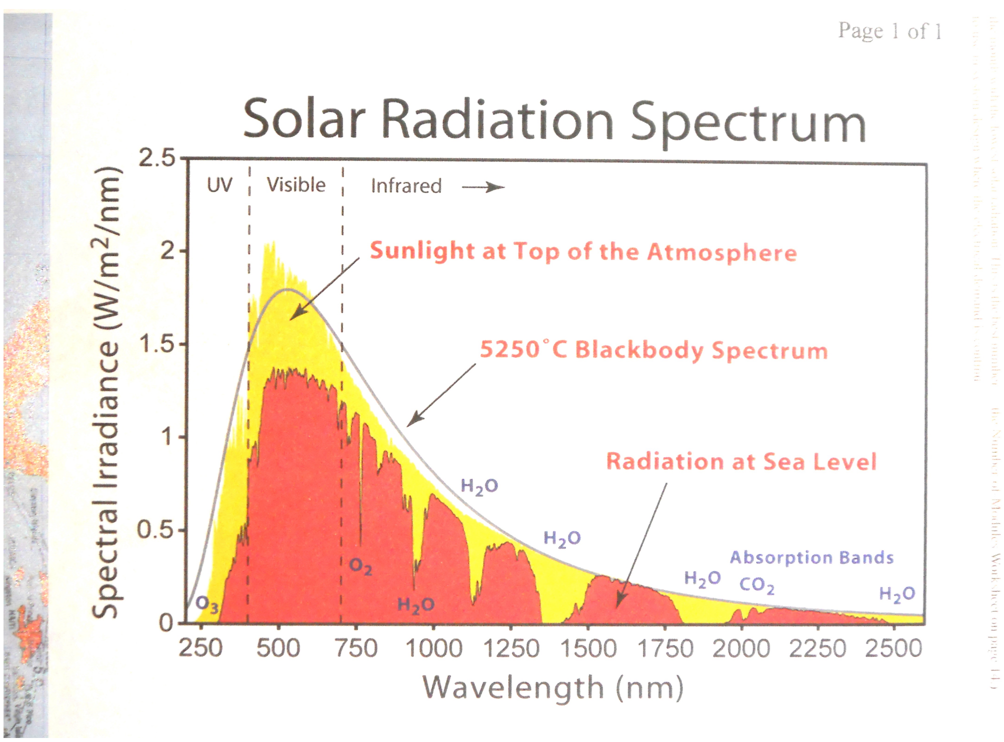
Holland Professional Club

The Business of Solar and Wind Energy

By John Fulenwider
March 8, 2013

When I read the disturbing article in the March 2013 issue of National Geographic ("America Strikes New Oil" by Edwin Dobb, pp. 28-59) about our new found source of oil and natural gas in the enormous reserves underneath North Dakota, my carbon footprint hackles went up and I shuddered. There is good and bad in this. The good is the job creation, and a chance that we will not have to import those fossil fuels. But the bad is fraking the underground rock and fouling the water aquifers. However we're not to worry. North Dakota's legislature has ruled that fraking is safe - - end of argument. In the end it all comes down to money. It is ironic that ND's other major energy resource is wind. Those in the business of wind energy, and solar energy are making money by converting earth's readily available and safe sources of energy into a saleable commodity that has a ready market.

Earth's main source of energy is from the sun, if we discount nuclear energy, which comes to us after a lot of work enriching Uranium that was left here when the earth was formed. So basically it is the sun's energy that we are getting directly, and indirectly through burning fossil fuels. All told we receive on average 1000 watts of energy per square meter at the earth's surface, midday. Some places get more depending on the clarity of the atmosphere. See FIGURE 1 Solar Radiation Spectrum. I'll get back to this FIGURE later.



With that amount of energy coming here it heats the oceans, the land, and our atmosphere. We get the winds, waves, heating of the land, and thermals. Our oceans, and land areas would continually heat up but heat energy is re-radiated back into space and earth almost reaches some sort of heat balance. But it's not quite balanced. There's more energy coming in than gets re-radiated back out. Because of our continued burning of fossil fuels, we have raised the CO2 level of the atmosphere to such a degree that we are experiencing global warming, climate change, and in recent years ever changing chaos with the weather.

