March 13, 2016...

I went into town today, and the trees along Canyon Blvd. were flowering. On the day before Allison’s birthday, in the middle of March! In the ‘80s, when I used to do the Kinetic Conveyance Race, those same trees always bloomed for the parade — which was the last weekend in April. A six-week advance in 30 years. Where will we be three decades from now?
Status of Work ........................................................................................................................................... 3
Energy Use Update ...................................................................................................................................... 3
Heat Loss Analysis........................................................................................................................................ 4
  Method 4
  Breakdown by Cabilow Area  5
  Golden Acorn Heating Budget   7
  Comparison to Original Reduction Matrix   10
“Heat Off” Experiment ................................................................................................................................ 10
Where to Now? ........................................................................................................................................... 16
Appendix A: Data ........................................................................................................................................ 17
Appendix B: Lynne’s Soapbox .................................................................................................................... 19
Status of Work

It’s a Wrap! Finally, in January, I finished building the closet between Allison’s bedroom and mine. I was able to move my bed out of the sunroom and into my own cozy little room after nearly 3 years! No more sleeping inches away from a window that ices up at night! When I started the air sealing and insulation work, I pretty much just launched into one room of the Cabilow (the laundry room), galvanized by the purchase of a new washer/dryer to replace the moribund ones that came with the house. After that, I just went room-by-room around the perimeter, fixing up each one in turn. Moving my bed out of the sunroom, and sealing up that room, completes the loop — everything obvious, and a lot that wasn’t, has been addressed from the inside. It’s time to move elsewhere.

Energy Use Update

During Year 1, the baseline year (May 20, 2011- end May 2012), our total energy usage was 90 MMBtu, consisting of 600 gallons of propane and 11,627 kWh of electricity. The efficiency measures, building upgrades, and renewable energy (PV) that we’ve implemented since then (thru the end of Year 4, May 30, 2015) have brought down our total annual energy usage to 44.3 MMBtu, comprised of 91 bags of wood pellets, 70 gallons of propane, and 2827 kWh of electricity (net). This was a 51% reduction in 4 years. I feel pretty good about that. However, if we’re to meet our 1000 Home goal (7268 kWh/yr, or 24.8 MMBtu), we still have a ways to go. I undertook this “midterm” assessment to illuminate the direction(s) I should go next. An additional benefit is that, in document form, the assessment also records the current status of the Golden Acorn project for the THC and any other interested parties.

Throughout each Cabilow Year, I keep track of electric bills, pellet use, and propane, and make projections every so often of where we may be at the end of the heating season or year. I count our heating season to be about 200 days, beginning when we first fire up the pellet stove in October and ending early in May when we mothball it for the season. The latest cumulative usage numbers, for the end of February (9 months), are:

pellets 58 bags
electricity (net, beyond our PV) 473 kWh
propane 11% of 500 gal tank = 55 gallons

Extrapolating these numbers (which is not always linear, because some things, like PV output, vary a lot with the season) gives an estimate of total Year 5 energy use of:

pellets 76 bags = 24.9 MMBtu
purchased electricity 594 kWh = 2.0 MMBtu
propane 14% = 70 gallons = 6.4 MMBtu

ESTIMATE YEAR 5 TOTAL SITE ENERGY 33.3 MMBtu, 25% below last year and 63% below where we started.

In previous years my mid-season projections have been surprisingly accurate, but they are, of course, subject to the vagaries of the weather, which significantly affects both solar panel output (snow, clouds) and pellet use (temperature).

For perspective, we can calculate the Cabilow’s energy intensity if we come in at the projected 76 bags of pellets this winter:
bags x Btus/bag = 24,928,000 / (880 x 7772) = 3.64 Btu/sq.ft-HDD
(area x HDD)

What does this mean? Well, I don’t know how reliable it is, but I found mention on the web that you can use this number to rank how energy-efficient your house is. Supposedly only 1/8 of the housing stock comes in below 4 Btu/sq.ft.-HDD; 40% falls between 5 and 10, and the other half is worse. This, then, is a benchmark that makes me feel good about the impact of all the work I’ve done. Our little Cabilow may not look like much to some people, but it’s really a diamond in the rough, getting more and more polished all the time.

Heat Loss Analysis

I envy those folks who can afford one of those in-depth IR scans of their homes to show where the heat loss is. Not only do they get all sorts of valuable info, but the pix of their houses are soooo cool! I got some snapshots of missing insulation and heat leaking in from the attic with my utility-sponsored energy audit, but none of the deluxe whole-house stuff. So one cold night in January, I got a wild hair and thought, I’ve got an IR gun (Black & Decker thermal leak detector) — I wonder if I could use it to shoot a bunch of temperatures from both the inside and the outside of the house, and work up something of my own, just for me? I’m fairly deft at Photoshop, and math doesn’t scare me. This is gonna be fun!

