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Affordable and Sustainable Housing

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DESIGN OF SUSTAINABLE AND AFFORDABLE HOUSING

The University of Akron Williams Honors College

Honors Research Report

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Section 1 – Executive summary

1.1 Introduction

As times have changed in recent years due to a global pandemic, homeowners have started to invest more money into building their homes. Market demand, material costs, and lack of qualified builders have caused the average price of a new home to increase from $391,900 in 2020 to $453,700 in 2021 (*1*). Trends are projected to continue rising, and consumers are starting to look at cheaper alternatives for home building. A recent method has emerged that looks to be a promising solution, shipping containers.

Though shipping containers have utilized for commercial applications, builders have started to use the modular-like metal structures for residential homes. The containers are an affordable material alternative, eco-friendly, and add ease to the construction process.

1.2 Goals and Objectives

The project design outlined in this research project should provide enough space for an individual, or a small family, to live comfortably. This is approximated to be between 1,000 to 1,500 square feet. Additionally, the project design should set benchmarks with relation to cost and sustainability. Each material and design choice should be related back to these two principles.

The project design has been broken down into three critical steps:

1. Site Investigation
2. Exterior Design
3. Interior Design

Each step of the design process above will be broken down even further to research and discuss different material and design choices. After the design of the container home, along with material selections made, a theoretical construction estimate can be generated. Material costs will be discussed throughout the research project, and a summary will be formed in later sections.

1.3 General Considerations and Assumptions

For the completion of project estimating, some considerations should be taken. To begin, a multitude of sources will be used to identify an approximate cost of varied materials. Though the articles and resources should be from a reliable source, it should be noted that the resource may be outdated in relation to current costs. As stated previously, material costs have drastically changed due to a multitude of factors. It should be expected that if this design were used for future construction, the construction estimate may differ. For the sake of this research project, the information found from various resources will suffice for the construction estimate.

Another assumption that should be made is regarding permitting. Due to shipping containers being a non-traditional method of construction, permits are typically difficult to obtain. Though commercial methods and applications will be used for this project design, it should be assumed that all permits and inspections are capable of being acquired for construction.

In conclusion, it should be noted that this report is a theoretical design. Though extensive research and design processes have been undertaken, the design has not been cleared for construction purposes.

Section 2 - Site Investigation

2.1 Site Introduction

The site chosen for the project design is located at 281 E Thornton St, Akron, OH 44311. **Figure 1**, taken from Regrid Parcel Data (*2*), shows the property lines of the proposed site location. The site totals to be approximately 7,546 square feet.

Figure 1: Proposed Project Site

The parcel is estimated to be worth 12,000 US dollars.

2.2 Soil Investigation

Due to design requirements by The Residential Code of Ohio (*3*), a soil investigation must be completed to identify soil engineering properties located on site. Survey data collected on September 14th, 2021, by the United States Department of Agriculture will be used for this project design. An in-depth soil report and analysis can be found in the appendix B.

The soil located on site consists primarily of silt, clay, silty sand, and clayey sand. The United States Department of Agriculture (USDA) describes these soils as a silt loam. Table 401.4.1 of the Residential Code of Ohio (RCO) provides approximations on the load-bearing pressure of soil classifications. The soil present on site provides a load-bearing pressure of 1,500 pounds per square foot. This load-bearing pressure will affect foundations calculations and designs found in section 3.1.4.

Additional soil properties and qualities are found below in **figure 2**.

Properties and qualities

Slope: 2 to 6 percent
Depth to restrictive feature: 15 to 30 inches to fragipan
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low (0.01 to 0.14 in/hr)
Depth to water table: About 10 to 21 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Available water supply, 0 to 60 inches: Low (about 4.8 inches)

Figure 2: Site Soil Properties and Qualities

2.3 Site Constructability

Before design proceeds, the site should be investigated for impediments of design and construction.

To begin, the slope of the site should be considered. Though the site is flat with a slop ranging from two to six percent, the slope may need regraded depending on the choice of foundation design. Additionally, regrading may be needed depending on choice of utilities. The slope of the site as it should not pose any critical issues with design and / or construction. **Figure 3**, obtained from Topozone (*4*), is a topographical map to show elevation changes for the chosen site. The approximate site location is outlined in purple for reference.

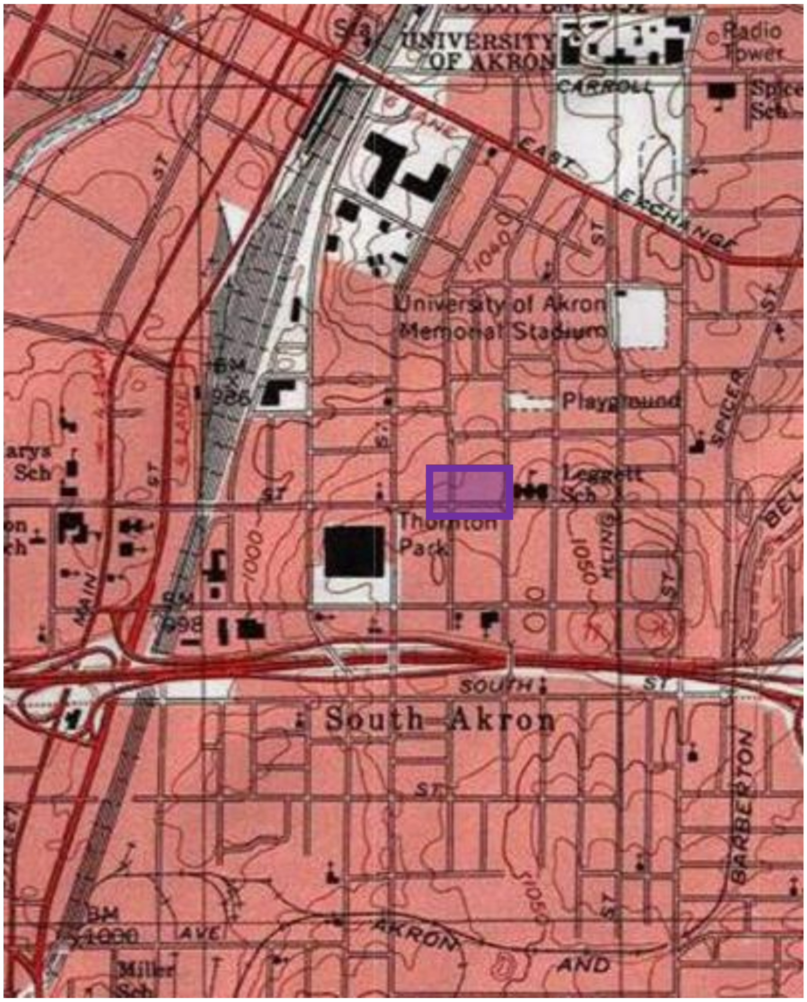

Figure 3: Topographical Map of Akron, Ohio

Another predicament that could be faced while construction of the site proceeds will be managing the delivery and staging of material. The site consists of 7,500 square feet to be built upon. With a design of 1,000 to 1,500 for the residential dwelling, this leaves approximately 6,000 square feet for material staging. It is currently assumed that no construction office will be needed on site. Thus, the site provides ample space for material storage. However, because the site is in an urban area, material delivery may be difficult. It has been identified that materials will arrive from the east of the site location on Thornton Rd. Delivery vehicles will park on the northern side of the road and proceed as needed post material delivery. **Figure 4** below displays the material staging area (highlighted green). The red arrows indicate direction of delivery vehicles should be bringing material.

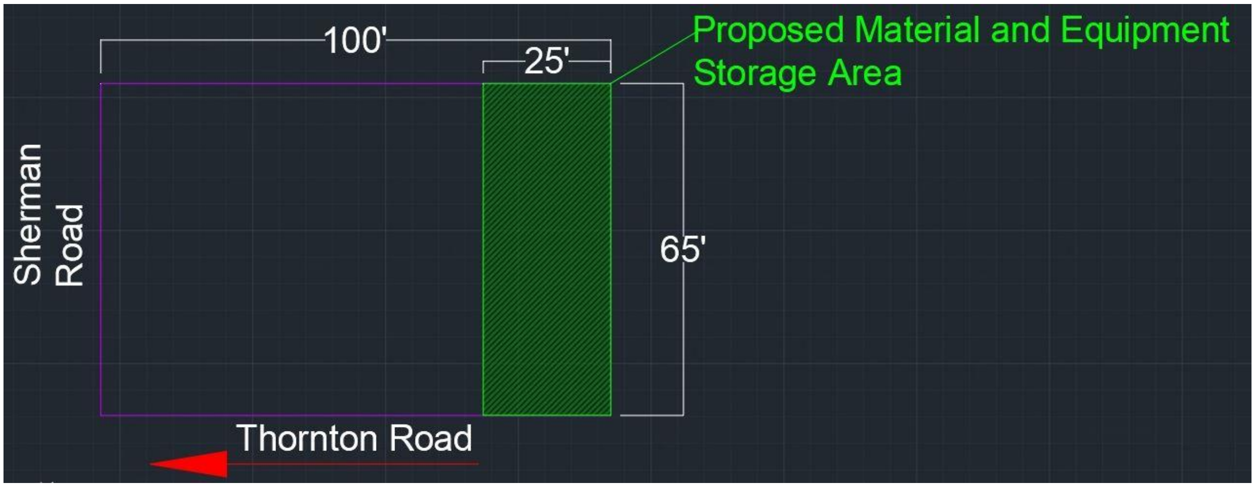

Figure 4: Material Delivery and Storage Plan

The chosen site offers few design and construction issues. However, the construction manager should be on constant alert and review construction plans and designs as needed. If issues are identified throughout the design and / or construction process, improved plans should be implemented.

