OPTIMUM POPULATION SIZE REVISITED.

By

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Abstract.

In 2019, average world energy consumption per capita was 22.308 MWh (total energy consumption = 171,240 TWh, for all purposes; global population in 2019 = 7.676 billion), but total non-nuclear and non-CO_2-emitting renewable energy sources only contributed ~17,400 TWh, or ~2.267 MWh per capita per annum. This would only be enough to sustain a global population of 779,989,242, approximately that of 1750.

Key words: population; energy consumption; energy; CO2; renewables; nuclear.

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The question of optimum global human population size was examined by Daily, Ehrlich, A.H. and Ehrlich, P.R. (1994). They concluded that it was between 1.5-2 billion, stating their preference for the lower figure on p. 474.

It is perhaps time to re-visit the question, as it is arguable that the Daily, Ehrlich and Ehrlich paper is now somewhat dated. They base their argument on global energy consumption (see pp. 472-474), and the present author will do the same. It should be noted, however, that the argument depends, just as theirs did, on the assessment of the Earth's biological (or *ecological*) carrying capacity, see Daily and Ehrlich, P.R. (1992, which cites Ehrlich, P.R. and Holdren, 1971), del Monte-Luna, *et al* (2004). Pimentel, *et al* (1999), noted the constraints on human numbers due to the limitations of Earth's resources – which ought, frankly, to be self-evident.

Compare and contrast, alas, the utter absurdity of the EAT-Lancet Commission's[i] claim that we could, *sustainably*, feed a human population of 10 billion in 2050 on the basis of their recommended diet. This is based on the manifestly false assumption that modern agricultural methods can produce the cereals, fruit, nuts, vegetables and dairy products, *inter alia*, to supply each of these 10 billion people with 2,500 kilocalories per day = 10.46 MJ/day = ~3.82 GJ/year of nutritional energy. Daily nutritional energy intakes of between 1,400-3,200 kilocalories = ~5.86 MJ to ~13.39 MJ are recommended by the US Departments of Health and Human Services and Agriculture (2015) – no-one seems to have noticed the potential for conflict of interest between these two departments (see Shill, *et al*, 2012) – depending on age, sex, and activity levels.

Yet these same farming methods are based on monoculture and the intensive use of chemical fertilisers and pesticides, which are degrading soils, destroying soil biodiversity, and killing insect pollinators (Woźniak, 2019; Kalia and Gosal, 2011; Pahalvi, *et al*, 2021; Connolly, 2013). They are also leading to widespread deforestation and loss of wildlife habitats, and *not* just where they involve livestock (Goldman, *et al*, 2020; Weisse and Goldman, 2021; Scanes, 2018). Furthermore, climate change will exacerbate soil degradation over time, leading either to the drying-out of soil, or to its super-saturation, depending on local climatic conditions (Brevik, 2013; Qafoku, 2014; Jannson and Hofmockel, 2019).

The FAO, *et al*, 2021, reported that 'close to 12% of the global population was severely food insecure in 2020, representing 928 million people – 148 million more than in 2019' (p. xii). Yet of the 9.4 billion tonnes of primary crops produced globally in 2019, sugarcane accounted for 1.9 billion tonnes (~20.22% of the total), outstripping maize (not all of which was for human consumption, and the same applies to sugarcane: ~40% of the US maize, or 'corn', crop is converted to ethanol annually), 1.1 billion tonnes (11.7%), rice, 800 million tonnes (8.51%), and wheat, 800 million tonnes (FAO, 2021). Were the world's hungry supposed to survive on a diet of sugarcane?

Food was, and still is, very unequally distributed between countries. While some suffered high levels of malnourishment, others suffered from chronic obesity, caused by over-eating. Walpole, *et al* (2012) noted that in 2005, North America had 6% of the world's population, but 34% of human biomass due to obesity, whereas Asia had 61% of the world's population, but only 13% of human biomass due to obesity, which amounted, globally, to 3.5 million tonnes, 1.22% of a total world adult human biomass of 287 million tonnes.

In 2019, the world consumed 171,240 TWh[1] of energy, of which oil provided 53,620 TWh, coal 43,849, gas 39,292, 'traditional biomass' (i.e., wood or dung), 9,225 and 'modern biofuels' (e.g., ethanol derived from maize) 1,143 TWh. All of these, of course, produce carbon dioxide (CO_2) emissions, so 85.92% of the energy consumed in 2019 was carbon intensive (on biofuels, see Lark, *et al*, 2022).

Hydro-electric power accounted for 10,455 TWh, wind power 3,540, solar 1,793, 'other renewables' 1,614, and nuclear power 6,711 TWh (op. cit.), or 14.08%. 'Other renewables' include concentrated solar, geothermal and 'ocean power'. (Sources: https://ourworldindata.org/energy-production-consumption;

https://www.iea.org/fuels-and-technologies/other-renewables.)

