**WEBINAR QUESTIONS AND ANSWERS**

The following questions were asked by attendees of one of my Zero Carbon, Zero Bills webinars or by email. They are reproduced here, together with my answers.

In my opinion, the Q&A is the most valuable part of the webinars and these interactions provide a gold mine of information to anyone wishing to cut their bills by cutting their carbon footprint. The Q&A is organized roughly by HITS (heat pumps, insulation, triple-glazed windows and solar panels), but the questions often address multiple issues at once or come at an issue from a different perspective like the role of carbon offsets, how to apply the fab four to new construction, condensation, or how the fab four recipe changes based on which climate zone you are in.

# General questions, not specific to one element of HITS:

## Shouldn't air sealing come first, even before insulation?

Q: since this is talking about what makes sense financially, it would be useful to add air sealing to your fab 4, and I think you would find that this is the best investment, even better than making your basement cold (insulating the ceiling). I think the conclusion that you hinted at is that you should not "wing it", but do the shortest payback measures first, and this results in the least expensive net zero result. Anyone can be net zero by adding solar collectors, but the question is how to get there most cost effectively. So, things like doing air sealing, should be done first, always. Yes?

A: I believe air sealing is important, it just wasn't a big issue on our house. This is because both our roof and our walls were already well sealed. I have seen houses where air-sealing alone has cut the energy bill 25%.

Our house has a flat roof with a rubber membrane waterproofing layer on the top of the roof. Under this waterproofing layer are two layers of 2" ISO boards. This makes my roof air-tight as well as water-tight. This makes my roof far more draft-proof than a typical roof with sloped sides, shingles and a lot of small air cracks between the walls and the roof.

Also, our siding is vertical boards with tongue and groove connections, and it is well painted. This makes my siding almost impenetrable to wind. This cannot be said of unpainted shingles or standard shiplap horizontal siding, both of which allow a lot of drafts. Also, because our house is two stories high with a flat roof, the top of our house is about 20' high which is much lower than the 30' or so of a house with a pitched roof. The low height of our roof reduces the "stack" effect which is where rising warm air forces air to leak out of the top of the house and sucks cooler air into the basement. So, our house did not have many of the causes of drafts in typical houses. In contrast, our windows were terribly drafty. Our windows were all replaced with well-sealed and well-insulated triple-glazed windows. We paid particular attention to making these windows air tight.

The biggest source of drafts through the walls in our house was along the sill plate, which is the place where the top of the concrete of the basement joins to the wood studs of the walls. I sealed obvious drafts with a few cans of spray foam and I weather-stripped the bulkhead door. I also stuffed the fiberglass that I used to insulate the ceiling of the basement into the sill plate and this cut down the drafts. Since this was done at the same

time as I did the insulation, I could not separately measure the contribution of the draft sealing compared to that from the insulation. Hence, you can say that the money savings I attribute to insulation alone are actually due to both insulation and air-sealing. I just think the insulation was by far the bigger contributor because the drop in my energy bills was almost exactly what was predicted from my energy model which directly accounts for insulation but, back then, did not account for drafts.
Early on in my zero-carbon renovation, I added weather-stripping to my external doors, but I could not detect any change in the energy bills from sealing the drafts on the doors alone. That is why I do not call it out as one of the fab four. That does not mean that draft-sealing is unimportant. In fact, on most homes with sloped roofs, shiplap siding and no sealing of the top or bottom of the walls, drafts can be a major factor in heat loss. Air-sealing is generally cheap, easy to do and highly effective. Unlike other things like heat pumps, solar and triple-glazed windows, it is something that you can do yourself, which makes it a very good return on investment.

There are quite a few other things I did that did not warrant being called out specifically (I wanted to keep it simple) such as: insulating the hot-water pipes in the basement, insulating the ductwork in the basement, replacing an old fridge and adding a heat-pump hot water tank. I think all of these had very good returns on investment, but they were too small for me to be able to quantify with any confidence (except the fridge which paid for itself in 18 months on the electric bill savings). So, I do think they are important, and they have high ROI’s, but they each only cut my carbon footprint by relatively small amounts.

# What if I live in the South? Does HITS work in a hot climate?

The fab four recipe for cutting your carbon footprint will work in the southern half of the country as well as in the northern half. From the point of view of the laws of physics, a house is just a box. It has a top, a bottom and four sides. Energy comes into the box from electricity and heating fuel. Energy goes out through the walls, windows, attic and floor/basement. This is the same whether we call the box a house, an apartment block, an office or a factory.

In a cold climate you need to keep the heat in. In a hot climate you need to keep the heat out. The answer is insulation and triple-glazed low-E windows in both cases. So, these parts of HITS (the I and the T) are the same in cold climate or a hot climate. However, a heat pump (the H in HITS) in cooling mode is the same efficiency as an air-conditioner. It is only in heating mode that a heat pump has four times the efficiency of an oil-fired or natural gas-fired furnace or boiler. So, the year-round gain in heating/cooling efficiency is bigger in a cold climate than a hot climate.

Solar panels (the S in HITS) work better in the southern half of the US because there is much more sun there than in the northern half. In fact, where we live in Massachusetts, we have a rather poor solar crop to harvest. The desert southwest has almost 40% more solar energy per year. This makes solar power about 40% cheaper per kilowatt-hour in the southwest compared to Massachusetts. See this map from the NREL:

In addition to how much sunshine you have in your area, the price you pay for utility electricity will have a big impact on the payback period for solar panels. High electricity prices make the payback period on solar panels faster, because you are saving more

money per kilowatt-hour of electricity generated by your solar panels.
Other than Hawaii, which has very high electricity prices, the highest prices for electricity in the U.S. are in New England, California and Alaska where you will pay about 20c per kilowatt-hour. In a band of states running down the center of the country from North Dakota to Louisiana, electricity is about 10c per kilowatt-hour. In most of the rest of the country it is about 15c per kilowatt-hour.
So overall, with insulation and low-E triple-glazed windows cutting your carbon footprint and utility bills across the entire country and with the lower benefit of using heat pumps for heating in the southern half of the country combined with the higher solar production in the southern half of the country, HITS will benefit you no matter where you live. The recipe just needs to be fine-tuned to your exact location and local financial subsidies.

# What would be the difference between Passive House and Green Zero Carbon houses?

1. What would be the difference between Passive House and Green Zero Carbon houses?
A: PassivHaus focuses on passive solar gain as a big part of its energy saving. I do not. Passive solar gain from big south-facing windows leads to massive overheating on sunny days in winter which leaves people using their AC in winter, which is very bad for energy efficiency. Windows (good ones are R4-5) are less insulating than a wall (a bad one is R12) so any time you have a window rather than a wall, you have heat leaking out in winter and heat leaking in in summer. If you have big windows you have big holes in your thermal envelope. PH also is a philosophy of perfectionism. I am totally pragmatic and have no ideology. I look

FIRST at what saves money and makes a good return on investment. PH does not look at cost effectiveness at all. This is why the PH movement has really struggled to become established in over 30 years of trying. At the end of the day PH is expensive to implement and very time consuming because of their detailed audit requirements. Frankly, it is also a lot of hassle to do everything to the Germanic standards of perfection and record everything in their software package (the PassivHaus Planning Package), which is so complicated it takes days of training to get certified to use it. Also, PH makes no accounting for where the house is located (you may have noticed that Canada has colder winters than Florida but the PH standard is the same in all locations) or how big the house is. Both location and size are key drivers of energy use and energy efficiency. PH has no standard for a renovation, it only applies to new construction, which means it is irrelevant to the 99% of all houses that are already built each year. Finally, the PH emphasis on air-tight construction has led to excess condensation and mold in PH construction. My fab four recipe was developed for retrofits, but when applied to new construction it is cheaper and easier to implement than on a renovation. See my post here: https://greenzerocarbonhome.com/2020/06/can-you-use-hits-to-build-a-new-house-with-a-zero-carbon-footprint/
Also see this article on better ways to measure energy efficiency:https://greenzerocarbonhome.com/energy-and-finance-terms-explained/net-zero-passivhaus-leed-certification-zerh-and-hers/

Q2. Is there any certification to build Green Zero Carbon homes like Passive homes?
A2:  If you use my Zero Carbon Home consulting service then I will certify the house.

Q3. As far as cost comparison which would be less costly and more benefits value v/s money
A3: I do not yet have the side-by-side data to prove this, but since I start with cost-effectiveness I think it is likely that a Green Zero Carbon house is more cost effective than a PassivHaus.
Q 4.Any other thing that you would like to highlight and add from your experience.
A4: Overall, I think my approach is practical and sensible. I am also completely independent and am not paid by or employed by any manufacturer or installer in the industry.

