



On the Inability of Wind and Solar Electric Generation to Power Modern Civilization

Wallace Manheimer^{1*}

¹*US Naval Research Laboratory, USA (Retd.).*

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JENRR/2021/v8i430220

Editor(s):

(1) Dr. Davide Astiaso Garcia, Sapienza University of Rome, Italy.

Reviewers:

(1) Gheorghe Grigoras, Technical University Gheorghe Asachi Iasi, Romania.

(2) Jamal M. Rzajj, University of Anbar, Iraq.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/75338>

Original Research Article

Received 30 July 2021
Accepted 06 October 2021
Published 07 October 2021

ABSTRACT

There is a societal push to replace fossil and nuclear fuel, which currently generate ~ 85% of the world's electric power, with wind and solar powered generation of electricity. However, there are significant physical, economic, reliability, and environmental barriers to this replacement. This paper discusses them and concludes that for the foreseeable future, we are stuck with the more conventional sources if we want civilization for the masses to survive.

Keywords: Solar; civilization; energy; solar panels.

1. INTRODUCTION

President Biden's plan is to achieve zero carbon emission in the electrical sector by 2035, mostly by employing wind and solar energy [1]. The purpose here is to avoid what he calls a 'climate crisis', generated by extra CO₂ in the atmosphere, caused mostly by burning fossil fuel. However, there is almost certainly no climate crisis, and there is definitely no possibility

that wind and solar can replace more conventional means of generating electricity; in short, this proposed replacement is an impossible, and extremely costly non-solution for a non-problem. We concentrate here on the energy aspects, but first, to set the stage, we very briefly discuss our assertion that there is no a climate crisis. Richard Lindzen, probably the world's leading authority on geological fluid motion, and youngest scientist to be voted into

*Corresponding author: E-mail: wallymanheimer@yahoo.com;

the National Academy of Science, described it well:

“What historians will definitely wonder about in future centuries is how deeply flawed logic, obscured by shrewd and unrelenting propaganda, actually enabled a coalition of powerful special interests to convince nearly everyone in the world that CO₂ from human industry was a dangerous, planet-destroying toxin. It will be remembered as the greatest mass delusion in the history of the world- that CO₂, the life of plants, was considered for a time to be a deadly poison.”

Recently there have been three books written demolishing the notion of a climate crisis, the first by one of the foremost physicists of our era [2], and the latter two by two environmental scientists second to none [3,4]. Furthermore, there has been a petition disputing the notion of a climate crisis, signed by 31,000 scientists, 9,000 with Ph.D's [5]. If 97% of scientists really believe that atmospheric CO₂ is a 'deadly poison', where is the other petition, signed by a million scientists, asserting this? Finally, there is an organization of highly qualified scientists, academics, and other professionals who show that not only is there no climate crisis, but atmospheric CO₂ is actually mostly beneficial [6]. It is plant food; without it, life could not exist on earth.

Hence this essay leaves the discussion and denial of a climate crisis to others, and instead, concentrates on the energy aspects, the inability of wind and solar power to support modern

civilization. It starts with the axiom, if you will, that civilization needs a source of available and reasonably priced energy. Before fossil fuels became widely used, civilization was a thin veneer atop a giant mass of human squalor and poverty. Historically this veneer was maintained by such institutions as slavery, colonies, and tyranny. The argument now made against fossil fuel seems to neglect the crucial role that fossil fuel makes in our lives right now. The conclusion is simple, for civilization to survive, it needs a power source, if not fossil fuel, one at about the same quantity and price.

If wind and solar, are to be the only power source, as some insist, and they cannot do the job, civilization as we know it will perish. People will live the way they did in the vast majority of human history, with civilization only for the privileged few. It is that simple.

An excellent source of relevant data is the BP Energy Outlook [7], which is published every year. Fig. 1 is a plot, taken from their 2019 issue, of the energy use by region, by end use sector, and by fuel, as a function of year,. To the left of the vertical dashed line is the historical record, to the right, BP's extrapolations for the future.

