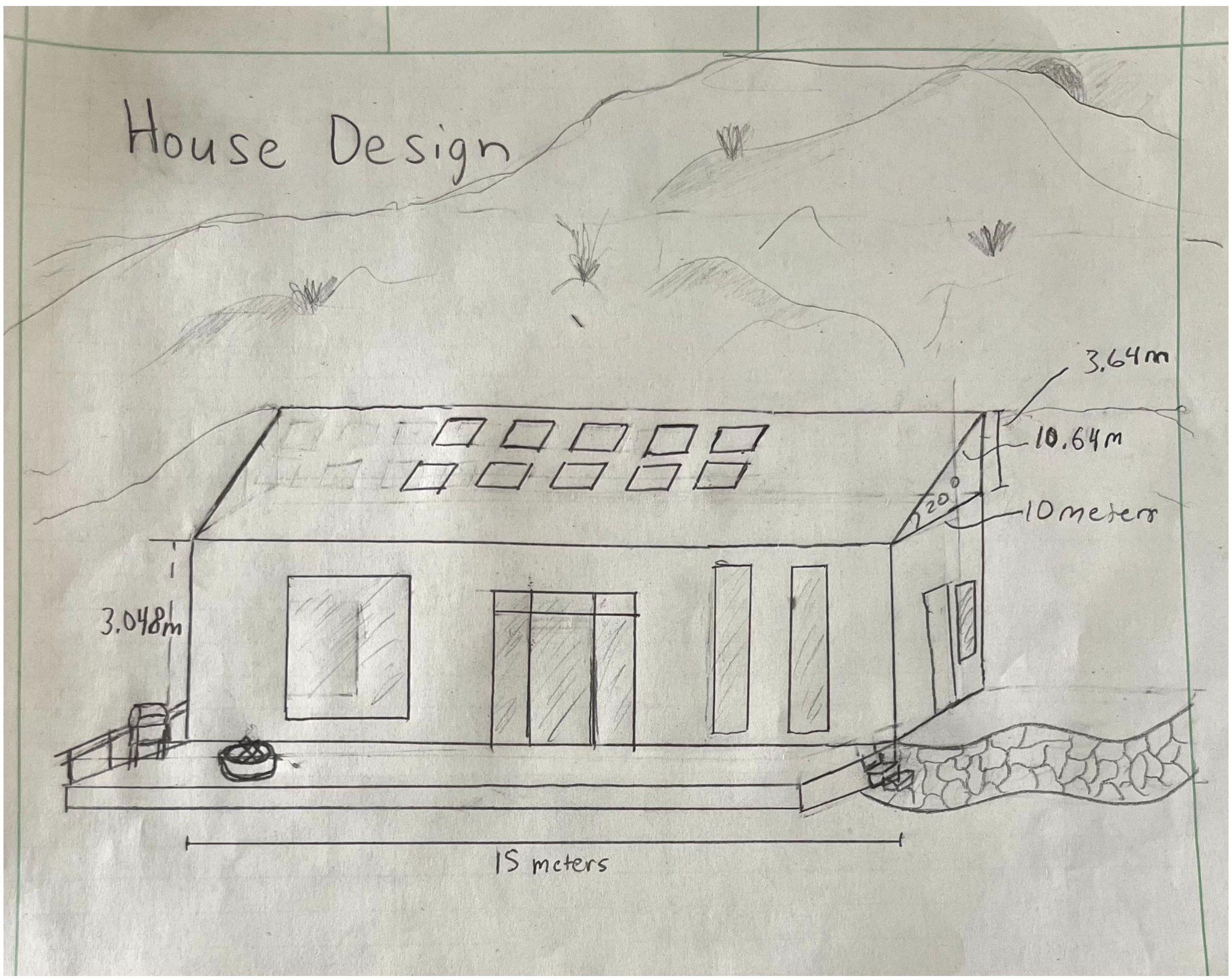
Nicholas Valianti, Thomas Heer, Tommy Sanda, Max Harkness, Strickland Davis
Final Due Date: May 6, 2022

