# Why oil (and helium) are still underpriced

Posted by Prof. Goose on December 1, 2005 - 12:34am
Topic: Supply/Production
Tags: helium, oil, peak oil [list all tags]

**[ED: by Prof. Goose]**This is a guest post by Marty Sereno, Professor of Cognitive Science at UCSD.

Economists often like to argue that the prices set by markets are simply right. In this way of thinking, it doesn't make sense to ever say that oil is ever overpriced or underpriced. The problem with this for human civilization is that capitalism is an optimization method that finds optimal behavior a short time into the future. Unfortunately, as we all witness the slow depletion of an obviously finite resource absolutely central to the operation of modern human industrial society, it is obvious to many that we need to pursue strategies that might not have an immediate payoff. Optimizing for results with a longer look-ahead window isn't rocket science, and it isn't unprecedented. The whole field of molecular biology was founded by decades of research paid for by taxes with no immediate payoff in sight. Capitalism had nothing to do with it.

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To make an impact on the general public and to help them better deal with rogue economists and cornucopians, I think we should remind them of basic facts about the energy density and convenience of fossil fuels that used to be patently obvious to virtually everybody in 1900, but which have now been forgotten by all but a few engineers over the past 100 years in modern industrial cultures.

A useful, easy-to-remember aphorism is: ONE BARREL of oil is equivalent to ONE YEAR of very hard labor by a human. I tried it out on my scientific colleages here at UCSD, and to a person, they were astonished.

A barrel of oil contains 42 gallons. It can be made into about 20 gallons of gasoline (give or take, depending on the grade of the oil). Each gallon of gasoline contains about 36 kilowatt-hours of chemical energy (kilowatt-hours are the number of kilowatts, a measure of power, times the number of hours, yielding a measure of energy). An efficient internal combustion engine turns about one quarter of that energy into useful work, with the rest lost as heat. One horsepower is equivalent to about 3/4 of a kilowatt. However, one human working hard continuously can only put out about 1/10 to 1/5 of a kilowatt (compare the power output of a human to a one-horsepower horse). A recent article in *Bicycling* on the Tour de France showed that the average power output (during the several hours per day of the race) of a top-finishing bike racer, Floyd Landis, was 0.23 kilowatts, or about 1/3 horsepower, continuous. In a 75 minute time trial, the same cyclist was able to put out 0.38 kilowatts continuously -- a full 1/2 horsepower!

The 20 gallons of gasoline made from one barrel of oil contains about 180 useful kilowatt-hours. If we divide that by say, 1/8 of a kilowatt -- a generous continuous output for a fit person -- we get 1440 hours of hard human work. Let's assume that a person can put out this 1/8 of a kilowatt for 6 hours per day. That is, half of the output of a top Tour de France cyclist for a continuous 6 hours (not counting breaks) per day. This means that you would need 240 days to get 180 kilowatt-hours (or more, if you are a dimmer bulb), which is minimally equivalent to one year of 5-days-a-week very hard labor by a fit human. This boils down conveniently to: ONE BARREL of oil = ONE YEAR of hard human labor.

This calculation makes sense when you compare digging a foundation or grading a road by hand, Roman empire style, to doing the same thing with an oil-powered bulldozer, roadgrader, and backhoe. A barrel of oil currently costs $57. I think this price *waaaay* underestimates its true worth to us humans. Even in the poorest third world country, you currently have to pay a human more than that to do hard labor for a year. In the US, the minium legal wage is over $10,000 a year.

The hope is that scientists will help us to avoid the "garden show that never ends" -- and the construction methods of the Roman empire -- by inventing some new, convenient source of energy before fossil fuels are depleted. The problem with many of these alternatives is that they all now rely crucially on depleting fossil fuels and resources. Determining whether it is actually possible to manufacture, say, photoelectric cells using only renewable energy sources at every stage (mining, steel-making, furnaces for growing large silicon crystals, saw blades and saws to cut the ingots into wafers, transportation, assembly, installation, servicing) is a topic for another day. Here, let's just consider how resource limitations color the prospects for thermonuclear fusion for generating electricity.

The recent revival of the fusion research project, ITER, suggests that there may still be hope that we will be able to maintain energy-indulgent ways. However, current approaches to fusion are based on magnetically-confined plasmas. The enormous confinement fields needed are generated by superconducting magnets that are similar to those found in high-field MRI machines, but even more powerful, and arranged into a torus (doughnut) instead of a cylinder. All high-field superconducting magnets contain metal wires bathed in large amounts of liquid helium, the only substance that won't freeze at the temperatures required for low temperature superconductivity to appear. A little over 1/4 of all helium produced is used for cryogenics.

Helium is only found in useful concentrations in the 'fossil' gases emitted by relatively a small number of oil and natural gas wells with especially impermeable caps (in the US, mainly in Texas). The helium was trapped and concentrated there after it was generated by radioactive decay of uranium and thorium in the crust and mantle. Helium is on a depletion curve closely related to that of natural gas (data here and here). In 1996, the US helium reserve was privatised and is now in the process of being sold off (The Impact of the Selling of the Federal Helium Reserve, 2000, Openbook here). Helium production appears to have already peaked in the US. After helium boils out of the huge refrigerated thermos bottles around a superconducting magnet, it escapes into the atmosphere and then diffuses into space, where it is lost forever. Helium is an element and cannot be synthesized. The amount generated by a hypothetical working fusion reactor is negligible. After 20 years of high temperature superconductors, no one has come up with one that is both strong enough and capable of carrying enough current. Such a thing may not exist.

Tokamak-style fusion is predicted to become practical in a few decades. But by then, we may near to past the world peak in helium. Helium demand will soar and helium price will soar, too, but it will be too late. Perhaps it really is true that fusion is the power source of the future, and it always will be, as the joke goes. The New Scientist had an article this month (summary here) about ITER, explaining that new approaches to plasma stabilization just might solve some of the chronic problems that have made continuous confinement difficult. But the inconvenient facts about helium did not appear. Perhaps as yet hypothetical superstrong permanent magnets will save the day (although a permanent magnet fusion project was recently cancelled by NSF). Or perhaps a strong high-temperature superconductor will be found. Perhaps.

Economists often say they care little about energy considerations because markets and prices will motivate the discoveries that can solve any possible problem. Scientists, by contrast, try to find out how the world actually is. The world is not infinitely pliable. It may or may not be possible to manufacture strong high-temperature superconductors. It's an empirical question -- not something that will automatically be solved just by increasing the price of strong magnetic fields.

If us scientists fail to come up with a convenient portable energy source for digging up fields and house foundations (and unused pavement!), at least we can continue to discuss this with them -- while we each sweat out our 1/8 of kilowatt. To put off that day, we should all stop acting like spoiled kids and start planning further into the future now.

Martin Sereno
Professor, Cognitive Science
University of California, San Diego
(B.S. Geology)