Net Zero Home Evaluation

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Pushing Net Energy Consumption to Zero

This report covers a suburban 2,060 ft2 ranch-style home in Hightstown, New Jersey. It was originally constructed on a 0.7-acre lot in 1964 and has undergone 2 major renovations in the last 10 years. Hightstown, being only about 4 square miles in area, offers plenty of services within walking distance. Home to shops, restaurants, and offices, downtown is about a half-a-mile north relative to the house. The local supermarket is only a mile away, and two elementary schools and the high school are easily walkable. Unfortunately, the middle school is in the next town over and is not easily accessible on foot. The front- and backyards are dotted with several large trees that offer substantial shade throughout much of the day. In tandem with bushes, the trees also offer a home for small creatures such as squirrels and birds. The lawns are well taken care of throughout the year, and professional landscapers service it during the summer.

Several parts of the house contribute positively to energy efficiency. Throughout the house, including the attic, there is 8-inch-thick fiberglass insulation in the walls. Fiberglass is one of the most common types of insulation in modern homes, but the 8 inches used in this case allow for much better heat storage. Specifically, insulation allows for minimal energy use with respect to heating. In addition to hefty wall insulation, all windows are double-layered – each window is two panes of glass thick. The extra layer provides a greater level of insulation while still allowing for the same visibility as traditional windows. These windows are on each side of the house, meaning that at all times of day, sunlight can enter. In the winter, this is especially helpful for minimizing heat loss – one of the largest consumers of household energy. Two-layer windows are also found in the basement of the home, which allows light to radiate in and keep it warm.

In addition to the construction of the house, the location also has benefits. The house is proximal to multiple important resources, such as schools, grocery stores, and the central town area that has multiple other stores. Walkability to these areas is especially important in energy-conserving homes because using cars regularly creates an additional energy-dependent source that negatively impacts the efficiency of the household. With the consideration that public transportation could also be used, all the necessities of everyday life are within a reasonable distance from the house so that car usage is minimal.

Many of the appliances used in the house allow for a greater efficiency rating while still maintaining everyday life and not altering the life of the residents much. The house uses LED lighting for most of the lights around the house, which operate with higher efficiency when compared to incandescent or compact fluorescent lighting. LEDs are crucial to homes hoping to get close to net-zero since lighting is a daily requirement and using as little electricity as possible each day is important. In a similar fashion, the current water heating system is tankless. More modern homes are opting to have tankless water heaters due to their energy efficiency, and since heating is one of the biggest challenges when lowering the energy consumption of the house.

Unfortunately, as is very typical of homes of this era, there is plenty of room for improvement towards net-zero energy consumption. The first problem is the heating efficiency. Baseboard heating systems are effective but require a large amount of energy to constantly radiate heat. This makes them very inefficient because they are constantly using energy. The combination of baseboard and gas heating systems helps efficiency because gas heating systems use large amounts of energy to increase the temperature to the desired temperature and then a small amount of energy to maintain that temperature. A heat pump system would be much more efficient since it does not generate heat, rather, it simply moves it from one volume of air to another. There are also controllers for each room so that they are not all on one master switch.

Another problem with the house is the lack of renewable energy sources. Since no domestic energy is produced, clean energy is supplied to the house entirely by the renewable portion generated by JCP&L, all other energy is produced in fossil-fuel power facilities. This is perhaps the greatest sin of the home, as net-zero implies that all energy used is produced on-site. Another aspect of the home that is a problem is the building materials. The house is built out of, mostly, wood and concrete which are two of the most common and highest emitting building materials. This means that the environment is getting destroyed to provide the building materials. Not much can be done about this since the home is already built, but environmentally friendly materials should certainly be kept in mind for future renovations. Additionally, while the windows are double-paned, they are lacking in some areas. One way to improve this is to install thermal curtains or films on the windows to help increase thermal efficiency and conservation throughout the home. Shown clearly by Figure 1, the amount of heat absorbed by the house is highly dependent on what is absorbing the light. Having thermal curtains installed would result in the curtains absorbing the sunlight and heat while the curtains are drawn, meaning that even though light may not get through, the heat can still be absorbed. One way to reduce the cost is by only installing curtains on south-facing windows, as they encounter the most sunlight throughout the day.

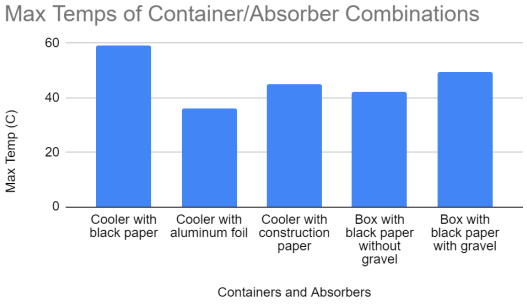

Fig. 1
Effectiveness of Curtain Materials and insulation

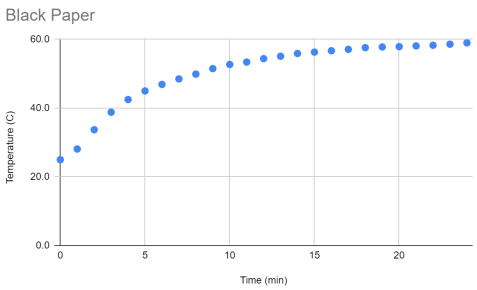

Fig. 2
Best performance of the heat transfer lab

As shown in the graphs above, material definitely matters in terms of absorbing heat. As far as containing and maintaining, the black paper in the insulated cooler performed the best out

of itself, the colored paper and the aluminum, as well as both of the cardboard box experiments. Knowing that materials make a difference could and should be taken into consideration for this house.

