THE SUSTAINABLE SINGLE-FAMILY HOUSE

BRIDGING THE GAP OF EXISTING SINGLE FAMILY HOUSING AND THE NEW STANDARD OF SUSTAINABILITY

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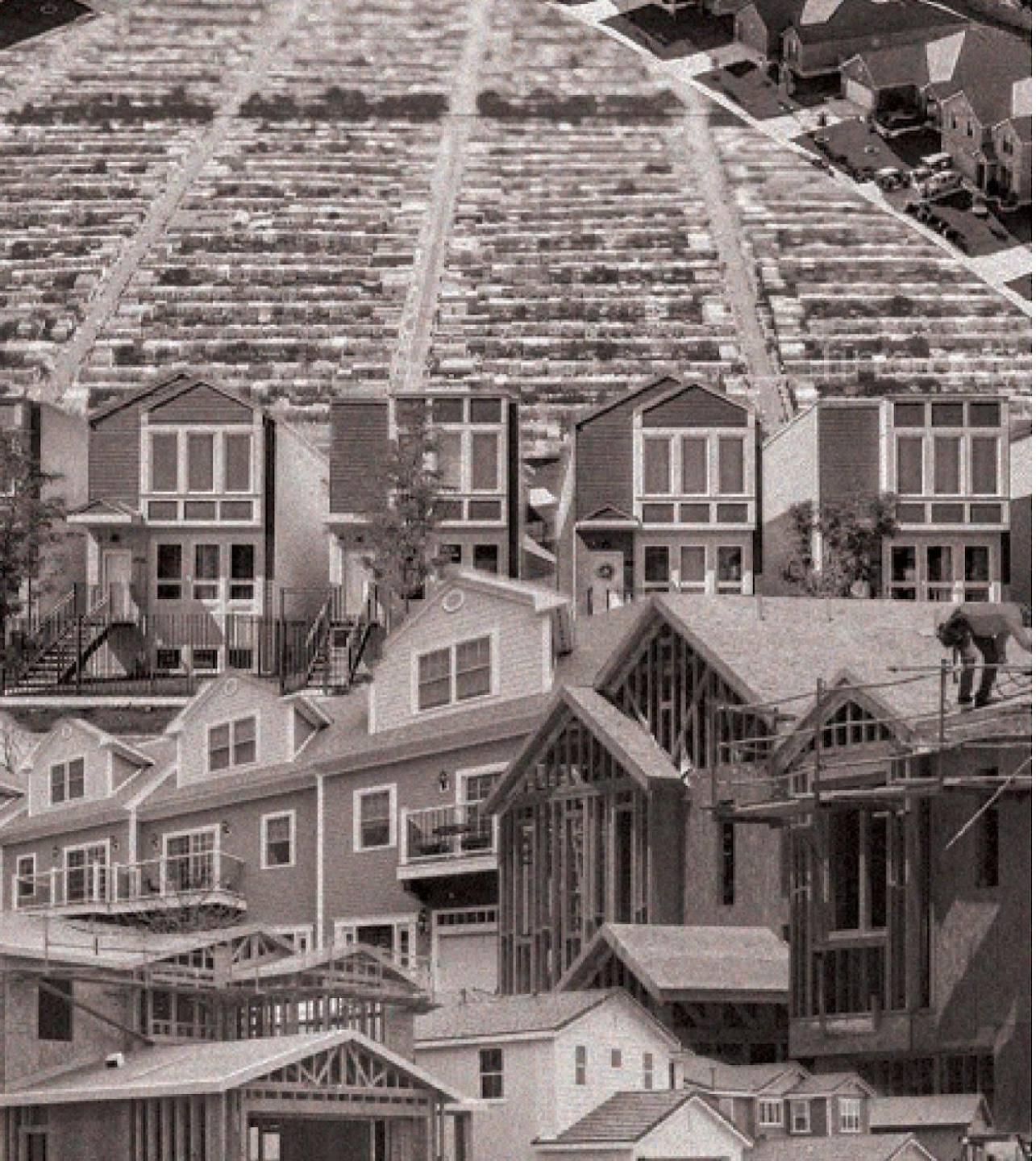


DEFINITIONS

Tract Housing: When a Developer or Builder purchases a large plot of land, divides it into smaller parcels, and then builds the same or similar houses multiple times around the land to create neighborhoods.

Sustainability: Minimizing the negative environmental impact of buildings.

Single-Family House: A free standing (detached) residential unit that houses one household or family. Typically ranging from 1,500 S.F. to 2,500 S.F.

2030 Baseline: Energy Consumption anticipated for a modern building - 2030.

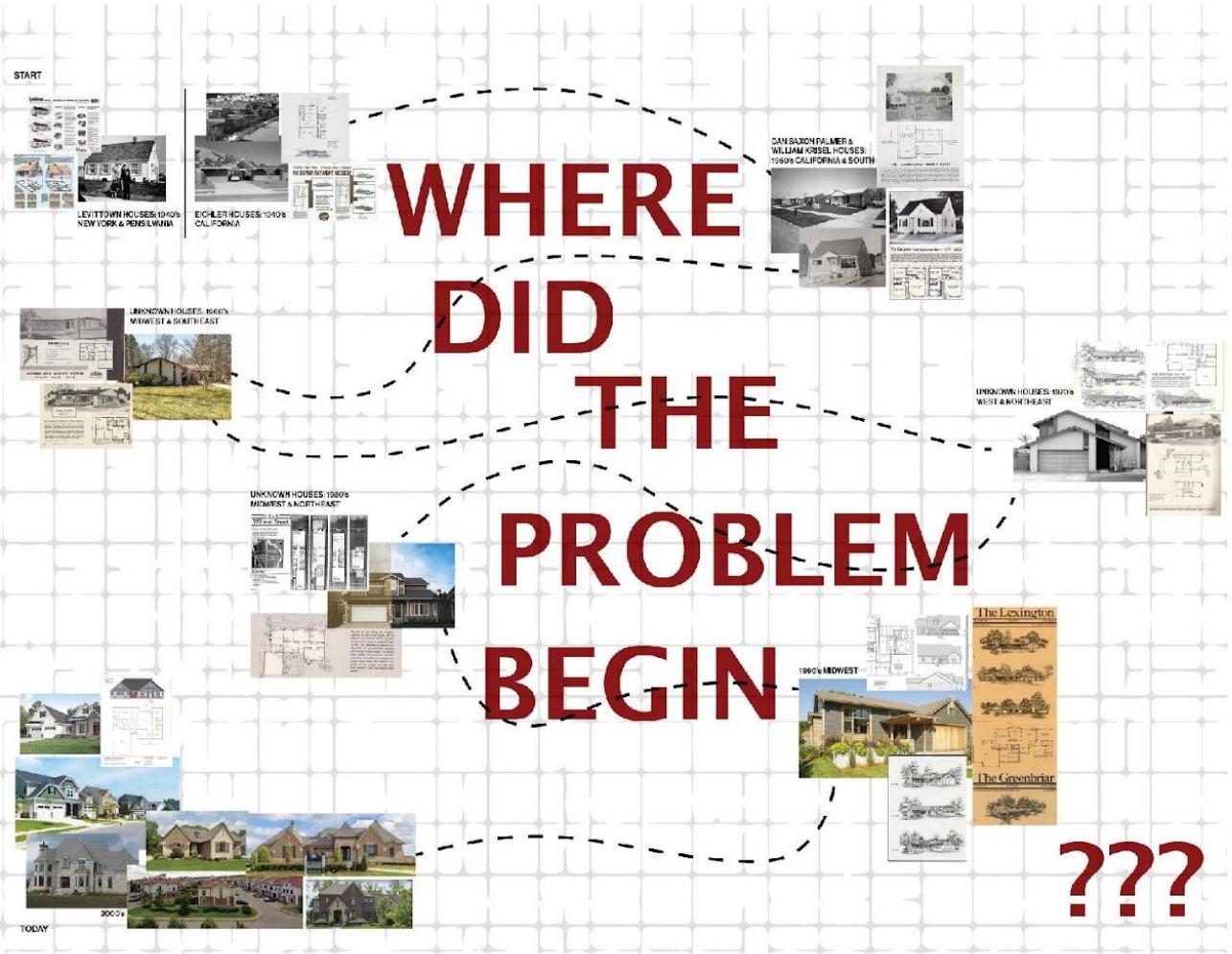
Carbon Emissions: Amount of CO_2 released during the life cycle of building materials

EUI: Energy Use Intensity - Amount of energy per S.F. annually.

BACKGROUND

When imagining the issues within residential architecture, it is easy to think of the mass production of the single-family house, the tract housing industry. Presenting the idea of sustainable tract housing comes with some difficulties. Nonetheless, it is a relevant issue in today's society and has the potential for multiple solutions.

The houses within these developments have begun to increase in size at an alarming rate. There is a want for bigger and better houses each year. This past year, there was an all-time high of the average single-family house square footage at 2,500 s.f. Which is almost 10% larger than the previous years. With the growth of the houses, the overarching question is; is it the development of the houses or the single-family house itself that is having the greatest impact?

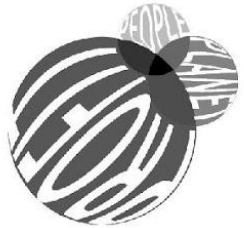


The History of Tract Housing

Tract housing arose in the 1940s with the construction of Levittown. William Levitt designed and built the one single-family house that was accessible to the masses and built quickly, and affordably. The idea came about from the lack of housing for the soldiers and their families coming home from the war. The creation of a community, a neighborhood. There were plenty of other ideas as such that followed Levittown. Some include; Sears Houses, Eilicher Houses, Palmer and Kriesle Houses.