Section 3 – Building Design

3.1 Exterior Design

Exterior design incorporates two critical components. To begin, the site design refers to all the area surrounding the house. This includes foundations, site regrading, and utilities. The exterior design will also comprise design methods of "dry-in." The design of exterior sheathing, along with roofing, will create the dwellings shell. This shell will protect interior construction from wind, rain, or other inclement weather.

3.1.1 Foundation Design

Shipping container homes typically apply a pier or crawl space type foundation. Though these foundations are preferred due to ease of installation and decreased material usage, the soil located on site does not provide sufficient bearing pressure to apply these foundation designs. With a low soil bearing pressure, a wide strip / slab on grade foundation must be used. Table 403.1(1) within the RCO outlines the required width and thickness of the slab based on snow load, foundation type, and maximum load bearing value of the soil. The snow load map provided below in **figure 5** displays that the site location, outlined in purple, has a ground snow load of twenty pounds per square foot (*3*).

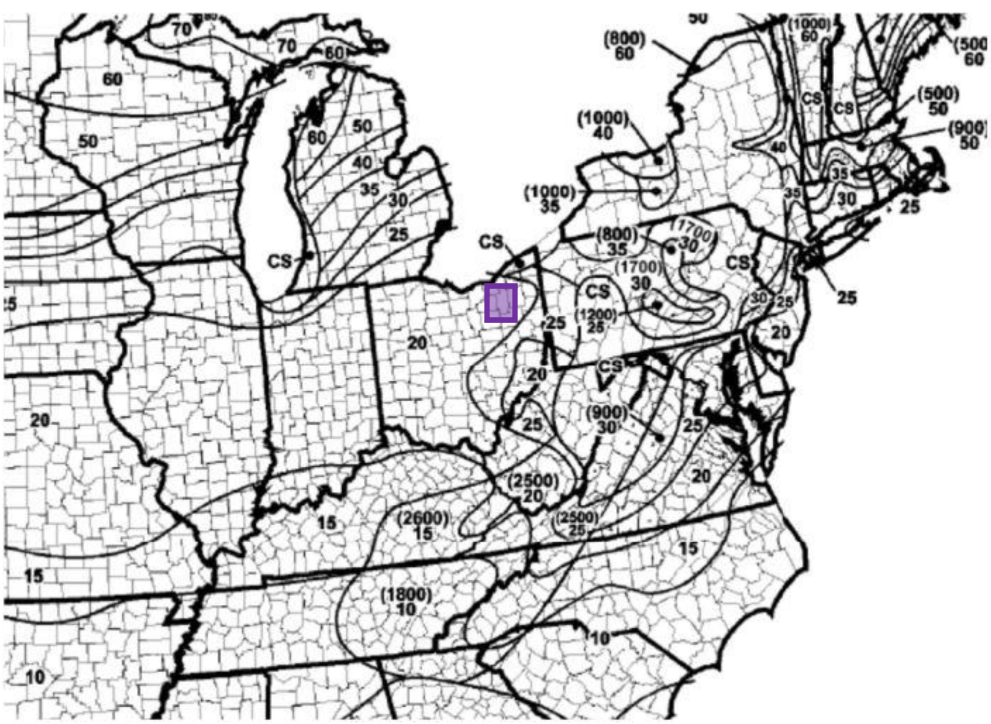

Figure 5: Snow Load Map

Table 403.1(1) states that with the site conditions, the minimum width of the foundation should be twelve inches, with a minimum thickness of six inches. The walls of the shipping container are to be considered as load bearing walls. To accommodate for this, the width of the foundation should be increased by six inches such that the wall can be placed in the middle of the strip footing portion. A typical cross section of the foundation design where exterior walls are located is found in **figure 6**. **Figure 7** displays a typical cross section of the foundation design where interior walls are located.

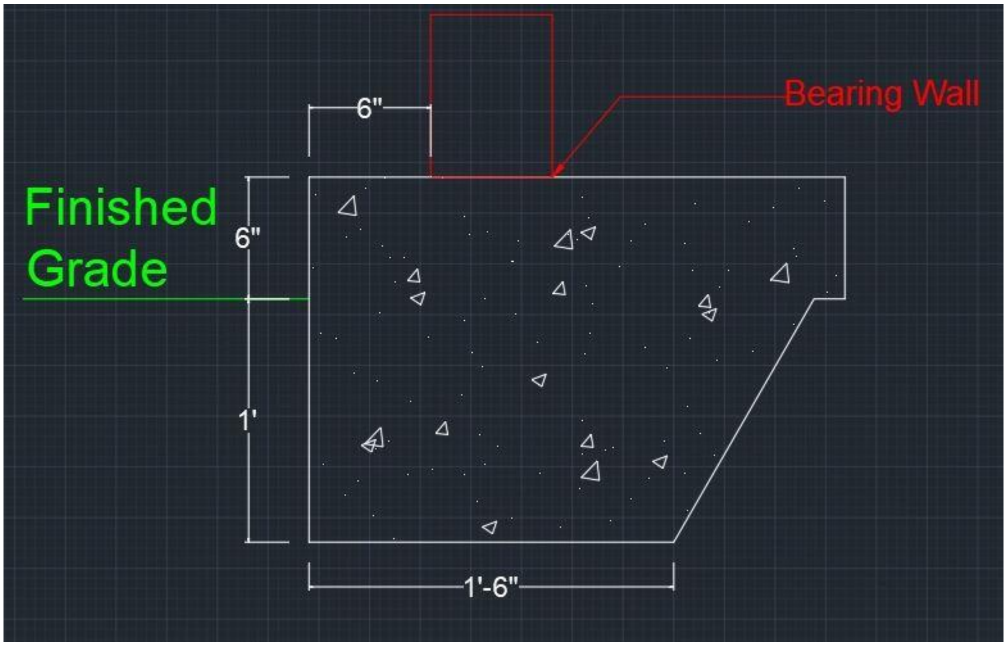

Figure 6: Exterior Wall Foundation Design

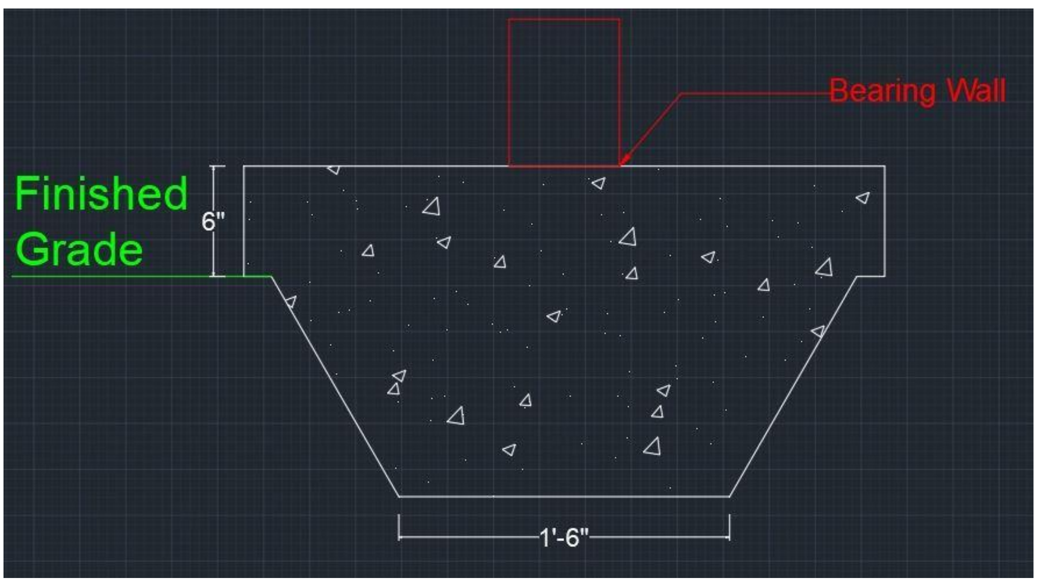

Figure 7: Interior Wall Foundation Design

After the general foundation design has been created, an outline of the foundation plot should be produced. Two shipping containers will be used for the project and will be connected by typical framing. A thorough floor plan design is outlined in section 3.2.1. In total, the foundation will be 41 feet in width and 31 feet in length. **Figure 8** below shows the proposed foundation in relation to the property lines.

