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Alternative Paths to Net -Zero Energy Homes

by Bruce Eugene Davis

Here is an idea. Let's make it possible for many, many more families to enjoy living in "Net Zero Energy Homes" (NZEH) than live in them today. What if we could demonstrate that in many parts of the United States this could take place within a week—a month at most? This option could be available to individuals and families concerned about climate change, who want to personally make a difference, and who have some wiggle room in their budgets.

Wonderfully, the production of new structures that are built to provide healthy, comfortable, durable habitations, and that are very energy efficient—with all their energy needs sustainably produced onsite—is a growing sector of the new home building industry.

Unfortunately, to focus on new construction alone can leave a huge sector of the housing inventory and their occupants "up

Left: Scionwood Retreat. At the time of construction in 1996, we had not done the research and worked with the codes folks to insert "properly closed crawl spaces" into the code, which was changed in North Carolina in 2004. The foundation was built with foundation vents. Once the building inspector signed off on the house, I plugged and sealed the foundation vents on the inside and completed the other construction elements so that I would have a "properly closed crawl space." On the roof are the Santa Fe architectural asphalt shingles with an SRI of 47.

the climate change river without a paddle." I want to offer the story of our family home as an alternative to new construction, but an equivalent path toward creating and living in a net-zero energy home.

SCIONWOOD RETREAT

At the time of this writing, April of 2020, Kathryn and I have lived in a 100% sustainably sourced NZEH, Scionwood Retreat, since 2006. It happened instantaneously nearly 14 years ago in September of that year. Maybe our experience will encourage others to pursue our approach to creating their own NZEH, an approach that is available to many homeowners right now.

In 1996 we moved into our modestly built but high-performance HUD Code doublewide home built on a properly closed crawl space foundation. This building was our privately funded demonstration that any homeowner can have a home that achieves a much higher percentage of its efficiency potential, if a few key elements of its building envelope and mechanical systems are properly installed and perform as intended. Yes, we have lived in a very comfortable, durable, healthy, and energy efficient home now for 24 years. No, it is not an energy efficient World Record Setter, but it is reasonably efficient and performs well enough for us.

THE HOUSE THAT BRUCE BUILT

The site was prepared so that all water drains away from the building. The foundation is waterproofed, and the footing has a properly installed drain that flows to daylight. The crawl space is a "properly constructed" closed crawl space with a sealed plastic liner and a water vapor control mechanism–a dehumidifier in our case–to maintain the relative humidity below 60%.

The construction has continuous and parallel thermal, vapor retarder, and air barrier layers. The insulation levels are, attic R-30, wall R-19, and floor R-22. Our 1,800-square-foot home tested at 1,100 CFM50 with distributed, small size air leakage, which is substantially tighter than the average home.

The building is oriented, and the windows are sized and placed to take advantage of solar tempering and shading.

Solar power management system and battery storage.

The heating and cooling equipment was selected based on a *Manual J* room-by-room load calculation and it provided the required cfm for each room. Since it is an air delivery-based system, the duct design is based on a *Manual D* set of calculations. There is an emphasis on sizing the ducts to establish a low-pressure system for near soundless delivery. The air handler and duct system are air sealed, and in our case to less than 5 CFM25, of air leakage. The heat pump was set up with the correct amount of total air flow and the correct amount of refrigerant charge. Air flow to each room is measured and air balanced. The heat pump's auxiliary heat strip was locked out to 25^{0}F. The return air flow is filtered at the two return grilles by medium filters and at the air handler by a deep pleated April Air filter. With closed interior doors and the air handler on, building air pressure problems that cause wasteful increased building air changes, room to room temperature differences, and other problems are eliminated by adequately sized door undercuts.

Two bath fans and the rangehood are ducted to the outside air, not stopping in the attic. The Energy Recovery Ventilator has a Total Recovery Efficiency (TRE) rating of greater than 60%. This rating addresses both sensible and latent recovery. The separate ERV duct system is sealed, and in our case to less than 5 CFM25 of air leakage.

