Revisiting the Olduvai Theory

Posted by Heading Out on March 6, 2006 - 2:54pm
Topic: Supply/Production
Tags: coal, energy production, gas, hydro, nuclear, oil, olduvai [list all tags]

This is largely a guest post by Lads, although, given that I am somewhat less skilled than he in HTML it has been reformatted a little and shrunk a wee bit. I should also mention that I first posted it after watching the Oscars last night, and whether that befuddled me or what it was there, and then it was gone, so if it reappears as a somewhat duplicate be patient and I will delete one of the two. Anyway, here is Lads post:

The Olduvai Gorge Theory was laid out by Richard Duncan in 1989, after seeing that world energy per capita (WEPC) has been declining since 1979. Although others had seen this, Duncan felt that they missed the point that if it kept falling, modern civilization would collapse.

Duncan defined the Electrical Civilization as the way-of-life enabled by widespread and abundant electricity, and set its limits as the period where WEPC is above 30% of its peak, i.e. the period beyond 1930.

The Olduvai Theory assumes that after peaking, WEPC will decline at a rate that mirrors its growth. This brings the Electrical Civilization to an end after 100 years. Duncan defined the idea without using a model, but his concept has been built into other models. Of these, the Meadows team's World3 is probably the most famous, giving the Electrical Civilization a lifetime between 100 and 105 years in all three reference simulations, 1969, 1989, and 1999.

And thus the Olduvai Theory evolved to:

> Electrical Civilization can be described by a single pulse waveform of duration X, as measured by average energy-use per person per year. It has a life-expectancy of less than one-hundred (100) years.

At first Richard Duncan probably wasn't aware of Peak Oil, but by the nineties, working with Walter Youngquist, he began to include it, and refined the post-peak period into three phases:

1. The Olduvai Slope - a period of slow decline;

2. The Olduvai Slide - a period triggered by Peak Oil when decline would accelerate;

3. The Olduvai Cliff - the collapse of Electrical Civilization with overwhelming decline of energy per capita.

The Olduvai Theory Pulse.

Electric Civilization endures for no more than 100 years, between 1930 and 2030.

You can get a better insight of the Olduvai Gorge Theory in these papers available at Jay Hanson's dieoff.org site:

The Olduvai Theory

The World Petroleum Life-Cycle

The Peak Of World Oil Production And The Road to The Olduvai Gorge

In the last of these Duncan included this graph:

Oil production per Capita.
A strong link between oil and population is clear from 1983 on.

When I first saw this graph, my chin fell so hard that I had to dig to find it, and I think I've still yet to fully understand what it means. It was like finding the missing link of Mankind (in this case Oil-Mankind). Since 1983 Oil Production per Capita has been flat. This has to mean one of two things:

* Population Growth drives Oil Production, or;

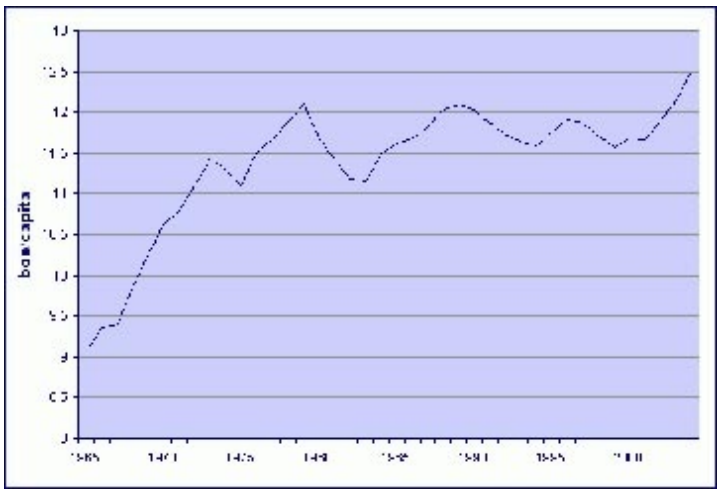
* Oil Production drives Population Growth.

I'm more inclined to the first assertion; though claims that, since the mid-eighties, production has been below capacity make sense, otherwise OPEC wouldn't have been able to control prices.

Re-assessing the Olduvai Theory

The last projection I have, by Duncan, is from 2000, with data to 1999. So I thought I'd see if we were already in the Olduvai Slide. I used BP's Statistical Review, Duncan's source, and the medium projections up to 2050 published by United Nations' World Population Prospects.

