MY SOLAR ODYSSEY

The beginnings

It seemed just the right time to put solar cells on our roof. Our daughters were through college, so the tuition bills had ceased. The stock market had been kind to us (mainly through investments in fuel cell companies). We already had our Toyota Prius electric hybrid car, having been the first in Ohio to put down our deposit, and still had some money left in the bank. The time seemed just ripe.

True, Cleveland is not the sunniest spot in the world, but we do get the occasional glimpse of the golden orb. To put it in a positive light, even Death Valley doesn't get twice as much sunshine as we do. The sunshine we do get is mostly in the summer, when fossil-fuel and nuclear power plants are at their least efficient, and electrical power is in greatest demand. We would be making our contribution to reducing the amount of greenhouse gases emitted into the atmosphere, and showing leadership in moving to renewable resources. In addition we would be protecting ourselves against the lengthy power outages we had suffered in previous years after summer storms brought trees down on our neighborhood's power lines. We would be able to feel virtuous all the time, and smug on those occasions when we were the only house on the block with its lights still blazing.

My first step was to look in Solar Today for the full-page advertisements from manufacturers of solar cells. In the issue I looked at there were only three -- one from BP, one from Solarex, and one from Astropower. Having read that Solarex is now totally owned by BP, I discounted that one, and called the toll-free numbers for BP and Astropower.

Now came my first piece of disillusionment. BP Solar, the world's largest photovoltaic manufacturer, sent me their list of distributors. There were just seven. Of these, only two were east of the Mississippi, and they were in Florida and Maine, at distances of 909 and 720 miles, respectively, from Cleveland.

I couldn't imagine anyone loading up a truck and driving for two days to come and install cells on my roof, but I phoned the firm in Maine, anyway. The fact that they were located in Kennebunkport, the family home of Big Oil's biggest booster, didn't fill me with too much hope. I reached the owner of this firm, Pete Talmage, who turned out to be a very pleasant and helpful individual. He sent me some of his literature, including a useful little booklet on solar electric design, but it quickly became clear that he was just too far away to be able to do my installation.

This left me with Astropower as my only other option. They put me in contact with a firm called Integrated Solar who were, to my great relief, actually located in Ohio, albeit a two-and-a-half hour drive away in Maumee. The owner, John Witte, agreed to come to Cleveland to check out our house. He duly came, and saw that we did indeed face south, had a nice 45 degree slope to our roof, and had a useful crawl space in the attic to accommodate the inverter. This is the device that would change the direct current from the cells into the alternating current that matches the power supplied by the electric utility company. John agreed to undertake the project, and I paid him a small deposit.

A major disappointment was when John telephoned to say that our plan to have a bank of batteries connected to the system was starting to look impractical. There were a couple of reasons for this. The first difficulty was that the batteries would only be

sufficient to power a few essential items, like the refrigerator and a light on each floor, and these would all have to be wired into the same circuit. I never did figure out just which appliances I thought most essential (Microwave oven? Cell phone charger? Computer? Electric toothbrush? TV?) but they were surely all on different circuits. The second obstacle was that with batteries as part of the system the inverter would be constantly connected, and would consume power even when the sun was not shining. In Cleveland in winter this would be most of the time. Reluctantly I abandoned the image I had of being a smug island of self-sufficiency whenever the power went out.

Bureaucratic encounters

The next hurdle in our path was the Architectural Board of Review of the City of Cleveland Heights. This group is concerned with maintaining the aesthetic appearance of buildings in the city. They apparently needed some sort of drawing or illustration of what our modifications would look like. I took on this task with enthusiasm, taking a digital photo of the back of the house and using computer software to paint in my impression of how the panels would look when in place.

Here I made a serious error of judgment. I had assumed that the role of the Architectural Board was to preserve property values by preventing homeowners from blotting the landscape with excrescences of cinder block and corrugated iron. I, by contrast, was proudly enhancing the neighborhood with the outward and visible signs of the inward beauty of renewable energy. Photovoltaics are no hole-and-corner shameful activity to be camouflaged and concealed lest outsiders divine our guilty secret. They are a badge of honor worthy of prominent display, a medal for valor in the war against pollution and global climate change! The anti-reflection coating that most solar cells carry gives them a characteristic purplish-blue tinge, and I chose an appropriately vibrant hue to paint the image of a twelve-foot-square panel onto the gray asphalt tile of our roof. How naive could I be?