The total mid-year 2019 global human population was 7.676 billion (US Census Bureau, 2022). Thus total energy consumption per capita in that year – for all purposes, household, industrial, agricultural,

[1] 1 Wh (watt-hour) = 3,600 J = 3.6 kJ; 1 kWh = 1,000 Wh = 3.6 MJ; 1 MWh = 3.6 GJ; 1 GWh = 3.6 TJ; 1 TWh = 3.6 PJ (petajoules); 171,240 TWh = 616.464 EJ (exajoules); 22.308 MWh = 80.3088 GJ; 17,400 TWh = 62.64 EJ.

and for transport and construction – was, therefore, ~22.308 MWh. If that figure is reduced by 85.92%, so that all CO_2-emitting forms of energy are eliminated, the available energy per capita is reduced to ~3.141 MWh. This includes nuclear power as well: if *that* is also eliminated, a further 3.919% reduction is necessitated, making for a total 89.839% reduction, and leading to a figure of ~2.2667 MWh per capita.

The arithmetic is now very simple: 7.676 billion could not have been sustained on a total energy consumption of ~17,400 TWh.

Yet countries varied considerably in their consumption of primary energy in 2019: China consumed 39,361 TWh; the USA 26,291; India 9,461; Russia 8,279; Japan 5,187; Canada 3,948; Germany 3,650; Brazil 3,445; France, 2,689; the UK, 2,178; Italy 1,770; South Africa 1,500 TWh: G7 + BRICS total = 107,759 TWh (source: ourworldindata, op. cit.), or ~62.93% of the world's 2019 total energy consumption, leaving the remaining 186 countries[ii] (182 UN Member States + Taiwan[2], Kosovo, the Holy See and Palestine, the last

[2] Taiwan, as the 'Republic of China', *was* a UN Member State, and a Permanent Member of the UN Security Council, from 1945-1971, when it was expelled from both, and replaced by

two having 'observer status' at the UN) to divide up what was left (~37.07%) between them. China's[iii] population was 1.408 billion in 2019, India's[iv] 1.366 billion, the USA's[v] 328.33 million, Brazil's[vi] 211.05 million, Russia's[vii] 144.4 million, and South Africa's[viii] 58.56 million; the total population of the BRICS[3] countries + the USA in 2019 being 45.81% of the global human population.

Canada's[ix] population was 37.53 million; Japan's[x] was 126.3 million; Germany's[xi] 83.09 million; France's[xii] 67.25 million; the United Kingdom's[xiii] 66.84 million; and Italy's[xiv] 59.73 million, these countries therefore contributing an additional 5.74% of the world's population. Thus 51.55% of the world's population consumed 62.93% of its energy in 2019.

We can see from the above the energy consumptions per capita in 2019 for each of the G7[4] and BRICS countries, and the extent to which they deviated from the then global mean of 22.308 MWh. In the USA, it was 80.075 MWh; in China, it was 27.955. In India, the energy

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the People's Republic of China (PRC), following the PRC's recognition by the then President Richard Nixon of the USA.

[3] BRICS = Brazil, India, China and South Africa.

[4] G7 = the USA, Canada, Japan, Germany, France, the United Kingdom, Italy.

consumption per capita was 6.926 MWh; in Russia, it was 57.33; in Brazil, it was 16.323; in South Africa, it was 25.615. Japan's was 41.068 MWh, Canada's was 105.196 (making the country the world champion energy consumer), Germany's was 43.928, France's was 39.985, Italy's 29.633, and the UK's was 32.585 MWh. Average UK household energy consumption[xv] in 2019 was ~15.4 MWh.

There was no necessary correlation between a country's energy consumption per capita and its GDP per capita: Russia's energy consumption per capita was higher than Japan's, but Japan's GDP per capita, at $40,777.609 that year (current US$)[xvi] was considerably higher than Russia's at $11,497.649 (same basis)[xvii]. Canada's was $46,338.341 (same basis)[xviii], only $5,560.732 a year more than Japan's, in spite of the enormous disparity in their energy consumption. Clearly, however, energy must be taken into account in all discussions of international equity and equality, along with other factors, such as income and wealth distribution[xix].

Waste of energy has to be taken into consideration: Forman, *et al* (2016) estimated that 72% of primary energy consumption is lost, mainly as waste heat into the environment. This figure can, undoubtedly, be diminished, but the Second Law of Thermodynamics places a strict limit on the extent to which it can be (see: Lior and Zhang, 2007). Furthermore, it is arguable that increased energy efficiency, far from *reducing* energy consumption, as might be thought to be the case, actually *increases* it, due to Jevons' Paradox (Jevons, 1865; Alcott, 2005), at least within the context of a profits-driven, capitalist economy, requiring never-ending economic (and therefore demographic) growth in order to survive (see Khazzoom, 1980; Brookes, 1990; Saunders[5], 1992; Kallis, *et al*, 2018).

If annual global mean per capita energy consumption remains at 22.308 MWh, but that is supplied exclusively by renewable, zero-CO_2 emitting sources (and the reasons for excluding nuclear are well-rehearsed by Green America [2021] and Greenpeace UK [no date], and perhaps more impartially, by Ramana, 2009), there is sufficient for a global human population of 779,989,242, assuming no increase in the total annual renewable energy supply of 17,400 TWh.

