Suburban New York home with Solar Panels

When are Solar Panels **Green**?

by Bill Menke, March 9, 2015

Solar panels, a technology for turning sunlight into electricity, are widely viewed as *green*. They cause much less pollution than fossil fuel or nuclear power plants and emit no CO_2 (the greenhouse gas that is driving global warming).

After a slow start in the 1980's, the use of solar power has soared in the United States, with approximately 16 GW of installed capacity that produced, in 2014, about one half of one percent of US electricity (roughly equivalent to five large conventional power plants)[1]. Though small, this percentage is increasing every year; furthermore, solar panels are being installed at a growing rate.

Solar-electric power production is an industrial process relying on high tech components, so calling it *green* is an oversimplification. Like many other technologies, its greenness depends as much upon the intended application as on its inherent qualities. As I will argue below, it is very green when used in already built up settings where it does not further increase the geographic footprint of human activities. In contrast, it is decidedly not green when natural habitat or agricultural land is destroyed to make room for solar farms. Habitat loss is thought to be the greatest threat to global biological diversity and is the primary problem faced by 85% of species considered *endangered* and *threatened*[2].

Perhaps the greatest virtue of solar power production is that an economically-significant amount of low-CO_2 footprint electricity can be produced entirely within the existing geographical footprint of urbanized (and suburbanized) society. Solar panels installations can be comingled with houses, streets, parking lots and commercial buildings, while other low carbon-footprint methods cannot. Flooding a neighborhood for hydropower or converting parks and flower gardens to ethanol-producing corn fields are not viewed as socially-acceptable practices. (Wind power is somewhere in between these extremes of acceptability, owing to the noise produced by the turbines, but is not widely used in urbanized settings in the US).

In a suburban setting, significant electricity can be produced by the people who use it. A typical household in the US annually consumes about 11,700 kWh of electricity[3]. A typical rooftop solar installation on a suburban house can produce about half that amount[4, 5]. A large, single-story commercial building like a suburban supermarket consumes about 250 times the power of a house[6,7], but also has proportionately at least as much suitable surface area (if parking lots with solar awnings are included[8,9]) and so can also meet, within its own geographical footprint, a substantial fraction of its needs. Furthermore, rooftops and parking lots so far have been only minimally utilized for solar power; substantial growth is possible. The situation is less favorable in highly urbanized areas, since the energy demands of high-rise buildings typically exceed their solar power production potential. Nevertheless, solar power can contribute a few percent of a city's needs.

Solar panels are area-intensive. The installation needed to power a suburban house, which has only modest power needs when compared to, say, a factory, nevertheless covers a substantial fraction of its roof. In fact, solar panels are only a factor of two more efficient, in terms of their power to land area ratio, than hydroelectric dams[10]. The differential decreases substantially and arguably disappears when *severity of impact* is taken into account. The reservoir behind a dam is very environmentally destructive, but at least leaves some habitat for fish[15] and waterfowl. A solar panel farm leaves nothing.

Hydroelectric dams account for 16 percent of global power production[16] and have a very low CO_2 footprint. However, they are widely condemned by environmentalists, because they replace highly diverse, biologically-productive forests with reservoirs that have a much lower degree of diversity and almost no biological productivity[17]. Solar farms are no better; many of the environmental arguments that have been used to argue against the building of new dams in wild areas apply equally to solar farms. Any attempt to supply even a modest percentage of a city's electrical needs by creating large solar farms in "undeveloped" outlying area would destroy large amounts of habitat. For instance, New York City would require a solar farm thirty miles on edge[18, 19] enclosing a land area just a little smaller than the state of Rhode Island[20].

Solar is only one of a wide arsenal of low CO_2 footprint energy production techniques; wind power is one of several alternatives. Wind power also has a low power to land area ratio, but its impact factor is much lower[9], so that it can be generated in agricultural areas[21] without significantly affecting farm productivity and exported to cities. By choosing the low-CO_2 footprint best suited for a particular setting, global CO_2 emissions can be substantially reduced[22] without causing widespread habitat destruction.

Notes

[1] http://en.wikipedia.org/wiki/Solar_power_in_the_United_States
[2] http://wwf.panda.org/about_our_earth/species/problems/habitat_loss_degradation/
[3] http://shrinkthatfootprint.com/average-household-electricity-consumption
[4] http://www.nrel.gov/docs/fy04osti/35297.pdf
[5] Estimated based on 400 sq feet (4kW) solar panel installation array with 12% PV efficiency producing 6400 KW-hr/yr (54% of consumption).
[6] http://www.p2pays.org/energy/smallbus/Supermarket.pdf
[7] Estimate based on 50000 sq ft supermarket and power usage of 50 $kWhr/ft^2$-yr, yielding 2,500,000 kWhr/yr. for the supermarket (compared to 11,700 kWhr/yr for a house).
[8] http://slpmn.org/uploads/Parking_Lot_Guide.pdf
[9] Estimate based on 50000 sq feet rooftop plus 250 cars parking lot occupying 2.5 acres.

[10]Table of power to area ratio for various types of energy production. Note that solar power is only a factor of two more efficient in land use than hydroelectric dams. When corrected for impact, the differential is even smaller. (The impact figures I use here, of my own devising, are intended to roughly account for the severity of habitat destruction associated with the different types of power).

Name	Location	Type	Power	Land	Efficiency	Impact	Corrected Efficiency
			MWhr/yr	Acres	MWhr per acre	0-1 scale	MWhr per impacted-acre
Manicougan[10]	Quebec	Hydro	23266560	480000	48	0.50	97
Waldpolenz[11]	Germany	Solar	52000	544	96	1.00	96
MapleRidge[12]	New York	Wind	900000	21000	43	0.10	429
Gowanus[13]	New York	Gas Turbine	4826760	25	193070	1.00	193070

[11]http://en.wikipedia.org/wiki/List_of_largest_hydroelectric_power_stations
[12]http://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations
[13]http://www.uspowergen.com/portfolio/astoria-generating/gowanus/
[14]http://www.tughill.org/wp-content/uploads/2011/10/HarnessingTheWind2010.pdf
[15]I do not want to understate the habitat destruction associated with dams and the reservoirs that they create. Dams are bad for fish; furthermore, the fish living in reservoirs are typically different from the species that lived in the former river.
[16]http://www.earth-policy.org/data_highlights/2012/highlights29
[17]http://www.internationalrivers.org/environmental-impacts-of-dams
[18]http://engineering.mit.edu/ask/how-many-wind-turbines-would-it-take-power-all-new-york-city
[19]Calculated as 60,000,000 MWhr/yr divided by 100 MWhr/acre, which equals 600,000 acres or 938 mi^2.
[20]http://en.wikipedia.org/wiki/Rhode_Island
[21] http://www.ucsusa.org/clean_energy/smart-energy-solutions/increase-renewables/farming-the-wind-wind-power.html#.VP4Iui4YF8E
[22]CO_2 emissions are difficult to completely eliminate because some conventional capacity is needed to even out fluctuations in wind and solar production, which vary strongly with weather and time of day.