This approach to housing was a revolutionary idea at the time of creation. Tract Housing, also referred to as "cookie-cutter houses", is popular in the suburbs because of time and cost efficiency in addition to the ease with which profit margin increases. These houses, however, have caused many debates in the architectural field. The argument against this type of building is that the developers give little to no attention to sustainability. Their focus remains on financial gains. That being said, most houses need to be illuminated and conditioned at all times. It adds considerable cost to the homeowner's bottom line and is creating small, yet impactful damage to the environment as each new build contributes to the next.

Somewhere along the line, changes were made to the intentions of the houses. The houses once built to grow families and communities are now built with the priority of profit and ease of development. The builders and developers who are building these neighborhoods' first concerns are what is in their best interest rather than the future homeowner.



DISTRIBUTION OF EFFORTS

PREVIOUS DEVELOPED METHODS

MAXIMIZED PROFITS

FEAR OF PRICE INCREASE

LACK OF EDUCATION IN SUSTAINABILITY

OUT OF DATE POLICY

Assumptions

During the beginning process of this research, one of the most valuable driving factors was the assumptions on the topic of single-family housing. In this thesis, six assumptions came about from the beginning of the idea. These assumptions were as follows; Distribution of Efforts, Previous Developed Methods, Maximized Profits, Fear of Price Increase, Lack of Education, and Out of Date Policy.

First is a lack of distribution of efforts from the developers who are building these houses to design and think sustainably. Leading to the questions:

Where did the problem begin? Why did the efforts shift out of focus?

Second and third being that there is already a predetermined method that the developers have that allows them to maximize their profits. Guiding the conversation to become more of:

How can sustainable methods be integrated into today's housing design without disturbing developers' existing methods and profits?

Fourth, the developers are worried that the sustainable methods will increase the price of materials and production.

How to find alternative materials and methods that would be more sustainable and affordable for the production of a single-family house?

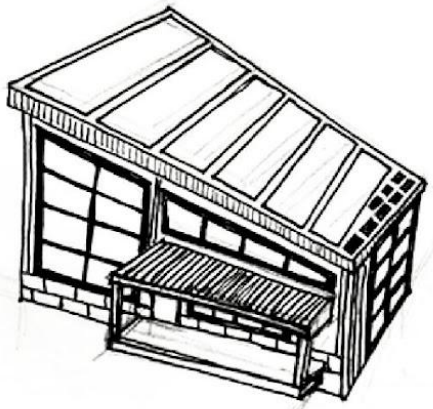
Can sustainability become affordable?

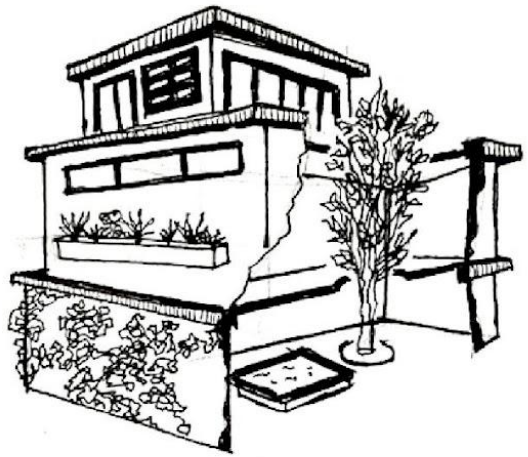
Fifth and most importantly, there is inadequate education of the developers and even architects. Dominating the discussion in this thesis with the questions of:

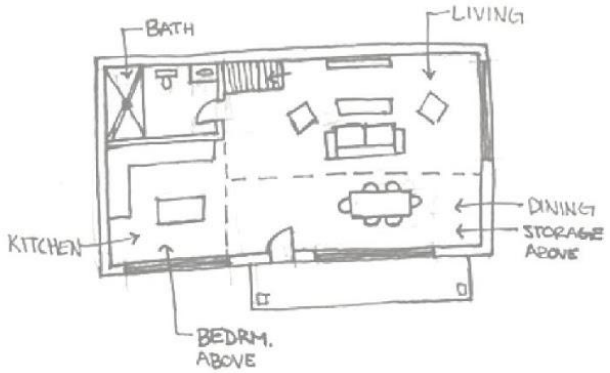
How can education begin to meet the sustainability standards? How to teach the older generation that sustainability needs to be implemented now?

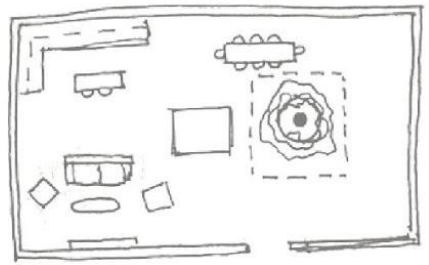
Lastly, the policy created for the construction of houses is out of date. This originally led to the question of:

What would entice developers to change their building methods without increasing the policy standards?









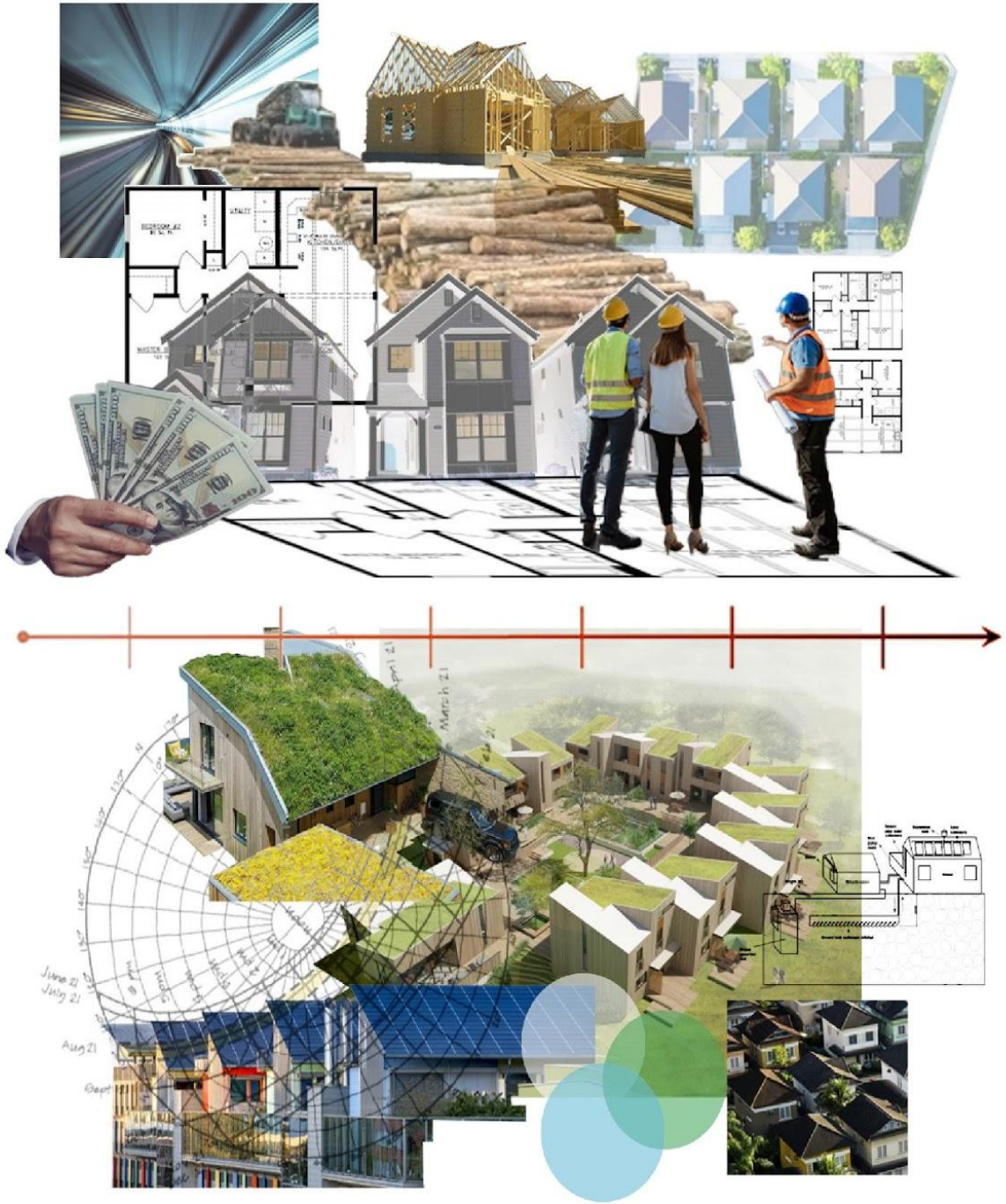
Precedence: Sustainable House

During the development of the idea of creating a Single-Family house that is also sustainable, the first step was to look into existing sustainable houses.

In order to do so, a predominant method of assessing the houses was sketching to truly understand the form and concept. The sketching process allows for creativity of the mind. For interpretation of each project from the eye of the artist. It best represents where the research understanding is coming from and highlights the aspects that stand out the most to the one who drew them.

Originally the research started with interior analysis. Looking into the layouts of many of the houses to see what the impact of interior walls and placement has on the health of the inhibitors. Quickly the layouts started to form a pattern of open spaces and biophilic integration. With that being said, there was no interior spaces that had the ability to affect the sustainability of a house in the way that it would greatly benefit the exterior environment.

