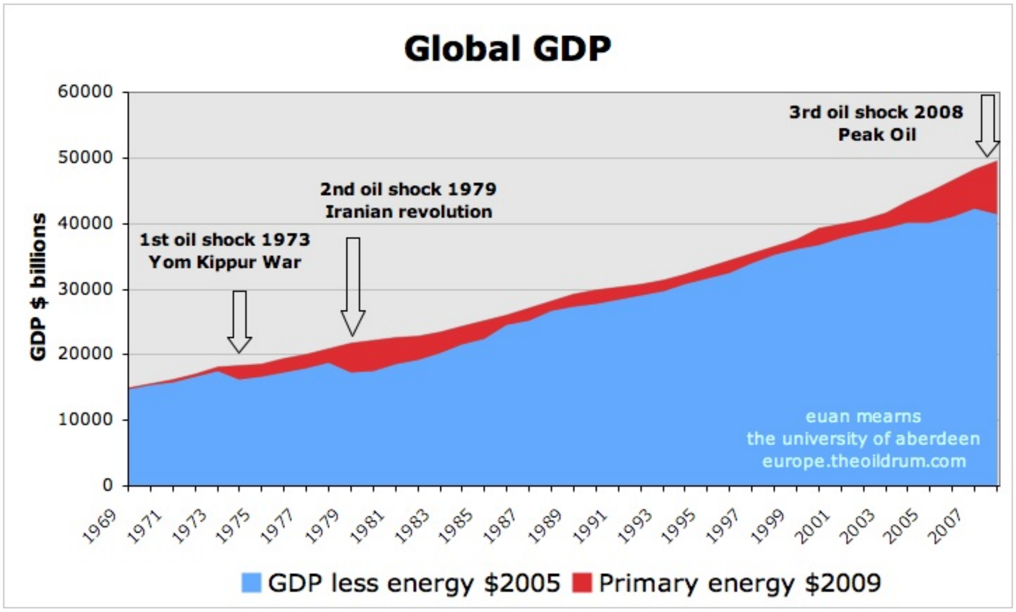


Global GDP data from the USDA. Primary energy data and energy prices from the BP statistical reveiw of world energy 2009.

Global GDP has grown steadily and continuously since WWII, in step with a growing global population and primary energy consumption (see below). Oil shocks have caused recessions compensated by higher energy prices that have bolstered global GDP at time of recession in the non-energy economy.

A number of recent posts on The Oil Drum have explored the relationship between energy and the economy. Francois Cellier provided an overview of links between **energy consumption and GDP on a per capita basis**. This post will expand on the work of Francois taking a somewhat different approach. In a guest post, Ian Schindler provided an overview of the **Ayres-Warr model of economic production** which I found easier to read and understand than the original Ayres-Warr paper. Ian made some valuable points about the role of energy efficiency in promoting higher prices and higher energy production. David Murphy looked at the relationship between **oil prices and rates of oil price change in relation to US GDP and growth** whilst drawing attention to the view that the current recession was in part caused by high oil prices.

In this post I want to explore further links between energy consumption, GDP and energy prices. But first a quick note on data limitations.

GDP data are taken from the **US Department of Agriculture** who provide historic data for all countries dating from 1969 based in 2005 $US (table titled: GDP Shares by Country and Region Historical).

Energy data and prices are taken from the **2009 BP statistical review of world energy**. Primary energy consumption = coal+oil+natural gas+nuclear+hydro, all re-based in millions of tonnes oil equivalent (mmtoe). A $ value is attached to total primary energy consumption using the historic oil price data provided by BP which are based in 2009 $US. Clearly coal, natural gas and other energy sources should not be priced as if they were oil so this is a gross simplification. It would be a major task to provide true energy costs since there are huge regional variations in the price of coal and natural gas. Using the oil price provides an approximation that likely over estimates the real price.

Furthermore, using raw energy prices does not provide the full cost of energy to society since much of the energy consumed is processed and costs society significantly more; for example gasoline and electricity, and this will lead to an under estimation of real costs.

These two major sources of error will therefore to a degree cancel each other and this imperfect exercise does I believe provide some interesting trends that are useful in conceptualising the role of energy in the global economy.

