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Data Trimming, Nuclear Emissions, and Climate Change

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Abstract Ethics requires good science. Many scientists, government leaders, and industry representatives support tripling of global-nuclear-energy capacity on the grounds that nuclear fission is "carbon free" and "releases no greenhouse gases." However, such claims are scientifically questionable (and thus likely to lead to ethically questionable energy choices) for at least 3 reasons. (i) They rely on trimming the data on nuclear greenhouse-gas emissions (GHGE), perhaps in part because flawed Kyoto Protocol conventions require no full nuclear-fuel-cycle assessment of carbon content. (ii) They underestimate nuclear-fuel-cycle releases by erroneously assuming that mostly high-grade uranium ore, with much lower emissions, is used. (iii) They inconsistently compare nuclear-related GHGE only to those from fossil fuels, rather than to those from the best GHG-avoiding energy technologies. Once scientists take account of (i)–(iii), it is possible to show that although the nuclear fuel cycle releases (per kWh) much fewer GHG than coal and oil, nevertheless it releases far more GHG than wind and solar-photovoltaic. Although there may be other, ethical, reasons to support nuclear tripling, reducing or avoiding GHG does not appear to be one of them.

Keywords Climate change · Conservation · Data trimming · Energy · Energy efficiency · Greenhouse-gas emissions · Renewables · Solar photovoltaic · Wind

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Introduction

To reduce greenhouse-gas emissions (GHGE) by curtailing use of fossil fuels, many people propose tripling (the largest increase deemed reasonably achievable) nuclear plants, from about 450 to 1,000–1,500, so they supply 20 percent of year-2050 global electricity [1]. Underlying this ethical question (should we triple nuclear plants in order to reduce GHGE?) is a scientific question: Is nuclear tripling an effective GHGE-avoider?

On one hand, many say "yes." Accepting the "climate-necessity" argument for increased nuclear power, the US Department of Energy (DOE), UK Environment Secretary, and others say tripling is needed because nuclear energy is "carbon free" [2–7]. Official US-government, Nuclear Energy Institute, and World Energy Council documents, respectively, say tripling is needed because nuclear is "clean" and "emissions free," "does not emit greenhouse gases," and is "not a source of carbon-dioxide" [8–11].

On the other hand, this article shows the climate-necessity" argument has at least two flaws. (1) It "trims the data" on nuclear-related GHGE, perhaps partly because Kyoto-Protocol conventions do not "count" nuclear energy as releasing GHG. (2) It inconsistently fails to apply this climate-necessity argument to better GHGE-avoiders, among energy technologies. Consider both flaws.

The nuclear-fuel cycle has 13 stages: (1) uranium mining, (2) milling, (3) conversion to uranium hexafluoride (UF6), (4) enriching UF6, (5) fuel fabrication, (6) reactor construction, (7) reactor operation, (8) waste-fuel processing, (9) fuel conditioning, (10) interim waste storage, (11) waste transport, (12) permanent storage, and (13) reactor decommissioning and uranium-mine reclamation. When proponents of the climate-necessity argument claim nuclear energy is "carbon free," they err by trimming GHGE data. Even under optimum conditions, only one or two nuclear-fuel-cycle stages—often (7)—s carbon free [12].

If one excludes all fuel-lifecycle GHGE analyses that rely on secondary sources, are unpublished, or fail to explain GHGE estimation/calculation methods, 103 fuel-lifecycle, GHGE analyses remain. These calculate nuclear-fuel-cycle GHGE ranging from 1.4 to 288 g carbon-dioxide-equivalent emissions per kWh of electricity (gCO_2/kWh). Nuclear-industry studies give total GHGE as 1.4 g but consider only one/two nuclear-fuel-cycle stages. Environmental groups give total GHGE as 288 g but appear to double-count some emissions. The mean total GHGE calculated by these 103 studies is 66 gCO_2/kWh—roughly what independent university scientists (funded by neither industry nor environmentalists), at places like Columbia, Oxford, and Singapore, calculate [13–15]. These university analyses use current, refereed, published, empirical data on facilities' lifetime, efficiency, enrichment methods, plant type, fuel grade, and so on. Their calculations (fairly consistent across universities), show the COAL:COMBINED-CYCLE NATURAL GAS:NUCLEAR:SOLAR PV:WIND ratio—for mean, fuel-lifecycle GHGE—is 1010:443:66:32:9—a ratio of 112 coal : 49 gas : 7 nuclear : 4 solar : 1 wind. If reasonably correct, these calculations show nuclear emits about 16 times fewer GHG than coal; about 2 times more than solar; and about 7 times more than wind [5].