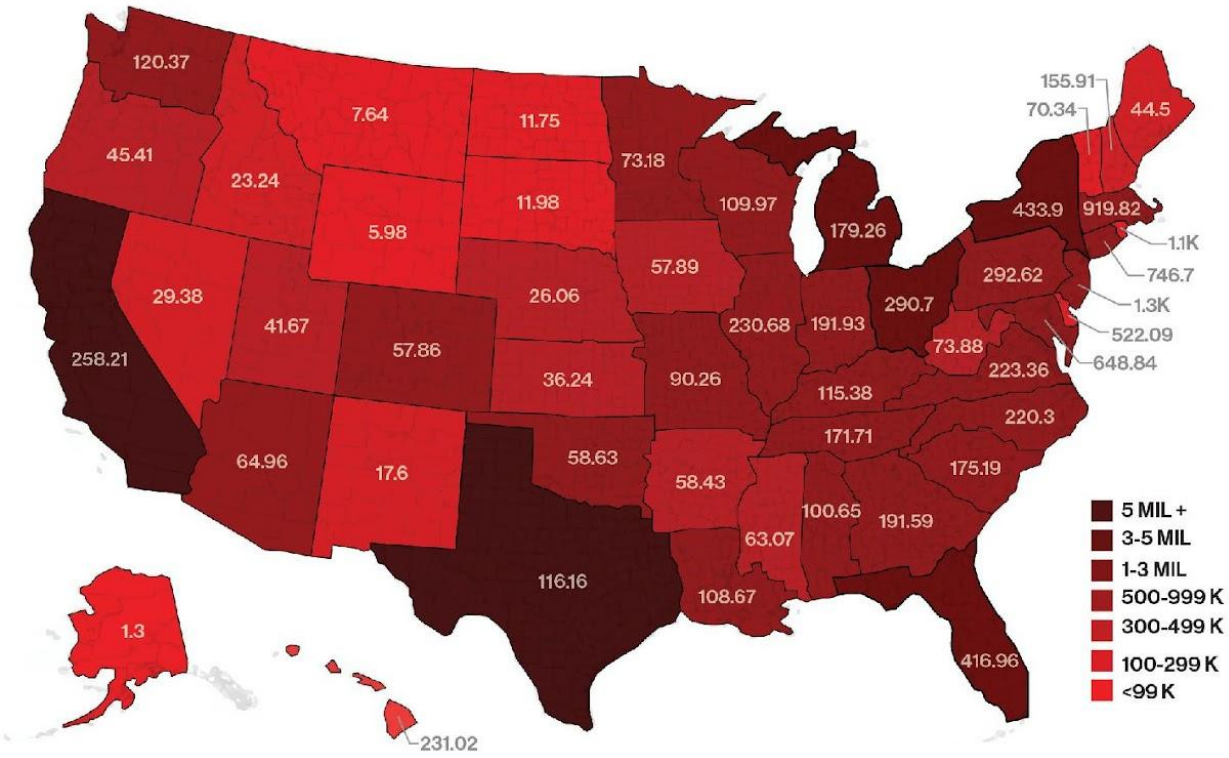
Having said that, the facade of the houses and the make of the construction components were found to be the most impactful after first glance of the precedence. Looking at the houses found, it was clear through the exterior that a major impact of these houses were their form. Each one was simple and modern. Mainly in a box formation and it was clear that each were specifically oriented to maximize sun integration. Exercising the use of large windows on all faces of the building for better interior health. Along with flat - low angled roofs for solar panel energy utilization. Each of the sustainable methods listed have the potential to be integrated into the typical single-family house, but the questions are, is it affordable to use these methods in typical homes and can a single-family house sustain modern methods and materials?



How Houses are Built Today

In order to understand the abilities that a single-family house has to become sustainable, one must understand how they are built today.
The initial objective of a house was to provide shelter from weather, animals, and create privacy from others. There was little to no thought on aesthetics or grandiose motions to create 'lavish' conditions. This was the most sustainable way of building as everything was locally source and constructed.
Assumptions aside, it is known that not all houses are built in the most sustainable way. Yet, assumptions lead to the idea that little to no single-family houses in suburbs are built to be sustainable at all.
Starting with the idea of mass production leading to the larger problem of the houses within these development themselves. The single-family house holds more sustainability issues than where and why they are built.

What is the future of housing?
Sustainability is a major driving factor into the future of housing. But, how do houses go from where they are now to becoming more ecologically friendly?
Assuming the focus is within existing houses, the integration of sustainability will come with limitations. Incorporating conditions into the reconstruction where materials, elements, and structure are analyzed and kept or replaced in the house based on their energy usage, carbon impact, and material lifespans.



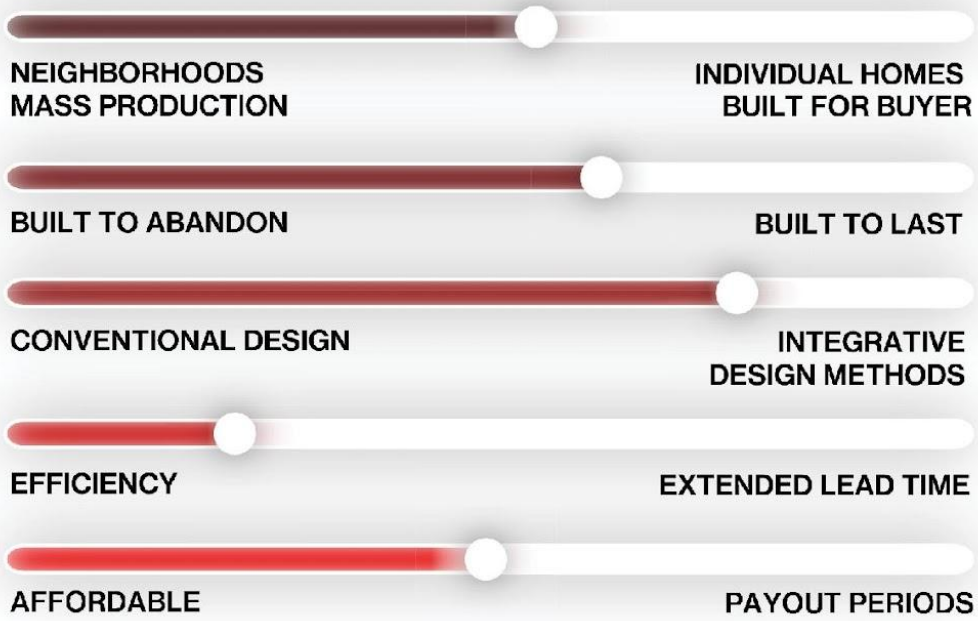
145 MILLION HOUSING UNITS IN THE U.S.

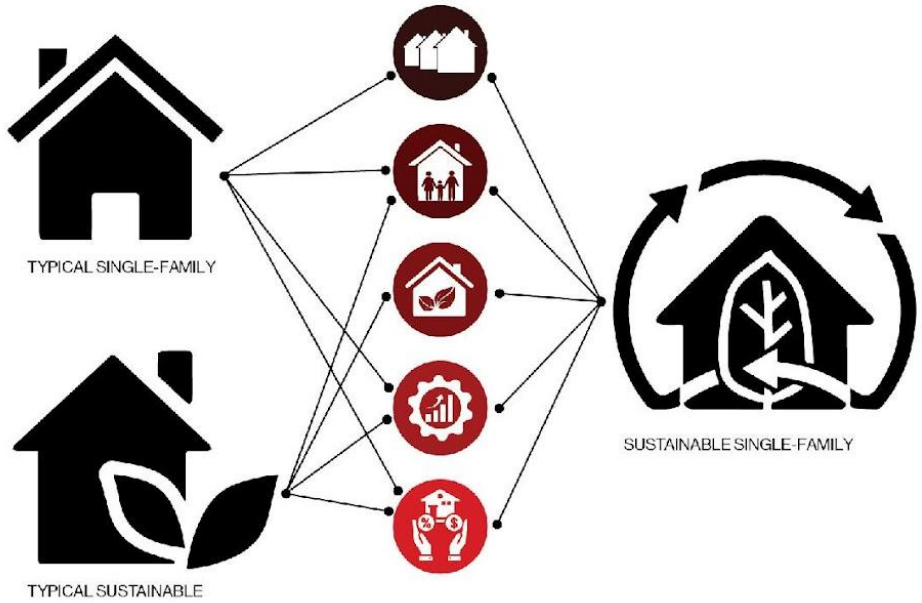
67% OF HOUSING UNITS ARE SINGLE FAMILY

Relevance

As of today, 2023, there are 145 million housing units in the United States alone. This is including all types of houses. As expected, more than half of these housing units are single-family. Specifically, 67% are single-family houses. That equates to 97 million single-family houses in the United States.

This map shows the density of single-family housing in the United States compared to the population density of each state. One of the more obviously dense states is Michigan.