At this point, the world uses about 14 TW. As we can see from the middle graph, the power use is very unequal. The 1.2 billion in the OECD countries use about 6 TW, or 5 kW per capita. In the USA, we use ~ 8kW per capita. The other 6 billion people use ~8TW, or about 1.3kW per capita. How much longer will this be acceptable?

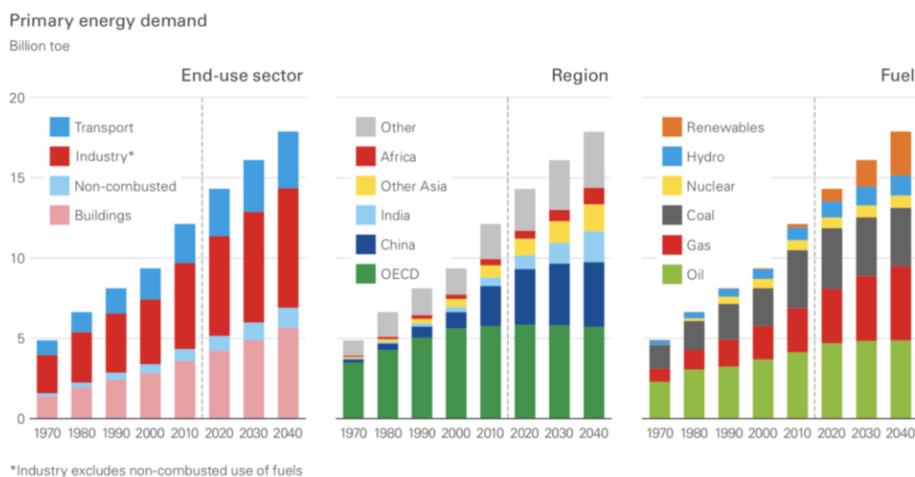


Fig. 1. Plot of energy use from BP Energy Outlook 2019

The vertical scale is in billions of barrels of oil per year equivalent. To switch into more familiar units, 1 Btoe per year is about one terawatt (TW)

By midcentury, the world population is expected to level off at ~ 10 billion, each of whom will demand a middle class life style. Bringing the world up to OECD standards would seem to necessitate 50 TW of world power. However, energy efficiency (i.e. gdp per Watt) would be expected to improve as well (typically 0.5-1% per year) [8] so optimistically, the number might be closer to 35-40TW. There is no way this is anything but an extremely necessary and desirable goal.

According to BP's estimates, fossil, hydro, and nuclear will be the main power sources as far into the future as they can foresee. Hence for the foreseeable future, the world is almost certainly stuck with fossil and nuclear fuel if we want modern civilization for the masses to survive. In the less foreseeable future, nuclear fuel breeding and fusion may play an important role. These seem to be the only realistic options. Solar and wind will not only be unable to supply the midcentury world, they cannot even supply today's world. The essay makes argument that this is due to very simple constraints of physics, economics, and the environment.

Most reports on solar and wind apparatus quote the 'nameplate' power. This is the maximum power the device generates when conditions are exactly right. But conditions are rarely exactly right. Nameplate power is not important, average power is. For instance, a solar panel might produce a kilowatt at high noon on a summer day, but averaging over all conditions, it would be more like 200 Watts. A wind turbine might produce 2 Megawatts (MW) when the wind is blowing at the right speed, from the right direction, but perhaps only 500 Kilowatts (kW) averaged over all conditions. It is only the average power that is meaningful. In most conventional power stations, coal, gas, nuclear, the average power is very nearly the peak power, so there is little confusion. However, reports on solar power have a tremendous potential for confusion, as the nameplate power (usually reported) is typically a factor of 4 or 5 times the average power (the more meaningful number). It is important to keep this important fact in mind when going over claims of delivered power. Advocates of solar and wind, unfortunately, often talk of nameplate power, as if it were average power.