# Structurally insulated panels and heat recovery ventilator (HRVs)

Q1. There was a question during the most recent webinar and I missed your response.  The question was what do you think of SIP's (structurally integrated panels) – what are your thoughts about SIP's?
Q2. BTW, I was just watching a Fine Home Building webinar entitled "Principles of Residential Ventilation," most of it over my head, but the core message was that ERV's (energy recovery ventilators) are the bee's knees.  Do you have any thoughts on ERV's (sort of outside your wheelhouse, I know)?  The sub-messages are moisture management & indoor air quality).
A 1. I think SIPs are great, but they are only one of many ways to get insulation and structure. Walls have to perform a lot of functions in addition to holding the roof up. They must block rain, block wind, block cold/hot and block moisture that is in the air as vapor or humidity. The latter is because humidity/vapor becomes liquid water (condensation or dew) when the temperature drops. You do not want liquid water in a wall – it will lead to mold, rot and likely asthma for the family. This is not theoretical. A house in our town was condemned by the board of health after the owner was

taken to the ER with asthma that was caused by mold ultimately caused by vapor condensing inside the walls that did not evaporate. See my other answers on the topic of condensation. Mold and rot, caused by condensation, are probably the most insidious problems in housing today.

Blocking rain and wind are fairly easy, this is what siding is supposed to do. However, shiplap (overlapped) siding and shingles do a great job of blocking rain and a fairly poor job of blocking wind. This is why, today, most builders install an air-tight membrane under the siding. Products like Tyvek house wrap allow humidity to pass through from the inside but block both water and wind. For Tyvek to be effective as a wind barrier the Tyvek sheets need to sealed by having their seams taped from the outside. This allows a wall to dry to the outside when it gets condensation inside it. This is exactly the same idea as in a GoreTex jacket – the fabric prevents rain from getting in but still allows humidity created by sweating to escape to the outside. Condensation in walls (and inside jackets when exercising) is inevitable but mold is not inevitable – you just need to allow that condensation to evaporate. This is the job of a vapor-permeable membrane like Tyvek. Or GoreTex. Some very high-end custom builders will now install vapor tight membranes on both the inside and the outside of the wall, which keep the interior of the wall completely free of condensation because vapor cannot even enter the wall and hence cannot condense. These membranes still allow vapor to travel from the inside to the outside (just like Tyvek or GoreTex) so, if the inside of the wall gets wet for some reason other than condensation (like a water leak) it can still dry out. This is best practice in wall construction today and is so far beyond code that most builders will not be familiar with it.
And I have said nothing so far about insulation. Best practice is to have some insulation outside the air blocking layer (e.g., outside the Tyvek layer) to prevent (or reduce) thermal bridging which is

where heat leaks out through less-well insulated parts of the wall like the studs – wood is a poor insulator compared to the air trapped in insulation like foam or fiberglass. Then have even more insulation in the cavities of a wood-framed wall. This would normally be the 4” cavity created by the 2”x4” wood studs (the upright planks of wood that hold up the roof). This cavity is normally filled with insulation like spray foam, fiberglass or dense-packed cellulose. When you combine this outer layer of insulation with the cavity insulation, plus the membranes to block wind and rain, plus the siding (which blocks most of the wind and rain), plus the painted drywall on the inside you have the perfect wall.

This “perfect wall” is more difficult to build than making a wall from SIPs, but SIPs at least get you insulation and structure. Some SIPs come with the outer surface painted with a waterproof and windproof paint with the joints sealed with tape on site. This makes a very good, but probably not quite the best, wall at a reasonable cost. At the end of the day, SIP or no SIP, your wall must must block rain, block wind, block cold/hot and block moisture. Oh, and hold the roof up. How you get there is less important than that you get there.
A2: I hope this answers your first question, but it is also a lead into to the answer to your second question. When you have a very tight building envelope, (that is, less than about one air-change-per-hour at 50 Pascals, know as 1ACH50. A pascal is a unit of pressure similar to pounds per square inch. Fifty Pascals is about the pressure of a 20 mile-an-hour wind) the air leakage into the house will not be enough to evaporate all the condensation that inevitably happens in walls. You are effectively living inside a Ziplock bag. Hence, with tight building envelopes, you need great walls that can dry effectively – see above. To make a great house that is low cost to run, low carbon footprint and healthy to live in, all these separate parts (walls, windows, ventilation, insulation

etc) all need to work together. You can’t fix one without fixing the others.

So to provide the fresh air you need when you have a tight building envelope, you need ventilation. Heat recovery ventilators (HRVs) bring air into the house through a pipe rather than through gaps and cracks in the walls. The air that comes through this pipe is warmed up with the air that is leaving the house. This gives you fresh air without losing all the heat. If you have a very tight building envelope a ventilator is not really an option, you need to have it. An HRV is better than just an air pipe. I have never installed an HRV because retrofits are almost impossible to get to 1 ACH50 and my consulting work so far has been entirely on retrofits. So neither I, nor my clients, have ever needed an HRV.

So, I think that HRVs make good energy sense and you really need one if you are going to have a very tight building envelope. Whether they are cost-effective is another matter and I do not know the answer to that. I would definitely ask the installer how much energy and money they will save you and then calculate the payback period. Payback periods on heat pumps, insulation, triple-glazed windows and solar panels range from about 1 to 9 years.

# Can you use HITS to build a new house with a zero-carbon footprint?

Q: Does HITS apply to new construction?

A: The HITS recipe makes it fairly easy to make money by cutting your carbon footprint dramatically on existing houses. It is far easier to do the same on a new house. This is because it costs very little more to install 6” cavity walls and fill them with insulation than it does to install 4” cavity walls. If the sheathing (plywood) outside layer is made from structurally-insulated panels (which are boards made of an insulating layer like a 2” ISO board glued

to a plywood structural layer which is painted in the factory to have a water-proof and vapor-proof layer on the outside which then has the seams between the panels taped and sealed on site) you can prevent water penetration, prevent vapor penetration, prevent drafts, gain rigidity and increase insulation in a single installation. This takes far less labor time to install than it does to install each component separately. Adding triple-glazed low-E windows costs only a few % more than double-glazed windows.
Hence, it costs very little extra to build new a house with an excellent thermal envelope that will dramatically cut the carbon footprint and heating bills than it does to build a standard house.
Since the heating and cooling loads in a well-insulated house are far lower than in a code-built house, the house probably needs smaller heat pumps to heat and cool the house, which saves money compared to a standard house.
If the house is designed to have one side facing south with no shade, then the roof can generate all the electricity needed to cut the carbon footprint and energy bills to zero.
Estimates of the additional cost to build a zero-carbon house above that of a standard ("code-built") vary from 0% to about 5%.
The moderator on our call, Bruce Sullivan, built his own house with 10" thick walls. He heats it entirely with a single air-sourced heat pump, even in the depths of winter in St. Louis. He powers the entire house with solar panels on his roof. He pays no utility bills.
While I have not built one of my own, I think the ROI on newly built zero carbon, zero bills houses can be excellent.

# What is the source of the $20 house-price increase for every $1 in utility bill savings?

Q: Can you link to the DOE study on home value?

You can download it here: https://www.thefreelibrary.com/Evidence+or+rational+market+valuations+for+home+energy+efficiency.-a021276611
It was published in The Appraisal Journal in October 1998 and authored by Rick Nevin and Gregory Watson. Their conclusions are based on Census Bureau data on 49,000 houses across all states and with all types of heating fuel. The studies were done over several years in the 1990s. Remarkably similar results were obtained by different researchers using different data sets in both the 1970s and 1980s.
Q: for this DOE study of $20 gained for $1 savings – is that $1 per annum or $1 per month?
A: It is $20 for every $1 in annual bill savings.

## Q: Where do you find state/federal subsidy programs?

A: www.dsireusa.org

## Q: I just replaced my natural gas furnace so I don't want to do heat pumps. Does it still make sense to do the other 3. If so, in which order?

Yes it does. Insulation (and air sealing), and triple-glazed windows (either replacing the whole window if the window is rotten or adding window inserts if the window is in good shape) will cut your energy bills not matter what the source of heat is. I suggest doing insulation and air sealing first because they have the highest return on investment and often pay for themselves in a few months. Until September 30th 2020 those who live in MA can get the insulation (up to $2,000) paid for by MassSave – it is literally free. Windows take longer to pay for themselves. The incremental cost of triple-glazed windows over the cost of double-glazed windows paid for itself on our house in about 6 years. The cost of window inserts pays for itself in about 5 years – see chapter 3 in Zero Carbon Home for details. After that, I would do enough solar to offset your entire electric bill. If you are thinking of getting an electric vehicle or two then add on about 3,000kWh a year for each car. This will get you about 12,000 miles per car. at around 2c per mile. A gasoline car doing 30 mpg costs about 10c per mile. An average roof in MA can generate 3,000kWh per year from a 3kW array which will cost you about $8,000 before subsidies and about $3,000 after the federal and MA subsidies.