The afternoon of the hearing arrived. We were second on the list, ahead of all the drugstores and car dealerships pleading to enlarge their huge illuminated displays and inch them closer to the street. First up were a young couple who had been caught reducing the number of windows in their house during the course of some renovations. Their case took all of five minutes, ending in a peremptory order to restore the missing window. Having satisfactorily achieved the refenestration of Cleveland Heights, the board turned their attention to my application.

Their first objection was that the solar panels were visible! This took me completely by surprise. Here were the board, fresh from their triumph of ordering a few square feet of aluminum siding replaced with a glass window. I was proposing to cover a few square feet of asphalt tile with a glass-covered panel. What was the difference? Well, for a start, my panels were blue, and stood out magnificently from the gray of the roof. At this point John Witte stepped in, and, with more respect for the environment than for the truth, said that the panels were really sort of grayish, quite dull, and hardly noticeable.

The next objection was that there was only a single panel, on the sunny left side of the roof. To make the appearance acceptable I should also have one on the shady right side to restore symmetry. Neither the fact that solar cells work best in the sunshine, nor that doubling the area would have doubled the cost seemed to sway the board. Luckily, I still had my trump card to play. I pointed out that the installation was to be on the *back*

of the house, where nobody would see it. This argument carried the day. Reassured that property values would not plummet as a result of my turning our street into some sort of slum haven for addicts of renewable energy, the Architectural Board of Review signed their reluctant approval.

It was in December that the electrical permit was issued, just as the first heavy snows of winter were starting to fall. I had imagined that installing solar panels was something like house painting -- an activity that only happened in warm weather -- but I was wrong. I paid John half of his estimate and he ordered in the panels and the inverter, and prepared to make the installation.

January 1, 2001, was the date on which deregulation became effective in Ohio. Included was the splendid provision known as “net metering," which stipulates that the utility’s electric meter must run backwards as well as forwards if the customer is a net producer of power. I had thought that I might have a battle to fight to have them install a reversible meter without dragging their heels. Here again I was wrong, this time on technical grounds. The sort of meter that is commonly installed by utilities is already reversible, and is equally happy spinning forwards or backwards.

The next problem we encountered was that the antique electrical wiring in our 1920 house was not in compliance with modern electrical codes. While John would be permitted to install the panels and inverter, the connection to the house wiring had to be made by an electrician “bonded within the City of Cleveland Heights." (This sort of bonding apparently is not the usual sort that involves spending quality time together, but requires guarantees of large amounts of money.) Dave, the duly bonded electrician, shook his head sadly at the sight of our fuse box. Here were another few hundred dollars to be added to the cost of the project.

The cells installed

The snow was still thick on the ground, but a bitter wind had blown most of it from the roof when John and his two assistants arrived in late January to make the installation. They spent most of the morning on the roof attaching the mounting brackets on which the panels were to sit. Our house had originally been roofed with cedar shingles, but these now had a layer or two of asphalt tiles on top of them. I have no idea how John and his team figured out where the rafters were so that they could anchor the panels securely.

It gradually grew dark, but work continued. It continued in the attic crawl space, in the basement, in the flower bed by the electric meter, and on the wind-swept roof until 10, at which point the team retired to a motel. The next morning they returned and completed the work. From the panels on the roof a thick cable curved down around the eaves and through a hole in the brick wall into the attic crawl space. There it entered the inverter, a rectangular white enameled metal box that resembled nothing quite as much as one of those dispensing machines that one finds in bathrooms at rest areas on the Pennsylvania Turnpike. From it the 240 volt AC cable emerged, left the house through another hole in the brickwork, descended the wall past the electric meter, and entered the basement. There Dave found it when he arrived to make the official connection to our brand-new circuit-breaker box.

Our installation was now complete! All we needed was sunshine. I was eager to see the system in action, and was up early the next morning. This, of course, was

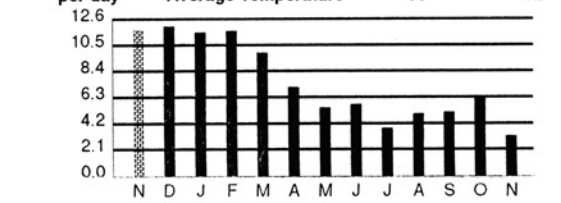
For the Architectural Board of Review, I added to a snapshot of our house my artistic impression of how the cells would look.

The weather was bitterly cold when John and his team began the installation.