We discuss various aspects of solar and wind power, and how they are limited by basic physics and environmental constraints, and basic easy to

comprehend economic conditions. Section II discusses the basic constraints in terms of wind and solar power coming to earth. Numbers without specific references are well known numbers and can be easily be checked with an internet search. Section III discusses the reliability or unreliability of wind and solar power. Section IV discusses the cost of wind and solar. There are many conflicting elements of this cost, including government subsidies, which are difficult to unravel. The Washington Times [9] estimates the US government subsidies for constructing wind turbines between 2016 and 2020 was ~\$24B, for systems which just give a small fraction of the electric power to the country. However, there is one simple way to evaluate the cost, discussed there. Section V discusses a tsunami of cost yet to come, namely cost of decommissioning these monsters (a modern 4 MW nameplate wind turbine is as tall as the Washington monument); once they reach the end of their lives, typically 25 years.

There are other negative aspects of solar and wind, mentioned only briefly here. One is the tremendous requirement for material to construct these power sources. There is no in place or planned infrastructure to meet the requirement for mining or moving these materials, which are solid and cannot be moved by pump or pipeline, but once on land must be moved by truck or rail [10].

Another is the need for backup power when the sun does not shine or the wind does not blow. There is talk of a revolution in battery technology, but this seems far-fetched. A Tesla car's Lithium ion battery stores about 100,000 kWhrs. The country uses 400 gigawatts (GW) of electric power, and if one section of the country is out of wind or sunshine, say Texas or California, the battery backup would have to provide this power, probably 100 GW. The Tesla battery would provide this backup for 3.6 milliseconds! We would need ~300 batteries to provide a second's worth, ~1,000,000 for an hour, and about 12 million to provide 12 hours; and this is probably not sufficient. We would need probably half a dozen of these battery stations across the country. In addition, there is the safety issue of so much chemical and electrical energy stored in one place, particularly for a battery like the Tesla lithium ion battery, which has a well-known fire danger, even if the battery is not delivering power. The 12 million batteries in each station stations have a stored energy of $\sim 5 \times 10^9$ Megajoules, about the energy of a one megaton nuclear explosive.

2. THE SOLAR AND WIND POWER AVAILABLE

When considering solar and wind power, the very first issue is what is the available power? First to reiterate, we speak only about average power here. Solar energy, in mid latitudes, at high noon on a summer day is about 1Gigawatt (GW) per square kilometer. However, averaging over night and day (cutting it in half), solar angle and added absorption from the longer path (cutting it about in half again), sun, rain, snow, clouds.... , it is roughly 200 MW/km². The maximum efficiency of a solar panel is given by the Shockley Queisser [11] limit of ~30%. Most operating solar panels have an efficiency of ~ 10-20%, so they are near the theoretical maximum. Assuming this maximum figure, a 1GW solar power plant would cover about 25 km², and the land could not be used for anything else. While this sounds small compared to the area of, say the United States, it would be difficult to find this amount of land available in say the northeast. The cost of rural land in the northeast is about \$5000 per acre, so 25km² would cost ~\$25M. This is not that great a deterrent, but finding 25 available contiguous square kilometers in a place like the American northeast probably is. The 15-20% efficient solar panels cost ~\$3/nameplate Watt, so these would cost ~ \$15B for the 1 GW average power solar farm. Then there is the cost of installation and hook up. To do this one needs a team of skilled workers, working over every square inch of the 25 km². This author has no idea of the cost of this labor, but it does not sound like it would be cheap. Likely it will or already does dominate the cost of the solar panels.

Actually, the estimate here is most likely very low. The American Institute of Physics (AIP), in their flagship publication [12] proudly announced that the cost of a "10 MW utility scale (solar) PV plant in the US will drop by more than 50% by 2030, to \$400 million, from \$840 million today". The article does not say whether this is the nameplate value or average value, which this author finds to be shocking for a physics publication. However, assuming it is the average value, this would put their lowered cost of a 1GWe solar facility at \$40B in 2030, and if it is the nameplate value, \$200B then. Either way, large scale solar power, sounds quite expensive, no matter what its proponents and publicists claim.

