The Oil Drum
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World Energy Consumption - Beyond 500 Exajoules

Posted by Rembrandt on February 16, 2012 - 4:42am
Topic: Supply/Production
Tags: biomass, coal, data, energy, global, hydro, natural gas, nuclear, oil, primary energy consumption, renewable energy [list all tags]

Today's post goes into the global consumption of energy and provides a dataset in Excel for researchers on global primary energy consumption from 1830 to 2010. In other words, the energy contained in fossil fuels, uranium, and biomass in their raw form before processing into electricity, heat, or liquid fuel, and direct electricity production from hydro, solar, wind, and geothermal. The dataset, based on an assessment of seven different data sources, shows the following:

- We are now burning 10 times as much energy as a century ago to provide the goods and services we consume.
- Energy consumption is still increasing rapidly, with an approximate 550 exajoules (523 Quadrillion BTUs) consumed at the primary energy level in 2010.
- Of this total 80% was provided by fossil fuels, 11.3% by bio-energy mainly from wood combustion, 5.5% from nuclear, 2.2% from hydro, and 0.4% from other renewable energy sources.
- The historic time for each energy source to grow from 1 to 10 exajoules in primary energy production was 12 years for nuclear, 33 years for crude oil, 39 years for natural gas, 52 years for coal, and 59 years for hydro-power.

A graphical depiction of the data and comparison of sources can be found below the fold.

The charts below can be found in the Excel file, source attribution can be found at the bottom. The data in the charts is normally displayed in exajoules (10^18 joules) and in a few cases in Quadrillion (10^15) BTU's for data comparison. The following conversion factors were used:

- 1 joule = 9.48×10^{-4} BTU.
- 1 boe (barrel of oil equivalent) = 5.45×10^{6} BTU.
- 1 cubic feet of natural gas = 983 BTU.
- 1 metric ton of coal = $22.72 * 10^{6}$ BTU.
- 1 exajoule = 174 million barrels of oil equivalent.

A few notes on calculations made to make a data comparison:

- The dataset displays primary energy for oil, gas, and coal, as well as nuclear power. To obtain primary energy data for nuclear power, electricity produced has been adjusted for the efficiency losses assuming a 33% efficiency factor, as per IEA standards.
- The historic data for bio-energy from Fernandes (2007) and Smil (2010) is calculated by estimating the average energy use per person for a large number of countries, multiplying this value with the population, and adjusting for other energy sources. In this manner, a reasonable estimate can be obtained for bio-energy consumption across historic time. Smil

(2010) covers not more than a dozen countries in this manner, while Fernandes (2007) covers more than a hundred and is more complete in his decadal time series.

- The data for coal is normally best taken in million tonnes of oil equivalent (mtoe) as this filters out the energy differences between coals, as opposed to taking data in million tonnes of coal. To convert these values to joules/btu's the lower heating value of the coal was used. Similarly, for natural gas the values were for BP Statistical Review (2011) converted from cubic feet to BTUs and exajoules using lower heating values.
- To convert installed solar pv, geothermal, and wind power capacity to electricity produced, a number of conversion factors were applied. For solar a capacity rating of 15% was assumed, for wind a capacity rating of 23.4%, and for geothermal 90%. In case of hydropower, no conversion efficiency loss has been applied in the data.

Global Primary Energy Consumption per source stacked and individual graphs

The first two charts in this section display the evolution of primary energy consumption broken down by energy sources. Figure 1 shows the evolution from 1830 to 2010 and Figure 2 from 1970 to 2010. The same is shown in Figures 3 and 4 but by the individual curves of each energy source.