I got this:

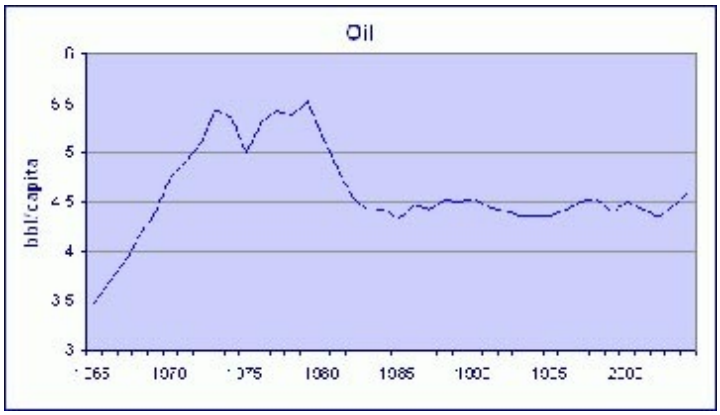


World energy per capita 1965-2005.
After a local peak in 1979, energy/capita went again above 12 boe in 2004 and 2005. Source data:

UN for population, BP for energy; 2005 calculated with IEA data.

So much for the Olduvai Slide. In 2004 and 2005 World Energy per Capita was above 1979, and rising. If we are on the road to Olduvai, we are moving backwards. So, what's wrong? Were did Duncan fail and what's going on?

BP's spreadsheet gives numbers for the different fuel types, so let's look at them.



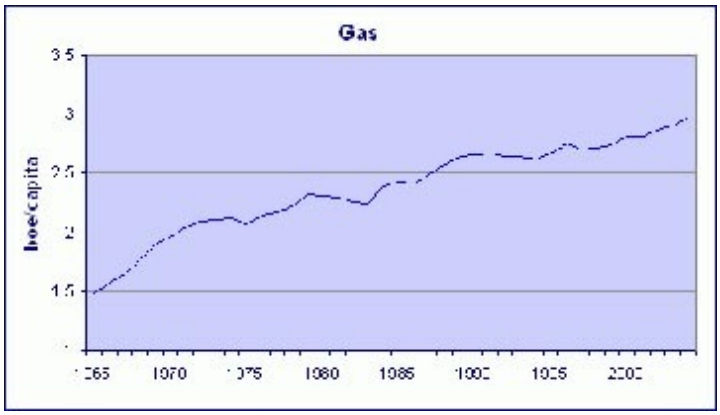
Oil per capita 1965-2005.

Since the last Oil Shock things have been pretty calm, with a plateau since 1983. We can identify 3 periods in this graph, each separated by an Oil Shock:

1. Exponential growth till 1973;
2. Bumpy plateau from 1973 to 1979 (5,0 - 5.5 bbl/cap.);
3. Mind-blowing smooth plateau from 1983 (4.3 - 4.5 bbl/cap.).

These periods explain the difficulty in correctly modeling oil production history. After an Oil Shock we reset our lives to a new level of Oil per Capita, which reshapes the curve and, in my view, completely validates depletion models based solely on post-1983 data.

In the last couple of years there's a slight rise above the plateau, which explains part of that new Olduvai Peak. As for the future of Oil, I guess we all have an idea of what it will be.



Gas per capita 1965-2005.
There has been a steady linear growth, doubling production per capita in 40 years. Gas isn't itself responsible for the rebound in energy/capita, but its growth has been steady.

But for all these sources one has to ask what'll happen after Peak Oil. I don't know, but even if

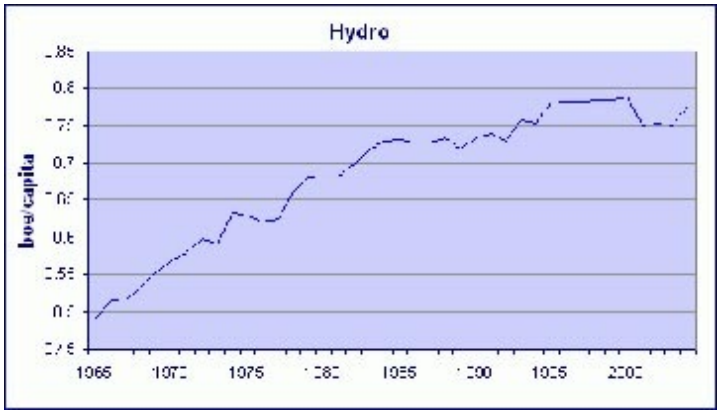
Peak Oil doesn't affect Gas production Gas will peak before the middle of the XXI century.

Coal per capita 1965-2005.

Found it! Coal production was on a carrousel `til the nineties, when it started a sharp decline, then all of a sudden it sharply rebounded after 2000. This has most likely been due to the emerging economies of Asia. Good old Coal is always there for us. Remember Henry Grope's address at the ASPO-USA Denver conference? Well, what he said is happening already.

