

**The Ghost of Don Quixote: The Increased Likelihood of Attacks on
Windmills and Solar Panels During Conflict**

**Bob Feldman
LTC, USAR
Foreign Military Studies Office**

15 Nov 2012

Introduction

They seem to be sprouting up everywhere, these windmills and solar stations, testaments to the world's efforts to reduce fossil fuel usage by harnessing the wind and sun. Be it Colorado or Cape Verde, alternative energy systems, as they are sometimes called, are frequently large structures, or from a military standpoint, large targets, for inevitably windmills will fall and solar cells will go blind as they are targeted, either deliberately or accidentally, during conflict.

On a smaller scale one might find a few houses with solar panels here and there in a city, or a few farms with some relatively small windmills to pump water. However, larger concentrations of windmills into windmill farms, and larger collections of solar panels into solar stations, are becoming increasingly common, providing significant amounts of electricity to homes and industries. These large windmill farms and solar stations are clearly visible, readily identifiable, and perhaps easily destroyed by any enemy wishing to knock out key components of a power grid.

Windmills and solar cells are not just sources of energy; they represent optimism that a catastrophic future can be averted. As burning fossil fuels such as coal and oil releases carbon dioxide, a greenhouse gas implicated in global warming, many have pinned their hopes on windmills, solar cells, and other alternative energy systems to save the world from self-destruction.ⁱ Thus, to destroy modern windmills and solar cells would likely be perceived as a particularly heinous act.

Miguel de Cervantes' fictional character, Don Quixote, perched atop his skinny horse, Rocinante, and accompanied by his not so skinny squire, Sancho Panza, tilted at windmills, thinking they were giants.ⁱⁱ Four centuries have passed since Don Quixote set out on his adventures, but perhaps the great turmoil in so many lands today has awaken his ghost, perhaps

once again the world, in confused thinking, could find itself tilting at windmills, and maybe their alternative energy brethren, solar power stations.

Understanding Solar and Wind Energy

Before proceeding further it's helpful for the reader to become familiar with some key terms and concepts related to solar and wind power. These will be presented in the least technical manner possible but still capturing the essentials necessary to understand the paper.

The sun's rays can be harnessed to produce electricity in one of two ways, directly using photovoltaics (PV) and indirectly using concentrated solar power (CSP). Let's begin with photovoltaics. Photovoltaic cells, also called solar cells, are semiconductor devices.ⁱⁱⁱ Light strikes them and electricity is produced. Solar cells can be assembled into solar panels, which are often still called solar cells but also referred to as modules, some of which are quite large, such as those used by utility companies. Many people are familiar with photovoltaics on a much smaller scale; solar cells power their calculators.

Unlike photovoltaics, concentrated solar power systems take an indirect approach to power generations. They use lenses or mirrors to concentrate the solar rays into a beam focused onto devices such as steam or Stirling engines which when heated generate electricity. Numerous CSP designs exist, such as the parabolic trough where mirrors focus the light on a fluid filled pipe, or the solar power tower where heliostats, mirrors that track the sun, focus solar rays on a receiver atop a large tower. These CSP designs, because they heat a fluid, are called solar thermal plants.

Large collections of solar panels or large collections of mirrors in trough or tower arrangements are called solar power stations, sometimes just solar stations for short. Large collections of windmills are called windmill farms. Electricity generated by the sun or wind can

be on grid, meaning it feeds into a system of transmission lines where other generating plants are also sending their electricity production, all to be tapped by homes and industries connected to the same grid. The power produced by solar cells and windmills can also be off grid; for example a single windmill generating electricity that is directly connected to a pump. The windmill in this example is off the main power grid. When it spins and the pump doesn't need to work, it can't send any power it produces someplace else that could use the electricity. Conversely, when the windmill stops spinning, and the circuit does not include a battery, the pump stops working as there is no connection to the main power grid which would have provided backup electricity.

Growth and Characteristics of Alternative Energy Systems

The worldwide push is on to harness the wind and sun. Worldwide wind power installations capacity increased 22% in 2010, with Asia showing the greatest gains.^{iv} There has also been a tremendous increase in the installation of photovoltaic devices. President Obama, in his goal to double the amount of renewable energy generated by the US is proposing special energy zones on public lands in six western states – Arizona, California, Colorado, New Mexico, Nevada, and Utah - where utility-size solar power facilities would be constructed.^v Coincidentally, five of those six states also have a large number of military facilities, and as we will soon see, another state with a large number of bases, Texas, has huge windmill farms. These are interesting facts to keep in mind when discussing what might happen should an enemy attack bases in those western states.

