Taylorville High School Pretty Good House Project

Status Update and Report 2 – PGH Annual Energy and Comfort Conditioning

Figure 1 October 10, 2023 installation of ICCF (Insulated Composite Concrete Form) walls by Taylorville High School students.

This article describes annual energy use and “design day” heating, cooling and dehumidification requirements for the Taylorville High School Pretty Good House (THS PGH) project. An update of project activities describes THS PGH team’s continuing progress.

What a Difference a Month Makes!

Figure 2 November 15, 2023 photo of THS PGH work site. Follow Matt Blomquist's build_learn_teach instagram site to watch the progress as it happens. Solar power from the work shed powers house construction activities!

Matt Blomquist's Taylorville High School students have been very busy. Since our October 10 visit when students were setting ICCF (Insulated Composite Concrete Form) blocks (see Figure 1), concrete has been poured in the foundation walls, gravel spread over crawl space floor, floor joists and subflooring are installed, and double-stud walls are being erected.

Figure 3 Matt Blomquist isnttructing his students on installing double stick mastic for sealing crawl space poly film to ICCF foundation wall.

Follow Matt's Instagram site for day-to-day progress. The site is a nice activity diary and includes Matt's expert description of building materials and construction processes.

November 15, 2023 visit was a beautiful day to visit the site, although we spent the afternoon in the crawl space. If you're going to be in a crawl space for an extended period of time, this is the one to be in. Dimple matting placed over the gravel is easy on the knees. Air in this "inside" crawl space will be healthy with radon removal and CERV2 ventilation!

No insulation is placed under the dimple matt and poly barrier sheeting, saving cost and beneficially coupling the house to the ground's thermal mass. Insulated ICCF foundation walls provide the heat loss barrier to outside temperatures. The soil's thermal mass helps to stabilizes house indoor temperature. As in Equinox House, coupling the house interior to the ground's thermal mass prevents the house interior from ever dropping below freezing. Ground coupling does not impact house comfort (ie, floors are not cold!). Beyond our three dimensional, transient computer modeling of house-ground performance, Build Equinox has several years of data to prove it.

Figure 4 Students working to tape and seal poly sheeting.

Students will continue installing double stud framing, with a goal of installing roof trusses by Thanksgiving.

Figure 5 THS afternoon class. A great group of future builders ready to construct their community's next generation of healthy, high performance, net zero homes!

PGH Design – Using ZEROs for Economics, Energy, and Comfort Conditioning Modeling:

PGH is based on economically optimized design of a home's components and systems. Home insulation, comfort conditioning system, lifetime cost, monthly financing, indoor air quality, and more should be addressed simultaneously. For example, economically optimized wall insulation depends on heating and cooling components efficiency and utility cost.

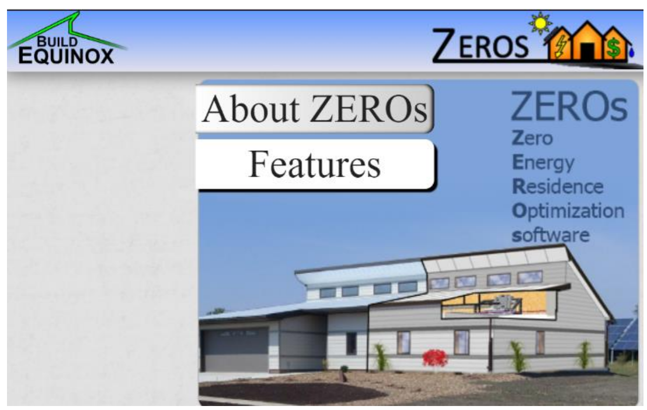

Figure 6 Build Equinox ZEROs online, free-to-use modeling suite includes economic optimization, financing, solar array sizing, comfort conditioning capacity (Manual J) and more!

Our report series compares performance and economics of three identical looking homes built by Contractor Loose, Contractor Tight and Contractor Smart. Physical descriptions of the three homes (insulation R-values, window performance, infiltration, etc) are included in the first THS PGH report.

Build Equinox ZEROs (Zero Energy Residential Optimization software) is used for all analyses. Next month's article will describe how to use ZEROs for "Manual J" room-by-room modeling of space conditioning loads. ZEROs' 500 North American international locations makes it easy to determine how the THS PGH would perform in Wuhan, Frankfurt, and Istanbul as well as in Taylorville Illinois.

ZEROs is free-to-use, online building simulation software developed by Build Equinox. We developed it as an important part of our research to understand interaction and inter-dependence of all building systems. Our interest in sharing ZEROs is to help designers create accurate models of home performance, providing critical information beyond simple energy analyses. We're all in this together, and better designed and better constructed homes makes our work to keep us healthy easier.