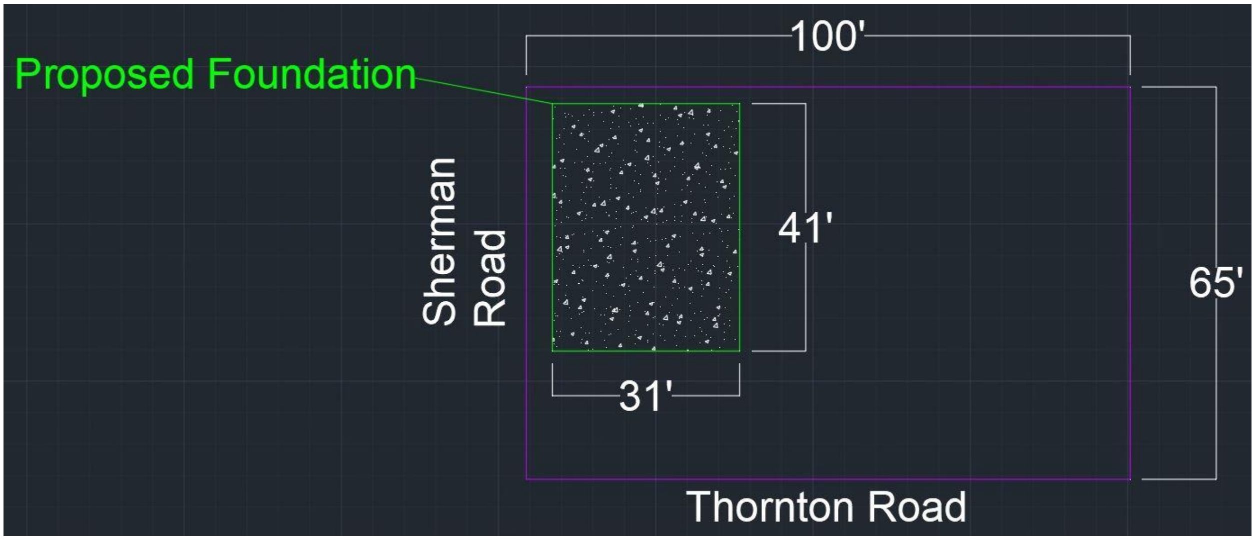

Figure 8: Proposed Foundation Outline

Concrete is the widely used material for foundation construction. Other materials such as concrete masonry units (CMU), and steel beams can also be used in conjunction with concrete. A new class of concrete has emerged as a nonpolluting material. Green concrete is like its' original design but consists of recycled materials. The concrete mix design includes materials such as slag, power plant wastes, recycled concrete, mining, and quarrying wastes, and waste glass (*5*). Though green concrete does not solve the construction industry's high demand of energy, it does offer greater strength and durability. This will prevent the need for additional costs for concrete remediation in the future of the residential dwelling.

Due to the environmentally friendly and cost-efficient aspects, green concrete will be used for this project design. A material take off has identified that 37.1 cubic yards (1,001.7 cubic ft) will be required for this foundation design. The average cost of concrete ranges from $119 to $147 dollars per cubic yard, along with a $5 to $10 installation fee per square foot (*6*). These numbers would then produce a cost of $4,414.90 to $5,453.70 for material and delivery. Installation would cost $6,355.00 to $12,710.00. The total cost of the foundation would range from $10,769.90 to $18,163.70.

3.1.2 Utility Selection

Electricity

A multitude of options are available to help power a residential dwelling. Solar panels, wind turbines, and hydro power are three examples of methods to supply electricity. A flowing water source is not located on the proposed site location. Thus, hydro-electric power is not feasible for this project design. Ohio has a mean annual wind speed of 4 meters per second at a height of 30 meters (*7*). This lack of wind speed would require a significant amount of wind turbines to be present on site. The small, urban site does not provide ample space for the addition of wind turbines.

The only practical method of supplying self-distributed energy to the residential dwelling is solar energy. According to the U.S. Energy Information Administration, the average residential consumer uses 10,715 kilowatthours (kWh) per year (*8*). Because this proposed design is attempting to remove nonrenewable sources such as gas, additional electricity will be required to power the home. A system equipped to support an estimated 12,000 kilowatthours per year should be installed. To find the number of panels required to produce this energy, the annual kilowatthours must be divided by the production ratio and wattage of the proposed panels. The average residential solar panel has a production ration between 1.3 to 1.6 and wattages ranging from 250 to 450-watts (*9*). A production ratio of 1.3 will be used for the design, along with a panel wattage of 350. **Equation (1)** below shows the calculations for the number of panels required.

$$(\mathbf{1})\ Panels\ Required = kWh\ usage\ \div\ production\ ratio\ \div panel\ wattage$$

$$(\mathbf{1})\ Panels\ Required = 12{,}000\frac{kWh}{year} \div 1.3 \div 350\ watts = 26.37\ panels\ \approx 27\ panels$$

As shown above, a minimum of twenty-seven panels will be required to power the home. This value will be rounded up to thirty panels to ensure the home has enough energy. Remaining energy can be sold back to the providing utility company for additional savings / income to the residential consumer.

The average residential solar panel takes 17.5 square feet of roof space. With a proposed design of thirty panels, the required square footage of roof is 525 square feet. The proposed dwelling has two, forty feet by eight feet containers incorporated into the design. The rooftops of both containers will provide ample space for the panels to be placed. **Figure 9**, retrieved from Google Project Sunroof (*10*), shows the potential energy generation from the proposed site location. As shown, the panels will generate the most energy on a flat, south-facing roof.

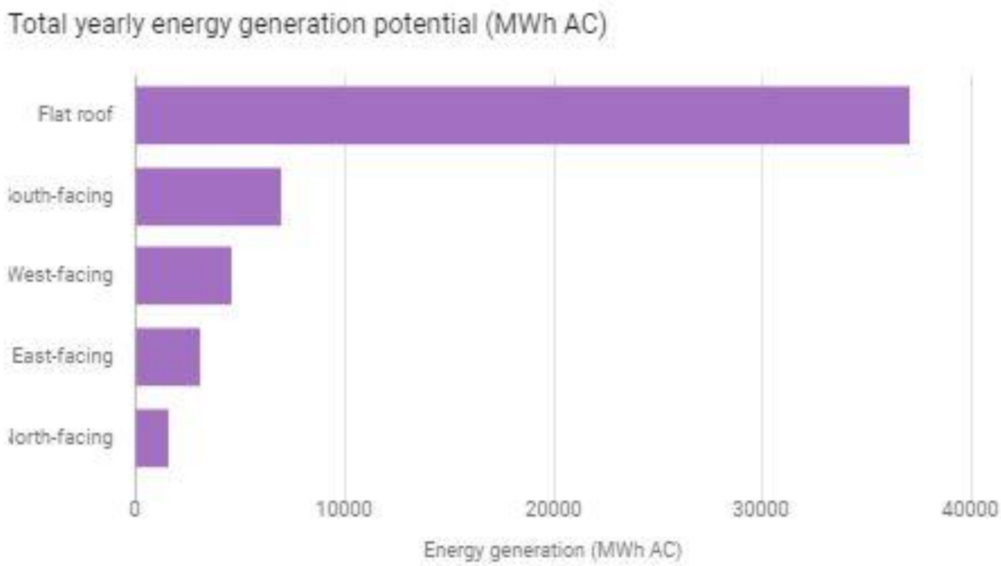

Figure 9: Potential Site Energy Generation

As of January 2022, the average cost of solar in the U.S. is $2.77 per watt. The proposed design requires a minimum of a 10-kilowatt solar system. With the average U.S. solar price used, the solar system would cost $27,700 before state and federal incentives.

Gas

This project design is aimed towards making advancements in reducing environmental impacts from residential dwellings and their construction.. According to the U.S. Environmental Protection Agency, natural gas produces about 29% of total U.S. methane emissions and about 3% of total U.S. greenhouse gas emissions (*11*). Because of these emissions, natural gas should be eliminated from the project design. This removal of an energy source will affect certain design aspects that will be discussed further in this report. The first will be heating and cooling, found in section 3.2.3. An electric water heater will also be installed, which is discussed below.

Water and Sewer

The Akron Water Distribution and Water Plant Divisions both provide potable water to the City of Akron. **Figure 10** below shows the service areas of these divisions.