Current Charges		**$9.52**
The Illuminating Company	5.71	
FirstEnergy Solutions Corp	3.81	
Total Amount Due By November 23, 2001		**$9.52**

Your Energy Use Pattern

	This Year	Last Year
Average KWH per day	3.3	11.9
Meter Reading	(Actual)	(Actual)
Average Temperature	53 °	52 °



With the cells on the roof and the sun in the sky, our electricity bills plummeted.

completely pointless, as the probability of seeing the sun on a Cleveland winter day is small even at noon. Seeing it before sunrise would have been even more remarkable. Nevertheless, I waited patiently outside the crawl space as the sky started to brighten, my attention fixed on the inverter.

According to the manual, the liquid-crystal display on the inverter would give me five pieces of information. It would tell me the AC voltage that I was getting from the utility, its frequency, the DC voltage coming from the roof panels, the power I was producing (this would be the *exciting* number) and the cumulative energy produced (cumulative since when? I had no idea). As the sky grew brighter the display started to flicker, and then lit steadily, but showed only a blank panel. A watery sun showed its face, and the inverter leaped into action.

At this point I had the first inkling of suspicion that the inverter might not be a complete masterpiece of design. The DC voltage reading from the panels rose quickly from 35 V to 42 V, then 51 V, 62 V and 71 V, whereupon the inverter decided it was in business, and for the merest fraction of a second the power registered 616 watts. A cooling fan started whirring into action. This effort instantly drained all the charge from the cells. The fan stopped and the power was zero. Then the voltage started its climb back up to start the whole process again. Discouraged at this inability of the inverter to make up its mind what it was trying to do, I went downstairs to breakfast.

By the time I had finished breakfast, I was happy to see that a full sun was shining. I went outside and looked at the electric meter. Oh, joy! It was actually moving backwards. It is hard to describe the pleasure of seeing for the first time this so unambiguous signal that one is producing power. It was not just the movement of an aluminum disk in our meter that had been reversed. It was our whole relationship with the world of fossil-fuel-burning, polluting, climate-changing energy production. Even if only for a few brief hours, we were no longer consumers contributing to the degradation of our atmosphere. We were suppliers of pollution-free energy to the community. I went upstairs and studied the inverter. The fan was now running steadily, and the display was reading 600 watts. All was well in the world.

Half an hour later all was not well. As I passed the attic door I listened for the sound of the fan. There was no sound of the fan. Silence poured from the attic door in a steady stream. I went up to the crawl space and read the display. It said that we were generating 5569 watts, which would have been a major miracle, given that the panels were only rated for 960 watts. Back outside in the sunshine the meter was spinning *forwards*. We were consumers, not producers. The display was lying to me.

This was the second indication of a malfunction in the inverter. It was definitely not performing up to the standards of reliability that I am sure the Pennsylvania Turnpike Commission demand of the condom dispenser that my inverter so closely resembled. I called John and told him of the problem, and he agreed to ask the inverter manufacturer for a replacement.

As the sun started to set, the display on my mendacious inverter flickered and extinguished itself. The next morning it awoke and started its little bursts of fan noise at five-second intervals. The display was supposed to register how many cumulative watt-hours it had generated. It registered zero. In fact, it registered a string of eight consecutive zeros. During the night, when it was receiving no power, its circuitry had evidently lost all memory of the previous day's production, and had reset itself. Its

designers had equipped the dial with enough digits to record 99,999,999 watt hours, which is the amount of power our panels would produce over a period of 100 years. They had failed, however, to give it the capacity to remember what had happened the previous day.

The singular uselessness of this display suddenly became apparent. On a weekday I would leave for work as the sun was starting to shine on the panels. All during the day, the display would be glowing, announcing to the empty crawl space the voltages and wattages it thought it was producing. This brought to mind the old philosophical question about the tree that falls in a forest: If nobody is there to hear it, does the falling tree make a noise? If nobody is in the crawl space, does the display give a reading? In my case, of course, it would be telling fibs to the empty crawl space until the day when the replacement inverter arrived, and so the answer seemed unimportant. More to the point was the fact that the sun would have already set by the time I arrived home in the evening. The display would by then have lost its power, and with it all memory of the voltages and wattages that it had been mumbling to itself all day. I decided that the designer must have been the same individual who invented the teapot with no handle.