However regardless of global warming, we do get winds, and wind power is one of the things I will talk about. A related topic is a brief tour of solar energy. Finally some comments about natural gas fueled combined cycle turbines will be made as this relates to HBPW's plans.

Business Schools will teach that business success is built on providing a "good" or "service" aimed at a perceived market, that produces revenues to pay off expenses, retire debt, and produce income for the business owners and employees.

A Wind Farm is a Revenue Producing System the Converts Wind Energy into Electric Energy that is sold for Dollars.

A Wind Farm consists of numerous Wind Turbines and Connecting Cables. Example of a wind farm in Huron County, Michigan is shown in FIGURE 2.

Electric energy is the "good", produced by the "factory", and the energy is sold to the "market" of consumers. A 100 megawatt wind farm can cost 150 to 200 million dollars, to build it and get it up and running ready to produce electric energy. Wind Farms as we see are capital intensive. Capital is raised from private lenders, banks, and by bond sales.

Attracting capital is another issue. Just after the first oil crisis in 1974 wind energy seemed like a new avenue for attracting some venture capitalists. Electric Utility companies at first were not ready to jump in and build wind farms, as they were happy to continue generating and selling electricity burning coal, oil, and natural gas. As the wind industry has matured it is viewed like a utility, large, stable, long lived, and retaining salvage value.

For most wind farms the builder erects the turbines, connects them to the grid and gets them running producing electricity. Through an agreement with the electric utility the builder operator sells the bulk energy and they sell the energy to consumers that are connected to its distribution lines.

Incidentally Electric Energy is a commodity that is bought and sold in real-time as energy demands fluctuate 24/7. Energy dispatchers are buying and selling bulk energy in real time from consoles at the utility, not unlike those in an investment house's trading room. (But this is a subject for another HPC paper.)

Making a success out of the venture of getting into the wind business is sensitive to these three factors: amount of debt, interest rate & lifetime, the bulk energy purchase agreement, and the operating expenses that include tower footprint lease charges, taxes, & maintenance.

A typical owner operator the John Deere, Inc. company made an investment to build and operate a Wind Farm near Pigeon, Michigan. Their farm cost over $90,000,000. It has 32 wind turbines each rated 1.65 MW, making farm capacity 52.8 MW. It has been operating since 2008. Excelon now owns and operates the farm.

Tower footing lease payments: for example in the 'thumb region' leases have been running $6000 per year per tower. ($500 per month) With 32 towers this amounts to $192,000 per year.

Maintenance costs: typically a 6 man crew plus supervisor maintains 32 tower farm $18/hour with benefits including insurance, 1 supervisor $22/hour with benefits comes to $350,000 per year. Maintenance costs + lease payments amount to $542,000 per year.

Using the John Deere experience as a model suppose a new group of investors proposes to build another 32 turbine wind farm. This group plans to sell $95 million worth of bonds, 30-year 3%. Based on 32 turbines at the installed price per turbine of $2,970,000 ($1.80 per nameplate watt) the farm would cost $95,040,000. Using the above the owner operator was paying annually to his creditor: principal + interest=$4,810,000, clearly swamping the yearly lease, and maintenance costs.

Operating sales revenues are based on how much energy he can produce in a year, and what the utility will pay him for it. In Michigan's thumb region (Huron County) the winds are fairly steady, so a capacity factor of 0.35 (like 35% efficiency) is used. (Capacity factor takes into account the variability of the winds - - some days the winds blow fiercely, then die down, the weather pattern shifts and only briefly there is only a slight breeze, then they start up again blowing from a different direction. Wind speed fluctuations follow the Rayleigh statistical model very closely.) This means for every megawatt of nameplate capacity one obtains 35% of the nameplate capacity times the 8,760 hours in a year. In other words the number of megawatt-hours of energy produced per year is (number of hours in a year) X (capacity factor) X (nameplate rating of the farm). Doubters may be concerned with the variability of this one farm's energy output, but it feeds into the grid, and the energy produced is used instantaneously somewhere.

Think of a variable streams of water being added to a huge bucket, the grid, that has numerous holes in it, the holes being analogs to consumers' electricity needs. Like this our electric grid is vast, and acts like a huge capacitor, accepting these miniscule charges at the different locations around the grid, and elsewhere there are electric loads that take it immediately.