To demonstrate the positive impact of applying the above construction standards toward a building achieving a much higher percentage of its efficiency potential, we installed inexpensive, single pane, plain glass with aluminum frame windows. Each opening has a single hung primary window and an interior, single hung storm window. The primary positive attri-

This building was our privately funded demonstration that any homeowner can have a home that achieves a much higher percentage of its efficiency potential.

Left: Bruce in the Scionwood Retreat's country kitchen. *Right:* Meet Omar, our heat pump water heater. Kathryn stuck some magnetic pieces from a magnetic game and created the face on the water heater before she named it. We set the unit to operate only in heat pump mode. Omar saved enough kWh to make room for our charging the Bolt EV without a noticeable jump in our kWh consumption.

bute of the windows was that they are tight enough with regard to air leakage.

Between moving into our new home in 1996 and our decision in 2006 to pursue our alternative path to be a NZEH we made a few efficiency improvements.

- We installed low flow shower wands in our bathrooms.
- We began using compact florescent bulbs for all of our lighting needs.
- Our old upright *manual d*efrost freezer died and we did not replace it.
- The 1986 refrigerator was replaced with a well rated Energy Star unit (2003).
- Lastly, our children were growing up and moving out—less hot water and clothes dryer use.

THE HOUSE THAT BRUCE REBUILT

We have benefited from already having a reasonably efficient home. We have added onsite sustainable energy production in stages over time. However, we have also pursued the parallel path of improving the energy efficiencies of our home, to great benefit.

Following our 2006 transition to net-zero energy, we installed

- a new and improved heat pump (2007),
- an Energy Star washer (2008),
- upgraded to LED lighting,
- installed an Energy Star frost-free freezer (2012), and
- replaced our ERV with a significantly more efficient unit that has a TRE of 75% (2012).
- We upgraded our asphalt shingles to ones with an SRI of 47 (2015),
- we added a second fridge for garden produce (2017), and
- we replaced an electric resistance water heater with a heat pump water heater (2018).

GREEN POWER

By September 2006 we had lived in our home for ten years. Kathryn and I had been to watch the Al Gore inspired film, "An Inconvenient Truth". As we walked out Kathryn said, "I wish that we could personally do something". I said that maybe we can. "Let me do some calculations when we get home." Once home I added up the kWh from our utility bills for the previous 12 months for our all-electric home that includes an electric well pump. In our state of North Carolina, we had and continue to have a homegrown sustainable energy production program called NC GreenPower. The nonprofit pays generators to produce renewable energy, referred to as green power. It is defined as electric energy provided from solar, wind, small hydro, landfill methane, animal waste methane, agricultural waste methane, and other biomass resources. That power is fed into the electricity grid. Anyone could support renewable energy through NC GreenPower for as little as $4 per month, which provided one block of electricity equal to 100 kWh.

We divided our total energy needed annually, 12,537 kWh, by 12 months. Ten blocks would not meet our need but eleven blocks per month, 13,200 kWh annually, more than met our requirements. We filed our request for NC GreenPower to provide us with eleven blocks of electricity for $44 per month and poof we were a 100% equivalent sustainable electrically sourced net zero energy home. Each month the electric bill arrives with all the electric company's standard charges on it–basic customer charge, kWh energy used charge, non-regulated surge protection charge, and sales tax—plus an additional NC GreenPower charge for $44. We made one payment, and all was done for the month.

If you want to get more into the technical details and address electricity transmission and distribution losses, which the U.S.

Energy Information Administration estimates to be 6% on average, we could have been at times only a 99% sustainable energy home in any given year. However, as you will see we addressed that in subsequent years and actually became a home providing substantially more energy than we needed even when counting line losses.

As of January 1, 2020, each $4 block of renewable energy purchased now supports 125 kWh of green electricity to the grid. Plus, it also supports the state's Solar + Schools initiative. Yippee! At that point in time we transitioned to donating directly to NC GreenPower. They continue, as they always have, arranging for renewably sourced electricity to be fed into the grid.