Well, next thing I knew, I was tromping all around the cabin in my boots and pajamas taking temperature readings in the snowy dark. But I kept discovering exciting things! Sure enough, the old plain-glass windows in the sunroom were some of the warmest windows in the house from the outside — and the coldest inside. Major heat leak! (The ice was testament to that, but now the numbers also showed it.) I found that the outside walls of the bathroom were a degree or so warmer than any other cabin walls. And I knew why: those two walls are the only walls left that are insulated with 3-1/2” of fiberglass alone. I couldn’t install styrofoam on the inside because of lack of plumbing clearance, so the eventual plan is to beef up those 2 small walls from the outside (using breathable rock wool board because of the polyethylene sheathing in the walls). Here was something hidden in those walls that my little IR gun was confirming! What a gas!

Method

This was so much fun that I decided to attempt a whole-house heat loss estimate. Again, people usually pay big bucks for these and have them done on a computer, using software that considers the thermal impact of every stud. But a ballpark estimate can be done by hand using simple math, and from what I read, can come out just as close (within 30-50% of test results) as the computer analysis (within 50-100% of test) if done carefully. Well, that’s certainly good enough for me, and it’s free. This required breaking up the cabin’s envelope into zones, measuring their size, calculating an effective R-value for each (not as bad as it sounds, as I know those windows and walls intimately by now), and shooting temperatures from both the inside and the outside of the house.

Most online sources advise that the majority of the heat lost from a house is via conduction, such that radiation and convection losses are usually ignored. The heat loss equation is then

\[ \text{heat loss } Q = \text{Area} \times (T_{\text{in}} - T_{\text{out}})/R \]

Evaluating this for each zone, and summing them, gives an estimate of the Cabilow’s heating needs in Btu/hr. I was curious to see how close this would come to the heating value of the amount of pellets we’re
using. There are a lot of assumptions and simplifications involved in making an estimate like this, so I wasn’t expecting pinpoint accuracy.

**Breakdown by Cabilow Area**

I broke the cabin into 22 zones as shown on Figure 1. These are grouped together as windows, doors, etc. and the height of the bar indicates the relative heat loss in Btu/hr-sq.ft. Yellow indicates a zone with high heat loss per unit area, blue means low heat loss. This gives an indication of how well-insulated the various areas are. Walls and ceilings, for the most part, are looking pretty good.
It’s obvious that all but two of the high-heat-loss zones are windows. The exceptions are the back door and
the laundry floor. The door is such a heat hemorrhage that even though the sensor for our indoor/outdoor
thermometer is mounted 6 feet away, it reads 6º high in the wintertime.

However, the purpose of this analysis is to show me where I should focus my efforts next. Therefore, what’s
more useful to me is not the relative heat loss between zones but the absolute quantity of the heat loss. So
Figure 2 presents the same set of zones, but this time the height of the bar shows the total heat loss in Btu/hr.
The tallest — worst — ones are colored yellow, and are the items I have selected as work priorities.
Golden Acorn Heating Budget

When summed, the total heat loss across all zones is 7147 Btu/hr (see Appendix A). This is the Cabilow’s heating budget — the amount of incoming energy it needs to balance the outgoing heat loss when we keep the temperature “the way we like it.” This amounts to having the programmable thermostat on the pellet stove set to 69º at 9 am, 72º at 6 pm, and 60º at 11:45 pm. (More precisely, it represents the heat loss from the Cabilow when its interior temperature was around 70º and the outdoor temp was 20º on a night in late January, 2016, but we’ll call it close enough. This is not an exercise in designing for “worst conditions”.)

This heat, mostly, comes from wood pellets. There are other, lesser sources too, such as passive solar gain, standby losses from the water heater, and a 1500W Chihuahua that warms Allison’s bed; but again, supposedly these are usually ignored. I’m not so sure the solar contribution is trivial (see below), but let’s start with the simplification.

\[ 7147 \text{ Btu/hr} \times 24 \text{ hrs} = 171,528 \text{ Btu/day} \]

171,528 Btu = .523 bags pellets; actual pellet use during this time was .54 bags/day (ave over past month; see Fig. 6 on p. 14)

It may be blind luck, but that puts the calculated value within 4% of the actual measured value. This tells me that I am most likely somewhere in the ballpark. It also suggests that the effective R-values I used for the zones are realistic.