Energy consumption and GDP

Figure 1 shows how global GDP has marched upwards since 1969 in lock step with global energy consumption. This trend also correlates with growing global population and in simple terms global economic activity has grown with growing population, a larger percentage of the global population participating in economic activity and all of this requires a growing amount of energy use.

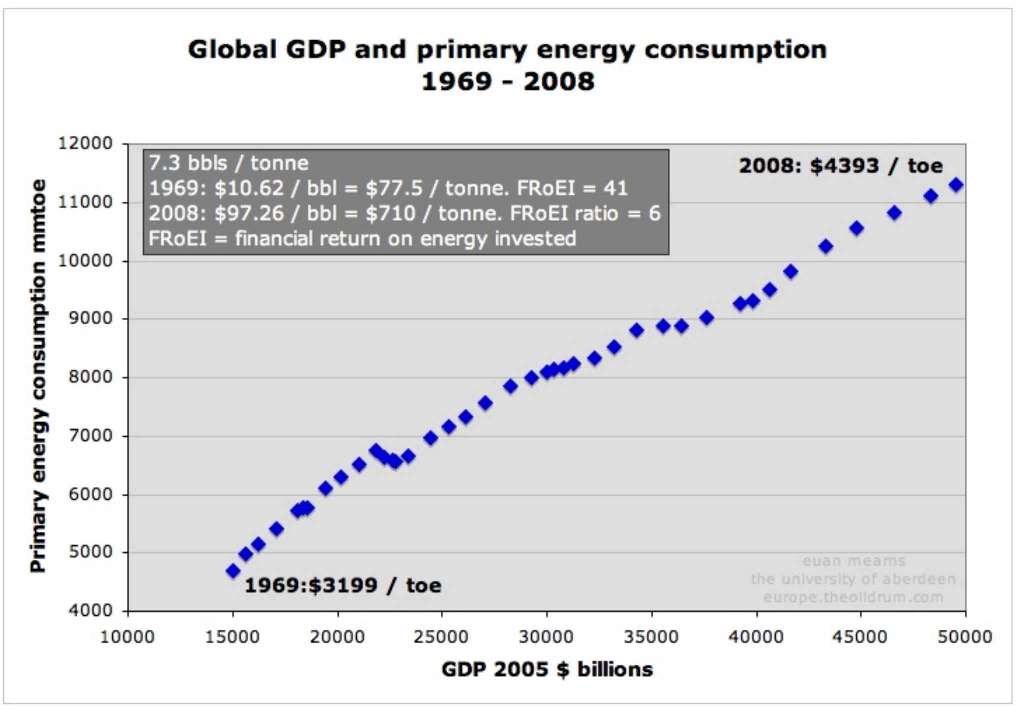


***Figure 1** Correlation between global GDP and primary energy consumption in millions tonnes oil equivalent (mmtoe). Primary energy = coal+oil+gas+nuclear+hydro; data from the 2009 BP statistical review of world energy. Global GDP data from the USDA, "GDP Shares by Country and Region Historical". FRoEI = Financial return on Energy Invested (see below for further explanation). Click charts to enlarge.*

The trend is not linear owing to two factors:

1 Energy efficiency gains
2 Phantom GDP (which is discussed below)

The energy - GDP trends for individual countries (Figure 2) are also affected by the energy embedded in imported / exported manufactured goods.

The apparent growth in GDP/TOE from $3199 in 1969 to $4393 in 2008 may be attributed to efficiency gains and phantom GDP.

Energy - GDP national trends

The simple picture of looking at energy and GDP on a global scale (Figure 1) masks significant complexity at national scales. The GDP - energy trends are plotted for a number of key countries and federations in Figure 2 which shows vast disparities between countries. For example, China appears to be using over 4 times the amount of energy as Japan to produce similar GDP.

