Energy Modeling & Renewable Implementation of a Single Family Residence

Arwen Pearson, Kara Nichols, and Firdowza Isse
Mechanical & Electrical Engineering
Faculty Advisor: Dr. Zhiquan Shu

INSTITUTE FOR INNOVATION & GLOBAL ENGAGEMENT
W UNIVERSITY of WASHINGTON | TACOMA

U.S. DEPARTMENT OF ENERGY Solar Decathlon

ABSTRACT

Our team is currently designing the retrofit of a single family residence in order for it to become more energy efficient and sustainable. The design and organization of the project is based on the **2024 U.S. Department of Energy Solar Decathlon Competition**. This house was chosen as its standard design can be applied to most suburban two story homes. With minor changes to each house, the recommendations produced by this retrofit will allow other homes to make improvements to their houses so that they can rely less on the power grid and more on energy produced through on-site renewables. Results conclude that **active energy solutions** such as heat pumps and **renewable energy implementation** (i.e, solar panels) can greatly reduce the environmental impact and energy consumption within the home. **Life cycle analysis** was then conducted to better understand the impacts of construction and continued use throughout a residence's lifetime.

INTRODUCTION AND PURPOSE

There have been many houses that have been built in the past and many more being built today. It requires a tremendous amount of energy and resources to keep all these homes powered and temperature-controlled. The **US** alone **consumes** a staggering **100 quad (~2.9*10^13 kWh) of energy** in modern years, with 12 quad coming from the category of residential electricity. This is a significant portion of our energy demands. Creating and maintaining houses that are sustainable is a primary motivation for the world with the large population growth the world is facing, and how large our energy demands are becoming. **Sustainable building design** encompasses a wide variety of areas including energy efficiency, material selection, envelope efficiency, life cycle analysis, renewable energy sourcing, and more. The purpose of this project is to **retrofit an existing house** such that it is net zero energy and can support itself on energy produced by onsite renewables. This team has analyzed the yearly energy consumption, HVAC load, and LCA carbon emissions at both baseline, and a series of proposed retrofit profiles.

PROPOSED SOLUTION/RECOMMENDATIONS

The house will need an energy modeling and life cycle analysis before and after the hypothetical retrofit.

Using four primary softwares:

1. REM/Rate
2. One Click LCA
3. Ekotrope
4. System Advisor Model by NREL

The increased **passive** energy efficient options incorporated into this design includes updating appliances, insulation, window glazing etc,. While the **active** renewable energy efficient options involves solar panels and control system improvements.

METHOD(S)

Through the **Global Innovation Design Lab (GID Lab)** at the University of Washington Tacoma campus, this team was allotted the space and skills necessary to better organize solutions and teamwork styles. Below is a timeline figure that approximately represents the series of events undergone to determine these results.

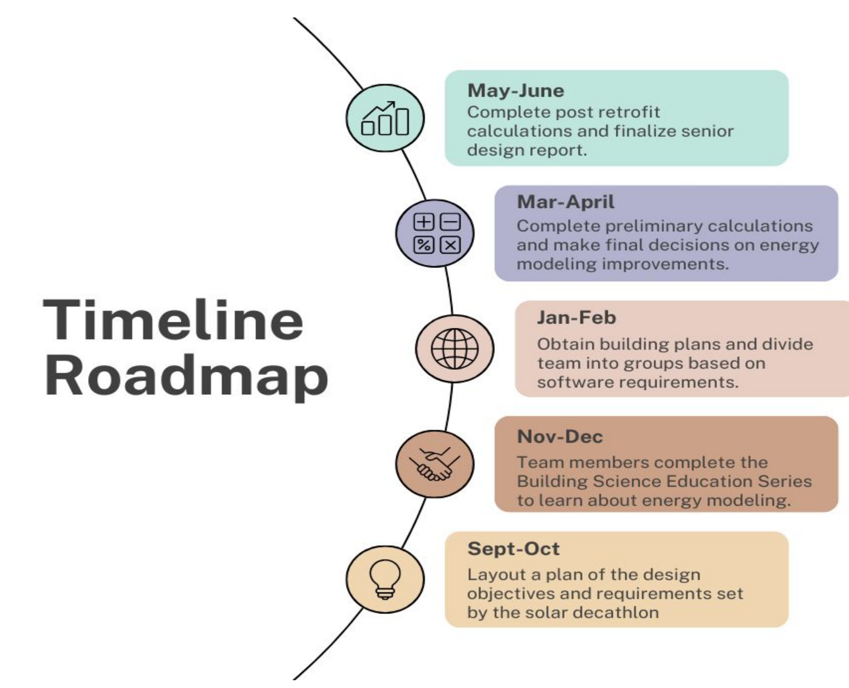

Figure 1. Timeline of events throughout 2023-2024.

