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ARE WIND AND SOLAR

UP FOR THE CHALLENGE?

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CONTENT

Driving through Northeast Germany reminded me of one of those dystopian movies like Mad Max, depicting a dreadful future filled with shortages of all kinds. Looking at the rows of slowly moving or idle wind turbines, grey skies, a large solar field here and there, and crawling traffic… I was wondering what happened to bustling life and major industry which Germany is known for.

This may not be a fair depiction of Germany, my home country, despite recent forecasts of a 2nd year of recession [2]. It was just a part of Germany I experienced to not be as cool as the city centers of Berlin, Munich, Hamburg, Cologne, or Frankfurt.

With the questions … Why are these wind turbines and solar panels such a topic of debate? Isn't this supposed to be the future? Isn't the "energy transition" supposed to be exactly that… a transition towards utilizing more wind and solar and less coal, oil, and gas? … ring in my mind, I write this blog.

I want to start by unpacking why such a transition towards wind and solar, and with it, the envisioned wind and solar derived EVs, hydrogen and heat pumps, (1) is unsuccessful thus far and (2) can never be successful without a tremendous cost to our environment and the economies.

Let's dig deeper and find the source of the problem. Today is not about numbers, but rather about basic energy economics!

My motivation to write critically about wind and solar is often misunderstood. But consider this: I am of the opinion that our world needs to unite, not divide.

Division comes from different beliefs… that, in extreme cases, lead to wars. Such wars do not always have to be fought with deadly weapons. Discrimination, or even hurtful words, have a negative impact enough and are often nothing but an expression of different beliefs.

I also have beliefs. I believe that knowledge reduces aggression and anxiety about the unknown. There is even a peer-reviewed paper on this Zacher & Rudolph 2023: Environmental Knowledge Is Inversely Associated with Climate Change Anxiety [1].

We should focus our time on reducing division and fostering unity, which can be fostered with knowledge and love. I can spread knowledge that allows people to critically think and come to their own conclusions (fyi, I am still working on the love 😉). I don't claim to have found the ultimate truth, I am learning every day. I do claim to have spent enough time on energy and material economics to be able to reduce division about the "energy transition", amongst those interested to understand. By understanding the advantages and disadvantages of different systems, we can make better informed choices.

1. Transition or addition?

There is no question anymore that the so called ***"energy transition" has not even started yet.*** While economically stagnating or shrinking countries like Germany, are able to reduce its coal, gas, and potentially even oil consumption, it remains an unpopular truth that the world at large is far away from even the start of a "transition". Instead, the use of conventional energy sources reaches new peaks year after year except during global recessions.

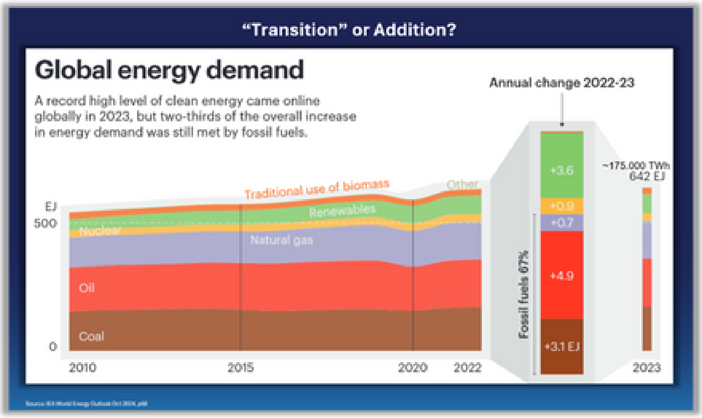
The recent IEA World Energy Outlook 2024 [3] confirmed that 2/3rd of the total energy added in 2023 came from coal, oil, and gas, Figure 1. Thus, while it appears that the percentage of energy derived from conventional sources decreased slightly from the current 80% global average, with wind and solar only adding a relatively small part thus far… and this came at a significant cost to our economies, the people, and the environment.