## In what ways do you cut your non-home carbon footprint, such as that from traveling, driving, products you purchase, etc., if at all?

We work hard to minimize the carbon footprint we create from all sources not just our home and swimming pool, both of which have zero carbon footprints. Any carbon footprint from air travel, selling paperback versions of Zero Carbon Home and selling the T-shirt  is offset with audited, verified-incremental, carbon offsets that we buy from Cool Effect.

We are big recyclers. We buy only organic food in the first place. We throw out almost nothing. Any edible waste goes to our chickens. The chickens fertilize our garden making our fruit and vegetable gardens very productive. We have done a taste test of our tomatoes compared to the most expensive, local and organic tomatoes from Whole Foods Market and ours tasted far better. The chickens give us eggs and meat. So, we eat very well. We are not even close to being self-sufficient and do not aspire to being so. But we do love the taste of asparagus in April, rhubarb in May, tomatoes and peas in June, cherries in July, peaches in August, just about everything in September, apples in October, pears even into November and fresh eggs year-round. Last October, I succeeded in transplanting peppers and tomatoes in pots to be grown indoors (growing under LED grow lights powered by my solar panels) and we were eating them up until Christmas. Anything the chickens won't eat (onions and citrus for instance) gets composted as do all our used paper tissues. Almost everything else such as paper, glass, metal and plastic gets recycled and we trash only about a single 50-liter (13-gallon) kitchen waste bag each week.

I bought a Tesla this year, which I charge from my solar panels which means it costs 2c per mile compared to my old SUV which cost 10c per mile on gasoline. The Tesla, when charged by solar panels, has a zero-carbon footprint. This covers most of our local travel, but we still have two gasoline-powered cars. When they die they will be replaced with EV's too.

When we buy things, we buy almost always local and sustainable. For examples:

- For clothing we only buy organic, mostly cotton and almost all grown and sewn in the U.S.
- For food we buy only organic and usually U.S.-grown only though we do make a few exceptions for some rather excellent Swiss cheese and Italian balsamic vinegar. I used to drink mostly French wine but now drink mostly Californian organic wines. We have visited farms that provide many of our favorite foods like tomatoes grown at Longwind Farm in Vermont, cheese made at Gray Barn Farm on Martha's Vineyard, and blueberries grown at D'Ottavio's farm in New Jersey.
- For construction products (wood, paints, door hardware and light fixtures) and furniture almost everything we buy is made in the U.S. including many made in New England. We buy a

lot of construction products because we are renovating, or have renovated, three properties. The wood that will become the flooring in the extension that we are currently building on our house will come from trees that fell down on our land. We had these trees sawn into “1 by” dimensional lumber, and they are currently drying out.

- For cars, our Tesla was made in the U.S., the first American-built car we have ever bought. Before this, we bought only BMW and Mercedes.
- We buy almost no gasoline or heating oil and we buy zero electricity as everything is powered by U.S. sunshine.
- For air travel, when we do travel by air (which we have not done so far this year, but not by choice) we offset the journey with carbon offsets. Any remaining purchases of gasoline, heating oil and electricity are zeroed out each year as Christmas presents from me to the other family members.

## Q: If you purchase carbon offsets, how do you decide where to buy the carbon offsets from? What do you look for when purchasing carbon offsets? What are your purchasing criteria?

A: I am quite skeptical of the claims of many types of carbon offsets especially those that depend on planting trees in the Amazon. Trees grow really well in the Amazon all on their own. Hence it is hard to say that planting trees is removing more carbon dioxide than nature would remove by herself. I buy my carbon offsets from Cool Effect precisely because they are audited to be incremental. Even then, I buy only carbon offsets from a project that captures methane that would otherwise leak into the atmosphere from exposed coal seams on the Ute Indian reservation in Utah. This is genuinely incremental, and it is supporting U.S. jobs and Native American tribes.

## Q: If you have purchased carbon offsets, what prompted you to purchase them at the specific moments you've made the purchase? How did you decide how many offsets to purchase? With what frequency do you purchase offsets?

A: I do it annually to offset any secondary carbon footprint we have from both cars and air travel. I also offset the carbon footprint of any paperback books I sell (the vast majority are sold as e-books) and any T-shirts I sell in the Zero Carbon business. The T-shirts have the lowest carbon footprint possible because they are made from unbleached, un-dyed organic cotton grown and sewn in the USA. However, I still offset the small carbon footprint they still have.

## Q: What about all the carbon it took to create, deliver and install all the materials to get your house to zero?

A: Solar panels erase the carbon footprint produced by manufacturing them with the first 18 months of the carbon-free electricity they produce. The heat pumps will pay back the carbon footprint of their manufacture in about 4 months. The insulation repays its carbon footprint of manufacturing in just a few weeks and the triple-glazed windows in a few months.

# Q: How accurate is your house energy model compared to tools like Rem/RATE?

The energy model I use I built myself. There are lots of software packages out there but the reviews of them are terrible. They have a very poor track record of predicting the real world energy performance of any particular house. See this review I wrote a couple of years ago:

**Zero-Energy Ready Home (ZERH) and Home Energy Rating System (HERS)**

The Department of Energy offers its Zero Energy Ready Home (ZERH) program but it is more aimed at certifying builders rather than buildings. Hence, just like the PassiveHaus and LEED programs it is focused on new construction, not how to go zero on your existing home. The ZERH program relies heavily on EnergyStar standards for appliances and windows and the HERS (Home Energy Rating System) for performance. HERS is focused on energy use relative to a benchmark house (i.e., how your home compares to a model house of the same floor area) rather than minimizing energy or spending. A HERS rating is only available on new houses, not for existing ones. A review of the HERS rating system in Home Energy magazine found that, in practice, “there was no clear relationship between the rating score of an individual home and actual energy cost.” Hmmm.

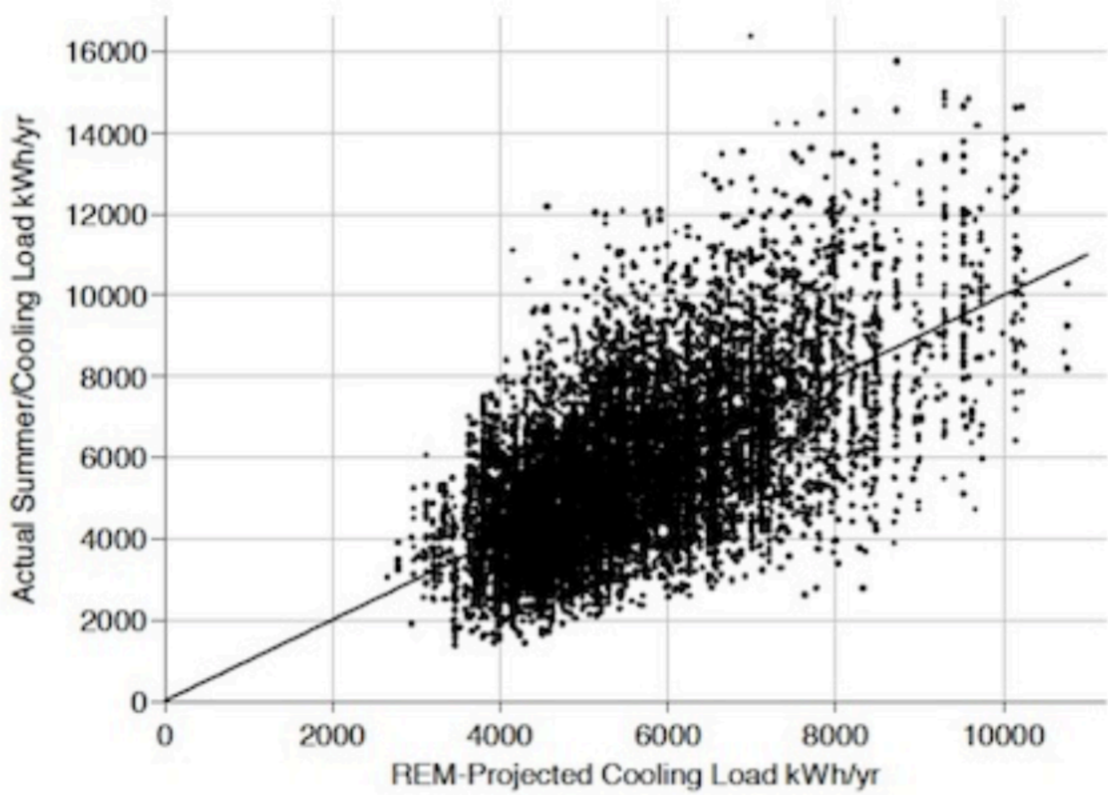
My model began with simple curiosity. I began with just correlating (drawing a line graph) the actual energy (heating fuel plus electricity) that was used every day in my home (I have two years worth of daily data) and the average outside temperature. The r-squared (statistical correlation) of these models (there were 5 of them – one built each time I added one of the fab four) was over 80%. This is a very high correlation for a model that left out known influencers of energy demand like solar heat gain and drafts.