In 2011 we added an onsite pole mounted 3.5 kW solar electric panel array with battery backup. At that time, we continued to purchase the eleven blocks of NC GreenPower to help cover some of the other toes of our overall carbon footprint. In 2015 we added an additional 3.4 kW array to our roof following shingle replacement with shingles with a Solar Reflectance Index, SRI, of 47. The SRI values scale goes from 0 to 100. The lower the SRI, the hotter a material is likely to become in the sunshine. A standard black asphalt shingle would have an SRI in the low single digits. At that point we reduced to five blocks our purchase of NC GreenPower. On an annual basis we now produce approximately 61% of our kWh needs onsite. With the flexibility of our NC Green Power purchase, we continue to provide more kWh than we need for our home. The excess kWh is left in the grid and is a benefit to some unsuspecting souls. Finally, we purchased a Chevy Bolt EV and began using a level 2 home charging station in March of 2019 that replaced our primary transportation, combustion engine car.

Table 1. Most Recent 12 Months of kWh Data

Date	PV	NC GreenPower	Available	Total Used	Surplus/ Deficit
Apr 12	878	500	1,378	1,154	+224
May 12	802	500	1,302	888	+414
June 12	863	500	1,363	913	+450
July 12	845	500	1,345	1,062	+283
Aug 12	904	500	1,404	1,119	+285
Sept 10	700	500	1,200	956	+244
Oct 12	768	500	1,268	709	+559
Nov 12	514	500	1,014	1,154	-140
Dec 12	406	500	906	1,283	-377
Jan 12	364	625	989	1,350	-361
Feb 12	462	625	1,087	1439	-352
Mar 12	571	625	1,196	1,246	-50
Totals	8,077	6,375	14,452	13,273	+1,179

This Venmar DUO 1.2 ERV photo was taken before I moved it to the crawl space and connected it to the ERV ducts that are located there.

MANY PATHS, SAME GOAL

There are several important aspects to our alternative approach to achieving a NZEH. We did not need to make a large financial investment. We did not need to figure out what equipment to purchase. We did not need to maintain any equipment. And we did not need to find a qualified contractor. Our home could be located anywhere and be of any orientation or construction type. It could be an apartment or townhome and one could still pursue this alternative approach. It is an approach that is compatible with the realities of families that have fewer financial resources but who want to be a part of and help build toward our sustainable energy future. Some homeowners may need to start with work that improves the efficiency of their home. Others may want to start down both paths–energy efficiency improvements and purchasing the energy to become a NZEH–at the same time.

If you use a combination of fossil fuel and electricity in your home, there are conversion formulas that will provide you with the total equivalent amount of sustainably produced kWh that you need to buy. Purchase the necessary amount of sustainable energy monthly from any number of available sources and take an important step that improves the potential for humans' continued presence on this good earth.

THE HAPPY DANCE

Here are some kWh numbers for your consideration (see Table 1). These are available because our home was built with a submeter for all the HVAC equipment (heat pump, ERV, closed crawl space dehumidifier), additional submeters available for the ERV and dehumidifier, and occasional use of submeters for other household appliances. We have submeters for each of the two solar electric installations as well.

The kWh numbers are available because we've kept monthly records throughout the home's 24-year life, and they continue monthly.

For comparison, the first annual energy use report in mid 1997 was 16,311 kWh. By the time we examined our annual consumption in 2006 in preparation for becoming a renewable energy NZEH we were using 12,537 kWh annually. In 2015 we recorded 12,562 kWh for our annual consumption of electricity. During the most recent 12 months, following the addition of a second refrigerator for our garden produce and holiday family gatherings, and our replacement of the 1996 tank type electric resistance water heater with a heat pump water heater, our total recorded consumption has been 13,273 kWh (see Table 1).

