Other Considerations Associated with The Carbon Costs of the proposed 500kW Solar Array off of Upper Loveland Road in Norwich, Vermont

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It is important for citizens of Norwich and society at large to know whether industrial energy developments are producing at a net energy gain or loss. Those who propose photovoltaic systems in regions of moderate insolation such as ours owe us realistic expectations about the energy returned on energy invested, and not arbitrary and highly improbable assumptions untethered from reality.

“Solar generated electricity in regions of moderate insolation offers an extremely low yearly capacity factor of 9% or of 3% during the winter period instead of a range of 65–85% for other high-density energy sources such as fossil or nuclear power plants. The solar electricity supply does not align in general with the demand profile, and is stochastic, volatile, intermittent and non-dispatchable.” – Ferroni, Guekos, and Hopkirk, Further considerations to: Energy Return on Energy Invested (ERoEI) for photovoltaic solar systems in regions of moderate insolation

The German experience on what to expect from photovoltaic generation in regions of moderate insolation such as Vermont is instructive. According to Vaclav Smil, “In 2020, two decades after the beginning of *Energiewende*, its deliberately accelerated energy transition, Germany still had to keep most of its fossil-fired capacity (89 percent of it, actually) in order to meet demand on cloudy and calm days. After all, in gloomy Germany, photovoltaic generation works on average only 11–12 percent of time, and the combustion of fossil fuels still produced nearly half (48 percent) of all electricity in 2020.” - Smil, Vaclav. *How the World Really Works*

When Russia throttled its natural gas exports to Europe earlier this year, Europe suddenly realized how dependent it was upon fossil fuels to power its economy. When the gas was shut off the European industrial landscape -- along with its alternative energy plans -- was dramatically altered, possibly forever.

“Europe's hard-earned climate champion credentials are being tarnished after it boosted thermal coal imports by more than any other region in the first eight months of 2022. The Continent was the only region to increase coal imports from January through August compared with the same slot in 2021, bringing in 35.5% or 15 million tonnes more of the power generation fuel, according to data from Kpler. “The increased coal purchase “undermines efforts made over the past decade to establish Europe as a renewable energy leader and serious advocate for cutting coal use.” Reuters

“It wasn't supposed to be like this... But with Russia cutting natural gas deliveries to Europe, and with no quick options to replace that energy, Germany is warily turning to its most reliable -- and environmentally polluting -- fossil fuel. At least 20 coal-fired power plants nationwide are being resurrected or extended past their closing dates to ensure Germany has enough energy to get through the winter.” - NPR.ORG

In the autumn of 2022, as a direct consequence of the European fossil fuel energy shortage and subsequent soaring energy costs, European Union metal companies face an existential threat from rising energy prices. Due to these challenging circumstances Eurometaux, the European metals industry association, recently delivered an open letter to the European Commission to express their fears:

“50% of the EU’s aluminum and zinc capacity has already been forced offline due to the power crisis, as well as significant curtailments in silicon and ferroalloys production and further impacts felt across copper and nickel sectors. In the last month, several companies have had to announce indefinite closures and many more are on the brink ahead of a life-or-death winter for many operations. Producers face electricity and gas costs over ten times higher than last year, far exceeding the sales price for their products. We know from experience that once a plant is closed it very often becomes a permanent situation, as re-opening implies significant uncertainty and cost.” - Eurometaux

“Companies across Europe are going into sleep mode,” reported NPR’s Eleanor Beardsley on November 28, 2022, in a story about Europe’s energy crisis. “Gas-heavy fertilizer makers have all but halted production. Steelmaker ArcelorMittal has temporarily shuttered mills in France, Spain, Germany and Poland,” she reported.

"My concern as a European citizen is that these industries will be closed and will not start again," says François-Régis Mouton, regional director for Europe at the International Association of Oil and Gas Producers. "They kept saying 'fossil gas, we have to kill fossil gas.' OK, we've killed it but how do we survive? Instead of doing that they could have said it would be better to produce it in Europe and not be dependent on Russia. As a consequence of this, domestic energy production is declining a lot in Europe. Because we don't invest."

“The EU dismissed fossil fuels in its effort to reach carbon neutrality by 2050, says Thierry Bros, a specialist in global energy at Sciences Po university in Paris,” Beardsley reported.