These problems with the house can easily be solved, assuming an unlimited budget. First off, to improve heating efficiency, the baseboard and gas heaters currently installed must be replaced with vastly more efficient heat pumps. Not only would the heat pumps be more energy efficient by transferring heat around the house, but they can also focus their energy into select rooms instead of heating the entire house on one master switch. Furthermore, according to *Woolley Home Solutions*, with the implementation of new technology, they are now ideal for the moderate New Jersey climate. As far as energy solutions, installing solar panels and wind turbines would be a leap in the right direction. The solar panels would absorb energy from the sun during the day, while the wind turbines would gather energy from the wind both day and night. Solar panels in particular work better/worse at certain altitudes and azimuth angles. From the data found, the most consistent orientation of the solar panels is when it has an azimuth angle of 0 and is in a parallel circuit as opposed to a series circuit, as shown in the graph below.

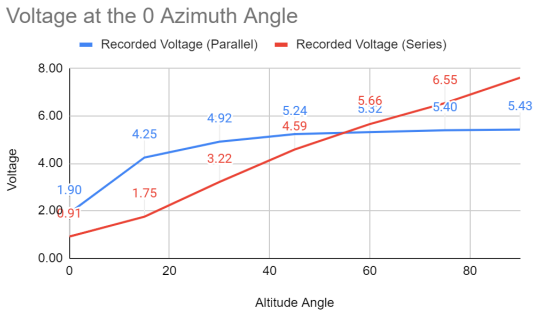

Fig. 3
Comparison of circuits in the most effective Azimuth angle

The graph shown above was the test that gave the best possible data and is the optimal choice when installing solar panels (additional data provided in Appendix A). An azimuth angle of 0 and an altitude angle of 90 means that the optimal placement of solar panels would be perpendicular to the sun at all times. The movement of the sun throughout the day, however, means that the angle with which the sun is in relation to the solar panels means that the angles are changing. The house faces west, so the sun's altitude angle would change throughout the day, and the shift in the sun placement over the course of the year would change the azimuth angle. The house is located slightly past 40° North, so if solar panels were placed on the roof of the house, the azimuth angle would not be zero, but we were not able to calculate what this angle would be for the actual home. Regardless of this, the change in altitude angle means that having the solar panels wired in parallel would result in a greater overall increase in energy output throughout the entire day. This trend was shown throughout all tests, so in this scenario, the preference of being wired parallel would not be dependent on the actual azimuth angles.

A combination of both would lead to a surplus of energy. According to *Solar Panel Network USA*, not only would the house have multiple sources of power, but redundancy would minimize the risk of an outage due to generator failure in storms – a fairly common occurrence in the area. While the financial aspect of installing solar panels and wind turbines is a deterrent for some, a net-zero energy home's energy production would most likely lead to a profit gained from redistributing excess energy produced from the home, meaning that at some point after installation, on-site production is more financially sustainable. In addition to production, adding thermal curtains to the windows would insulate heat inside the house, therefore mitigating energy loss. As shown in Figure 2, the black paper kept thermal energy inside for a longer period compared to tin foil or colored construction paper, as shown below.