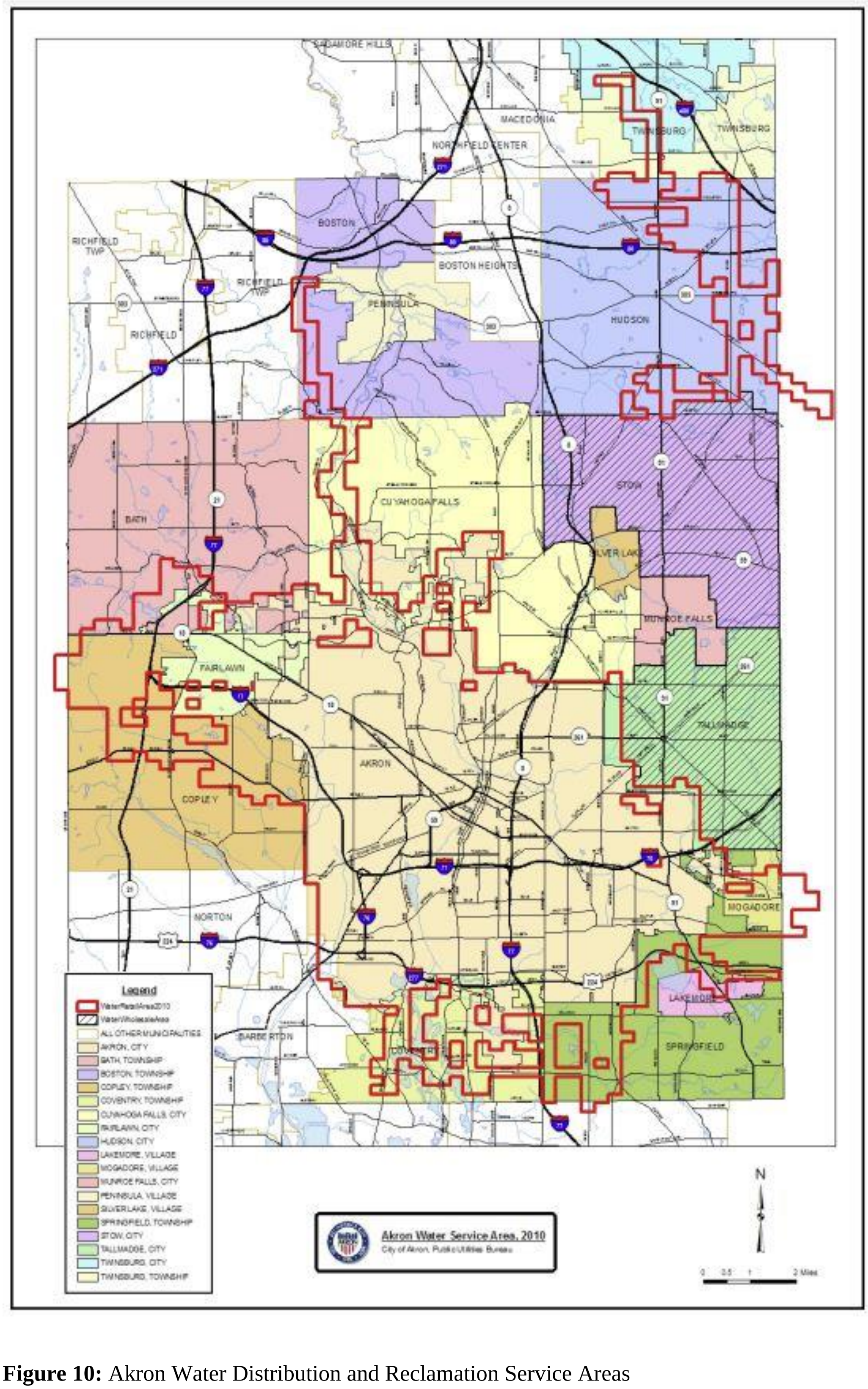

Figure 10: Akron Water Distribution and Reclamation Service Areas

Because the proposed site location is within the boundaries of service, it can be assumed that a connection can be made to existing water and sewer lines. According to Manta, homeowner surveys have estimated water line installations to average between $1,735 to $3,947 for the Akron, Ohio area (*12*).

After installation of the water lines, a sustainable method of water heating should be identified. As mentioned in previous sections, water heaters typically use natural gas. As natural gas has been eliminated from the project design, an electric heater will be used for design purposes. Electric water heaters provide higher efficiency, a longer life span, and cost less when compared to a gas water heater (*13*). The average electric water heater costs $500 to $800, while a gas heater costs $600 to $800. Installation fees range from $800 to $1,500 (*14*).

3.1.3 Roofing

Roofing material is critical in preventing the elements from entering the building envelope. Typical residential roofs consist of a rigid board, felt underlayment, and then an exposed layer of roofing material. Solar panels will also be present on the roof, so a material suitable for the panels must also be selected. Two types of materials have been selected to compare due to their environmentally friendly qualities, cost effectiveness, and ability to support solar panels.

Asphalt shingles are a common residential roofing material. They are durable, provide an extensive life span, and can be recycled once replacement is needed. Installation of solar panels on an asphalt roof is straight forward. Panel mounts are drilled into rafter studs, and drill holes are caulked to prevent any leaks or openings in the roof. In conclusion, Asphalt shingles require a minimum slope of 2:12 (*15*). This indicates that a rafter of 30 feet would have a ridge height of approximately five feet.

One square of asphalt roof shingles covers 100 square feet and ranges in price from $80 to $550 per square of material (*16*). 12 squares of asphalt shingles are required for this project design, resulting in a cost of $960 to $6,600 for material. Installation fees range from $4.75 to $8.50 per square foot, resulting in a cost of $5,700 to $10,200. The closing price estimate ranges from $6,660 to $16,800. This price estimate does not include the installation of rafters or the underlayment.

Metal roofing is another common roofing material. Comparable to asphalt shingles, metal roofing is a durable material to weather elements and is recyclable. Metal roofing is also considered a “cool” roofing material as its’ solar reflectance assists in a home’s insulation. Metal roofs average 40% savings to homeowners’ energy consumptions (*17*). The minimum slope for a metal roof is a 3:12 pitch (*18*). This indicates that a rafter of 30 feet would have a ridge height of approximately 7 ½ feet.

Metal roofing shingles cost between $4.00 and $6.50 per square foot, with an additional cost of $10.50 to $16.50 for installation (*19)*. This results in a cost ranging from $17,400.00 to $27,600.00.

Both materials produce advantageous properties for roofing. However, the minimal price for metal shingles is greater than the maximum price of asphalt shingles. Because of this, asphalt shingles will be selected for the roofing material in this project design. **Figure 11** shows a typical cross section of the proposed roof.

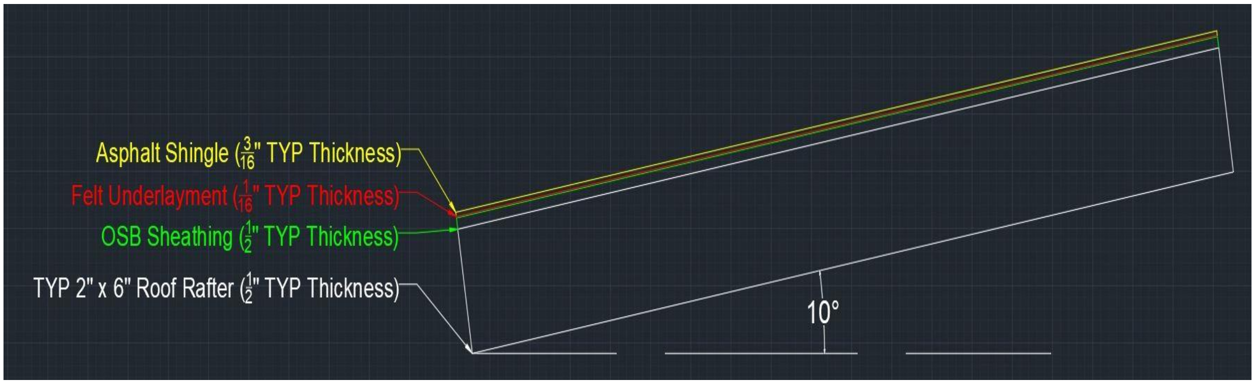

Figure 11: Typical Roof Cross Section

3.2 Interior Design

Interior design and construction bring a shell of a building to a comfortable living space. Design steps such as a floor plan, framing and insulation, HVAC, and interior finishes will be selected in this section.

3.2.1 Proposed Floorplan

It is estimated that 1,000 to 1,500 square feet of living space is needed to accomplish the desired goals and objectives outlined in section 1.2. A proposed design for a residential dwelling with the use of shipping containers is shown in figure 12 below.