Thermodynamics and Heat Transfer: Final Project
Heer Me Out

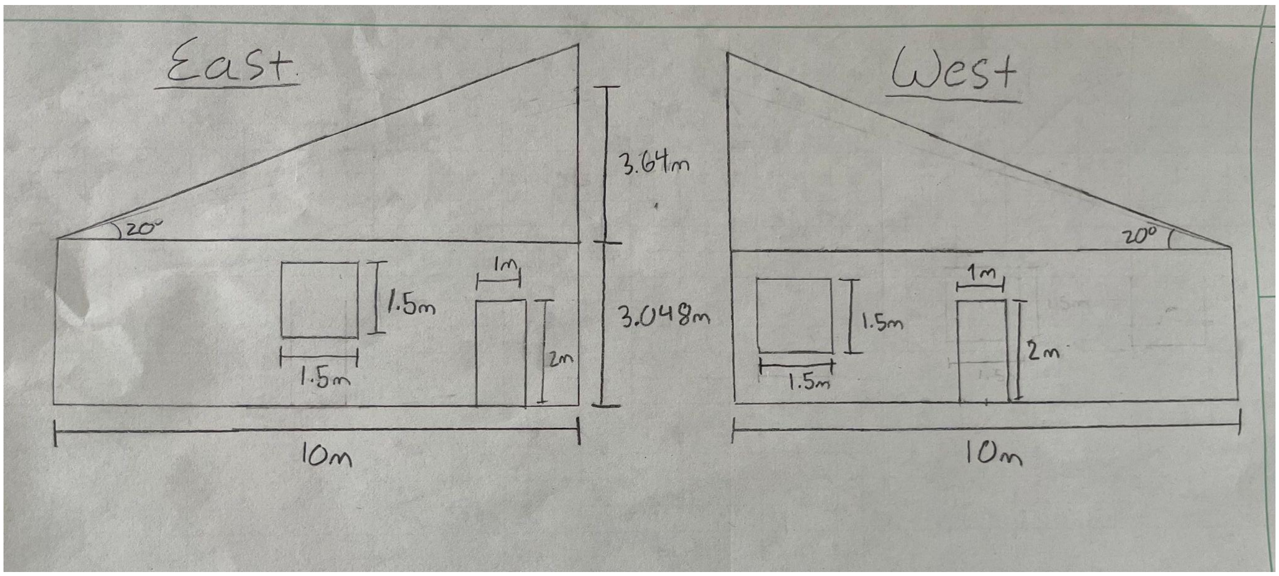
Intro

Gifted with ten solar panels and a Tesla battery, team “Heer Me Out” has designed a passive home using only solar power. The orientation of our house is optimal for heat transfer indoors during the winter months. Our home will be built on a plot of land on a hillside (figure 1).



(Figure 1.)

Our intention is that the windows on the south facing wall will maximize radiative heat from the sun, as well as natural light. The northerly side of our home will be built into the slope of the hill to avoid heat loss. In other words, this orientation will maximize solar irradiance and heat retention. It would be wise to add an overhang into the design to shade the sun during the warmer summer months. However, this is beyond the scope of this project. The goal for our home is to thrive off grid with no reliance on government sourced energies like natural gas. Being energy neutral means we need to design adequate insulation, appliances, and materials to accommodate the people living inside. Predicting energy consumption from the lights, oven, heating system, etc. is pivotal in this design. In this report, you will learn about the key features of our passive home, including the layout, a description of heat sources impacting heat gains and losses, and lastly, methods for achieving a net zero energy balance.



(Figure 2.)

Home Design and Energy Analysis

Per the class discussion following the "Passive Solar Home" video, we realized that using all these materials to construct a brand new house is actually not very sustainable ("Passive Solar Home"). Even if the house is planned to be energy neutral, there are existing options that won't require as much consumption. Reducing consumption is an important step in sustainability. That being said, the project is to design a new home, not move into an existing home. So, we decided to choose Northern White Cedar wood to frame the walls and roof of our home. This lumber will be locally sourced, and is a "renewable resource that is actively managed to ensure biodiversity, wildlife habitat and high-quality forest products" (Gray). Sourcing locally will reduce shipping costs and save on gas. We also think it will make for an elegant finish. This material has an R value of 1.41 per inch of thickness (Gray) and will hold sturdy for years to come. This allowed us to come up with a 10 in thickness for our exterior walls or 0.254 meters with an R value of 13.87. Heat loss through the house was kept minimal using a high R value for the walls and triple paned windows with an R value of 5.6 found on the Alpenglass website ("Alpenglass"). The general design concept aims to have minimal heat loss from the north wall due to a warmer ground temperature than air in the winter. The Standard design of the foundation and floor was used with locally sourced gravel that was 12 inches thick 8 inches of sand and had a 12 inches of concrete ("Concrete construction"). Which had a combined R-value of 3.31. The heat loss calculations can be found in table C.2. where the surface area of the section was multiplied by the temperature difference and they were divided over the total R-value for that section.