Now, in truth, we do not receive the full heating value of the pellets we burn — approximately 15% of the heat goes straight up the chimney. So multiplying our pellet usage by the efficiency of the stove (~85%) gives us the heat that the Cabilow actually garners from those pellets:

\[ .54 \text{ bag/day} \times .85 = .459 \text{ bag/day heat received} \]

Leaving a \[ .523 - .459 = .064 \text{ bag gap between the two data sets (20,992 Btu/day or 875 Btu/hr)} \]

This is about 12%. Again, it is not a bad match, even if it is entirely due simply to a discrepancy in the two data sets. Moreover, it is possible that it can at least partially be explained by passive solar gain. In January, with the weather and at the latitude of Denver (40 ºN), one m² of ESE-facing vertical surface will collect (on average) 3.51 kWh/day of sunshine. We have just about 5 m² of windows on that side, which should make 17.55 kWh (59,883 Btu) of solar energy theoretically available. Since

\[ 59,883 \text{ Btu} > 20,992 \text{ Btu} \]

by about a factor of 3, the possible solar gain is obviously enough to close the gap (even if the unknown SHGCs are taken into account). As mentioned above, I’ve read that passive solar gain is typically ignored. Perhaps in a bigger, more typical house, without the earth-sheltering and sunspace, this is appropriate. But if you look at Fig. 4 (p. 11), you can see the cabin’s indoor temperature rising and falling with the sun when the pellet stove is off — something it wouldn’t do (in the wintertime) if the passive solar input were negligible.

Regardless of exactly how close the theoretical and empirical numbers are, they clearly support each other with respect to the general neighborhood in which the Cabilow’s heat budget lies.
Meanwhile, back at the ranch...

Most of the energy cut necessary to make our 1000 Home threshold will have to come from our pellet usage, because we’re pretty low already on both electricity and propane. The best we can probably hope for next year (Year 6) is 60 gallons of propane and net zero on the electricity. I think that’s optimistic but doable. Then we’d need to get down to a little over one ton (59 bags) of pellets for the winter, which is about 80% of our current usage. That means cutting \( \frac{1}{5} \) off of our approximately 7000 Btu/day heating budget (~1400 Btu/day). This is where the information in Fig. 2 becomes helpful.

The following five areas need attention:

1) Broken sunroom window: the large fixed window in the sunroom cracked in November, and it wasn’t convenient to open up a 3’ x 10’ hole in the house at that time of year, so we’ve gone thru the whole winter with it broken. Dave (my carpenter) wants to wait till late in April to fix it, when things will be drier and there’ll be less chance of snow. The replacement windows are going to be a pair of fixed panels flanking a 3’ square awning window, brand-new snagged from the salvage yard for $50. This little gem is a vinyl window with a U-factor of .26 and a light charcoal tint. What a find, eh? The operable window in the middle will give us some additional ventilation, which is always nice, and the support posts between panels will be positioned much better structurally than they are now. This big window biting the dust may be a blessing in disguise, because it’s been a huge heat sink and now I can justify replacing it with something better.

2) Back door: I had no idea how bad this was. I knew it was old (original to the house), and I’d weatherstripped it the best I could, but it really needs to be replaced. However, it’s a nonstandard size, so I’ll need a custom door, and when I bought a new custom-size door for the vestibule entrance 5 yrs ago, the whole kit and caboodle cost me a grand. Thus we’ll live with it unless and until the money loosens up. I thought I’d attach a piece of polyiso to the outside of the back door, where it’s not in anyone’s way, to quell the heat loss in the interim.

3) Laundry floor: When I fixed up the laundry room, I was a lot greener, and I put vinyl tiles right over the concrete floor. I’d read somewhere that heat loss from basement and slab floors wasn’t much so insulating them was a waste of time, and I believed it. Now I’ve lived with that cold floor for 4 years, and it’s a terrible heat sink. I think that info was bogus. So the plan is to go back there and lay a new floor that is 2” of styrofoam over the concrete topped with reclaimed flooring from the salvage yard.

4) Rest of ceiling: This means the main ceiling, exclusive of the add-on ceilings of the sunroom and vestibule, which are not open to the attic, and the laundry ceiling, which is concrete. In other words — the ceiling that can be accessed from the attic. We already have quite a bit of fiberglass up there (a base layer of rock wool topped by two 6-inch fiberglass layers near the eaves, and three 6-inch layers over most of the middle), but Megan, the energy auditor, looked it over and said that the bottom layer of fiberglass (installed by previous owner) was not done well and should be redone. I also now know about the need for foaming cracks in the attic before covering them with insulation, which I didn’t know before. And, I happened to be at the salvage yard just after they’d unloaded a truck bringing 4 huge bags (new & unopened) of unfaced R-30 fiberglass batts. Stuff like that does not hang around long, and I’d been figuring on picking up some more fiberglass to complete the 3rd layer — and they only wanted $10/bag for these ($90/ea retail at Home Depot). So those are now stuffed up in the attic, waiting to be installed. This is going to be a nasty task, so I figure on picking away at it as the season unfolds and the temp in the attic becomes comfortable.