Now let us consider wind power. Only about 1-2% of the solar power impinging on earth goes

into wind. Generously granting 2%, and considering the Betz limit [13] on the maximum efficiency of the conversion of wind power to mechanical energy of 60%, we assume 50% efficiency, and assume the wind is always blowing at the optimum speed and from the optimum direction. Hence a 1GW average power wind farm would cover at least 500 km². Unlike a solar farm, this land could be used for some other purposes, but not many. It could be used for grazing animals, and perhaps for growing some crops not requiring much human intervention, but it is unfit for human habitation. The noise would be deafening, and in the winter, in the cold regions of the country, large chunks of ice, hundreds of kilograms, fall off the turbine blades, killing anyone that were struck by them. At least in the northeast, are 500 km² of reasonably contiguous land, without human habitation really available anywhere?

The cost of a turbine is typically ~\$2/Watt of nameplate power, or ~\$8/Watt of average power. If one considers 4 MW nameplate power turbines (about the height of the Washington monument), the 1GW plant needs ~1000 of them cost ~\$8B. This does not account for the cost of installation, putting up 1000 structures the size of the Washington monument could not be cheap! And how much does 500 km² of contiguous land cost, especially in a place like the American northeast or west cost?

3. THE (UN)RELIABILITY OF SOLAR POWER

Solar power from photovoltaic sources can only be used when the sun is shining; wind power, only when the wind is blowing. Thus, to have reliable power, solar and wind power must be backed up by another power source which runs under all conditions. While solar power advocates claim large batteries will take up the slack, these batteries are very far from being developed [14]. Instead gas-powered plants are used for this purpose. This is not an unreasonable approach, but of course the cost of the gas plants, often idle, must be added to the cost to wind or solar. As the Wall Street Journal phrased it "A big problem is that subsidies and mandates have spurred an over-development of renewables, which has resulted in gas plants operating at lower levels or even idle much of the time. Keeping standby units in top condition is hugely expensive. So when plants are required to run all out to meet surging demand or back up renewables, problems crop up – as they did this week." [15].

Recently, under adverse weather conditions, at least 3 places which relied heavily on solar and wind lost power for substantial periods of time. These are not places in poor areas of the world, which struggle to afford minimum power, but in 3 of the richest places in the world, Germany, California and Texas.

Texas is usually a warm state, but being located in the great plains, every few years it experiences a frigid winter. That was its experience in February 2021, where it was snow covered and was frigid (for Texas) for a long period of time. Texas has made a large

investment in solar and wind power, one quarter of the wind power of the United States is in Texas. In the winter this failed; see Fig. 2. Much of the state experienced long periods without electric power as windmills froze [16] and solar panels became snow covered [17].

With the failure of wind and solar, gas powered plants rushed in to take up the slack, but were only able to partially fill in, especially with the increased demand due to the weather. Fig. 3 is a graph of the power supplied by various power sources in Texas during the week of worst power loss [18].



Fig. 2. Frozen windmills in Texas, February 2021

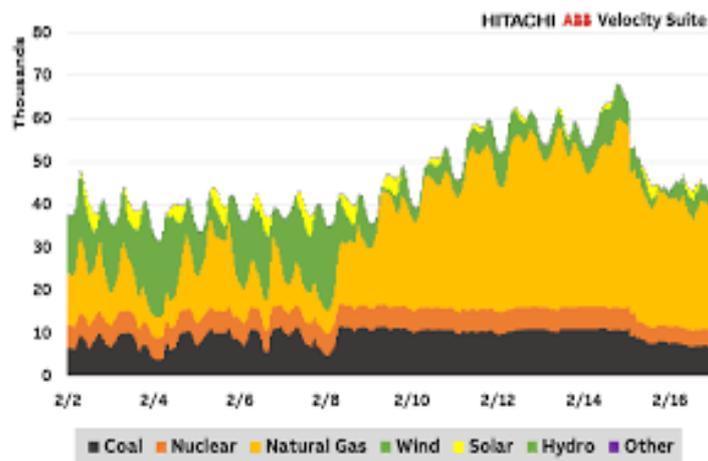


Fig. 3. Power delivered to Texas from various sources during 2 weeks in February 2021
Notice the great reduction in wind and solar, and the struggle of gas to keep up

The Wall Street Journal [15] even mentioned that the Texas problem in the winter was not its only problem. In June, there was a heat spell, certainly not unusual for Texas, and again solar and wind largely failed, with gas rushing to take up as much of the slack as it could.