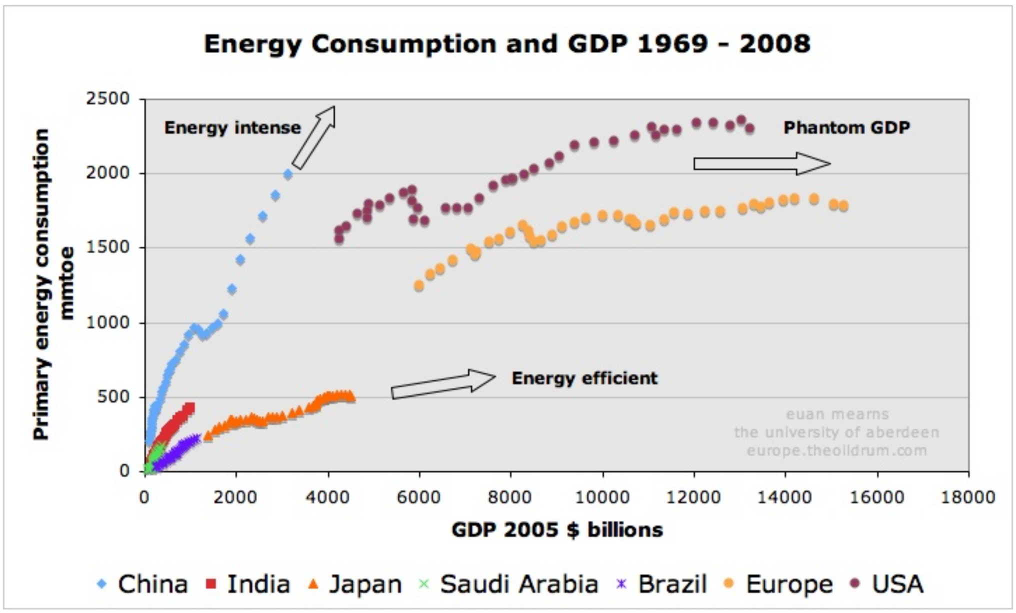


Figure 2 *GDP - energy trajectories for key countries and federations. Europe = 25 countries making up W and E Europe, some small countries excluded. Data sources as before.*

The trends are influenced by population size and demographics; the type of economy; trade balances; endowments of natural resources including food production; the % of population involved in economic activity; climate; global power position etc.

Indutrialising China is on an energy intense trajectory whilst the "post-industrial" mature economies of Europe and the USA appear to be on energy efficient trajectories. This, however, is oversimplified. The flattening of the European and US trends introduces the possibility that GDP may be generated without increasing energy use. To an extent energy efficiency may allow this to happen (Figure 3). However, the mature economies benefit from generating GDP from imported goods, which has also caused growth in unsustainable trade imbalances (Figure 3). The energy embedded in these goods should rightly be added to the importing countries and deducted from the exporting countries to present a true picture. This is averaged out in the global view. The mature economies also benefit from phantom GDP which is described below.

