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Reply

Reply to Fthenakis et al. Comment on "Seibert, M.K.; Rees, W.E. Through the Eye of a Needle: An Eco-Heterodox Perspective on the Renewable Energy Transition. *Energies* 2021, *14*, 4508"

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As many of the criticisms in this rebuttal echo those in the earlier Diesendorf rebuttal, to which we thoroughly responded, we direct Fthenakis et al., to that lengthy response.

That said, we do feel compelled to make a few additional comments on specific faults in this rebuttal.

To begin with, Fthenakis et al., do not seem to have read our paper. Most importantly, they ignore our opening argument that the climate/energy debate must be framed within the real-world context of ecological overshoot [1]. Overshoot means that modern techno-industrial (MTI) society is on a fatal course driven by overconsumption and overpopulation (Figure 1). The authors simply restate the case—which we called out as flawed—for 100% so-called renewable energy (RE) as a means of sustaining the unsustainable status quo. This runs the debate right off the rails.

In their defense of so-called RE, Fthenakis et al., accuse us of unscientifically cherry-picking data to support our "opinion", of citing "known climate change deniers", of citing sources while not agreeing with the conclusions of their authors, of not being critical of fossil fuels (FF), and, worst of all, of being unethical. *Of course* we refer mainly to studies that refute many of our critics' assertions and support our perspective. Is this not the same approach they and others in the modern renewables camp also use? Our critics' base resort to ad hominem attacks is regrettable. Not only that, but some of these attacks are flat-out untruths. Ozzie Zehner cannot, by any stretch of the imagination, be construed as a climate denier. While Mark Mills is routinely attacked for being critical of so-called RE, and indeed champions the continued use of FF, he recognizes that civilization has had, and continues to have, an impact on the climate. In any case, it is entirely acceptable to cite a source without agreeing with the entirety of its material or the ideology of its author. Sounding the alarm about techno-distractions from the real existential crisis facing humanity can hardly be considered unethical. Is it not ironic that the tone and tenor of the Fthenakis et al., rebuttal is reflective of the approach some members of this camp tend to employ in responding to its detractors and that we called out in Eye of the Needle? As we noted, "this myth [of business-as-usual by alternative means] has become so well accepted in the public and academic mind that to question it is to be perceived as anti-renewable, pessimistically discounting human ingenuity, or even a shill for the FF industry. Those who do venture critical observations often do so with trepidation and constraint".

The authors' claim to be representing the scientific consensus overlooks three important points. First, the "scientific consensus" to which they refer is the self-referencing consensus of so-called RE proponents only. This narrow engineering focus is chronically blind to overshoot, a phenomenon of population dynamics well-known to ecologists and even sociologists [1–3]. Second, no scientific consensus is set in stone. Our core understanding is constantly changing with the introduction of new information and as new perspectives are validated. This often happens when outside viewpoints challenge conventional thinking à la Kuhn's paradigm shift or Planck's paraphrased observation that "science progresses one funeral at a time". Third, it is well-known that, like many other institutions today, the academy has, in some instances, become unduly influenced by the financial sway of the corporate sector. It is not difficult to see how this might affect the "scientific consensus" of the energy transition debate.

Fthenakis et al., claim that our use of "the phrase 'so-called renewables' is misleading, and fundamentally wrong from a scientific point of view", because the sun continues to shine and "most of the materials used to produce the solar modules will still be recoverable". Again, the authors appear not to have read our paper. Their statement epitomizes the "starry-eyed optimists" whom we noted "argue that the amount of solar radiation that reaches the Earth's surface far exceeds global energy consumption" and therefore "confuse total energy flow with practical harvestability ... " We were, of course, pointing out the obvious fact that solar panels and wind turbines are physically perishable and have to be periodically replaced. Need we restate yet again the simple fact that sunlight and wind flows are continuous (not renewable) but that the technologies that capture and convert those flows to useable energy are not?

As to the claims by Fthenakis et al., on the efficacy of resource recovery, it may be that recycling is often materially superior to starting from scratch, but energy can be used only once, no material can be 100% recycled, and the process produces dangerous waste. We wrote that recycling "requires copious amounts of energy, water, and other inputs, and exposes workers to toxic materials that have to be disposed of". This is simple truth. There is nothing "misleading and fundamentally wrong" about it.