"We've been saying to this [fossil fuel] industry that it's passé, that we don't need it," says Bros. "Well at the end of the day, if people want to heat themselves, if you want to cook, if industry needs to continue to produce, you need fossil fuels." **-** NPR.ORG

ELECTRICITY GENERATION AND CONSUMPTION

Electricity Generation in Vermont

According to the United States Energy Information Agency (EIA), “Vermont has the lowest energy-related carbon dioxide emissions of any state.”

According to the EIA, “Vermont’s total energy consumption is the smallest among the states.”

According to the EIA, “In 2021, Vermont generated almost 100% of its electricity from renewable resources, a larger share than in any other state.”

According to the EIA, "12% of Vermont households use wood, the highest share in any state."

According to the EIA, "More than one-third of Vermont schoolchildren attend facilities heated by wood products."

Global Energy Consumption

Notwithstanding a popular narrative that photovoltaic electricity will soon replace all hydrocarbons, solar only has the potential to decarbonize a portion of the electricity we produce, which is by itself a small share of final energy consumption. "Energy is among the most elusive and most misunderstood concepts, and a poor grasp of basic realities has led to many illusions and delusions," writes Vaclav Smil in his book *How the World Really Works*.

"Despite its profound and rising importance," writes Smil, "electricity still supplies only a relatively small share of final global energy consumption, just 18 percent. - Vaclav Smil, *How the World Really Works*

"Global consumption of fossil fuels rose by about 45 percent during the first two decades of the 21st century, and despite extensive and expensive expansion of renewable energies, the share of fossil fuels in the world's primary energy supply fell only marginally, from 87 percent to about 84 percent... The extraordinarily difficult nature of the global warming challenge is best illustrated by the fact that three decades of large-scale international climate conferences have had no effect on the course of global CO2 emissions - Vaclav Smil, *How the World Really Works*

"Alas, a close reading reveals that these magic prescriptions give no explanation for how the four material pillars of modern civilization (cement, steel, plastic, and ammonia) will be produced solely with renewable electricity, nor do they convincingly explain how flying, shipping, and trucking (to which we owe our modern economic globalization) could become 80 percent carbon-free by 2030; they merely assert that it could be so." – Vaclav Smil, *How the World Really Works*

Renewables did grow almost 5% per year between 2009 and 2019, outpacing growth in fossil fuels at 1.7%. But in absolute terms, the consumption of fossil fuels increased much more than renewable energy. The world is now burning more fossil fuels than ever before. Today, the share of fossil fuels in the total energy mix is as high as a decade ago and the share of renewable energy increased only slightly. – REN 21 Renewables Now