5) Floor/crawl: This one’s the biggie. Between the original 1” tongue-and-groove pine planking, the 3/4” plywood laid over it as carpet backing when the cabin was rented, and the 5/8” bamboo we installed,
the floor is about 2-1/2” of wood. But there’s no way to directly insulate it. The crawl space is unvented, inaccessible, and so low in places that no human could get in there to do an insulation retrofit. Thus, if heat loss thru the floor is to be curtailed, it must be done in some other manner. A top-secret stealth plan to stem some of this heat loss is currently being finalized, and will be revealed at such time as empirical data sufficient to evaluate its effectiveness becomes available.

Fig. 3 shows the zone data again, but this time with the action items paired with an estimate of how much energy we might save after each one is addressed. The savings are calculated based on educated guesses of, say, the increased R-value of a window after the quilt is made, or of the laundry floor after the styrofoam has been installed. So they are halfway reasonable numbers, but still guesses. The top bar totals up to between 1900 and 2000 Btu/hr, more than the 1400 we need to cut. However, I’m not so optimistic as to think that each measure will yield the maximum savings I project. For planning purposes, I’ll assume that the across the board savings are ~50% of what’s calculated, or something in the neighborhood of a cumulative 1000 Btu/hr. That’ll still put us most of the way there.

**Golden Acorn Plan of Attack**

*Based on heat loss analysis*

![Figure 3.](image-url)
Comparison to Original Reduction Matrix

Just for fun, I thought I’d compare our energy breakdown to the guesstimated allotments both I and the THC algorithm projected in the application’s Reduction Matrix. We’re not there yet, but we’re getting close enough to draw meaningful comparisons.

Our current breakdown (end yr 5 est):

- pellets 76 bags = 24.9 MMBtu = 7306 kWh (75%)
- purchased electricity 594 kWh = 2.0 MMBtu (6%)
- propane 70 gallons = 6.4 MMBtu = 1876 kWh (19%)

My original predictions:

- purchased electricity 1935 kWh (27%)
- pellets + propane 18 MMBtu = 5275 kWh (73%)

THC algorithm predictions:

- heating (= pellets) 4375 kWh = 14.9 MMBtu, or 45 bags (60%)
- hot water (= propane) 1318 kWh = 4.5 MMBtu or 49 gallons (18%)
- all else (= electricity) 1574 kWh (22%)

Both the THC algorithm and I guessed high on the electricity and low on the others, compared to where we are tracking now. We have found electricity relatively easy to conserve on, especially when we tighten up on a few things at a time over a period of years. This past year we focused on turning computers off and using the clothesline when possible. (I also diligently gave the snow rake a few more tries, but that hasn’t been such a resounding success.) Hot water is difficult, as we’re already so low on usage, and replacement heater options are seriously limited. We have low-flow fixtures, keep the temp at 110º, do not shower every day, and wash the laundry on cold. The burner rarely comes on; mostly the pilot light heats our water. Wood pellets depend a lot on both the progress of my insulation work and the weather — there is, however, some malleability left here, as the next section will detail.

“Heat Off” Experiment

One night around 10 p.m., Calcifer (our pellet stove) ran out of pellets, and there were no more in the house. I wasn’t inclined to trudge out to the car in the dark and snow, and the heat would be going off for the night soon anyway, so I just went to bed.

I asked Allison the next morning if she’d please bring in a bag of pellets. It was midafternoon before she did; the sun was streaming in thru the windows, and we weren’t cold. I was busy and didn’t get around to filling the hopper for awhile. Before I knew it, darkness was descending and we hadn’t had the pellet stove on all day. In January. Now, Colorado winters aren’t as severe as many people think (the Hg does, truly, rise well above 0°F most days, even in the mts), and it had been above 40º that day, but it would go well below freezing at nighttime. I’m used to heating a house all winter. But I had been watching the temperature. It had risen in the morning with the sun, without any supplemental heat. I knew it would drop at night, it always did; but the stove was set to come on at 60º. What if I turned the stove off altogether? At this time of year? How low would it go? What kind of effect, if any, would I see from all my insulation work?
I had to promise Allison that if it got down to 55 inside, we’d call it off. (As it turned out, we stopped at the onset of a major winter storm, not wanting to head into a possible power outage with a cold house.) I don’t like these cold temperatures either, but this was in the name of science. So — off the pellet stove went. This is portrayed in Fig. 4.