More inverter problems

The next week, John arrived with the replacement for the defective inverter. I took advantage of his presence to have him install a *real* watt-hour meter in the basement so that I could get an accurate reading of what power the solar cells were actually producing at any time, and also have a cumulative record of energy delivered. I was very impatient to show off my solar installation, and hoped that I would now have something that I need not apologize for.

The next three days were stubbornly overcast, and so no test of the new inverter was possible, but the following day dawned crisp and clear. I waited for the full sun to hit the panels and then checked the display. Everything seemed fine -- plenty of volts from the panels and lots of watts from the inverter. Yet there was something that seemed not quite right. What was it? Of course – no noise from the fan! Had they fixed the circuitry so that it only came on when needed? I raced down the three flights of stairs to the basement and went to look at the new meter with its dials and spinning disk. Its spinning disk? No. Its stationary disk. Its immobile, wretched, motionless, stupid, stationary disk. Not a single watt of power was coming down.

I made another call to John, who had by this time heard of someone else with the same problem. Up in Wisconsin there was another unhappy soul watching the sun shine uselessly on his solar panels.

A well-designed inverter chooses exactly how much current it should take from the photovoltaic modules. If it takes too much current then the voltage falls to a low value, and the power, which is the product of current times voltage, drops. If it takes too little current, then the product is again small. Somewhere in between, there is just the right amount of current to maximize the power. It is the task of the inverter to find this value by checking the voltage from the cells and adjusting the current accordingly.

The problem with my inverter was that its designers had built it for the Californian market. It was the cool winter temperatures of Cleveland that were confusing it. Silicon solar cells are more efficient at low temperatures, and so the voltages mine were producing were outside the design range of the inverter. Not smart enough to recognize

80 volts when it encountered it, the inverter went into a sulk, and shut itself off. To compound its sins, it tried to cover up its inadequacy by lying cheerfully through its display.

At this point I was totally exasperated with the situation. I resisted the impulse to tear the inverter out of the wall, and instead called John to come and do it, and replace it with something that worked. John felt as badly as I did about this fiasco, and offered to pay the extra cost for the more expensive replacement inverter. This sounded like a great offer, which I was about to accept with gratitude until I paused to collect my thoughts. Why had I started this whole exercise in the first place? It was to support the concept of solar energy in Ohio. If I ended up bankrupting the only installer I knew of in the state, then I would hardly be achieving my objective, so I insisted on paying the extra cost myself.

I was so grateful that those guys had come in the bitterest cold of winter to do the installation on that icy wind-swept roof. If they had waited for warmer weather I might not have learned about the deficiencies of the inverter until the fall. By then it would have been too late to demand my money back.

This train of thought sent me to read again the warranty on the old inverter. In light of what I now knew about how it was a piece of junk, rushed prematurely to market and designed by someone with all the skill and thoughtfulness of a lobotomized toad, the wording of the warranty took on new meaning. It was screaming at me that they fully expected the inverter to fail. Not only that – they expected it to fail because of design errors. They said that the manufacturer "reserves the right to improve the design of its products without obligation to modify or upgrade those previously manufactured." They could as well have said "we know that what we have sold you probably has about the same shelf life as a pastrami sandwich. If you were dumb enough to buy something that wasn't ready for prime time, or even for a 5 AM infomercial slot, then you can just eat your heart out watching us selling modified products to other poor suckers until we finally get a design that works."

Into the sunlight

It was early April by the time the new inverter arrived. It was a great pleasure to see the old one pulled out and put on the back of the truck. Installing the new inverter was not completely simple. For one thing, the old one had generated 240 V, while the new one produced 120 V. The wiring had to be changed accordingly, and the 240 V watt-hour meter I had bought had to be bypassed. (It was only some months later that an electrician friend told me about an ingenious way to fool a 240 V meter into working at 120 V, and generously came round and implemented this scheme.) Murphy's Law kicked in to make sure that the terminals on the new inverter were placed where the old wires would just not quite reach, but that caused only a minor delay.

I immediately fell in love with the new inverter. It had all the virtues that the old one lacked, foremost among which was the fact that it *had no fan!* There really should be no need for a fan, anyway, as a 90%-efficient inverter working on 800 watts would only produce 72 watts of heat. That is less than a bedside lamp, and hardly needs an industrial-strength blower to keep it cool. More importantly, the most elegant aspect of photovoltaics is that there are *no moving parts,* and so there are no bearings to oil and no

brushes to wear out. Designing an inverter with a fan is like designing a bicycle with square wheels. It might work, after a fashion, but misses the point of the exercise.

