Trouble with Carbon

by Martin Hanson (October 2017)

Gas, Edward Hopper, 1940

A little historical background

As the physicist Ludwig Boltzmann put it: “The life contest is primarily a contest for available energy.” Courtesy of television, we can marvel at the contest without even leaving our armchairs. We see how hard predators have to work to earn their dinner, and how hard prey have to work to avoid becoming someone else’s dinner. This is most obvious when we watch a cheetah outrunning a gazelle, or when lions rush and kill a zebra or wildebeest. But even a motionless spider, waiting for an insect to blunder into its web had to expend energy in producing the silk and spinning its web. Even for spiders, there’s no free lunch.

In this contest, there’s only one rule: the energy in the food must exceed the energy expended to get it; that is, there must be a net energy gain. The technical term for net energy return is Energy Return On Energy Invested (EROEI). The unbreakable rule is that to survive and grow, EROEI must be greater than 1 or the animal will die.

If I seem to be laboring this point, it’s because the concept of EROEI is central to an understanding of the predicament our species is facing. It’s also a concept that our rulers either don’t understand, or more likely, don’t want to understand. But first, a little history.

The oldest fossils of biologically humans are about 350,000 years old, recently found in Morocco. Throughout this time, our ancestors were just like other animals, getting all their energy from their food. Some of this food energy was converted to mechanical work in muscle to get more food. In this respect, we were thus just like other species.

Then, beginning about 12,000 years ago, humans began to domesticate animals and plants. But though farming was profitable in that the EROEI could be high, food was still obtained using muscle power—albeit supplemented by the muscles of domestic animals such as oxen. And by keeping animals in captivity, energy didn’t have to be expended in hunting.

Then in the 18th century, 99.99 percent of the human journey to the present day, humans discovered how to use steam to convert heat energy into mechanical work. Though little used today, the steam engine was arguably the most important invention in the Industrial Revolution, for two reasons.

First, it enabled humans to do mechanical work from a rich, cheap and abundant source of non-food energy. This was coal, a form of carbon laid down in trees that had trapped carbon dioxide in photosynthesis, millions of years ago. As such, fossil fuels can be thought of as fossilized solar energy. Moreover, the deposits of coal were immense and at the time, seemingly limitless.

Second, and arguably equally important though less obvious, it led to a situation in which, just as animals need expend energy in order to get more energy, humans had to burn coal in order to get more coal. At first, coal could be extracted from surface or shallow seams using muscles to drive picks and shovels, but as the ‘low-hanging fruit’ became exhausted it had to be mined. But mines tended to get flooded with water, and pumping it out was beyond human muscle power. So, the invention of the steam engine made it possible for ever-deeper seams to be exploited. Coal mining thus began to depend on the use of some of its produce in order to enable the extraction of more coal. In so doing, industrial society became impaled on the hook of needing fossil fuel to get more fossil fuel, a situation that has been repeated and as we shall see, exacerbated, with oil.

If the steam engine kick-started the industrial revolution with coal, 1859 was arguably the year that the use of oil began to go into overdrive, when Edwin Drake struck oil at Titusville in Pennsylvania. People had been collecting oil seeping out of the ground for a long time, but Drake was the first to extract it from the underlying rock by drilling. At a depth of 70 feet, he found it. As a fuel, oil is far superior to coal; a kilogram contains 50 percent more energy, and unlike coal it can easily be transported through pipes. Moreover, crude oil can be separated into numerous fractions with different uses, such as lubricating oil and later, diesel oil, petrol (gasoline), diesel oil and others.

Today, it’s hard to grasp the scale of our dependence on fossil fuels. Everything we make, move or eat depends directly or indirectly on coal, oil or natural gas. Transport goes a lot further that personal transport; without regular delivery of food by diesel driven trucks, supermarkets would run out of food within three days. Mining would stop without diesel-driven heavy machinery. Air travel is totally dependent on liquid derivatives of crude oil.

Most of our clothing is made from artificial fibres such as nylon, rayon, polyester and many others call made from oil. Of the clothes I'm wearing, only my woolen jersey is not made from oil. And even this was wrapped in plastic when I bought it, as are most purchased goods.

And then there's food. Whereas our pre-industrial ancestors produced food profitably, modern agriculture runs at a massive loss because by the time it reaches our stomachs we've spent more energy producing, harvesting, packaging, transporting and cooking it than there is energy in the food. On average, every calorie of energy in the food we eat comes courtesy of an energy subsidy of 7 calories of fossil fuel energy. This subsidy is needed to make nitrate fertilizer (from natural gas), to mine phosphate fertilizer, to produce pesticides from oil, to drive farm machinery, to package it in plastic, and to transport it to the supermarket.