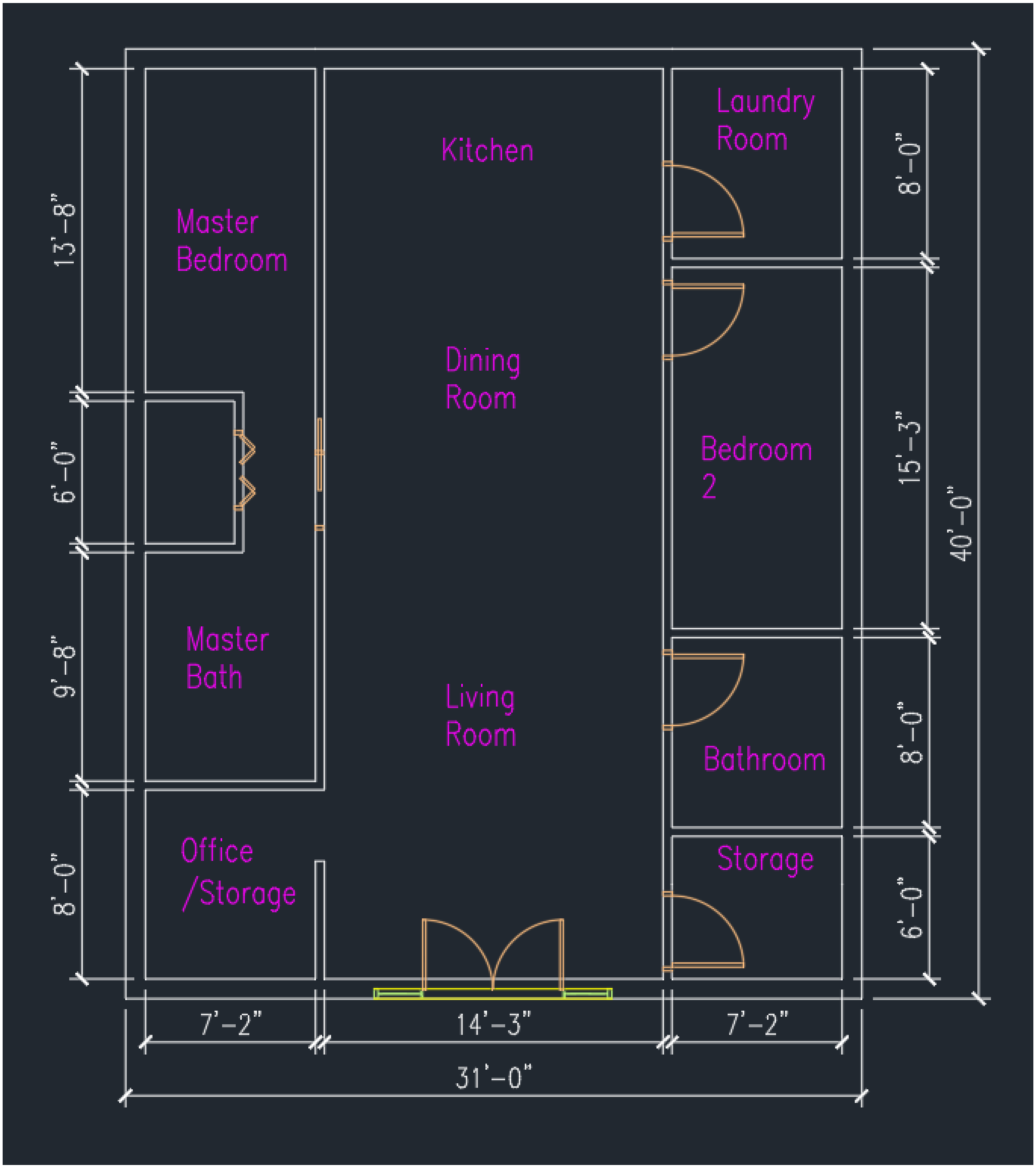

Figure 12: Proposed Floor Plan

The proposed floor plan offers approximately 1,065 square feet of living space. The shipping container located on the left of the proposed plan primarily houses the master bedroom and bathroom. A small home office or storage area is also located in the bottom left corner. The middle section connecting the two containers boasts a large, open-concept floor plan consisting of a kitchen, dining room, and living room. The shipping container located on the right of the floor plan consists of another storage area where mechanicals will be housed. Another bedroom and bathroom are also located within this shipping container. Finally, a laundry room is placed in the top right corner of the floor plan.

3.2.2 Framing and Insulation

Framing

Residential framing is typically completed with the use of wood. However, lumber prices have seen a 250% increase in cost per thousand board feet (*20*). This price increase has drastically affected the cost of wooden framing in residential dwellings. Metal stud framing, particularly in shipping container-based homes, has emerged as another method of framing.

Metal studs provide an abundant of advantages when compared to its' wooden counterparts. Unlike wood framing, metal studs are predictable. The studs do not warp, twist, or bend. Metal studs are also durable against fire, pests, and rot. This durability ensures the homeowner that the structural safety behind the wall finish is sturdy and protected. According to Home Advisor, metal stud materials cost $2 to $5 dollars per square foot. An additional $5 to $10 per square foot is required for installation cost (*21*). The proposed design of 1,065 square feet will result in a cost ranging from $7,455 to $15,975. 2 inches by 6 inches metal studs will be used for this design proposal.

Though the steel decking of the shipping container creates a barrier to external elements, the container alone is still subject to thermal bridging. Thermal bridging, the movement of heat across an object, is a major source of energy loss in residential homes. As preceding design steps have created sustainable methods of energy production, proper steps should be taken to ensure the home prevents thermal bridging.

Wall Insulation

A typical residential wall consists of an exterior sheathing, a vapor barrier layer, insulation, and then the finishing layer of drywall. The steel decking of the shipping container will function as the exterior sheathing of the proposed design. The next decision is the type of insulation that will be implemented. Types of insulations include:

1. Blanket batts and rolls
2. Foam board and rigid foam
3. Loose-fill and blown-in
4. Sprayed foam and foamed-in-place

Before a type of insulation can be determined, the required R-Value of the wall should be identified. **Figure 13**, acquired from Home Depot (*22*), shows the regional climate zones. These climate zones correspond to the R-value. The proposed site location has a climate zone of five. **Figure 14** then shows the required R-value for the designed walls. The walls of this proposed design must meet an R-value of R-19 to R-21.

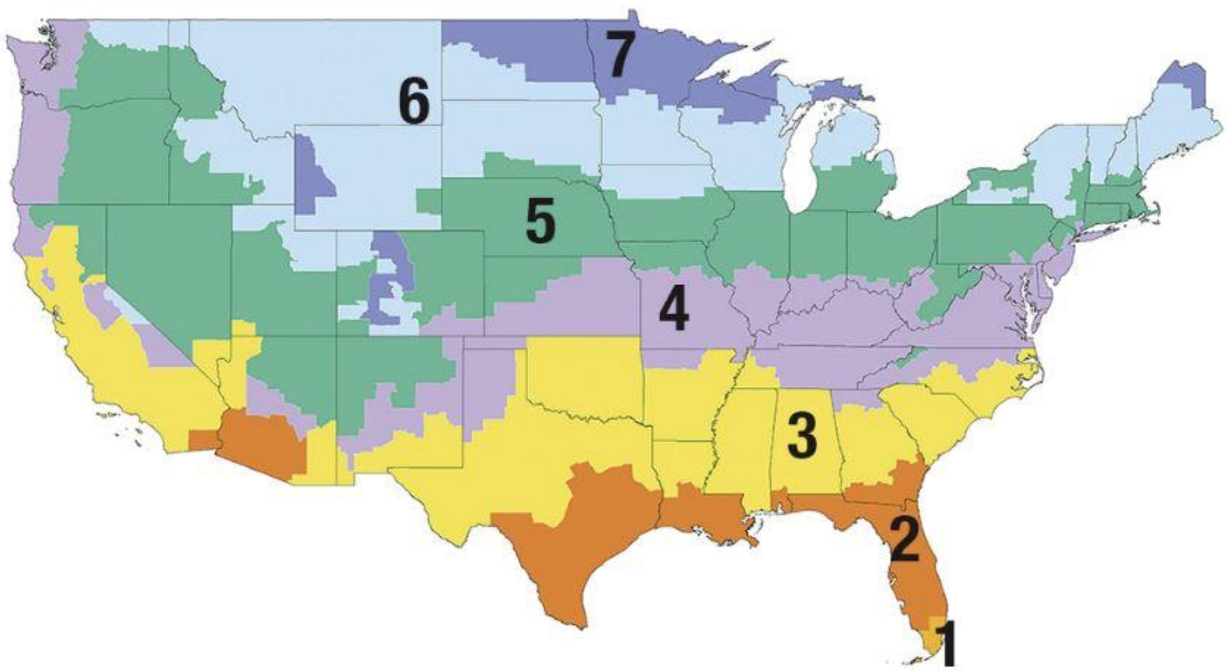

Figure 13: Regional R-Values

		WALLS			
Zone	Attics	2x4	2x6	Floors	Crawlspaces
1	R30 to R49	R13 to R15	R19 to R21	R13	R13
2	R30 to R60	R13 to R15	R19 to R21	R13	R13 to R19
3	R30 to R60	R13 to R15	R19 to R21	R25	R19 to R25
4	R38 to R60	R13 to R15	R19 to R21	R25 to R30	R25 to R30
5	R49 to R60	R13 to R15	R19 to R21	R25 to R30	R25 to R30
6	R49 to R60	R13 to R15	R19 to R21	R25 to R30	R25 to R30
7	R49 to R60	R13 to R15	R19 to R21	R25 to R30	R25 to R30

Figure 14: Required R-Value Insulation Chart

All available options of insulation provide the required R-value. However, certain materials will not be feasible for this project. Batt and roll insulation, as well as rigid foam board will not properly seal the container close. The shipping container deck has ruts that pose potential air pockets, which must be closed by the insulation. As batt insulation and rigid foam board are not shape forming materials, these methods of insulation will be disregarded.

Though blown in insulation is shape forming, spray foam creates a bond to the shipping container and metal studs. Spray foam also typically yields higher R-values and can fill small cavities, creating an effective air barrier. Because the spray foam fills all voids and creates an air barrier, a vapor barrier is no longer required. Spray foam insulation will be used for this design proposal due to its ease of installation, ability to fill small cavities, and the reduction of additional materials.