The second day was sunny like the first and even a little warmer, so the indoor temperature rose with the sun and then began to fall after midday. Late in the afternoon, the cold front moved in. You can see the temperature drop as night comes on, and the overnight low was in the teens. But remarkably enough, during this whole time, the Cabilow maintained an even temperature between 58 and 63°F, never going above, never below. It’s possible that it would cool down more if the test were run longer, but any further cooling would certainly be quite slow. Even when it was snowing, the cabin gained a little passive solar heat, and on sunny days, it was enough to raise its interior temperature several degrees. And the thermal mass of the hill provides so much buffering that it makes the cabin largely insensitive to changes in the temperature outside, now that essentially all the styrofoam is installed. Theoretically, the cabin would cool down (if the heat stayed off) until the passive solar gain balanced the heat loss, and then the temperature would stabilize. My back-of-the-envelope calculations suggest that this is likely around 54° (temp of hill is 49.8°). So even...
though we’re warm wimps and can’t take 55, or 54, degrees ad infinitum, I have to admit that it is a perfectly habitable temperature temporarily if one prepares for it. Who hasn’t gone camping when it got colder than that? (Try the North Slope of Alaska, even in July. At least, 20 years ago it was still cold.) So in truth, if we really had to, we could live here throughout the entire winter without any heating system at all other than popping the window plugs in and out at the right times. Wild, eh?

Ok, so that’s interesting, but can it juggle? Oops, I mean, is that knowledge good for anything? Well, in fact, yes, it is. I had missed the early hours of the cabin cooling off because it was overnight, so I ran that part of the experiment again later, resulting in Fig. 5. Now I wanted to know how the Cabilow’s cooling performance compared to other houses, good, bad, or indifferent. I had no idea how difficult it would be to find this information. It was even hard to find people blowing smoke without any data, and that’s usually a cinch. Articles — still looking. Graphs — forget it, practically nonexistent. I found two: one from an R-2000 house in Canada and one from a condo in San Diego. Each only covered a few hours, and neither house was very much like mine, but at least they gave me some ballpark comparison data. The Canadian house lost 2.5°C over a 4 hr period, or .625°C (1.1°F) per hr in the first 4 hrs, with an outside temp of -8.5°C (17°F).

It’s important to specify the outdoor temp and the time period over which the data was taken when discussing the heat loss rate — although this is rarely done — because that rate (slope of the curve) is not constant, but continuously decreasing as the temperature gap closes. The condo in San Diego also lost about a degree an hour during the first few hours, but the outside temperature was not as cold — 38°F. He kept the heat off, and his house stabilized and then cycled with the sun between 54º and 61º for the rest of the day, but the outdoor temperature averaged about 50 — only 7º below the inside temp — during that time.

The Cabilow’s cooling curve, Fig. 5, shows that it lost 3.1º the first hour, then 1.6º the second, .8 the third, and 1.2 the fourth. If averaged, this would be 1.7º/hr, on an evening with an outdoor temp in the low 20ºs. Over the 7 hour experiment, the total loss was 8.5º, an average of 1.2º/hr. This is the worst performance of the 3 houses, but I do not feel bad about it. In fact, I feel pretty good. One dwelling was a condo in San Diego, a climate very much milder than ours. It was in the winter, but a southern California winter can’t shake a stick at January in the Colorado mountains (even if it’s not as frigid as flatlanders imagine). Also, he did not say what kind of condo it was, but it probably shared walls with other units. So the fact that his house cooled more slowly than mine is not at all surprising. And the other house was a Canadian R-2000 house. I don’t know exactly what this is, except that I gather it’s some sort of beefed-up energy-code house, so it would be expected to perform well. Over the first 4 hours, with only slightly warmer outdoor temperatures, the Golden Acorn cooled about 50% faster than the R-2000 house. I don’t think that’s half bad, considering:

- the Cabilow was built in 1929 and the R-2000 house was built recently
- all air sealing and much insulation work had to be done to the cabin as retrofit, whereas this was built-in to the R-2000 house
- none of the cabin work (except a few window installations) was done by pros, whereas the R-2000 house was presumably designed and constructed to highest standards and “best practices”

Besides just being interesting, these experiments made me realize just how stable our little Cabilow has become. Back when we moved in, if the furnace wasn’t running all winter, you froze. In fact, most places that I’ve lived, that was so. Maybe the furnace wasn’t heating every minute, but it sure better be on, and you’d hear it cycling in the background if you cared to listen. If you came home after being out while there was a power outage, the house was always cold. That’s just the way it was in winter. But not any more. We can turn our pellet stove off for hours, and the temperature inside will only drop a few degrees; maybe not at all, if it’s sunny. Our consciences have struggled with not being able to handle turning the thermostat way down, to 58º or 62º or even 65º, to save pellets. It just makes us too uncomfortable. But the “heat off”
experiment showed us an alternative that would accomplish the same thing. If Allison is at work, I turn the stove off if I don’t need it: if I’m moving around enough to be warm, if a lot of sun is coming in the windows, if I’m napping, or if I go out. Then when I need it again, or Allison gets home, I turn it back on. It usually only takes an hour or less to get the cabin toasty warm, which is little bother for all the energy we save. Fig. 6 shows our pellet usage throughout the winter, a week at a time. Where it says “new routine” is when we started turning the heat off when we don’t really need it. After a month of that, we’ve cut 40% off our pellet usage without touching the thermostat and without feeling any hardship!
Now, Punxsutawney Phil did prognosticate an early spring this year (we watched him on YouTube), but it’s the marmots in the mountains here that foretell our weather. And Feb. 2 saw us in the middle of a blizzard that dropped 16” of snow on the Golden Acorn and twice that on the high country. Those marmots couldn’t even dig their way out of their holes to look for the sun, let alone be scared by any shadows it didn’t cast! It started warming up the very next week, and things in the garden are greening already. The couple of snows since then have melted in no time. So I looked at the HDDs in hopes of teasing out how much of the 40% pellet savings might be due to warmer weather and how much to conservation. It turned out to be a roughly even split, 18% warmer weather and 22% because of turning the furnace off sometimes.