Since 2010, around 90% of Southeast Asia's "energy addition" (44.7 TWh)) came from coal (40.2 TWh). The IEA also confirms that 80% of primary "energy addition" during that period came from conventional fossil fuels. The ASEAN and even the IEA have to admit that coal will power the region's future [4]. ASEAN says, "In fact, ***coal currently outperforms other energy sources in terms of supply of security, affordability, and – to some extent – sustainability*** in ASEAN's power generation". [4]

"Transition" should be to move away from something old and inferior towards something new and superior. During operation, wind and solar appear to be superior with no apparent negative environmental effects… a seemingly free and abundant power source!

Yet wind and solar are not superior…and why they are in fact inferior, we will explore here. In light of the current political turmoil and changes, please hear me when I say, that this is NOT about politics.

Figure 1: Energy "transition" or "addition"?



2. At the core of electrical supply

We understand that electricity only consumes about 40% of all primary energy, the other 60% is relatively evenly distributed among transportation, heating, and industrial use. We also understand the trilemma of energy policy striving to ensure reliable and affordable supply of energy with the least possible environmental impact. This perspective I covered in **"The 'Energy Trilemma' And The Cost Of Electricity"**

When we now try to compare wind and solar (currently about 12% of global power, Figure 2) with coal, gas, and nuclear (currently about 70% of global power), there are ***three main differences at the core of the "energy transition" challenge.***

- **Energy density**
- **Operational lifetime**
- **Intermittency**

These three points are the exact reasons why wind and solar face such struggles. They explain why the "clean" operation of wind and solar using "free" and abundant wind and solar forces, does not make the technology superior to that of conventional energy sources. They clarify why the "transition" appears problematic, why the "green electrification" is so expensive, and why ***electric vehicles EVs, heat pumps, data centers, or hydrogen derived from wind and solar cannot be seen as a smart approach.***

> *Note: You may have noticed that I am not implying that EVs, heat pumps, data centers, or even hydrogen are inherently poor choices per se, quite the contrary. Depending on the application, they cannot only be beneficial but sometimes essential. I also don't mean to suggest that hydro power or geothermal energy are unsuitable options… rather to point out that hydro power, is constrained by river flows and comes with environmental concerns, while geothermal is still in its infancy. The challenges and limitations of biomass are insightfully explored in Michael Moore's documentary "Planet of the Human" [6].*

2.1 At the core of electrical supply: Power Density W/m2

Energy density is simple, it is expressed **volumetric** in *E per liter* or **gravimetric** in *E per kg* or spatial in *E per m2* (often "power density" in W/m2)

I would indeed agree that we have "almost" unlimited energy from the sun and maybe slightly more limited energy from the wind. Wind, as a global power resource, lies between 45 and 100 TW. This compares to less than 9 TW of current global installed electricity capacity of all types, so it seems to be more than enough? … Maybe not!… ***as the energy available from wind and solar on our surface per m2 for us to collect is very little…***

We understand that the 1st law of thermodynamics also applies to wind and solar: Energy is never lost only "moved" or "transferred" from one form to another ("lost" energy leads to warming of our surroundings, think of your smartphone or computer). Naturally, as we "take" wind from the air, we are slowing down wind speeds. Such wind speeds will be "replenished" in time and the energy restoration rate ERR for wind tells us that only about 1 to max 2 MW/km2 are available for "renewable" human use turning those turbines. This low "power density" of wind comes with a raw material and energy inefficiency consequence.

Probably the best study on power density is Miller & Keith 2019: Observation-Based Solar and Wind Power Capacity Factors and Power Densities [6b].

> If all of Germany would be covered with wind turbines, at 1.5 W/m2 they would generate, on average and wrongly assuming no losses, enough electricity to cover a bit more than Germany's electricity needs, but not enough for all energy needs.

Also take into consideration that, the sun's power density per m2 is by nature limited, not only by daylight (night) and cloud cover, but also by the solar irradiance or the "power of the sun shining on your head". There is a difference between standing in the bright mid-summer sun at noon in Arizona or in Northern Russia. Again, this low power density of about 5.000 kWh in Germany vs. 10.000 kWh per installed kW per year in Arizona has a direct influence on primary energy. Figure 3 compares the power density of different technology in W/m2. There is no doubt that wind and solar are so dilute, that it is unbelievable when knowledgeable business and political leaders truly believe that they can be the driver for a "sustainable" energy future of our industrialized planet.