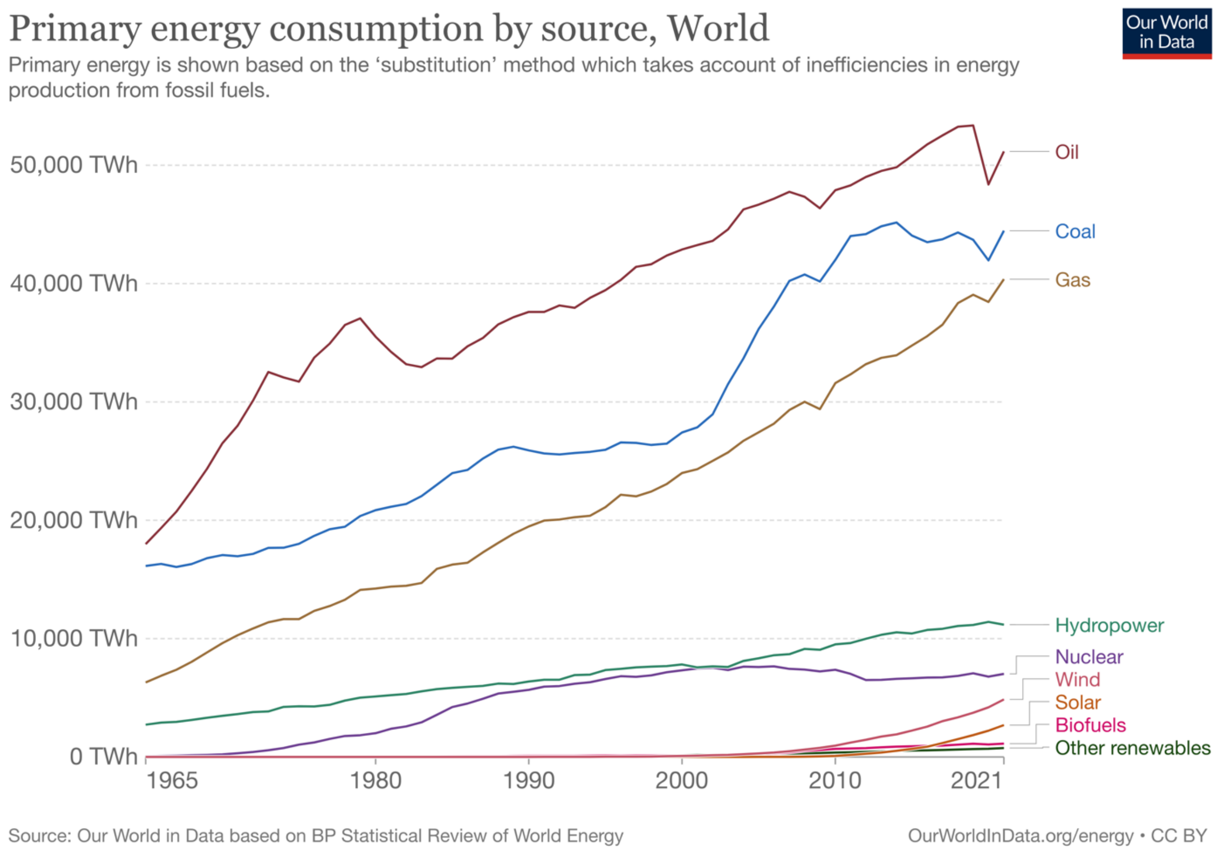


Figure 1. Primary Energy Consumption by Source, from 1965 to the present. Taken from Our World in Data, based on a BP Statistical Review of World Energy.

Solar Cannot Replace Fossil Fuels in This Civilization

To understand what we are trying to replace with electricity, we must understand how fossil fuels are used in modern civilization. According to the *BP Statistical Review of World Energy*, in 2021 oil companies extracted 78 million barrels of crude oil per day. Each day these were distilled into 23 million barrels of gasoline, 5 million barrels of jet fuel, and 27 million barrels of diesel/heating oil. The remaining 23 million barrels of oil extracted per day were used in chemical production to create products that modern civilization depends upon. – BP Statistical Review of World Energy

"Petrochemicals derived from oil and natural gas make the manufacturing of over 6,000 everyday products and high-tech devices possible. Major petrochemicals – including ethylene, propylene, acetylene, benzene, and toluene, as well as natural gas constituents like methane, propane, and ethane – are the feedstock chemicals for the production of many of the items we use and depend on every day.

"Modern life relies on the availability of these products that are made in the United States and around the globe. We zero in on some of these common household and commercial products below. The list may surprise you!" - U.S. Department of Energy

DRAWBACKS ASSOCIATED WITH SOLAR ENERGY

Solar's Dependence Upon Fossil Fuels

Solar electricity is not renewable. It is merely rebuildable using fossil fuels for every single step of its life cycle and maintenance. All energy-producing machinery must be built out of materials extracted from the earth. No energy system is actually renewable since all machines require the continual fossil-fueled mining, processing, refining, smelting, manufacture, and transportation of millions of tons of primary materials followed by the disposal of hardware and infrastructure that inevitably wears out.

Norwich Solar on its website claims that "Solar Photovoltaics (PV) directly reduces demand for fossil fuels and therefore reduces the associated pollutants. Nearly all manmade global warming and air pollution emissions which include, nitrous oxide (NOx), sulfur oxide (SO2), carbon monoxide (CO) and particulates are the direct result of fossil fuel energy usage, whether for electricity or transportation." – Norwich Solar

This claim is disingenuous. "We like simplistic answers to complex problems because they require no thinking which demands study and work. While sunshine and wind might be abundant (at least in the spring and the summer), the materials needed to build panels, electric motors, batteries and turbines require fossil fuels in every step of their lifecycle. These products are just as dependent on oil as the gas-guzzler SUVs they aim to replace. They cannot be produced without burning fossil fuels. These 'green solutions' are only an extension to the coal, oil and gas infrastructure, not a replacement." - Vaclav Smil, *How the World Really Works*

The manufacturing processes used today to make solar panels and batteries involve very high temperatures that are currently generated using fossil fuels. This is a problem for the solar industry, given that solar panel manufacturing requires temperatures ranging from 2700 °F to 3600 °F, and manufacturing the steel and cement used in installation requires temperatures ranging from 1800 °F to 3100 °F. Solar panels cannot produce anywhere near the high temperatures required to manufacture solar panels and associated hardware and infrastructure.