Essentially business success here depends on the three factors:

1. capital investment in dollars per megawatt nameplate,
2. interest rate on the debt, and
3. bulk energy price agreed in dollars per megawatt-hour.

To illustrate this an engineering-economic model is created. I used it to manipulate the relative values of these factors to reach a starting point for the would be wind farm owner-builder. Then negotiations can begin with investors, vendors, and the energy buyer.

It employs the well known Mortgage Algorithm where:

L = loan amount
I = interest rate
N = number of monthly payments
M = monthly payment

$$M = L * (I / 12) / \{ 1 - (1 + I / 12) \} ^\wedge - N$$

Two charts below summarize ***net revenues per nameplate megawatt*** for ranges of **Interest rates** on a 30-year fixed interest loan, and **Bulk Power Purchase Agreement** in $/MWh for **capacity factors** of 0.35, and 0.30.

Net revenues are the before tax income, based on my model, and it is obvious that the Wind Farm Owner/Operator must negotiate the highest Bulk Power Purchase price. (Bulk Power is a misnomer, it should be Bulk Energy, but Bulk Power has been used in the industry for years).

For the Utility buying the energy, it will negotiate the lowest bulk power price. For this model Payments of $30 per megawatt-hour always result in substantial losses for the Wind Farm Owner/Operator. But $40 to $50 per Megawatt-hour always gives a profit with the lower interest rates of 3 to 3.2 %. For comparison BPW has paid above $50/MWh for bulk power.

In the model maintenance and lease expense are $10,000 / yr. / MW.

Noteworthy Disadvantages, and Advantages of Wind Farms

Disadvantages:

- Site selection preferred near electric transmission line
- Takes a lot of Acreage
- Winds are not steady
  - Some regions in the U.S. yield more energy than others
- Birds and Bats are killed or injured by them
- Local residents say Farms ruin the beauty of their pastoral scene

Advantages:

- No fuel required
- No CO_2
- Jobs are created in the:
  - Fabrication of the more than 7500 parts that make up a wind turbine
  - Planning, and Construction of the Wind Farm
  - Maintenance of the Farm over its Lifetime

Some facts about Wind Power as of March 4, 2013:

DTE Energy: The company's ECHO Wind project, slated for 2013, will have a combined levelized cost of approximately $52.50 per megawatt-hour (MWh), down substantially from power purchase prices several years earlier, according to the Michigan Public Service Commission. DTE says its investment in that and two other recent wind parks will contribute $150 million in economic benefits to Michigan.

- Consumers Electric Power estimates that Mason County and the state of Michigan received an economic boost of nearly $10 million from the development of the company's first wind farm, the Lake Winds Energy Park. (Near Ludington, MI and connecting to the CEP transmission line to the pumped storage facility)

The Michigan Public Service Commission said Feb. 15, 2013, in releasing its "Report on the Implementation of the P.A. 295 Renewable Energy Standard and the Cost-Effectiveness of the Energy Standards," that: "Compared to building a new, conventional coal facility, renewable energy contracts are significantly lower in price…**less than any newly built generation including new natural gas combined cycle plant**s. Based on contract pricing trends and the January 2013 announcement that federal legislation extended the eligibility of the Production Tax Credit for projects that begin construction by December 31, 2013, Commission Staff anticipates that **the cost of renewable energy will continue to decline, while the benefits from energy optimization savings and emission reductions from offset generation will continue to increase."**

As the Michigan PSC noted, utilities are cutting pollution by purchasing more wind energy. Currently installed wind turbines will avoid nearly 100 million metric tons this year of carbon dioxide emissions, for instance, equal to 1.8% of the entire country's carbon emissions.