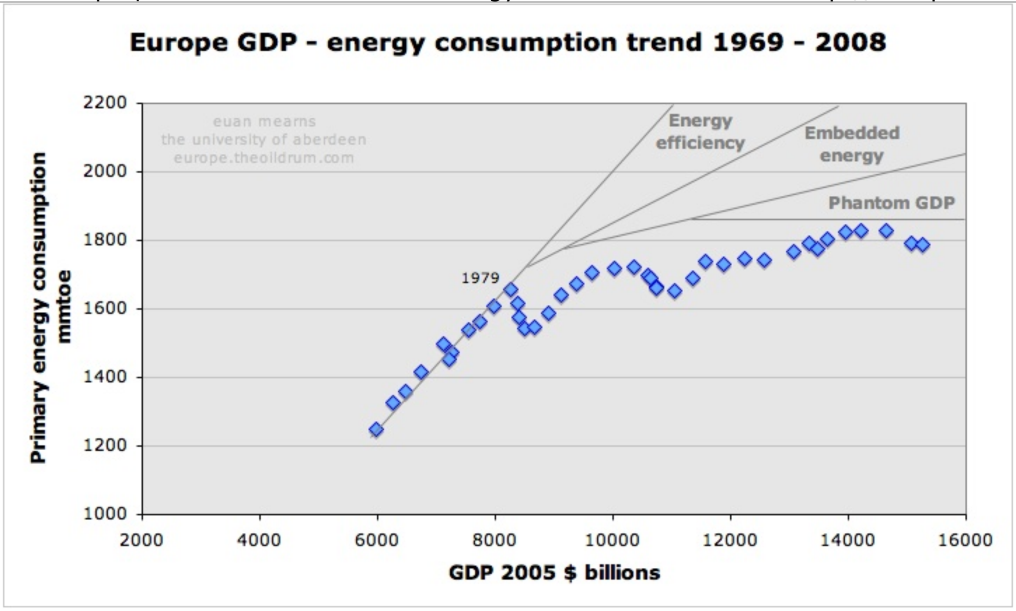


Figure 3 *GDP - energy trend for Europe illustrating conceptually how the trend may flatten by the action of energy efficiency, energy embedded in imported goods and from phantom GDP.*

Phantom GDP

Phantom GDP as the name implies does not actually exist. It is generated from trading the assets of other countries; trading financial instruments that have no intrinsic value; unmetered inflation; trading on artificial asset values generated from unregulated and unsustainable fractional banking; and GDP generated from unsustainable levels of unsecured debt etc. Phantom GDP may lead to real GDP since the profits produced may be used to purchase goods and services.

Energy cost and GDP

With global GDP, energy consumption and energy price data available, it is worthwhile trying to combine these to further explore the relationship between GDP and energy. The significant limitations of this exercise are discussed above, but the data trends produced are I believe worthy of consideration.

A $US value has been attached to primary energy consumption by multiplying total primary energy in mmtoe by the annual average oil price (WTI). This sum was then deducted from total GDP to produce an estimate for global non-energy GDP and the result is plotted in Figure 4.

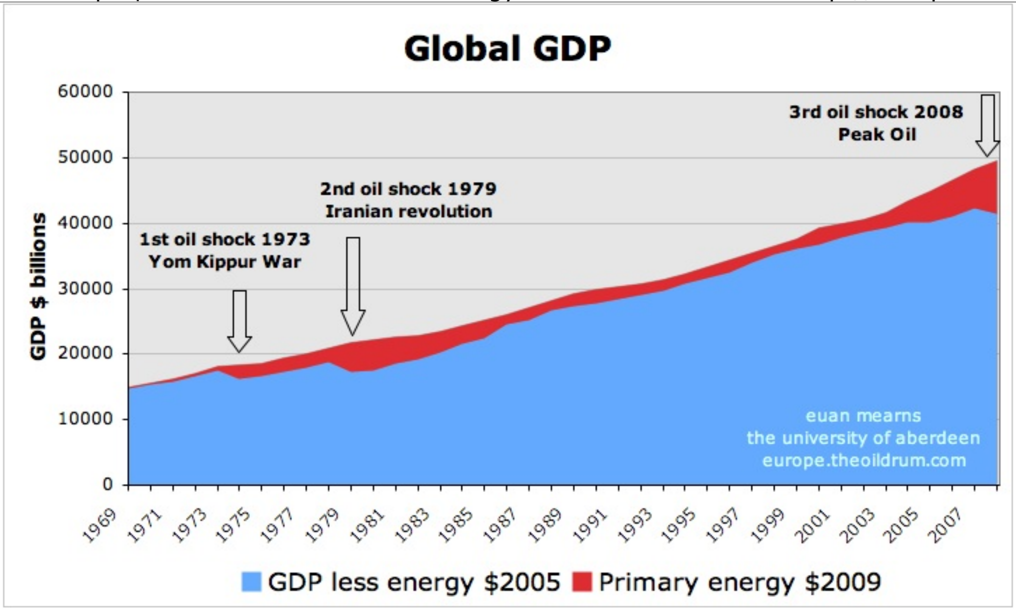


Figure 4 *The fractional energy cost of GDP. Global GDP data from the USDA. Primary energy data and energy prices from the BP statistical reveiw of world energy 2009.*

Whilst global GDP has shown near linear growth since 1969, the negative impact of high energy prices on the non-energy economy is clearly shown for the three oil shocks (1973, 1979 and 2008). This exercise also affords the opportunity to plot the ratio of total GDP over total energy cost which I have called the Financial Return on Energy Invested (FRoEI) (Figure 5).