"Currently, no alternative energy exists without fossil fuel inputs, and no alternative energy process can reproduce itself -- that is, manufacture the equipment needed for its own production -- without the use of fossil fuels," writes David Fridley, staff scientist in the Energy Analysis Program at the Berkeley National Laboratory. "In this regard, alternative energy serves as a supplement to the fossil fuel base, and its input requirements may constrain its development in cases of either material or energy scarcity." Post Carbon Institute

Reliability of Solar Power

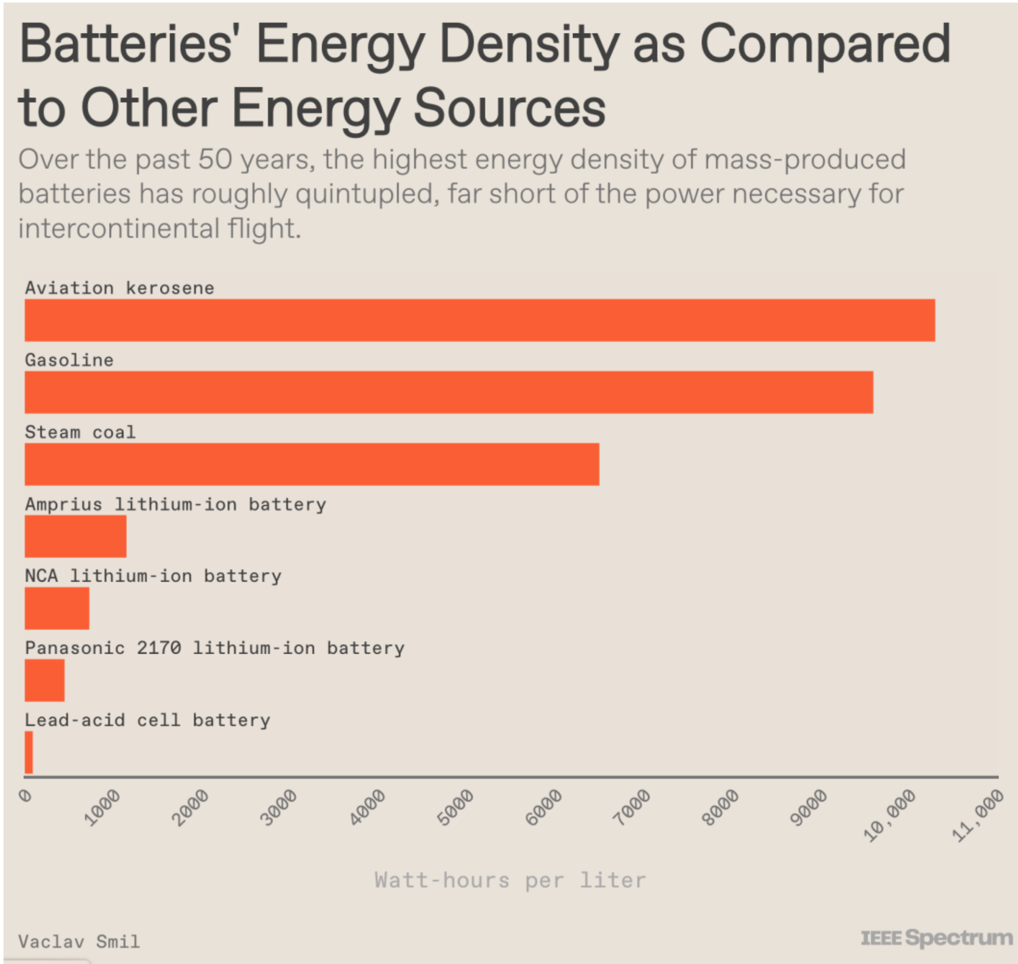
Society cannot trust solar power to keep the lights on, make sure elevators don't cease functioning, or keep heart-lung machines operating during open-heart surgery without interruptions. Due to the intermittency problem, solar power must always be backstopped by fossil fuel, hydropower, or nuclear power that can be switched on immediately when necessary. Currently the backstop most commonly used is natural gas. Maintaining reliable energy sources in the background, always ready to be turned, on is a hidden cost of solar power; and the larger the share of solar in the energy mix, the higher these background costs are.