The use of **wind power in the United States** has expanded quickly over the last several years. Construction of new wind power generation capacity in the fourth quarter of 2012 totaled 8,380 megawatts (MW) bringing the cumulative installed capacity to 60,007 MW.[1] This capacity is exceeded only by China.[2] For the 2012 months the electricity produced from wind power in the United States amounted to 140.089 terawatt-hours, or 3.46% of all generated electrical energy.[3]
New wind farms can produce electricity in the 5-8 cents per kWh range, making wind power more competitive with the cost of fossil fuel electricity generation.[4] Fifteen states have installed over 1,000 MW of wind capacity, and a total of 39 states now have installed at least some utility-scale wind power, with Nevada the latest in the 3Q of 2012.[5] Texas, with 12,212 MW of capacity, has the most installed wind power capacity of any U.S. state, followed by California and Iowa with 5,549 MW and 5,137 MW respectively.[1] The Alta Wind Energy Center in California is the largest wind farm in the United States with a capacity of 1020 MW of power.[6]

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Footnote:
Wind Farm in Pigeon, MI (near Bad Axe) erected in 2006, and 2007, was operating by January 2008. It cost the John Deere Co. $90,000,000, installed, consists of 32 Vestas V-82 wind turbines. Rated capacity is 60 Megawatts. From this one calculates $1.50 per watt at that time. Allowing for inflation of 3% p.a. today's equivalent cost would be 1.23 X $1.5 = $1.84 per watt.

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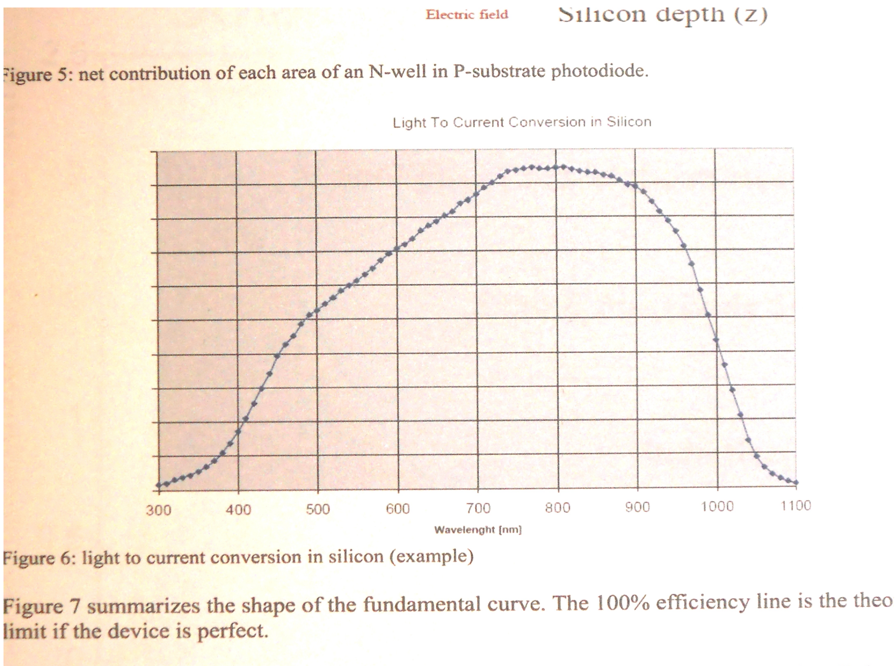
Solar Energy.

A business model for solar energy would be a Revenue Producing System that Converts Solar Energy Into Electric Energy that is used to offset the owner's electricity purchases from his utility, or in the case of a grid connected solar array owner operator, sells the electricity to the utility. Many very large solar energy systems are being installed in our nation's southwest in California, Arizona, and New Mexico by utilities such as APSCO, California Edison. Total U.S. installed solar electric capacity exceeds 6,400 MW.

As I mentioned at the beginning of this paper earth receives about 1000 watts per square meter at mid-day as illustrated in FIGURE 1 Solar Radiation Spectrum. At any location incoming energy rises at dawn reaches the peak and falls at sunset. Photovoltaics are used to produce electrical energy from sunshine. Photovoltaics, PVs, are thin films, or thin wafers of elemental silicon, with small amounts of other elements, like phosphorus (donor), or boron (acceptor) that have been diffused into the silicon. Sunlight shining on the surface creates hole-electron pairs that move in opposite directions inside the film, or wafer; electrons toward the wafer surface, holes toward the wafer bottom. PVs are direct current (DC) devices and can be connected in series, or parallel strings like batteries. Series strings in some installations produce voltages in the range of 600 to 1000 volts DC.

