Janus Revealed

The Mythology of Solar Energy

BY J. JOSEPH COHEN

The deity associated with twin perspectives, Janus (Roman mythology) frequently symbolized change and/or transitions. A single being with dualistic vision, Janus oversees the progress of past to future, from one condition to another, from one vision to another, and growth to adulthood. The absolute convictions under which we perceive our reality may, through this omniscient lens, be less absolute than we can imagine. Complicated systems are very difficult to describe, yet we are involved with them daily. We make assumptions, born of belief, that may mislead us into a "fact space" that maybe inconsistent with reality. It is too bad that unlike Janus, we cannot see into the past and future with sufficient clarity to sharpen our focus for the here and now.

If the Janus transition for solar power were to occur on a massive scale, it would not bode well for Earth environmentally.

A prime example of this problem is that of the "Green" movement's love affair with solar energy; they believe it to be simple, free, plentiful, and harmless. Yet, it is very complicated, and certainly not as available, economically or environmentally friendly as they would have everyone believe. Nevertheless, the sycophants who sit at the feet of the Solar oracle are imbued with absolute conviction, that the greenest of the green solution for electrical power are solar photovoltaics (PVs).

Unfortunately, magic doesn't exist, and, alas, PV's are not the panacea that one would hope for. Nor are PVs a significant solution to our appetite for energy. They fall very short of the mark. Worse, solar power is an environmental and economic Trojan-horse.


At the Ivanpah Solar Electric Generating System, more than 300,000 computer-controlled mirrors beam concentrated sunlight to three 460-ft-tall towers. (Photo courtesy NRG Renew)

What is Solar?

Other than heliostat thermal, and PVs, all other derivative solar energy solutions are the result of biological activity which convert solar irradiance into high density chemical storage.

It is true that our Sun presents abundant, reliable and emission free power. Indeed, stored solar-power, in the form of bio-carbons (coal, oil, and natural gas), have been the driving force of industrialization and advancement. However, Sun alone cannot do the magic to provide useable power.

By the Numbers

It is convenient to view solar panels as harmless fancy glass windows that, with no negative effect, converts the free sunlight into useable electricity. But, they are constructed from a variety of materials and chemicals which, in their manufacture, harm the environment. With a smile, users proclaim this to be a clean energy solution. But they forget the life cycle involved in harnessing solar energy.

The sun continuously bathes the earth with light energy (irradiance) with only modest interruptions by solar eclipses. The illuminated area (at any given time) of the earth is 255 million km^2. Of these, 74 million km^2 is land. The rest is ocean.

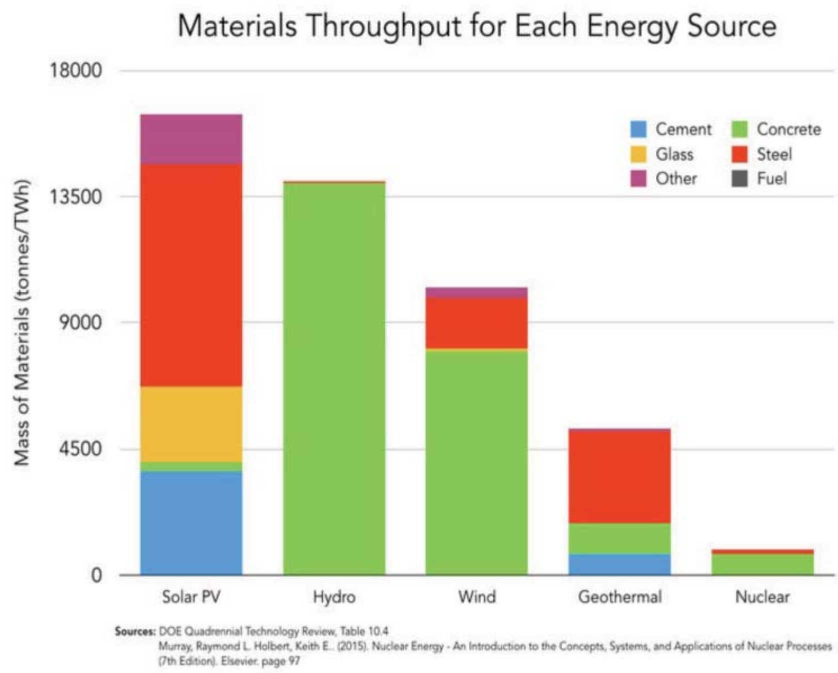
These oceans are teeming with single and multicellular organisms that convert solar insolation into chemical energy. So too are the land areas rife with photosynthesizing flora. From these activities, a chemical cornucopia of compounds provides the foundation for life, through the storage and transport of vital energy. These activities began about 3.4 billion years ago, the bounty of which is stored solar energy ready for our use, now!