Affordances

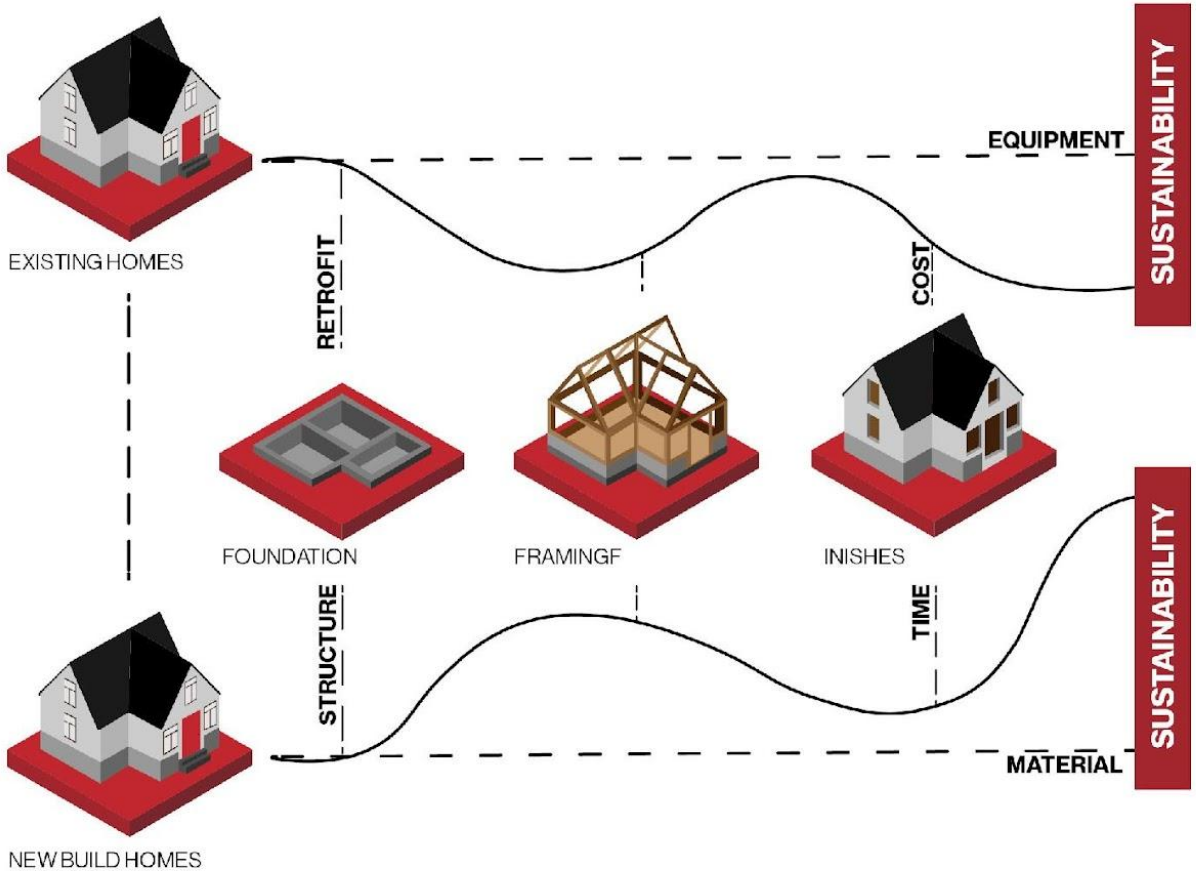
An affordance of a concept is what somethings original intent is versus what it is actually used for. This means that there is a balance between the two intentions of a building. This thesis uses the precedent studies of both a 'typical' single-family and sustainable house. Forming affordances of the beneficial aspects of each type of house to create a scale in which this thesis will decipher where the sustainable single-family house will lie within each comparison.

Looking at each house, there were 5 points that stuck out for the best outcomes. The intention of build, lifespan, design methods, timeline, and budget. These particular prospects are thought out with every project from the beginning which gives every reason to explore other options and opinions when deciding where to move towards in the future.

When scaling each of the components, it is important to note that no aspect has the ability to 'fix' the issue by itself, nor will it be valuable when it is overpowering the other scales. The top image is showing this thesis' placement of each element is used to give an overview of goals for the Sustainable Single-Family house.

TOPIC

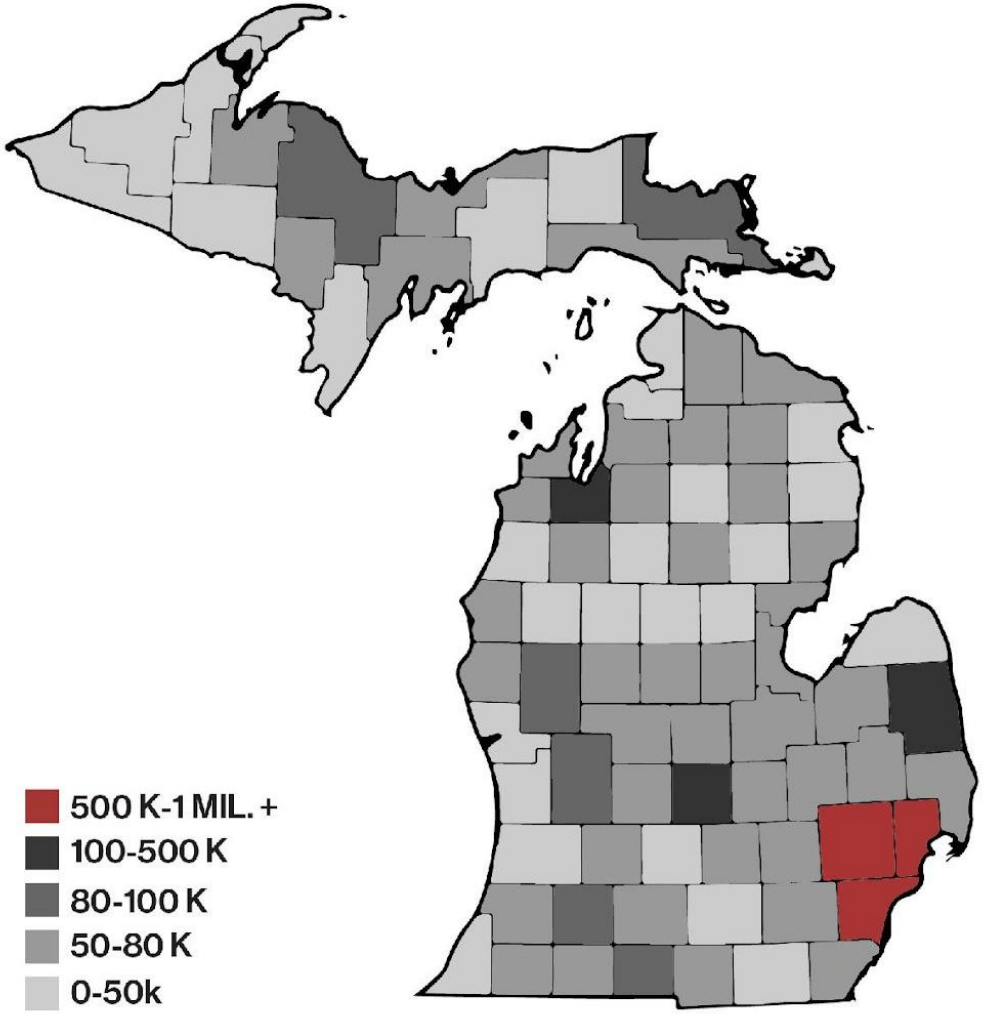
Moving forward, this thesis is focused on the sustainable rehabilitation of existing single-family houses. Exploring conditions of energy usage, carbon emissions, and material lifespans to see where the greatest impact is created by the houses. Researching both the negative and positive effects of each.
Proposing a location of research along with a illustration of the ‘typical’ house to be studied and manipulated.
Utilizing modeling as a majority method of research. Operating out of Rhino, Grasshopper, Cove.Tool, and physical crafting to demonstrate ideas and discover new information on the sustainability of the proposed house.



Affordances

At this portion of the research, the sustainability of both an existing and new build single-family house seemed equivalent. Needing the same research and information to form a solution to their environmental impact. This lead to the comparison and affordances of the two types of builds rather than sustainable versus unsustainable. As shown in Figure _ there are similar details along the transformation of the houses such as the foundation, framing, and finishes. Some of the differing elements are the structure, materials, time, cost, and equipment. In a new build house, all of the elements of a house are open to evaluate and change. Whereas in an existing house, there are only certain portions that can be manipulated in the favor of sustainability without exceeding the affordability aspect shown prior. It was clear that the construction types needed to be separated in research. Which lead to the decision to study the retrofit of existing houses in order to solve the pre-existing problem before finding a solution for the future.

Circling back to the affordances created now and previously, the application of these findings will be crucial in this portion of the thesis research. Finding how to integrate the scale of elements into the houses.

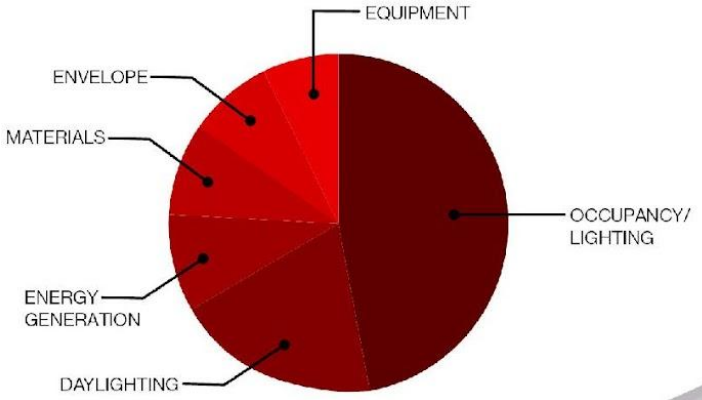


3 MIL.

SINGLE-FAMILY HOUSING UNITS IN MICHIGAN

Location

As pointed out, Michigan has an extremely dense population of single-family houses. Michigan specifically takes up about 3% of the single-family houses in the United States with 3 million units.
Focusing more on this, one of the more densely populated areas of Michigan is in the Metro-Detroit cities. Just under half of the population of houses are located. Taking this into consideration, this thesis will be based in a city within Metro-Detroit, Berkley, Michigan.
Located Northwest of the city of Detroit, Berkley is a small place populated with majority houses that specifically meet this thesis' definition of single-family with detached units ranging in size from 1,000-2,500 S.F.
The exact house that will be utilized is at an average of 2,000 S.F. and located centrally in the city on the cross roads of 12 Mile and Prairie Street. This house will allow for neutral data to apply for most of Michigan's existing houses.