So it's more realistic to think of modern industrial agriculture as a process of turning fossil fuel energy into food, with an efficiency of one seventh, or 14 percent. Our lack of awareness of this is illustrated by the fact that agricultural efficiency is normally measured in terms of output per hectare. By this yardstick, our highly mechanized agriculture is considered to be very efficient, but the reality is that it is the labour-intensive, small scale organic farm that yields an energy profit. In a world of unlimited fossil fuels, this inefficiency might not seem to matter, but times are a-changing, as we shall see.

Cassandras of oil

In Greek mythology Cassandra was daughter of King Priam and Queen Hecuba of Troy. In trying to seduce her, Apollo gave her the gift of prophesy, but when Cassandra rejected him he added a curse: that she would never be believed.

In modern times a Cassandra is someone who makes dire predictions that turn out to be true. Winston Churchill tried to warn Britain of the military ambitions of Hitler and the Nazis, but in vain. People didn't want to believe what they didn't want to, and the result was World War II and the deaths of at least 50 million people.

Churchill was a politician, but most of today's Cassandras are scientists. One of the most eminent was Marion K. Hubbert, a petroleum geologist working for the Shell Oil company. In 1956, after mathematical analysis of depletion rates in oilfields, he proposed that in any given area, oil 'production' (the oil industry's deceptive word for extraction) would at first rise exponentially until, when about half the oil is gone, it would reach a peak and then decline, in a roughly bell-shaped curve that became known as 'Hubbert's peak'. And the painful news was that U.S. oil extraction would peak around 1969 give or take a year, before entering a permanent decline. He went on to predict that world oil production would peak around the turn of the century.

For an oil industry that didn't like the idea of limits, this was not good news. Hubbert's prediction elicited the standard reaction to a Cassandra: derision. Then, in late 1970, U.S. oil extraction peaked. To be sure, it was followed by the discoveries in Alaska's Prudhoe Bay in 1967 which temporarily raised U.S. oil extraction, but Alaskan output peaked in 1988 and U.S. extraction resumed its downward trend.

Hubbert was only the first of many 'peak oil' Cassandras. Another was Colin Campbell who, drawing on Hubbert's work, co-authored a 1998 article "The end of cheap oil" in Scientific American. Its most important conclusion was that "From an economic perspective, when the world runs completely out of oil is not relevant: what matters is what happens when production begins to taper off. Beyond that point, prices will rise unless demand declines commensurately". But, as explained later, oil will never 'run out'; there will always be some that will be uneconomic to extract. The article went on to point out that about 80 percent of the oil produced in 1989 was flowing from fields that were found before 1973, and the great majority of them were declining.

Even more sobering is how discovery and consumption have changed over time. Oil discoveries peaked in the early 1960s at levels that were 5 times greater than the rate at which oil was being used. By 2004 the situation had been reversed; oil consumption was over 4 times greater than discoveries.

What the oil industry and Wall Street investors couldn't stomach was the self-evident idea that the quantity of oil in the world is finite. Campbell put the situation simply: "As every beer-drinker knows, the glass starts full and ends empty. The quicker he drinks it, the sooner the glass will be empty". Though they shouldn't have needed to, Campbell also pointed out that in country after country, oil production has risen, peaked and gone into decline.

A case that illustrates how oil can distort political thinking is North Sea gas, discovered in 1965, and North Sea oil, discovered in 1969. The prospects of Britain becoming self-sufficient in oil were greeted in government circles with whoops of delight, and you could almost hear the licking of lips in the popular media. The certain knowledge that the oil was a temporary gift from nature that had taken millions of years to form and that would eventually run down was hardly mentioned, let alone its implications discussed. Moreover, the advisability of using the oil wealth to prepare Britain for the lean, post-oil times ahead received little or no attention in the media. The royalties could have been spent on reducing energy expenditure by improving insulation of houses and public transport. But no, the temptation to party in the present rather than prepare for the future was just too great, and the North Sea largesse was squandered.

So, although Britain became self-sufficient in 1980 and a net exporter in 1981, in 1999 oil production peaked and in 2005

Britain became a net importer.

While it’s true that some oil-producing countries have not yet peaked, the global trend is inexorable. Whereas discovery of conventional oil fields peaked in the early 1960s, global discoveries of conventional oil are now running far behind consumption. To show how serious this is, consider the following:

- Between 1998 to 2005 the world oil industry spent $1.5 trillion, an average of $200 billion a year on exploration and production, yielding 8.6 million barrels per day in added production.
- Between 2005 and 2013 the oil industry spent $4 trillion, an average of $500 billion a year, yielding 3 million barrels a day in new production.