We are assuming that two people live in our house. This laid the baseline for predicting energy consumption within the home. There are a total of forty LED lights in our home, with an average of 5 hours of illumination per day. We decided on five hours of illumination because some lights might be on for twelve hours, some might only be on for one hour, but in total they will average out to around five. One person emits 350,000 J/hr of heat, 24 hours a day ("Do LED Lights Produce Heat?"). The oven is designed to operate for one hour every day to make meals. It requires 2400 watts for one hour, and 3.6 kj/hr. The Heat emitted by the oven is assumed to be equivalent to the amount of energy required to power the oven. This means that we ignored any inefficiencies the oven may have because those inefficiencies result in the dispersion of heat from the oven anyways ("Electricity Usage of an Oven").

The final component of heat gain for the house is from solar irradiance. Given data for Massachusetts on each wall and for the roof, given in kilowatt hours per square meter per day, we can calculate the heat gained. We are assuming that the heat gained through the walls is negligible, so there will only be heat gained through the windows. The total heat gained through the windows can be calculated by multiplying the total irradiance by the solar heat gain coefficient (shgc). The window we chose was the alpenglass 5H, which has an shgc of .47, which means that 47% of the heat coming into contact with the window will be in the house ("Alpenglass"). This is a large shgc that would not be practical in the summer months, but we are only accounting for the -5 degree January day, so the higher the shgcl, the better. There are only windows on the south, east, and west side of the house, and their total surface areas are 15.6 square meters, 2.25 square meters, and 2.25 square meters respectively. These surface areas then get multiplied by the given solar irradiance. The given solar irradiances were 3.81 kWh/m^2/day for the south side, 1.44 for the west, and 1.52 for the east (figure 2). These numbers are then multiplied by the shgc, and summed. The total heat gained from irradiance is 111,834 kJ/day ("PVWatts Calculator").

Our house was able to effectively stay independent with our solar panel generation because we were able to farm the sun's energy using photovoltaic solar. We retrofitted 10 of the 1.5 square meters solar panels on our roof. With a 97.5 percent efficient Tesla battery (Powerwall). With a generated 47385 KJ/day. We tried to minimize our lighting electrical needs using our LEDs which minimized our heat loss and uses a 0.65 percent efficiency of heat and our oven is used minimally for an average of an hour each day to limit electrical needs. The bulk of our electrical load is coming from heating the house using the baseboard heaters. In order to prevent the battery from becoming overloaded, we set the capacity of the battery equal to the total energy used throughout the house. We had already calculated the loads of the lights and oven so I solved for the amount of energy that would be required to deplete the energy in the battery in one day. Since we are assuming that all of the energy that is used to power the heaters is also turned into heat that goes into the house, we set up an equation setting the heat in equal to the heat out plus the heat required to maintain a house with 2 people in it and the determined size of the house. Within this equation, all of the calculations requiring an R value were summed and put over X to represent the needed R value for the wall. Since the R value of cedarwood is directly linked to the thickness of the wood, we used this equation to solve for the needed R value inorder to balance out the Heat in/Heat out equation (“Insulation Primer for Log Homes”).

Total Energy Balance:

Source	Heat in (kJ/day):	Source	Heat Out(kJ/day):
People	16800	Windows/Walls	83137
Oven	8640	Heat required	91789
Lights	2808		
Solar Irradiance	111834		
Total	174689	Total	174927

Source	Electric Load (kJ/day):	Source	Electric Generation(kJ/day):
Heating	34605	Solar Panels	47385
Oven	8460		
Lights	4320		
Total	47385	Total	47385

The two tables above show the total energy balances for the heat of the house and for the electrical load of the house. As can be seen in the table, the heat in and heat out is net negative by 235 kJ/day, which amounts to .13%. For the electrical load, the energy balance is exactly equal to zero.