Gas started replacing Coal when the first declines occurred in the late sixties. This is important because Gas is more efficient than Coal, so we're using less primary energy and getting the more final energy. This is what probably baffled Duncan into predicting an early slide.

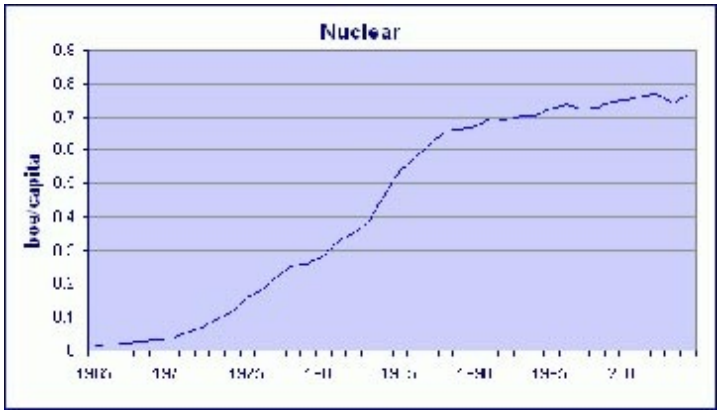
The future of Coal is uncertain, huge reserves are still there, but mining is hard. There's a unique characteristic about Coal, you can't send it through pipelines. Coal has to be transported in Oil-run vehicles. After Peak Oil its price will surely rise, and I doubt its production will continue to grow at this rate. Coal's dependence on Oil might also be responsible for the latest small surge in Oil/capita.
(Ed note:- coal can and is transported in pipelines).



Hydro-energy per capita 1965-2005.

After a strong growth up to the nineties, Hydro-power per capita is having trouble staying at a high level and follows a quadratic, rending down since 2000. Hydro-electric power generation is still growing worldwide, but it's losing its impact on our daily energy needs. From what I've learned this drop will continue. Dams are viewed mostly as strategic reserves, and lakes are kept full for use in emergencies. Moreover, countries face problems in building dams without damaging the environment. There's another increasingly important function for dams that limits their use,

hydrologic management. We are fighting the northward spread of the Sahara, and Alqueva, the dam with the largest artificial lake in Europe, has a major role of keeping Guadiana flowing, otherwise it would dry-up during the Summer.



Nuclear power per capita 1965-2005.

This is a beautiful creaming curve, which though stable in the last decade, has a big question mark over the future. Since 1990 Nuclear power seems to be also driven by population growth, with a residual upward trend. Those aware of Peak Oil have learnt to. at least. respect Nuclear as one of our true answers to the challenges ahead. Lately the alarm has been sounded that we may soon face a Uranium shortage. Demand for Uranium is 40% above supply, and worse, it seems that the amount of Uranium mined every year is about half that consumed.

We are now reaching a time when a large number of reactors will be decommissioned due to aging, and replacements aren't on the way (at least in Europe). The future of Nuclear is uncertain, but further growth in Nuclear-power/capita is very unlikely, in fact the opposite is more likely.

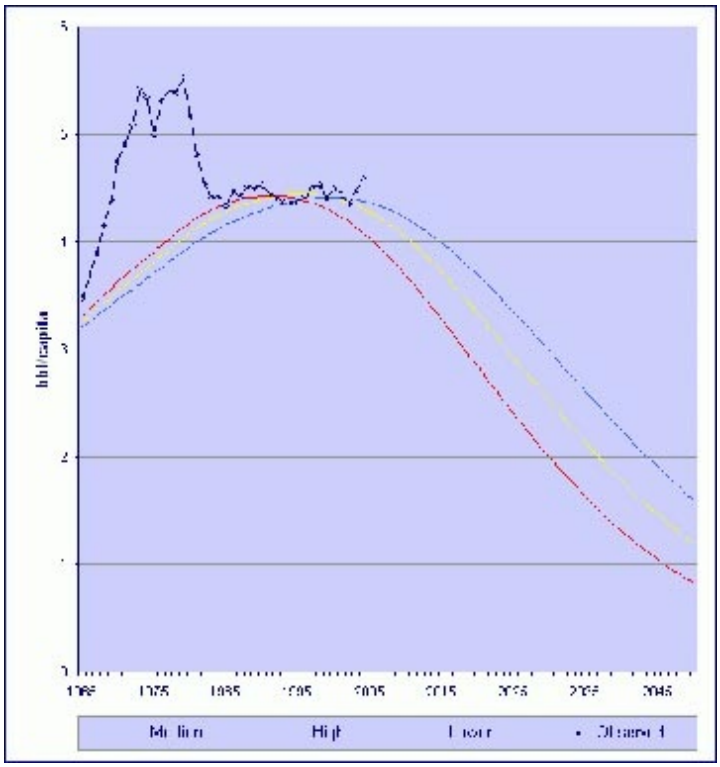
World energy per capita by source 1965-2005. (Over this period Oil has been dominant).

