The Olduvai Theory: Terminal Decline Imminent

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1. Abstract

The highpoint of industrial civilization followed by its terminal decline will be a watershed of human history. Ackerman's Law defines it. The goal of this essay is to predict the highpoint and the initial decline. Energy production and population data from 1850 to 2005 are the foundation of the forecast. To these are added estimates of the Earth's carrying capacity, the attractiveness principle, and 2007 as our forecast for peak oil. Further, the energy and population *history* of the U.S. is shown to be an invaluable guide to forecast the energy and population *future* of the world. Specifically: U.S. energy production per capita has gone from growth, through stagnation, and now into terminal decline. The world has gone from growth and now into stagnation. The terminal decline of industrial civilization – according to these calculations – is imminent. The life expectancy of industrial civilization is about 100 years.

[Key Words: *energy; population; carrying capacity; attractiveness; peak oil; fuel stages; energy intervals; regress to coal; media taboo; collapse.*]

2. Background

> As we go from this happy hydrocarbon bubble we have reached now to a renewable energy resource economy, which we do this century, will the "civil" part of civilization survive? As we both know there is NO WAY that alternative energy sources can supply the amount of per capita energy we enjoy now much less for the 9 billion expected by year 2050. And energy is what keeps this whole game going. We are currently involved in a Faustian bargain – selling our economic souls for the luxurious life of the moment, but sooner or later the price has to be paid in some way.
>
> Walter Youngquist
> (Letter, 3/22/06),

The Olduvai theory states that the life expectancy of industrial civilization is approximately 100 years.[1] World energy production per capita *(e)* defines it. The

duration of industrial civilization begins when *e* reaches 30% of its 'plateau value' and it ends the year that *e* falls back to that value.[2] Historic energy and population data, multitude estimates of the Earth's carrying capacity, the attractiveness principle, our ten forecasts of peak oil, the regress to coal, and the U.S. analogue – taken together – betoken that the terminal decline of industrial civilization is imminent.

The theory has five postulates:

1. The exponential growth of world energy production ended in 1970.
2. U.S. *e* intervals anticipate Olduvai *e* intervals: (1) growth, (2) stagnation, and (3) terminal decline.
3. The terminal decline of industrial civilization will begin circa 2008-2012.
4. Brownouts and blackouts are reliable leading indicators of terminal decline.
5. World population will decline proximate with *e.*

A British astronomer first brought the subject of overshoot and collapse to my attention in 1964. I discussed the Olduvai theory with a U.S. Senator in Albuquerque, New Mexico in 1979. Ten years later I presented it to a receptive audience in New York. (Duncan, 1989) Data show that the theory I sketched out on those occasions has held up remarkably well.

Explaining, refining, and testing the Olduvai theory continues. To wit: My energy and population database for testing the theory runs from 1850 to yearend 2005. A scenario extends from 2005 to 2030. The 155 years of rigorous data are the basis for the 25-year scenario.[3]

3. The Earth's Carrying Capacity

> The cheap oil age created an artificial bubble of plentitude for a period not much longer than a human lifetime, a hundred years. … So, I hazard to assert that as oil ceases to be cheap and the world reserves are toward depletion, we will indeed suddenly be left with an enormous surplus population … that the ecology of the earth will not support. No political program of birth control will avail. The people are already here. The journey back to non-oil population homeostasis will

> not be pretty. We will discover the hard way that population hypergrowth was simply a side effect of the oil age. It was a condition, not a problem with a solution. That is what happened and we are stuck with it.
>
> James Howard Kunstler
> (2005, pp. 7-8)

In my previous essay I quoted five sources that put the earth's long-term carrying capacity between 0.5 to 2.0 billion people. (Duncan, 2005-2006) Since then I've added the following five references for this vital – but media taboo – subject:

- Professor Howard C. Hayden (2004, pp. 230-31), author of *The Solar Fraud: Why Solar Energy Won't Run The World*, worked out the details, "The earth's population has long since exceeded the numbers that could be supported by those [solar] energy sources. As well, the agricultural technology existing a mere century ago could not possibly feed the world's billions. For those who long for the good old days of a sub-billion population, it is useful to note that the only path to that end is for many billion people now alive to become dead, even if not one baby were to be born in the next thirty years."
- Dr. Ross McCluney (2004, slide 24), Principal Research Scientist at the Florida Solar Energy Center, put it bluntly, "My warning of today: We are systematically taking apart the life-support system of Planet Earth. We've exceeded the sustainable carrying capacity of the planet by a factor of 3. For everyone to live like the average North American it would take *three Earths*."
- Lindsey Grant (2005, p. 17), author of *The Collapsing Bubble: Growth and Fossil Energy* and the former U.S. Deputy Assistant Secretary of State for Environment and Population Affairs, states, "The [population of the] less developed world has grown by two-thirds since 1950 — and they were poor in 1950. The need for a fundamental shift in the ratio of resources to people in the poor countries may itself justify an optimum world population figure of one billion. Barring a catastrophe, it might take centuries to reach such figures, even with a determined worldwide effort."
- Dale Allen Pfeiffer (2006, p. 1), author of *Eating Fossil Fuels: Oil, Food and the Coming Crisis in Agriculture,* writes, "Studies suggest that without fossil fuel

based agriculture, the U.S. could only sustain about two thirds of its present population. For the planet as a whole, the sustainable number is estimated to be about two billion."

