Global primary energy productions, 1800–2014

Note on methodology and data sources

When using my database on global primary energy production from 1800 to 2014, please, cite as: Court, V., 2016. *Energy, EROI, and Economic Growth in a Long-Term Perspective*. Ph.D. Thesis in Economics, Université Paris Nanterre.

Several studies deal with past primary energy productions, but to the author best knowledge, it is impossible to find a single publication providing consistent time series for all the different primary energy forms that have been used at global scale during the last two hundred years. Below is the methodology employed to provide the consistent time series of global energy productions (1800–2014) shown in Figure 1.9, p. 24 of my Ph.D. thesis (Figure 1 below).

Regarding traditional biomass energy (woodfuel and crop residues), average estimates were computed from Fernandes et al. (2007) and Smil (2010). Primary fossil fuels time series were retrieved from the online data portal of The Shift Project (2015), which builts on the original work of Etemad & Luciani (1991) for the 1900–1980 period and EIA (2014) for 1981–2010. From 1800 to 1900, the different fossil fuel time series were completed with the original 5-years interval data of Etemad & Luciani (1991), and gaps were filled using linear interpolation. The online data portal of The Shift Project (2015) was also used to retrieve productions of nuclear and renewable electricity, i.e., hydro, wind, solar, geothermal, wastes, ocean (wave, tidal, OTEC) electricity, and for modern biofuels (ethanol and biodiesel).

Concerning nuclear and renewable electricity values, the original time series were amended to correct a commonly agreed, yet not scientifically backed-up, convention: when expressed in primary equivalent terms, renewable electricity productions are usually expressed in raw electricity terms, whereas the expression of nuclear electricity is artificially boosted in heat equivalent terms. Indeed, when one speaks about a primary energy mix, a three-fold factor is systematically applied to the estimates of nuclear raw electricity production to take into account that the fission of uranium atoms first generate heat used to boil water into steam whose kinetic energy is then converted into electricity with an overall average efficiency of 33%. To the author's mind, such a convention to express nuclear energy in primary term is not a problem, as long as electricity from the so-called renewable technologies suffer the same kind of conventional arithmetic to boost the expression of their primary productions' estimates. Hence, just as a 33% efficiency is commonly assumed for nuclear primary-to-final energy conversion, equivalent factors should be applied to renewable electricity producing technologies. Based on Kreith & Goswami (2007) and Zarrouk & Moon (2014), the primary-to-final energy conversion efficiency provided by the EIA (2012, p.345) were slightly changed as follows: 33% for nuclear, 85% for hydropower, 25% for wind power, 15% for solar, 12% for geothermal power, 33% for biomass/wastes, and 50% for wave/tidal plants.

The human food-energy consumption was estimated by hypothesizing an average daily intake of 2500 kcal/capita which was multiplied by a year-to-year global population estimate based on the original data of the United Nations (1999, p.5; 2015). Draft animal food-energy (i.e., fodder) and traditional water/wind energy use (through waterwheel, windmill, and sail ships), were estimated using the following backward induction method: (i) the shares of these energy forms in the global supply mix have been arbitrarily chosen at different time step based on Kander et al. (2014) and basic linear interpolations were used to produce continuous times series for these relative shares; (ii) a counterfactual total global energy

consumption including food, fodder, and traditional water/wind uses is computed using the previously determined relative shares; (iii) multiplying fodder and traditional water/wind relative shares with the counterfactual total deliver year-to-year energy consumption estimates of fodder and traditional water/wind energy.