Figure 6.

*No pellet use during “heat-off” experiment saved about one bag.*
This is important, because it’s exclusive of the action items enumerated above. An across-the-board 20% cut in pellets, if started at the beginning of the winter, would have shaved ten bags off what we’ve used so far, and put us very close to our 1000 Home threshold. It’s exactly what I calculated would be necessary to meet that goal next year, if we hold propane to 60 and electricity to what our solar panels produce. Under those circumstances, any energy savings from the 5 action items would be a bonus — or a buffer — wiggle room, so to speak. If we apply our 50% factor to this savings too, and only expect it to get us a 10% “heat off” savings next year, that’s 700 Btu/hr. Our total heating budget next year would then be expected to be

\[
\text{current budget} - \text{savings} = \text{new budget}
\]

\[
7000 \text{ Btu/hr} - 700 = 6300 \text{ Btu/hr}
\]

\[
6300 \text{ Btu/hr} \times 24 \text{ hrs} = 151,200 \text{ Btu/day} = .46 \text{ bag/day}
\]

This is the Cabilow’s heating budget during the cold months (like January). It can’t be projected forward linearly to the entire heating season, because it’s not the same during the warmer parts of the winter. Applying a scaling factor (90% = 6300/7000) to the whole heating season may give us at least a ballpark figure:

\[
90\% \times 76 \text{ bags} = 69 \text{ bags of pellets}
\]

This is an estimate of how many bags of pellets we’d need if we did the “heat off” procedure, but fixed none of the action items. If we address all action items, and get half the calculated savings, that’s another 1000 Btu/hr:

\[
6300 - 1000 = 5300 \text{ Btu/hr}
\]

\[
5300 \times 24 \text{ hrs} = 127,200 \text{ Btu/day} = .39 \text{ bag/day}
\]

Applying the scaling factor (5300/7000) to estimate bags per winter:

\[
(53/70) \times 76 \text{ bags} = 58 \text{ bags of pellets}
\]

That’s IF everything goes according to plan, AND if I get all those things done by next year without any more medical emergencies! So if all goes well, in Year 6 (May 2016-June 2017) maybe, juooottt maaaybe, we’ll have:

- Propane - 60 gal = 5.5 MMBtu
- Electricity - all covered by PV
- Pellets - 58 bags = 18.9 MMBtu

Total = 24.4 MMBtu (7151 kWh) < our THC threshold, which is 24.8 MMBtu or 7268 kWh. That’s under the wire with a few Btus to spare, and with discounting all calculated savings by 50% (and with good weather, and good luck). So maybe next year?
Where to Now?

This project started out little and ballooned. It was so much fun, and I kept discovering such fascinating things at every turn, that I just couldn’t stop. But I’ve come to the natural end of the analysis I set out to do: figure out what my priorities should be henceforward. I’ve played with my numbers and made all sorts of pretty graphs, and they’ve spoken to me. This is what they’ve said:

- Work on that floor/crawl heat loss. It’s troublesome but significant. It’s not make-or-break, but any savings here will make everything else easier. (Plan in the works, as mentioned.)
- Get that sunroom window fixed as soon as Dave will do it. All preliminary footwork already done.
- Laundry room floor should be done ASAP and would be a good thing to work on in the summer when it’s too hot to work outside.
- Start on the attic when it warms up, but don’t fret about it. It’s really not performing all that badly. Other things are higher-yield per amount of aggravation.
- Work on window plugs and quilts as time permits. The big windows really need them.
- Keep on turning the pellet stove off whenever possible. In and of itself, this is probably the single-most important item to be diligent about.

Finish all these before starting on bathroom walls. That’s a big job that can only be done in the summer, and the small size of the walls means the $\sum$ heat loss is $<$ than for the items above. It’ll be nice to quit worrying about the pipes freezing, but otherwise it’s unlikely to make a large change to the overall heat balance.