What this means is that between 1998 and 2005 each million barrels of new production cost $23 billion, but between 2005 and 2013 each million barrels of new production cost $166 million. Thus, the cost of new oil had risen more than seven-fold.

But it’s even more serious than that. Of the $4 trillion dollars spent between 2005 and 2013, $350 billion went on unconventionals. The remaining $3.65 trillion was spent on conventional oil exploration and production. But the increase in production during this period was almost entirely due to unconventional oil, meaning that the $3.6 trillion invested in conventional oil yielded virtually no increase in production.

In an important way, Campbell’s likening of oil in the ground to beer in a glass was a seriously simplistic misrepresentation of the situation. Oil deposits can be likened to a pyramid, the top consisting of the ‘low-hanging fruit’, the cheap, easy-to-get oil that has sustained the industry and the world for more than a century. As you go down the pyramid the more there is of it but the harder it is to extract. The base is occupied by unconventional oil, consisting of tar sands, tight oil, and deep-water oil.

Although there is far more of this oil it has a much lower EROEI. There is a point below which the EROEI is less than 1, meaning that it costs more energy to extract the oil than is in the oil. No matter how great the amount of this oil, it is thus not a resource in any meaningful sense.

In the 1930s boom times in East Texas and Oklahoma, the EROEI was as high as 100:1, so an investment of one barrel of oil yielded a profit of 99 barrels that went back into the economy.

Things began to change in about 2010. Total oil production continued to climb slowly, but this was a result of exploitation of unconventional oil in the form of bitumen or ‘tar’ sands in Alberta, offshore oil, deep-sea oil, and ‘tight’ oil, all of which yield oil with a significantly lower EROEI.

The reasons for the lower energy profitability vary. With offshore and deep-sea oil it is the cost of the rigs, which can vary between $20 million and almost $1 billion, representing an enormous investment of energy to build and transport them.

Bitumen sands on the other hand are only just below the surface; in this case the energy cost is incurred in liquefying the bitumen using steam generated by burning natural gas. Bitumen sands have an EROEI of about 5, well below that needed for ‘the good life’ we take for granted.

While ‘tight’ oil had been known about for a long time to petroleum geologists, it had been ignored by oil companies because it was so difficult to extract the oil. It was only with the appearance of the writing on the wall for conventional oil that oil companies began to take it seriously. While conventional oil is located in rock with pores large enough for the oil to flow, tight oil is located in pores too fine to permit free flow. The oil can be freed by the use of high-pressure liquid to fracture the rock, a technique called hydraulic fracturing or ‘fracking’. The technique has boosted U.S. oil production close to the record set in 1970, and Wall Street began to talk of ‘oil independence’ for America, and even an oil exporting ‘Saudi America’.

Campbell had been labeled a ‘doomsayer’ by Wall St, so it was with savage pleasure that his critics announced ‘the death of Peak Oil’. Certainly it must have seemed so to the talking heads on Fox News and CNN.

But things aren’t so simple, as Richard Heinberg has made clear in his book, *Snake Oil*, and the YouTube video about it. As Heinberg points out, there are three big problems with fracking. First, depletion rates are far higher than with conventional oil, typically 40-60 percent in first year compared with about 5 percent for conventional oil wells. Consequently, production can only be maintained by continuously increasing the number of wells.

Second, fracking is extremely expensive, so fracking firms have borrowed heavily. Consequently, firms have had to keep producing oil even below market price just to repay the interest on these loans.

Third, and most fundamental of all, its EROEI is far lower than that of conventional oil. EROEI is the shadow looming over the oil industry that doesn’t often get much airing in the popular media. The reason is not hard to guess; the banking system depends on lending, and the interest can only be repaid in a growing economy. So the threat of the end of economic growth is a threat to the world financial system.

Underlining the reality of this threat, the trend in EROEI is relentlessly downward. It was 100:1 in the 1930s and now stands at a global average of 17:1. By the time it reaches 5:1 the proportion of extracted energy that will have to be re-invested will leave insufficient for health, education, the arts, and all the things we have come to take for granted.

But what about renewables? There can be no doubt that the sooner we massively invest in these, the better. But even here, there are problems, because hydroelectric dams, geothermal power stations, wind turbines are all built and maintained using energy from fossil fuels. And though solar electricity can be used to charge batteries that can drive cars, nobody talks about battery-powered aircraft, so tourism will become but a distant memory.