Because climate-necessity proponents fail to count most nuclear emissions, they commit a fallacy of composition**,** making an invalid inference from GHGE in 1–2, to all 13, nuclear-fuel-cycle stages. Trimming these data however, may arise partly from Kyoto-Protocol conventions. These conventions assess carbon content in nuclear fuels at their consumption-point (electricity generation) and hence ignore fuel-cycle carbon content [16].

Even when they consider GHGE from most nuclear-fuel-cycle stages, climate-necessity proponents typically trim nuclear-GHGE data through unrealistic assumptions, e.g., considering only nuclear-GHGE associated with higher-grade, not lower-grade, uranium ores. Yet cleaner, higher-grade ores are nearly gone [17]. Nuclear-fuel cycles using ten-times-less-concentrated ore (<0.01 percent yellow-cake) have total GHGE equal roughly to those for natural-gas-fuel cycles; all other things being equal, lower-grade-uranium-ore nuclear cycles release 12 times more GHGE than solar cycles, and 49 times more than wind cycles [18]. Some scientists even claim that low-grade-uranium-ore cycles could require more energy than they produce [14], [19].

Nuclear energy may be not only less effective than wind/solar for GHGE-avoidance, but also detrimental to it. UK business-school studies show capital-intensive, heavily-subsidized nuclear plants undermine funding for efficiency/renewables and delay more-effective technologies for GHGE-avoidance [20]. Germany's Oko Institute shows efficiency/wind/gas cogeneration currently has negative costs of GHGE-avoidance because each cuts energy demand and is cheap [21]. This may be one reason the pro-nuclear US DOE, National Academy of Sciences, and Office of Technology Assessment say that, using energy efficiencies alone, "the US could cut carbon emissions to 1990 levels by 2010 with no net cost to the nation's economy" [22].

Regardless of who is correct about energy efficiency, if earlier university data are correct, solar and wind appear more effective (than nuclear) at GHGE-avoidance. Because most industry and many government reports analyze GHGE from only coal, natural gas, nuclear, and petroleum [16], climate- necessity proponents are inconsistent in failing to assess/promote more-effective technologies. Yet the classic Princeton University study shows that each of more-than-seven options—including technological efficiencies, conservation, natural gas, wind, solar-PV, biomass, and hydrogen—could alone, cost-competitively, "at an industrial scale"—supply as much energy as nuclear tripling [1]. That may be one reason wind generates 20% of Danish electricity [23]. By 2020, the British (with Europe's best wind) plan to use wind to supply 6 times (and solar to supply 3 times) their nuclear increase of 6 plants [14], [20]. If preceding university data are correct, if climate-necessity proponents are consistent, and if their primary goal is GHGE-avoidance, climate-necessity supporters should assess/promote wind and solar before nuclear energy.

Of course, the climate-necessity argument is not the only (and perhaps not the most important) consideration relevant to future energy choices. Reasonable energy choices must rely on careful assessment of many claims. These claims cover topics from cost, to ease of implementation, to ethical consequences of various energy choices. Claims (that require assessment) include those of the investment/credit-rating firm, Standard and Poor's, which says nuclear "cost overruns are highly

probable" [3], [24]; those of the European Renewable Energy Council and Shell Oil, which say renewables can cost-competitively supply 50% of global energy by 2040–2050 [25], [26]; and of nuclear proponents, who say nuclear is "the only existing power technology which could replace coal in base load" [3].

Once all such energy claims—like those above—are scientifically and ethically evaluated, energy choices will be clearer. This article has not analyzed these other claims. Nevertheless, because of data trimming, fallacies of composition, and inconsistency, the climate-necessity argument errs. Of course, there may be other reasonable arguments for nuclear-tripling, but the climate-necessity argument is not one of them.

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