A STRIVE TO NET-ZERO: INSULATION IN RESIDENTIAL HOUSING

INCREASING THE APPEAL OF SUSTAINABLE HOUSING

An Undergraduate Thesis Portfolio
Presented to the Faculty of the
School of Engineering and Applied Science
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By

Jack Pazin

May 9, 2022

Carbon dioxide (CO_2) emissions are a large problem globally and residential buildings account for a sizeable portion of the global CO_2 emissions. The technical report discusses designing a heat exchanger for a ground source heat pump, a solar tracking device, and testing different types of insulation. Each goal contributes to the main goal of reducing CO_2 emissions in housing either by producing clean energy or by reducing the amount of energy consumed. The STS portion of the research is focused improving the accessibility and affordability of sustainable housing. STS research focused on using various methods such as subsidies, shared equity housing, and changing rating systems used to score neighborhoods on sustainability. The technical and STS portions are tightly coupled since they both work on improving access to sustainable housing and reducing CO_2 emissions from the residential sector.

The technical portion discusses powering a home designed and built by the UVA School of Architecture using clean energy sources. The project was split into a group testing different insulation types, a group developing a solar tracker, and a group designing a heat exchanger for a ground source heat pump. The insulation group designed and constructed a device that uses heating tape and a box to expose one side of the insulation to heat and expose the other side to a room temperature conditions. The R-value and thermal conductivity of each insulation sample were calculated using a 1D heat transfer analysis. The solar group designed and built a system that allows a solar panel to “track” the sun by keeping the solar panel perpendicular to the sun’s rays at all time in order to maximize efficiency. The heating and cooling group is testing scale models of different piping designs for heat exchangers used in ground source heat pumps.

Applying these three systems in homes should reduce emissions by adding clean energy sources and by reducing the energy needs of the residential sector.

Due to permit restrictions, the additions were not able to be added to the house. However, proof of concept was still feasible. The solar panel group was able to design a working scale model solar tracker and is currently building a full-scale system. They were able to generate enough energy to power household appliances during testing. The ground source heat pump group was able to create scale models of different heat exchanger piping systems and is currently testing them to collect data. Currently, mineral wool, fiberglass rolls, extruded polystyrene, and expanded polystyrene have been tested as insulation candidates. Data analysis still needs to be completed so the report is currently inconclusive.

The research question being addressed within the STS portion of the report is as follows: how can sustainable homes become more affordable and appealing to the average person? Support for the thesis was given by a combination of interviews and studies. For example, the suggestion of mandating the affordability component of the Leadership in Energy and Environmental Design for Neighborhood Development (LEED®ND) rating system for neighborhoods being considered for LEED®ND certification. Studies were used to back up claims about shared equity housing as a viable method for improving the affordability of housing in general. Those same studies found lower foreclosure rates and a high rate of people within the program eventually buying homes at market rate.

Overall, changing rating systems, expanding shared equity housing, and improving subsidies could improve access to sustainable housing. Changes to rating systems could either involve weighing the cost categories more heavily or making them mandatory for certification. Doing so would put pressure on builders focused on sustainable housing to lower the costs of

their products. Also, adding shared equity housing programs to sustainable housing neighborhoods would improve affordability and foreclosure rates as previous studies show over 90% of low-income homeowners in such programs remain homeowners five years later. Subsidies such as the California Solar Initiative allow for rebates that come with the initial installation costs and energy provided to the grid. These subsidies and rebates make sustainable housing practices more attractive by lowering upfront and overhead costs.

In conclusion, the attractiveness for sustainable housing is often determined by economic factors. Lowering the costs of clean energy technologies and providing incentives for implementing them in houses lowers overall CO_2 emissions by increasing the attractiveness of those technologies. Finally, lowering CO_2 emissions in the residential sector is difficult but fixing rating systems, expanding shared equity housing and subsidies, and improving energy efficient technologies can help.

TABLE OF CONTENTS