To pursue the material aspects further, our critics don't seem to recognize that, if wind or solar installations double, then the embodied energy and material more or less double; any absolute increase in scale requires a corresponding absolute increase in energy and material use, recycling notwithstanding. Consider that, if it were possible for wind and solar electricity to replace just half of the present FF use by 2030 (which would require that many difficult-to-electrify uses of FF actually become electrified), then the equivalent of ~1.1 times the total existing global stock of wind and solar installations would have to be constructed each year for the next nine years [4], i.e., wind/solar would require, every year, new energy and material inputs approximately equivalent to the entire quantity used by the sector in its entire history to date. Over the next nine years, until 2030, the demand for new energy and materials would be approximately ten times as much as has been consumed to date. This also assumes no growth on a planet projecting at least half a billion more people and a 27% increase in energy demand by 2030. The limitations of the growth-with-recycling argument are further highlighted when returning to the core problem of overshoot. Overshoot is a potentially terminal condition, the only "fix" for which is significantly reduced consumption and populations, not ten-fold increases in demand for rare materials involving even further ecological degradation from the mining, processing, and refining of declining quality ore.

The authors claim that the roughly $252 trillion cost we cited for a global solar program was wildly exaggerated, but to support their critique, they compare this sum mostly to cost estimates for the United States only.

They state that "the high temperature processes in the life cycle of PV panels are powered by electricity, not directly by fossil fuels; there is no fossil fuel input connection, for instance, to a Siemens reactor for the production of semiconductor- and solar-grade Silicon or to the sub-atmospheric semiconductor deposition chambers used in any of the various PV technologies [57]. In fact, the overwhelming majority, around 80–90%, of energy inputs to the manufacture of solar PV come in the form of electricity, meaning that solar energy could very easily be self-sustaining [58]". These assertions miss at least three points. First, we grant that electric arc devices are obviously powered by electricity. However, by referencing only one stage in PV silicon production (a classic cherry-pick)—the refining of metallurgical grade silicon (mg-Si) into polycrystalline silicon (called polysilicon)—Fthenakis et al., side-step the fact that metallurgical grade silicon can be extracted only by smelting quartz (SiO_2). This smelting process variously involves heating quartz, coal or coking coal, and charcoal/woodchip, clearly requiring large inputs of fossil and contemporary carbon. Coking coal is produced by heating coal in an oxygen-limited environment with wood to burn off impurities, leaving behind high-carbon coke (this process is nearly identical to that of making charcoal from wood). Smelting one ton of metallurgical silicon from about 2.5 tons of quartz typically consumes ~1.4 tons of coal and coke and an equivalent quantity of woodchips or charcoal [5]. This, of course, results in significant emissions. It is only after this unavoidable smelting process takes place that the Siemens process to which the authors refer to (purifying metallurgical grade silicon into polysilicon) can occur. Consider that a new silicon smelter proposed for Washington state, with an initial annual output of 73,000 tons of polysilicon, would emit about 320,000 tons of CO_2 and other greenhouse gases per year, as well as 700 metric tons per year each of smog- and acid rain-causing sulfur dioxide and nitrogen dioxide [6]. Second, manufacturing is only one stage in the life cycle of a solar panel. Every prior and subsequent step in the production of solar PV power systems "requires a perpetual input of fossil fuels-as carbon reductants for smelting metals from ore, for process heat and power, international transport, and deployment. Silicon smelters, polysilicon refineries, and crystal growers around the world all depend on uninterrupted, 24/7 power that comes mostly from coal and uranium" [5]. By neglecting the raw materials (including non-fossil sources of carbon) and the smelting process from the PV supply chain, various oft-cited assessments obscure the use of FF and the deforestation necessary for solar PV production. Third, Fthenatkis and colleagues conflate electricity with how that electricity is generated. As noted, most of the electricity that powers even the Siemens process is generated not by so-called RE but, rather, by FF or hydro and nuclear sources. Thus, it is disingenuous to assert that "there is no fossil fuel input connection" in the production of PV grade silicon and that " . . . around 80–90%, of energy inputs to the manufacture of solar PV come in the form of electricity". Finally, our critics create an illusory fog in asserting that "solar energy could very easily be self-sustaining" (emphasis added). Can they point to a single solar cell production process or manufacturing facility today that runs entirely on energy generated by solar panels or wind turbines? If it is so "very easy" for the solar sector to be self-sustaining, would not the industry have long-since built a self-promoting demonstration project? However, even this would be insufficient. To be truly viable as a candidate to replace FF, an RE technology must be able to generate sufficient energy to produce itself at all stages of its life cycle—from mineshaft to decommissioning/recycling—plus sufficient surplus energy to power all the other energy needs of society. At approximately 4% of the global primary energy, solar and wind have a long way to go, and time is running out.

Similarly, the authors' critique of our treatment of hydrogen has no legs. The so-called RE that would render it "green" suffers from the same challenges outlined above, not to mention other problems [7,8].

In yet another instance of overlook, the Fthenatkis team states, in response to our statement that charcoal generated from wood is the only replacement for coal, that our "claim is of dubious validity due to the fact that it remains unproven, and in fact it is highly doubtful, that enough wood could be sustainably harvested to even come close to replacing fossil coal in all industrial applications". How could they have failed to notice that this is precisely what we argued? To wit: "The remaining stock of woody biomass—vastly depleted during the Industrial Age—is nowhere close to supporting current manufacturing needs, particularly recognizing the need to set aside half of Earth's major eco-regions to ensure the functional integrity and health of the ecosphere".