Though a higher R-value promises a more efficient home, a materials environmental impacts and toxicity also dictate material selection. Typical spray foam materials such as expanded polystyrene, extruded polystyrene, and closed-cell polyurethane are all fossil fuel-based insulation methods (*23*). Biobased materials still offer the required R-value but is composed recyclable material. Cellulose insulation is a biobased material from recycled newspaper that provides an R-value of 3.5 per inch (*24*). With the six-inch metal stud framing, the R-value of the designed walls will be approximately 21. Though cellulose is typically a blown material, adding moisture to the material will allow the insulation to be applied as a spray. The cost of wet-spray cellulose material averages $1.20 per square foot. The cost to install the material ranges from $0.60 – $1.80 per square foot (*25*). The resulting cost of wall insulation is $1,917 to $3,195. **Figure 15** below is a typical cross section of the container walls.

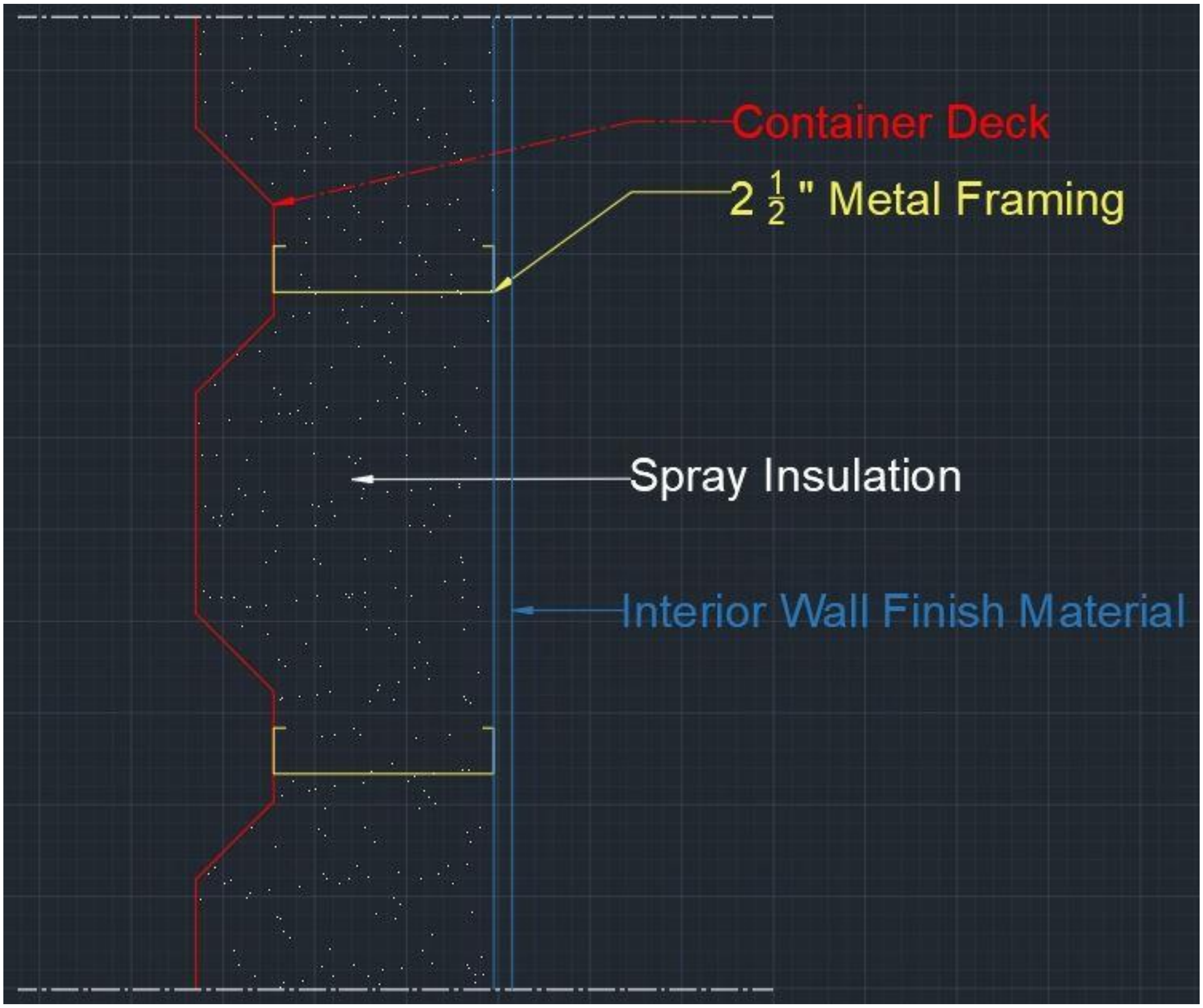

Figure 15: Typical Container Wall Cross Section

The two exterior walls that connect the two shipping containers are comparable to figure 15. However, the exterior shipping container decking is replaced with typical exterior OSB sheathing. **Figure 16** illustrates the differences.

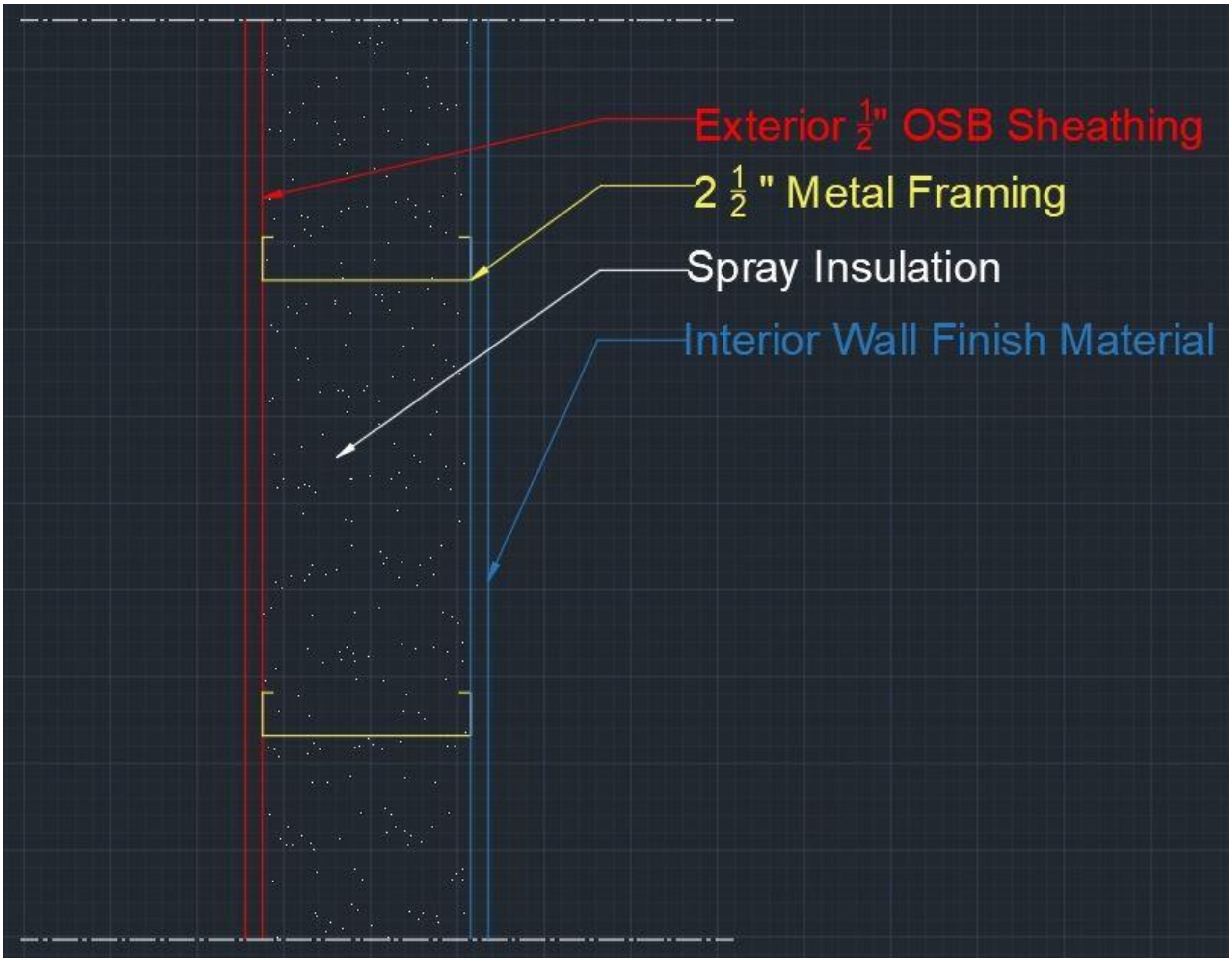

Figure 16: Non-Container Exterior Wall Cross-Section

3.2.3 Heating and Cooling

In section 3.1.2, it was determined that the proposed method of energy would be electric. Thus, an electric system will be used for the heating and cooling of the residential dwelling. Though shipping containers provide multiple advantages in certain categories, they lack in the ability to provide space for duct material. The proposed design of a slab on grade foundation also prevents the system to be placed under ground with air being pushed through the floor. Because of these design impediments, a ductless system will be implemented.

A form of an efficient and environmentally friendly electric heating and cooling system are heat pumps. Mini-split heat pumps do not require ducting, which in return avoids energy losses associated with ductwork. They are simple to install, provide warm and cold air, and provide directional airflow. An outdoor unit is paired with one, or multiple indoor units. Though duct systems are not required, refrigerant lines must connect the outdoor unit to all indoor units. **Figure 17** is an example of a mini-split system.