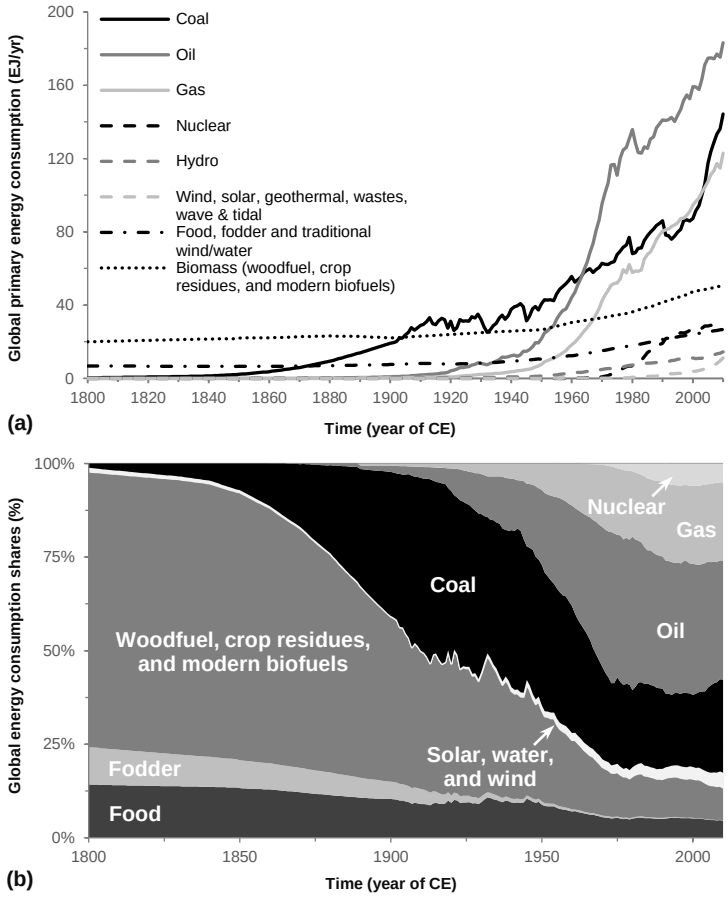

Figure 1. Global primary energy productions, 1800–2010 CE. (a) Annual quantities (EJ/year). (b) Relative shares (%). "Solar, water, and wind" aggregates traditional waterwheels/windmills with renewable electricity producing technologies (i.e. wind power, solar PV, solar thermal, geothermal, wastes, wave, tidal, and OTEC). Data source: see text.

References

Etemad, B. & Luciani, J., 1991. *World Energy Production, 1800-1985. Production Mondiale d'Énergie, 1800-1985*, Genève, CH: Librairie Droz.

Fernandes, S.D. et al., 2007. Global Biofuel Use, 1850-2000. *Global Biogeochemical Cycles*, 21(2), pp.1–15.

Kander, A., Malanima, P. & Warde, P., 2014. *Power to the People: Energy in Europe Over the Last Five Centuries*, Princeton, NJ: Princeton University Press.

Kreith, F. & Goswami, D.Y., 2007. *Handbook of Energy Efficiency and Renewable Energy*, Boca Raton, FL: Taylor & Francis Group, LLC.

Smil, V., 2010. *Energy Transitions: History, Requirements, Prospects*, Santa Barbara, CA: Praeger Publishers Inc.

The Shift Project, 2015. Historical Energy Production Statistics. Available at: http://www.tsp-data-portal.org/Energy-Production-Statistics#tspQvChart.

United Nations, 2015. Department of Economic and Social Affairs, Population Division, World Population Prospects, the 2015 Revision. Available at: http://esa.un.org/unpd/wpp/Download/Standard/Population/.

United Nations, 1999. *The World at Six Billion. Part 1 - Introduction and Table 1-4*, Available at: http://www.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf.

US Energy Information Administration (EIA), 2012. *Annual Energy Review 2011*, Available at: https://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf.

US Energy Information Administration (EIA), 2014. International Energy Statistics database. Available at: http://www.eia.gov/cfapps/ipdbproject/IE.

Zarrouk, S.J. & Moon, H., 2014. Efficiency of Geothermal Power Plants: A Worldwide Review. *Geothermics*, 51, pp.142–153.