66.27

ORIGINAL HOUSE:

Single-Family I 2-Story

West Facing I Berkley, MI

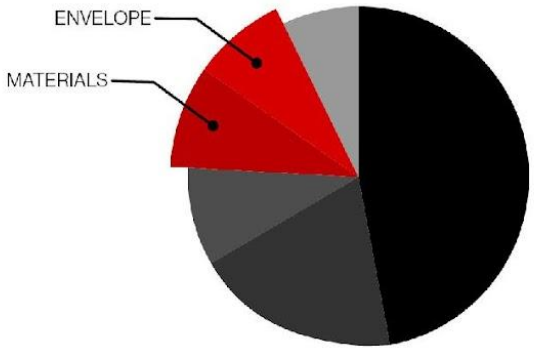
Original House

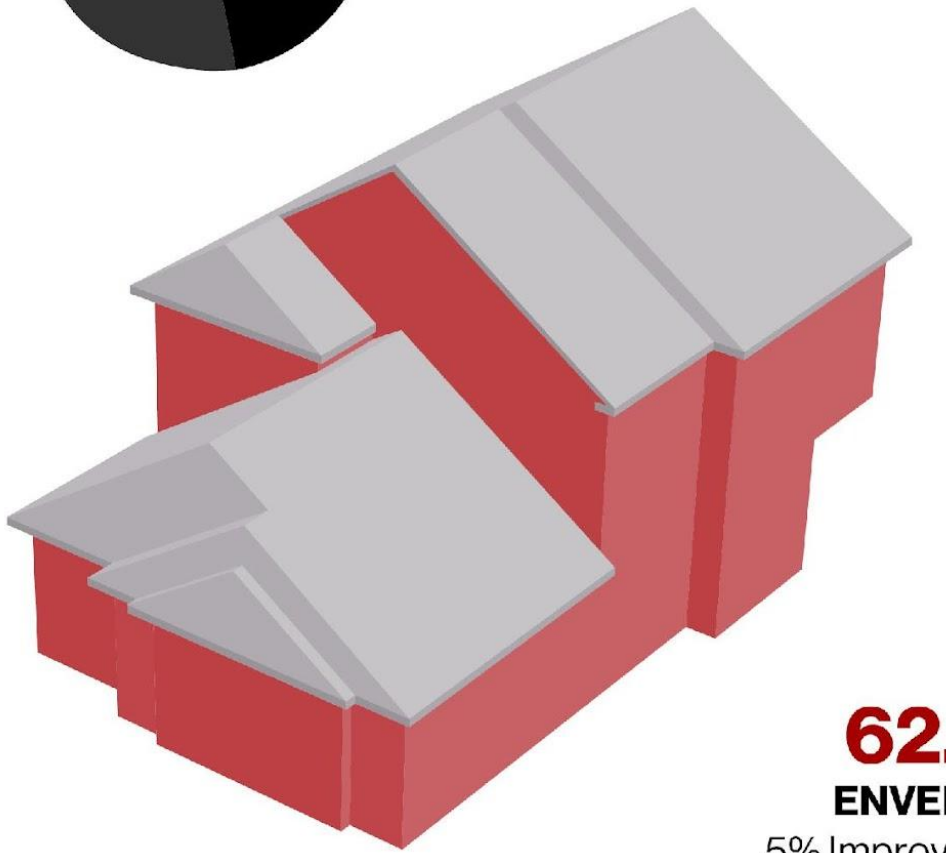
Energy usage of a single-family house creates an impact on the environment. Through multiple elements of energy including but not limited to, the envelope, energy generation, daylighting, and occupancy. The energy usage is measured as EUI, energy usage intensity. The baseline EUI expected for the year 2030 is 49.77. The 2030 target EUI is 9.95 which is significantly lower than the baseline for the year.

Putting this example house through the energy modeling program, it was found that the house was much higher than the baseline energy usage by 20 points and above the target by almost 60. It was interesting though that the house itself was not 'as bad' as expected. For a 2-story, single-family house in Michigan it could be retrofitted to becoming a much more sustainable version of itself.

49.77 : 2030 BASELINE EUI

9.95 : 2030 TARGET EUI





62.94

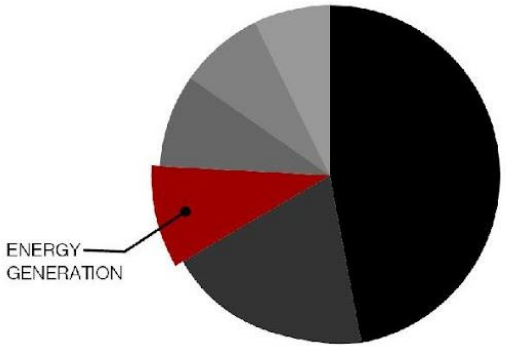
ENVELOPE:

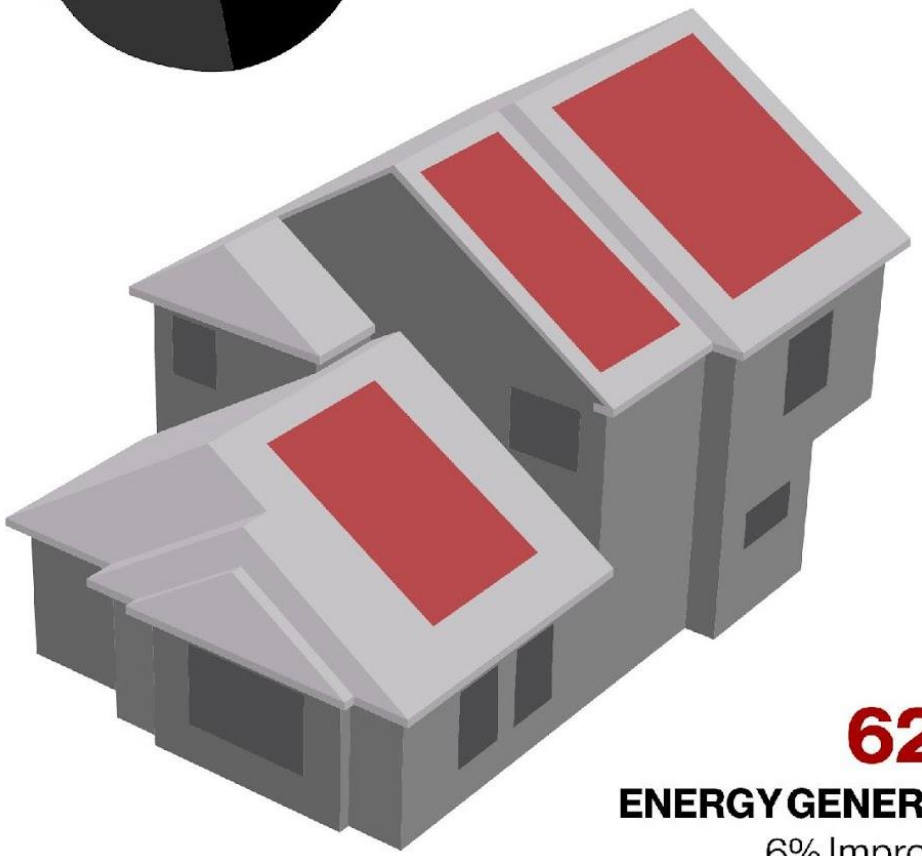
5% Improvement

Envelope

The first step of evaluating this house was the envelope. Especially after the material study, there was a need for the information on the amount of energy is used in order to support the envelope of a single-family house. Elements that were manipulated in this process included, but where not limited to materiality, insulation values, and emissivity.

After researching the best possible options for each of the topics, the values were entered into cove.tool and reevaluated to create the new EUI. This value ended up to be 62.94 which is a 5% improvement on its own.