Taking all these facts into account it is worth noting that, ***technology cannot increase the little power available per square meter from the so-called abundant wind and solar*** resources.

Figure 2: Electricity makes up 40% of Primary Energy

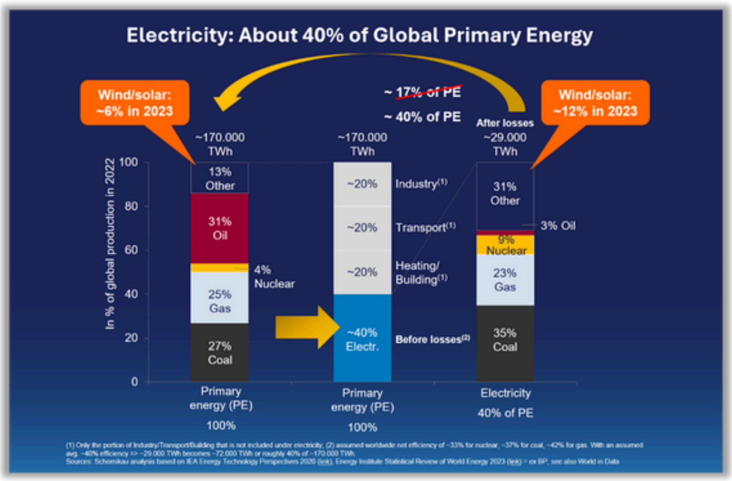
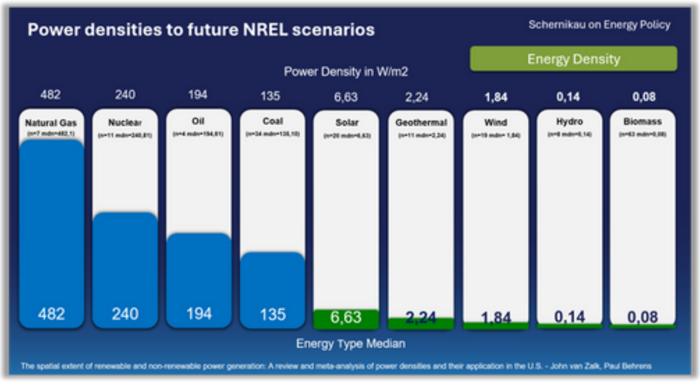


Figure 3: Power Density from Zalk et al 2018 [6]



Don't forget that you still need to build infrastructure to "collect this free energy" the same way you need to build – much less – infrastructure, i.e. mines or wells, to collect the "free energy" from coal, oil, gas, or nuclear. Mueller et al 2023 [6b] is a great source of information on the lifecycle analysis of solar.

The plan is to cover millions of sq.km of the planet with wind and solar installations, simply because the power density of the incoming wind or sunshine in W/m2 is so low… and no invention can increase the power density.

2.2 At the core of electrical supply: Operational lifetime

The operational lifetime of our energy equipment is a topic often overlooked despite it being so crucial and fundamental that it deserves a whole book on its own. For now, let's keep it simple and to the point.

Conventional power plants such as coal, gas or nuclear last decades, often significantly longer than 40 years with some upgrades to be made. ***Grid scale wind and solar technology, currently produced in China, on the other hand is expected to last far less than 20 years*** on average as multiple reports have detailed. I used to manage a wind park in Germany and can tell some stories about how the output of wind turbines decrease after just a few years of operation (Figure 4)

The US National Renewable Energy Laboratory NREL 2021 [9] notes that a large volume of partial and full repowering of grid scale solar installations occurs 10-12 years after installation due to five factors:

> *"(1) low cost, more efficient module technology, (2) power purchase agreement expiration dates, (3) inverter and other equipment replacement (4) early retirements due to extreme weather events (e.g., fire and hail damage) and manufacturer defects, and (5) tax incentives – retrofit investments may qualify for an investment tax credit, a tax deduction through the modified accelerated cost recovery system, and/or a 50% depreciation bonus".*

Additional noteworthy studies on the issue of short operational lifetime for solar and wind include