Problems With Solar Energy Density and Storage

"In a world that aspires to leave behind all fuels (except hydrogen or maybe ammonia) and to electrify everything, the preferred measure of stored energy density is watt-hours per liter. By this metric, air-dried wood contains about 3,500 Wh/L, good steam coal around 6,500, gasoline 9,600, aviation kerosene 10,300.

"How do batteries compare with the fuels they are to displace?

"The best energy density now commercially available in very large quantities for lithium-ion batteries is at 750 Wh/L, which is widely seen in electric cars." - Spectrum.ieee.org



Dependence on Foreign Minerals

Solar power accounted for 3% of U.S. electricity generation from all sources in 2020. Any significant expansion of today's modest level of solar energy will create an unparalleled increase in global mining for necessary minerals. This will drastically intensify existing environmental challenges and will dramatically increase both U.S. mineral imports and the vulnerability of America's energy supply chain. – U.S. Energy Information Agency

"As the world transitions to a clean energy economy, global demand for these critical minerals is set to skyrocket by 400-600 percent over the next several decades, and, for minerals such as lithium and graphite used in electric vehicle (EV) batteries, demand will increase by even more—as much as 4,000 percent. The U.S. is increasingly dependent on foreign sources for many of the processed versions of these minerals. Globally, China controls most of the market for processing and refining for cobalt, lithium, rare earths and other critical minerals." - The White House

As recently as 1990, the U.S. was the world’s number-one producer of minerals. Today, it is in seventh place. America is now 100% dependent on imports for some 17 key minerals, and, for another 29, over half of domestic needs are imported.” - Mark P. Mills, *Mines, Minerals, and "Green" Energy: A Reality Check*

Figure 2.—2021 U.S. Net Import Reliance[1]

Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2017–20)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany, China
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
VANADIUM	100	Canada, China, Brazil, South Africa
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
TELLURIUM	>95	Canada, Germany, China, Philippines
POTASH	93	Canada, Russia, Belarus
IRON OXIDE PIGMENTS, natural and synthetic	91	China, Germany, Brazil
RARE EARTHS,[3] compounds and metals	>90	China, Estonia, Malaysia, Japan
TITANIUM, sponge	>90	Japan, Kazakhstan, Ukraine
BISMUTH	90	China, Republic of Korea, Mexico, Belgium
TITANIUM MINERAL CONCENTRATES	90	South Africa, Australia, Madagascar, Mozambique
ANTIMONY, metal and oxide	84	China, Belgium, India
STONE (DIMENSION)	84	China, Brazil, Italy, India
CHROMIUM	80	South Africa, Kazakhstan, Russia, Mexico
PEAT	80	Canada
SILVER	79	Mexico, Canada, Chile, Poland
TIN, refined	78	Indonesia, Peru, Malaysia, Bolivia
COBALT	76	Norway, Canada, Japan, Finland
DIAMOND (INDUSTRIAL), stones	76	South Africa, India, Congo (Kinshasa), Botswana
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, crude fused aluminum oxide	>75	China, France, Bahrain, Russia
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Australia
SELENIUM	>75	Philippines, China, Mexico, Germany
RHENIUM	72	Chile, Canada, Kazakhstan, Japan
PLATINUM	70	South Africa, Germany, Switzerland, Italy
ALUMINA	58	Brazil, Australia, Jamaica, Canada
GARNET (INDUSTRIAL)	56	South Africa, China, India, Australia
MAGNESIUM COMPOUNDS	55	China, Brazil, Israel, Canada
ABRASIVES, crude silicon carbide	>50	China, Netherlands, South Africa
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
TUNGSTEN	>50	China, Bolivia, Germany, Canada
CADMIUM	<50	Australia, China, Germany, Peru
MAGNESIUM METAL	<50	Canada, Israel, Mexico
NICKEL	48	Canada, Norway, Finland, Australia
COPPER, refined	45	Chile, Canada, Mexico
ALUMINUM	44	Canada, United Arab Emirates, Russia, China
DIAMOND (INDUSTRIAL), bort, grit, dust, and powder	41	China, Ireland, Republic of Korea, Russia
LEAD, refined	38	Canada, Mexico, Republic of Korea, India
PALLADIUM	37	Russia, South Africa, Germany
FELDSPAR	32	Turkey
SILICON, metal and ferrosilicon	32	Russia, Brazil, Canada, Norway
SALT	29	Chile, Canada, Mexico, Egypt
MICA (NATURAL), scrap and flake	28	Canada, China, India
LITHIUM	>25	Argentina, Chile, China, Russia
BROMINE	<25	Israel, Jordan, China
ZIRCONIUM, ores and concentrates	<25	South Africa, Senegal, Australia, Russia
PERLITE	23	Greece, China, Mexico, Turkey
VERMICULITE	20	South Africa, Brazil

