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Renewable energy: too little, too late, for climate change mitigation?

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The world needs more renewable energy (RE), if only because, eventually, readily accessible fossil fuels will be depleted. RE sources can also greatly reduce energy-related CO2 emissions, but whether they can be properly called 'zero carbon' sources is another matter. At present, fossil fuels (FFs) are still dominate world energy supply: RE only provided 11.2% of all commercial energy in 2019, and nuclear another 4.3%, with the remaining 84.5% provided by FFs [1]. Not even the nuclear industry expects nuclear power to significantly increase its market share over the next few decades. Advocates for RE argue that not only can it rapidly supplant FFs, but also enhance economic growth. Others disagree; this short article attempts to resolve the issue. It does this by envisaging a future world with 100% of energy provided by RE.

First, some background to the argument. Clearly, for any energy project to make sense, it must deliver more energy as output than the sum of the energy expended to produce the materials needed, construct the device, operate and maintain it, and finally, deconstruct it at the end of its service life. This ratio of output to input energy is called the Energy Return on Investment (EROI) and must be greater than unity, or for some energy analysts, five or even greater [2]. As RE advocates rightly point out, FFs at present don't have to pay the energy (or monetary) penalty of dealing with CO2 emissions from combustion. One way this could be done is by capturing the exhaust CO2 from combustion and burying it deep underground. The problem is that some RE sources—such as tropical hydro plants—also directly emit some greenhouse gases, and all RE sources indirectly emit them from mining the necessary materials, and manufacturing the RE devices such as wind turbines. If RE sources are to be truly environmentally sustainable, it is necessary to expend additional energy to both deal with the mining wastes, and as for FFs, remove CO2 emissions.

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Citation: Moriarty, P. (2021). Renewable energy: too little, too late, for climate change mitigation? *Academia Letters*, Article 2895. https://doi.org/10.20935/AL2895.

Four factors are crucial to consider when assessing the potential for RE to wholly replace FFs as the dominant energy source; all act to lower the EROI for RE sources as output rises. First, like all energy sources, those sites producing energy at the lowest cost are generally exploited first. For a RE source like wind, this means siting wind farms in regions of high average wind speeds that are close to energy load centres such as cities. A consequence is that the EROI for a given energy source will fall as sites with lower wind speeds, or more distant from load centres must be progressively tapped. The input energy costs are unchanged, but the energy output over the wind farm's life is reduced.

The second point is that the energy costs of inputs will, in fact, also rise over time. All energy conversion devices need large amounts of input materials such as steel, concrete and copper, but per unit of electricity output, RE sources use far more than FF power plants do [2]. Just as for energy sources, the quality of mineral resources declines with increasing cumulative extraction, so that the energy costs of mining, and cleaning up after mining (for example, by building durable tailings dams), both rise, per unit of refined metal.

If RE output is to match present total energy output, let alone allow for its growth, then wind and solar output will need to grow many-fold, as the remaining RE sources, bioenergy, hydropower, and geothermal, cannot be expected to increase much [3]. But wind and solar are intermittent energy sources. If these two sources had to supply nearly all future energy, it follows that conversion and storage (perhaps as compressed hydrogen gas) of this intermittent energy wold be needed. Further, most of the energy produced by RE sources, not only wind and solar, is in the form of electricity. However, many energy end uses are not electric; think of air plane fuel or direct heat. Again, conversion of electricity would be needed. The catch is that each conversion step (eg electricity to hydrogen) and energy storage both entail energy losses, further lowering the EROI for an all-RE system.

The fourth point also results from RE progressively replacing FFs. At present, with the external costs not factored in, especially the damages from CO2 emissions, FFs have much higher EROI values than do RE sources. Since we presently live in a fossil fuel-dominated economy, most energy inputs to RE plants are from FFs, giving an energy subsidy to RE production. To demonstrate this, assume that the transport of wind turbine components is by diesel-fuelled trucks, with an EROI of, say, 10 or 15. If we replace the truck fuel by biodiesel with an EROI value of two, then clearly the fuel inputs into wind turbines will rise. When all energy for all uses is provided by RE, this energy subsidy will disappear entirely.

Together these four factors act to reduce the EROI for a 100% RE energy system. If a minimum EROI of say three is needed, the result is a much lower global technical energy potential for RE than is assumed by most RE advocates [4]. It may even be that this 'green' RE potential is much lower than present global energy use, implying that the world will need

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to cut its energy use.

So far it has been argued that RE may be ‘too little’, but it is also likely ‘too late’, as shown by dynamic energy analysis. RE projects in general are characterised by high input energy costs for materials and construction, which must be expended before any energy is generated, unlike FF, where much of the input energy costs are for mining and transporting fuels. If the EROI for ecologically sustainable RE projects is low, attempts to speed up FF replacement with RE means that a large fraction of output energy will need to go into building new RE projects, leaving little for the non-energy sectors of the economy. Meeting the shortfall by using more FFs is, of course, self-defeating from a climate change mitigation viewpoint.

At least until 2019, and as forecast for 2021 [5], far from RE replacing FFs, both RE output and FF output have risen in step. When the first report of the Intergovernmental Panel on Climate Change (IPCC) was published in 1990, major shifts from FFs to RE to avoid adverse climate change was a reasonable proposal. Now, the sixth IPCC report has just been published [6] With three decades of inaction on CC, shifting to RE is now an inadequate response. Given the doubts about the efficacy of both carbon dioxide removal and geoengineering, large energy reductions remain as a key means for an urgent response to the risk of catastrophic climate change. In summary, we need a more realistic assessment of RE, both its technical potential and its feasible rate of FF replacement.

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