ZEROs is the only software we are aware of that incorporates economics (life cycle cost), finance (monthly costs), and optimization tools with energy, moisture, solar design, and comfort conditioning capacity (aka, Manual J) analyses into one modeling package. Zeros is easy to use, and once you become familiar, you will be cranking out design analyses in minutes. ZEROs has been vetted with DOE's BESTEST and extensively compared to field data.

In our first THS PGH article, we compared first cost, life cycle cost, and monthly cost of conventional, improved, and PGH house constructed homes. We introduced Contractors "Loose", "Tight", and "Smart" who build three levels of construction quality. All three homes "look" the same. Anyone walking into each of the homes would think they are identical, but after a year or so of living in the homes, significant differences are apparent.

Contractor Loose has the lowest first cost, and lures unsuspecting buyers into their "better" deal. Ignorance is Contractor Loose's ally, with Contractor Loose avoiding discussions of lifetime costs, incursion of wildfire smoke, high utility bills, and poor indoor air quality. Perhaps buyers of Contractor Loose's home will renovate their "Loose" home after learning how much better it could be when talking to neighbors living in a Contractor Smart home?

Contractor Tight states that their house is higher quality than Contractor Loose's, with lower blower door ACH level, and touts the additional insulation levels. Contractor Tight also notes that Contractor Smart has gone overboard with excessive insulation that will never pay back. Tight comments that that CERV2 ventilation thing is overly complicated, and Tight states that their homes don't smell. Tight states that solar panels on Smart's homes will never pay for themselves, either. Of course, Tight has no data to back the claims.

Contractor Smart has taken time to understand the fundamentals of a healthy indoor environment, and knows that Smart ventilated homes help home occupants to avoid heart attacks, stroke, dementia, and depression as well as minimize asthma, allergen and other chronic and acute impacts of unhealthy, but non-odorous air quality.

Contractor Smart hires an architectural design team that uses ZEROs to develop economically optimized homes for their climate. Contractor Smart uses ZEROs graphical and tabular output results to explain to prospective buyers how their PGHs have a lifetime cost that is 50% less than Loose's house and 40% lower than a Tight house. And, Contractor Smart explains how a higher mortgage for Smart homes is countered by reduced energy bills resulting in total monthly payments that are lower than both Loose and Tight homes. "Invisible" benefits of Smart homes, such as enhanced durability and inherent freeze protection are also discussed.

<u>THS PGH Annual Energy and Comfort Conditioning Characteristics:</u>

In addition to the best economic and financing performances, Contractor Smart homes are the best performing from energy and comfort conditioning bases. The use of heat pumps for comfort conditioning and water heating coupled with CERV2 "smart" ventilation (sensing air quality, and fresh air ventilating at the level needed when it is needed) combine to lower annual energy to less than 1/3 of Loose and Tight home energy requirements. And, Smart's home is healthy, which can be proven at any time on any day with CERV-ICE ("service", CERV-Intelligently Controlled Environment), our online air quality and comfort monitoring dashboard.

All three homes are assumed to have 3 occupants in the 1700sqft home, as shown in Table 1. Contractor Loose does not spend any significant time sealing his house because his town does not require homes to reach any specified level of sealing. Contractor Tight lives in a town that specifies new construction homes must achieve 3ACH50 (3 air changes per hour at 50Pa blower door pressure difference), and so his crew puts in sufficient effort to reach that level. Contractor Smart knows that sealing is important for managing outdoor particulates such as wildfire smoke as well as improving energy performance, and works to achieve 1ACH50 or lower, regardless of local building codes.

Table 1 also shows ventilation air flow for each home, which is a combination of infiltration and ventilation. Ventilation air flow impacts carbon dioxide concentration and occupant IAQ dissatisfaction. Contractor Loose's home, on average, has 72cfm of infiltration air moving through the house under average wind conditions. 100% of Loose's home's "fresh" air is infiltration air that passes through Loose's construction flaws. When it is not windy, infiltration is low, worsening indoor air quality, while high wind conditions excessively ventilate the home, worsening energy performance and filling the house with wildfire smoke and other outdoor particles. Average CO_2 concentration Loose's home is 1064ppm is equivalent to ASHRAE 62.2's inadequate odor-based ventilation standard. 20% of the general populace would say they are dissatisfied with air quality in Loose's home.

Contractor Tight and Contractor Smart both install fresh air ventilation systems. Contractor Tight installs an unbalanced "exhaust" ventilation system that provides no energy recovery while Contractor Smart's home has a CERV2 smart ventilator. CERV2 smart ventilation efficiently provides fresh air to a home when needed by sensing air quality (CO_2 and VOCs). When fresh air is required, the CERV2 efficiently exchanges energy when beneficial, between incoming fresh air and outgoing stale exhaust air. When fresh air is not required, the CERV2 spends its time in recirculation, providing whole house MERV13 filtration and movement of fresh air “stored” in unoccupied rooms to occupied rooms for more efficient use of ventilation air.