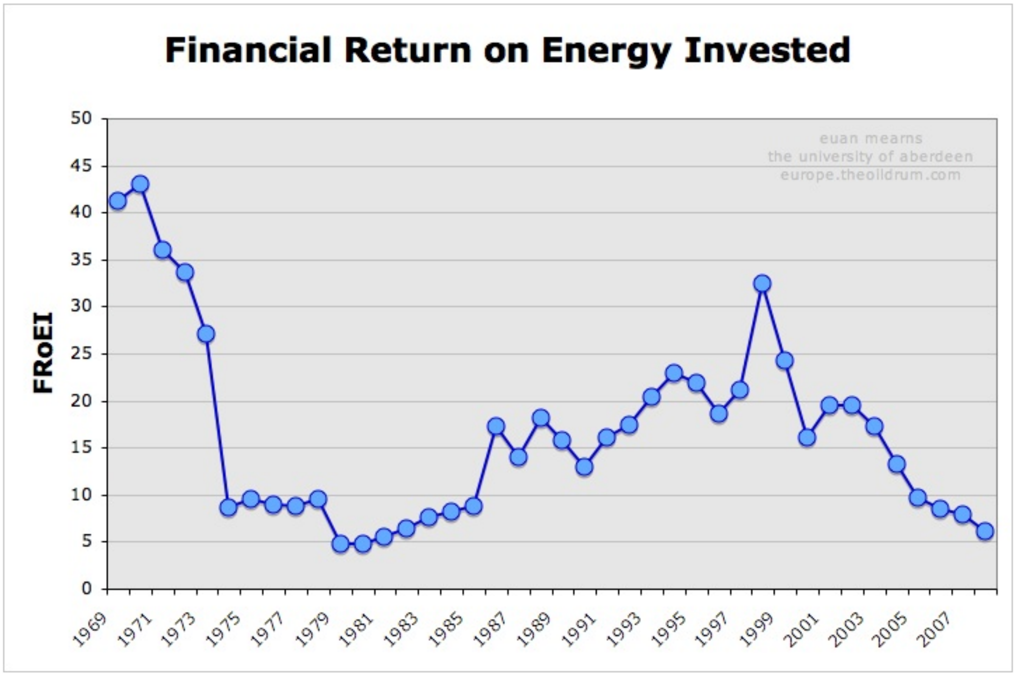


Figure 5 *FRoEI estimate for global primary energy consumption, 1969 to 2008.*

One thing that struck me from doing this was that the FRoEI figures are of similar magnitude and range to ERoEI data. The second oil shock of 1979 caused FRoEI to fall from 10 to 5 and a major recession followed. Since then, FRoEI grew rather steadily to 1998 where values over 30 were once again attained. Since then the ratio has declined registering a fall from 8 in 2007 to 6 in 2008.

The future

As others have pointed out, energy costs and the oil price are limited by the size of the global economy. For example Francois pointed out that **$590 / bbl was the theoretical upper limit for the price of oil** and that the practical limit was more likely less than $200 / bbl. The average oil price in 2008 was $97 / bbl. Figure 4 shows empirically how rising energy prices flatten growth in the non-energy economy until eventually a negative growth situation is reached. It is tempting therefore to believe that around $100 / bbl may the upper limit for the current configuration of the global economy since energy costs higher than this will push the non-energy part of the economy into recession (Figure 4) which has a corrective influence on energy demand and price. Price volatility affords the opportunity for brief excursions over $100.

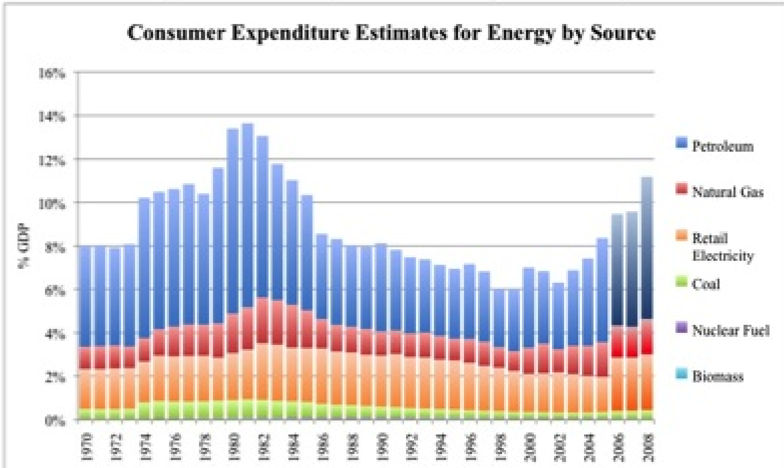
A crucial question that follows from this is what energy supplies (fossil and other fuels) can be accessed for $100 / bbl? With reports that finding and development costs for oil are running close to $80 per barrel, it seems that we are approaching the point where new fossil fuel supplies may be too expensive for our economies to bear. I am intrigued by the fact that ERoEI and FRoEI values lower than 7 may represent threshold values for industrial civilistation.