- Paul Thompson (2006, p. 6), author of *The Twilight of the Modern World: The Four Stages of the Post-Oil Breakdown,* describes the final stages of collapse, "Sooner or later, all the remains of our existing society will have gone, to become weed-clad ruins to rival those of the Aztecs and Mayans. By now, everybody who is unable to convert to a sustainable, self-sufficient lifestyle would have died off, leaving only those living in independent communities to continue human history. The world population may have fallen to as few as a thousand million, scattered in oases of agricultural land amongst deserts of buildings, rusting vehicles and forests."

Colin J. Campbell (2005, p. 315) gently but firmly sums it up: "We will have to change the way we live as [oil] production declines toward eventual exhaustion. I stress that it is the onset of terminal decline that is more relevant than the end of oil itself. It is not too soon to start thinking about what that may entail."

4. The Attractiveness Principle

BIEN VENIDOS A OREGON[4]

Welcome to Oregon. And they are sure coming! ! ! ! !

Jails, medical facilities, schools, and welfare agencies overwhelmed. We are getting buried. But somehow people don't catch on that the last thing we need is more people.

When I came to Eugene in 1957 – population 33,000 – now 144,000 and no end in sight. Crime, traffic jams, the most fertile land in Oregon paved over.

We are surely the frog-in-the-kettle with it slowly coming to the boil. I think we are already cooked. But, as you can see from this ad, there is no grasp of that situation here. …

I am going to say my piece, get out of the front line trenches, and watch the coming debacle from as safe a distance as possible – but really no safe distance

> as we are all caught in the coming tide, and the system as it begins to break down.
>
> Walter Youngquist
> (Letter, 11/24/05)

Jay W. Forrester in the 1950's invented system dynamics to model the behavior of complex social systems. In 1956 he started the System Dynamics Group at the Sloan School of Management at MIT. In 1970 he described his research in urban dynamics at the U.S. House of Representatives. "Why can public services not get ahead of demands? Why do the best of intentions for improving a city lead, instead, to greater social pressures, more commuting delays, increased drug addiction, higher crime rates, and greater welfare loads? The answer lies in what we have come to call the 'attractiveness principle'."

> The attractiveness principle states that, to any particular population class, all geographical areas tend to become equally attractive. Or perhaps more realistically stated, all areas tend to become equally unattractive. Why do all areas tend toward equal attractiveness? I use "attractiveness" to encompass every aspect of a city that contributes to its desirability or undesirability. Population movement is an equalizing process. As people move toward a more attractive area, they drive up prices and overload the job opportunities, the environmental capacity, the available housing, and the governmental services. In other words, rising population drives down all of the characteristics of an area that made it initially attractive. (Forrester, 1975, pp. 275-76)

While running Forrester's *World Dynamics* model – I found that his natural resource use per capita variable *(nr/pop)* and his material standard of living per capita variable *(MSL)* are nearly equal over the 400-year time span from 1900 to 2300. Further, the *MSL* variable in *World Dynamics* is a surrogate for *e* in the Olduvai theory. Attraction *(A)* is a difference between *MSL* values. In this manner Forrester's attractiveness principle can be applied to the U.S. and the rest of the world (RoW) as in the following example.

In 2005 the U.S. population was 297 million (4.6% of the world total) and that of the rest of the world (RoW) was 6,154 million (95.4%). The *MSL* for the U.S. was the 57.7 boe/c.[5] The *MSL* for the RoW was 9.8 boe/c. It follows that the attraction *(A)* from the RoW to the U.S. in 2005 was 47.9 boe/c. The attractiveness principle anticipates that

vast numbers of illegal immigrants will continue to enter and settle in the U.S. until the *MSL* of the U.S. falls to that of the RoW – or – until existing U.S. laws are enforced.[6]

We'll approximate the magnitude of the problem by assuming that: [1] all population numbers *(Pop)* remain at their 2005 levels through 2030, [2] the *MSL* of the U.S. remains at 57.7 boe/c, and [3] the *MSL* of the RoW begins at 9.8 boe/c in 2005. Then we'll compute to see if it's possible to increase the *MSL* of the RoW in year 2030 by a stated amount in each of the following cases:

- To raise the *MSL* of the RoW from 9.8 in 2005 to 57.7 boe/c in 2030 would require world energy production to increase by a factor of 4.8: *Impossible.*
- To raise the *MSL* of the RoW to 28.8 (50% of 57.7) in 2030 would require world energy production to increase by a factor of 2.5*: Impossible.*
- To raise the *MSL* of the RoW to 14.4 (25% of 57.7) in 2030 would require world energy production to increase by a factor of 1.4: *Improbable.*

Paul Thompson's website (2006) is forthright. "People in Third World countries, like Mexico, will do the only human thing, the thing we all would do in their circumstances – try to get into countries they perceive have wealth and jobs. The army, without oil will be unable to defend the borders. The sight of poor desperate people being shot in order to keep them out will not be pretty."

