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Disaster Relief Housing: A Passive Design Approach

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DISASTER RELIEF HOUSING: A PASSIVE DESIGN APPROACH

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Project Description

Hurricanes, forest fires, floods, and avalanches are only a few of the natural disasters that can devastate cities, communities, and families. Too often the individuals that have endured these catastrophes have nowhere to go. As traveling out of the area may not be possible, they are often crowded into shelters or given inferior, substandard housing. These living conditions are far from ideal, and what was initially presented as a housing solution for a week or two can quickly turn into a harsh reality for several months or more.

Why not provide better housing solutions during these trying times? The answer to this question is extremely complex. Companies and organizations producing and distributing temporary shelters have their own set of challenges when attempting to provide aid. They are faced with finding solutions to problems such as: How can we construct and distribute shelters quickly and efficiently? How do we provide electricity, clean water, and thermal comfort in very different habitats? And, how can we construct an economical, mass produced unit that could serve as a comfortable temporary home for these survivors over an extended period of time.

This project seeks to merge the two perspectives, that of the devastated community and that of the supporting organization, into one successful solution. A prefabricated unit capable of being a passive, self sustaining home in any climate, could be a viable solution. The key goal of this shelter is to create a home that minimizes the need for active systems, such as electricity, air conditioning, and heating, through the manipulation of materials and passive design. If achieved, the shelter would provide a comfortable living environment for those affected by natural disaster for a extended period of time while being sensitive to the practical concerns of the organizations contributing aid.

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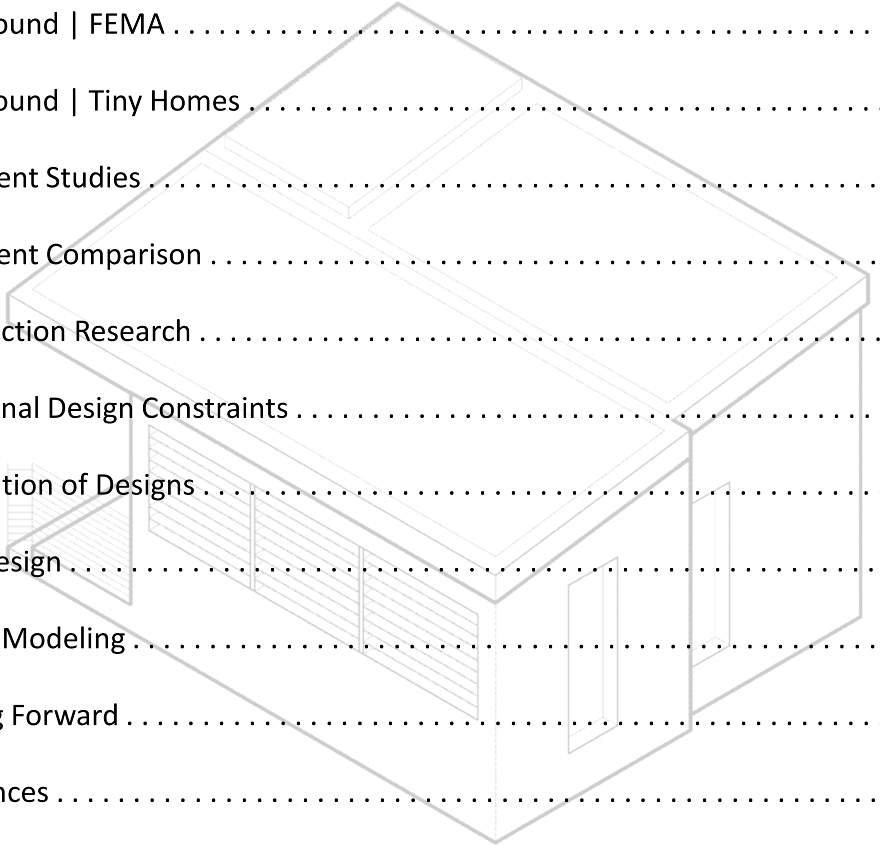


Background | FEMA

Federal Emergency Management Agency

This organization is responsible for responding to a national disaster. Perhaps one of the most notable actions from them is the creation and distribution of the manufactured housing unit known as the “FEMA Trailer” (FEMA, 2006).