Allowing for the incident fall-off of the sun's irradiance (insolation), it follows that at any moment the earth receives, on average, 6.375 petawatts (a petawatt is 1,000,000,000,000,000 watts) of solar energy at the surface of the planet (or about 56,000 petawatthours annually.) However, the mean efficiency for deployed photovoltaic devices is about 13% (to be fair, there are tested devices with maximum efficiencies of about 23% under ideal conditions). Therefore, if one could cover the earth with photovoltaic cells, the solar energy could continuously power 780 billion toasters or about 100 toasters per person living today.

But, most of the planet is water. Therefore, the maximum area available for practical use is significantly less. It is estimated that restricting the use of land only to that utilizable for solar irradiance would produce, at best, 1.855 petawatts, or annually 8,760 petawatt hours of electricity.

The current Annual power consumption of the world is 200 petwatthours or about 1/43rd the theoretically maximum recoverable amount of solar energy. To achieve this goal, at least 2 million km^2 would need to be covered with photovoltaic cells.

Unfortunately, since the world rotates, the actual land area needed to provide continuous power would be nearly 20 times larger — roughly 41 million km^2. This is about 11 times the size of the entire United States. Worse, this would have to be evenly spread out around the Globe. It would take a capital investment more than $13,325,000,000,000,000 or 300 times the entire economic output of the planet for 2016!



The chart above shows that Solar PV uses more materials per energy capacity than any other. Of course, this does not include the fuel.

It is universally acknowledged that a large amount of land is required to produce power from solar farms. But it is necessary to first look at the land use for conventional power plants. A non-solar utility scale power plant (coal, nuclear, etc.) requires an average of 2 acres or about 6 American football fields to generate one megawatt capacity of power. But as the scale of the power plant increases, the land use ratio drops dramatically. The site for a 1 gw, (1,000 mw) power plant is only about 12.5 times as large at about 25 acres. The extent of the reservation for some installations (security perimeter) is of course potentially larger, but that is normally primitive conditions and does not count as used area.

ENERGY DENSITY — SOLAR FARMS REQUIRE 10 ACRES PER MEGAWATT (MW), WHILE A 1,000-MW COAL-FIRED POWER PLANT REQUIRES LESS THAN 25 ACRES.

PV solar farms require about 10 acres to produce 1 mw and 1,000 acres to produce 1 gw. Yet this is not the whole story. A 1 mw solar farm needs to be six times larger just to produce the daily production of a 1 mw conventional power plant. This is because the peak solar power is only available for about 2-4 hours per day, if there is no weather interference.

If the solar farm is large, it must, like conventional plants, manage the power to grid delivery. This requires that the solar facility store this power on site and regulate its delivery to the grid demand. This requires either large scale battery storage, gravity, pressure, or inertial storage, all of which are under 65% efficient. That means the size must go up by an additional 25% for the solar field and must now include an area budgeted for the storage and grid matching substations.

Now the 10-acre site has grown to about 80 acres just to reliably produce 1 mw of continuous power. This does not include contingencies for inclement weather!

The site estimates for solar farms when they represent small additions to a dynamic grid are easy. When they are used to produce significant power, the site design must mirror the dynamics and reliability of conventional power generating plants. The solar pundits try to hide this problem by quoting maximum power density instead of levelized use. Solar, and other intermittent energy sources, must be regularized to compete with and supplement existing power generating schemes. Merely stating a peak power availability (overhead sun, low angle of incidence, clear sky, low ambient temperature) is meaningless. That condition, is at best, only realizable for 2-4 hours a day. With storage and regeneration, the peak number equates to more than 8 times the normalized power. This is smoke-and-mirrors designed to hide the poor economies of solar power.

Electric power is usually sold by the kilowatt hour, the product of power in kilowatts multiplied by running time in hours. Typically, solar farms do not provide a rating in commercial power units. They merely provide a watt rating which is 1 joule of energy per second. It is obvious that they cannot compete with conventional power generators.

Manufacturing Considerations

Manufacturing a solar panel is an energy and resource consuming process, which will eventually lead to scarcity. To generate photovoltaics capable of producing 1 mw of power from solar source, 13 tons of solar grade polysilicon is used. This equates to, roughly, 20 tons of silicon quartz before processing to PV grade silicon. Other more specialized materials are also used in the manufacture. Some are process materials that do not actually find their way into the device itself. Metals, including rare earths are major considerations as well.