- [10] ISF-UTS 2020: Report by the Sustainable Futures and University of Technology Sydney *"stakeholder insights suggest that early losses may reduce the average to 15 years".*
- [11] Libra et al 2023: Researchers from the Czech University of Life Sciences in Prague concerning 85 solar power plants deployed in Central Europe between 2009 and 2010, found that the actual lifetime of the plants is about 12 years.
- [12] IER 2024: Wind Turbines and Solar Panels Are Aging Prematurely. The claimed 25-year life span of wind turbines has in reality been just 7-10 years having to be replaced along with their enormous blades.
- [13] Duran et al 2022: "The combined effect of dropping prices and increased efficiency of newer PV panel technologies convince solar panel owners to replace their installations prematurely, i.e. long before their projected 30-year end-of-lives."

Offshore wind is probably the most problematic, as harsh seawater conditions far away from the shore not only make construction and maintenance problematic, but also translate to faster degradation resulting in earlier replacement [14].

It means that ***wind and solar need to be replaced at least twice, often three times, as often as conventional thermal power plants.*** You can imagine the impact this has on raw material input, energy input, and disposal operations (Figure 4).The short operational lifetime of wind and solar is critical and becomes worse when you consider the overbuild required to overcome intermittency and storage (next section).

2.3 At the core of electrical supply: Intermittency

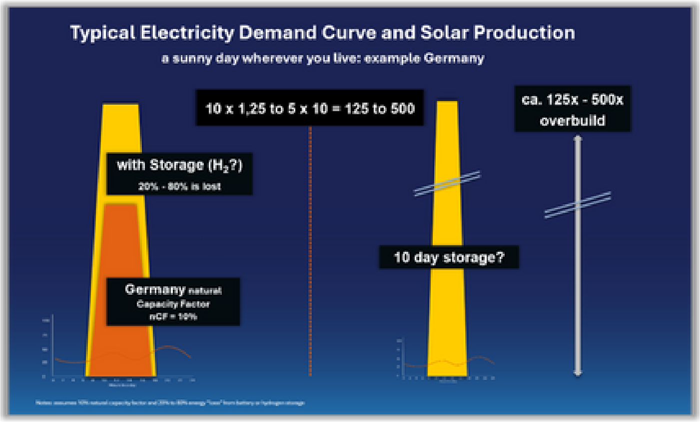
The third and last fundamental difference of intermittent wind and solar compared to dispatchable conventional coal, gas, and nuclear thermal power operations relates to the unpredictability of the weather – the intermittency. This is obvious and has been discussed "to death", but it is noteworthy and important to understand its implications.

The unpredictability of the weather, i.e. sunshine hours and wind conditions, cannot be changed by any technology and ***has three main consequences:***

- ***low utilization*** of the equipment … on global average the natural capacity factor of solar is 11% and wind 22% [15] also read **my blog post**
- you need to vastly ***overbuild*** to meet the full demand on average, and
- you need to build ***ancillary systems*** for (a) transmission and network integration and (b) storage and backup to cover period when weather conditions are not ideal.

Figure 4: Operational Lifetime of "renewable" technologies

Figure 5: Calculating theoretical required solar overbuild



A solar panel in Germany works about 10% of the time on average. To cover full demand day and night you would have to overbuild 10x assuming no losses. To move the energy from day to night you need to build storage that comes with between 20% (batteries) and 80% (hydrogen) energy "losses" that you also need to accommodate. If you want to have 10 days of solar power in storage ready for usage, you would need to overbuild 10 x 1.25 to 5 x 10 = 125 to 500x (Figure 5)… yes hundreds of times of overbuild is required.

Wind and solar complement one other? … well, not quite. Figure 6 illustrates three years of wind and solar generation in Germany and depicts the worst 4h period in any given month compared to peak power demand and installed capacity.

- Wind and solar combined are not peak power capable. As a result, ***wind and solar contribute practically zero to energy security, no matter how big the installation.***

3. Overcoming energy density, lifetime, and intermittency… how?

The logical argument is that we have technology to overcome the above-mentioned issues relating to low energy density, short lifetime, and intermittency. "Smart" systems, storage, or demand response are often named as solutions. Well, let's have a look.