Looking into the Future

This is the part when one risks his reputation, but what the heck.
In order to understand if the Olduvai Theory is still valid we'll have to look into the Future. Let's

first just look at Oil and then to the total Energy per capita scenario.

To project future Oil Production we'll use the bounds given by the method developed by Khebab and Stuart, that resulted in these Extrapolations (Low, Medium and High). Using population projections to 2050 we get this:



Projected Oil per capita up to 2050.

Using the error bounds set by Stuart, it is clear that the plateau of Oil per capita is set to end, replaced by a sharp decline, which is pretty scary. Stuart has been showing us how Peak Oil is a slow squeeze; the same is true for Oil/Capita. But from these projections we see that this slow squeeze is over, we're bound for a serious decline in oil production per inhabitant of this planet. Just take a look at peak moments and values:

	Peak year	Oil/capita at peak time (bbl/cap)
Low	1991	4.426
Medium	1996	4.446
High	1999	4.415

And to take an peek at the decline:

	2010		2020		2050	
	Oil/cap	Percentage of 2005	Oil/cap	Percentage of 2005	Oil/cap	Percentage of 2005
Low	3.686	80 %	2.834	61.8 %	0.824	17.9 %
Medium	4.035	88 %	3.326	72.5 %	1.186	25.8 %
High	4.219	92.3 %	3.686	80.4 %	1.599	34.8 %

Five years from now a fall of 10 % is more than likely, in fifteen years 20 % less is to be expected,

in 2050 all models are below 35% of 2005 oil/capita figures.

Remember the Hirsch Report? Twenty years from now the gap given by the medium logistic is 1.664 bbl/cap, which with a projected population of 7.9 billion gives a production deficit of 13 Gigabarrels (Gb) over the year.

There's another point to be stressed: in 2005 world oil production rose above 30 Gb/year, there's no reasonable logistic model that gives such a number. For instance Stuart's High Logistic has a peak of 28.9 Gb, with a generous URR of 2500 Gb. We're now on a local spike above the mathematical curve, one day we'll have to pay for this, diving below that curve. We might not see an Olduvai Cliff for Energy but one for Oil is almost guaranteed.

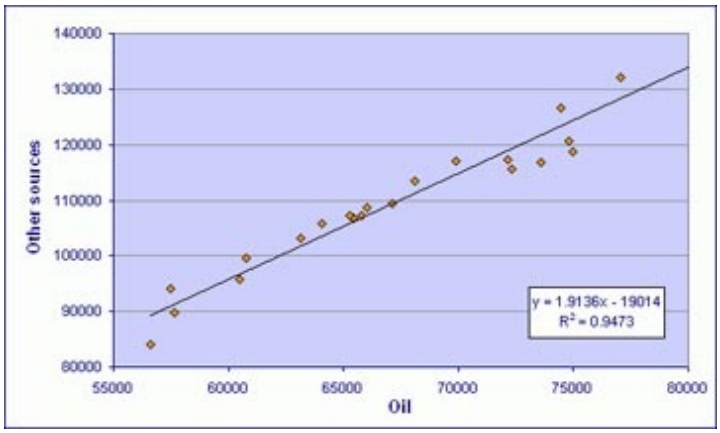
Projecting Future Energy per Capita

Here we have a problem; projecting future oil production is a well understood process, but not for other energy sources. Still I'd like to know how energy evolves into the future. Two models can be suggested:

* The world is perfect: in spite of Peak Oil other energy sources continue to grow, maintaining the same values per capita;

* The world is not so perfect: Peak Oil limits our ability to further increase production of other energy sources, but the levels of today can be maintained.

