The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

What is a Human Being Worth (in Terms of Energy)?

Posted by Luis de Sousa on July 20, 2008 - 9:50am in The Oil Drum: Europe
Topic: Sociology/Psychology
Tags: barrel of oil equivalent, human power, original [list all tags]

Days ago Euan got a ping from London based journalist Jonathan Ossoff:

> We've tracked down a lot of statistics that demonstrate just how remarkable oil is as a resource, but we're having a bit of trouble synthesizing and contextualizing that data to get a usable understanding of how oil compares to, say, human labour, or a hydroelectric plant, as an energy source.

This query prompted an interesting discussion among the TOD staff on the comparison of human labour to oil.

Right: Bradley Wiggins, one of today's top endurance athletes. He can sustain a power output of about 500 watts for extended periods of time. But how significant is that number?

Nate was the first to provide an answer:

> This has been argued and debated often on TOD, mainly in response to some of my own quotes in media about 1 barrel equating to 25,000 hours of human labour (12.5 years at 40 hours per week). Ultimately the answer to this question depends highly on assumptions - but we can arrive at a good approximation. 1 barrel equates to 6.1 Gigajoules (5.8 million BTUs). Depending on the 'job', humans use roughly 100-700 Kilocalories per hour (Computer work requires an estimated 119.3 Kcals/hr). 1 kilocalorie (Kcal) = 4,184 joules. So 1 barrel of oil has 6.1 billion/4,184 = 1,454,459 kcals. Using a range of 100-700 kcals per human hour of work then results in a range 2078 and 14544 hours per barrel of oil. At 2000 hours per year (40*50), this is would then be 1.0-7.25 years per barrel. This was discussed in the comment thread here.
>
> However, we aren't robots - we need to eat, sleep, breathe (we exhale energy), maintain, etc. So a wide boundary analysis would require other calories not devoted to doing work - thereby increasing the disparity between human work and a barrel of oil - there is a good discussion of human thermal efficiency here.
>
> Lastly, there is the quality issue. Though one could expend enough calories to chop down a tree or carry a cord of firewood by hand, there are many activities which would be

> physically impossible for humans to directly accomplish -e.g there wouldn't be room for the required number of humans to stand behind a semi-truck and push it down the highway at 100 kph. Or fly a jet, etc.
>
> The average american uses 60+ barrels of oil equivalent(oil, gas and coal) per year (360 billion joules), which implies a fossil fuel 'slave' subsidy of around 60-450 'human years' per person. Depending on assumptions another way to look at it is to take a midpoint of 10,000 hours per barrel. At $20 per hour average payroll compensation, that is $200,000 per barrel, not even quality adjusted....

I made a few calculations based on my experience:

> This is a very interesting question. The answers you usually see simply assume some fixed value for the human body energy output per day and divide the barrel by that.
>
> The problem is that the human body can produce motion at different power rates. An healthy person can produce close to 1 kw instantaneously; a top Olympic athlete, like a 100 metres runner, should go above 2 kw during those 10 seconds.
>
> But you know that no one would make that kind of speed for much longer. That's because to produce its maximum power output the human body has to shut down air intake – what's called anaerobic exercise. To keep normal breathing the body's power output can't go above a certain threshold; every person has a certain heart beat rate beyond which air intake shuts down – the anaerobic threshold. In theory the body's power output just below the anaerobic threshold should be maintained indefinitely – what is called maximum sustainable output.
>
> The fastest Olympic runners are those that do the 200 metres race. They do it in about 20 seconds or less, about the longest consecutive period the body can be at absolute maximum power output without breathing. In the old days in Greece this race was 180 metres, the distance the Greeks believed that Herakles could make on a single breath. A funny thing to note is that athletes that run the 200 meters look like oxen, while those who run the 400 meters look like gazelles.
>
> Down to the math, my anaerobic threshold is about 178 heart beats per minute (this can vary during the season). When I reach my top form, I calculate that my output is about 240 watts (w), about half of a professional athlete. So you could just hit the blackboard and multiply that by a number of hours and relate it to oil, to know how long I'd have to work to replace a barrel.
>
> But not so fast, at that power output I'm using over 1000 Calories per hour. The human body can't digest much over 2500 Calories per day. So all this math can be complicated. What happens is this, if you have your body working for a long time at maximum sustainable output the next day you won't do much.
>
> Why is it so? When exercising, muscles use essentially three fuels: oxygen, water and carbon-hydrates (which at high output are mainly sugars, the ones that can be used fast enough). So as long as there is water and easily digestible food (chocolates, fruit, marmalades, honey, etc) the body keeps on delivering. But at this high output level the muscle tissue slowly dies and more important than that, so do the red blood cells. Slowly the body's performance degrades, and replacing this cells requires the intake of proteins that are all but easy to digest and synthesize.