First "input energy and input raw materials"; you can clearly see that the dramatic overbuild required for wind and solar installation has a ***direct impact on the input energy and input raw materials required to build the equipment used to "collect" the free wind and solar power from nature.*** This energy and raw material input far exceeds that of building conventional thermal power plants or producing "free" coal, gas, oil, or uranium available for "combustion" [15].

These raw mineral resources need to be mined, upgraded, transported, processed, and manufactured into usable materials such as silicon, glass, aluminum, or copper. The energy input is tremendous. Practically every silicon smelter in China producing 99.999999999% pure silicon has its dedicated coal fired power station to provide the heat and electricity for the process. There is also not yet any silicon available without carbon from coal, oil, and very large old trees. For more details see my published article **Coal's importance for solar panel manufacturing.** (Figure 7)

There is a reason why the IEA [16] said, "***a clean energy system requires more mineral resources than an energy system based on fossil fuels".***

Second "Ancillary Systems"; it becomes obvious that a large array of ancillary systems is required to integrate wind and solar into our existing systems and to at least partially overcome the natural disadvantages of wind and solar namely: low energy density, short lifetime and intermittency.

These ancillary systems required include:

- A vast ***overbuild*** to overcome the low natural capacity factor, resulting in low utilization, as well as the intermittency and unpredictability challenges and to charge any storage
- ***Short duration energy storage,*** in the form of batteries, to overcome short duration fluctuations and to balance the grid
- ***Long duration energy storage,*** envisioned in the form of hydrogen, to overcome days and weeks of insufficient combined wind and solar generation
- ***Backup*** thermal power stations on standby when needed, in Germany 12-20GW of gas is required by 2030, in the future this backup is supposed to run on hydrogen
- A vastly more complex and larger ***transmission network and integration infrastructure***

These 5 systems, with low utilization contributing to the cost increase, are all required to replace one existing coal or gas or nuclear power station. These 5 systems – except for the thermal power plants – have a short operational lifetime, so they have to be replaced every few years, far more often than the conventional thermal power system alone (Figure 8).

Even more concerning is that the energy and raw material input required to build these ancillary systems – to be replaced every few years – could be larger and more significant than what is required for the overbuilding of wind and solar alone, which is already large. The IEA did NOT include those raw materials for ancillary systems in their statement ***"a clean energy system requires more mineral resources than an energy system based on fossil fuels"*** [16].

4. Summary: environmental consequences, high costs, and energy poverty

(A) Low energy density, (B) short operational lifetime, and (C) intermittency directly result in relatively (1) higher raw material and energy need as well as (2) an array of ancillary systems required to make wind and solar power useful (Figure 9).

Figure 6: Minimum combined wind and solar output in Germany

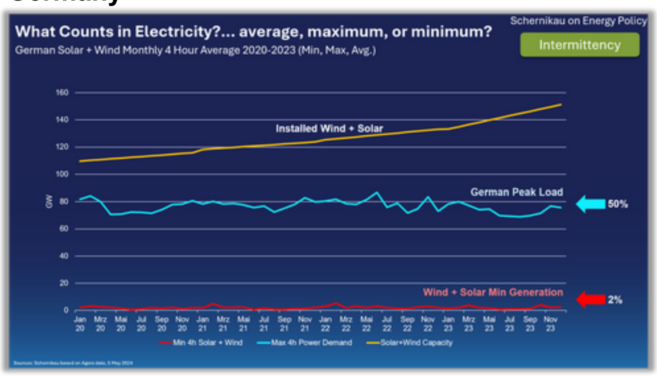
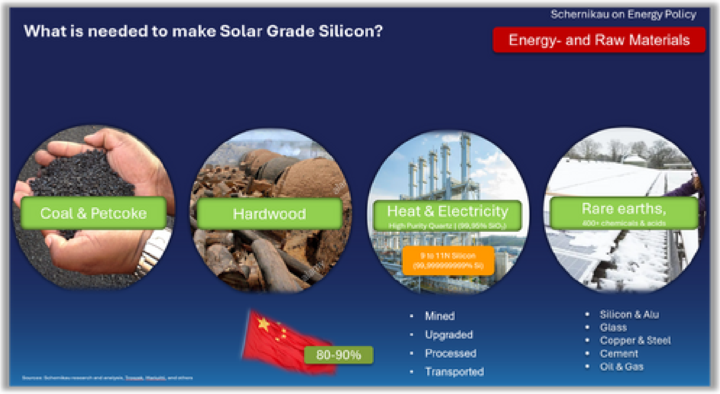


Figure 7: Raw materials required for solar



That is pure energy economics and explains the low net-energy efficiency, or low eROI, of wind and solar… which seems completely contrary to popular belief. Let's now build the bridge leading to environmental and monetary considerations.