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum; rare earths, mineral concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zinc concentrates) or less than 20% net import reliant (abrasives, metallic; beryllium; cement; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)—ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]Listed in descending order of import share.

[3]Data include lanthanides.

Figure 2. United States net import reliance for mineral commodities in 2021. Taken from United States Geological Survey's Mineral Commodity Summaries 2021. https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf

In a “Groundbreaking Report,” the U.S. Department of the Interior revealed that: “U.S. Reliant on China, Russia, and Other Foreign Nations for Many Critical Materials.” The report continued, announcing that the “U.S. 100 percent foreign-reliant on 20 minerals, Rare Earth minerals produced almost exclusively in China.”

“WASHINGTON – Today, the U.S. Department of the Interior and the U.S. Geological Survey released a report that detailed the extent to which the United States is fully, majorly, or partially dependent upon foreign competitors and even adversaries for our supply of "critical minerals." The report identified 23 of the minerals that are most needed to sustain our national defense and economy and are used in manufacturing everything from batteries and computer chips to equipment used by our military. The report shows a troubling trend of foreign dependency.” – U.S. Department of the Interior

A Brittle Solar Supply Chain

“Chinese companies produce over three-quarters of the world’s polysilicon, which is at the heart of solar panels. Some solar industry groups and researchers say that level of concentration poses a risk to the solar supply chain. [But] challenging China’s preeminence in solar manufacturing will not be easy. In addition to its massive polysilicon capacity, Chinese companies control the subsequent steps in the supply chain: the production of silicon ingot and wafers, solar cells, and final solar panels.

“It’s a complex process, and China dominates nearly every step of it. The country makes more than three-quarters of the world’s polysilicon, according to data compiled by polysilicon consultant Johannes Bernreuter. A report by the International Energy Agency (IEA) estimates that China also manufactures over 80% of all solar cells and assembled solar panels. The country produces virtually all the wafers used for solar panels.” - Chemical and Engineering News

Solar’s Environmental Degradation

Solar technology is not clean. For every 1 MW of solar panels produced, some 1.4 tons of toxic substances, including hydrochloric acid, sodium hydroxide, sulfuric acid, nitric acid, and hydrogen fluoride, and 2868 tons of water are used. At the same time 8.6 tons of emissions are released -- 8.1 tons of which are the perfluorinated compounds sulfur hexafluoride (SF6), nitrogen trifluoride (NF3), and hexafluoroethane (C2F6) that are thousands of times more potent than CO2. Other toxic byproducts, such as trichlorosilane gas, silicon tetrachloride, and dangerous particulates from the wafer sawing process are also produced. Amorphous solar panels are made with cadmium, which is a carcinogen and genotoxin. - IEEE Spectrum; Proceedings of the Materials Research Society

With respect to minerals, building solar panels to generate electricity, as well as batteries to fuel electric vehicles, requires on average more than 10 times the quantity of materials compared with building machines using hydrocarbons to deliver the same amount of energy to society. – Mark P. Mills, *Mines, Minerals, and "Green" Energy: A Reality Check*

The components in solar technology are mined, and the mining industry accounts for 10 percent of world energy use. The energy used in mining comes from burning fossil fuels, and mining is a dirty business. The industry uses some of the heaviest machinery on the planet, with some mining machines weighing over 800 tons. Manufacturing and operating these machines consumes massive amounts of fossil fuels and causes severe damage to humans and ecosystems.