What is most notable is that 12 months ago we replaced our primary vehicle, which had an internal combustion engine, with a 2019 Chevy Bolt EV. We keep it charged with our level 2 home charging station. This unit uses 240 volts and can provide a charging rate of 25 miles per hour of charge. The level 1, 120-volt unit charges EVs at 4 miles per hour of charge. Offsite charging is only necessary on long road trips where we use DC Fast Chargers. In the past 12 months we have driven 15,000 miles. Adding "transportation" to our home energy consumption is a big step in addressing more of our overall carbon footprint. Does this make us a Net Zero Energy Home, Plus?

Our two PV installations have provided 8,077 kWh over the last 12 months. Added to our 6,375-kWh purchase of sustainably produced electricity from NC GreenPower, we are providing 14,452 kWh to cover the 13,273 kWh required for our home and primary transportation. That leaves a few kWh to cover a couple other toes of our whole lifestyle carbon footprint. Think about, for example, some of the electricity to operate the refrigeration units at our local grocery store where we buy fruits, vegetables and meats. We are net metered, so this sharing is possible.

THE "OOOPS" FACTOR

Given that we have lived in our personally financed Applied Building Science demonstration, experiment home for 24 years, some of what could go wrong has. In 2001, we had installed a wonderful Jotul wood burning stove for use during power outages and special occasions. It has the added feature of being grounded which is a good thing since we were using a solid packed metal chimney. By 2007, we had to replace our heat pump. The original heat pump had to be repaired twice after having been struck by lightning twice. After the second strike, I went into our crawl space to investigate. I always preach that it is not so much the equipment that you purchase but the person who installs it that is of paramount importance. The Jotul installation person had grounded the Jotul to the electric power conduit that went to our heat pump air handler. Oops! I extended and rerouted the ground wire to properly connect to our home's set of grounding rods. No more lighting strikes damaging our equipment. Whew… On the bright side, we had a new, 2 stage heat pump that was even more efficient.

Because we were recording our monthly kWh use, at one point during a shoulder season of the year transitioning from winter, I noticed that the kWh use was going up when it should have been going down. At that time Kathryn mentioned that the water pressure seemed to be a little less than usual. I did not follow up on her clue. But there ensued a three- or four-month pursuit of what was causing our consumption to climb. It was our solar electric contractor who came out and confirmed his suspicion that the problem was our electric well pump. It had failed but only to the point that it had to run continually to provide the not quite right water pressure that Kathryn had mentioned. There was a small enough hole in the pump such that it could continue to provide water but could never achieve cutoff pressure.

We have influenced a few others to pursue our path. We hope that our sharing in this format will encourage additional participation.

A third story worth telling is the little Mimosa tree. Kathryn had it in the kitchen window in a pot for a number of years. At some point in time prior to our first PV installation in 2011, we had planted it in the front yard. It became a small shady thing. Nice. When we installed the 2011 PV, we had to remove a couple of medium size trees to allow the solar panels to receive the desired sunlight. The Mimosa was still a nice shady thing. However, I woke up to the reality this winter of 2019 with low sun angle and a nice Mimosa tree that had become quite healthy and big and was now shading the panels during the time of the year that I could not afford to have any shading. So, in January of 2020 my son and I modified the Mimosa to be a nice durable wood stump plaything for the grandchildren's entertainment.

The above items are not our only adventures with failure while living in our home for 24 years. These are just a few examples of the entertainments that all homes provide to us humans as we live in them.

OUR "ASK" OF YOU

Since we began in 2006, we have influenced a few others to pursue our path. We hope that our sharing in this format will

Grandchildren's Mimosa stump, pole mount PV, backup batteries, controls, and automatic power transfer building, Bolt EV, and level 2 home charging station.

encourage additional participation. Please consider pursuing this purchased power option as a valid approach to achieve a NZEH for yourself and your clients. It is not the answer, but it can be a contributing thread in the tapestry that together we weave to address climate change. Deciding to actually take steps toward the goal is the important element.

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