Onward and upward!
## HEAT BUDGET DATA

<table>
<thead>
<tr>
<th>location</th>
<th>T&lt;sub&gt;in&lt;/sub&gt; °F</th>
<th>T&lt;sub&gt;out&lt;/sub&gt; °F</th>
<th>ΔT</th>
<th>~R value</th>
<th>A sq.ft.</th>
<th>Q, Btu/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>front door</td>
<td>40</td>
<td>27</td>
<td>13</td>
<td>2</td>
<td>22</td>
<td>143</td>
</tr>
<tr>
<td>back door</td>
<td>55</td>
<td>32</td>
<td>23</td>
<td>2</td>
<td>17.6</td>
<td>202</td>
</tr>
<tr>
<td>vestibule window</td>
<td>41</td>
<td>20</td>
<td>21</td>
<td>2</td>
<td>5.9</td>
<td>62</td>
</tr>
<tr>
<td>cracked sunrm</td>
<td>52</td>
<td>28</td>
<td>24</td>
<td>1.6</td>
<td>56.8</td>
<td>552</td>
</tr>
<tr>
<td>new liv rm</td>
<td>45</td>
<td>27</td>
<td>18</td>
<td>2.13</td>
<td>15</td>
<td>128</td>
</tr>
<tr>
<td>bathrm Al</td>
<td>49</td>
<td>32</td>
<td>17</td>
<td>1.6</td>
<td>4.9</td>
<td>52</td>
</tr>
<tr>
<td>NW w/plug</td>
<td>61</td>
<td>25</td>
<td>38</td>
<td>5</td>
<td>8</td>
<td>61</td>
</tr>
<tr>
<td>vest E wall</td>
<td>47</td>
<td>21</td>
<td>26</td>
<td>11</td>
<td>63</td>
<td>149</td>
</tr>
<tr>
<td>sunrm walls</td>
<td>60</td>
<td>20.5</td>
<td>39.5</td>
<td>20</td>
<td>29</td>
<td>57</td>
</tr>
<tr>
<td>liv rm wall E</td>
<td>64</td>
<td>20.9</td>
<td>43.1</td>
<td>20</td>
<td>62</td>
<td>134</td>
</tr>
<tr>
<td>liv rm wall N</td>
<td>64</td>
<td>21</td>
<td>43</td>
<td>20</td>
<td>110</td>
<td>237</td>
</tr>
<tr>
<td>bathrm wall E</td>
<td>59</td>
<td>21.6</td>
<td>37.4</td>
<td>11</td>
<td>16</td>
<td>54</td>
</tr>
<tr>
<td>bathrm wall S</td>
<td>59</td>
<td>22</td>
<td>37</td>
<td>11</td>
<td>42</td>
<td>141</td>
</tr>
<tr>
<td>hill fdn wall</td>
<td>63</td>
<td>49.8</td>
<td>13.2</td>
<td>7.5</td>
<td>180</td>
<td>317</td>
</tr>
<tr>
<td>exposed W wall</td>
<td>63</td>
<td>21</td>
<td>42</td>
<td>20</td>
<td>155</td>
<td>283</td>
</tr>
<tr>
<td>laundry walls</td>
<td>58</td>
<td>49.8</td>
<td>8.2</td>
<td>7.5</td>
<td>182</td>
<td>199</td>
</tr>
<tr>
<td>laundry roof</td>
<td>58</td>
<td>21</td>
<td>37</td>
<td>7.5</td>
<td>63</td>
<td>311</td>
</tr>
<tr>
<td>laundry floor</td>
<td>58</td>
<td>49.8</td>
<td>8.2</td>
<td>1</td>
<td>63</td>
<td>517</td>
</tr>
<tr>
<td>sunrm ceiling</td>
<td>60</td>
<td>21.2</td>
<td>38.8</td>
<td>10</td>
<td>40</td>
<td>155</td>
</tr>
<tr>
<td>vest ceiling</td>
<td>47</td>
<td>20</td>
<td>27</td>
<td>9.5</td>
<td>40</td>
<td>113</td>
</tr>
<tr>
<td>rest of ceiling</td>
<td>65</td>
<td>40</td>
<td>23</td>
<td>38</td>
<td>700</td>
<td>424</td>
</tr>
<tr>
<td>floor/crawl</td>
<td>60</td>
<td>49.8</td>
<td>10.2</td>
<td>2.5</td>
<td>700</td>
<td>2856</td>
</tr>
</tbody>
</table>