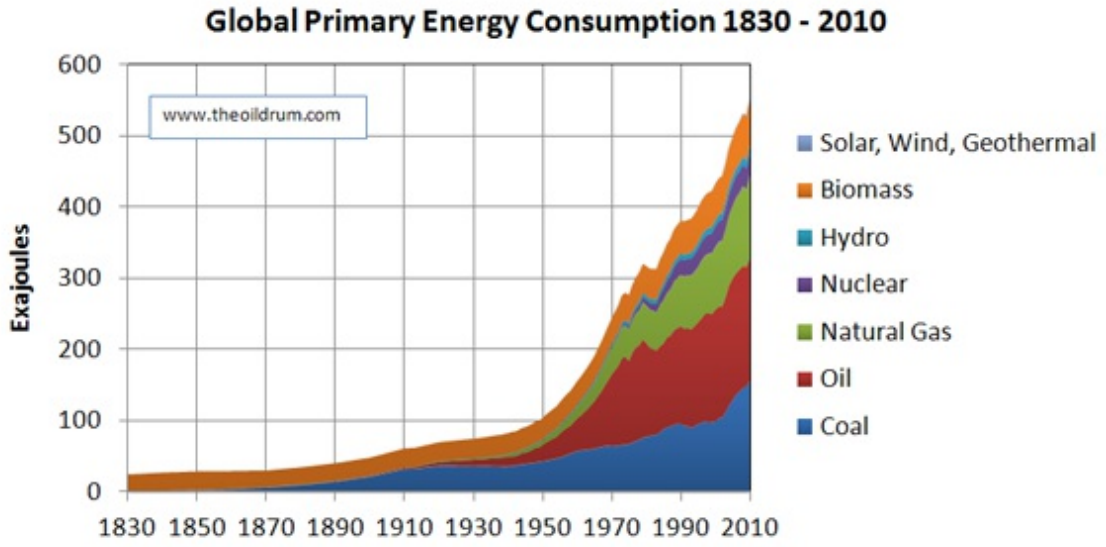

Figure 1 - Stacked chart of Global Primary Energy Consumption 1830 - 2010

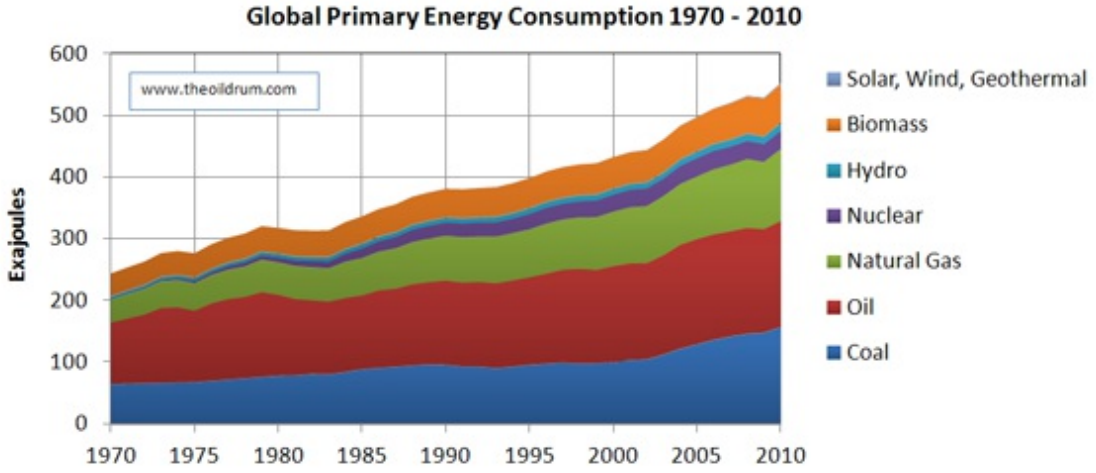

Figure 2 - Stacked chart of Global Primary Energy Consumption 1970 - 2010

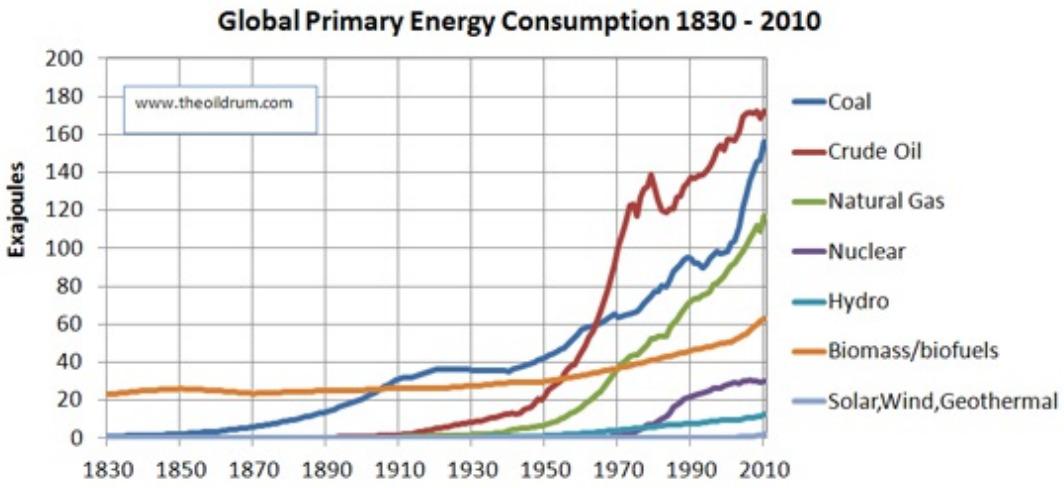

Figure 3 - Individual curves for energy sources of Global Primary Energy Consumption 1830 - 2010

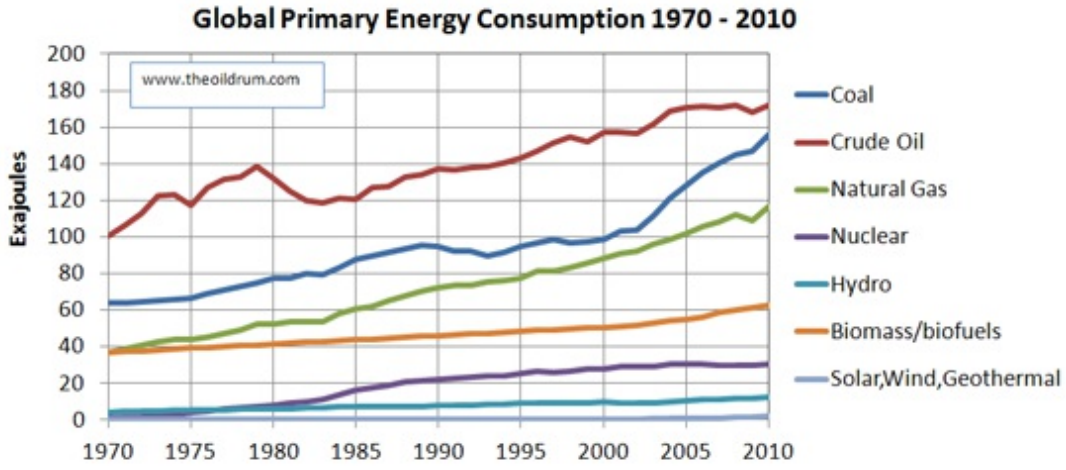

Figure 4 - Individual curves for energy sources of Global Primary Energy Consumption 1970 - 2010

Growth path comparison of Primary Energy delivered per source

In this section, a dataset is graphically depicted wherein a comparison is made of the number of years for each energy source to grow from 1 exajoule to 10 exajoules of energy production. By comparing these, it can be shown how long different energy sources took to become influential in global energy supply.