Table C.2.

Detailed Sample calculations for heat loss through windows, roof, floor, and walls.

	N	S	W	E
Surface area wall	0	15m*3.048 m - 29.6m = 16.12m^2	10tan(20)*10*.5 +10*3.045=48. 65m^2	48.65m^2
Material 1 wall		Cedar Lumber	48.65 - (1.5 x 1.5) - (2.4 x 1) = 44 m^2	44 m ^2
R wall	13.87	13.87	13.87	13.87
Surface area of door			2.4 m^2 1 by 2.4 m	2.4^2
Material 2 wall			Door 1	Door 2
R wall			5.55	5.55
	(SA of north wall) =6.688*15			
	(T2-T1)(SA)/(R)	(T2-t1)(SA) /(R)	(25C)(44m^2) /(13.88*.99)	(25C)(44m^2) /(13.88*.99)
Heat Loss wall	(20-7.22)(100.32)/(13.88*.99) = 92.39 W	(25)(16.12) /(13.88*.99) = 29.05 w	88.878 w	88.878 w
7.22 celsius soil temperature on the back north wall				
Surface area window	0	15.6m^2	1.5m^2= 2.25m^2	2.25m^2
Material window	triple pane	triple pane	triple pane	triple pane
[R value window]	5.6	5.6	5.6	5.6
Heat Loss Window		(15.6m^2)(25 C) / (5.6)	(2.25 m^2)(25 C) / (5.6)	(2.25 m^2)(25 C) / (5.6)
		132.14 w	10.04 w	10.04 w
Roof Heat Loss = (SA)(t2-t1)/(R-value)	SA = 15m x 10.64m = 159.6 m^2	(20 - (-5)) = 25 c	Norther Cedar R = 13.87	= 287.74 w
Floor Heat loss	SA = 15 m by 10 m = 150 m^2	(20-7.22)	Gravel 12 in + Sand 8 in + Concrete foundation 8 in	= 285.575 w
			3.31 R-Value 1.35+0.64+ 1.32 = 3.31	

Social & Economic Impacts

Building a home with renewable energy sources is not only a cost effective feature but creates a much bigger impact with its sustainability. Sustainable energy benefits the social and economic state of the world with its environmentally friendly properties if carried out properly. Meaning if the optimal technology is not maximized then problems can occur for example CO_2 emissions. The original energy sources used over time have all had their own negative impacts on the environment leading to social problems. Whether it is solar, hydroelectric, wind, ect, if a technology for renewable energy is found with no environmental damages it will allow for a more efficient energy economy. If everyone is able to use renewable energy sources this will allow for more economic benefits with no monopolies in the energy industry. Common energy sources like coal and petroleum require mining and they burn very dirty. Even though these sources create a large amount of jobs for the economy, a smooth transition into 100% renewable energy will be the most beneficial to society for the next generations. Having clean air and renewable energy is more important than continuing to drain the earth's resources for profit margins.

The home design tries to maximize sustainability with its characteristics that allow for renewable energy. It is an off grid design for 2 people that will allow them to live a sustainable lifestyle while being self-reliant. The home we designed has certain retrofitted triple paned windows and uses other sustainable materials that have upfront costs. When you consider the average or below average income for a family, they may not have the capital upfront to retrofit their house like this or buy solar panels. While our design gives us substantial benefits in the long run, many people cannot afford the upfront economic burden.

Conclusion

The Group learned that some aspects of Sustainability are easily achievable and can be done when retrofitting a house. It is really easy to have heat gain by getting passive solar heating through your windows which help limit your amount of heating. Placing windows on your south facing wall allows for maximal heat gain in the winter. The group also learned that there is much more energy loss in a modern house through more appliances like tvs, refrigerators and other modern household technologies. The solar power that supplies this energy needs to be managed as well. Turning off the battery when it reaches its capacity will prevent overloading the battery which can result in a burnout. It is also important to take into consideration that not everyone can retrofit their home and afford being energy independent with solar. The amount of money that needs to be spent up front for the retrofitting and construction of this house has a substantial cost and it is not feasible for a family that isn't well off.

If we were to design our own homes, I would add as much passive solar and windows as possible so we do not need to heat our house as much. This also allows for more appliance usage. In general, the home is a bit small, but for two people it's enough. I would want my house to be a tiny bit larger. It would also be nice to add a mancave and a garage to my house which requires more square footage and energy usage.