The public relations effort of the solar, wind and anti-fossil fuel effort is very strong and well-funded. Search the Texas dilemma on the internet, and everything but their reliance on wind and solar is blamed. The data presented here was not easy to find on the internet. But Oklahoma had about the same weather as Texas, but did not rely on wind and solar to nearly the same extent, and had no problem.

As we will see in the next section, Germany also has been relying very strongly on wind and solar, and the severe winter of 2020-2021 has played havoc with it. The country was exceptionally cold and snow covered and large parts of the country lost electric power for a long period of time. Germany attempted to purchase power from neighboring countries, but

there was none at any price to sell; these countries could supply only their own population. Fig. 4 below shows a snow-covered solar panel in Germany, and its effect on their school children as they attempted to do their homework [19].

California has been converting to solar power over the last decade or two. It had decommissioned all of its coal fired power plants, its nuclear power plants except for Diablo Canyon, and this is scheduled to be decommissioned in the next few years. It has some gas fired power, but minimizes it to the extent possible. The state had a great deal of solar power available on summer afternoons, but this faded away in the late afternoon and evening when air condition was most needed. In a heat wave last summer, it did not have enough power, and had to instigate rolling blackouts [15]. It attempted to purchase power from other states, but it already gets about 1/3 of its power from neighboring states, and none was available. Summer 2021 was predicted to be worse in California.



Fig. 4. Snow covered solar panels in Germany, and its effect on their school children

Again, most entries on the internet, blame these blackouts and failures on everything but reliance on wind and solar. But these are nearly the only large wealthy regions that had these problems. They are also the main large and wealthy regions strongly dependent on solar and wind power. Whom do you believe, what wind and solar advocates assure you, or what you see with your own eyes? Of course, the Wall Street Journal is not exactly minor media. They ended their editorial [15] with the sentence: “Pro survival tip: Buy a diesel generator – while you still can.”

4. THE COST FOR DELIVERED POWER

We have all heard on the media and on TV that solar and wind electrical energy is getting cheaper, and often much cheaper than that of generated by coal, gas, oil or nuclear. Here is a typical example [20]. However, there are enormous scientific, technical, and economic barriers that these ‘new’ energy forms must overcome before they can be regarded as economical; barriers, which are in reality, just about impossible to overcome. They have been described by Mark Mills [10] and many others. Furthermore, there are government subsidies in most countries which affect the price. These subsidies are very confusing to unravel, but in all likelihood, they are significant and have the governments of the world paying a portion of all of our electric bills, something governments have not historically done.

The skeptical arguments, while correct, are not necessarily easy for a layman to follow. After all who notices or cares if, to build solar panels and wind turbines, we have to dig up a lot of indium, lanthanum, neodymium, europium and other rare earth elements somewhere, most likely in some remote African country, which has much looser mining restrictions than do we in the west, and which will not complain about us trashing its environment, and paying its citizens slave wages.

It is now possible to compare nuclear to solar and wind on a large scale. There is what this author calls ‘a gigantic laboratory’ in Europe. It is France and Germany. France for years has generated most of its electricity (~75-80%) by nuclear power. Germany, in about 2000, had adopted a different route. It has embarked on an ‘energiewende’, a German word for energy transformation to solar and wind energy. Accordingly, it has decommissioned many of its coal fired power plants, and is in the process of

decommissioning what once were its 17 nuclear power reactors. At this point, it is getting about 25-30% of its electrical power from wind and/or solar; the rest from other sources. Look up articles on the energiewende, and you will see some articles calling it a smashing success [21], others calling it a dismal failure [22].

4.1 Where does the Truth Lie?

There is one thing anybody can easily figure out. Namely despite all the claims of low cost solar and wind, how does the cost of electricity in Germany and France compare? This is simple and noncontroversial. Furthermore, since the whole purpose of the energiewende is to reduce the CO₂ input into the atmosphere, how well do Germany and France do? Again, this is simple and noncontroversial. Fig. 5 shows a graph of the price of a kilowatt hour of electric energy in Germany, France and the United States, in euro cents, from 1980 to about 2020 [23]. Also shown on the graph are plots of per capita CO₂ emission into the atmosphere in tons per year [24].