One of the world's flashpoints for conflicts, Israel, is also the heaviest user per capita of solar energy, 3% of its primary national energy consumption.^{vi} Solar water heaters, ubiquitously dotting Israeli rooftops, account for much of that solar energy usage. However, there are also

numerous large scale solar stations already in operation, with more planned or under construction, which are also responsible for the high per capita use of solar energy. Israel, in fact, is an important research and development center for solar energy use. Unfortunately, since its independence just a little over six decades ago it's also been the focal point of several major conflicts as well as the target of repeated terrorist attacks. It is probably only a matter of time before one of its major solar stations is struck, maybe by one of the ever more accurate and powerful artisan rockets launched from nearby territories.

Like solar, wind power is also rapidly growing both in the US and internationally. Three of the largest onshore wind farms in the United States are the Alta Wind Energy Center in California, which began construction in 2010; the Horse Hollow Wind Energy Center in Texas; and the world's largest, also in Texas, the Roscoe Wind Farm.^{vii} Unfortunately for the Roscoe Wind Farm it won't be able to keep its title for long. When finished, the Gansu Wind Project in China will be even larger. Several hundred windmills operate on each of these wind farms, reflecting the economic potential of large-scale harnessing of the wind.

Regarding the rapid international construction of windmill farms and solar stations, keep in mind that electricity is exportable. Europe is already eyeing Africa as a potential source of alternative energy, and someday Morocco may be dotted with solar thermal plants sending electricity northward. This changes the security equation. Certain desert areas which previously, unless they had mineral resources, were considered uneconomical wastelands could now become valuable pieces of property sporting large solar stations, stations which to some might be considered supporting the infidel. For terrorists intent on harming the infidel's economy it might be easier to attack a solar station in North Africa than a power plant in Europe.

Numerous other solar stations and wind farms are on the drawing boards or already in construction throughout the world. The alternative energy race is on, and the earth's landscape will be forever changed, and with it international political, economic and security dynamics. Now, not only will people refer to oil rich or mineral rich countries when describing nations with wealth from natural resources, they'll describe sun rich and wind rich. Innumerable wars have been fought over oil and minerals; will the same happen over sun and wind?

Solar Panels Go to War

It is not just large scale solar stations that are multiplying, Photovoltaic panels are starting to appear in backyards of homeowners and businesses. They are also showing up in some high profile places: besides 100 wind turbines, Lincoln Financial Field, home of the Philadelphia Eagles, will be adding 2,500 solar panels.^{viii} And, portable solar cells are going off to war.

Each year troops in the field use tens of thousands of disposable lithium batteries. For a typical three day deployment an individual soldier, to power flashlights, night vision goggles, GPS units, and other necessary items may carry 65 batteries weighing up to 30 pounds.^{ix} By using solar cells the soldier won't have to carry as many batteries and the ones he or she does use won't be disposed of; they're rechargeable. Hook them up to the solar panel for a few hours and it will be like having a fresh supply. Besides the weight savings because not as many batteries have to be carried, and the fact that using rechargeable ones is better for the environment, by carrying fewer lithium batteries there could be fewer casualties. Should lithium batteries catch on fire, they can release toxic chemicals, seriously injuring soldiers nearby.^x

Recognizing the importance of battlefield capable solar cells, the Defense Advanced Research Projects Agency, DARPA, is investing \$3.8 million into their development.^{xi} The Low-Cost

Lightweight Portable Photovoltaics Program intends to deliver to the military of the future solar cells capable of surviving many battle conditions as well as environmental extremes.

There are already small photovoltaic systems going to the battlefield, but in the years to come their size and numbers will grow as the military pushes for more electricity to feed the ever increasing need of the troops.^{xii} With larger and more numerous solar cells, it's probably inevitable they will be caught in conflict.

Durability of Solar Panels and Windmills

Though at first appearance solar panels may appear easily broken as they incorporate a pane of glass over electronic components, ones that meet safety certifications UL 1703 or IEC 61730 are surprisingly durable.^{xiii} Their glass is tempered and in many cases has been designed to survive quite adverse weather conditions, including one inch hail striking it at 50 miles per hour.^{xiv} Should the glass crack but not destroy the underlying collectors electricity could still be generated though at a decreased amount proportional to the size of the crack. Punctures through both the glass and components, depending on their location, could also result in continuing though decreased performance.