Though a life without tourism may seem hard to imagine, long distance transport using heavy trucks is also totally dependent on diesel fuel because, as Alice Freedman has shown in her book *When Trucks Stop Running*, the batteries would account for a significant proportion of the load. So it's impossible to avoid the conclusion that since all industrial economies depend on diesel powered trucks, we are going to change the way we do things – and drastically. We are going to have to live more simply in more localized communities, using less energy, and repairing and recycling more materials. In such small scale, localized societies, cooperation rather than competition will be the order of the day.

Such a transition to a sustainable society is going to be the greatest challenge Homo sapiens has faced. Our dependence on fossil fuels is all the greater because it has distorted not only our thinking, but our values, as we shall see.

Addicted to Slavery

Sometimes a particular movie makes such an impact that it continues to stick in one's memory decades later. A video I used to show to my science classes, Confessions of a Simple

Surgeon, was about a campaign against cigarette advertising by an Australian surgeon who became sick of removing cancerous lungs and amputating limbs of smokers. The bit that really grabbed my attention was an interview with a lady who had had a cancer in her mouth after 30 years of smoking. I say 'interview' because after removal of part of her tongue and jaw, it was difficult to make out what she was saying. She looked decades older than her 45 years and, when asked why she continued to smoke, she answered "because I like it"—or that's what it sounded like, because her speech was barely intelligible. She must have known that her addiction to nicotine was ruining her life, but she just couldn't kick the habit.

Years later it struck me that her situation bore an uncanny resemblance to the dire predicament of humanity with regard to our dependence on fossil fuels. To get an idea of just how dependent we are, a barrel of oil contains 6.1 Gigajoules of energy which, depending on how you calculate it, approximates to the amount of energy an average-sized manual worker expends doing a 40-hr week for 12 years. That's 25 000 hours. At the peak of the oil price spike in 2008, a barrel of oil cost a mere $147. If you were to pay a human to do 25 000 hours of work a minimum wage, that works out at just over half a cent per hour. Yet in 2008 we were complaining about the 'high price' of oil.

There's no clearer illustration of this than the domestic car. Suppose you were to employ a fit, muscular man to push your small car a distance of 3 kilometres on level ground. Working very hard he might be able to do it in about an hour. Suppose you were to pay him $15—just over the minimum wage in New Zealand, where I live. The internal combustion engine would do it at a cost of about of about 35 cents, or less than a fortieth the cost. This illustrates what few of us appreciate—that people in our society use an amount of energy that in pre-industrial times only kings or queens could enjoy.

Yet we think this is normal.

Richard Buckminster Fuller likened our situation to a society in which each American citizen has at his or her disposal the equivalent of over 100 human slaves. The comparison is apt, in more ways than one. In his book, *The Energy of Slaves*, Andrew Nikiforuk explored this parallel further, pointing out that most people in industrialised societies enjoy lifestyles every bit as extravagant as Caribbean plantation slave masters.

Human slavery was common until Victorian times. As many as one-fifth of wealthy Victorian Britons derived all or part of their fortunes from the slave economy. For the most part, these people owned slaves in the Caribbean, so they were never directly confronted by the wickedness of it all.

Like the slave masters in historical times, we feel entitled to this once-only gift of fossilized sunlight, and ignore or rationalise the environmental damage it does. We don’t like to think of ourselves as modern-day slave masters, but in a sense, we are. And as with human slavery, energy slavery has a pernicious effect on our values.

There is a crucial difference between human and energy slavery. Human slaves can reproduce, so from the purely economic point of view, traditional slavery was sustainable. But oil does not reproduce; once used, a barrel of oil has gone forever. As the more readily accessible deposits are used up, the time will inevitably come when it costs too much energy to extract for a given amount of energy expended. Like it or not, the end of fossil fuels will be forced upon us. Wouldn’t it be nice if we could actually live up to our scientific name *Homo sapiens* (wise man) by severely cutting back our use of fossil fuels before the carbon dioxide we produce creates a hellish future for our grandchildren?

For the last half century a number of scientists and other academics have been raising the alarm about the consequences of treating the world as if it had an infinite provider of resources and for absorbing waste. These alarm calls are getting increasingly strident—but continue to be ignored or derided, particularly in the popular media. As the novelist Upton Sinclair put it: “It’s difficult to get a man to understand something if his salary depends on his not understanding it”. One is forced to wonder what the oil industry moguls will say to their children and grandchildren.

Martin Hanson was born and educated in the UK and emigrated to New Zealand in the 1970s where he taught biology for over 30 years. He is the author of a number of school textbooks.

Martin Hanson’s other work on NER.

To help New English Review continue to publish scholarly and interesting articles, please click here.