The graph shows that, at least up to now, after ~20 years, the German energiewende has failed on both counts. It has not reduced the price of electricity, but rather has greatly increased it. It has not reduced the per capita German CO₂ emission into the atmosphere as compared to France, or even the United States (in fact most of the German reduction shown here predates on the energiewende). The impact of the high cost of electricity in Germany is such that almost five million people there were unable to pay their electric bills in 2019, and were cut off from the grid [25].

In summary, France has cheaper electricity and emits less CO₂ per capita — both by about half — than does Germany. For those who say that nuclear power is too expensive and environmentally unviable, there is a simple one-word answer, France. The French have had a nuclear economy for decades, and have achieved this without going broke, having it harm or kill any of its citizens, or trashing their environment. At this point, it certainly wins hands-down over the German ‘energiewende’. The conclusion is obvious. By themselves, sunlight and wind are free but converting them to electricity is very, very expensive.

For all of the publicity and propaganda on how cheap solar power is, proponents estimate as

much as \$100 trillion will be needed by 2050 to decarbonize the world's energy systems [26]. Of course, skeptics, if they believed this were possible, would come up with a much higher figure. In any case, this is real money, for something the proponents say is cheap, likely is unnecessary, and for something most likely impossible to accomplish anyway.

5. THE END OF THE LIFE CYCLE

There is an additional cost and environmental effect of solar and wind power, which has hardly reared its ugly head yet. Namely solar panels and wind turbines are only expected to last ~25 years. What do you do with them after that? Since most solar panels and wind turbines are younger than this, we have only an inkling of the problem that is soon bearing down on us.

Let us first consider solar panels. These panels last about 25 years, so the 250,000 tons we have

to recycle this year is just a trickle compared to the deluge coming at us in 2050, when we will have had a total of 78 million tons to dispose of. These are not appropriate for landfills, as they contain hazardous and poison materials such as lead and cadmium, which can leech into the soil. However, recycling is expensive. The cost of the recycled materials is considerably more than the cost of the raw materials. For this reason, many places, including even (surprisingly) California are disposing worn out panels in landfills, which is cheap, but environmentally very harmful [27]. There are also efforts to export worn out solar panels to landfills in underdeveloped countries, most likely in Africa. Trashing their environment by taking advantage of their loose mining restrictions is not enough, we will also trash it by sending them our own dangerous garbage, which we cannot safely dispose of in our own country [27].

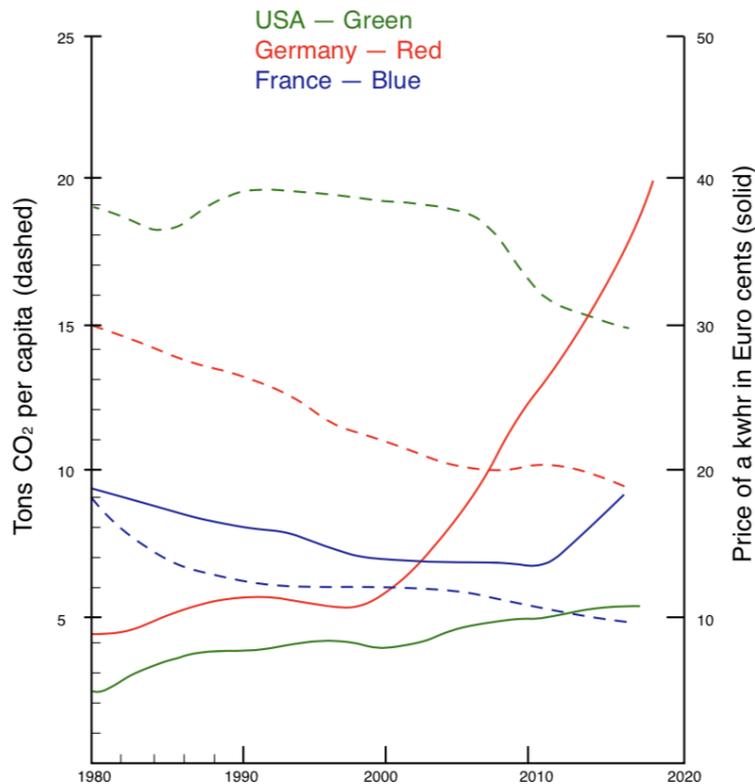


Fig. 5. Plot of the cost of a kilowatt hour of electric energy in euro cents in France, Germany and the USA (solid), and emission of CO₂ into the atmosphere in tons per capita per year