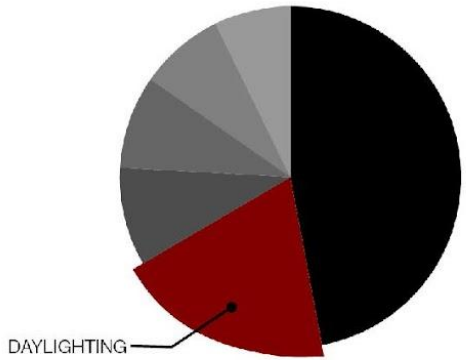


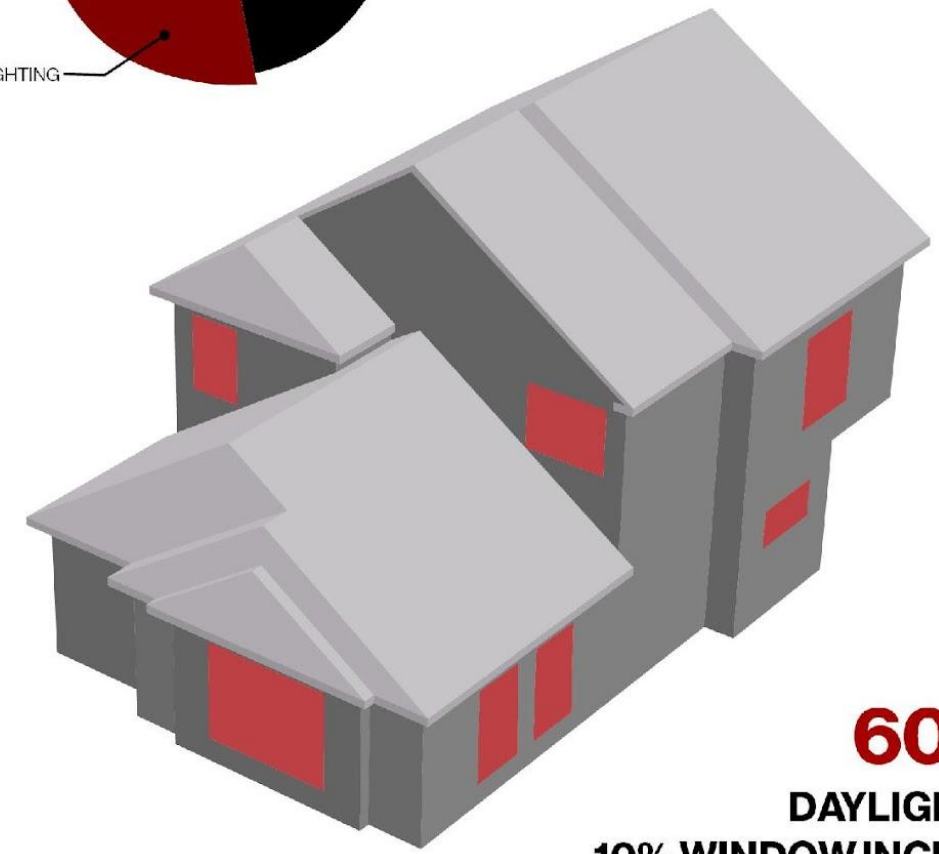
62.59

ENERGY GENERATION:
6% Improvement

Energy Generation

One of the more obvious and simple paths to research in a sustainable single-family house is the energy generation. Becoming self sustaining through energy generation of solar, water, and ventilation. Elements that can be manipulated in this process are mainly the solar generation.
With the addition of maximum solar panel square footage on the roof of the existing house, the EUI was lowered by 6% to a total of 62.59. This is a great improvement, however it alone is still not enough to reach the 2030 baseline for sustainability in energy usage.



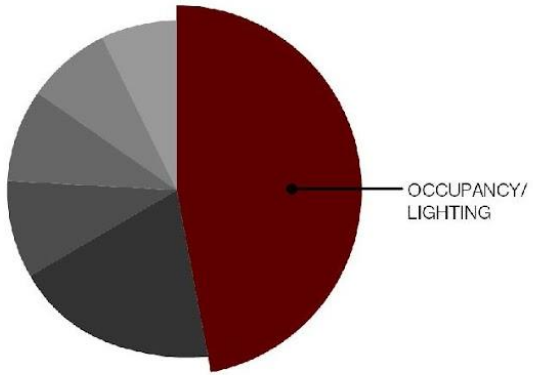


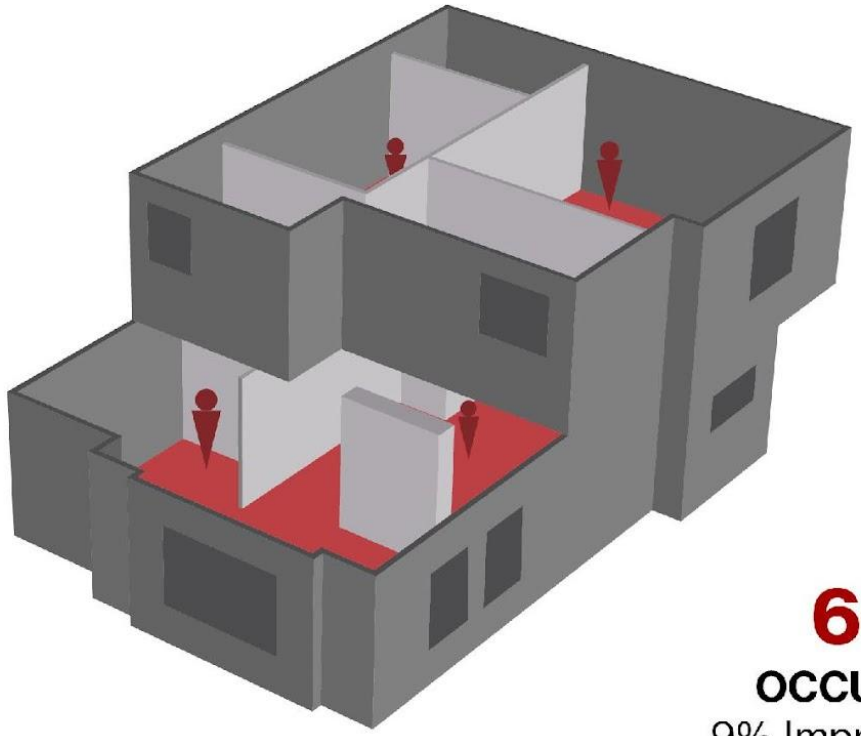
60.00

DAYLIGHTING/
10% WINDOW INCREASE:
+9% Improvement

Daylighting

For a greater improvement on the interior health of the house it is important to look into the daylighting as well. This is also important for the sustainability of energy usage as the more daylighting there is the less energy needs to be used during the day. It also benefits the heating and cooling systems which in turn lowers the energy.
Without being able to change the orientation of the home, the one thing to manipulate would be window sizing and placement. With this particular house, with a 10% increase of the window sizes, a +9% improvement can be in effect with a flat EUI of 60. This is the largest improvement outcome out of all of the sustainable methods for this house and location.





60.40

OCCUPANCY:

9% Improvement

Occupancy

The occupancy of a house effects the outcome of the energy usage because the more one is within the house the more energy they are bound to utilize.
The only portions that can be manipulated with this option is changing the amount of hours the house is occupied. Taking advantage of this, the EUI was lowered to almost as low as the Daylighting effect with a 9% improvement at 60.40. However, it cannot be expected of homeowners to simply stop using their power sources, so this is not a viable option for this thesis research even with the large impact.

In total, with all of the sustainable methods combined into one single-family house, the combined EUI was lowered to 47.05 which does meet the baseline for 2030. It also confirms that there is not one solution to the sustainability problems of the single-family house, but more of a plethora of options with different impacts that can be utilized based on budget, time, location, and house.

47.05 **: COMBINED EUI**

MILLION COMMERCIAL BUILDINGS

140 TONS OF CO_2 PER BUILDING

826 MIL. TONS TOTAL

MILLION SINGLE-FAMILY HOUSING UNITS

7 TONS OF CO_2 PER BUILDING

679 MIL. TONS TOTAL

Carbon Emissions

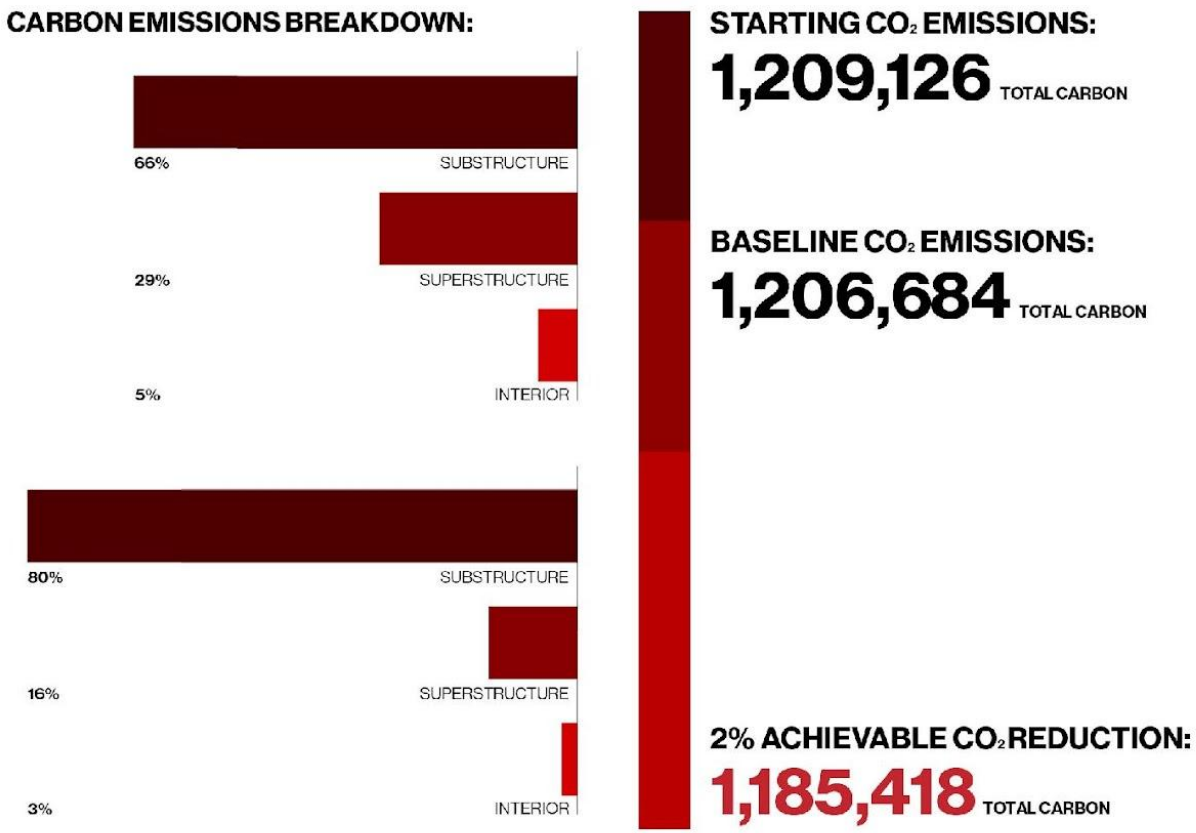
There is a misinterpretation of what a large impact residential architecture has on the environments. In today's society, it is very common for firms, builders, and laymen to think of sustainability efforts only towards commercial buildings.

