Several years ago, a Levittown Pennsylvania homeowner became interested in evaluating if his then 60-year-old home, built in the 1950s could be made energy efficient using readily available materials and technology. The desktop assessment determined that it could indeed become much more energy efficient. The results of that assessment were summarized in a report that can be found here Microsoft Word - Residential Housing (livin-in-l-town.com). That report became the guide for the actual upgrade of his own house. The upgrade of the Levittown house took several years. Homeowners followed a plan, lived within annual budgets, and did as much of the work as reasonably possible. Professionals did the big things, (heating system replacement and solar installation).

What Levitt Built

Levitt & Sons built 17,311 single-family homes in Bucks County, Pennsylvania (suburban Philadelphia) in the 1950s on what was then mostly farmland. These were slab-on-grade; wood framed houses constructed using an adapted assembly line approach – each work crew moved from lot to lot in a defined construction sequence. Six basic house models were built with some orientation and appearance differences within the model category. The house model that is the subject of this summary is what Levitt termed a Country Clubber (Type 4) as illustrated in the original architectural rendering in Figure 1. The subject house has been modified from the original to include a finished second floor (which was an option during original construction), a second-floor bathroom dormer (also an option), and an expanded garage. The total expanded living space is estimated to be 2,460 ft^2.

Figure 1: Levittown, Pennsylvania Country Clubber – Type 4. (Levittown Archive)

The Plan

It was understood at the outset that work on the house would span several years, in this case 16 years. Much of the work was performed by the homeowners during evenings and weekends as schedules and budgets allowed. A long-term goal was established to eventually install a roof-top solar PV system to offset much, if not all of the energy use of the house. This would be considered after other priorities were met. An early priority was set to move away from the use of an oil-based heating system to be followed by systematic efficiency upgrades that the homeowners could perform themselves. It was understood then that efficiency first is a preferred approach, but given the timeline, they wanted to pull the plug on the oil system as soon as possible.

Table 1 below, summarizes upgrade and efficiency elements that were implemented. Discussion of selected tasks follows.

Table 1:Summary of Upgrade/Efficiency Elements for the Project

Project Tasks
• Installation of electric hot water heater with time control. • Replacement of oil-fired heating system with SEER 13 heat pump system. • Replacement of glass sliding doors with Energy Star units. (24 lf) • Replacement of entry doors with Energy Star units. • Window replacement with Energy Star units. • Replacement of all appliances with Energy Star units. • Re-insulation of exterior walls from R-9 to R-15. • Re-insulation of attic spaces to R-30+. • Installation of fireplace enclosure. • Installation of bathroom exhaust fans. • Miscellaneous caulking/sealing. • Replacement and upgrade of garage door with insulated unit. • Conversion of lighting from incandescent to CFL to LED. • Installation of roof-mounted solar PV system. • Replacement and upgrade of heat pump system from SEER 13 to SEER 21.

HVAC (Replacing the Oil System)

Levitt committed to the use of oil-fired hot water systems that employed the use of radiant heating coils embedded in the concrete floor slab. This concept was Inspired by Frank Lloyd Wright's earlier use of radiant heating. (An anecdotal discussion of radiant heat experience in Levittown can be found here. Levittown Radiant Heat – A Focus on Levittown PA (livin-in-l-town.com) Compact York-Shipley boilers were custom designed for the Levittown projects to fit within cabinet spaces in the homes. These boilers were equipped with hot water insert coils that concurrently heated water for domestic use such as for

cooking, bathing and laundry. A notable requirement for this combined approach was that the heating system had to run year-round in order to produce domestic hot water.

To prepare for replacement of the heating system, an electric 50-gallon hot water heater was installed to separate hot water production from the heating system. The electrical distribution panel was upgraded to 200 amps at this time. Ductwork and mechanical systems were then installed for a SEER 13 heat pump system to provide heating and cooling for the home. The oil system was removed, including the underground storage tank. Room/wall air conditioning units were also removed. Later, after 16 years of service, the heat pump mechanical systems were subsequently replaced and upgraded to a SEER 21 system.

