10 Steps to Going Solar
by J. Alan Prechel

There are many reasons Solar energy is 'disruptive'. The term carries with it massive environmental, economic, social, and political weight. Energy produced by Solar PV systems is clean; no carbon emissions or pollution is generated for the 20+ years a typical system will operate. Additionally, the generated power earns the owner SRECS (renewable energy credits) used by businesses to offset their dirty pollution footprint. Most PV systems can be designed to reach ROI (return on investment) well within the lifetime of the equipment, and thus they create monetary profits thereafter. System owners are insulated from utility rate hikes and inflation and are less dependent on external energy sources.

I believe if Solar PV were the norm in US residential applications there would be no energy crisis, our grid and infrastructure could be modernized to promote sharing instead of commercial interests, and our political foreign-oil policies would be flipped on their heads, but that is a conversation for another time. If you are interested in going Solar, I have laid out a few steps to guide you on that path.

- **To go Solar first get GREEN:** Reduce electric consumption as much as possible by implementing every reasonable energy efficiency upgrade available before looking at Solar options. Reduced usage = a smaller, less expensive Solar PV system. Start with fixtures (LED bulbs), upgrade to energy star appliances, replace outdated (read: inefficient) HVAC systems which represent a large portion of annual heating and cooling costs, and also look into insulation and air sealing the structure. Most importantly ***change the HUMAN factor:*** Are the lights on in an empty room? Computers powered up 24/7? Vampire devices always ON? Aggressive thermostat setting year round?

- **Determine PV system size:** Once your home or business is as efficient as it can reasonably be, start by tracking the Kilowatt Hours (KWH) usage and monetary costs via utility bills for 18 months (current and prior year). Figure out what the expected annual KWH consumption is, and determine if that is a reasonable marker for the future. Here is the formula for a solar array based on daily need in the *Chicagoland* climate (*see detailed example below):

PV Array size = (A / 4.4) * (B / 78%)

'A' represents your *daily* KWH consumption calculated from your annual average, above.
'B' is the percent off-grid or the amount you want the system to cover, IE to be 100% off grid use 100%.
The value 4.4 is the average solar exposure for Chicagoland as indicated by NREL statistics.
78% is a 'magic number' of overall system efficiency, detailed below. *

- **Array Design and Space Limitations:** How many solar panels of specific physical dimensions and wattage are required to achieve the KW production from the formula above? Next, determine how much area on a roof, garage, or yard can be allocated to panels and if this space is clear of trees and other obstructions. ***HINT:*** Sometimes it can be better to buy a greater number of cheaper panels which produce less per unit provided you have a place to put them.

- **System Design; Inverter Technology:** With a plan for panels on a roof (etc.) the next challenge becomes how to collect that power for use. This is the job of the inverter: transforming the DC energy panels provide into AC for the house. The 'old school' method connects multiple panels together to form a 'string' with only two leads (wires) as the input for a large central inverter. This approach is the least expensive, but also the least efficient. Any shading on one panel limits all panels in the string. Microinverters are the newer technology and are attached to each panel individually. This allows each panel to operate independently of one another, maximizing energy collection under adverse conditions. However, this style also uses special components and wiring which adds cost and complexity. As a middle ground, some inverters (like the SolarEdge brand I chose) allow for optimizers to be installed on each panel (increasing production individually) while the strings are still wired to a single central inverter for the DC to AC conversion. This balanced approach uses standard materials while adding only a moderate total cost and component count to the system.

- **System Design; Mounting, Wiring, and Grounding:** Now for smaller but important details. How will the panels be secured to the structure? What is the expense and WEIGHT difference between rail based and non-rail based mounting solutions? Will the structure safely accept the added total load of the panels? Is structural carpentry required? What gauge wire will be necessary to carry the DC current to the inverter? How many strings and what size conduit will be required (remember there are 2 DC leads per string)? ***HINT:*** Remember to calculate wire size as expected max DC amperage / 80% as a safety overload factor. Can the DC wiring be added into the building / run to the inverter easily? How far a linear distance is that (voltage drops off as distance increases)? How will the Solar panels be grounded to earth? ***HINT:*** Exposed metal in an electrical system (outdoors) needs to be grounded to earth (called a General Equipment Ground) – think lightning protection- so be prepared to adjust the home's electrical system to accommodate for this. ***HINT:*** NEC (code) states a maximum safe operating voltage of 600 VDC. Based on the design, this is important for installer safety! For me the SolarEdge optimizers I chose tune to a max of 500 VDC with a 1VDC safety feature allowing me a safer experience as a self-installer.