Environmental consequences: It becomes obvious that the short lifetime and large installations of wind, solar, and ancillary systems need to be not only replaced but actually disposed of every few years. Additionally, the ***low power density and resulting large land use, have a direct impact on the flora, the fauna – such as whales, birds and insects – and the local climate*** such as humidity and temperature. Do a little experiment, go out and feel the temperature and measure humidity of the air just below and just above a solar panel in the sunshine.

The United Nations has highlighted that, over their entire lifecycle, wind and solar energy sources exhibit a higher potential for human carcinogenic toxicity than nuclear power, and even coal or natural gas. This metric, known as "human carcinogenic toxicity potential," measures the impact of substances released over a technology's lifespan that may increase cancer risk for humans. It's important to note that these figures may not account for the entire infrastructure needed for wind and solar systems—such as battery storage, extensive wiring, or support structures—but rather focus only on the core components like solar panels and wind turbines. This suggests that the actual carcinogenic toxicity impact of renewable systems may be underestimated in current assessments. [28]

Recycling sounds nice, but also has raw material, energy, and economic costs often larger than just disposing of wind and solar installations. See Harvard-INSEAD *The Dark Side of Solar Power* [24].

The new circular economy goes as follows: extract and upgrade raw materials in ***Africa***, ship to ***China***, process and manufacture in ***China***, assemble somewhere in ***Southeast Asia,*** ship to ***Europe or the US***, ship back to ***Africa***, dispose of in landfills in ***Africa***.

Here is a list of selected peer-reviewed papers covering the environmental effects of wind and solar

- [18] Long et al 2024: Large-Scale Photovoltaic Solar Farms in the Sahara Affect Solar Power Generation Potential Globally
- [16] Albanito et al 2022: Quantifying the Land-Based Opportunity Carbon Costs of Onshore Wind Farms
- [17] McCall et al 2023: Vegetation Management Cost and Maintenance Implications of Different Ground Covers at Utility-Scale Solar Sites
- [19] Duran et al 2022: Cleaning after Solar Panels: Applying a Circular Outlook to Clean Energy Research
- [20] Bellut-Staeck 2024: Chronic Infrasound Impact
- [21] Nover et al 2017: Long-Term Leaching of Photovoltaic Modules
- [22]Nguyen et al 2021: Benchmark Characterisation and Automated Detection of Wind Farm Noise Amplitude Modulation

The impact on the climate of emitted greenhouse gases from our energy systems is not covered in this article, but for this I highly recommend Prof. Koonin's book ***"Unsettled"*** or Chapter 4.3 in our recently updated book **"The Unpopular Truth… about Electricity and the Future of Energy"**

Economic cost: By now we also understand that the large overbuild and ancillary systems required to make wind and solar workable come at a large economic cost, that Germany is all too well aware of.

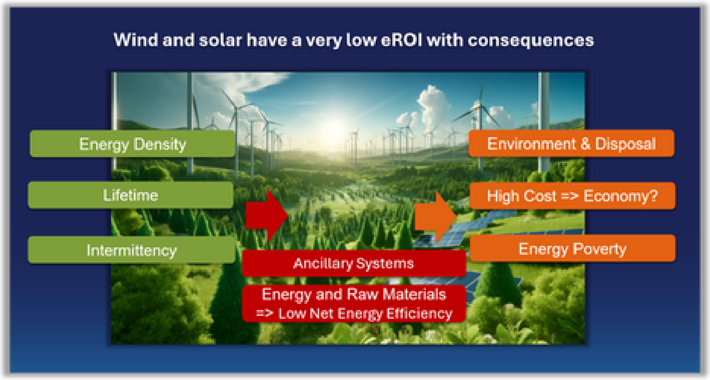
> *The prestigious Energy Institute (EWI – "Energiewirtschaftliches Institut") and thinktank of the University of Cologne summarized the money required for the Germany "energy transition" to stay on track.*
>
> *According to EWI's analysis Germany must invest over €2 trillion – or* ***€2,000 billion or €100k per family of four*** *– through 2030 to keep its "green" promises. This staggering figure almost dwarfs the €1.1 trillion through 2045 (under-) estimated by Handelsblatt in January 2024. For details see* ***What now Germany?… How do we get electricity…?***