Nevertheless, despite these obvious weaknesses, the outside temperature was by far the biggest driver of energy use and hence energy bills. This was an “ahha” moment.

In a separate “ahha” moment I realized that the u-value for windows was not just an arbitrary scale (unlike say a HERS rating) but actually was the rate of energy flow across the window. Since I could approximate the R-values of all my walls, attic and basement, (and the u-value is 1/R value) I could build a mathematical model of how the energy flowed out of my house. Basic physics requires that over any period longer than a few hours, the energy flowing into a house must equal the energy flowing out. This allowed me to build a predictive model of how the energy flows into and out of a house. Since I know the energy flowing in (the combined energy in the electricity plus that burned as heating fuel) I could anchor the model to reality before we even got started. Hence, the inaccuracies in my model are going to be in allocating where the energy flows out (e.g., I might over overestimate the energy flowing out through the walls and underestimate the energy flowing out through the attic) but the overall amount of energy lost must be correct because energy cannot be created or destroyed, the energy lost by your house must be equal to the energy you put in. Put another way, if you cut off the electricity and turned off the heating, your house would eventually reach the outside temperature.

As far as I know, all the other software modeling packages out there start with modeling the thermal envelope of the house. They then model the heating inputs and then hope that they have got it right. One of the most respected models out there is Rem/RATE. I have repeatedly asked the owners of this software for data on how accurate it is in real-world situations. They have never answered my questions. The most that they were willing to say is that “it meets the standards”, but could not even tell me what the standards were. There is almost no published data on the performance of Rem/RATE software. The only data that I have been able to find is the following chart from 2009:

Figure 7: REM/Rate projected cooling loads versus actual cooling loads




https://www.energyvanguard.com/blog/41919/How-Accurate-Is-REM-Rate-as-an-Energy-Modeling-Tool

Although the average prediction of the model (which is not plotted on the graph, the straight line is what at 100% r-squared would look like – clearly the model is no where near 100% r-squared, and they never publish this most basic statistic) it is obvious that there is enormous error in the predictions for one house vs another. In some cases the error is equal to the mean value! We use models to predict the heating or cooling load for one individual house, not the average of thousands of homes. Hence, I really doubt the value of Rem/RATE for helping homeowners cut their bills and carbon footprints. The HERS rating systems (which is reviewed negatively in the Home Energy magazine article that I quote above) is built on the Rem/RATE software. I, and Home Energy magazine, are not the only one with these concerns, see this quote below from the same article:

“Of course, modeling older homes and heating, water heating, lights, and appliance loads is a different matter, and the divergence between modeled and actual energy consumption may be quite different. According to Blasnik, “I know from experience that many energy modeling tools—REM included—often do a poor job of modeling heating loads in older, leaky, poorly-insulated homes.”

And yet, cutting energy use on “older, leaky, poorly-insulated homes” is exactly the problem we need to overcome!

So I built my own model, and it not only predicted my actual annual heating bills to within 10% of the actual bills but it has proven itself in practice with all of my consulting clients. It has enabled me to make predictions of the real-world impact on both the energy bills and the financial bills for actual changes to that home like adding insulation or adding triple-glazed windows. This is why I do not use any off-the-shelf energy modeling software. They simply have a poor track record of predicting real-world energy and financial performance on houses such as those most people live in.

If you use one of these software packages please let me know how you get on. I welcome any feedback that I can use to improve the model.

## Heat pumps:

# Can you put a ground loop for a geothermal system below the basement floor?

Q: For new construction, would it be possible or make sense to put in loops for a ground source heat pump below the structure?
A: I have not seen this done, but I have thought about it for new construction. Since you are excavating for the basement anyway, why not just go down a few feet more and put in ground loops? I think this would greatly reduce the cost of adding geothermal. However, I do not know if this would reduce the cost enough to compete with air-sourced heat pumps. The downside I can see is that your basement would get colder which could lead to increased condensation in summer when it is humid. It might be a good ideas to insulate the floor of the basement if you are going to do this and also make sure that the geothermal pipes are below the water table.

# A heat pump for a greenhouse?

Q: What about installing the heat pump in a greenhouse? Maybe removable for the summer.
A: I have not done this in a greenhouse, but I think it is a good idea. Effectively I have done something similar by bringing plants indoors in the fall and keeping them in our sunroom. The sunroom receives a very small amount of heat from our house heat pumps because it is at the end of the ductwork and has not return vent. But, using LED grow lights (powered by my solar panels) I was able to get red ripe peppers at Christmas. They tasted great!

# Insulation:

## Does spray foam have a high embodied carbon footprint?

Q: I understand the carbon footprint for the plastic foam insulation is pretty high. 475 Building Supply and PHIUS are recommending cellulose and wood fiber bd which can be carbon sequestering. Short of that they are also recommending ROXUL, much lower carbon footprint.

A: Spray-foam insulates well and hence helps to reduce global warming. However, the gas used to make the bubbles in the foam is often a gas called a hydrofluorocarbon or HFC. If these gases sound familiar it may be because of their cousins, chlorofluorocarbons, or CFCs, which became infamous for causing the hole in the ozone layer. CFCs were banned in 1996. They were replaced by hydrofluorocarbons, which don't deplete the ozone layer but were later found to cause global warming. Hydrofluorocarbons can be about 1,000 times as strong as carbon dioxide in causing global warming. Hence, installing spray-foam has a high carbon footprint even if it insulates well. Because of this, some companies are now using hydrofluoro-olefins or HFOs to make the bubbles in spray-foam insulation. HFOs have very low global warming potential. If you are going to use spray-foam insulation I recommend these HFO-blown foams. Rockwool boards are also great insulation and are fireproof, which is distinct advantage over sprayfoam which burns with a thick black smoke.

Dense-packed cellulose is also a good insulator. However, I am unconvinced by the argument that it is sequestering carbon out of the atmosphere because that wall will eventually be demolished and either decompose in a landfill or get incinerated. Hence, its carbon is returned to the atmosphere. I think it is more accurate to say that using dense-packed cellulose delays the carbon-dioxide emissions compared to the tree falling down and rotting in the forest, but I think it is inaccurate to think that it is permanently sequestering carbon dioxide in the sense that other carbon-sequestration technologies (such as turning carbon dioxide into rock and burying it underground) do.

All types of foam, whether sprayed or boards, have similar end-of-life issues as dense-packed cellulose and are likely to get incinerated (releasing their carbon dioxide) or buried in a land fill (where the carbon will be permanently sequestered) when the building is demolished.

Overall, I think that fiberglass and rockwool are the best insulating materials, because they does not have the global warming potential of releasing HFCs into the atmosphere like sprayfoam does, they are fireproof, and ithey can easily be separated when the house is demolished and recycled or reused. On a renovation we are going to be doing shortly, we plan to use rockwool boards outside the air-barrier membrane (as the thermal-bridging prevention layer) and rockwool batts in the 2”x6” cavity walls for the insulation. See my other answers to related questions on walls, SIPs, and controlling moisture in general in houses.

## Q: How cold does your basement get in the winter with the insulation in your joists and how did you airseal that area?

A: The basement temperature is 60°F to 65°F in winter even with the heat-pump hot-water tank cooling and dehumidifying the air in the basement. The temperature used to be about 8F higher than this before I insulated the ceiling of the basement and installed the heat- pump hot-water tank. I air sealed obvious gaps in the ductwork with aluminum tape (do not use duct tape for this) and also sealed gaps along the joint between the concrete and the walls with a few cans of sprayfoam.

## Q: If we need new siding on just one side of our home which has house wrap, can we add foam board on the outside side of the wrap and then replace the siding?

A: Yes. My preference would be to add rockwool as the insulation board – see my answers on insulation, wall construction and condensation problems in houses.

## Can you add foam board to the outside of house wrap?

Q: If we need new siding on just one side of our home which has house wrap, can we add foam board on the outside side of the wrap and then replace the siding?

A: Yes. My preference would be to add rockwool as the insulation board – see my answers on insulation, wall construction and condensation problems in houses.

