The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Energy Efficiency Leads to Higher CO2 Emissions?

Posted by Chris Vernon on February 2, 2011 - 1:09pm

Energy efficiency leads to higher consumption of fossil fuel and therefore higher carbon dioxide emissions.

Euan made this point in a recent discussion. It made me think. Euan's reasoning is that by increasing the energy efficiency we increase the *energy service* which in turn allows us to pay a higher price per unit energy. This enables higher ultimate production of fossil fuels with their associated CO_2 emission to the atmosphere.

It's a compelling argument, especially as we are seeing increasing production today from expensive deep water, tar sands, shale gas etc. Here I offer a few thoughts around this idea. Please note this post is entirely qualitative, the numbers (percentages and dollars) below aren't related to the real world at all, they are purely illustrative.

One of the few points that pretty much everyone agrees with here at The Oil Drum is that fossil fuels and especially oil, will reach a production rate peak. There are numerous arguments about the timing and mechanisms and many different modelling approaches. Euan's comment above led me to a simple definition of peak oil:

Peak oil occurs when efficiency improvements fail to support the price increase needed for marginal production increase.

To unpack that: on the efficiency side, if the efficiency of a process doubles, then the energy needed to deliver the energy service halves allowing twice the price to be paid for the energy without impact. If America doubled the nation's vehicle fleet efficiency, $6 gas wouldn't seem so bad. On the production side, higher prices allow resources previously too expensive to be produced to be mobilised into reserves and produced. $100 oil opens the doors for Canadian tar sands and ultra deep water oil.

As time progresses two things happen: energy efficiency of an economy improves and the quality of the remaining oil reserves decreases. The exploitation of non-renewable resources is characterised by declining energy return on energy invested (EROEI) as naturally the best resources are exploited first. This results in the cost (or price needing to be paid) of new production increasing with time. This is illustrated nicely in 2008 data from Cambridge Energy Research Associates (CERA) posted by David Murphy. High prices are allowing oil with a high cost of production to be brought to market.