- **Other Hardware Options:** With the major system components coming together it's time to pay attention to more minor details. Consider installing both AC and DC shutoff switches (think of a 'Frankenstein' lever) ***outside*** the building for emergency responders to shut down the system in case of a fire,

etc. *PLAN TO HIRE A LICENSED ELECTRICIAN* to help with installation of the conduit, wiring, switches, inverter, and panels. Does the home need any code compliant retrofitting (earthen ground rod, circuit breaker overloaded, etc.)? Better get that done now; it will be harder to pass electrical inspection with secondary issues looming.

- **Financial Round-Up:** Now it's time to look at the bigger picture. Shop around online and call everyone who sells the hardware you prefer. Request quotes from notable websites and get into the dollar figures with the sales reps. How much will it cost for the panels, inverter/s, mounting, wiring, and professional services (or installation, if applicable)? Don't be afraid to pick and choose. I was able to save roughly 15% off the initial complete package as quoted by one internet retailer simply by purchasing materials myself. ***Please consider buying USA made goods.*** This is probably a ***once in a lifetime purchase*** for most of us as most panels carry a 25 year expected lifetime / warranty. I chose Solarworld panels made in the USA. There was an added cost here but I felt it balanced support of my neighbors and fellow citizens with a worldly thing to do. Got contractor friends? See what they would charge for the professional services you may need. Get at least 3 estimates for comparison. Can you afford this outright? Would 30% back from Uncle Sam and maybe 25% back from the State of IL make it easier (or feasible)? **Federal incentives may expire in 2016!** Search for and apply for any and every state, local, and municipal grant or program related to green energy, Solar, and efficient upgrades to your home. Check out the DSIRE website for incentives and information. Remember the Federal rebates are included in the tax calculations around April. The IL State rebate comes as a check mailed to you after the system is running / completed obligations to the state. ***HINT:*** There is a form to fill out to have a Solar system's value **EXCLUDED from** the tax base for **Cook county property taxes**.

- **Plans and Permits:** Using the notes and calculations from the above steps, draw up detailed plans for the overall system and use these as documentation to submit to your local municipality to receive the appropriate permit. I showed calculations for wattage and amperage of the AC and DC components, made mockup layouts of the panels on the roof sections, drew a map of the electrical devices and where connections were made, and took pictures of the installation locations for tangible reference. The plan included hiring a carpenter to retrofit attic supports to bear the additional load and hiring an electrician *as required by law* to install the inverter (you cannot plug stuff into the grid, ComEd & your neighbors won't like it if you do).

- **ComEd and Net Metering:** Presuming your plans were approved, you have a State of IL Notice to Proceed, hardware on order, and you are getting excited; now it's time to contact ComEd. Why? The State of IL requires utilities to pay you fair market value for any excess generation. The law is referred to as **NET METERING**. Research it! ComEd has a department for this and in order to interface with the electrical grid your as-of-yet-not-

completed Solar PV system will need an Interconnection and Net Metering agreement with the utility. The application/s can be filled out online and it may take a few months for all the paperwork and validation to be completed. Get started on this early, I fudged this a bit and lost some generation credits so please learn from my mistakes!

- **Livening, Monitoring, and RRTP:** Once work is completed and inspections passed you can 'liven' the system (turn it on, watch it hum). Most manufacturers include some form of internet based monitoring so you can track panel, inverter, and overall system performance. Keep tabs on these metrics for validation with the pending utility bill credits and because watching the graphs of free and clean energy roll in is good fun. A note on real-time pricing: Generally speaking, switching from fixed rate electrical plans to hourly rates for electric supply benefits Solar PV system owners. Why? Because when electricity is most expensive tends to correlate well to hot July afternoons, when the sun is strongest, and thus when the $$ value of PV overproduction is greatest. Conversely the overnight rates are usually very low. Relating to #1 "*the Human factor*", shifting your usage habits for things like running dishwashers and laundry machines into the evening hours tends to bias your $$ savings/earning potential even further in your favor when Solar PV is combined with ComEd's RRTP.

***Magic number explained:** The 78% figure from #2 above is a widely used estimate of overall system efficiency including many 'derate' factors (like soiling of panels, array orientation, cloudiness / poor weather, losses in wiring / inverter / storage, and transmission). The Optimizer and Microinverter designs minimize these losses and thus increase overall production by as much as 25% versus a classic central inverter (according to advertising materials). In general, a lab-tested panel can only be *practically* expected to produce about 85% of its nameplate rating in real world conditions. So you may choose to 'oversize' your design based on these factors though always go below 100% of your annual need.