5. Peak Oil

> Ask anyone who remembers the 1980 crisis…. In 1980 it was a problem in distribution; the oil was there, but it wasn't getting to the corner gas station. In 2008, the oil won't be there. The psychological realization that the change is permanent may be as devastating as the shortage itself.
>
> Kenneth S. Deffeyes
> (2003, p. 186)

Geologist Walter Youngquist and I have made a series of ten forecasts of world oil production – one per year over 10 years. One of the forecasts put the world peak at 2005; two put it at 2006, six at 2007, and one at 2008. System dynamics software was

used. We call our approach “encircling the peak of world oil production” because – right or wrong – our forecasts for the world oil peak kept converging on 2007. Hence we can now look back to see if the oil production data support our forecasts.

Worldwide crude oil and condensate production averaged 72.5 million barrels per day in 2006 compared to 72.4 in 2005. (Radler, 2006) The result was an increase of 0.17% in 2006 over 2005. The importance of that minute increase becomes clear when we put it into context, as follows.

From 2003 to 2004 world oil production increased by 4.0%. Next from 2004 to 2005 it increased by 1.1%. (BP, 2006) And from 2005 to 2006 it increased by a mere 0.17%. (Radler, ibid) Thus in recent years the oil production rates have gone from strong growth to near zero growth. This rapid necking down of world oil production suggests that the peak is likely to occur in 2006, 2007 or 2008.

K. S. Deffeyes (2003, p. 158) highlights: “There is nothing plausible that could postpone the peak until 2009. Get used to it.”

Jeremy K. Leggett (2005, cover) foresees an unprecedented crisis: “The oil topping point — the day half of all the world’s oil is used up — will be reached, by many calculations, sometime soon. In fact, it may already be upon us. When the financial markets realize what’s happening, an economic crash and soaring energy prices will result. The entire global market place we all inhabit will crack and crumble.”

6. U.S. Fuel Stages Anticipate World Fuel Stages

> Before taking on [oil] data for the whole world, let’s begin with the United States. The purpose is to gain some perspective by looking at a mature area. Validating the method in a well-explored area gives us some confidence when approaching the less mature world picture.[7]
>
> Kenneth S. Deffeyes
> (2003, pp. 139-140)

A *dominant fuel stage* is said to occur when the production of one kind of fuel is significantly greater than that of another kind of fuel. Take coal and oil for example. When coal production exceeds oil production – then coal is said to be the dominant fuel: i.e., “a coal stage”. But when oil production of exceeds coal production – then the opposite is true: “an oil stage”.

If the sequence of fuel stages of one nation (1) is the same as that of another nation, and (2) each stage of the first nation precedes the respective stage of the second nation – then the dominant stages of the first nation can be used to help forecast the dominant stages of the second nation. Extending this idea: The *historic* fuel stages of the U.S. are an invaluable guide to forecast the *future* fuel stages of the world.

Dominant Fuel Stages of the U.S.: Wood (biomass) was the dominant U.S. fuel up until 1886 (stage 1). Next coal production dominated from 1886 to 1951 (stage 2, 65 years). Then oil dominated from 1951 to 1986 (stage 3, 35 years). Subsequently the U.S. has gone back to coal as its dominant fuel (stage 4, ongoing). Moreover, U.S. coal production is increasing while U.S. oil production is decreasing.

Dominant Fuel Stages of the World: Wood (biomass) was the dominant world fuel up until about 1900 (stage 1). Then coal dominated from 1900 to 1963 (stage 2, 63 years). Next oil dominated from 1963 to end 2005 (stage 3, ongoing but decelerating – as discussed above).

The hard coal facts: (1) China burned 36.1% of the coal that was consumed in 2005, (2) the U.S. burned 19.6%, and (3) India 7.3%. Further: (4) the world’s coal reserves are nearly 3 times its oil reserves, and (5) world coal production from 2000 to end 2005 grew at an average of 4.8%/y compared to oil’s 1.6%/y. (BP, 2006) All this suggests that the world will regress to coal as its dominant fuel in the near future.

K. Bradsher and D. Barboza (2006) report that very fine coal dust originating in China, containing arsenic and other toxic elements, is now detected drifting around the globe in increasing amounts.

K. S. Deffeyes (2003, p. 173) cautions: “Coal is the worst possible fossil fuel. Most of the fuel value comes from carbon, with the carbon dioxide added to the atmosphere. Sulfur and mercury are difficult to remove from coal; they are released to the air in ordinary burning.”