To be sure, despite the efforts of manufacturers to harden them against environmental damage, solar panels are far from indestructible. Mortar rounds, bombs dropped from airplanes, and many other explosive devices, including some which are homemade, could readily destroy banks of solar panels.

The undersides of solar panels, which are not expected to be exposed to harsh weather and consequently designed with little protection, are particularly vulnerable to deliberate damage.

Should terrorists decide to destroy solar panels, once inside a solar power station attacking the “soft underbelly” of individual cells would be a plausible scenario.

Minor damage to the electrical connections of solar cells can sometimes be repaired with solder or conductive epoxy. However, the type of damage caused by explosives would probably require the entire cell to be replaced, a very expensive proposition.

The situation could be even more precarious in less developed countries (LDC's) for solar power stations there frequently contain panels which are not manufactured to the standards required for safety certification present in the United States. These panels may have originated from several different countries where manufacturing costs were lowered by providing less durability. Thus, a bomb detonated in the middle of a solar station comprised of these panels would likely produce more damage than had a similar device been detonated in the middle of panels meeting certification requirements. With many poor countries unable and/or unwilling to pay the additional costs for the more durable panels, and also unable to afford adequate security, solar stations in these nations might be particularly susceptible to destruction. Additionally, as providing generator backup to a solar station is expensive, and therefore not always financially feasible in LDC's, the solar station may be the only source of power on the grid, and it being knocked out means no electricity for any of its customers.

Windmills, like solar panels, are also fairly durable, designed to survive extreme weather conditions. Unfortunately, like solar panels, they can also be readily destroyed. It's not necessary to knock the windmill over or remove its blades to take it out of commission; an explosive device striking the gear mechanism would incapacitate it.

Differences of Military Importance Between Alternative and Conventional Energy Sources

There are clearly marked differences between alternative energy plants, such as windmills and solar farms, and more conventional energy sources such as large diesel generators. As an example, the following chart compares an oil burning plant to a solar power station comprised of photovoltaic panels.

Oil Burning Plant	Photovoltaic Power Station
May cover a few acres	May cover thousands of acres
May be located within or very close to a city	Located outside a city.
If close to or within a city, relatively short transmission lines.	Long transmission lines which could be vulnerable to attack
Enclosed within a building which offers some additional security protection compared to being unenclosed.	Not enclosed within a building.
Attack might result in significant secondary explosions and fires.	No significant secondary explosions or fires.
Potential release of large amounts of toxic gases from an attack.	Probably only a relatively small amount of toxic gases released from an attack. ^{xv} Burning insulation in solar cells might release some harmful fumes, though the quantity of insulation used is generally quite small so the amount of fumes released would likely be fairly negligible. ^{xvi}
Potentially extremely difficult to extinguish	Probably little to nothing to extinguish following an attack
Oil burning plants have been attacked in the past, providing information regarding what would actually happen during an attack.	No known significant attack on a solar station, thus no information regarding what would happen during an actual attack.
Homemade mortar would probably cause little damage. Electricity output would not drop.	Homemade mortar could destroy several solar panels, resulting in a small drop in electricity output.
Nearby fire would not decrease electricity output.	Nearby fire, if it generated significant smoke, could decrease electricity output.

Thus, it appears that solar stations, spread across many acres and in the open, may be easier targets than oil fueled generators. Additionally, though there would initially be shards of glass

flying everywhere, overall an attack on a solar station would most likely not have the same degree of adverse physical damages in comparison to an attack on an oil fueled generator plant where toxic fumes and secondary explosions may occur.

Economic Effects of Attacking an Alternative Energy System

Over the years the cost per kilowatt hour produced from the wind and sun has dramatically declined to the point that it is hoped it will shortly be able to compete in many markets, without subsidies, against electricity generated from fossil fuel plants. That downward trend might reverse itself, at least temporarily, should even a small scale attack against an alternative energy system be successful. It's not just the replacement cost of the equipment, insurance and security expenses would also rise, making power from the wind and sun look a lot less promising than initially thought.

A similar small scale attack in a less developed country would probably be even more economically harmful. As most LDC's don't manufacture their own alternative energy systems, all replacement parts would have to be imported, an expensive proposition. Additionally, many LDC's lack a sufficient number of trained technicians capable of repairing extensive damage to windmills and solar panels, so that these, too, would have to be imported. The final price might be too high, and an LDC which suffered an attack on its alternative energy infrastructure might decide not to repair the damages and/or not to continue pursuing an alternative energy strategy.