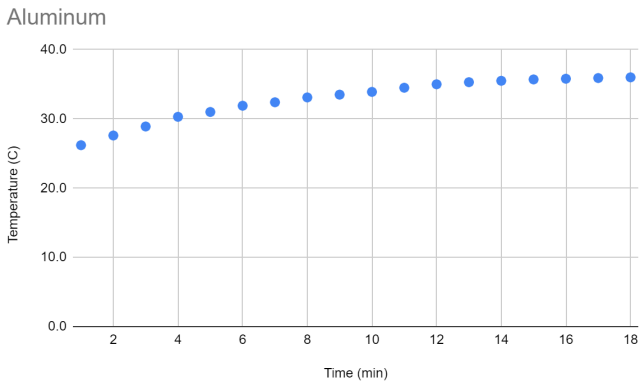

Fig. 4
Performance of Aluminum

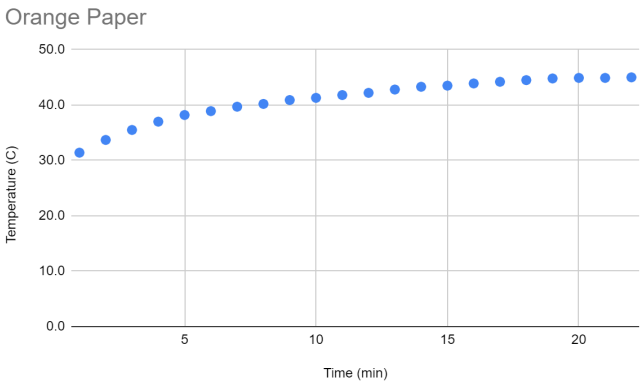

Fig. 5
Performance of Construction Paper

As for the basement, some of the appliances such as the freezer and the fridge can be replaced with energy-star rated models, which in turn would be more energy efficient. While the proposed solutions are foolproof in theory, budgeting is a huge factor. Regardless of financial situation, the amount of money that it would take to complete everything that was listed off may not be worth it just to cut down the energy bill a bit. Implementing the most reasonable would be beneficial. For instance, installing solar panels and wind turbines (which would be compensated for by the federal government in some cases) would be something to consider. Picking and choosing the best from the bunch is a more cost-effective way to do it.

One way to save money on electricity without making drastic changes to consumption habits is through thermal heat storage. As was discovered in heat transfer research, the material used to insulate a space has a huge impact on the temperature of the space. The 8-inch fiberglass insulation allows the home to drastically reduce the transfer of thermal energy. Additionally, the home has been fitted with a Google Nest thermostat system, which allows for fine programmable temperature control. The combination of a smart thermostat and strong insulation creates a system that can easily save money if managed properly. According to the *Technology Connections* YouTube channel, homes can be treated like thermal batteries. They can be charged

when energy demand and therefore price per kWh is low, and the energy can be used as demand and price increase. In the case of the host, he cools his home starting at 10 pm every night and turns off the air conditioning during the day when energy prices are higher. Since less energy is being used during peak consumption hours, this solution has the added benefit of putting less strain on the grid when supply is more limited. By automatically manipulating the heating and cooling cycles of the home, money is saved and the electrical grid is more balanced.

Despite being nearly 60 years old, the home is quite serviceable in terms of energy efficiency. It has seen numerous improvements over the years and will continue to make improvements for years to come. Perhaps the easiest solutions come in the form of upgrades rather than total overhauls. Cutting off the electrical grid is an accessible first step. Solar panels are abundant and becoming more cost-effective each year, however, may not be effective in this scenario. Due to shadows cast by trees and the orientation of the home, solar power is less viable and would have to be supplemented or replaced with domestic wind power from turbines placed on the roof. Furthermore, while disposing of old refrigerators may cause refrigerants, potent greenhouse gasses, to leak into the atmosphere, the energy efficiency of upgraded models will likely offset the refrigerant issue in the long term. It makes sense to look at upgrades as a primary solution, as they provide a minimally destructive, cost-efficient path forward. It is important to focus on what can be done in the short term, as it will likely provide a fast track to long-term solutions. Making incremental progress towards the goal of zero net energy consumption is key to an affordable and carefully considered solution.

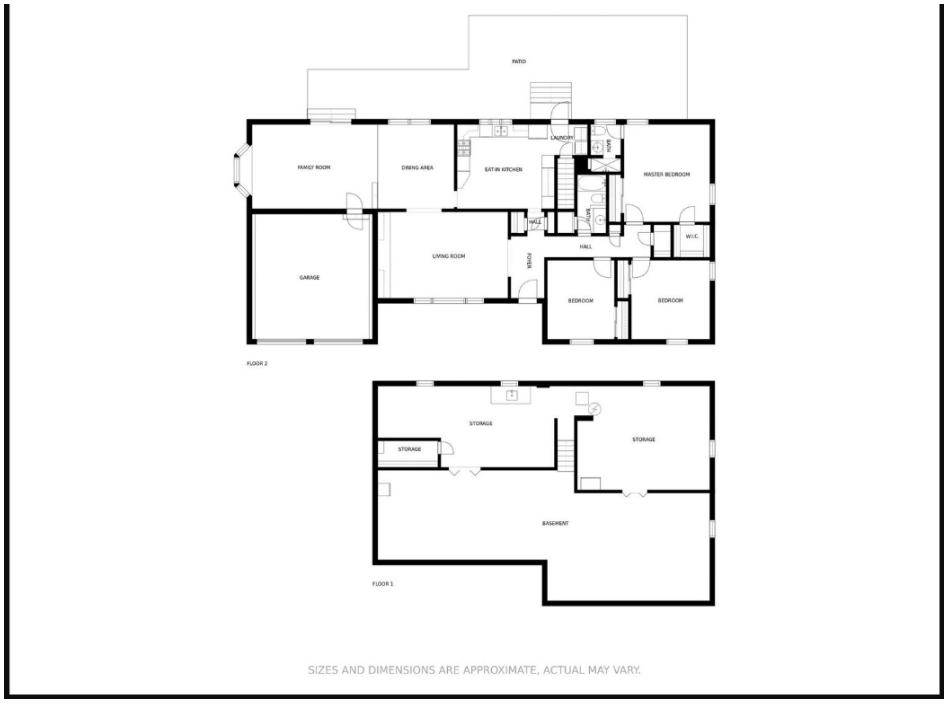

Fig. 6
Subject House's Floor Plan

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