J. K. Leggett (2005, pp. x-xi) writes: “Richer humans dispatched poorer humans underground to hack out the coal.... Many died as rock faces collapsed, water flooded into mines, or invisible and odorless methane gas built up and exploded. If they survived their job, many would spend what remained of their short lives fighting for each breath, their lungs clogged with [coal] dust.”

7. U.S. *e* Intervals Anticipate Olduvai *e* Intervals

> As the British historian, Toynbee, wrote “The U.S. will set a record in the rate of rise – and *fall* of an empire.” Between wide open borders and fall of the dollar and growing population against a declining resource base, the United States will be defeated from within. Mobs will rule the streets in the nation that is now the third largest in the world – right behind China and India – and unable to support its population except by taking resources from other countries.
>
> Walter Youngquist
> (Letter, 3/20/06)

F. Peter W. Winteringham (1992, p. 6) confirms, “In the so-called developed and industrialized nations, energy is used for almost every aspect of human activity: heating, lighting, refrigeration, transport, and every kind of industry, including agriculture, forestry, fisheries, manufacturing, communications, and construction. … Energy use [per capita] is probably the simplest and most reliable indicator of the level of development of technology-based society.”

Energy production is expressed in calorific equivalents, so-named “barrels of oil equivalent per year” (boe/y). Thus industrial development (social change, cultural evolution) can be quantified as the ratio of energy production and population as *e* changes over time: *e* = *Energy/Population*.[8]

The U.S. *e* equals the ratio of U.S. indigenous energy production and U.S. population. The Olduvai *e* equals the ratio of world energy production and world population. The U.S. and the Olduvai *e* curves from 1930 to 2005 are compared in Figure 1. *Curve 2 is also the historic portion of the Olduvai theory (abbr. OT).* The arrows indicate the analogous intervals.

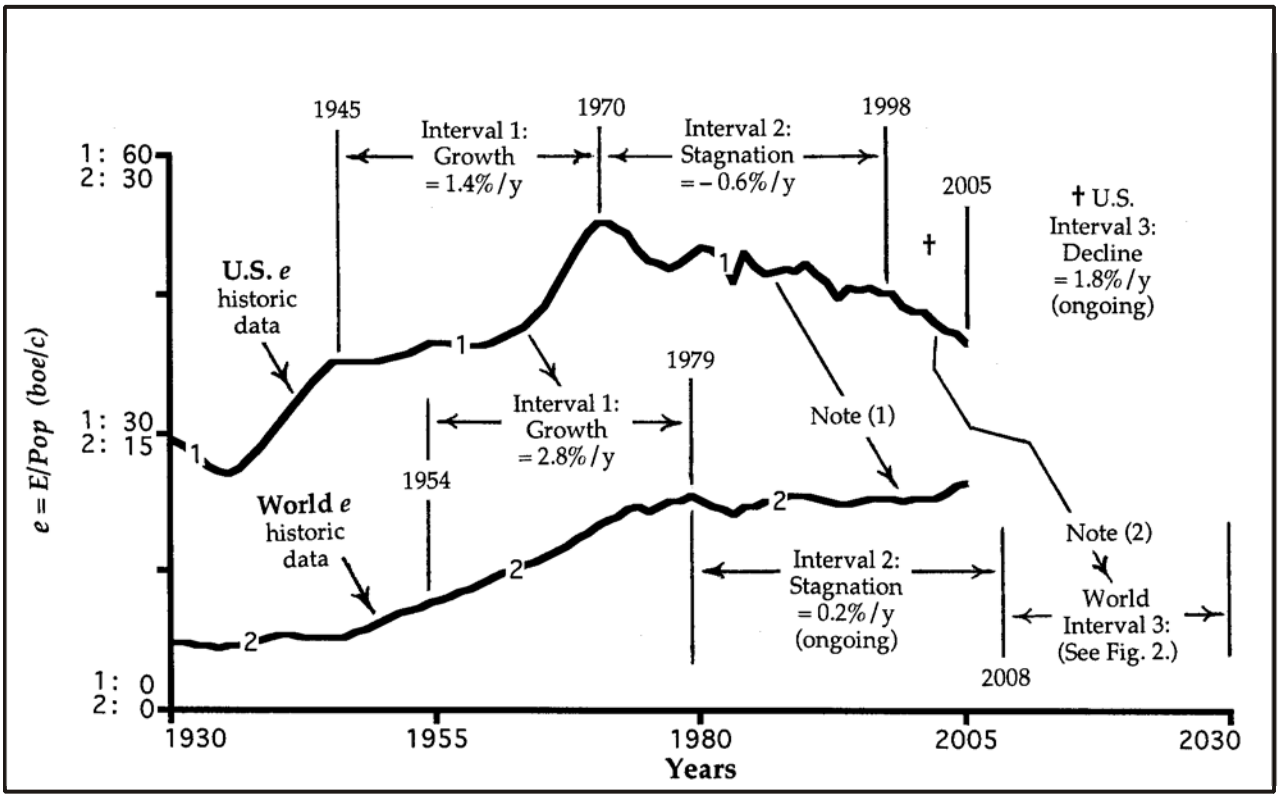

Figure 1. Energy production per capita *(e):* U.S. data vis-à-vis OT data. Notes: (1) The remainder of OT interval 2 will be inferred from U.S. interval 2. (2) OT interval 3 will be inferred from U.S. interval 3. Data sources: [1] For energy – Romer (1985) and BP (2006), [2] For population – USCB (2006) and UN (2006).