While these trailers were meant to be used as temporary or intermediate housing, residents have often struggled to acquire new permanent living situations. The organization allots a time period for use of the trailer with the requirement for the tenant to maintain the home. At the end of this timeline, the trailer is inspected and reacquired by FEMA (Stuckey, 2005). Families also have the option to purchase the trailers for around $1,100 depending on the model (Brown, 2013). This alternative becomes the only solution for many who cannot afford to rebuild or move.

There are different opinions about living in these trailers. Some people do not mind the close quarters and are thankful for the water, power, and electricity. However, many individuals have complaints after living in them for an extended period of time. (Stuckey, 2005).

(Brunker, 2008)

(Associated Press, 2010)

(Sullivan, 2006)

Background | FEMA

Federal Emergency Management Agency

Living in close quarters is not the worst issue one could have when residing in a FEMA trailer. Instead, it's the possibility of mold, high levels of formaldehyde, and mass fire.

Mold

Mold can result from a variety of factors, and the risk factor for it increases in hot humid climates. Numerous trailers sent to New Orleans after Hurricane Katrina developed black mold. Although the trailers were equipped with an air conditioner and dehumidifier, it was not enough. FEMA encouraged occupants to frequently open windows to vent out the space. Under normal circumstances, the A/C unit should have been enough, but due to the need for thousands of trailers in a short time period, construction suffered and is the main contributor to these mold outbreaks (Reeder, 2008).

Formaldehyde

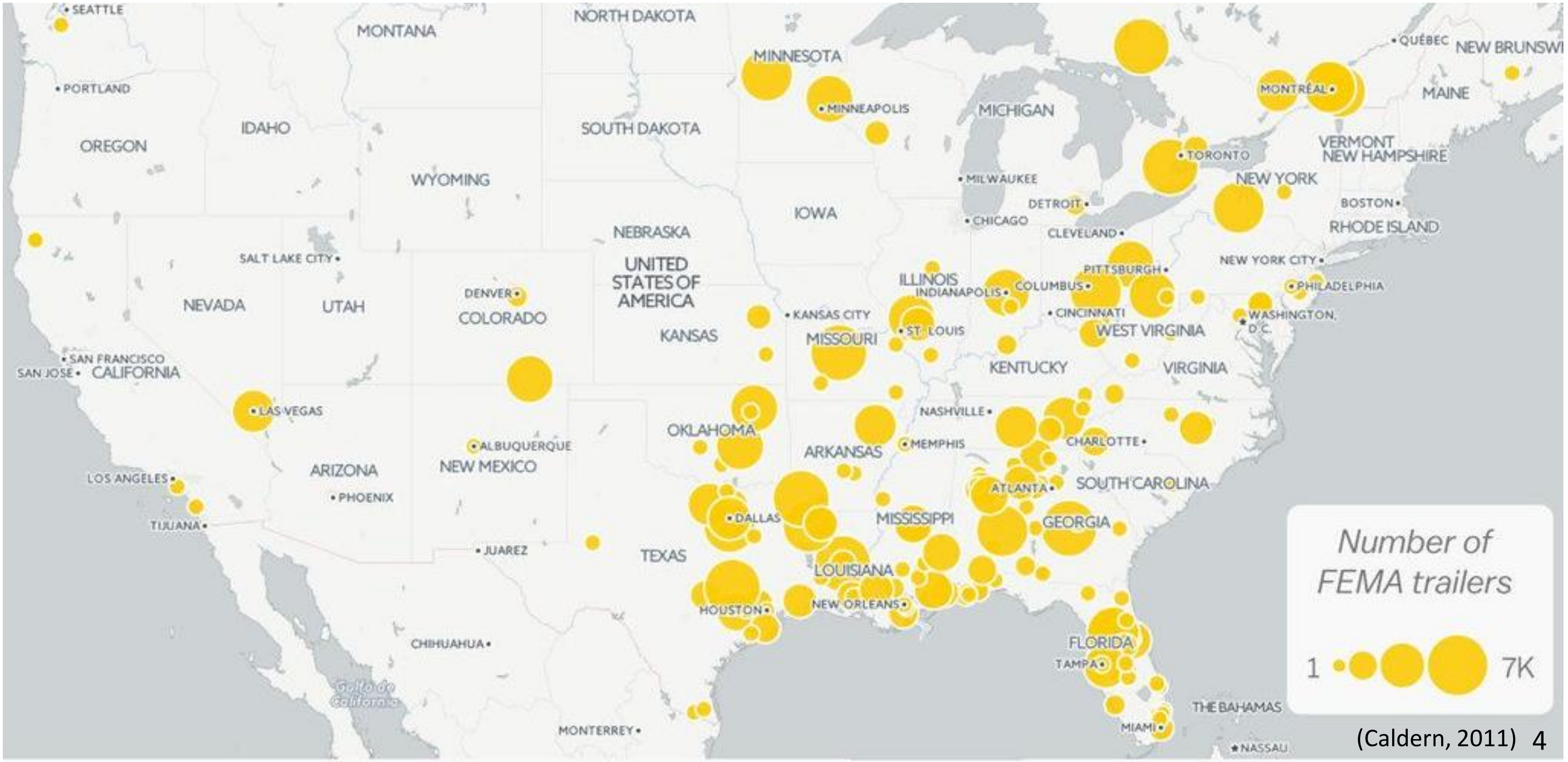
The high levels of formaldehyde were a result of the building materials used for the trailers. Plywood and particleboard commonly contain the chemical, and there are options of each that have reduced levels. It is argued whether FEMA used the low emission materials in the rush to mass produce trailers.