Since only Hydro-electric power is a renewable energy none of these scenarios is realistic. When formulating the Olduvai Theory, Duncan implicitly assumed that a decline in oil production would imply a decline in production from other energy sources. So I checked the relation between the two, plotting the stable period of 1983 to the present:



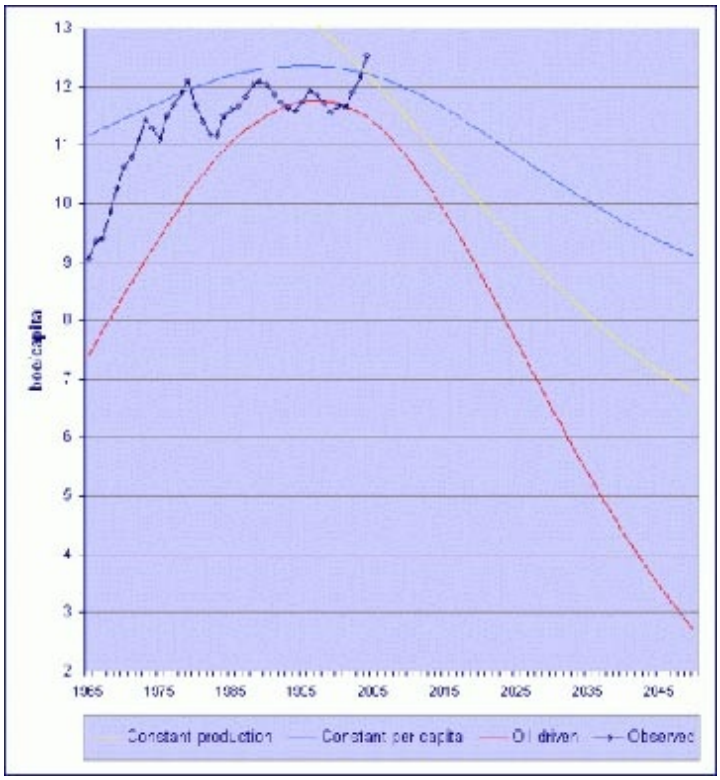
Oil vs Other Energy 1983-2004.

This turned out to be better than I thought. There's a clear link between oil and other energy sources. But don't think we've got it, this might just mean that the other sources are also population driven.

We've now got 3 models for future production from Non-Oil energy sources:

1. Constant production per capita at 2004 values (increasing every year);
2. Constant production over time at 2004 values (every year the same);
3. Oil-driven production (decreasing every year).

To each of these I added the medium Oil/capita model we've seen before, obtaining this:



Projected Energy per capita up to 2050.

Three very different outcomes. In 2050 these models project a fall to 72.6 %, 53.9% or 21.5% of 2005 values. For the friendliest model to work, energy production from sources other than Oil will have to be 71.1 Gboe; that's a 42% increase over today's 50,5 Gboe. And we are talking mainly of finite resources.

The constant production scenario is more reasonable, but both Gas and Nuclear will most certainly start falling before 2050. It's assumed that Coal will replace these losses, given the difficulties in increasing output from Hydro-electric plants.

In the last and ugliest scenario, Olduvai unfolds in the next 40 years.

Reformulating the Olduvai Gorge Theory

I'll now allow myself the liberty and eccentricity of reformulating the Olduvai Theory. After all, without doing this, it wouldn't be fun.
The Olduvai Theory sets the Electrical Civilization to the time frame where Energy per Capita is above 30% of its all time peak. In 2005 that was 12.522 boe/capita and we know this:

* We're at a plateau in Oil production, above any value predicted by any reasonable logistic model;

* Population is still increasing steadily;

* Peak Oil will highly likely arrive in the next 5 years (if it hasn't yet).

So we can assume that 2005 is very likely to be a peak year in Energy/Capita. Thirty percent of 12.522 is about 3.756, a value first crossed in 1950. In the Oil-driven world scenario this value is

crossed again in 2044. I guess we can now reformulate the Olduvai Theory:

> Electrical Civilization can be described by a single pulse waveform of duration X, as measured by average energy-use per person per year.
>
> If it turns out that Oil drives the production of energy from other sources, the life-expectancy of Electrical Civilization is less than one-hundred years: i.e., X < 100.
>
> In case Oil isn't the driving force behind production from other energy sources, the life-expectancy of Electrical Civilization is greater than or equal to one-hundred years: i.e., X >= 100. In such case X will be limited by a yet to be assessed upper bound, set by the decline of other-than-oil finite energy sources: i.e., X < U.

Homework: find a value for U.

Conclusions

The Olduvai Theory shows us something very simple, without renewable energy sources our modern way of life will end some time in the future. I'm an optimist and I believe we can drive away from the road to Olduvai. We can do it by controlling population or by using other forms of energy like Solar and Wind. Of course Oil will be hard to replace, but maybe cellulosic ethanol or something like it can help us in the long run.

Duncan introduced a very important concept, energy per capita, a measure of our Civilization. It's something that let us get a better understanding of the place Energy has in our life, and how can it affect our Future.

From the Olduvai Theory we learned that modeling resource depletion is also modeling population, and that there is a strong link between the two.

Acknowledgements

I'd like to thank TOD editors for letting me share these thoughts with this fantastic community.