## How cold does your basement get with the ceiling insulated?

Q: How cold does your basement get in the winter with the insulation in your joists and how did you airseal that area?

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# I have no insulation in my walls

Q: So, your walls are insulated with 4″ fiberglass batting?  Earlier I had the impression that your house has no wall insulation.  What about homes much older that ’74 with NO wall insulation?
A: Yes, our house has 2” by 4” stud cavity walls filled with fiberglass. The only answer, John, is to get wall insulation. You can do this without having to remove and replace all your siding by blowing in spray-foam insulation or dense-packed cellulose from the outside. This requires drilling holes in the siding, but these can be patched afterwards, or a small section of the siding can be replaced. If you have no insulation today in your walls you are losing money through the walls the way that water runs through a sieve.

# Adding insulation to a wall

Q: I watched a presentation of yours a few weeks ago, the one sponsored by Sherborn and Holliston. Impressive and informative…many thanks.
As a result of the presentation I’m interested in adding 2” insulation board, as well as Aerogel, when I re-side the house. My wife does not like foam off-gassing, so we will leave our fiberglass batting alone and add the insulation board outside of it.
There are LOTS of insulation panel types to choose from. Any recommendations on which are best?
In your presentation you mentioned the aesthetic problem with adding 2” or 4” insulation boards, i.e. that they strand the window a few inches inside the siding. I wonder if this problem could be overcome by cutting the insulation board surrounding the windows into picture frame dimensions by making – a 3-d mitre

cuts of the insulation at the window corners. One would end up with thin insulation board at the edge of the windows, but gain a lot of insulation everywhere else.

Any thoughts much appreciated.

A: You can certainly do this kind of mitre cut to lessen the impact of installing the insulation. If you are adding only 2” it might still look good. I think it is best to discuss this with the window installer.

The Aerogel product has the best R value per inch at R10, so 1” has the same insulation as a 2” ISO board, but it’s only an inch deep. It is more expensive psf than ISO board. I do not know what it’s flammability rating is though.

A more fire-proof alternative than the foam boards is to pull out the fiberglass and replace it with rockwool batts (Roxul comfortbatt is the most widely available). It is about R4 per inch vs R3 for fiberglass. Rock wool cannot burn (it is literally strands of melted rock) so it is better fireproofing. You can add a 1.5” rockwool board (R6) instead of the ISO board outside the studs too. If you are going to go to all this trouble it is probably worth adding an airtight/waterproof membrane on the outside too. Siga makes these type of specialized membranes. They have to be properly installed (with the seams sealed) to create the air-tight barrier. After this your house will be far better insulated and far less drafty.

I am glad your wife is concerned about off gassing, but I think there is an even bigger concern: fire resistance. Sometimes I feel like a lonely voice on the flammability of foam products. I intend to use rockwool when we add insulation on our rental property for precisely this reason. It is not just the flammability that bothers me, it is the thick black smoke created when foam insulation burns. I will also be adding the Siga membranes for air tightness and humidity control too.

# Should I insulate my doors?

Q: What about insulated non-glass doors – are they am important adjunct to triple glazed windows?

A: A typical wood door is only about R1-2 or only slightly better than a single-glazed window. So, having insulated doors will help cut your carbon footprint. However, I do not know of any way to improve the insulation of a door other than by replacing it. So, you would need to do the calculations to see how much carbon footprint and money you would save. Very roughly, if you improved the R-value of a door by R1 (say from R2 to R3) you might save about $40 a year on heating bills. Before you do this though, I would make sure the door has no drafts around it. Sealing these drafts with weather stripping is cheap, easy and effective. A triple-glazed glass door can be R4-5 which is better than any wood door. Most of the external doors in our house are actually sliding patio doors and they are R4 triple-glazed doors. Our front door is wood and it is only about R1.5.

# Is it worth adding insulation to a ceiling with 8″ already?

Q: Could you talk a little about financials of adding iso board to a pitched roof-cathedral ceiling with 8″ cellulose in rafter bays and shingles that otherwise wouldn't be ready for replacement?

A: If you have 8" of insulation already, then paying a contractor to add more insulation is unlikely to save enough money on the bills to pay back the investment in a reasonable period of time. However, it might make sense if you did it yourself, which is easy if you are installing fiberglass. I have found with my client work that even with 6" of insulation already, the savings on going to 12" is only about $150 a year. If you have no insulation today it is worth adding 12" but going from 6" to 12" will not save very much money. If you did this very cheaply, by just buying rolls of fiberglass and installing it yourself it would shorten the payback period. Please see also my other answer (below) on cathedral ceilings.

# Insulating a cathedral ceiling

Q: Insulation recommendations for cathedral ceilings?
A: Cathedral ceilings are tricky to insulate. Most building codes require them to be vented to remove the inevitable condensation caused by warm, moist, air rising to the top of the ceiling and penetrating the ceiling through light fixtures, skylights, cracks and just from diffusion through the drywall. The moisture in this air then condenses when it hits the cold roof surface. If this does not evaporate you will get mold and rot. This is especially problematic on north facing roofs that do not warm up in the sun. You can now get vapor barriers specially designed for this situation. One supplier is Siga in Switzerland. I have not used this myself, but I intend to use it when converting unfinished space in our rental property to finished space. With a proper vapor barrier, you can add insulation behind the barrier. Check out Martin Halladay's posts on this topic on Green Building Advisor (GBA). One of his posts states: "GBA gets more inquiries about rotting cathedral ceilings than any other type of building failure. That's why I'm conservative about recommendations for cathedral ceilings. It's important to get these details right. If you screw things up, everything gets damp and begins to rot." See below information on condensation problems in general.

# Should I insulate a crawl space?

Q: What about sealing/insulating crawlspace walls and plastic on soil to insulate crawlspace?
A: Insulating walls in crawlspaces is a very good idea. It is a lot easier to insulate the underside of the floor than to try to insulate

the soil because you can just push fiberglass in between the joists.

Response: Hi David, Thank you for replying. I had noticed condensation problems in the crawl space due to uninsulated HVAC ducts sweating in the summer. Venting the space in the summer allows humid air into the space where colder pipes sweat badly. Researched this and found a revised opinion on what to do with crawl spaces. The advice I read (sorry, no references) was to seal the wall vents, insulate the inner walls and cover the soil base with heavier plastic. Wetness due to water inflow may require drains and a sump pump. I am moving in that direction (DIY) having previously insulated the joists under the floor and ducting but still experiencing the moisture issue. Thank you again for sharing.

Reply: It sounds like you have two sources of moisture in the crawl space. The vents and the soil. I think you will need to deal with both to stop the water condensation on the HVAC ducts when the AC is running. Sealing the vents will help, but without dealing with that wet soil it will probably not be enough. I think the plastic sheeting on the soil will help, but it is a band aid, not a cure. The real question is why is there so much moisture in the floor in the first place? Is the ground water high near you? If not, are your gutters in good shape? Overflowing gutters can put a lot of water in the soil right by the house and this will wet the soil under the crawl space. I have seen this at our rental property. Repairing the gutters (I put a perforated metal plate on the top of the gutter to stop leaves blocking the gutters and causing them to overflow) and replacing split downspouts (and adding extenders to the bottom of the downspouts to keep the water away from the foundation), worked. I also sealed cracks in the basement concrete with a can of spray foam – cheap and effective as a water barrier as well as an air barrier. Once you have solved this problem, I think replacing your hot-water tank with a heat-pump hot-water tank will help. It will not only cut your bills and carbon footprint, but it will dehumidify the basement air too. Once you have done all this, I would insulate the HVAC ducts, but if you don't deal with the moisture first, you will risk getting dampness and mold on the insulation.

## What insulation should I use in a stone basement?

Q: What about solid stone walls/floors and insulation? Ensuring breathability.
A: Probably the best solution here is to use a product like rockwool boards for insulation. They are breathable so you reduce the risk of mold behind the boards. They are also fireproof, unlike most foam insulation. Most building codes require a fireproof layer (like drywall) over a flammable material like foam insulation. Unless you want to paint the surface of the drywall I think it is easier to just install rockwool. Also, it is probably a good idea to also install a heat-pump hot-water tank. Unless you have very high electricity prices, these are cheaper to run than heating water with a boiler, even one powered by natural gas. If you use solar panels to generate your electricity it will be much cheaper than heating your hot water with natural gas. They dehumidify your basement which will reduce the risk of mold behind those rockwool boards.