Regardless, air quality tests show elevated levels of formaldehyde in the trailers at .34 parts per million. The EPA defines an elevated level of formaldehyde as .1 parts per million. These levels can cause respiratory problems, watery eyes, nausea, and burning in the throat and eyes (Brunker, 2008).

Fires

The trailers use gas operated equipment and is the source of most fires. The problem does not lie with the equipment and appliances. The trailers are placed close to one another in many scenarios to accommodate more people, but this makes it easier for fire to spread rapidly from one trailer to the next. FEMA has issued several different precautionary lists to help people practice safe habits (FEMA, 2006).

(Moore, 2011)



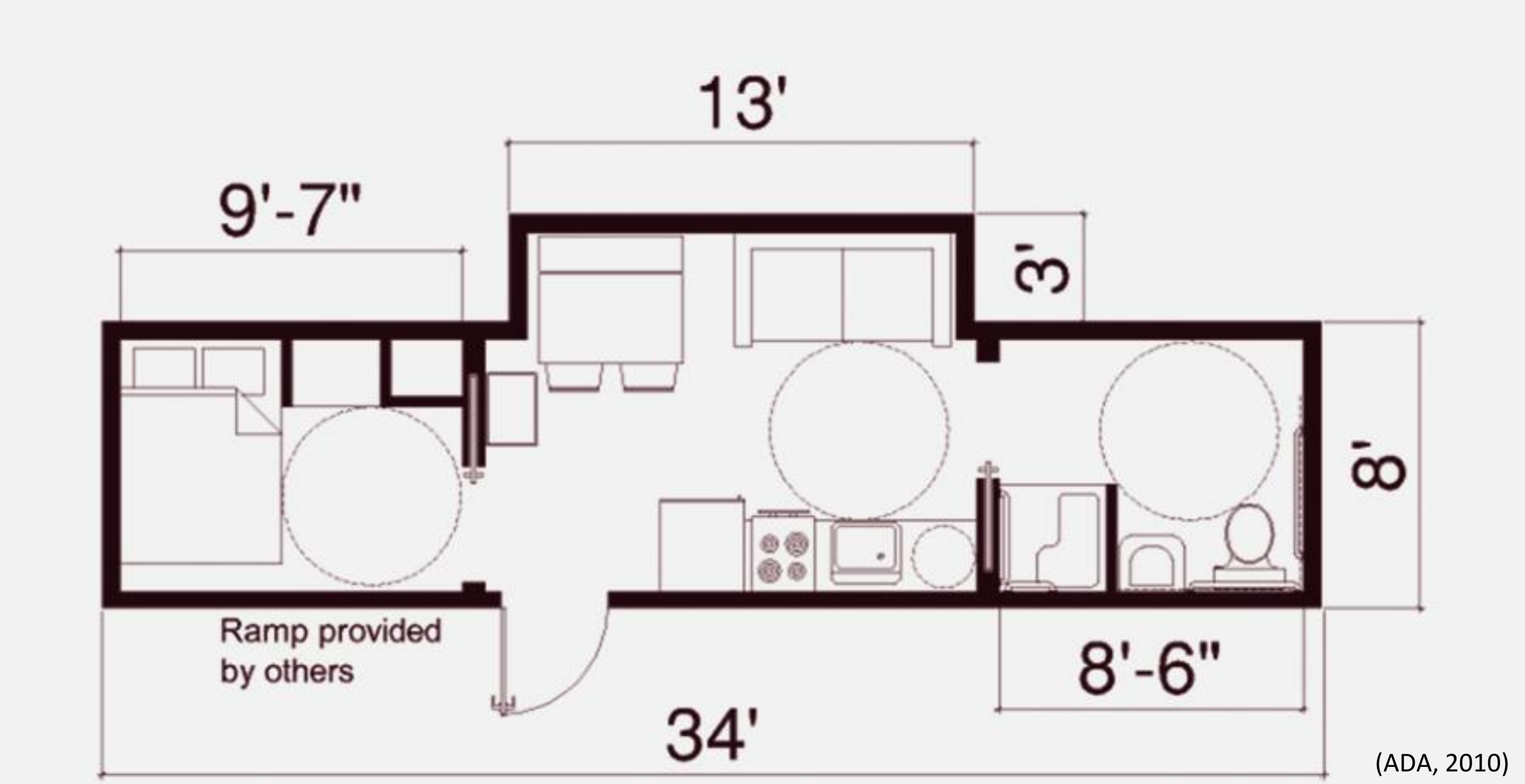
(Caldern, 2011)