If you place a square meter of PV material, such as silicon, facing the sun's rays, it will generate electricity in the rate range of 150 to 200 watts per square meter. That is the conversion is only 15 to 20% efficient. Photons from the sun come in a wide spectrum of wavelengths, but the photovoltaics receiving them are sensitive to a narrower spectrum of wavelengths. From an inspection of FIGURE 3 Solar Spectrum Sensitivity for Silicon it is evident that Silicon PVs can only capture a portion of the sun's energy. Silicon's sensitivity spectrum is narrower than the sun's spectrum. Hence silicon PV's 20 % efficiency is close to a fundamental limit.



Half the time on average the solar panel has sunshine, the other half of the time it is in the dark. On the other hand most of our energy needs are maximized during the day, and minimum at night, and that fits nicely with solar energy availability. This is most pronounced where air-conditioning, factory machinery, and office lighting are load components. Lastly, there is the effect of cloud cover, and weather affects.

Geographic location on the planet plays a very important role in deciding whether or not to invest in a PV array to augment the electricity supply. Obviously southwestern States get more yearly sun energy than northeastern states. For example Phoenix, AZ gets a high of 7.13 kilowatt-hours per day per square meter of surface area. Boston, MA gets a high of 4.27 kwh/day/ m^2, and E. Lansing, MI gets a peak of 4.71 kwh/day/ m^2.

Year long averages for these three cities are Phoenix: 6.58, and Boston 3.84, and E. Lansing 4.00. FIGURE 4 shows a map of U.S. and Canada with colors depicting regions receiving various amounts of solar energy measured in 'sun hours per day' with optimally tilted surface facing the sun.

For Phoenix, a year's worth of electric energy per square meter would be $6.58 \times 0.15 \times 365 = 360.26$ kwh/m^2. This is the total electric energy obtained from the terminals of a one square meter pv solar panel @ 15% efficiency, for the year in Phoenix. In E. Lansing total electric energy would be 219.00 kwh/ m^2.

My house in Holland, MI used 5,913 kwh last year. To power my house it would need 27.00 m^2 of solar panels if I lived in E. Lansing. But due to lake effects of cloudiness, in

Holland probably I would need more because the sun hours per day is less here than in E. Lansing.

For example the equipment necessary for a grid-tie PV solar energy system for a home, or a large industrial plant consists of the wired solar panels, support frames, and one or more DC to AC Inverters. A grid-tie PV system like this uses the utility's electrical system as the storage battery. When the sun is shining the house's or building's electricity comes from the PV array. If the PV array generates more energy than is needed at the time the excess is sold back to the utility company, by running the electric meter backward. If the house or industrial building needs more energy than what the PV array can supply the utility makes up the difference. Very simple, but if the utility power goes down, so does the inverter even though the sun may be shining.

A more expensive system also includes a battery backup and charge controller.
In this simpler system for my home in Holland the estimated cost would be:

$0.80 X 27 m^2 X 150 W/ m^2 = $ 3,240 for the PV solar array, and $3,750 for a 4000 watt DC to AC Inverter, for a total cost of $6,990. Rated capacity of the system is 4050 watts, for a net cost per watt of $1.73 per watt.

As a counter example consider a solar energy system to supply an isolated homestead. It needs the following:

1. Solar array of PV panels, including support frames
2. DC to AC Inverter.
3. Charge controller for batteries, mounted in the control panel.
4. Batteries, deep-cycle, including supporting steelwork.
5. Transformer
6. Electric Load Center w/motor switches & circuit breakers
7. Interconnecting cables and ductwork, AC outlets, light fixtures.

Here is a engineering/cost analysis of a free standing solar powered electrical system that was planned for a 60,000 watt capacity coffee mill in a remote location in Ethiopia. All the electrical energy needs are to come from the sun.

Engineering calculations for the solar panels:
Lowest average incoming sun hours per day = 4.5 kwh/ m^2/day
times 365 days per year = 1,642.5 kwh/ m^2 /yr.
Required energy per year = 136,860kWh/yr based on numbers from site planners.
Average area getting this energy = 136,860 / 1642.5 = 83.324 m^2
Efficiency of solar panels 0.15, area of solar panels must be 6.66 times larger.
Area of solar panels needed = 83.324 / 0.15 = 555.495 m^2 (= 5979.3 sq.ft.)
Round this up to 556 square meters of silicon PV solar panels.