## Condensation and moisture problems.

These last few questions raise issues related to dampness or moisture control. While moisture control is not explicitly part of a zero-carbon retrofit, I think it is very important to pay attention to it or you will get mold and eventually rotten timbers. This is not a trivial problem. A house in our town was condemned by the board of health because mold issues sent the occupant to the hospital with asthma. The risk of condensation/mold/rot increases if you do a lot of air sealing because air sealing reduces the flow of air in the house. It is this air flow that evaporates the condensation and prevents mold. Early-generation PassiveHouses, which rely on exceptionally tight building envelopes, often developed mold issues. These problems can be overcome with good humidity control.

In the winter, drafts rob you of heat (and dollars), but they are also a source of dry air that evaporates any moisture that has condensed in your walls, basement or attic. Condensation happens when the temperature of the air falls below the dew point. This is what causes dew on the grass in the morning. Overnight the temperature dropped below the dew point of the air. The dew point of the air varies with its humidity, but it is often around 40-45°F. This is why you see dew on the grass in October and April because we have fairly warm days with lots of humidity in the air, followed by cold nights. If there is dew on the grass, there is dew in your walls.

At these times of year (spring and fall), condensation in your walls and roof is inevitable because if the house is at 70°F and the outside is at, say, 40°F. Somewhere in the wall, the temperature is at the dew point and condensation happens. Air flow up your cavity walls and through your roof evaporates this condensation. This air flow is not driven by wind. It is driven by the stack effect which creates vertical air flow in the house caused by warm air rising. Condensation does not cause mold as long as it evaporates within about 24 hours. Condensation is inevitable, but mold is not.

The best way to prevent mold in a zero-carbon retrofit (or any house) is to control the humidity. If the humidity in the house is lower than that in the walls (which it will be as long as the house is warmer than the dew point of the air, which it almost always will be unless you keep your house at 50°F) then condensation can dry to the inside of the house by diffusion. Even drywall allows moisture to dry through it by diffusion. This provides moisture a way out of the wall cavity even if there is very little air flow up the wall cavity. Air-sourced heat pumps come with humidity control. On mine, I can set the humidity level as easily as I can set the temperature. I set it to 40% year-round which feels comfortable because it does not leave your skin feeling dry, but the air is still dry enough to dry out the bath towels or the laundry.

In addition to the humidity control on the heat pumps, I also have a heat-pump hot-water tank in the basement. This dehumidifies the air in the basement. Humid air is less dense than dry air and so it rises. Warm air is also less dense than cold air, so it rises too. If the air is both warm and humid, it really rises. Basements are often damp and are often warm because of the furnace or boiler. The warm humid air in the basement rises through the house, reaching the roof where the moisture often condenses on the cold roof surface. The source of mold and rot in cathedral ceilings can often be traced to dampness in the basement.

Hence, if air sealing is part of your zero-carbon retrofit, I think it is essential to control the humidity in the house and the basement. Heat pumps with humidity control, heat-pump hot-water tanks and air sealing play very nicely together.

## Triple-glazed windows:

## Are triple-glazed windows a waste of money in hot areas?

Q:  Just had a contractor tell me that triple glazed windows are a waste of $ in the desert southwest – – true?

A:  Replacing any windows is expensive. Windows are expensive to buy and expensive to install. The full cost of installing any windows is unlikely to pay for itself with energy bill savings, at least not for decades. However, in our home the additional cost of triple-glazed windows above the cost of double-glazed windows paid for itself (with the additional saving from triple-glazed windows above the savings from double-glazed windows) in about 5 years for a return on investment of 19%. I think something similar would be true in Texas. See Chapter 3 in Zero Carbon Home.

# Is it OK to measure the R-value of a window at the center of the glass?

Q: How are you calculating the R value? are you using the center of glass U value only? should you consider the frame?
A: The R-values I measured for the window inserts are taken in the center of the glass or plastic. As you can see from the infrared photographs in Chapter 3 of Zero Carbon Home, the frames are all considerably warmer than the glass or plastic sheet. The frames also have far smaller area than the glass or plastic sheet. Hence, I think that the center of the glass measurement is a good approximation of the overall performance of the window insert.

# How do I improve the insulation on historic windows?

Q: Do you know about the availability of high efficiency windows that will be acceptable for homes in historic districts with strict regulations to adhering to historic accuracy?

A: I think probably the best way to deal with this is to add the window inserts you can see in Chapter 3 of Zero Carbon Home. These are invisible from the outside so historical commissions usually are OK. If you use the glass ones and get the low-E version, you can add about R2 to an existing window. If the existing window is R1 you now have an R3 window, which isn't great compared to modern low-E triple-glazed windows at R4-5 but it is 3-times better (meaning it loses one third of the heat) than a single-glazed window. They are also far cheaper than replacing windows and you can fit them yourself, you don't need to hire a contractor.

# Solar panels:

## Q: Do you recommend owning or leasing solar panels?

A: It is usually a much better deal (i.e., it is cheaper) for the homeowner to own the panels than to lease them. If you do not have the cash available to buy them today, you can get low cost financing. In Massachusetts it is called a Heat Loan and there are also federal loans available see here for details: www.dsireusa.org The Heat Loan is a 0% interest loan. It is literally free money.

## Q: Are there solar systems that will provide enough power for our home during a power outage?

A: Yes, but probably not the whole house, probably only the circuits you would power from an emergency generator. Since solar panels must, by law, disconnect from the grid during power outages (to prevent the linemen getting electrocuted by your solar power) you will need to install a re-connect switch at your electrical panel just like that for a back-up generator. This usually needs to be installed with a battery, but when the grid is out and the sun is shining you will be powering the house from the sun. Nice. I intend to do this on my house this year.

# Q: What is the ROI (return on investment) of a Tesla Powerwall battery?

A: In general batteries have two uses.

The first is to take advantage of time-of-day (TOD) tariffs. A TOD tariff is where your electricity company charges different rates for electricity at different times of the day. You can use this TOD tariff to buy electricity at a cheaper rate and sell it back at a higher rate. We do not have a TOD tariff where we live so I have no direct experience of using batteries for this application.

The second use is as an alternative to a diesel or propane emergency back-up generator for when the power lines go down in a storm. I have not bought a battery for this application, but I am planning to do so.

The Tesla Powerwall is considerably cheaper per kilowatt-hour of electricity stored than other batteries from companies like Sonnen and Simpliphi. However, at about $7,000 it is considerably more expensive than a diesel generator which costs $2-3,000. However, I have a propane back-up generator and it costs me $500 a year to get it serviced so that it actually works when we need it. I have learned this lesson the hard way – our previous back-up generator was not serviced, and it stopped working right when we needed it. Over 10 years this maintenance cost is $5,000. So, the full cost of a back-up generator over its lifetime is about the same as a Powerwall.

Also, in Massachusetts, the new SMART subsidy program for solar panels includes an extra subsidy (an “adder” they call it) for a battery. This is currently about 4c per kWh generated by the solar panels. If you have a 10kW array generating about 10,000 kWh a year then this is worth $400 a year for 10 years which brings the cost of the Powerwall down to about $3,000 which makes it similar to the upfront cost of a diesel back-up generator.

Only now you have no maintenance cost. This is why I intend to install a Powerwall to replace my defunct back-up generator in the near future. The regulations on qualifying for this adder are very complicated!

## Q: If the roof is 15 years old, would you replace it before adding solar panels?

A: In most cases, yes. It will be expensive to remove the solar panels in order to replace the roof. However, this is not true is the roof is flat and the solar panels are held on to the roof with weights (called a ballasted system).

## Q: If you have a flat roof and have solar panels, can one walk on them if one needs to remove tons of snow in a bad winter?

A: You cannot walk on solar panels. They need to be installed on a flat roof with some walking paths between them for maintenance and snow shoveling. In the first winter with solar panels I shoveled the snow off, but in subsequent years I did not. I calculated that I was only making about $2 worth of electricity on those winter days and it was taking me over an hour to shovel the snow off. $2 an hour is well below minimum wage!

## Q:  Tips on planning new construction for solar panels on the roof?  Metal roofing?

A: Metal standing-seam roofs are very good roofs that last well beyond the life of a shingle roof. Solar panels install easily on standing-seam roofs because the panels are clamped to the standing seams and no penetration of the roof is required. If I were designing a new house, this is how I would do it. I would also design it so that the panels fit exactly edge-to-edge on the roof, so the entire roof is just solar panels with no shingles or membrane showing. Keeping the sun off the waterproofing will make the waterproofing last much longer. It will also make the roof look much nicer because the solar panels will look like they are the roof rather than them looking like they are on the roof. If you use the all-black panels (most manufacturers offer them, but they are about ½ % less efficient than the ones with the grid pattern on the front) then it will be hard to tell there are solar panels on the roof. I think this is a better solution today than solar tiles.