[5] Saunders (1992) refers to the Jevons Paradox (Jevons, 1865) as the 'Khazzoom-Brookes Postulate' (see Khazzoom, 1980, Brookes, 1990).

This population is ~55.4% of China's in 2019, or 57.1% of India's. It would constitute just 10.16% of the 2019 global population. It is also the world human population of 1750 (see US Census Bureau, 2021), the year which marked the beginning of the Industrial Revolution, and is taken as the baseline year for atmospheric CO_2 in calculations of global warming, the figure for that year being 278 ppm (UK Meteorological Office, 2021).

If we overlook all the objections to nuclear power, as Lovelock (2004) urges to do – and it should be noted that his argument is predicated on the assumption of a global population of 'six billion, and growing', which is what it was in 2004 – then adding the 6,711 TWh of nuclear energy produced in 2019 to the 'green energy' total brings it to 24,111 TWh, which would support, at the same level of energy consumption per capita, a global population of 1,080,823,023, or 14.08% of the 2019 number. This is approximately the global population of between 1800 and 1850 (see US Census Bureau, 2021, op. cit.). It was 1 billion in 1825, according to the *Encyclopedia Britannica* (no date). Of course, we can reduce the amount of energy consumption per capita, in order to increase the size of the population that may be sustained, but increased energy efficiency can only accomplish this in a post-capitalist economic environment, as we have seen. Otherwise, it will be a case of having to reduce activity, for example in transport and construction. Transport accounted for 19% of global final energy demand in 2015 (Khalili, *et al*, 2019), and 8.3 billion tonnes of CO_2 in 2019 (IEA, 2020, p.138), 22.548% of the 36.81 billion tonnes emitted that year (Hausfather, 2019).

The human impact on the biosphere is not confined to animal populations, nor indeed to vertebrate populations, but Ceballos, Ehrlich, P.R. and Raven (2020), have pointed out the impact of increasing human numbers and consumption rates on the ongoing sixth mass extinction in general, and the loss of vertebrate species in particular, saying this 'may be the most serious environmental threat to the persistence of civilisation' because of its irreversibility, and because of the loss of what they term 'humanity's crucial life-support systems.'

If that impact is to be limited to what the biosphere can tolerate in future – a matter for our *own* survival, as well as for the survival of the other species, both animal and plant, with which we share this planet, a global population of not very much more than 10.16% of the

2019 one is the *maximum*, as well as the optimum, acceptable. If the Gaia theory (see Grossman, 2020) is accepted, it could well be that, if we fail to curb our population as needed, then the biosphere will do it for us, and – if so – will do so suddenly, quickly and drastically. The result is likely to be decidedly unpleasant, and anything *but* humane. As David Attenborough said in 2013 (quoted by Grossman, op. cit.),

> **‘We [humans] are a plague on Earth. It’s coming home to roost over the next 50 years or so. It’s not just climate change… Either we limit our population growth, or the natural world will do it for us, and the natural world is doing it for us right now.’**

Pace Attenborough, it is not merely population *growth* that needs to be limited, but the size of the population itself – indeed, it needs to be reduced considerably from its current excessive size. Attenborough’s point was reiterated by James Lovelock, the originator of the Gaia hypothesis (Lovelock, 1972, 1989), in an article by him published in the *Guardian* newspaper on Tuesday, 2nd November 2021:

‘We... need to address the problem of overpopulation and to urgently halt the destruction of tropical forests. Most of all, we need to look at the world in a holistic way... But my fellow humans must learn to live in partnership with the Earth, otherwise the rest of creation will, as part of Gaia, unconsciously move the Earth to a new state in which humans may no longer be welcome. The virus, Covid-19, may well have been one negative feedback. Gaia will try harder next time with something even nastier.’

It will be no good then for the *Guardian* journalist, George Monbiot, to accuse Gaia of being ‘racist’ (see Monbiot, 2020, and response from Mynard, 2020), as he generally accuses anyone who dares to talk about population of being, because Gaia will be wholly arbitrary with regard to whom she kills or doesn’t kill. Yet this is one and the same George Monbiot who talks about the need for ‘rewilding’ (Monbiot, 2019), and who laments the destruction of wildlife habitats (Monbiot, 2014). In any case, the cull of our species is likely to be considerable.

The benefit of a smaller human population, and a very much smaller global economy, at a simpler level of technology, is likely to be a much greater space for the rest of the biosphere to flourish.

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[xvii] See: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=RU.

[xviii] See: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=CA.

[xix] See: World Inequality Database: statistics on (1) top 1% share of wealth: https://wid.world/world/#shweal_p99p100_z/US;FR;DE;CN;ZA;GB;WO/2018/eu/k/p/yearly/s/false/14.2165/80/curve/false/country; (2) top 1% share of income: https://wid.world/world/#sptinc_p99p100_z/US;FR;DE;CN;ZA;GB;WO/2018/eu/k/p/yearly/

s/false/5.17549999999999995/30/curve/false/country; (3) top 10% carbon emitters: https://wid.world/world/#lpfghg_p90p100_z/US;FR;DE;CN;ZA;GB;WO/2018/eu/k/p/yearly/l/false/2.92/100/curve/false/country.