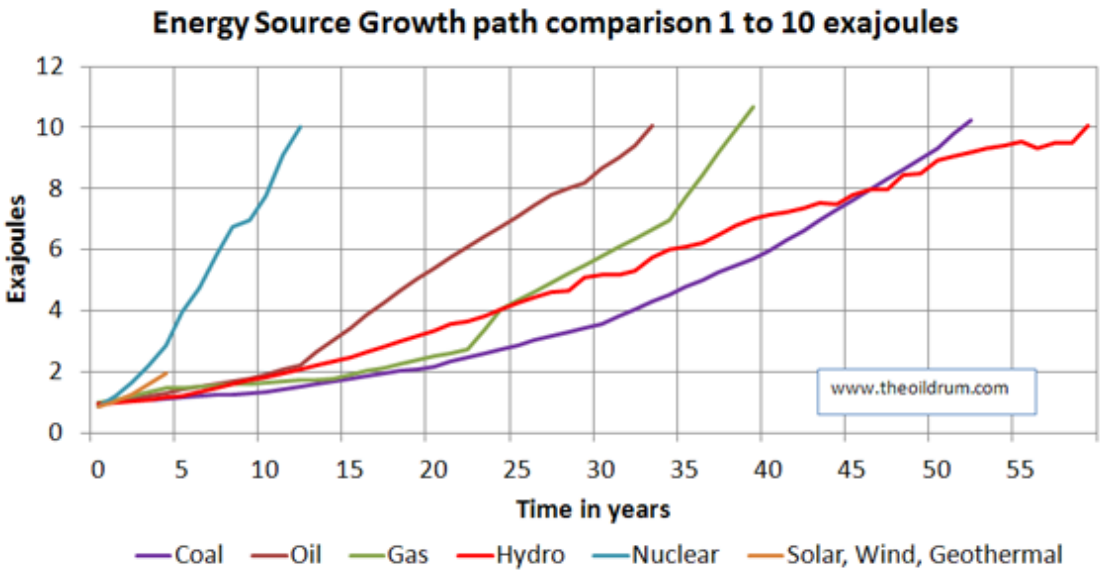

Figure 5 - Energy Source Growth Path comparison 1 to 10 exajoules

Comparison of different Primary Energy Data sources

Four charts are shown below that outline the differences between datasets for bio-energy (biomass + biofuel), coal, natural gas, and crude oil. The main differences in the datasets can be found in the years after 2000 for biofuels, 1950 to 2000 for natural gas, and 1945 to present for crude oil.