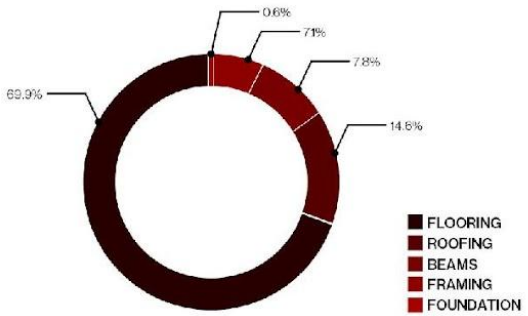
In order to show how great of an impact there is through the single-family houses, this diagram compares the carbon emissions of commercial buildings in the to single-family houses in the United States to illustrate the equality of the issues.

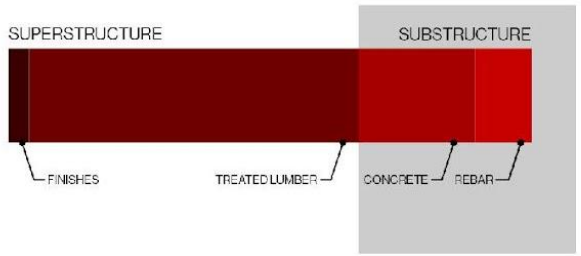
There is the impact of commercial buildings, starting with the number of buildings in the United States at 5.9 million. Each of these buildings produce 140 tons of carbon which in total equates to 826 million tons. Which may seem like an excessive amount that a house simply cannot compare to. However, the opposing diagram shows that there are 97 million single-family houses at 7 tons of carbon per house. This adds up to 679 million tons total. In turn, single-family houses are less than 200 million tons away from having the same impact as the commercial buildings and it is growing every year as the houses get larger. For every 20 houses retrofitted, the carbon impact would average the same as one commercial building. This is the average subdivision size, meaning that one subdivision can make the same carbon impact as an office building.

Taking this information into account, it is critical without even looking into one house specifically, to start looking into the sustainability of a single-family house through its carbon impact.

After affirming the sizable carbon impact that single-family houses have on the environment, this thesis turned towards diving in to finding a solution. Answering a similar question from previously in the energy impact of, what in a house is creating the largest impact and is it feasible to fix within an existing home?

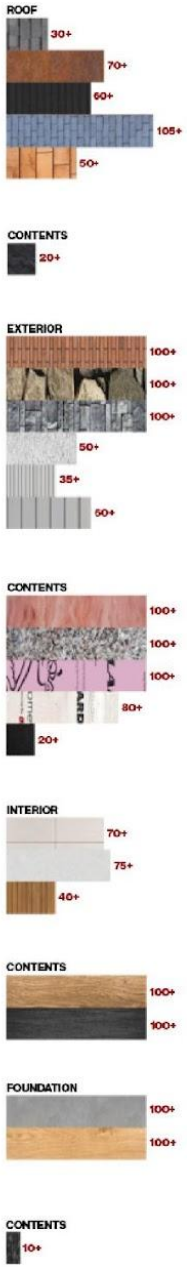






Carbon Emissions

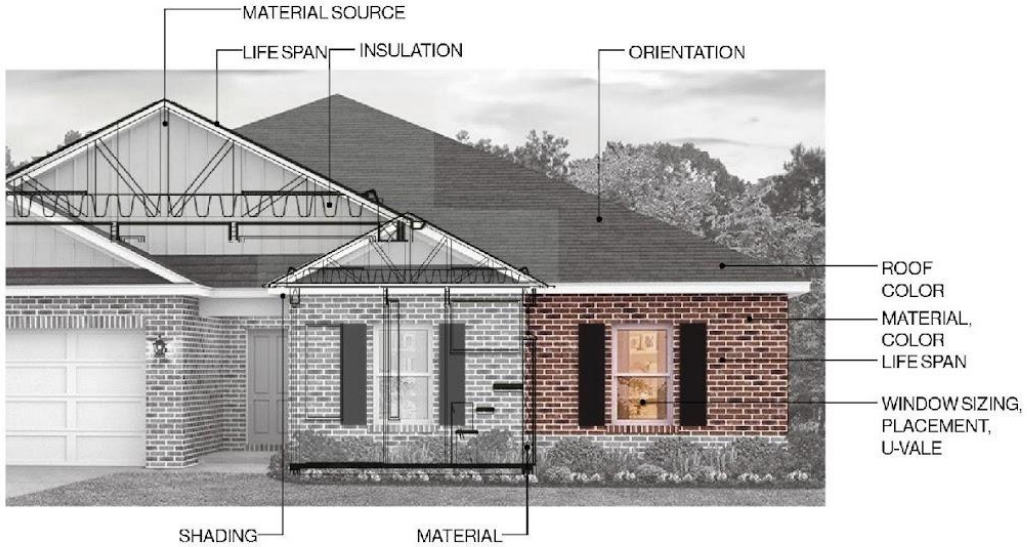
In response to the search for the greatest carbon impact within a single-family house, a review of the structural systems was needed. In Figure _ the carbon emissions are broken down into substructure, superstructure, and interior. These diagrams demonstrate the impact of every element within the superstructure that can be manipulated.
Before making any changes to the Rhino model, the substructure was obviously creating a much larger impact than the other influences and they overall started with 1,209,126 total carbon.
Surprisingly, this was not far from the baseline carbon emission for a house in this area. With only a 2% decrease, the example single-family house could potentially fall below the baseline with a carbon total of 1,185,418.