Windows

Aluminum framed, single pane windows with a separate removable storm window were originally installed in the 1950s. The aluminum frames were thermal bridges to the exterior and cold to the touch in winter. All windows (20 units) were replaced with double-pane, Energy Star rated units sized to fit into the original framing. Homeowners did the removal and installation of new windows one room at a time over several weeks during mild weather weekends.

Doors

This house model was constructed with two sets of exterior sliding glass doors that provide passage to a back patio area. One set consisted of two, four-foot-wide glass panels and the other was a double set of four, four-foot glass panels. These units were aluminum framed, and like the windows, were thermally bridged to the exterior and cold to the touch in winter. These doors were replaced with Energy Star rated, thermally isolated versions which maintained the same exterior access.

The original wood entry door was replaced with an insulated fiberglass unit and the garage entry door was replaced with an insulated, metal clad, thermally isolated unit. Two wooden, roll-up garage doors were replaced with one insulated unit.

With the exception of the roll-up garage doors, all door replacements were done by the homeowners.

Insulation and Sealing

Although re-insulation was anticipated, a blower door test and thermal scan identified some problem areas that could be addressed during the process. As an example, a thermal scan shown below, indicates cold air intrusion behind the trim moldings in multiple rooms. Wall headers were subsequently caulked and foamed during re-insulation.

Ceiling insulation was increased from R 13 to approximately R 44 by the addition of batting insulation to an approximate depth of one foot. Upper roof slope insulation was relatively new, structurally supported and left intact.

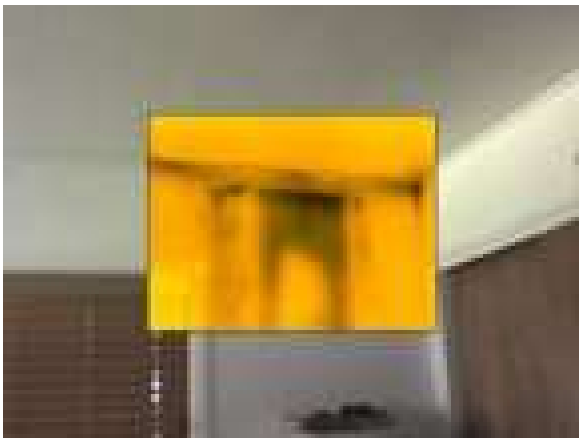

Figure 2: IR Scan of Bedroom Exterior Wall Section

Exterior walls were re-insulated room by room over a series of months. It is a disruptive process requiring drywall removal, old insulation removal, sealing/caulking, new insulation installation, drywall replacement, trim replacement, and painting. The house was lived in throughout the entire process and the homeowners chose to complete each room before moving on to the next.

Original insulation was expected to be 3" of rock wool batts in the stud bays, but 2" batts were found instead. This discovery downgraded the original insulation value to R 7.5 and made the re-insulation effort even more important. Existing insulation was removed and replaced with high density 3.5" fiberglass batts with an insulation rating of R 15. All joints and seams were caulked/sealed prior to re-insulation. All exterior wall re-insulation was performed by the homeowners.

Additional information regarding insulation for Levittown homes can be found here, InsulationNotes.pdf (livin-in-l-town.com) and here, SlabLoss.pdf (livin-in-l-town.com)

Fireplace

This house model was originally equipped with a 2-sided fireplace. (Some house models had a 3-sided fireplace.) The fireplace was equipped with an open/close flue dampener but otherwise had no air control capability. It was fitted with 2-sided glass doors that permitted control of combustion airflow.

Lighting

All permanent fixtures were replaced and fitted with LED lamps. All corded lights were also fitted with LED lamp bulbs.[1]

[1] Due to the relatively long timespan, lighting conversion took place twice as technology options improved; initially from the original incandescent to compact fluorescent (CFL) and then to light emitting diode (LED).