Negative Impression of Targeting Alternative Energy Plants

While destruction of an enemy's power plant may cause angry repercussions in the international media, especially when lights go out in civilians' homes and factories are forced to

shut down, there may be additional negative publicity generated if the electricity was from an alternative energy plant. Windmill farms and solar power stations, in the world of public opinion, appear to be relegated a certain status above conventional energy plants. Destruction of a diesel generator means there is one less piece of noisy equipment spewing forth dirty fumes, but destruction of a green technology carries with it the loss of a means to generate electricity quietly and with little or no pollution. It might not be too farfetched to say that for some an alternative power plant is a bit more sacred. Destroying that plant would be the same as destroying a bit of humanity's hope for a better future.

One only has to ask which would be easier to sell to the American public: the need to destroy an enemy's large diesel generator or its solar farm? The answer is more than likely the diesel generator. In fact this author would not be surprised if destruction of windmills or a solar station by American forces did not result in a large outcry. Though both conventional and alternative plants may be used to power the enemy, the alternative ones might need to be taken off the table when developing lists of potential targets. At the very least there needs to be additional consideration of the potential for immense international blowback should they be destroyed.

Though the American people might be hesitant to put an enemy's alternative energy sources on the target list, it is doubtful America's potential enemies would feel the same when deciding what they would like to hit. From a terrorist perspective destroying windmills or solar panels on US soil might be more damaging to the American psyche, as well as capable of garnering more publicity, than targeting a conventional power plant. One must remember that laying waste to a oil fueled generator is attacking America's past whereas laying waste to a windmill farm or solar station is attacking America's future.

Military/Security Questions

Based in large measure on the previous discussions, there are several military/security questions related to alternative energy systems which need to be asked. These include:

- Should an enemy's alternative energy system be considered a legitimate target? If so, should the US be testing weapons already present in the arsenal or should it develop new ones specifically designed to destroy it?
- Besides cutting transmission lines, are there feasible ways to temporarily knock alternative energy systems off the grid, for example a sunblocker bomb which would temporarily blind the photovoltaics? Such capabilities would allow American troops to complete their combat mission but not permanently destroy the infrastructure so that reconstruction of the country, if occupied by American forces, could rapidly proceed.
- What are the particular vulnerabilities of alternative energy systems?
- To what extent should national security decisions play a role in determining the type and location of alternative energy systems being built?
- Are there sufficient redundancies built into the American power grid that even destruction of a large of alternative energy station would not result in a prolonged absence of electricity?
- How vulnerable are these systems to cyber attack?
- What are the unique vulnerabilities of windmill farms placed off the coast of the United States and how can those vulnerabilities be reduced?
- Are we rushing ahead with alternative energy systems without full consideration of the military/security impacts?

These are important questions which need to be answered. It would not be the first time that introduction of new technologies outpaced the ability of a government to fully understand their military and security implications.

Conclusion

Windmill farms and solar plants provide great promise. For far too long the United States has been tied to foreign oil, oil which frequently comes from unstable and/or hostile regimes. By adopting alternative energy systems America can cut its dependence on hydrocarbons. Furthermore, by turning to the wind and sun for energy instead of fossil fuels, it can cut its output of carbon dioxide, a gas implicated in global warming. Finally, it can manufacture the solar cells within its own borders, helping to rebuild an industrial base that has been severely eroded over the years. Yes, windmills and photovoltaics promise all that, but at what price? Have the security and military implications been thoroughly thought through, or has the rush to erect the next windmill or solar module precluded deliberate, thoughtful concern? Maybe there are some tradeoffs we should consider.

It is not just America where windmill farms and solar stations are springing up. In China, in France...everywhere there is a thirst for electricity alternative energy systems are being developed to quench it. With each passing day finding more of the earth incrementally covered by solar panels and windmills, how easy it will be to avoid striking them during conflict? Is it only a matter of time before nations or terrorists deliberately target them? Wars have been fought over "old" energy sources such as oil and gas; can we expect the same for the new energy sources of sun and wind?

Less developed countries, like wealthier nations, are also rushing to adopt alternative energy systems. Unfortunately in the process they are sometimes cutting corners to save money. Cells aren't as durable, security surrounding plants not as strong, and repair capabilities not, well, as capable. Thus, LDC's are perhaps more vulnerable to an attack of their alternative energy systems, less able to repair the damage, and less able to use other power sources to offset the electricity losses compared to richer countries. Still, even with these downsides, windmills and especially solar plants are increasingly dotting their landscapes.