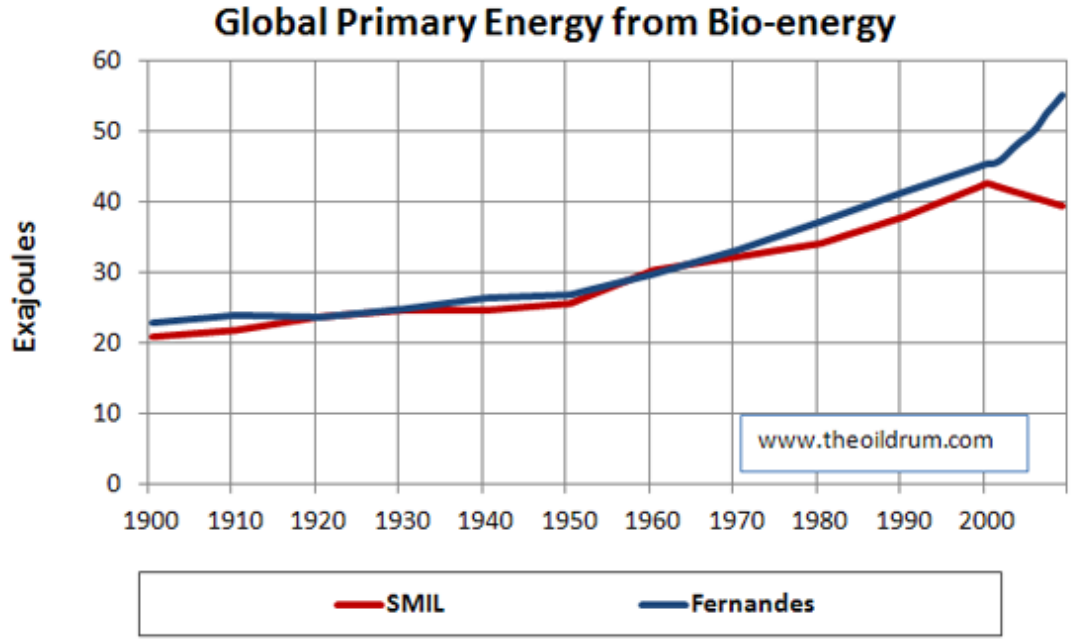

Figure 6 - Global Primary Energy from Bio-Energy comparing Smil and Fernandes 1900 to 2008

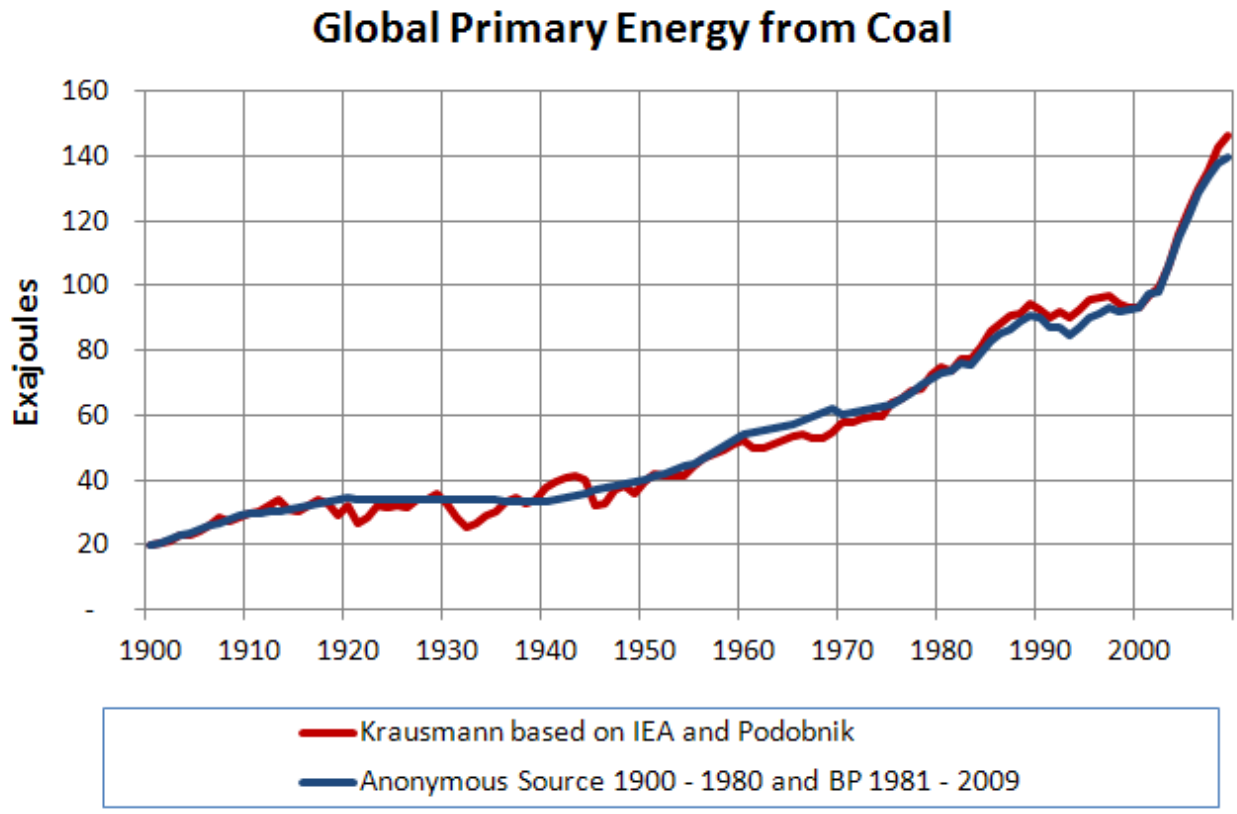

Figure 7 - Global Primary Energy from coal comparing Krausmann, Anonymous Source, and BP Statistical Review 1900 to 2008