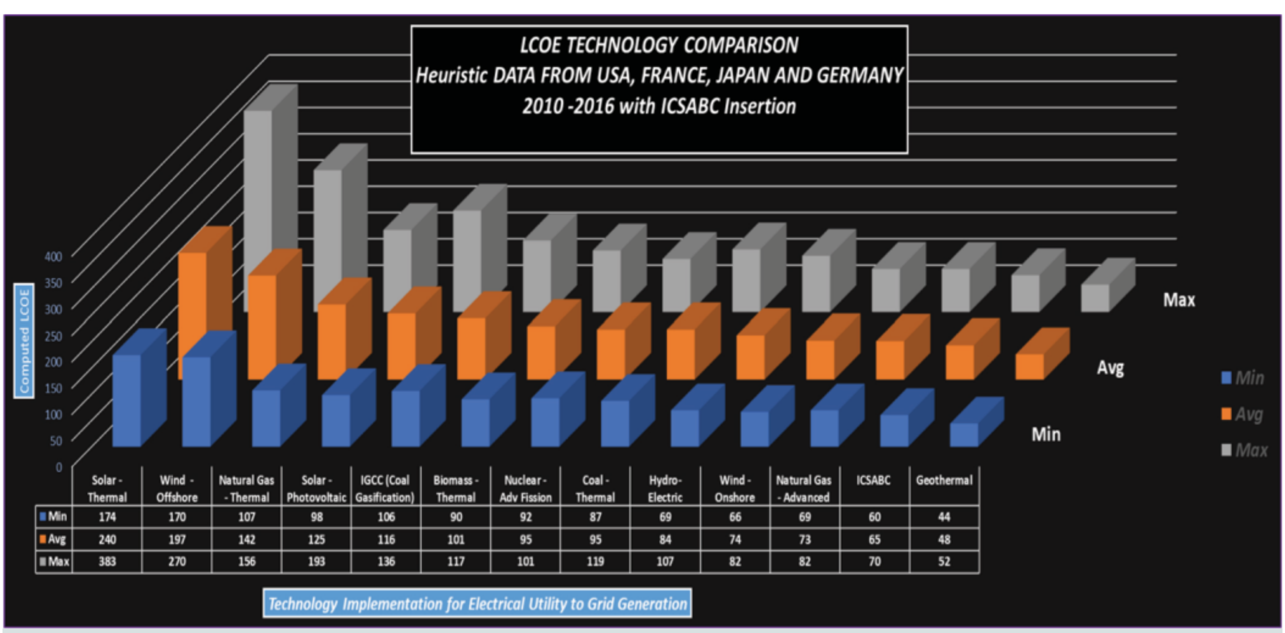
Yes, solar energy is green, clean and emission free but at what cost? Problems associated with solar energy are vast and mostly blindfolded.

Demand for energy consumption to manufacture solar panels continuously increases. A one megawatt — peak power — solar plant uses nearly 3,240 solar panels with the average panel area at about 1.626 m^2. The total area of solar cells required to provide a 1-megawatt capacity is 5,268 m^2. Approximately 0.25 megawatt hours of power is required to produce a 1 m^2 panel. This is a total of 1,317 megawatt-hours to produce the panels for one megawatt of solar. Assuming other forms of energy support the production process it is apparent that the carbon footprint is not minimal in solar energy's life cycle. To repay this manufacturing energy debt, the solar farm would have to operate continuously for 1 year. Adding in the installation energy and ancillary equipment necessary to operate the farm, the energy payback time budget easily exceeds 3 years.

Solar energy is harvested using solar panels. Solar panels are not available freely, they must be manufactured — just like any other electronic device. This involves a dirty and energy consuming process. Firstly, raw materials must be mined to remove quartz sand for silicon cells. A series of chemical stages are carried out to make silicon as a semiconductor which can conduct electricity. Finally, upgraded materials must be manufactured into solar cells and assembled into modules.

All these processes produce air pollution, emissions of heavy metals, consume energy and encompass environmental impacts like land deterioration, loss of biodiversity, pollution, logistical infrastructural damages, deterioration of ground water and natural drainage system.

Assembling individual solar cells typically needs to be soldered with copper wire coated with tin; some manufactures use lead and other toxic materials. This results in release of harmful



	Solar - Thermal	Wind - Offshore	Natural Gas - Thermal	Solar - Photovoltaic	IGCC (Coal Gasification)	Biomass - Thermal	Nuclear - Adv Fission	Coal - Thermal	Hydro-Electric	Wind - Onshore	Natural Gas - Advanced	ICSABC	Geothermal
Min	174	170	107	98	106	90	92	87	69	66	69	60	44
Avg	240	197	142	125	116	101	95	95	84	74	73	65	48
Max	383	270	156	193	136	117	101	119	107	82	82	70	52

The Levelized Cost of Energy (LCOE) projected for 2020 using heuristic date from 2010 - 2016. As notated in the above chart (which uses averaged data from US, France, Japan, and Germany); Solar and Offshore Wind are outliers for the most expensive power production. While Advanced Cycle Natural Gas, Onshore Wind, and Geothermal represent the other end of the cost spectrum.

gases into the environment and adds to global warming.