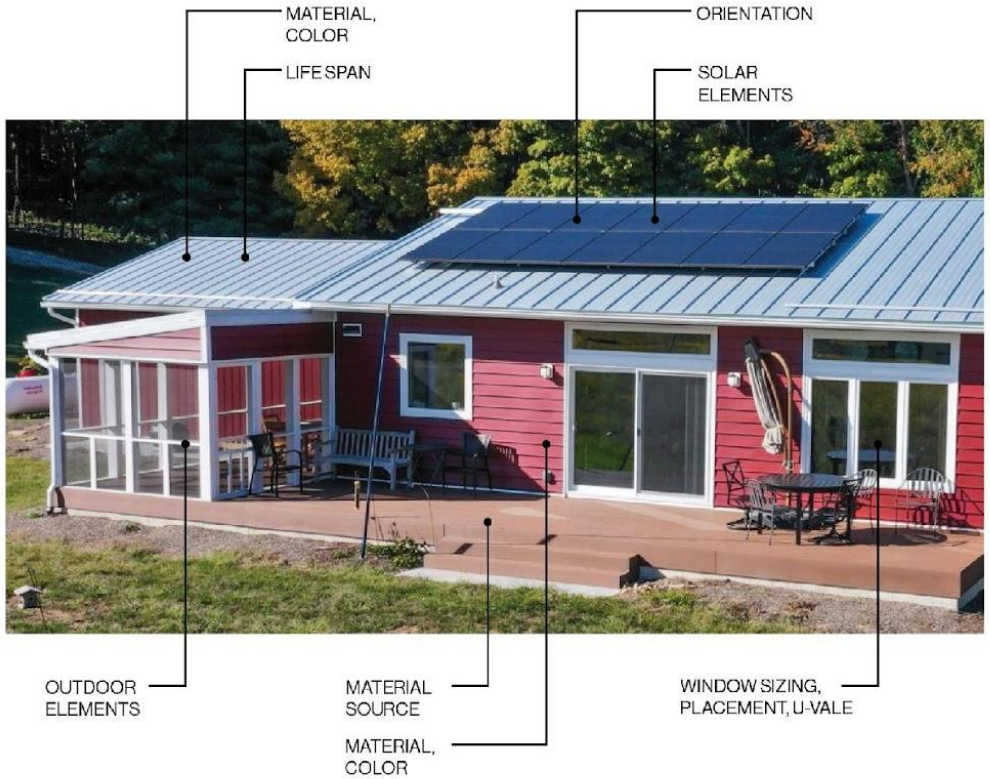


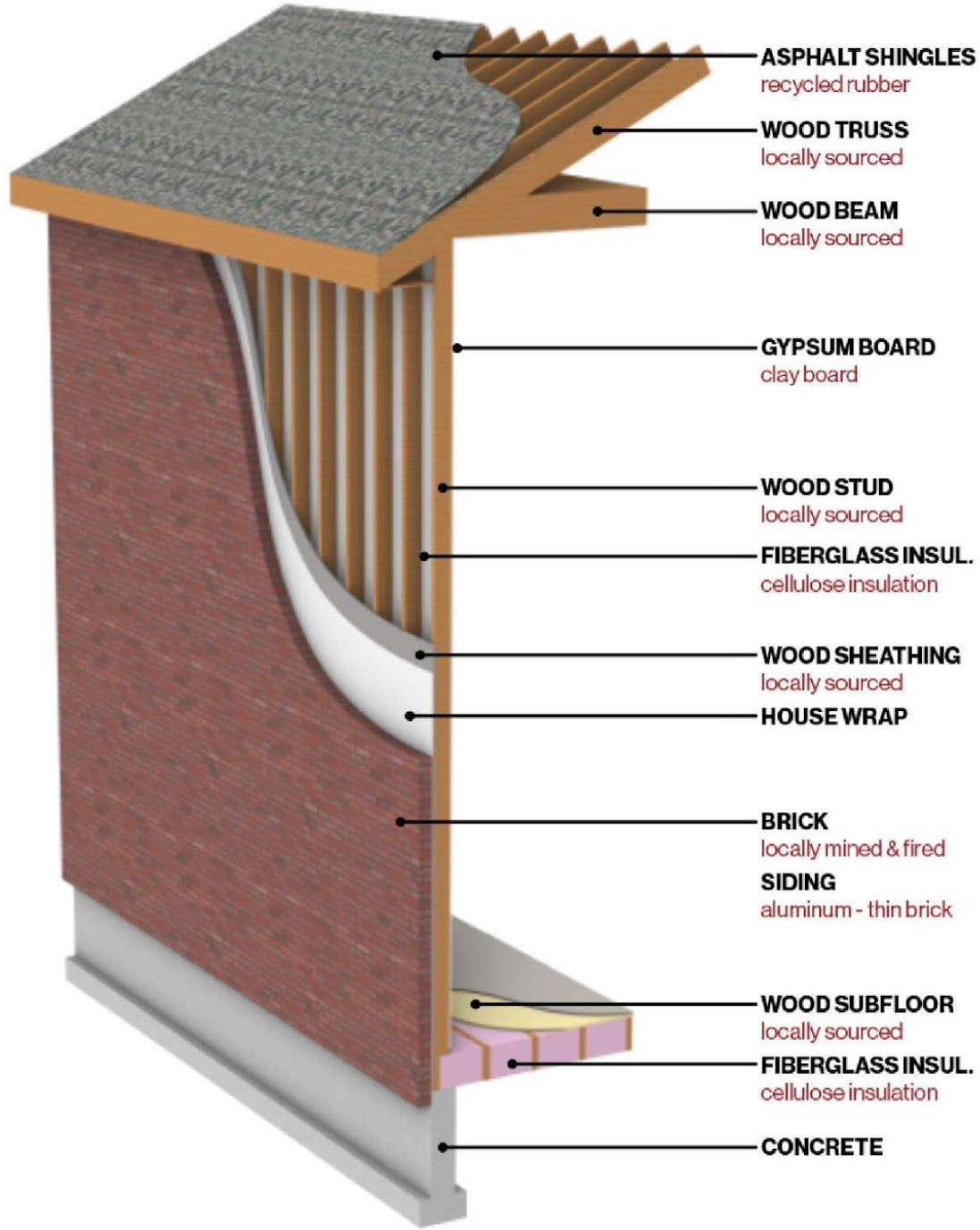
Material Study

MATERIAL LIFESPAN COMPARISON
Studying building element's lifespans to visualize and decipher which materials are best suited for a sustainable home.
The intent of this study is to analyze the building elements of a home and decipher which are best suited for a long-lasting home. An important aspect of a sustainable home is the idea that the house is built to last 'forever' and not to be abandoned like many of the homes built today.
The main focus of this model is to pull out the core elements that make up a house and extrude them to their lifespan. Implementing the 3D aspect of this graph uses a method that creates a visual effect for the viewer to clearly point out which elements will last the longest and then decipher whether or not these elements will be suitable for a sustainable home in terms of their impact on the environment.

Thinking materialistically, going into the innards of the walls of a house is an extremely important step. Each of the materials that come together to make up a wall have their own impact on the environment. Each different in their own way. Some may already be sustainable, some not so much.


MATERIAL SOURCE
LIFE SPAN
INSULATION
ORIENTATION
ROOF COLOR
MATERIAL, COLOR
LIFE SPAN
WINDOW SIZING, PLACEMENT, U-VALE
SHADING
MATERIAL


MATERIAL, COLOR
LIFE SPAN
ORIENTATION
SOLAR ELEMENTS
OUTDOOR ELEMENTS
MATERIAL SOURCE
MATERIAL, COLOR
WINDOW SIZING, PLACEMENT, U-VALE


ASPHALT SHINGLES
recycled rubber
WOOD TRUSS
locally sourced
WOOD BEAM
locally sourced
GYPSUM BOARD
clay board
WOOD STUD
locally sourced
FIBERGLASS INSUL.
cellulose insulation
WOOD SHEATHING
locally sourced
HOUSE WRAP
BRICK
locally mined & fired
SIDING
aluminum - thin brick
WOOD SUBFLOOR
locally sourced
FIBERGLASS INSUL.
cellulose insulation
CONCRETE

ARCHITECT

50 YEARS
1K HOUSES
1-3K S.F.

RESIDENTIAL

ARCHITECT

40 YEARS
1K HOUSES
1-2K S.F.

RESIDENTIAL

ARCHITECT

25 YEARS
12 HOUSES
2-5K S.F.

RESIDENTIAL

CONTRACTOR

10 YEARS
10 HOUSES
1K S.F.

RESIDENTIAL

DEVELOPER

34 YEARS
1K HOUSES
2-4K S.F.

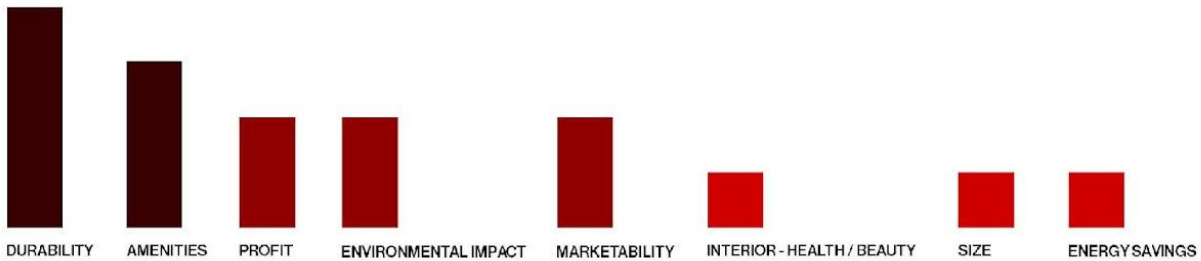
RESIDENTIAL

BUILDER

25 YEARS
14 HOUSES
2-5K S.F.

RESIDENTIAL

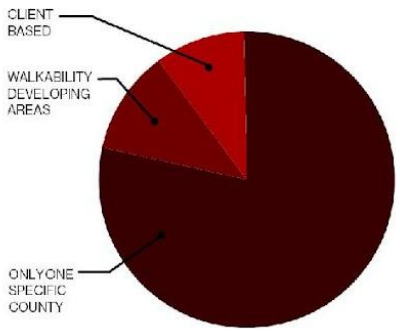
PRIORITIES



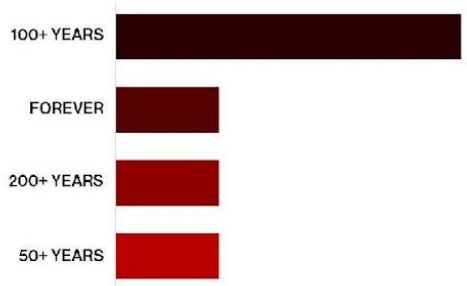
How Houses are Built Today

This interview process consisted of 17 questions about the interviewee's experience in the field of residential building.
The beginning 9 questions start with personal questions such as job title, how they started out, how many houses they have built, what their priorities are, and their definition of sustainability. The answers to these questions helped understand the interviewees answers to the next set of questions as each definition of sustainability differed.
Similarly to the responses to the definitions of sustainability, the responses to these questions were vastly different. When asked the durability of the houses built, the responses ranged from 50 years to forever (Figure _). This was an interesting response in regards to this thesis as through the material study research, it was found that most building materials used do not last 50 to 100 years confirms the assumptions that the builders and architects are not aware of how their houses are actually preforming. Then when questioned about the future of housing, many responded with the shrinking of square footage. Interestly enough no matter what profession, sustainability is not a knowledgable topic in the field of residential construction.

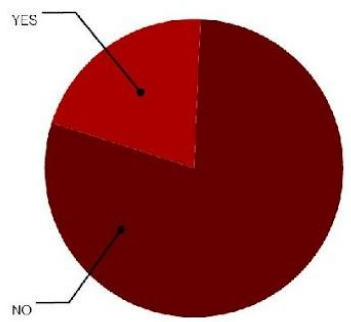
LOCATION



DURABILITY OF A HOME



SUSTAINABLE DESIGN



DEFINITION OF SUSTAINABILITY

Indefinitely repeatable in concept.

My design instincts lead me to seek efficient layouts and use of space, craft homes that weathers well, and use materials that require minimal maintenance.

Being able to continue doing something the same way and still remaining feasible regarding budget and supply.

Using natural products and earth friendly construction.

Being able to self sustain.

How you preform with the house.