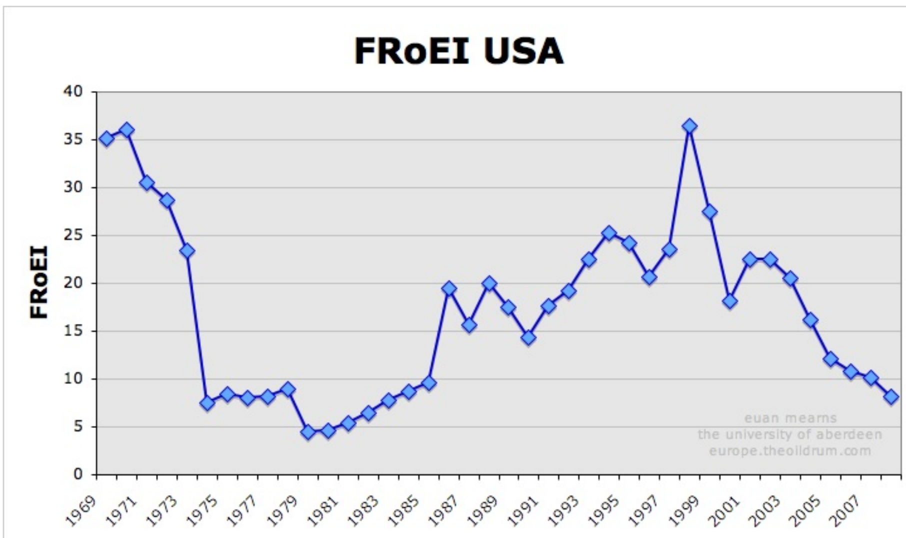
We are not yet at the point of peak fossil fuel supply though we are likely close to peak oil supply and since oil is the most convenient of the fossil fuels to use this is likely to exert a destabalising influence. **When fossil fuel supplies do begin to fall, the only way that GDP can genuinely grow is through energy efficiency**. As Ian Schindler pointed out, energy efficiency will facilitate higher energy prices and thus energy efficiency will promote higher GDP/ mmtoe, higher mmtoe produced and higher prices.

This may enable the global population and economy to grow beyond the date of peak fossil fuel supplies for a while at least? Herein lies one of the greatest paradoxes and threats to the human race. Improving energy efficiency is arguably a major part of our salvation from fossil fuel energy decline but this will merely allow population to grow to higher unsustainable levels. In arguing for energy efficiency measures one must therefore also argue for measures to ration energy use and population management. What chance in a world obsessed with extending life expectancy, reducing mortality rates and averse to birth control?

End note added 21st June
I was reminded about the paper by **Hall, Balogh and Murphy** (pdf from TOD server) who deal with similar issues to to those dealt with here for the USA. In particular, their Figure 1 (below) provides in greater detail the % of US GDP spent on energy and this provides an opportunity to compare with the somewhat cruder approach adopted in this post.

Figure 1. Percentage of GDP that is spent on energy by final consumers (2006-2008 estimated, source: http://www.eia.doe.gov/emeu/aer/txt/ptb0305.html).





The 1981 peak from Hall et al of 14% translates to FRoEI = 7. The 1998 trough of 6% translates to FRoEI = 17. And the 2008 peak (estimated by Hall et al) of 11% translates to FRoEI = 9.

The comparability is open to debate. Both data sets I believe need to incorporate energy embedded in imported goods.