Observe in Figure 1 that: (1) the general shape of the U.S. *e* curve is similar to that of the OT *e* curve, and (2) the start of each U.S. interval precedes the start of the corresponding OT interval.[9]

We now compare each U.S. interval in curve 1 – left to right – with its analogous OT interval in curve 2. *Procedure:* If the U.S. interval and the OT interval are both complete, then proceed to the next interval. However if the U.S. interval is complete or at least partially complete, then select aspects of the U.S. interval to help forecast the analogous OT interval.

First: Notice that U.S. interval 1 is complete and it preceded OT interval 1 that is also complete. Hence proceed to the next interval.

Second: Observe that U.S. interval 2 is complete and it began 9 years before OT interval 2. As a result we will use U.S. interval 2 to help forecast the missing portion of OT interval 2. This will be done later.

Third: Notice that U.S. interval 3 began in 1998, but OT interval 3 has not yet begun — so we will use the existing 7-year portion of U.S. interval 3 – and other information – to forecast OT interval 3. This too will be done later.

Important comparisons of the U.S. and OT *e* intervals in Figure 1:

- *Interval 1 (growth):* U.S. interval 1 and OT interval 1 are both complete and show solid growth (U.S. growth was 1.4%/y and OT growth was 2.8%/y).
- *Interval 2 (stagnation):* The U.S. interval 2 and the OT interval 2 both show stagnation (the U.S. stagnated at a negative 0.6%/y and the OT stagnated at a positive 0.2%/y). Further, the U.S. interval 2 is complete at 28 years, while OT interval 2 (the “plateau”) is still ongoing after 26 years.
- *Interval 3 (terminal decline):* The U.S. decline began in 1998 and shows a decrease of 1.8%/y for 7 years. The OT decline has not yet begun.

Looking ahead: The historic data, the two analogies, and all of the other information discussed above are the basis to forecast the remainder of OT interval 2 and all of OT interval 3, as shown and explained below.

8**. The Olduvai Theory**

> It has often been said that, if the human species fails to make a go of it here on the Earth, some other species will take over the running. In the sense of developing intelligence this is not correct. We have or soon will have, exhausted the necessary physical prerequisites so far as this planet is concerned. With coal gone, oil gone, high-grade metallic ores gone, no species however competent can make the long climb from primitive conditions to high-level technology. This is a one-shot affair. If we fail, this planetary system fails so far as intelligence is concerned. The same will be true of other planetary systems. On each of them there will be one chance, and one chance only.
>
> Sir Fred Hoyle
> (1964, page 64)

The idea that high civilization is likely to overshoot and collapse has a fascinating history dating back at least to the Greek lyric poet Pindar (c. 500 BCE) and continuing right up to the present. (Duncan, 2001)

The OT spans the 100 years from 1930 to 2030. The theory is quantified by *e* and explained by the interaction of world energy production and population growth. Figure 2 illustrates the theory as three interrelated curves: world energy production (*E*, curve 1), world population (*Pop*, curve 2), and the curve for the OT itself (*e,* curve 3).