Although Table 1 shows average CO_2 levels in Contractor Tight and Contractor Smart homes are similar, there are significant differences in actual air quality. Contractor Tight’s home, as is true for all constant flow ventilation systems, provides too much fresh air when the home is unoccupied, and not enough fresh air when the home is occupied. Contractor Smart’s home provides higher fresh air flow when occupants are home, and reduces fresh air flow when no one is home.

Table 1 Occupancy, ACH50, total ventilation, %infiltration, CO_2 and IAQ dissatisfaction comparisons of Contractors Loose, Tight, and Smart homes.

	Occupants	**ACH50**	**AirFlow(cfm)**	**%Infil**	**CO2 (ppm)**	**IAQ Dissat**
Loose	3	6	72	100	1064	20
Tight	3	3	111	32	827	14
Smart	3	1	124	10	782	13

Table 2 compares annual electric energy consumption for the three contractors. Contractors Loose and Tight install electric resistance heaters while Contractor Smart installs a heat pump that uses three times less energy than electric resistance. The CERV2 smart ventilation unit’s heat pump contributes a significant amount of space heating and cooling, which is shown in the ventilation column in Table 2.

As homes are sealed, moisture management becomes more important, as seen by the difference of dehumidification energy usage in Contractor Loose and Contractor Tight homes in Table 2. Although Contractor Smart’s home is even more sealed than Tight’s, the CERV2 contributes to dehumidification needs, and which are included in the ventilation energy column.

Table 2 shows the significant reduction of annual water heating energy needs between electric resistance water heaters (Contractor Loose and Tight homes) and a heat pump water heater (Contractor Smart home). A HPWH reduces annual water heating energy by 2600kWh, enough for 9000 miles of Electric Vehicle (EV) driving!

Plug loads (refrigerator, lighting, TVs, aquariums, computers, etc) are the same for all homes. Improvements to plug energy usage tend to be dictated by occupant behaviour and energy awareness. Note that plug loads and DHW energy are more than 50% of Contractor Smart’s home while they are much less than 50% (but still important) in Contractor Loose and Tight homes. Build Equinox defines a high performance home as one in which climate loads (heating, cooling and moisture management) are less than 50% of total house energy. Overall, annual energy differences between Smart homes and Loose/Tight homes is enough for 50,000 miles of EV driving per year! That is, a properly designed and built PGH with two EVs uses less electricity per year than conventional and improved homes.

Table 2 Annual energy loads for heating, cooling, dehumidification, ventilation (CERV2 smart ventilation), domestic hot water, and "plug" loads (refrigerator, lights, TV, etc).

	Heat(kWh)	AC(kWh)	Dehum(kWh)	Vent(kWh)	DHW(kWh)	Plug(kWh)	Total(kWh)
Loose	17303	426	654	0	3917	3066	25370
Tight	13174	278	803	0	3917	3066	21250
Smart	727	18	637	965	1306	3066	6814

Table 3 provides information related to comfort conditioning capacity required for the three homes. Winter design day temperature for central Illinois is -7F and summer design day temperature and relative humidity are 105F and 29%rh. Under these conditions, Contractor Loose's home requires somewhat more than 2 tons of heating (24,000Btu/h) capacity. Contractor Tight and Contractor Smart have similar heating and cooling capacity requirements, with somewhat less than 2 tons of capacity required. As discussed, tightly sealed homes have higher moisture management needs as reflected in Table 3, which also shows the amount of water condensed at summer design day conditions. For more in depth information on moisture management in homes, read our four part Handling Humidity report series (moisture generation, climatic effects, moisture management equipment, and overall moisture impact on energy use).

Table 3 "Design Day" heating, cooling, and humidity parameters and comfort conditioning capacities.

	W T (F)	S T (F)	S %RH	Heat(Btuh)	Cool(Btuh)	Dehum(Btuh)	Dehum(L/d)
Loose	-7	105	29	26000	12000	1930	20.4
Tight	-7	105	29	20000	9700	2590	27.3
Smart	-7	105	29	17500	9600	2775	29.3

In summary, we have shown the progression from a conventional home to a better insulated and better sealed home with higher performance heating/cooling and water heating equipment. Significant gains in economic feasibility, monthly cost, and energy performance are achieved by building economically optimized, high performance homes.

Our next step is to select heating, cooling and dehumidification equipment for the home. For this, we conduct a "Manual J" analysis with ZEROs, and then we choose an equipment configuration to satisfy these load and size the ducts.