## Q:  Are you aware of solar panel company called FaFco they make a combination solar panel PV / Thermal….. The thermal output is about 10,000 BTU per 10 FT. SQ. These are making an impact in the swimming pool

## industry. Have you looked at these FAFCO ?

A: I have not heard of this panel, but it does not overcome the biggest issue with solar thermal panels for home heating which is that you cannot store the heat generated in summer and use it in the winter. With solar PV you can effectively store the energy because of net metering. However, using them to heat pool water is a good idea. I would have to check the economics compared to just installing solar PV and using it to power a heat-pump hot-water heater for the pool.

## Will a battery like a Tesla Powerwall last for 3-5 days?

Q: How much can a Tesla power wall store? Will it be enough for 3-5 days in case of an outage?

A: One Tesla Powerwall stores 14kWh of electricity. If you are using fossil fuels for heating, then you are probably using about 20kWh a day to run all the lights and appliances in your house. If you are using heat pumps to heat or you are using AC in the summer, then you are probably using about double this. Hence it is not practical to use a Powerwall (or any other type of battery) to power your entire house electrical load. However, this is not how most people use a Powerwall. Most people use them as an alternative to a diesel or propane back-up generator. So, the battery or generator is powering an emergency panel which usually runs just the fridge, the furnace burner circuit and the circulating fans or pumps, plus some lights and a few outlets. This is typically under 1kW in total load so a Powerwall can last about a day. This is usually enough to get you through a power outage. To last 3-5 days you would probably need 2 Powerwalls and to reduce the load on your batteries to just the lights, the wifi, a few outlets and the fridge.

# Subsidies for battery storage with a solar system

There are now three separate subsides for batteries in MA: if you have an array enrolled in SMART you get an “adder” for having a battery. The SMART subsidy today is about 11c/kWh. The adder for the battery is about 5c/kWh. For a typical 10kW array producing 10,000kWh a year the SMART subsidy is worth $1,100 a year and the battery adder is worth another $500 on top. Both are for 10 years so the adder is worth about $5,000. Both decrease with time – that is the structure of the SMART subsidy scheme. However, once you get your subsidy rate it is locked in for 10 years.

A Powerwall battery costs $10,000 to $15,000 fully installed. So the $5,000 SMART adder cuts the price by a third to a half. The SMART adder is (as is all SMART income) taxable income.  In addition, Eversource has a subsidy called Connected Solutions where ES pays you to have access to your battery during peak power demand. This payment seems to be about $1,500 a year but the it is not really clear exactly how this is calculated or for how many years it lasts. It is not clear if this is considered taxable income (like SMART) of if it is considered more like a rebate or a credit (the way net metering works, and that is not taxable income). If the Connected Solutions program lasts 10 years it would pay for the entire cost of the battery which seems excessively generous and therefore unlikely. However, it will be something else to reduce the cost to you. Finally there is a brand new subsidy, called CPEC (which was just announced in August 2020) or Clean Peak Energy Certificates. Power stations are now required to buy these CPECs to reduce their carbon emissions during peak demand on the grid. They are a bit like SRECs which is what SMART replaced. Peak demand (say on a hot summer afternoon when everyone has their AC on) brings the fossil fuel "peaker" plants into operation. These are not only the most expensive power generating plants on the grid but they are often also the dirtiest, i.e., cause the most pollution and CO2 emissions. Hence, the state has a strong interest in reducing the use of these peaker plants through encouraging batteries. CPECs are brand new and no-one can even tell me how much I can earn from them or whether they are taxable income. However, it is sure to be favorable to you. So, overall, and despite all the uncertainty, batteries are looking like a better and better bet. I intend to install two battery systems (probably of two Powerwalls each) in our home and rental property this year.

My final point is not about batteries but about generators. A diesel or propane generator costs about $500 a year to set serviced so it will work when you actually need it. This is $5,000 over 10 years. The generator itself will probably cost you $3,000 up front. So, the 10-year cost of a generator is $8,000. The 10-year cost of a battery is between $5,000 and $10,000 with the current SMART subsidy alone. Add in Connected Solutions and CPEC and batteries are looking like a really good investment. Oh, and did I mention that they have a zero carbon footprint and emit no soot, nitric oxide or sulfur dioxide?

Note this post was current as of August 14th 2020. The subsidies for batteries are a moving target and one that changes by state, by utility, over time and even by zone you are in within a utility's service area. Please check the latest information for your home before deciding to install a battery.

# Why do you not recommend solar hot-water panels?

Solar photovoltaic panels are sometimes called solar P.V. panels to distinguish them from solar thermal panels, or solar hot-water panels, which use the heat from the sun to directly heat water. Solar thermal panels can be over 70% efficient, which sounds great compared to solar P.V. where the maximum commercially available efficiency is 22%. However, if you are using that solar electricity to power a heat-pump hot-water tank (please see page 66 in Chapter 2 of Zero Carbon Home), with its 400% efficiency, you get a total heating efficiency of 84% for the solar P.V. panel that is heating your hot water with a heat pump. This is better than the efficiency of a solar thermal panel.

Because of net-metering (please see page 82 of Zero Carbon Home), solar P.V. panels can generate the electricity in the summer, and you can use it in the winter. This is not possible with solar thermal panels, which don't generate enough hot water in the winter and generate far too much in the summer. Also, the solar-P.V.-plus-heat-pump-hot-water-tank option has no pipes and hence cannot leak. Better overall efficiency, energy "storage" via net-metering, and no burst pipes make solar P.V., in my opinion, a far better solution than solar thermal panels.

# How long do solar panels and inverters last?

Q: What is the life span of the PV array panels and inverter?

A: Most solar panels are warrantied for 25 years to produce at least about 90% of their initial power production. This varies a bit by manufacturer. They will probably last for many years beyond that. My inverter is warrantied for 15 years, but new ones today come with a 25-year warranty.

# What about buying 100% clean energy from my utility? Is that better than solar panels?

Q: Do you still prefer installing solar panels rather than purchasing 100% clean energy from National Grid through suppliers like Eligo Energy. 8.9 cents/Kwh for 6 months. Have you done a financial analysis of paying 9 cents to 14 cents/kwh to receive 100% clean energy from National Grid compared to installing solar panels on roof?

A: I am assuming that the 9c per kWh is the cost of generating the electricity. Utilities charge separately for distributing that electricity, often about 12c per kWh in MA. This means that you actually pay about 20-24c per kWh after you add in all the other charges, including the $7 a month they charge you for being a customer. When you add solar panels you eliminate the entire bill (except the $7 a month which is effectively what you pay for maintaining the option of drawing power from the grid which you need it) so your cost drops from 24c/kWh (what I am paying today for Eversource electricity) to between 4c and 11c depending on how much shade you have on your roof and which subsidies you get. So, generating your own solar power is far cheaper than even the generating cost of electricity from Eligo, let alone the full cost of that electricity.

If your roof is so shady that solar panels on your roof will generate electricity at more than the full cost of electricity from your utility (21c/kWh in the above example) then buying 100% clean power may make sense for you. However even a half-shaded roof (I have one) generates electricity at 11c per kWh which is less than half of what I pay Eversource today.

# Does it make sense to use solar panels to charge an electric vehicle?

Q: Does it make sense to use solar panels to charge an electric vehicle.

A: When my Tesla is charged from my solar panels (which generate electricity at 7c per kWh) I can drive for 2c per mile. A gasoline-powered car getting 30 mpg on gas at $3 a gallon costs 10c per mile. It is 80% cheaper to drive on solar power than on gasoline! And that is without even mentioning the zero-carbon footprint of driving my Tesla on solar power.

# What is the embodied carbon footprint of a solar panel?

Q: Can you discuss the embodied energy and natural resource use of the active systems, such as solar panels, that are necessary to achieve a "net zero" status?

A: The embodied carbon footprint of solar panels (i.e., the carbon dioxide released by making the panel) is about equal to 18-months' worth of the carbon footprint avoided by generating zero-carbon electricity. So, from a carbon-footprint perspective, you can think of the solar panel paying for itself in about 18 months. Financially, ours will pay for themselves in about 6 years.

# If you sell your SREC are you double counting the carbon footprint reduction?

Question: Hi David, I really enjoyed your talk last week on your zero-carbon adventure. I did have a question, which didn't get answered. I have a friend that works at National Grid and she told me if you sell your solar RECs, which I believe you did, you cannot claim to be carbon free as those rights go with the REC?

After your talk, I went back to her and she felt that this was definitely the case and that you would need to buy RECs to offset the ones' you sold, to make the carbon free claim and you should also tell people you sold your RECs and brought other ones.
Just wondering your thoughts on this
Thanks and thanks again for a wonderful talk. I plan to share this with some folks
Hi Rob, I have occasionally heard this perspective before, and I think that reasonable people can disagree on this one.