Appliances

All appliances were replaced with Energy Star rated units, as available.

Solar PV

Installation of a roof-mounted solar PV system was one of the latest additions to the house. The system consists of 50 panels with a combined rated capacity of 15.5 kw. The panel layout is illustrated in Figure 3 which was installed by Exact Solar of Yardley, PA. An additional discussion of Solar PV in Levittown can be found here. [Levittown Solar – A Focus on Levittown PA (livin-in-l-town.com)]

Initial Results

The solar PV system has been in operation for a little over 1 year as of this writing (December 2021). Since the conversion of the heating system to a heat pump system, the house is essentially all electric – the fireplace is seldom used. The last few years of electric use data were summarized and plotted for comparison as shown in Figure 4. The solar PV system became operational in November of 2020. After the first year of operation the energy balance was +359 kwh; not quite energy neutral but getting close. As indicated in the graph, the heat pump system was upgraded at the end of this period and the efficiency improvement from this change has not yet been recorded. Given the highest energy use is due to heating demand, the 60+ % improvement in the rated heat pump system is expected to translate to a zero (or negative) energy balance in the coming year (2022).

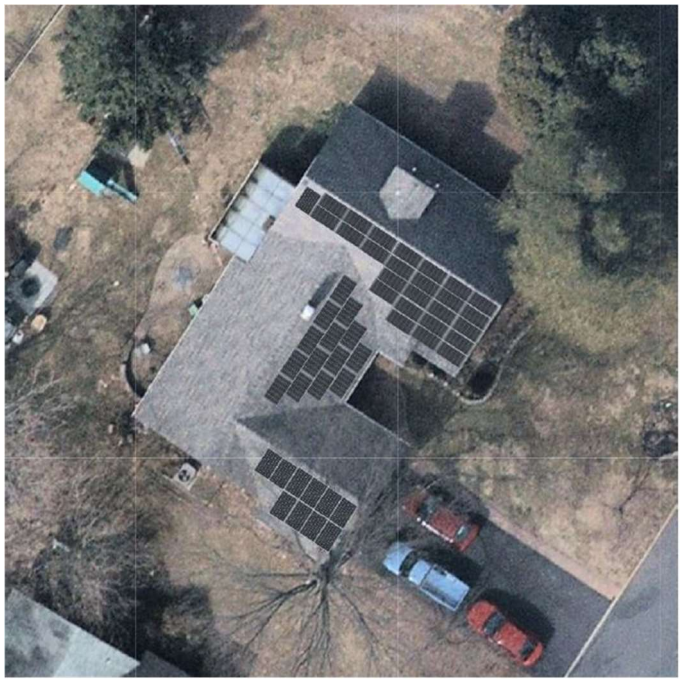

Figure 3:Solar Panel Layout by Exact Solar (Levittown - Country Clubber)

