Zero Carbon® Home

Questions and Answers on Cutting Your Bills and Carbon Footprint That Were Asked During Webinars

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. They are organized roughly by HITS (heat pumps, insulation, triple-glazed windows and solar panels), but they often address multiple issues at once or come at an issue from a different perspective like the role of carbon offsets, condensation or the role of subsidies.

My next live webinar on how to get paid to cut your carbon footprint will be Thursday, July 23rd, 2020, at 7pm Eastern Time. It is hosted by the Charles River Green Coalition. You must register in order to attend this event because that helps reduce the risk of Zoom bombing. You can register here: live webinar

1. 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?

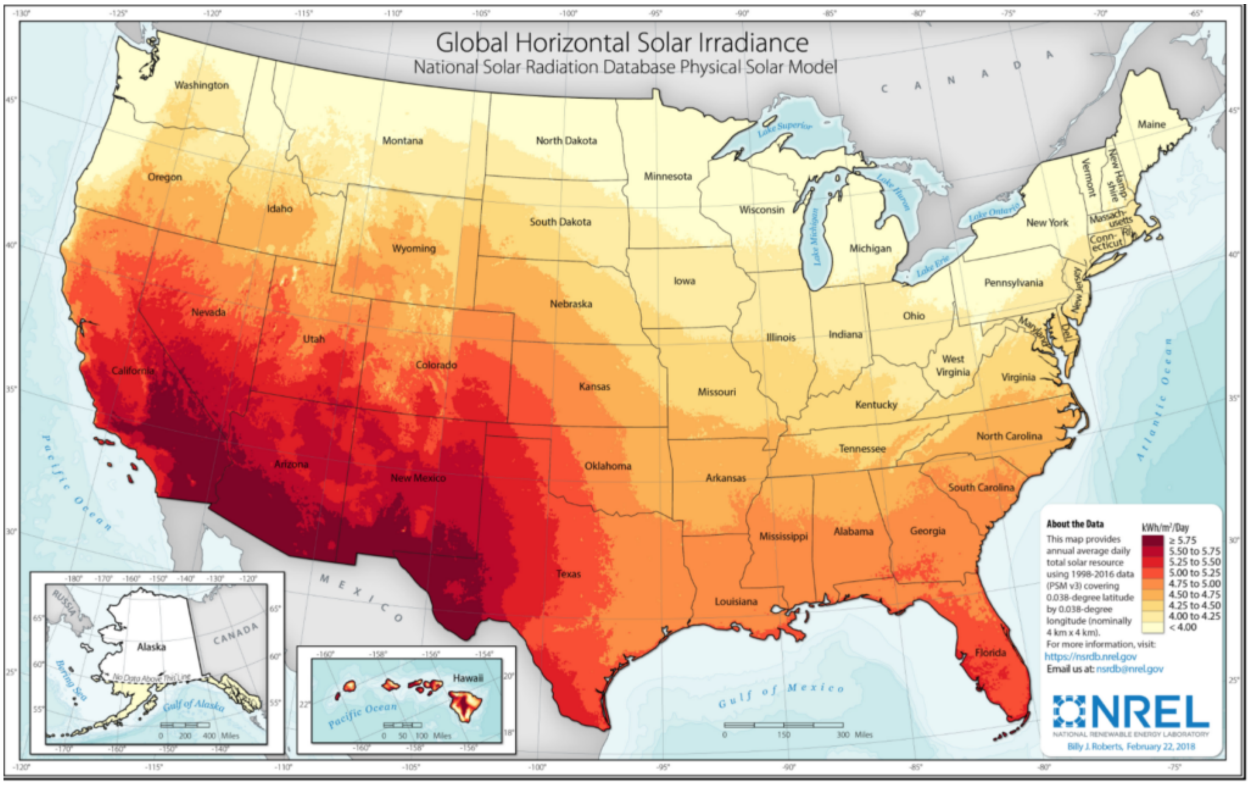
The fab four recipe for cutting your carbon footprint will work in the southern half of the country as well as in the northern half.

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.

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.

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. And they 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.

> 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?

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.

> 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?

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.

2. Questions related mostly to 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!

3. Questions related mostly to insulation:

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.

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.

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 Majrex 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."

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.

4. Questions related mostly to triple-glazed windows:

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.

5. Questions related mostly to solar panels:

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

Q: Please comment on the utility/ROI of Tesla power walls.

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!

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.

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 June 29th 2020 I have not heard back.