Figure 17: Mini-split Heat Pump (*26*)

For the proposed design, three indoor units will be placed within the dwelling. One located in the master bedroom, another in the middle living area, and a final one located in the second bedroom. **Figure 18** shows the outdoor and indoor units, as well as the refrigeration lines connecting them.

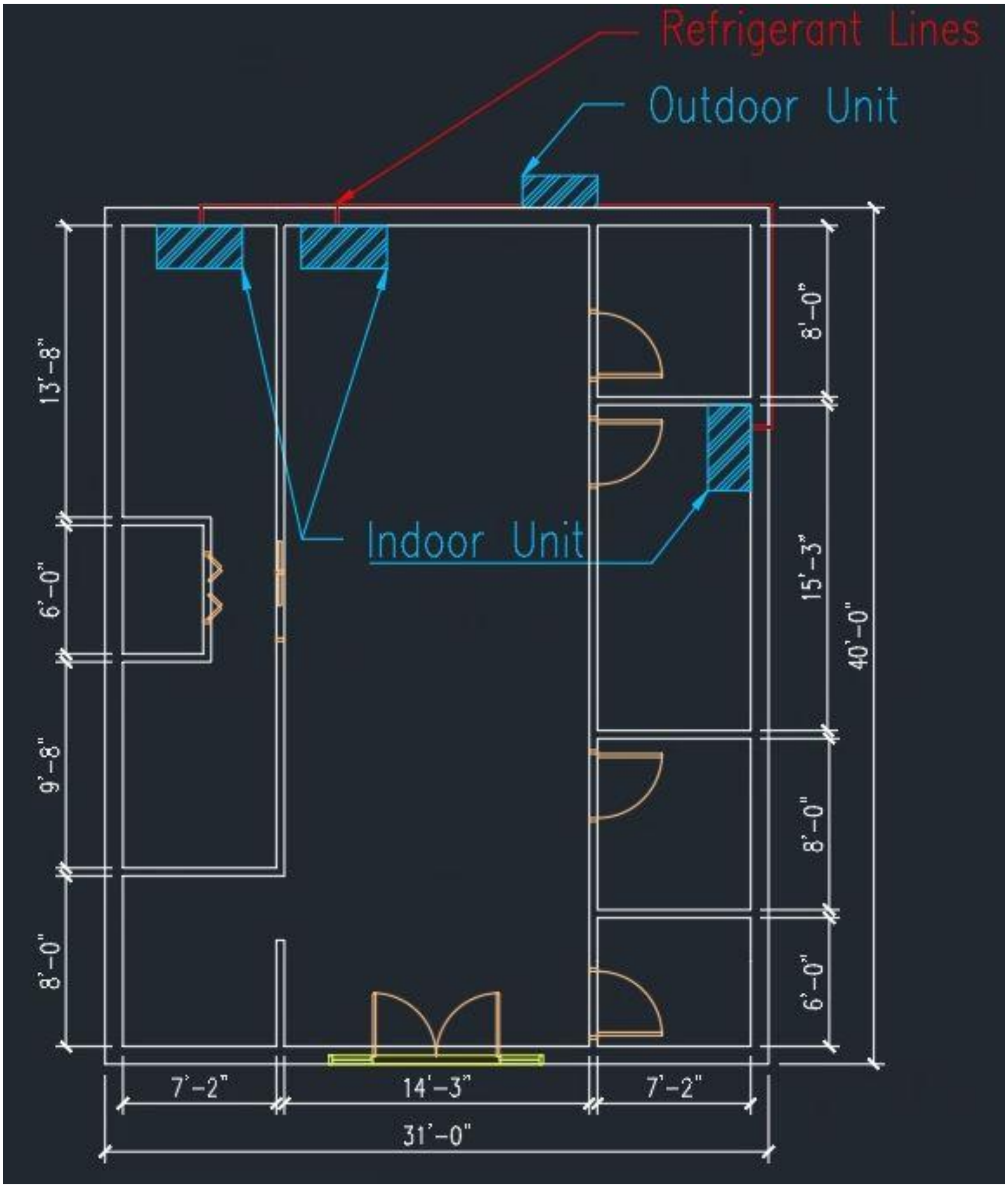

Figure 18: Mini-Split Heat Pump Locations

According to Calculator.net (*27*), a 19,000 British Thermal Unit (BTU) system is required to heat and cool the proposed design. A three zone, 24,000 British Thermal Unit system costs $2,469 (*28*). Installation costs range from $1,800 to $7,542 (*29*).

3.2.4 Interior Finishes

Interior finishes outline materials that are permanently affixed to the buildings structure. Decorations, furnishings, and appliances will not be outlined in this design proposal. Three interior finishes have been identified as having possible environmentally friendly alternatives.

Drywall

Though typical gypsum drywall board is an eco-friendly material, the production process, transportation, and disposal of the material raises environmental impact concerns. Synthetic gypsum has emerged as front runner for a green alternative drywall. Synthetic gypsum is created by using the byproduct of coal-fired power plants (*30*). By creating a valuable product from waste, material is kept out of landfills and environmental pollution is reduced. The creation of synthetic gypsum also conserves natural gypsum and removes the need for mining resources. In conclusion, synthetic gypsum is price ranges from $1.30 to $4.00 per square foot for material and installation (*31*). This results in an overall cost of $1,384.5 to $4,260.

Flooring

Flooring materials have drastically increased in price during the pandemic. Materials such as hardwood, laminate, luxury vinyl tile, and carpet have all seen price increases of 4% to 8% (*32*). Because of increasing material pricing, a method of material usage reduction should be found. The slab foundation provides the opportunity to simply seal and polish the concrete to use as a finished floor. Polished concrete provides a stain resistant surface, cost effective for installation and maintenance, and eliminates the need for additional materials and labor. The bottom decking of the shipping containers will be removed to reveal the polished concrete underneath. The price to seal and polish concrete ranges from $3 to $8 per square foot (*33*). This would result in a cost of $3,813.00 to $10,168.00.

Section 4 – Cost Estimate

Cost estimates have been provided throughout the project proposal. Additional cost will be incurred for other materials, labor, and installation. Detailed cost estimates can be found in appendix C. Pricing assumptions have been referenced for materials and design previously discussed. Other material and installation pricing references can be found in at the end of the paper.

Table 1 below shows the final cost breakdown per design aspect.

Table 1: Final Cost Estimate

Description	Total Cost	
	Low Price	High Price
Preliminary Design	$15,510.00	$38,050.00
Foundation / Concrete	$16,582.90	$38,331.70
Utilities	$35,404.00	$45,558.00
Construction Materials	$43,503.40	$79,943.90
Total	$111,000.30	$201,883.60

4.**1 – Cost Analysis**

As stated at the beginning of the project proposal, new build home prices have risen to $453,700 in 2021. Another study found that the average cost to build a house in Ohio ranges from $100 to $250 per square foot in 2022 (*41*). With the proposed design, the average cost to build a home should range from $120,000 to $300,000. As seen in table 1, the proposed design offers a potential savings of $9,000 to $100,000. The objective of designing a cheaper residential dwelling has been achieved.

Conclusion

As homeowners continue to prioritize the quality of their home build and restorations, material and labor pricing will continue to rise. Additionally, previous material choices have contributed to greenhouse emissions and other environmentally harming acts. Building operations and construction generate nearly 40% of annual global CO_2 emissions (*42*).

This research project preliminary design has outlined a cost efficient and environmentally friendly building. With an overall cost ranging from $111,000.30 to $201,883.60, the proposed design offers potential savings of $9,000 to $100,000. Every material found within the design offers material savings and assists in protecting the environment. As the world continues to adapt and change shape, residential dwellings could start to take the form of a shipping container.