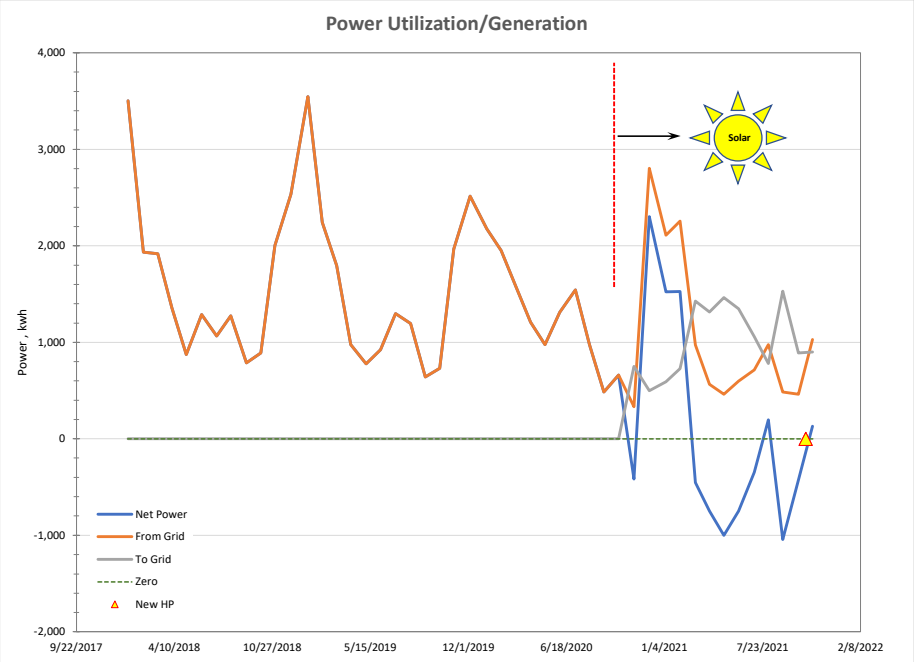

Figure 4:Electrical Use 1/18 through 11/21

Going Forward

The historical energy use data provided the opportunity to estimate the base loading for non-heating and cooling use such as water heating, refrigeration, lighting, etc. Figure 5 illustrates the relationship between electricity use and the heating/cooling temperature differential, i.e., the difference between the outside temperature and the thermostat (Tstat) indoor setpoint. For this estimate, the Tstat setpoint was assumed to be a constant 70°F. When the difference between the outside temperature and the inside temperature approaches zero, neither heating nor cooling is required and the energy consumption under those conditions is attributed to other uses such as water heating, refrigeration, lighting, etc. The linear regression y intercept indicates that this baseline energy use is approximately 550 kwh/month. This will be the focus of efficiency improvements going forward.

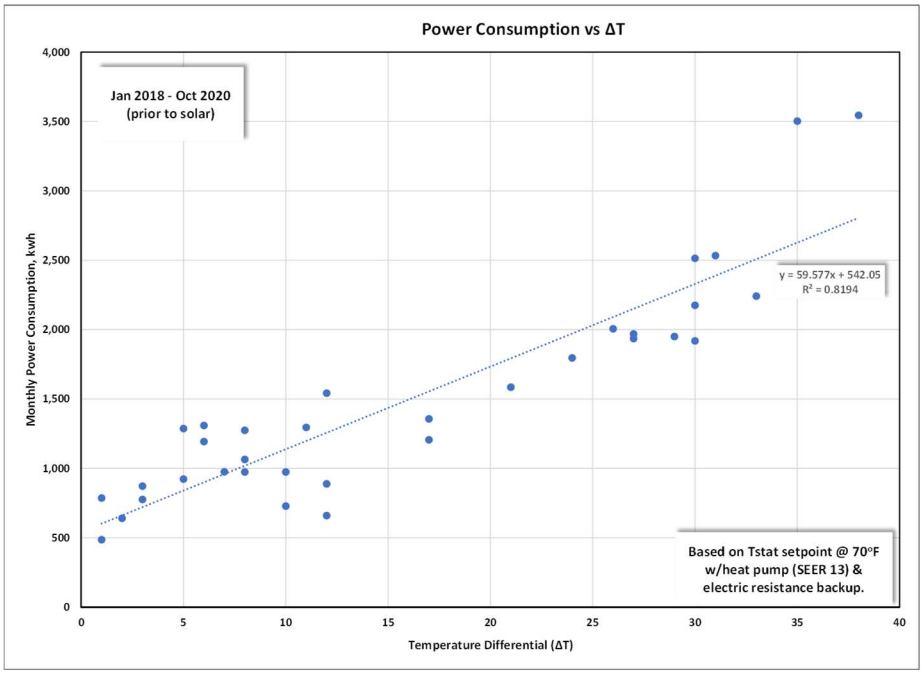

Figure 5:Electrical Power Consumption vs Temperature Differential (70°F @ Tstat setting)