In the United States, "mining activity has left deep scars across the American West, where the Environmental Protection Agency estimates that 40 percent of watersheds have been contaminated by hardrock mines. This environmental degradation has had particularly severe consequences for indigenous communities because many live close to the country's largest deposits of nickel, lithium, cobalt, and copper." - Grist

Many of the remaining untapped deposits of the metals critically needed for U.S. solar energy development are located either near or within areas of cultural and environmental importance to Native Americans. 97% of nickel, 89% of copper, 79% of lithium and 68% of cobalt reserves and resources in the U.S. are located within 35 miles of Native American reservations. MSCI

For most of American history the mining industry has privatized financial gains and socialized environmental costs. The consequences of this unregulated activity have been disastrous. Today, more than 22,000 abandoned hardrock mines around the country still pose an environmental hazard to the surrounding area. - U.S. Government Accountability Office

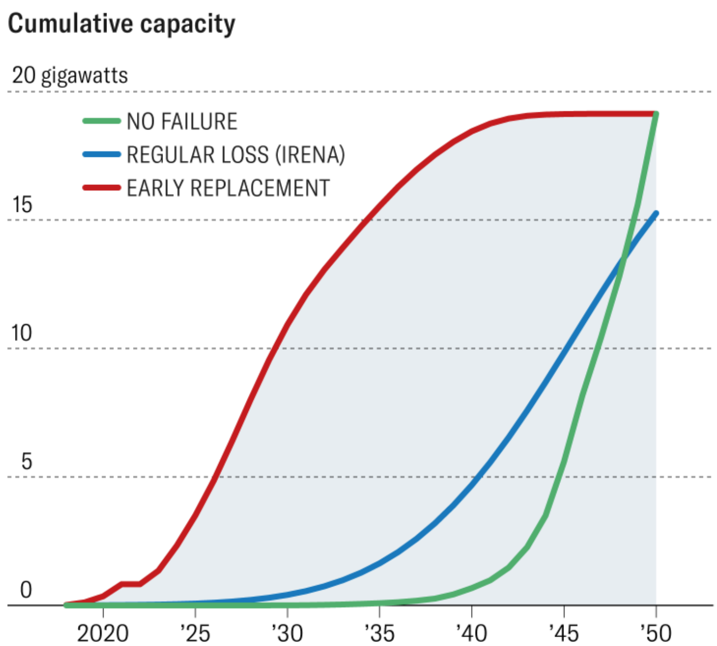
By 2050, with current plans, the quantity of worn-out solar panels --much of it nonrecyclable -- will constitute double the tonnage of all today's global plastic waste. By 2030, more than 10 million tons per year of batteries will become garbage. - Mark P. Mills, *Mines, Minerals, and "Green" Energy: A Reality Check*

"The [solar] industry's current circular capacity is woefully unprepared for the deluge of waste that is likely to come. The financial incentive to invest in recycling has never been very strong in solar. While panels contain small amounts of valuable materials such as silver, they are mostly made of glass, an extremely low-value material. The long life span of solar panels also serves to disincentivize innovation in this area.

"As a result, solar's production boom has left its recycling infrastructure in the dust. To give you some indication, First Solar is the sole U.S. panel manufacturer we know of with an up-and-running recycling initiative, which only applies to the company's own products at a global capacity of two million panels per year. With the current capacity, it costs an estimated $20–$30 to recycle one panel. Sending that same panel to a landfill would cost a mere $1–$2."
– Harvard Business Review

The Solar Trash Wave

According to our research, cumulative waste projections will rise far sooner and more sharply than most analysts expect, as the below graph shows. The green “no failure” line tracks the disposal of panels assuming that no faults occur over the 30-year life cycle; the blue line shows the official International Renewable Energy Agency (IRENA) forecast, which allows for some replacements earlier in the life cycle; and the red line represents waste projections predicted by our model.



Source: International Renewable Energy Agency, Electricity Data Browser, Global Solar Atlas

HBR

Figure 4. Projections for solar waste, taken from the Harvard Business Review.