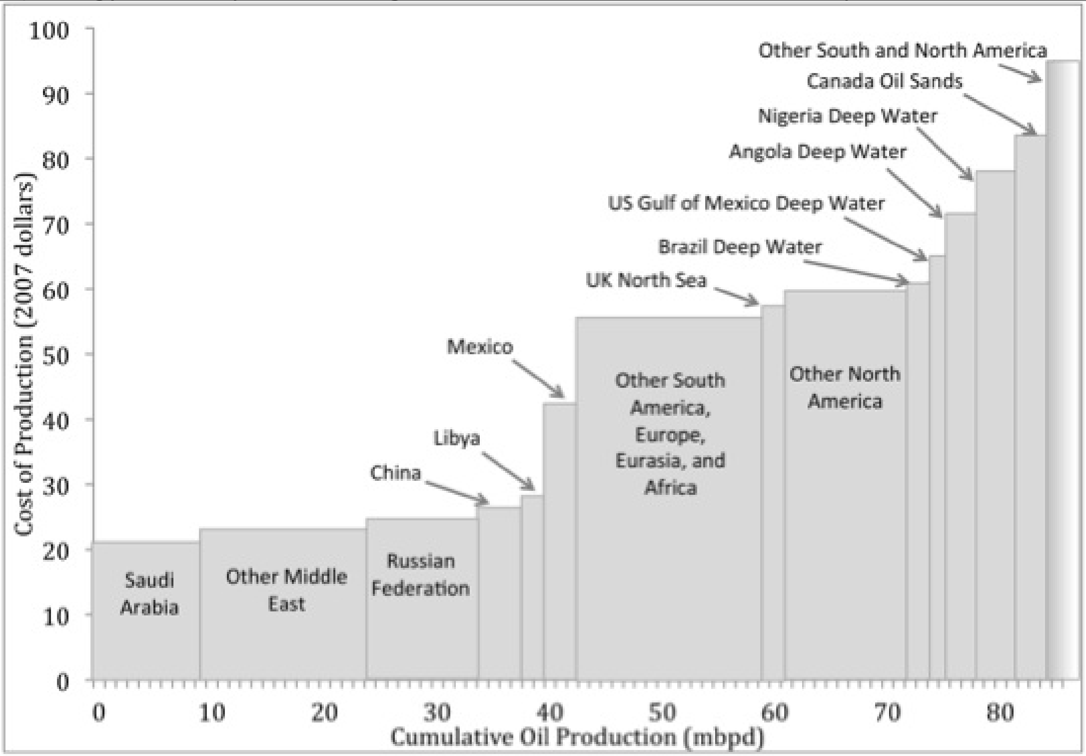

Figure 1. Estimates of the cost of production for oil production form various locations. Data from CERA.

These two functions of efficiency improvement and cost increase are key to defining when the peak occurs.

My hunch, and without further research it is just a hunch, is that the rate of efficiency improvement decreases over time and the price needed to bring new marginal production online increases with an increasing rate. The key points are that efficiency asymptotically approaches some thermodynamic limit yet the marginal cost of production increases without bound. I'm more comfortable about the efficiency aspect of this hunch than the marginal price, it would be nice to see data. Dramatic technology change in production processes has potential to significantly change the marginal cost of production curve.

The following two charts illustrate my hunch.

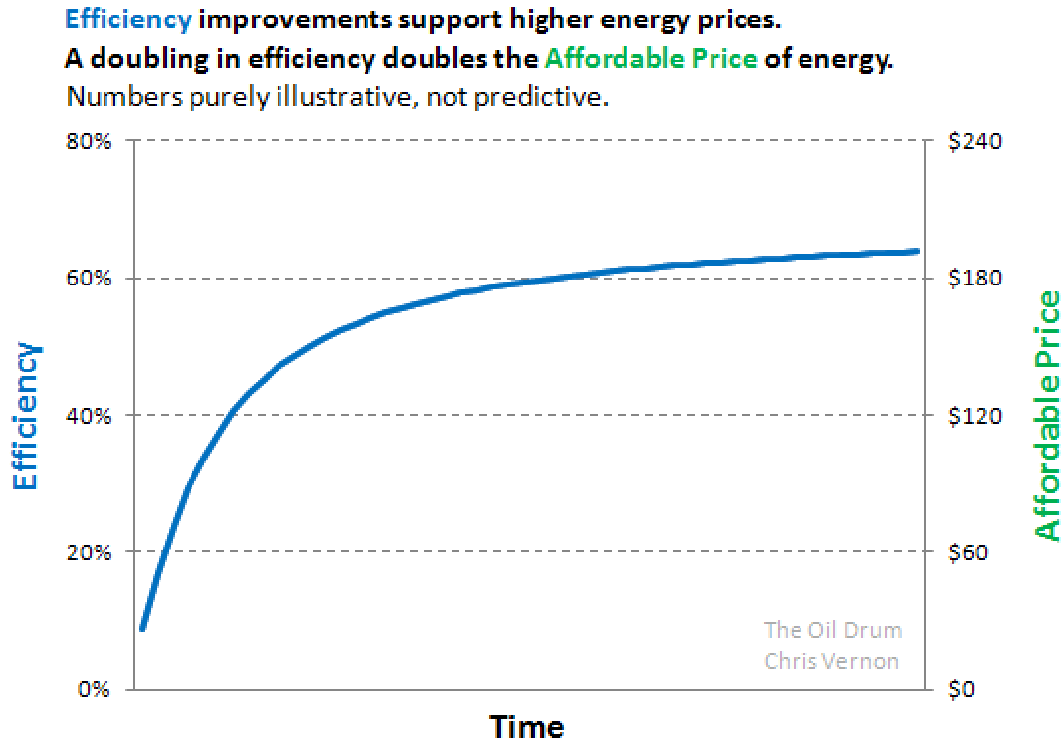

Figure 2. Efficiency increases asymptotically to some thermodynamic limit.