I have two concerns with your friend's perspective.

The first is that I have not counted either RECs or SRECs in my calculation of my carbon footprint. I am not offsetting any of my carbon footprint with credits such as SRECs. I have actually cut my carbon footprint to zero by using the fab four. It is Eversource (our electric utility company) that is claiming it has cut its carbon footprint when it has not done so. So, I think it is more accurate that I say I have cut my carbon footprint to zero and it is Eversource that has been allowed by the state regulators to claim it has cut its carbon footprint (by buying my SRECs) when it has not done so. But I have genuinely cut my carbon footprint and it is zero. The SRECs have not been counted in any part of my carbon footprint reduction. My carbon footprint is zero because I no longer burn heating oil and I generate all my own electricity, including that to heat my house, using heat pumps, powered with zero-carbon solar panels.

My second point is that, where I do count the SRECs is in the financial subsidies. I genuinely receive this cash, so I do not think it is right to remove it from the financial forecasts. There are many subsidies involved in going zero, from net metering and zero-interest loans (which are essentially funded through all of us in MA paying the highest price for electricity in the US, other than

Hawaii) to federal and state tax credits. SRECs are calculated per kWh I generate. The federal tax credit is calculated based on the price you pay for the solar system you install. Why should one subsidy not count just because it is based on kWh generated rather than on the price of the solar system? In 2018, SRECs were replaced with SMART and so it is only owners of legacy systems that receive them. I do not see why a subsidy should be dismissed for those who installed systems prior to 2018 but should be allowed for those who installed systems after 2018.
In my opinion, SRECs are just a form of subsidy, paid from a regulated utility to an owner of solar panels, which means they are ultimately paid by all electricity customers. This is essentially a regressive form of taxation because it takes money from everyone who uses electricity (including poor people) and funnels it to those who can afford to install solar panels which tend to be wealthy people or investors. I think this is rather unfair, but I do not make the laws Rob, I just abide by them.
Please share these thoughts with your friends, I am interested to hear what she says.
As of Aug 3rd 2020 I have not heard back.

## Q:  Are there solar systems that will provide enough power for our home during a power outage?

A: Yes, but probably not the whole house, probably only the circuits you would power from an emergency generator. Since solar panels must, by law, disconnect from the grid during power outages (to prevent the linemen getting electrocuted by your solar power) you will need to install a re-connect switch at your electrical panel just like that for a back-up generator. This usually needs to be installed with a battery, but when the grid is out and the sun is shining you will be powering the house from the sun. Nice. I intend to do this on my house this year.

### Q: If the roof is 15 years old, would you replace it before adding solar panels?

A: In most cases, yes. It will be expensive to remove the solar panels in order to replace the roof. However, this is not true is the roof is flat and the solar panels are held on to the roof with weights (called a ballasted system).

# Swimming Pools

## Combination solar PV and solar thermal panels for swimming pools

Q: Are you aware of solar panel company called FaFco they make a combination solar panel PV / Thermal….. The thermal output is about 10,000 BTU per 10 FT. SQ. These are making an impact in the swimming pool industry. Have you looked at these FAFCO .?

A: I have not heard of this panel, but it does not overcome the biggest issue with solar thermal panels which is that you cannot store the heat generated on a sunny day and use it on a cloudy day. With solar PV you can effectively store the energy because of net metering. However, using them to heat pool water is a better idea than using them to heat a house. I would have to check the economics compared to just installing solar PV and using it to power a heat-pump hot-water heater for the pool.

# Free AC in my house from heat pump heaters for swimming pools and heat-pump hot -water tanks

Q: I haven't yet read your pool topic & wonder if you've seen the pool heater that uses waste central AC heat?

A: You are well ahead of the pack on your thinking on swimming-pool heaters. My pool heater is a standard issue AquaCal heat pump – it is very good and very economical to run. On warm days when we are heating the pool, (say a warm day in May) it exhausts cool dehumidified air into the atmosphere, truly global cooling! My pool is too far from my house to capture this and use it as AC in the house. But if ever built a house with a pool I would design it so that the heat pump for the pool would dump its cool air into the house. Free AC! I do not know of any heat pumps designed to do this but it would be fairly easy (i.e., you would need to hire an HVAC tech to do it) to run the refrigerant line from the heat pump to the head of a mini-split unit in the house. If you do this, please let me know, I would very much like to publicize stories like this.

While I have not done this on my pool I have done something similar on my house. I do this by opening the vents (where the air filters slot in) in my air-handler units in my house in about May through September. This is when it is warm enough outdoors that I need AC indoors. Rather than turning on the AC, I open the vents on the air handlers in the basement. This draws air out of the basement and into the circulation of the house. I lean the filter pads against the open vent so that the air circulation is still filtered. The air in my basement is cool and dry. Why? My heat-pump hot-water tank cools and dehumidifies the air in the basement. This works because the ceiling of the basement is very well insulated at approx. R38 because I added 12" of fiberglass in

between the floor joists. Using this source of cool, dry air allows me to avoid using the AC units for about 4 weeks in the year when previously I had to use them.  It is not a major cost saving but it is a nice one. I like anything I can get for free! If houses were properly designed, things like this and the integration of pool heating with house cooling, would be built in from the start. Sadly these people seem to not talk to each other.
If you are seriously thinking of putting in a pool then the $15 you spend on Zero Carbon Pool could be one of the best investments you will ever make. I am saving about $3,000 a year. My pool is big, but even on a standard sized 20'x40' pool you would save about $1,000 a year by following the pool fab four recipe.

## Designing the pool to be efficient from the start

Q: We currently have a Hayward H250 natural gas heater on our 16' X 28' In ground pool and have thought about replacing it with a heat pump. Several years ago I installed a 2 speed pump on the pool and we now save a lot of kilowatts by using the lower speed. However when we want to heat the water we must run the pump on high speed to meet the gas heaters minimum pressure requirement. It's not really much of a problem because we only use the pool from mid May till mid September and with the solar cover on it holds the heat in pretty good unless we have some unusually cool weather. We also have what I call an indirect solar heating system on the pool that adds a little extra heat as well so we don't have to run the gas heater very much once we get the water up to temperature. As such I was wondering if the heat pump pool water heater that you use requires you to run your pool pump on high speed to keep your water warm?
My indirect solar pool heating system consists of 400' of polybutylene tubing that I put in the concrete that surrounds the

pool. I feed it with pool water coming off a tee fitting that I installed after the filter but before the heater. Of course I have a ball valve installed so that I can shut it off at night. Once the water exits the 400' of tubing that is buried in the concrete it just gravity flows back into the pool. I can send you som photos of it if you're interested in learning more about it. Another benefit of using this indirect solar system or maybe we should call it a reverse radiant system is that it keeps the concrete a little cooler on those very hot sunny days. My grandkids really appreciate that.

A: This sounds like a well thought out installation – I like the passive pool heater which heats the water and cools the deck, a very nice two-for! I think this would work on most pool decks, but obviously you need to do this from the start. If I were designing a pool from the start I would also connect the pool heat-pump heater to the house AC system, but that is a different subject, you can read more about it here if you like: https://greenzerocarbonhome.com/2020/07/free-ac-in-my-house-from-heat-pump-heaters-for-swimming-pools-and-heat-pump-hot-water-tanks/

Our pool heat pump is made by AquaCal and it has proven to be both reliable and efficient. When we installed it, we left the old propane heater in place but we no longer use it at all. If it did not cost me money to take it out, I would have taken it out by now. The heat-pump pool heater does have a minimum water-flow requirement to work and on our pool and it is at about 1,400 rpm on the variable-speed pump motor for the water-circulating pump. I usually set the water pump at 2,000 rpm so that it circulates the entire pool volume once per 24 hours, which is necessary to keep the pool water filtered. So it is usually enough flow to allow the heater to come on. However, if the skimmers and filter are clogged, the heat pump will shut down because the water flow is insufficient even at 2,000 rpm.

The pool-water circulating pump now runs 24/7 at 2,000 rpm compared to the old fixed-speed motor that ran at 3,450 rpm about 12 hours a day. This alone is saving me about 75% of the electricity used to run the pool. If you already have a 2-speed motor it is probably not going to save you a lot more money to go with a variable-speed motor. But when you need to replace the pump, I would recommend a variable-speed one as then you can set it to the lowest flow rate needed to circulate the entire pool volume in 24 hours. There is a lot more information on how we got to a zero-carbon footprint on our pool in the book Zero Carbon Pool which you can order here: https://greenzerocarbonhome.com/shop/