Background | FEMA Designs

Typical Design

The FEMA Trailer comes in two standard sizes. One is 14’ x 22’, 308 sq. ft., and the other size is longer but shorter at 8’ x 32’, 256 sq. ft. There is a living room and attached kitchen equipped with a refrigerator, propane stove and oven, and a microwave. There is a master bedroom, bunk beds, and a bathroom. The organization also developed an ADA accessible design that is 8’ x 34’ with a 3’ x 13’ pop out area. The other two trailers are not ADA accessible. Each model varies slightly in design, but they are all equipped with heating, air-conditioning, electricity, and running hot and cold water. The trailers are also elevated off of the ground and have metal or wooden stairs. For accessible entry, a separate ramp attachment can be connected to the trailer.

They are constructed using 2” studs 16” o.c., R-7 fiberglass insulation, aluminum siding, and particle board. The floors are comprised of 5/8” 5 ply plywood and wood joists sitting on a metal trailer frame. The roof is a rubber sheeting on 3/8” roof decking and 5” bowed truss roof rafters.



(ADA, 2010)


(Stuckey, 2005)


(Stuckey, 2005)


(Stuckey, 2005)

Background | Tiny Homes

The tiny home movement has been very popular in recent years within the architectural community. While there is no definitive size of a tiny home, it is generally 500 sq. ft. and smaller.

There are many different types of tiny homes. Some are stationary, while others are built on trailers or wheels to be transported freely. Different levels of sustainability have also been incorporated with them. Many of these structures boast being completely self sustaining through the use of solar panels, solar hot water, gray water systems, and other more elaborate systems.

The layouts, creative use of space, and mechanical systems used in these homes could be integrated into new designs for disaster relief housing. One such approach was proposed by Marianne Cusado in 2005 as a more permanent and pleasant alternative to the FEMA trailer. The “Katrina Cottage” presents a home that is styled in the vernacular of New Orleans’ homes, but reduced in size for cost effectiveness and ease of construction (Heavens, 2007).

The main challenge with tiny homes, and the original Katrina Cottage, is accessibility. Due to the small nature of the floor plan it is hard to maneuver a wheel chair within the space. Additionally, many of the tiny homes have a loft space and/or have the main level elevated off of the ground. These conditions also pose several difficulties with accessibility.


(Windriver, 2016)


(Tumbleweed, 2016)


(Katrina Cottage, 2007)


(Katrina Cottage, 2007)

Precedent Study | Selections

Prescott House

Climate Zone: Temperate
Location: Kansas City, KS
Architect: Studio 804
Area: 1,700 sq ft.
Cost: $93/sq ft.
Certifications: LEED Platinum & Passive House

Description

Studio 804 is a design/build program at the University of Kansas. This home is their sixth project and focuses on affordability, sustainability, passive design, and efficient systems. Key features include super insulated walls, large southern exposure, and an energy recovery system (Studio 804, 20010).