\[ \Sigma \quad 7147 \]
HEAT OFF EXPERIMENT — Jan. 28 - 31, 2016

<table>
<thead>
<tr>
<th>hours</th>
<th>T&lt;sub&gt;in&lt;/sub&gt;, °F</th>
<th>T&lt;sub&gt;out&lt;/sub&gt;, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>70</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>10</td>
<td>58</td>
<td>34</td>
</tr>
<tr>
<td>16</td>
<td>62.5</td>
<td>44</td>
</tr>
<tr>
<td>18</td>
<td>61.5</td>
<td>-</td>
</tr>
<tr>
<td>27</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>36</td>
<td>59.6</td>
<td>49</td>
</tr>
<tr>
<td>39</td>
<td>61.7</td>
<td>51</td>
</tr>
<tr>
<td>43</td>
<td>61.5</td>
<td>39</td>
</tr>
<tr>
<td>48</td>
<td>60</td>
<td>24</td>
</tr>
<tr>
<td>52</td>
<td>58</td>
<td>24</td>
</tr>
<tr>
<td>55</td>
<td>58</td>
<td>22</td>
</tr>
<tr>
<td>57</td>
<td>58</td>
<td>18</td>
</tr>
<tr>
<td>60</td>
<td>58</td>
<td>25</td>
</tr>
<tr>
<td>63</td>
<td>59.1</td>
<td>25</td>
</tr>
</tbody>
</table>

COOLING CURVE — February 6, 2016

<table>
<thead>
<tr>
<th>hours</th>
<th>T&lt;sub&gt;in&lt;/sub&gt;, °F</th>
<th>temp drop, °F, since prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>66.9</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>65.3</td>
<td>1.6</td>
</tr>
<tr>
<td>3.5</td>
<td>63.7</td>
<td>1.6</td>
</tr>
<tr>
<td>4.5</td>
<td>63.0</td>
<td>0.7</td>
</tr>
<tr>
<td>5.25</td>
<td>62.2</td>
<td>0.8</td>
</tr>
<tr>
<td>6</td>
<td>62.1</td>
<td>0.1</td>
</tr>
<tr>
<td>7</td>
<td>61.7</td>
<td>0.4</td>
</tr>
</tbody>
</table>
I nearly cried when they announced that everyone had approved the Paris Agreement. I know it’s only a start, but I really believe in my heart that now we, as a World, are going to save our planet. I was really worried about that for a long time. I still worry about how much damage will be done before things stabilize, and am fully aware that this is not a time to rest on our laurels but to throw ourselves whole-hog into this critical work. But I don’t feel like I’m helplessly watching Armageddon unfold any more. Nay, I’m materially participating in one of the most important times and events in history.

It came out of COP21 that we need to batten down the hatches and head full sail for complete decarbonization by mid-century, and that this requires us to cut CO$_2$ emissions by 7% a year, starting right now. Of course there are all the pessimists saying it can’t be done, or it can only be done with all the gold in Ft. Knox, yadda yadda. Well, since moving to the Cabilow 5 years ago, I’ve learned a lot about energy and how to conserve it, enough I think to have something valid to say on the subject. And what I want to tell the naysayers is this: take off your black glasses, roll up your sleeves, grab a can of foam, and let’s get to work! I started with an old cabin that was home to mice and spiders, overgrown by chokecherries, had a leaking roof and a busted well, and was hours away from foreclosure, and despite frequent migraines, a perforated ulcer, and three surgeries for a twice-ruptured colon, in less than five years I’ve insulated, air sealed, and fixed up that cabin so that it performs on par with a good many respectably-energy-efficient houses. Over a four year timespan I’ve averaged a 22% energy reduction per year, and that includes the past two years, much of which I spent recuperating (while finishing my fourth book, a global warming novel). So don’t tell me it can’t be done. And don’t give me that Ft. Knox crap either. I shop at the salvage yard.

The singlemost unexpected revelation I’ve had in doing the Cabilow energy renovation is how easy it is. There is not one single thing I have done that has been difficult, beyond carting around unwieldy items like big pieces of styrofoam or rolls of insulation. Probably the worst job has been laying fiberglass in the attic. That’s not difficult, but it is nasty. I’m lucky that even at 60 I’m still flexible, so the confines of the attic don’t bother me nearly as much as all the dust, and sweating and itching behind a dust mask. Grunge work, but not hard. Why do so many people think this stuff is difficult, even to the point of being undoable? What’s so hard about it? Just that you have to be persistent and careful? You need those traits for a lot of things in this life. Honestly, it just is not all that hard to fix up an older house, once you understand what needs to be done. We used to have $400 wintertime utility bills at our previous house in town, a 1963 ranch. It was a bigger house, but we’d added fiberglass to the attic, had cellulose blown into the walls, replaced the windows, turned down the thermostat, and none of it seemed to help much. By now I can look back and say, “No one ever mentioned any air sealing. The north wind probably whipped right through the cellulose in those walls.” Without that knowledge, we were at a loss as to how to fix it.

Understanding and commitment. Then it’s really not hard at all. If an old bag like me can manage 22%, 7% a year should be a breeze.