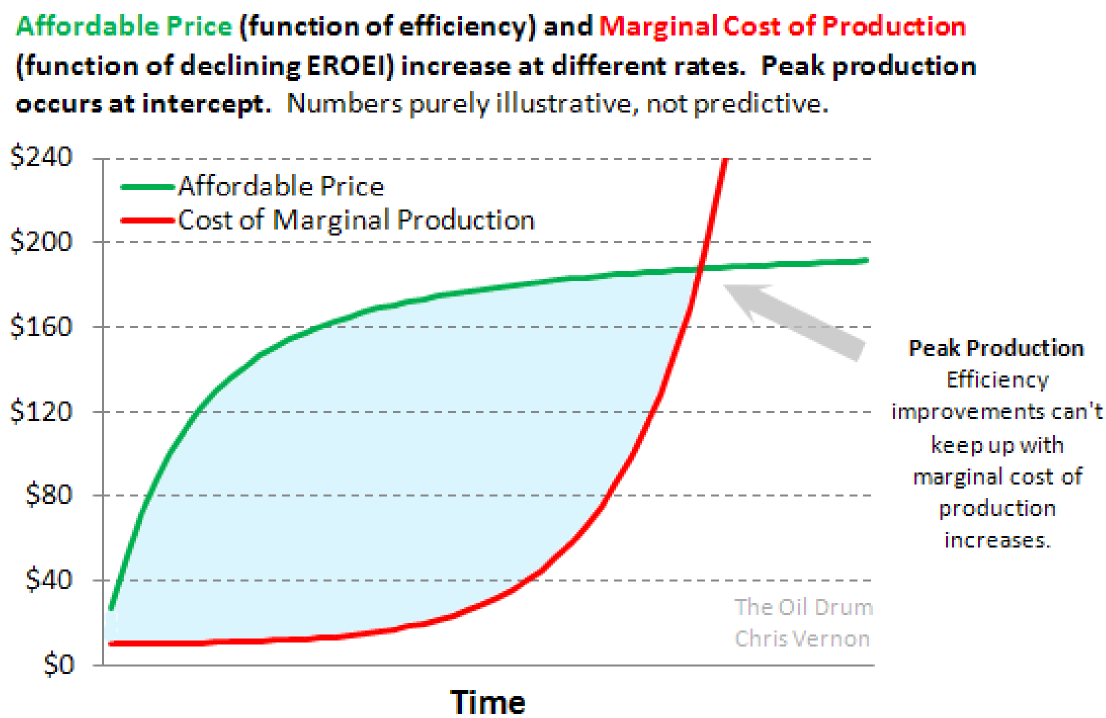

Figure 3. The area in blue bounded by the two curves is the area we have been operating in during the fossil fuel age. It represents profit and growth.

Back to Euan's point of efficiency increase, increasing production and the associated CO_2 emissions. I expect he's technically right; however, I suspect the impact of efficiency improvement on medium term (couple of decades) production is small as the marginal price increase will quickly outrun the efficiency improvements with the peak occurring before this process is able to make significant additions. The slope of the marginal cost curve, by definition, is greater at the peak than the slope of the efficiency curve: thus, large gains in efficiency correspond to smaller price increases. Quantifying the exact increase in ultimately recoverable reserve (URR) due to efficiency improvements would be challenging.

I am, however, wary about the potential resource to be produced well beyond the peak. A highly efficient global economy may not have much impact on the timing and magnitude of the peak, but could produce a significantly fatter tail (containing a lot of CO_2) in the decades following the peak than an inefficient economy. For example, if a post peak economy was so efficient in its energy use to be able to afford $200 oil, then billions of barrels of Canadian tar sands may ultimately be available, however, if an economy could only afford $50 oil, that resource remains unexploited with its CO_2 sequestered forever.