****ROI estimates:** Solar systems will generally pay back and then profit the system owner within 25 years--but usually much sooner. The basic payback formula for this is:

Total $ spent / estimated Annual Production $$ = time period to break even in years

This formula does not take into account many factors such as panel derate (panels tend to lose 0.7% capacity each year) or inflation (cost of electricity tends to rise) but this does serve as a reasonable estimate for returns and profits. There are advanced ROI calculators available on the internet.

Example with calculations: Here is a hypothetical EXAMPLE run-through from the beginning:

- Household annual consumption is roughly 6250 KWH.
- House is in Oak Park and NREL weather data website lists 4.4 peek Solar exposure hours avg. per day for this climate.
- Owners want to generate 100% of consumption via Solar PV.
- 6250 / 365 = 17.12 Daily KWH.
- Array size = 17.12 / 4.4 x (100% / 78%) -> 3.89 x 1.28 -> 4.98 KW array. Let's call it 5 KW even.
- A standard size **60 cell** solar panel produces 275 watts, so this array would require 5000 / 275 = 18.18 panels, call it 18.
- A single panel measures about 40" x 66" which is 18 1/3 square feet each.
- The owners have a limited area of rooftop space for panels and can only fit 15.
- 15 * 275 = 4.125 KW array or about 82.5% coverage. Not too bad given design constraints.
- SHORTCUT past the grant and funding application process. They hire an installer, etc.
- Let's say the owners pays $15,000 to have a company install the system for them.
- SHORTCUT past village permits, net metering, etc. (DON'T presume contractor will handle this for you!)
- A 4.125 KW array will produce an estimated: 4.125 * 4.4 * 78% = 14.15 KWH daily or 5167 yearly.
- Electric supply rate is fixed at 7.9 c per KWH, so annual generation can be estimated at 5167 * 0.079 = $408.
- Return on investment (other factors aside) would take $15,000 / $408 = 36.74 years, which is beyond the lifetime of the system.

So why the 'bad' example? ***To highlight a few pitfalls:***

First, if annual consumption from #1 is reduced by a factor of 20% in the form of MANY, MANY "green" upgrades then it becomes 5000 KWH yearly, which leads to a reduced array size of 4KW for 100% self-sufficient generation which CAN fit as 15 x 265 watt or better panels. ***GO GREEN FIRST!!***

Second, as of 2014 if the owners use federal, state, and local grants they can offset as much as 50% of the total system costs. This looks like a State of IL refund check for $15,000 * 25% = $3,750 and a federal tax credit of $15000 * 30% = $4,500. For the sake of comparison take the credit at face value. The adjusted ***NET*** total system cost is now $15,000 – $3,750 – $4,500 = $6,750. Much better!!

Now let's review the ROI again with those things taken care of:

Annual generation is: 4KW * 4.4 NREL hours/day * 365 * 78% = 5,010 annual KWH x * 7.9 c/kwh fixed rate = $395 annual credits.

Now take the Adjusted system cost as $6,750 / $395 (annual credits) = 17 years. BINGO! The investment will pay for itself and then PROFIT for about 8 more years. Yes, 17 years is a long time. Remember: **Solar is a 25 year plan** and it will pay

for itself eventually. Also, this was a simple comparison. The **sale of SRECs** and other factors like inflation and derate (and optimizers!) were not considered.

Worthy of Note: Enrolling in a real time rate program breaks the above example because generation credits or consumption costs will vary dynamically. The value of annual dollar credits may decline vs. a fixed rate, but for most that still equates to money savings. For example; one month we generated 643 KWH. The dollar value of this credit on the bill was far below what we would have gained at 7.9 c / KWH due to the RRTP. However, during that month we consumed more than we generated so even though our generation was discounted, so too was the total cost on the bill for our remaining consumption. We saved at least $10 under RRTP vs. the fixed rate, before solar credits are included. Once solar credits are applied we *earned* even more.

Please remember that I researched, designed, purchased, and self-installed my system in order to keep the total costs feasible. I hired professional help when needed and went through the required channels with the utility and municipality to ensure this system is safe and well built. You should do your own research as I did, even if you are leaning towards hiring a solar contractor to do the labor. Best of luck, I hope you have many sunny days ahead!

About the author: We try to live as sustainable as is *reasonably* possible in an urban area. There is a lot *you can do*: conserve all resources (the Human Factor), choose efficient alternatives, invest in renewable technologies, and focus on simple habitual solutions. We have electric cars supported by the Solar PV system, we garden with water reclamation (rain barrels), and we raise chickens and bees for eggs and honey, and (mostly) make our own bread, butter, yogurt, jam, salsa, pasta sauce, canned goods, and cider. We try to cook as many meals at home as possible using non-GMO, organic, and locally grown ingredients. We agree with the sayings ‘waste not want not’ and ‘live close to the Earth’; there is, after all, only one.