> On certain occasions I spent over 6000 Calories in the same day but on the next I was close to dead. By experience I can say that if I spend anything over 3000 Calories on a given day, my performance the next day will be visibly affected. It is as if there's some energy budget that can't surpassed, even if at lower output rates. This may change from person to person but let's use that round number.
>
> So you could just multiply the maximum sustainable output by 3 and get the body's daily energy delivery? Not yet. Anyone that would go on spending 3000 Calories per day every single day for an extended period of time will eventually hit problems of hormone production (those that stimulate tissue regeneration) and even psychologic induced performance losses. Any serious training program also includes rest periods, which equate to at least one day per week, more likely two.
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> So the calculation I'm comfortable making is this:
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> Empirical maximum sustainable energy output per day (240 w * 3 hours)
>
> multiplied by
>
> the number of workable days per year (365 * 5 / 7)
>
> That would give about 187 kwh in a year.
>
> But no one is able to keep itself at top form during the whole season and there are also vacations. So, 150 kwh might be a more realistic number (3*220*230). A top athlete should be able to double that.
>
> I would take 11 1/3 years to replace a barrel of oil (equivalent to 1700 kwh), while a top athlete would make it in about 5 2/3 years.

But in face of all this Chris had an interesting remark:

> It's an interesting calculation but I don't think it really answers the question in a useful way. Rather than thinking about energy maybe it's better to think about *useful* work done.
>
> "how many days / years labour does one barrel equal?"
>
> Pick a task - cutting wood, moving dirt, harvesting a crop etc...
>
> Compute how many man hours it takes to complete the task without external energy sources and how many hours with external energy. Assume any tools are available and ignore the tool's embedded energy. For a more holistic approach include the embedded energy in the tool divided by the fraction of its lifetime used to complete the task (likely to be minimal).
>
> The question is hugely complicated though as some tasks are far easier to mechanise and therefore apply external energy to than others - cultivating/harvesting grain is easy to mechanise, picking strawberries far less so. The equivalence between human energy and oil energy is highly dependent on the task.

Glenn had a more down-to-hearth perspective:

> C'mon everyone, we're just talking about brute force labour here. Humans add "smart labour" which is worth a lot more than the wattage equivalent of energy output.
>
> There is a trade-off between human smarts, capital/tools and energy. In the cheap energy era, we relied too much on the energy inputs and not enough on our brains and building the right capital stock. In the very expensive energy era, we will have to make more use of our brains and technology and build infrastructure that does not require heavy energy inputs.

On which Chris built up:

> It's a good point Glenn. Historically we've had lots of "brute force" available in the form of fossil fuels. This availability has let us maximise tasks for which this kind of energy can be applied. In pure energy terms many of these activities are hopelessly inefficient though (hence the 10:1 oil:food ratio).
>
> This is why direct energy comparisons between oil and human labour don't make much sense. Without oil, the "task set" would be completely different. We wouldn't even think about running a 10:1 food system on human labour for obvious reasons!
>
> Take away the large amount of brute force fossil fuel energy, and we also take away all this hopelessly energy inefficient tasks. We don't attempt to maintain the same task set on human labour and therefore average task energy efficiency rockets automatically. Looking at the global economy as a whole, we only need to use so much gross energy because the fossil fuel source of energy tends to be used for very inefficient tasks. As fossil fuel supply declines, the overall efficiency, measured as Joules in per unit of useful work out, will improve - we'll need less energy to deliver the same output.

And Euan finished:

> A Human Being may have around 45 useful working years. From Luis' calculation detailed above, this computes to around 4 barrels of oil equivalent which at today's price equates to a value of $540 for lifetime human slave labour.
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> However, in today's oil slave wealth inflated economy a healthy human body **sold as spare parts** may fetch up to $45 million.
>
> The not so healthy human body **rendered into constituent compounds** is worth only $4.50.
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> Somewhere between these extremes lies true worth based on human intellect, ingenuity and compassion on the one hand and the enormous chemical potential energy of oil on the other. Survival of humanity must lie in Mankind using the second half of Earth's oil endowment more wisely than the first.

So, what has the TOD readership to say in face of all this?

Earlier on The Oil Drum, a guest post by Professor Marty Sereno, UCSD:

Why oil (and helium) are still underpriced