RESULTS AND DISCUSSION

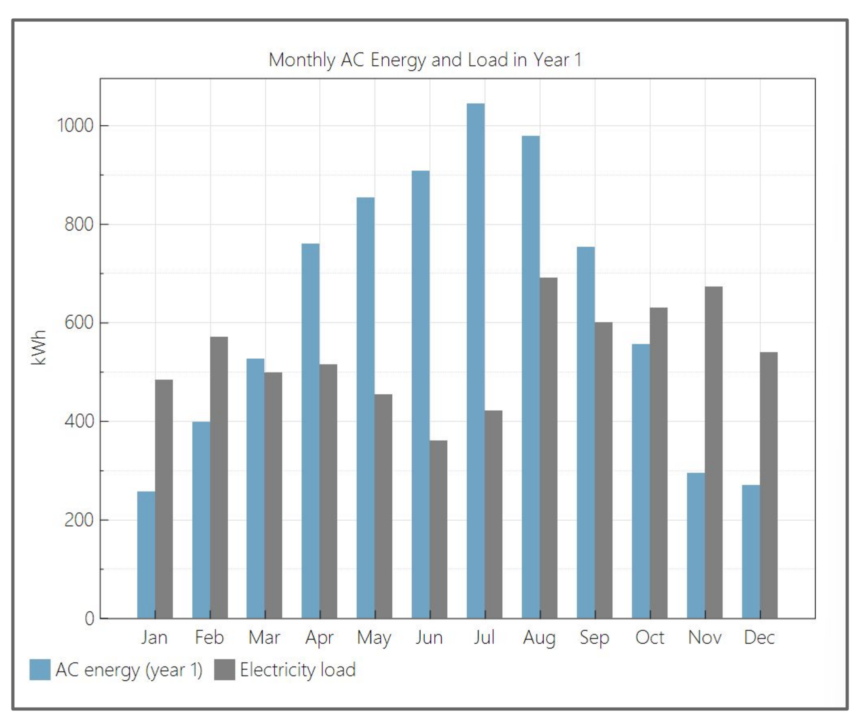

Figure 2. Energy required and harvested in a year with a 20 panel system.

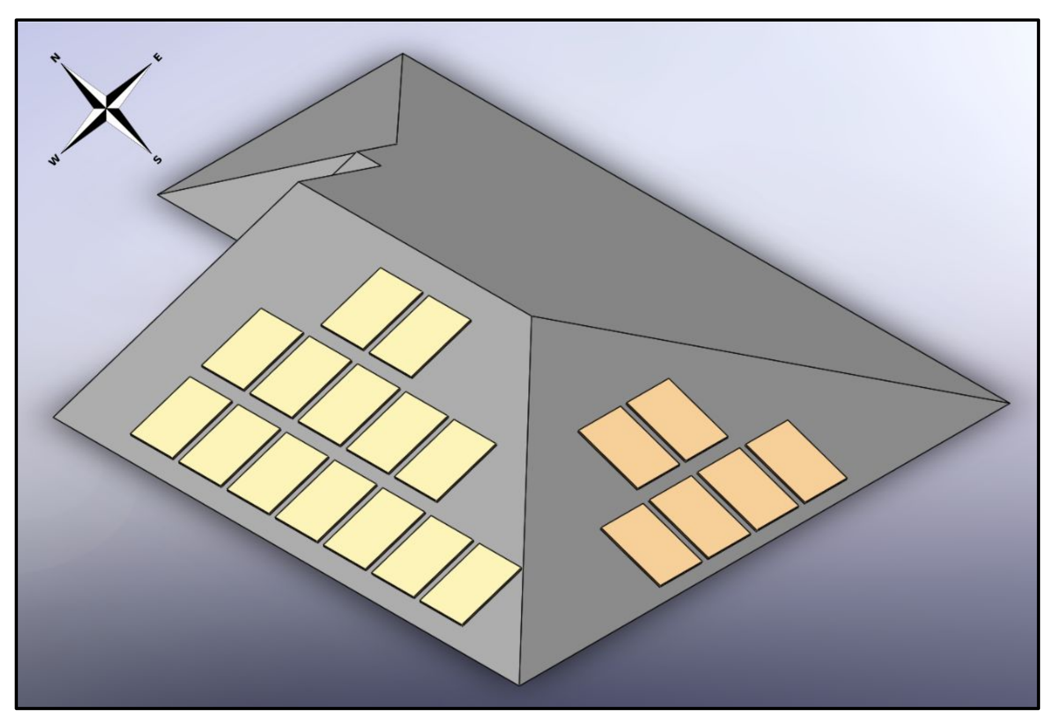

Figure 3. A solar panel design and layout.

Table 1. Heating methods with their resulting annual consumption and energy cost.

		Natural Gas	Electric Heat Pump	Electric Boiler
Annual Consumption [MMBtu/yr]	**Heating**	49.0	17	46.0
	Cooling	1.5	1.4	1.5
Annual Energy Cost [$/yr]		1093	1232	1975

Figure 3 shows the solar panel design with 20 solar panels. The panels were laid on the roof such that it would face towards the **South** and **West** in order to maximize the energy harvested by the system.

Additionally, Figure 2 shows a month by month graph of the energy required by the house and the energy harvested by the solar panel system. For five months of the year, the house will need to receive energy from the grid to supplement the system. This is due to the decrease in sunlight and increase in energy required during the winter months.

Table 1 describes the energy modeling results from a change in just one variable: the space heating and cooling. The initial home includes a **natural gas** boiler for space heating which then requires a split system for cooling. An **electric heat pump** provides both heating and cooling while also consuming the least amount.

CONCLUSIONS

- Passive improvements for energy efficiency is already optimized in new construction.
- Energy efficient appliances & updates can be more expensive, but that cost can be offset with onsite production and rebate options.
- Carbon emissions and environmental impacts do decrease with energy rated items.
- Onsite generation & renewable energy implementation must be strategic and balanced with other personal factors.

Acknowledgements

Special thanks to all the groups and organizations such as UWT and the Solar Decathlon that supported this research and design including but not limited to our industry advisor Gus Takala, Dr. Mithra Sankrithi, and Dr. Mark Pagano as the instructor for this course.