(Studio 804, 2010)

(Studio 804, 2010)

(Studio 804, 2010)

(Studio 804, 2010)

Precedent Study | Selections

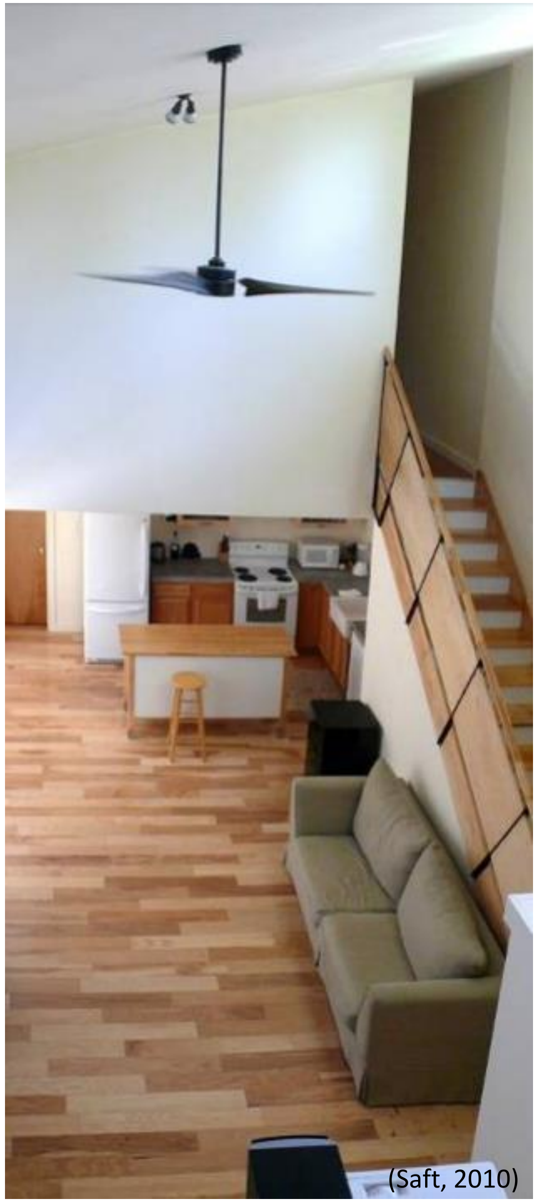
LeBois

Climate Zone: Hot Humid
Location: Lafayette, LA
Architect: Saft Architecture
Area: 1,200 sq ft.
Cost: $110/ sq ft.
Certifications: LEED Platinum, Passive House, and Energy Star

Description

This long narrow house was the first Passive House in the American South as well as one of the first ten in the country. Strategies used for passive certification included air tight construction, high R-values, thermal mass, and a vented rain screen (Goodman, 2012).


(Saft, 2010)


(Saft, 2010)


(Saft, 2010)


(Saft, 2010)

Precedent Study | Selections

VOLKsHouse

Climate Zone: Hot Arid
Location: Santa Fe, NM
Architect: MOSA, Mojarrb Stanford Architects
Area: 1,717 sq ft.
Cost: $161/sq ft.
Certifications: Passive House and Green Build

Description

The goal of this project was to create a low energy, high performance, and affordable home with a focus on seeing how marketable it was to prospective owners compared to standard homes. The architects are striving for affordable net zero energy making it feasible in the housing market. (VOLKsHouse, 2012).


(VOLKsHouse, 2012)


(VOLKsHouse, 2012)


(VOLKsHouse, 2012)


(VOLKsHouse, 2012)

Precedent Study | Selections

NewenHouse

Climate Zone: Cold
Location: Viroqua, WI
Architect/Designer: Sonya Newenhouse
Area: 600-1,000 sq ft.
Cost: $175/sq ft.
Certifications: Passive House

Description

This home is a small home kit that comes in sizes from 600-1,000 sq ft. The home is sustainable, super insulated, and boasts that it is furnace free even in Wisconsin. Sonya designed it using Passivhaus criteria, the German predecessor to the American Passive House certification.