The installation of solar panels requires tons of materials like aluminum, steel, plastic and rubber for infrastructure. These industrial scale efforts cause considerable damage to the environment and use a great deal of energy. The harmful gases and materials released during the process, are dumped back into the environment an omen of calamitous consequences as capacity ramps up.

Solar panels create 300 times more toxic waste per unit of energy than nuclear power plants.

A 2013 investigation by the Associated Press found that from 2007 to 2011, the manufacturer of solar panels in California "produced 46.5 million lb of sludge and contaminated water. Nearly 97% of it was transported to hazardous waste facilities in the state, whereas more than 1.4 million lb were transported to nine other states."

How Solar Farms Affect the Ecology

Land — many thousands of acres — is cleared and used to develop glistening solar power facilities adversely affecting native vegetation and wildlife adding imbalance to the environment resulting in loss of habitat, interference in rainfall and drainage. Indigenous fauna is injured or killed by direct contact with solar farm installations. Worse, the land is not available for use or for access. It is a fenced reservation, a virtual parking lot with the same albedo. It will adversely affect the local climate in dramatic fashion. These are massive, contiguous, impervious hot zones that do not find similarity in nature. It is the embodiment of instant urbanization.

Land Use

Solar development projects in Ivanpah Valley are not the kind of wildlife-friendly renewable energy projects one would have expected.

There are no global warming emissions that are formed during the power generation by solar energy. But the change in albedo in massive areas does significantly fuel climate change. Also, there are harmful gases associated with other stages of solar life cycle, including manufacturing, materials transportation, maintenance, installation and during recycling. Yet the interruption of flora growth below the installed panels can and does impact the take up of greenhouse gases normal to a thriving ecosystem

Solar farms require vast tracts of land. Typically, these are found far from the market where power is most needed. Expensive transmission lines are deployed to bring the power to a distant market impacting surrounding land and wildlife. Merely clearing and grading the land results in soil erosion, compaction and alteration of drainage channels.

The sun shines continuously, but Earth is not solar synchronous. It presents a changing face to the sun throughout its 24-hour diurnal cycle. Also, it is not only the hours of daylight that matter, but various places receive less energy at times which changes with the weather, and the season. Therefore, every solar/alternative energy installation requires co-generation facilities, which are installed to run in concert with Farms and are designed to run continuously. This too adds cost to the project.

Storage is another major problem solar industries face today. They have the equipment to harness energy but not to store it. The cyclic nature of the sun and the unknowable weather requires significant expense to have off-generating capacity. Storage facilities in a matching capacity may exceed the cost of the solar farm itself.

The LCOE - Cost per Kilowatt Comparisons

Powerplants have an economic lifecycle that is governed by the cost-per-kilowatt. The comparisons are called "Levelized Cost of Electricity" or "LCOE".

The levelized cost of electricity (LCOE) is calculated by the following expression above.

$$\mathrm{LCOE} = \frac{\text{sum of costs over lifetime}}{\text{sum of electrical energy produced over lifetime}} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

I_t	:	investment expenditures in the year t
M_t	:	operations and maintenance expenditures in the year t
F_t	:	fuel expenditures in the year t
E_t	:	electrical energy generated in the year t
r	:	discount rate
n	:	expected lifetime of system or power station

It must be noted that Solar Photovoltaic has an average LCO of 125 compared to Solar Thermal at 240, Coal at 95 and Natural gas at 73. Taken alone this is only a 30% – 40% increase. However, this does not include power leveling storage facilities which are necessary for grid scale solar farms. Adding them in, the LCOE jumps to 198! Taking out the government incentives for solar initiatives, adds an additional 31 to bring the total to 229. Certainly, this economic landscape is bleak. Worse, it does not contain the decommissioning costs at the end of life.

Ignorance Is Not Bliss

Solar panel manufacturers are not aware how much damage they could cause to the environment and social life. Solar companies must adopt sustainable procedures and techniques from manufacturing to disposal before making the claim …. "Solar Energy is Really Clean and Green."

As a small complement to conventional power plants, Solar Thermal and Solar PV is both desirable and needed. For low power consumption devices attached to a rechargeable storage media, it is a great solution. But, for powering our civilization as a significant adjunct, it will portent a nightmare.

Like Janus we must look beyond to comprehend the effects of a Solar economy. Earth is not ready for the pain Solar will bring.

Joseph Cohen is an Executive Scientist at Casimir Systemics LLC. A physicist since the mid 1980's he has designed high energy laser systems, high d epitaxial HgCdTe FPA's, fluid separation techniques, plasma polymerization systems, chalcogenide fiber lasers, laser gyroscopes, and developed energy carrier recovery technologies. Currently he runs the R&D department for Sarc Global Inc.*