Solar array:
Output power is rated 60,000 watts. Because of a recent breakthrough in the price of solar

panels a supplier quoted **$36,000** for the total solar array.
From Shenzen Sunrise Solar Co. Lyd. FOB U.S. see: www.sunrise-srt.com

DC to AC Inverters:
Price estimate for one 60 kW DC to AC three phase inverter FOB US = **$17,315.**

Batteries: 100 2.2volt/3000 ampere-hour batteries = **$64,600**

Charge Controllers: 8 required @ $610 each = **$4,880**

Transformer: 1- 2000W transformer 220-110volt single phase = **$ 86**

Labor connecting solar panels, and other equipment **$3,000**

Electric Load Center Cabinet with circuit breakers **$1,500**

Estimated Equipment cost ……………………………………… **$127,681**
Construction costs for installation: ………………………………… **$19,000**
Total ……………………………………………………………… **$146,681**

Estimated installed cost per watt of this 60 kW system is $2.45/watt. Cost of batteries is the major component of costs of a free-standing solar energy system. Development of less costly methods of energy storage is obviously needed in this industry.

Noteworthy Disadvantages, and Advantages of solar arrays:
For residential, industrial; grid connected
Disadvantages:

- Requires Net-Metering
- Requires unobstructed south-facing location
- Requires relatively large surface area: rooftop location most efficient
- Sun shines half the day; and is affected by meteorological conditions
- Some regions yield more energy than others; e.g. southwest vs. northeast U.S.
- Requires expensive battery back-up for night or during periods of little sunshine

Advantages:

- No fuel required
- No CO_2
- Job Creation
    - Fabrication of all components
    - Planning and installation of the solar array

Maintenance of the array over its Lifetime is minimal
Provides a source of electricity for remote, isolated areas

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HGPW is planning A Natural Gas fueled combined-cycle gas turbine generator at an unspecified location to supply electricity to Holland.

Think of a jet engine. From front to back along the shaft axis:
Compressor-what you see when you look out the passenger window of the jet plane.
Combustion chamber – jet fuel injected here and combusts with compressor supplied air.
High energy hot gases from the combustion chamber drive the turbine blades on the shaft.
Reaction force from the hot gas exhaust provides the thrust that moves the plane.

In the combined-cycle gas turbine generator an electric generator is connected to rear end of the turbine shaft. Jet thrust is not needed.
A compressor is needed to compress air and force it back to the combustion chamber.
Next the Combustion chamber where natural gas is injected and combusts with air in.
Hot combustion products CO_2 and steam (yes steam- vaporized H_2O!) and other gases such as Nitrogen push against the turbine blades, spinning the shaft. There is more energy that can be extracted from the very hot (more than 1200 degrees F.) exhaust after spinning the turbines blades. Exhaust gases are piped to a heat exchanger that generates steam. The steam operates a conventional steam-turbine connected to another electric generator. It is also possible that this steam could be used for sidewalk heating in downtown Holland.

How economically feasible is it? This is a question for HBPW.
Capital needs to be raised for the procuring and installing the CC gas turbine, and generator.
Piping and building construction, controls and instrumentation, and switch-gear are part of the investment.
Natural Gas fuel will be needed, maintenance and operating engineers will be hired.
Revenues from the electricity sold will accrue, and will be used to retire debt, and cover all operating expenses.

John Fulenwider

Large arrays for augmenting utility power plants
How many big solar arrays are there?

Hello,

Here are the new features of The Wind Power database :

- 130 wind farms added (Netherlands, France, Switzerland, Austria, Poland, USA...)
- 10 turbines added (WESPAS range, Norwin 33-STALL-200 kW, Siemens SWT-4.0-130, EWT Directwind 2000/96)
- 1 manufacturer added (WESPA)
- 242 photographs added (France, Greece, Turkey, Brazil, Netherlands...)

See you soon on The Wind Power,

Michaël Pierrot
The Wind Power
The Wind Power products
Access to GlobalData reports
Se désinscrire

10.76391 sqft/sqmeter