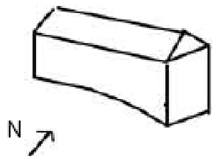
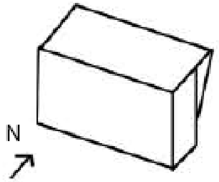
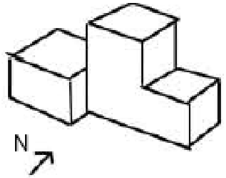
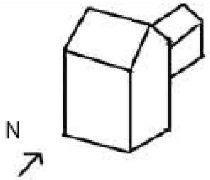
(Laylin, 2014)

(Laylin, 2014)

(Laylin, 2014)

(Laylin, 2014)

Precedent Research Comparison

Climate Zone	Case Study	Orientation	Form-Description	Form-Sketch
Temperate	Prescott House	Long Axis East/West	Long and Thin Two Levels Double Height Space	
Hot Humid	LeBois	Long Axis East/West	Tall and Thin	
Hot Arid	VOLKsHouse	Long Axis East/West	Three Rectangular Volumes	
Cold	NewenHouse	Long Axis North/South	Two Square Masses Two Levels-South	

Orange text notates similarities among case studies

Precedent Research Comparison

Climate Zone	Case Study	Wall Assembly	North Façade Features	East Façade Features	South Façade	West Façade
Temperate	Prescott House	-Engineered Wood 12” joist @ 19.2” o.c. -Cellulose Insulation -3” Polystyrene -Charred Douglas Fir cladding -UV Protective Coating	No Glazing	-15% Glazing -Triple Pane Argon Filled Window	-40% Glazing -Triple Pane Argon Filled Window -Operable Windows -Horizontal Louvers	-10% Glazing -Triple Pane Argon Filled Window
Hot Humid	LeBois	-Type X Drywall -1” Polyisocyanurate Insulation -¾” Air Gap -Modified Rain Screen	--10% Glazing -Dual Pane Windows -Clerestory Windows -Overhang	-10% Glazing -Dual Pane Windows -Overhang	-10% Glazed -Dual Pane Windows -50% Metal Cladding on Facade	-15% Glazing -Dual Pane Windows
Hot Arid	VOLKsHouse	-2 x 6 studs @ 24” o.c. -Zip Panels -10” EPS foam Panels -Light Color Stucco	-20% Glazing -Triple Pane Windows	-10% Glazing -Triple Pane Window	--20% Glazing -Triple Pane Window	-15% Glazing -Triple Pane Window
Cold	NewenHouse	-2x4 stud@ 16” o.c. -Cellulose Insulation -OSB -8” Larson Trusses @ 25” o.c. -Fiberboard and Tyvex -Shiplap Cedar Siding	-20% Glazing -Triple Paned Fiberglass	-40% Glazing Triple Paned Fiberglass	-60% Glazing -Triple Paned Fiberglass -Overhang	-10% Glazing -Triple Paned Fiberglass

Orange text notates similarities among case studies

Precedent Research Comparison

Climate Zone	Case Study	Roof Assembly	Roof Features	Interior Features	Equipment	Passive Features
Temperate	Prescott House	-Engineered Wood 16" joist @ 19.2" o.c. -Cellulose Insulation -4-1/2" Polyisocyanurate -White 26-Guage Galvanized Roof	-Gable Roof -Two Operable Skylights on Northern Slope -Double Glazed Low-E Argon Filled Window	-Thermal Mass -Concrete Floors -White Walls	-Energy Recovery Ventilator	-Interior Thermal Mass -Cross Ventilation -Operable Horizontal Louvers -Daylighting -Air Tight Construction
Hot Humid	LeBois	-11" Open Cell Insulation -2" Isopolyisocyanurate -Light Metal Roof	-Shed Roof-South Facing -3.2kw Thin Solar Cell Array	-White Walls -Thermal Mass -Concrete Floor and Counters -LED and CFL Lighting	-Energy Recovery Ventilator -Low Flow Sink Aerators -1.5 gpm Shower Head -Dual Flush Water Closet with Integrated Sink -1.5ton Split Heating and Cooling	-Interior Thermal Mass -Daylighting -Cross Ventilation -Air Tight Construction
Hot Arid	VOLKsHouse	-EPS Foam Panels	-Flat Roof -Photovoltaics	-LED Lighting -White Walls	-Mini Split Heat Pump -Energy Recovery Ventilator -2kw PV Array -Solar Hot Water -1.5gpm Faucets and Shower Heads -1.28gpf WC with Integrated Sink	-Air Tight -Daylighting -Thermal Envelope
Cold	NewenHouse	-12" Energy Heel Truss -Cellulose Insulation -OSB -Air Barrier -Standing Seam Metal Roof	-Two Gable Roofs -N/S Axis -One Skylight -E/W Axis -Overhang on South Facade	-Recycled Materials	-Solar Hot Water -PV Ready -1,000 Rainwater System -Green Roof Option	-Daylighting -Air Tight Construction -Central Core -Interior Thermal Mass

Orange text notates similarities among case studies

Precedent Research Summary

The data presented in the previous charts notes the features each case study has within it. Many of the components in the wall assemblies, roof assemblies, equipment types, and passive strategies, are similar between two or more homes. This suggests that for building a singular passive home in each climate zone, there are basic principles that apply rather than several drastically different designs.