The analysis herein also explains why the statement ***"wind and solar are the cheapest and cleanest"*** is only true on a marginal cost basis, but not on a system cost level, which is relevant for electricity. Because ***electricity is a service (kWh on demand when you need it), not a product (kWh).*** But the famously used LCOE cost metric or Levelized Cost of Electricity treats electricity as a product (kWh) and does not consider any of the required items mentioned in this post. More details are covered in my published article ***The Energy Trilemma.***

People cost: The economic cost has a direct impact not only on industries (see Germany's deindustrialization, source [25]) but also impacts citizens, especially the less affluent. It is obvious **that high energy costs and resulting taxes will have a bigger impact on the financially less fortunate.** In Germany, the Bundesrechnungshof – the government auditor – confirmed that energy poverty increased, now effecting 25% of households in 2023, which is up from a previous 15% in 2021 [26]. According to the Economist, expensive energy,during the 2022/2023 winter, may have killed more Europeans than Covid-19 [27].

Figure 8: Ancillary Systems: Replacing one "dirty" system with five "clean" systems?

Figure 9: Summarizing the impact of wind and solar



Imagine now what higher energy cost means for people in Africa, Pakistan, or Bangladesh? You may not be surprised that although energy poverty in Africa had been stagnant for 20 years, it has been increasing since 2021.

People with less or no energy are poorer, they live unhealthier, and unhealthier people have a decreased life expectancy. So how many people die from increased energy cost? Who has ever modeled this "small" issue relating to the "energy transition"? To address these challenges, my recommendations are straightforward yet impactful:

1. Invest in Research and Development: By committing resources to innovative R&D, we can work toward an energy future that is both economically viable and environmentally sustainable. A "New Energy Revolution" will enable us to transition away from fossil fuels without the compromises currently demanded by wind and solar solutions.
2. Enhance Existing Energy Systems: In the interim, investing in and improving our current energy infrastructure can help meet today's energy demands. By making these systems more efficient, we can reduce their environmental footprint while ensuring reliable energy supply.

These steps lay the groundwork for a balanced approach to achieving sustainable energy without sacrificing economic stability or environmental health.

5. Links and Resources

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About the Author

Dr. Lars Schernikau - With two decades immersed in the commodity industry, his journey began at The Boston Consulting Group in the USA and Germany from 1997 to 2003, shaping his deep understanding of global markets. Lars also managed a Germany based wind farm from 2003 to 2006. As a co-founder, shareholder, and former board member of the supervisory board at both HMS Bergbau AG (www.hms-ag.com) and IchorCoal NV – German-based, publicly listed, international commodity marketing and mining companies.

Lars´ experience spans across Europe, Asia, Africa, and North America. He has founded, steered, and advised enterprises across the global raw material sector, leaving a lasting imprint. Currently, Lars directs his expertise towards further enhancing HMS' global commodity operations and driving energy and commodity marketing across Asia, Africa, the Americas, Europe and the Indian subcontinent. Notably, HMS has been a key player in coal, ore, and cementitious product markets since 1995. The company develops and operates various logistics and mining assets.

Beyond the commodity business, Dr. Schernikau is a renowned energy economist and keynote speaker at global energy and commodity forums world-wide. His counsel on macro and energy economics extends to governments, banks, educational institutions, and conglomerates, shaping energy policies. With published books, scientific research, and press articles on energy policy and raw materials, his insights are held in high esteem. Lars has also peer-reviewed energy related books and research paper. His latest book, ***The Unpopular Truth… about Electricity and the Future of Energy*** discusses the energy transition and how to meet global growing energy demand from an energy economic point of view.