Another welcome feature of the new inverter was the wealth of information it provided about its performance. It came with a liquid crystal display with several buttons on it. By pressing these repeatedly one could interrogate it to find out how much power it had been producing at 15-minute intervals every day for the past week, or maybe the past month -- I don't know which, as my thumb developed fatigue after punching the button a few hundred times. If I had been desperate to know, I could have hooked it up to a PC through the cable they provided.

Finally everything was in place and working satisfactorily. I could at last start to show off my new toy to the world. I wanted to rush out onto the street, grab the arm of each passer-by, drag them to the back of the house to see the backward-turning meter, haul them upstairs to the attic crawl space to listen to the gentle hum of the inverter, and then force them to gaze at the digital display.

Luckily, I had a more effective way of getting public attention to the fact that photovoltaics were at work in Cleveland Heights. I teach a course on "Energy and Society" at Case Western Reserve University, and had a captive audience of the 32 students in the class. I organized a field trip in which the students would make the 2-mile journey from campus to my house, have a pizza lunch, and see the cells at work. I alerted the public relations office at the university, who lined up the press and TV stations to cover this photo opportunity.

When the day arrived we were blessed with brilliant sunshine. By 10 AM all the preparations were made, and the TV crews were on their way. Then the phone rang. Somebody had chosen that particular morning to fire the coach of the Cleveland Cavaliers basketball team, and the press and TV were now doing U-turns on Euclid Avenue and rushing back downtown to capture the story.

The one crew that remained faithful to their original plans were the reporter and photographer from the Sun Press, which is the local weekly paper that covers Cleveland Heights and neighboring suburbs. The reporter listened intently, peered dutifully into the crawl space, and asked the students their opinions. The photographer snapped everything, starting with me demonstrating the power of the sun by using a Fresnel lens to burn a hole in a slice of pizza. He ended by indulging my wish that he photograph the backward-turning electricity meter while sadly acknowledging that a still photo would not do it justice.

When the Sun Press appeared the next week I was thrilled to see that it devoted the entire front page of its Community section to our solar cells. The article fully captured the spirit of the project, showed the students' enthusiasm, and accurately reported my answer to the question whether it was difficult to have solar cells installed. "No," I had answered, "the hardest part was writing the check."

An unexpected publicity bonus arrived in the form of a phone call from Channel 3 News, the Cleveland NBC affiliate. They had been one of those who dumped me in favor of the basketball story, but now they were back on board. They had an arrangement with the Sun Press to cover that paper's lead story each week, and so they sent out their reporter and cameraman. At last I could have someone show the world my backward-running meter! The only snag was that they would not be at the house until after 5 PM, and the sun was sinking in the sky.

I anxiously watched the backward motion of the meter slow down as the minutes ticked by, and was relieved when the crew arrived. I impatiently let them wire me up with a microphone and transmitter, and then led the cameraman to the meter. I had rigged up a hair dryer on a long extension cord, and turned it on to make the meter run forwards while he shot some video. I then turned off the hair dryer, and the spinning disk in the meter stopped and reversed itself. Its backward speed was something of a crawl, but it was enough to make the point. While the crew packed up their equipment I went indoors and described the taping session to my wife. Luckily my remarks were highly complimentary of the crew's skills, as I had completely forgotten that I was still wired up with microphone and transmitter, so the crew heard every word I said!

The TV station promoted the story with 10-second clips throughout the evening, and then showed the feature during the 11 o'clock news. It was widely seen, and resulted in many phone calls and letters. It had planted the idea in people's minds that photovoltaics were not just an energy source for the distant future. Solar cells had arrived now, and they were practical. With just one kilowatt of cells I was avoiding the emission of over two tons of carbon dioxide per year into the atmosphere. Photovoltaics were an opportunity for anyone who could afford them to make a positive environmental statement.

My experience with solar energy has convinced me that there are thousands of environmentally minded citizens who would be willing to pay extra for their energy if they knew it would help preserve the health of the planet. Most of the inquiries I received came from people who were much more concerned about helping the environment than in cutting their electricity bills. Just a few asked how long the "payback time" was to recoup my investment in dollars and cents. To those I at first answered "never" or "30 years times the square root of minus one," but now I give them a different answer. The investment is paid back in full, I say, the very first day you see your meter run backwards, and know that you are part of the solution and not part of the problem.