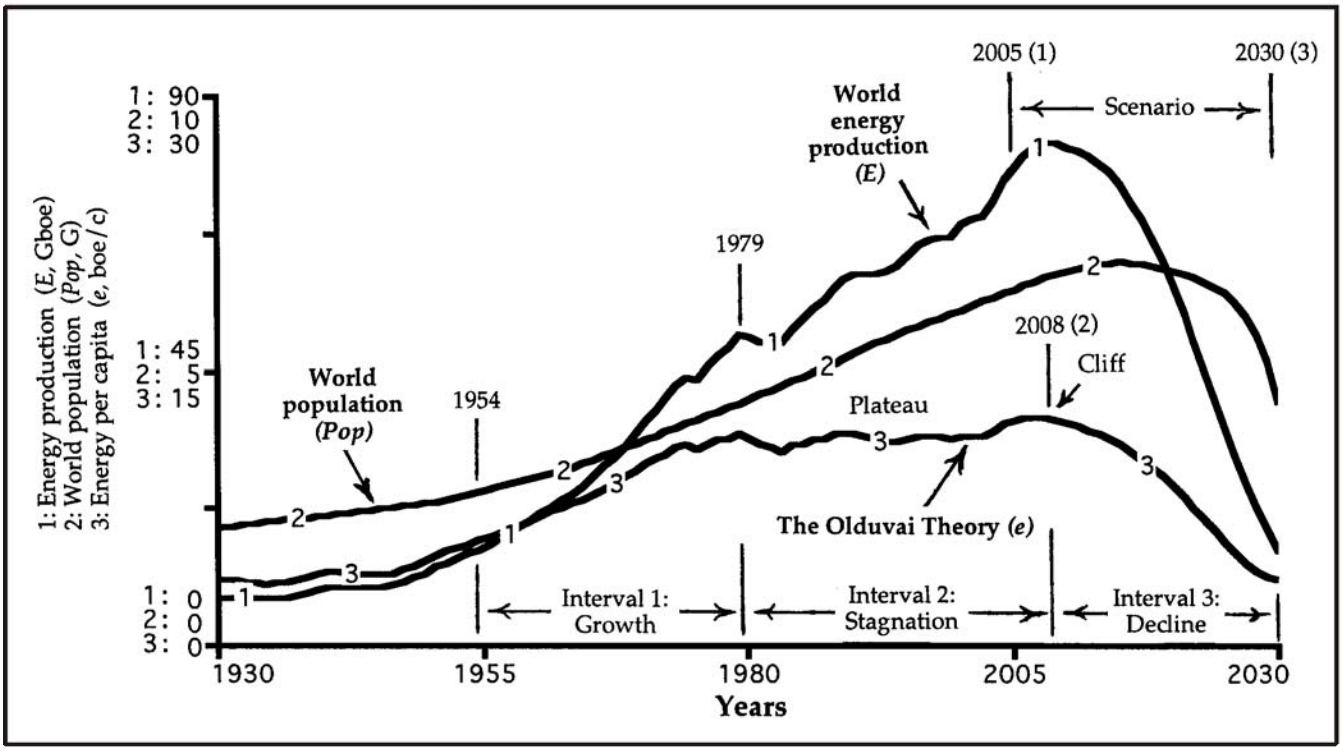

Figure 2. The Olduvai theory disaggregated: 1930 to 2030. The milestones along curve 3 depict and delimit the OT's three intervals. Notes: (1) The data for 2005 are: *E* = 78.5, *Pop* = 6.5 and *e* = 12.2. (2) The scenario values for 2008 are: *E* = 82.8, *Pop* = 6.7 and *e* = 12.4. (3) The values for 2030 are: *E* = 15.1, *Pop* = 4.4 and *e* = 3.4. Data sources: [1] For energy – Romer (1985) and BP (2006), [2] For population – UN (2006).

W. Youngquist (Letter, 04/07/06) explains why energy production and population growth – subjects so vital to our society and shown in Figure 2 – are banned from open discussion. "I have complained to [a journalist and long-time friend] about the fact that the media – newspapers in particular – ignore the matter of population pressures, especially on Earth resources and energy in particular. Lots of noise about energy problems but they never tie it to population growth. It is my view that the papers don't touch growth and population, one reason being they depend on growth of population in effect for their income. They want more subscribers but more importantly they get ad revenue from companies who love growth: retailers – more sales, car dealers – more

sales, department stores – more sales, etc. real estate developers – build more houses. So growth in population is a taboo subject."

Before discussing the details, it is foremost to confirm that the historic part of the OT (i.e., curve 3 from 1930 to 2005, Figure 2) is identical to all of curve 2 in Figure 1. In this way we're assured that the U.S. is a useful analog for the OT (i.e., the world).

Now we ask of Figure 2: How do the values of the variables *E* and *Pop* determine the values of the OT over time? The answer is found by comparing the relative rates of change of *E* and *Pop* as they vary over time:

- OT interval 1, growth from 1954 to 1979: *E* grew at an average of 4.3%/y, much faster than *Pop* at 1.9%/y. The net result was that the OT (their ratio) grew at an average of 2.8%/y for 25 years.
- OT interval 2, stagnation (the "plateau") from 1979 to 2008: *E* grows at 1.7%/y and *Pop* at 1.4%/y. The result is that *e* stagnates at 0.25%/y for 29 years.
- OT interval 3, terminal decline from the "cliff" in 2008 to 2030: *E* plunges at an average of 6.3%/y while *Pop* increases at 0.6%/y from 2008 to 2015, but then *Pop* falls at an average of 3.0%/y from 2015 to 2030. The overall result is that the OT curve declines at an average of 5.1%/y from 2008 to 2030.

By reviewing Figures 1 and 2 and relevant parts of the text we can distinguish: 1) what we know from historic data, 2) from what we infer from that data, and 3) from what is hypothetical.

1) We *know* from historic data that: [1] world oil production decelerated from 2003 to end 2006, [2] meanwhile world population grew at 1.2%/y, [3] the three most populous nations in the world were also the top coal burners, and [4] world coal production from 2000 to 2005 grew 3 times faster than world oil production. We also know that: [5] OT interval 2 (stagnation) grew at a scant 0.21%/y from 1979 to 2005. Finally we know that: [6] the U.S. interval 3 (terminal decline) decreased at an average of 1.8%/y from 1998 to 2005.