Solar cells are also increasingly being found on the modern battlefield. Who would have thought thirty years ago a laptop computer would be on the frontlines or that banks of desktops would be in the rear? In order to meet those and other energy needs it's only a matter of time before relatively large banks of solar panels are routinely deployed by militaries to tap into the sun.

In the final analysis, the push in LDC's as well as the developed world to construct electrical generating capacity, for use during times of peace and times of war, which doesn't use fossil fuels means at some point alternative energy systems will likely be targeted, either deliberately or accidentally, during conflict. It could be a domestic terrorist with a homemade bomb, it could be a foreign air force with precision guidance munitions, but somehow, somewhere, sometime large windmills will fall and massive solar panels will shatter. Don Quixote's ghost has been stirred by the turmoil in the world, and he's ready once again to tilt at giants, real or imaginary.

Disclaimer

The views expressed in FMSO publications and reports are those of the authors and do not necessarily represent the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

Notes

-
- ⁱ G. Tyler Miller, Jr. *Living in the Environment, Fifth Edition* (Belmont, California: Wadsworth Publishing Company, 1988) 440-445.
- ⁱⁱ Miguel de Cervantes Saavedra, *Don Quixote*, Translated by John Rutherford (London: Penguin, 2003).
- ⁱⁱⁱ Thomas Floyd, *Electronic Devices* (Columbus, Ohio: Charles E. Merrill Publishing Company, 1984), 502-504.
- ^{iv} "Global Wind Capacity Increases by 22% - Asia Leads," *Growth Global Wind Energy Council* (Mar 2, 2011), [http://www.gwec.net/index.php?id=30&no_cache=1&tx_ttnews\[tt_news\]=279&tx_ttnews\[backPid\]=4&cHash=ada99bb3b6](http://www.gwec.net/index.php?id=30&no_cache=1&tx_ttnews[tt_news]=279&tx_ttnews[backPid]=4&cHash=ada99bb3b6) (accessed 11 Mar 2011).
- ^v Tom Dogget, "Government Pushes Solar Power in Six Western States," *Reuters* (Dec 16, 2011), http://news.yahoo.com/s/nm/20101216/us_nm/us_solar (accessed Dec 10, 2010).
- ^{vi} The Samuel Neaman Institute for Advanced Studies in Science and Technology — Publications — Solar energy for the production of heat Summary and recommendations of the 4th assembly of the energy forum at SNI
- ^{vii} "9 of the World's Most Amazing Wind Farms" *WebEcoist* (2009), <http://webecoist.com/2009/04/10/9-of-the-worlds-most-amazing-wind-farms/> (accessed Dec 12, 2010).
- ^{viii} Sandy Bauers, "Eagle's aim to turn Lincoln Financial Field into world's greenest stadium," *Philadelphia Inquirer* (Nov 18, 2010).
- ^{ix} Allison Barrie, "Recharge: American Troops May Become Their Own Batteries," *Fox News* (July 11, 2008), <http://www.foxnews.com/story/0,2933,380602,00.html> (accessed Dec 12, 2010).
- ^x Paul Bibby, "Solar panels Go to War," *The Age Company Ltd.* (Sept 25, 2007), <http://www.theage.com.au/news/national/solar-panels-go-to-war/2007/09/24/1190486225439.html> (accessed Dec 12, 2010).
- ^{xi} Katie Drummond, "DARPA Push: Solar Cells Tough Enough to Handle a War," *Wired.com* (June 25, 2010) <http://www.wired.com/dangerroom/2010/06/darpa-push-solar-cells-tough-enough-to-handle-a-war/> (accessed Dec 15, 2010)
- ^{xii} "The Marines are coming! With solar panels," *Spotlight* (March 10, 2010), <http://www.spotlight-online.de/news/technology/the-marines-are-coming-with-solar-panels> (accessed Dec 11, 2010).
- ^{xiii} Jennifer Granata, PhD, Member of the Technical Staff, Photovoltaics and Grid Integration Department, Sandia National Laboratories, personal communication with author, Dec 17, 2010.
- ^{xiv} "The Strength and Durability of Solar Panels," *BrightstarSolar*. (2010), <http://www.brightstarsolar.net/2010/08/strength-and-durability-of-solar-panels/> (accessed Dec 21, 2010).
- ^{xv} Sarah Kurtz, Principal Scientist, National Renewable Energy Laboratory, personal communication with author, Dec 16, 2010.
- ^{xvi} Electric Power Research Institute, "Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells." *Report to the California Energy Commission, Palo Alto, CA* (2003).