There need not be just one efficiency curve. The asymptotic curve I plotted in Figure 2 might be for one application (say oil fuelled transport). If a new application was invented, that managed to extract dramatically more *value* from oil than using it for transport, a new curve would be needed. If an alchemist worked out how to turn oil into a vital element in photovoltaic manufacture, facilitating a GW of PV to be manufactured for a barrel of oil, suddenly oil would be worth millions per barrel. Figure 4 attempts to illustrate the impact of demand-side technology shifts.

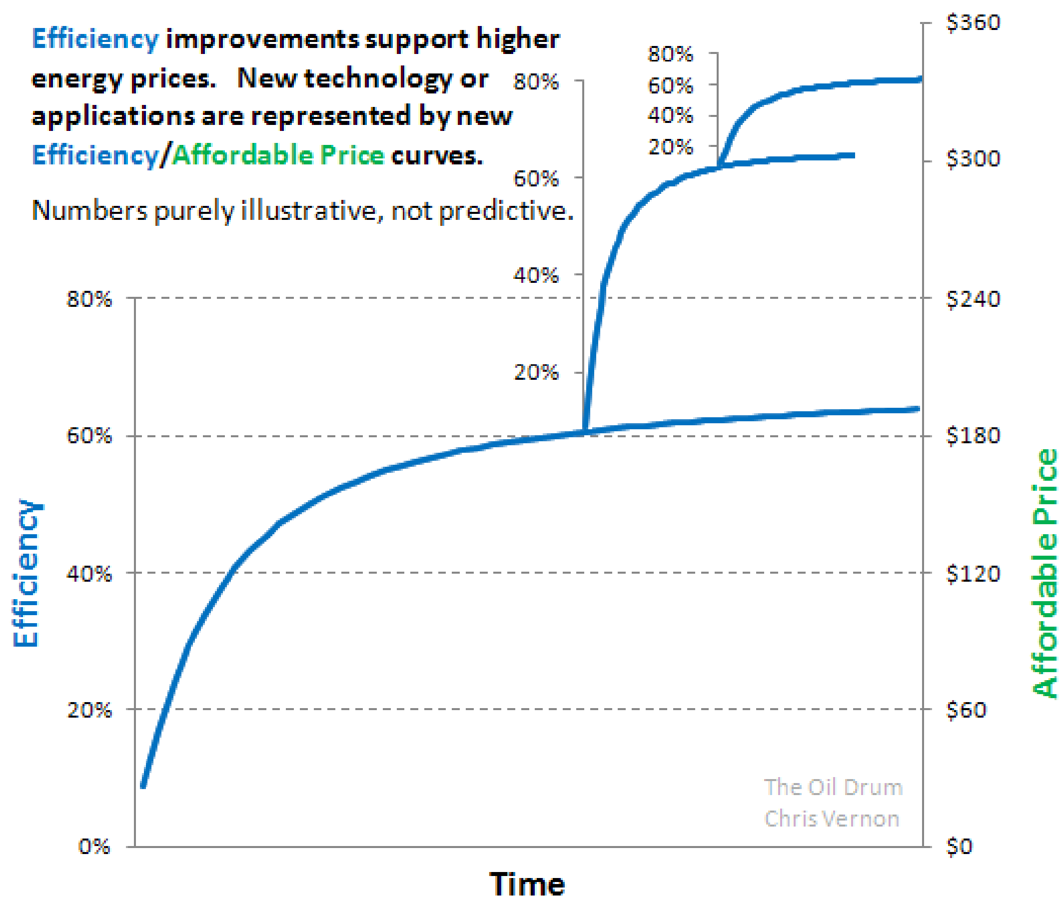

Figure 4. New technologies or applications may have new efficiency / affordable price curves.

Finally, this post has only discussed fossil fuels. As increases in efficiency push up the affordable price for energy, and declining EROEI increases the marginal cost of new production, there will come a time when renewables (which don't suffer from declining EROIE as fossil fuels do) become affordable in absolute terms and cheaper relative the fossil fuels. This scenario could have a dramatic effect on the post peak fossil fuel tail, truncating it fairly rapidly.