2) We *infer* from our oil forecasts and from the recent trends that: [1] world oil production is likely to peak before 2009. We infer from the world's coal reserves that: [2] world energy consumption will soon be dominated by coal. Further we infer from the U.S. interval 3 that: [3] the OT interval 3 (terminal decline) is imminent, and [4] it will be much steeper than was the U.S. decline.[10]
3) The OT scenario is *hypothetical*.

Of course an infinite number of scenarios are possible, but each is constrained by three conditions. [1] The curves for each scenario must meld with their respective data curves at 2005. [2] The OT requires that – sooner or later – the world population will decline to a sustainable 0.5 to 2.0 billion. [3] The value of *e* for the OT will approach 3.4 boe/c in 2030 – the same value that it had in 1930.

Brinkmanship – sad to say – is our *de facto policy*.

The OT is widely discussed and debated. Search the web for "olduvai theory" to access various web sites and newsgroups.

Rigorous tests of the theory are most welcome.

9. Conclusions

The Olduvai theory states that the life expectancy of industrial civilization is approximately 100 years: c. 1930 to 2030. Ackerman's law defines it: *e* = *Energy/Population.* Its duration is starts the year *e* reaches 30% of its average plateau value and ends the year *e* falls back to that value.

Five postulates follow:

1. The exponential growth of world energy production ended in 1970.
2. U.S. *e* intervals anticipate Olduvai *e* intervals: (1) growth, (2) stagnation, and (3) terminal decline.
3. The terminal decline of industrial civilization will begin circa 2008-2012.

4. Brownouts and blackouts are reliable leading indicators of terminal decline.
5. World population will decline proximate with *e*.

Postulate 1 has been verified. (Duncan, 2005-2006, pp. 138-139.)

All of the U.S. *e* intervals precede the Olduvai *e* intervals and are analogous to them. *Postulate 2 is verified for Olduvai interval 1 and for 26 years of Olduvai interval 2.*

The beginning of Olduvai interval 3 (terminal decline) was inferred from: [1] U.S. *e* interval 3, [2] our series of forecasts of peak oil, [3] the recent deceleration of world oil production, and [4] the rapid acceleration of world coal production. *Postulate 3 can be tested within about 8 years.*

Postulate 4: Increasing brownouts and blackouts were predicted in my previous essays (see Duncan, 2000, 2001, 2005-2006). Readers can study this ominous trend by searching the web for “blackouts” + “electricity”.

Postulate 5 waits testing.

Wrap up: It took Homo sapiens over 200 years to accept the Copernican theory and the species has yet to accommodate the Darwinian theory. Consequently I see little chance that it will face the looming decline of industrial civilization in time to change course.

10. ACKNOWLEDGMENTS

Walter Youngquist's knowledge, wisdom, and good humor have helped me over many an impasse. Keith Wilde, Virginia Abernethy, David Burghardt, Mark Lindley, David Pimentel, Robert Hickerson, Lee Johnson, and Roy DeBritz have helped in many ways. Richard Pelto and Patrick McNally provided important suggestions. Joe McMullen and Gerald Sehlke affirmed the importance of the system dynamics approach. Brian Bloom, Eugene Marner, and Hiroaki Wakabayashi helped answer (their own) tough questions. The web sites of Jay Hanson, Tom Robertson, Ron Swenson, and Paul Thompson have brought forth a wealth of comments and suggestions.

11. ENDNOTES

1. The Olduvai Gorge is located in northern Tanzania and commonly called "The Cradle of Mankind". It is a very steep sided ravine (a k a "the cliff") some 30 miles long and 300 feet deep. Exposed deposits show rich fossil fauna, many hominid remains and items belonging to one of the oldest stone tool industries, called Olduwan. I visited there in 1989 and chose the name as the theme for the theory.
2. The standard definition of a pulse calls for "30% of the peak". However the world *e* has not gone into a peak, but rather a "broad plateau" wherein its average value is 11.4 boe/c. Then 30% of 11.4 is 3.4. Thus we arrive at 3.4 boe/c as the beginning and ending values of *e* for industrial civilization, a k a "the Olduvai theory".
3. For completeness I've estimated energy production back to its beginnings: Coal was first burned in England in the 11th century and it was the first hydrocarbon used for doing mechanical work in about 1700. Natural gas was used for street lighting in Fredonia, New York in 1821. Oil was produced from shovel-dug pits in the Chechen Republic before 1833. Oil was first produced from a drilled well near Titusville, Pennsylvania in 1859. Hydroelectricity lit Niagara Falls Village in 1881. Nuclear electricity from an experimental breeder reactor lit several buildings near Arco, Idaho in 1951. Nuclear electricity fed a power grid in the USSR in 1954, in England in 1955, and in the U.S. in 1956.
4. "BIEN VENIDOS A OREGON" is the headline in an advertisement by station KEZI 9 and published in the Eugene Register-Guard (11/23/05) that reads, "Lane County's population is growing rapidly. Latino families make up the largest portion of this new growth. Discover the challenges our new neighbors face. Tonight @ 6pm & 11pm."
5. *Energy consumption per capita* must be used to calculate the material standard of living of a nation (i.e., indigenous energy production plus imports).
6. Population migrations, of course, are also caused by sporadic events such as war, famine, and ethnic violence. However the *attractiveness principle* operates incessantly – day-after-day and year-after-year.
7. Similar statements apply to natural gas, coal, nuclear electricity, and hydroelectricity.
8. Frederick Ackerman in 1932 was first to discover the importance of *e* and Leslie White independently discovered it in 1943. (Duncan, 2005-2006.)
9. In the vernacular, "As goes the U.S. – so goes the world."
10. The Olduvai interval 3 (terminal decline) is expected to be much steeper than the U.S. decline because it won't be moderated by energy imports.