The date of january 1st is in the middle of the winter so it is the coldest during this time. The baseboards need to be used for heating which requires energy. If it is cloudy and there is minimal sunlight in the winter the house will not be heated to where we would like it. Another point is that it will get hot in the summer months and we will need air conditioning. Due to our house being built into the hill we get benefits of heating in the winter and cooling in the summer because the ground temperature does not fluctuate as much as the air temperature. It will be wise to add an overhang on the south roof for the summer months. Overall, it is more difficult to predict the other months considering the variables including temperature changes and weather patterns.

The house will need to be cooled and have air conditioning in the summer. It will be hotter than in the winter inside the house, but with an overhang we can counteract some of the solar heat gain through our windows. This would be important because a solar heat gain coefficient of .47 is high for a climate like Amherst. Having these windows in direct sunlight all summer will cause very large heat gains due to solar irradiance, which would increase the cooling needs greatly. It will fair well at night because not much heat is going to be lost. The design is reasonably versatile for the summer considering we only needed to account for one date in the winter.

References:

Admin in Building Cost, Building Cost USA. *Estimation QS*, https://estimationqs.com/.

"Cedar vs. Pine." *Classic Cedar Log Homes*, http://www.classiccedarloghomes.com/cedarvspine/.

Concrete Construction Staff. "R-Value of Concrete." *Concrete Construction*, 1 Mar. 1995, https://www.concreteconstruction.net/how-to/r-value-of-concrete

"Do LED Lights Produce Heat? All about Led Heat Generation." *LampHQ*, https://lamphq.com/led-heat-generation/.

"Electricity Usage of an Oven." *Electricity Usage of an Oven - Energy Use Calculator*, https://energyusecalculator.com/electricity_oven.htm.

"Heat Pump Water Tank." *Jinyi Solar Ltd.*, https://www.jinyi-solar.com/heat-pump-tank.html#:~:text=Air%20source%20heat%20pump%20tank%3A%20The%20heat%20pump,air%20from%20the%20surrounding%20space%20through%20an%20evaporator.

"Insulation Primer for Log Homes." *Katahdin Cedar Log Homes*, 24 Sept. 2015, https://www.katahdincedarloghomes.com/blog/insulation-primer-for-log-homes/#:~:text=Cedar%2C%20because%20of%20its%20lower,used%20in%20log%20home%20manufacturing.

Passive Solar Home, YouTube, 23 Dec. 2015, https://youtu.be/Bx0aDeru_Xw. Accessed 6 May 2022.

Passivhaus Primer: Designer's Guide A Guide for the Design Team and ... https://passivehouse-international.org/upload/BRE_Passivhaus_Designers_Guide.pdf.

PhysLink.com, Anton Skorucak. "How Much Heat per Hour Do Humans Dissipate?" *PhysLink*, https://www.physlink.com/education/askexperts/ae420.cfm.

"Powerwall." *Tesla*, https://www.tesla.com/powerwall.

"PVWatts Calculator." *PVWatts - NREL*, https://pvwatts.nrel.gov/pvwatts.php.

"Clean Energy." *Energy.gov*, https://www.energy.gov/clean-energy#:

Contributions:

Thomas Heer:

- Solar irradiance calculations, heat of people calculations, helped on heat out house, typed sections of house design, energy balance tables, formatting, bibliography, in text citations

Strickland Davis:

- Solar panels and battery calculations, overall heat in heat out calculations, electrical load calculations, finding the correct R-value/thickness of the cedarwood,final energy balance calculations, portion of Home design and energy analysis,

Tommy Sanda:

- Heat out calculations for the windows, wrote the 'Social & Economic Impact' section and also contributed to the conclusion. Drew out the figures of the home design & dimensions.

Max Harkness

- Initial sketch of building, intro, home design and energy analysis, discussion notes, kept track of references but did not convert them to mla citations, revised and edited overall report

Nicholas Valianti:

- Heat out calculations for the walls roof and floor, Heat in for the lights and oven, Sketched house design, wrote the conclusion and parts of the home design and energy analysis.Wrote second paragraph of social and economic impact. Worked on reference with Thomas Heer.