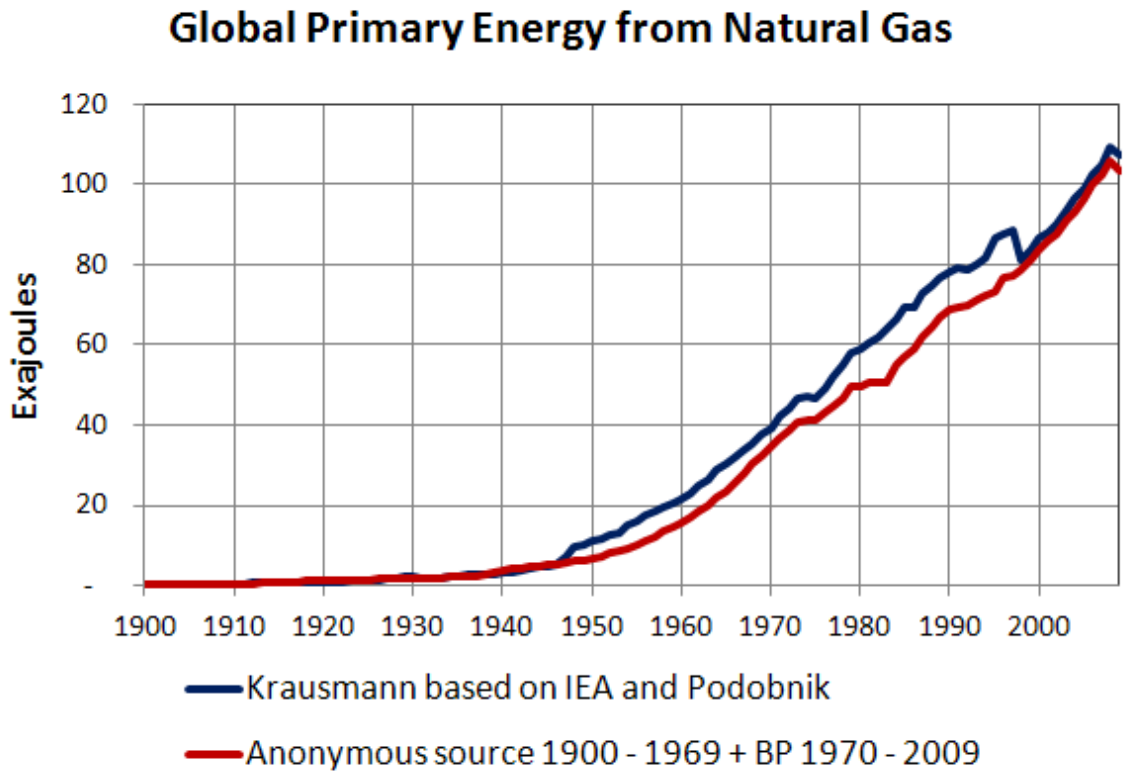

Figure 8 - Global Primary Energy from Natural Gas comparing Krausmann, Anonymous

Source, and BP Statistical Review 1900 to 2008

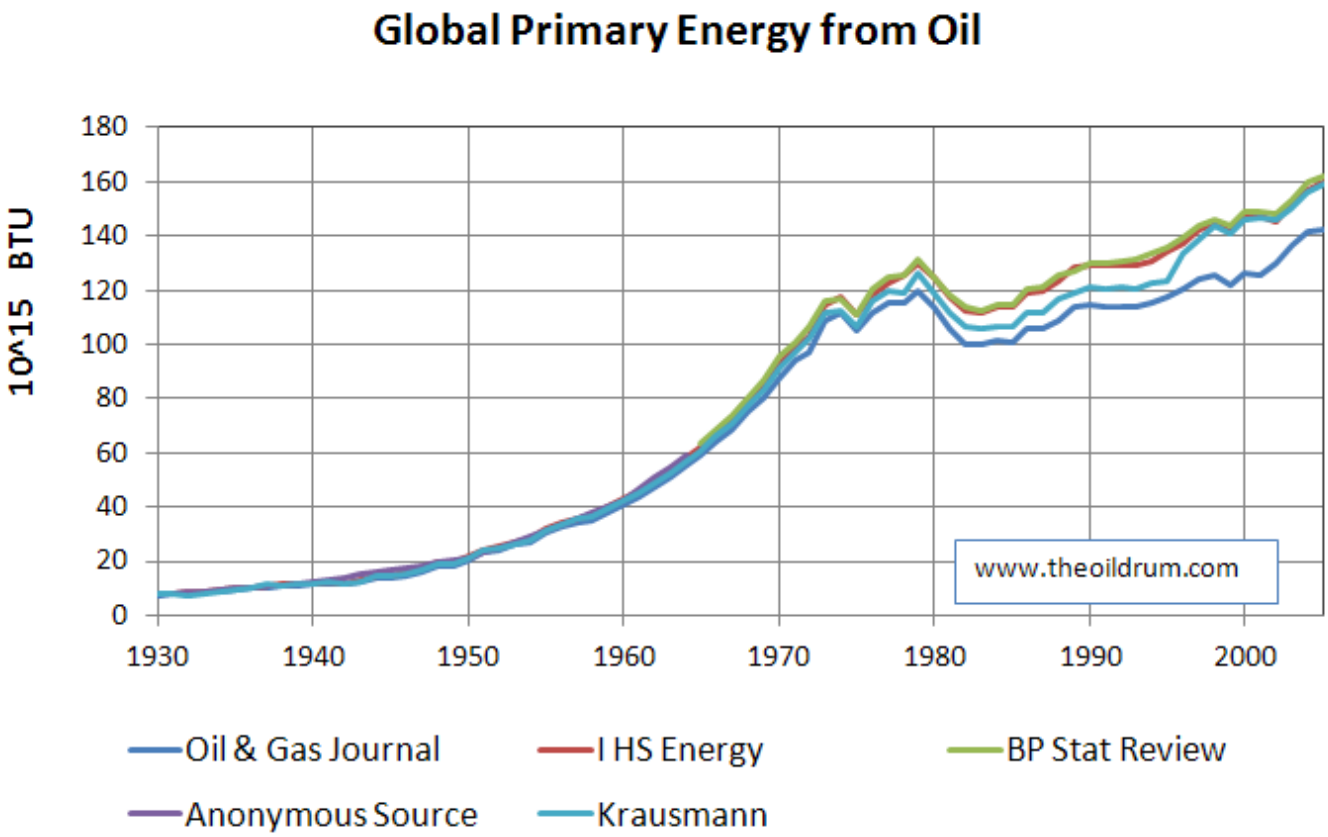

Figure 9 - Global Primary Energy from Crude Oil comparing O&G Journal, IHS Energy, Anonymous Source, Krausmann, and BP Statistical Review 1930 to 2005

Sources of data

Anonymous Source - Book reference not available due to permanent library closure
BP Statistical Review - BP Statistical Review of World Energy 2011
Fernandes - Fernandes et al. 2007. Global Biofuel Use 1850 - 2000. Global Biogeochemical cycles. Vol. 21
IHS Energy - old petroconsultants database
Krausmann - Krausmann et al., 2009. Growth in material use, GDP and population during the 21st century. Ecological Economics. 68
Oil & Gas Journal - Oil & Gas Journal
Smil - Smil, V., 2010. Energy Transitions: History, Requirements, Prospects. Praeger: Santa Barbara, California