12. DEFINITIONS

"Analogue" means the likening of one thing to another on the basis of some similarity between the two. "Scenario" means an outline for any projected series of events, real or imagined. "Imminent" means within about 6 years. "Brinkmanship" means the policy of pursuing a hazardous course of action to the brink of catastrophe. "Energy" *(E)* means the combined production of oil, natural gas, coal, nuclear electricity and hydroelectricity. *"Pop"* means population. *"e"* means energy production per capita. "G" means billion. "Gb" means billion barrels of oil. "Gboe" means billion barrels of oil equivalent (in joules). "RoW" means rest of world (e.g., the world minus the U.S.). "Cliff" means the year that industrial civilization goes into terminal decline. "Brink" and "cliff" are synonymous. All equations and variable names are italicized.

13. REFERENCES

BP (2006). *British Petroleum statistical review of world energy June 2006.* www.bp.com.

Bradsher, K. and Barboza, D. (2006). Pollution from Chinese coal casts shadow around globe. www.nytimes.com, June 11.

Campbell, C. J. (2005). *Oil Crisis.* Essex, UK: Multi-Science Publishing Co.

Deffeyes, K. S. (2001, 2003). *Hubbert's Peak: The Impending World Oil Shortage*. Princeton, NJ: Princeton University Press.

Duncan, R. C. (1989). Evolution, technology, and the natural environment: A unified theory of human history. *Proceedings of the American Society for Engineering Education: Science, Technology, & Society*, 14B1-11 to 14B1-20.

Duncan, R. C. (2000). The peak of world oil production and the road to the Olduvai Gorge. *Geological Society of America Summit 2000, Pardee Keynote Symposia,* Reno, NV, Nov. 13, 13 p.

Duncan, R. C. (2001). World energy production, population growth, and the road to the Olduvai Gorge. *Population and Environment,* 22 (5), May, 503-522.

Duncan, R. C. (2005-2006). The Olduvai theory: Energy, population, and industrial civilization. *The Social Contract*, Winter, XVI (2), 134-144.

Duncan, R. C. and Youngquist, W. (1999). Encircling the peak of world oil production. *Natural Resources Research,* 8 (3), 219-232.

Forrester, J. W. (1971, 1973). *World Dynamics*. Cambridge, MA: Wright Allen Press.

Forrester, J. W. (1975). *Collected Papers of Jay W. Forrester*. Cambridge, MA: Wright-Allen Press.

Grant, L. (2005). *The Collapsing Bubble: Growth and Fossil Energy*. Santa Anna, CA: Seven Locks Press.

Hayden, H. C. (2004). *The Solar Fraud: Why Solar Energy Won't Run The World*. Pueblo West, CO: Vales Lake Publishing.

Kunstler, J. H. (2005). *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century.* New York: Atlantic Monthly Press.

Leggett, J. K. (2005). *The Empty Tank: Oil, Gas, Hot Air, and the Coming Global Financial Catastrophe.* New York: Random House.

McCluney, R. (2004). *The Fate of Humanity*, slide 24. www.futureofhumanity.org.

Pfeiffer, D. A. (2006). *Eating Fossil Fuels: Oil, Food and the Coming Crisis in Agriculture*. www.newsociety.com/.

Radler, M. (2006). Oil production, reserves increase slightly in 2006. *Oil & Gas Journal,* 104 (47), Dec. 18, 20-23.

Romer, R. H. (1985). *Energy Facts and Figures.* Amherst, MA: Spring Street Press.

System Dynamics (2006). http://sysdyn.clexchange.org/people/jay-forrester.html

Thompson, P. (2006). The twilight of the modern world: The four stages of the post-oil breakdown. www.wolfatthedoor.org.uk.

UN (2006). *World Population to 2300*. United Nations. www.un.org.
USCB (2006). *Total Midyear Population.* U.S. Census Bureau. www.census.gov.
Winteringham, F. P. W. (1992). *Energy Use and the Environment*. London: Lewis Publishers.
Youngquist, W. (2005-2006). Letters to R. C. Duncan.