Fthenakis et al., claim that "unfortunately for [us], the major truck manufacturers in the world are already transforming their production lines to enable an almost entirely battery-powered truck fleet [142–146]". The references they provide, however, do not support this statement. One is a modeling exercise that examines the projected integrity of California's electricity grid system in the face of so-called RE expansion and increased electric vehicle usage. Two cannot be accessed; one is simply a press release about a company's increased investment into e-mobility research, and one is for a company that appears to have a line of a few small trucks but no large semis—the highway trucks to which we referred to as the key ingredients in the globalized MTI system and that are a long way off from electrification.

The authors conclude by asserting that Eye of the Needle "views the energy transition in the abstract, divorcing it from the realities of the world and the energy context in which policy-makers must make decisions" and that we "do not acknowledge the obvious counterpoint that our current energy system is wholly unsustainable and unviable even in the short run. Where is the 'Problems with Oil' section?" These ludicrous assertions again demonstrate that our critics did not read our paper or that they failed to comprehend our main points. We in fact reestablished contact with biophysical reality by framing the debate within the context of overshoot and emphasizing that it is within this context—not merely climate, energy, and economics—that energy policy ought to be framed. We further pointed out that, in the finite real world, the modern RE energy transition, should it succeed, would not be better than the current fossil energy system; it would extend our MTI society's ongoing gutting of the ecosphere, exacerbating the overshoot and worsening the climate change. None of this is an endorsement of FF. We agree entirely that the current fossil-based energy system is unsustainable and unviable, as anyone who actually read our paper would realize. Our objection is to the illusion that business-as-usual by alternative means is a viable, sustainable, and desirable path. We argue that the lust for wind and solar is a costly diversion that delays society's acceptance of, and planning for, a low-energy, low-consumption, and low-population future (Figure 1).

In short, we reject our critics' central arguments. Their techno-fix approach to climate change side-steps overshoot altogether. Their arguments obfuscate many of the technical, ecological, and social impacts of any wholesale "green" energy transition. Even if successful, the shift from FF to quantitatively equivalent 100% "green" electricity would serve mainly to propel society further along its catastrophically unsustainable, growth-bound trajectory. This makes even the theoretical possibility of a 100% so-called RE transition virtually irrelevant. This is a world in overshoot headed for implosion (Figure 1). What the passengers on the MTI Titanic need for survival is a dramatic course change, but what many of the ship's engineers are proposing is to replace its FF engines with electric motors.

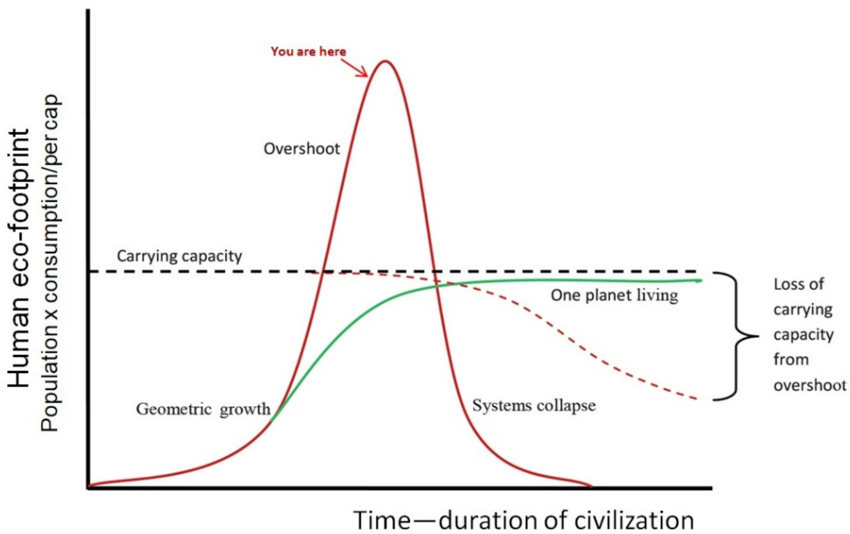

Figure 1. The human enterprise is in overshoot. We are long past the global carrying capacity, nearing the peak of an anomalous 200-year population and economic expansion enabled by fossil fuels and facilitated by improved public health (solid red line). The cost of overshoot is a reduction of long-term carrying capacity (reduced productivity of ecosystems). A more sophisticated civilization would have self-regulated to achieve "one planet living" (solid green line). The best our MTI society can do now is a controlled contraction that comes off the peak and stabilizes at or below Earth's remaining biocapacity (dotted red line to the right).

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