Even if we had perfect recycling of used solar panels, there is still the environmental danger of their destruction by natural events. A tornado destroyed a solar farm in Southern California, and Hurricane Maria destroyed a large solar facility in Puerto Rico [28]. Who knows what damage was done to the local environments? Fig. 6 is a photo of the Puerto Rican facility after the Hurricane.

Regarding wind turbines, the problem is twofold. Since the blades are fiber glass and last only about 10 years, we have had considerable experience here. These blades are gigantic, and are very costly to ship and dispose of, but a land fill is a reasonable option if it is large enough. Once they are buried, they will do little if any harm to the local environment. There are just a

few landfills in the United States capable of handling these blades. One is near Casper Wyoming. Fig. 7 is a photo of a portion of this landfill [29].

The difficulty of disposing of the blades pales in comparison with disposing of the towers, which last ~25 years. Companies typically have to put up decommissioning costs at the outset, but these are claimed to be ridiculously low. The cost claimed by the wind company is apparently \$100,000, but this sounds incredibly cheap for dismantling and moving long distance, a steel tower the height of the Washington monument. In fact, the Washington Times estimates that a better cost estimate is \$500,000 [9], but even that sounds cheap to this author.



Fig. 6. A photo of the Puerto Rican solar facility after Hurricane Maria



Fig. 7. Photograph of fragments of wind turbine blades at their ultimate resting place in a landfill near Casper Wyoming. The small feature in the upper right is a bulldozer driven by a landfill employee

The alternative is to walk away and leave them for someone else to worry about. As Tom Lehrer sang in his song about Werner von Braun:

Once rockets go up, who cares where they come down,

That's not my department says Werner von Braun.

Perhaps the wind power providers think that properly disassembling aging turbines is 'not their department', they are too busy saving the world. There are dueling web pages on this, one saying that there are 14,000 abandoned wind turbines littering the country [30]. Another says nonsense [31]. However, there are

certainly many thousand abandoned wind turbines. There are documented to be 1600 in Altamont pass in California alone in 2014 [32]. The internet mentions other abandoned wind farms in California, Texas, Hawaii, Oklahoma and Wyoming.

For the most part the media ignores this even though it is shaping up to be an enormous problem. In fact, the few articles this author found were in small local newspapers, discussing a local issue [32,33]. The one article from a major news outlet was from the Daily Mail, an English newspaper discussing abandoned wind turbines in Hawaii [34]. Fig. 8 are photos of abandoned wind turbines in California, Texas, and Hawaii.



Altamont Pass, California 2014 [32]



Near Harlingen, Texas 2017 [33]



Oahu's north shore, Hawaii 2012 [34]

Fig. 8. Abandoned wind turbines in the United States

At their birth, solar and wind installations appear to be environmentally benign, at least, if one discounts the enormous amount of land they occupy and the enormous amount of material they require. At their death, they are anything but environmentally benign. Then, they almost certainly form more of an environmental crisis than any other power source.

6. CONCLUSIONS

So, what is one to make of the claims that solar and wind are infinitely available, reliable, inexpensive, and environmentally friendly. This article proves conclusively, that at least up to now, none of this is true. These false gods have been worshiped by many; what is one to do? Perhaps the answer is that when thinking of solar and wind power, and the deluge of articles and experts telling us how wonderful, reliable, environmentally viable, and cheap it is; it pays to keep in mind Richard Feynman's famous

statement on the Challenger disaster: "When introducing a new technology, reality must take precedence over public relations, for nature cannot be fooled."

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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