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Appendix

Appendix A – Residential Code of Ohio References

Table 2: Soil Load-Bearing Values

TABLE 401.4.1
PRESUMPTIVE LOAD-BEARING VALUES OF FOUNDATION MATERIALS [a]

CLASS OF MATERIAL	LOAD-BEARINGPRESSURE (pounds per square foot)
Crystalline bedrock	12,000
Sedimentary and foliated rock	4,000
Sandy gravel and/or gravel (GW and GP)	3,000
Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000
Clay, sandy, silty clay, clayey silt, silt and sandy siltclay (CL, ML, MH and CH)	1,500[b]

For SI: 1 pound per square foot = 0.0479 kPa.

a. Where soil tests are required by Section 401.4, the allowable bearing capacities of the soil shall be part of the recommendations.

b. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

Table 3: Minimum Width and Thickness for Concrete Footings

TABLE 403.1(1)
MINIMUM WIDTH AND THICKNESS FOR CONCRETE FOOTINGS FOR LIGHT-FRAME CONSTRUCTION (inches) [a, b]

SNOW LOAD OR ROOF LIVE LOAD	STORY AND TYPE OF STRUCTURE WITH LIGHT FRAME	LOAD-BEARING VALUE OF SOIL (psf)					
		1500	2000	2500	3000	3500	4000
20 psf	1 story—slab-on-grade	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—with crawl space	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—plus basement	18 x 6	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—slab-on-grade	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—with crawl space	16 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—plus basement	22 x 6	16 x 6	13 x 6	12 x 6	12 x 6	12 x 6
	3 story—slab-on-grade	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	3 story—with crawl space	19 x 6	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	3 story—plus basement	25 x 8	19 x 6	15 x 6	13 x 6	12 x 6	12 x 6
30 psf	1 story—slab-on-grade	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—with crawl space	13 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—plus basement	19 x 6	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—slab-on-grade	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—with crawl space	17 x 6	13 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—plus basement	23 x 6	17 x 6	14 x 6	12 x 6	12 x 6	12 x 6
	3 story—slab-on-grade	15 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	3 story—with crawl space	20 x 6	15 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	3 story—plus basement	26 x 8	20 x 6	16 x 6	13 x 6	12 x 6	12 x 6
50 psf	1 story—slab-on-grade	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—with crawl space	16 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—plus basement	21 x 6	16 x 6	13 x 6	12 x 6	12 x 6	12 x 6
	2 story—slab-on-grade	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—with crawl space	19 x 6	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—plus basement	25 x 7	19 x 6	15 x 6	12 x 6	12 x 6	12 x 6
	3 story—slab-on-grade	17 x 6	13 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	3 story—with crawl space	22 x 6	17 x 6	13 x 6	12 x 6	12 x 6	12 x 6
	3 story—plus basement	28 x 9	21 x 6	17 x 6	14 x 6	12 x 6	12 x 6
70 psf	1 story—slab-on-grade	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—with crawl space	18 x 6	13 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	1 story—plus basement	24 x 7	18 x 6	14 x 6	12 x 6	12 x 6	12 x 6
	2 story—slab-on-grade	16 x 6	12 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	2 story—with crawl space	21 x 6	16 x 6	13 x 6	12 x 6	12 x 6	12 x 6
	2 story—plus basement	27 x 9	20 x 6	16 x 6	14 x 6	12 x 6	12 x 6
	3 story—slab-on-grade	19 x 6	14 x 6	12 x 6	12 x 6	12 x 6	12 x 6
	3 story—with crawl space	25 x 7	18 x 6	15 x 6	12 x 6	12 x 6	12 x 6
	3 story—plus basement	30 x 10	23 x 6	18 x 6	15 x 6	12 x 6	12 x 6

For SI: 1 inch = 25.4 mm, 1 plf = 14.6 N/m, 1 pound per square foot = 47.9 N/m^2.

a. Interpolation allowed. Extrapolation is not allowed.

b. Based on 32-foot-wide house with load-bearing center wall that carries half of the tributary attic, and floor framing. For every 2 feet of adjustment to the width of the house, add or subtract 2 inches of footing width and 1 inch of footing thickness (but not less than 6 inches thick).

Appendix B – United States Department of Agriculture Soil Report

Summit County, Ohio

CfB—Canfield-Urban land complex, 2 to 6 percent slopes

Map Unit Setting

National map unit symbol: 2v03v
Elevation: 590 to 1,970 feet
Mean annual precipitation: 33 to 52 inches
Mean annual air temperature: 43 to 52 degrees F
Frost-free period: 135 to 215 days
Farmland classification: Not prime farmland

Map Unit Composition

Canfield and similar soils: 45 percent
Urban land: 35 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Canfield

Setting

Landform: Till plains
Landform position (two-dimensional): Summit, shoulder
Landform position (three-dimensional): Interfluve, side slope
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Till

Typical profile

Ap - 0 to 6 inches: silt loam
BE - 6 to 9 inches: silt loam
Bt1 - 9 to 15 inches: silt loam
2Bt2 - 15 to 21 inches: loam
2Bt3 - 21 to 26 inches: loam
2Btx1 - 26 to 38 inches: loam
2Btx2 - 38 to 45 inches: loam
2C1 - 45 to 62 inches: loam
2C2 - 62 to 80 inches: loam

Properties and qualities

Slope: 2 to 6 percent
Depth to restrictive feature: 15 to 30 inches to fragipan
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low (0.01 to 0.14 in/hr)
Depth to water table: About 10 to 21 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Available water supply, 0 to 60 inches: Low (about 4.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: C/D
Ecological site: F139XY004OH - Moist Acidic Slopes
Hydric soil rating: No

Description of Urban Land

Setting

Down-slope shape: Linear
Across-slope shape: Linear

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydric soil rating: Unranked

Minor Components

Udorthents

Percent of map unit: 10 percent
Hydric soil rating: Unranked

Ravenna

Percent of map unit: 10 percent
Landform: Till plains
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Interfluve, base slope
Down-slope shape: Concave
Across-slope shape: Linear
Hydric soil rating: No

Data Source Information

Soil Survey Area: Summit County, Ohio
Survey Area Data: Version 18, Sep 14, 2021

Appendix C- Detailed Cost Estimates

Table 4: Preliminary Design Estimate

Preliminary Construction Cost Estimate						
Description	Bulk Price	Price per Unit		Quanitity	Sub Total	
		Low Price	High Price		Low Price	High Price
Construction Permit Fee	-	$400.00	$1,000.00		$400.00	$1,000.00
Building Permit Fee	-	$1,000.00	$3,000.00		$1,000.00	$3,000.00
Electrical Permit Fee	-	$30.00	$50.00		$30.00	$50.00
Plumbing Permit Fee	-	$30.00	$500.00		$30.00	$500.00
HVAC Permit Fee	-	$50.00	$1,500.00		$50.00	$1,500.00
Architecural Drawings	-	$2,000.00	$20,000.00		$2,000.00	$20,000.00
Site Location	$12,000				$12,000.00	$12,000.00
				Total	$15,510.00	$38,050.00

Table 5: Foundation Estimate

Foundation Cost Estimate						
Description	Bulk Price	Price per Unit		Quanitity	Sub Total	
		Low Price	High Price		Low Price	High Price
Excavation	-	$50 / cubic yard	$200 / cubic yard	40 cubic yards	$2,000.00	$10,000.00
Concrete	-	$119 / cubic yard	$147 / cubic yard	37.1 cubic yards	$4,414.90	$5,453.70
Concrete Installation and Labor	-	$5 / square foot	$10 / square foot	1,271 square feet	$6,355.00	$12,710.00
Concrete Sealing and Polishing	-	$3 / square foot	$8 / square foot	1,271 sqaure feet	$3,813.00	$10,168.00
				Total Cost:	$16,582.90	$38,331.70

Table 6: Utility Estimate

Utility Cost Estimate						
Description	Bulk Price	Price per Unit		Quanitity	Sub Total	
		Low Price	High Price		Low Price	High Price
Solar System	$2.77 / watt	-	-	10 kilowatts	$27,700.00	$27,700.00
Water and Sewer permit	-	$400.00	$1,600.00	-	$400.00	$1,600.00
Water and Sewer connection	-	$1,735.00	$3,947.00	-	$1,735.00	$3,947.00
Water Heater and Installation	-	$1,300.00	$2,300.00		$1,300.00	$2,300.00
Mini-Split Heat Pump System	2469	$0.00	$0.00	-	$2,469.00	$2,469.00
Mini-Split Heat Pump System Installation	-	$1,800.00	$7,542.00	-	$1,800.00	$7,542.00
				Total Cost:	$35,404.00	$45,558.00

Table 7: Construction Materials Estimate

Preliminary Construction Costs						
Description	Bulk Price	Price per Unit		Quanitity	Sub Total	
		Low Price	High Price		Low Price	High Price
Asphalt Shingles	-	$80 / square of shingles	$550 / square of shingles	12 squares	$960.00	$6,600.00
Asphalt Shingle Installation	-	$4.75 / square foot	$8.50 / square foot	1,200 square feet	$5,700.00	$10,200.00
Roofing Underlayment	-	$4.00 / square foot	$5.55 / square foot	1,200 square feet	$4,800.00	$6,660.00
Shipping Containers	-	$3,500 / container	$5,000 / container	2 containers	$7,000.00	$10,000.00
Steel Framing Studs and Installation	-	$7 / square foot	$15 / square foot	1,065 square feet	$7,455.00	$15,975.00
Wet-spray cellulose Insulation and Installation	-	$1.80 / square foot	$3 / per square	1,065 square feet	$1,917.00	$3,195.00
Exterior OSB Sheathing	$2.40 / per sqaure foot	-	-	496 square feet	$1,190.40	$1,190.40
Mini-Split Heat Pump System	2469			-	$2,469.00	$2,469.00
Mini-Split Heat Pump System Installation	-	1800	7542	-	$1,800.00	$7,542.00
Drywall	-	$1.30 / square foot	$4.00 / square foot	1,065 square feet	$1,384.50	$4,260.00
Plumbing	$4.50 / square foot	-	-	1,065 square feet	$4,792.50	$4,792.50
Paint	-	$3 / square foot	$4 / square foot	1,065 square feet	$3,195.00	$4,260.00
Cabinetry	-	$60 / linear foot	$200 / linear foot	14 linear feet	$840.00	$2,800.00
				Total	$43,503.40	$79,943.90