In the table on the right, the design priorities are listed for each climate zone in order of importance. Many of these priorities are the same across all zones, but in a different order of importance. Highlighted in orange are the priorities that are in at least two different climate zones. The red notes priorities that are of the same importance across two or more climate zones.

Temperate Design Priorities	Hot Humid Design Priorities	Hot Arid Design Priorities	Cold Design Priorities
1. Retain heat and block the cold during winter	1. Allow for natural ventilation to cool and remove excess moisture during the summer	1. Keep hot temperatures out during the summer	1. Retain heat and block the cold during winter
2. Let winter sun in	2. Protect from summer sun	2. Protect from summer sun	2. Brace from winter winds
3. Use natural ventilation	3. Avoid creating additional humidity during the summer	3. Use evaporative cooling in the summer	3. Let winter sun in
4. Brace from winter winds	4. Let winter sun in	4. Use thermal mass to reduce temperature swings in the summer	4. Use thermal mass to reduce temperature swings
5. Protect from summer sun	5. Brace from winter winds	5. Retain heat and block the cold during winter	5. Protect from summer sun
6. Avoid creating additional humidity during the summer		6. Let the winter sun in	6. Use natural ventilation
		7. Use natural ventilation	

Wall Section Research | Insulation

Since a commonality in the precedent studies were super insulated wall sections and roof cavities, further research was done on the types of insulations that were used in those buildings.

Insulation Type	Approx. R-value/in	Cost	Moisture	Customization	Warranty	Ratings	Process	Recycled Content	Hazardous Materials	Compressive Strengths
ISO-Polyisocyanurate	Up to 6.5	$0.70/sq. ft. for 1" panel	--	Variety of facings Most popular: foil	R-Value degrades over time	--	Chemical heavy	--	--	--
EPS- Expanded Polystyrene	4.6	Highest R-Value/dollar 10-30% less than XPS for equivalent R-Value	15 year study in St. Paul below grade application—4.8% moisture content	Faced or unfaced Faced is considered a vapor retardant or barrier	100% R-Value retention	-Can be used in structural panels -Rated for ground contact	Expanded polystyrene resin molded to form closed cell material to trap air	Up to 15%	No HFC, CFC, HCGC, formaldehyde or dyes	15, 25, 40, 60 psi
XPS- Extruded Polystyrene	5	$0.42/sq. ft. for 1" panel	15 year study in St. Paul below grade application—18.9% moisture content	Faced or unfaced Unfaced is not a vapor retardant with a 1 perm rating	90% R-Value retention	--	Polystyrene resin extruded through dye to form closed cell material	Depends on company	Typically uses HFCs-134a Color dyes	15, 25, 40, 60, 100 psi
Cellulose	Dense Pack: 4	More expensive than fiberglass batt insulation	If exposed to a lot of moisture, potential for corrosion of pipes and wires	Dense Pack Loose Fill	+100 years if sealed and installed correctly	Treated w/ non toxic borate compounds to resist fire (class 1), insects, and mold	Made with recycled paper or wood particles. Blown or sprayed in cavity	85%	None	--

Wall Section Research | Components

Components

While looking at the other components of the wall sections used in the case studies, a few key options stood out. The first was a 2x4 stud wall, which is one of the more common wall supports, and the rain screen. Although the rain screen was only used in one of the case studies, it is capable of shading the building well and serves as a buffer zone for the elements. Another interesting component is the air gap between the rain screen and the exterior building skin. This gap can produces up to a 20 degree temperature difference (Goodman, 2012).

From the previous chart, two insulation types were selected based on a review of all of their properties. Dense pack cellulose insulation will be used for the fill between the studs, and EPS foam will wrap the entire building to create an air tight condition. Instead of using normal plywood sheathing, the Zip panel system was selected. The system is installed by a worker from the manufacturer. The sheathing and building wrap are applied and then sealed with an insulating tape.

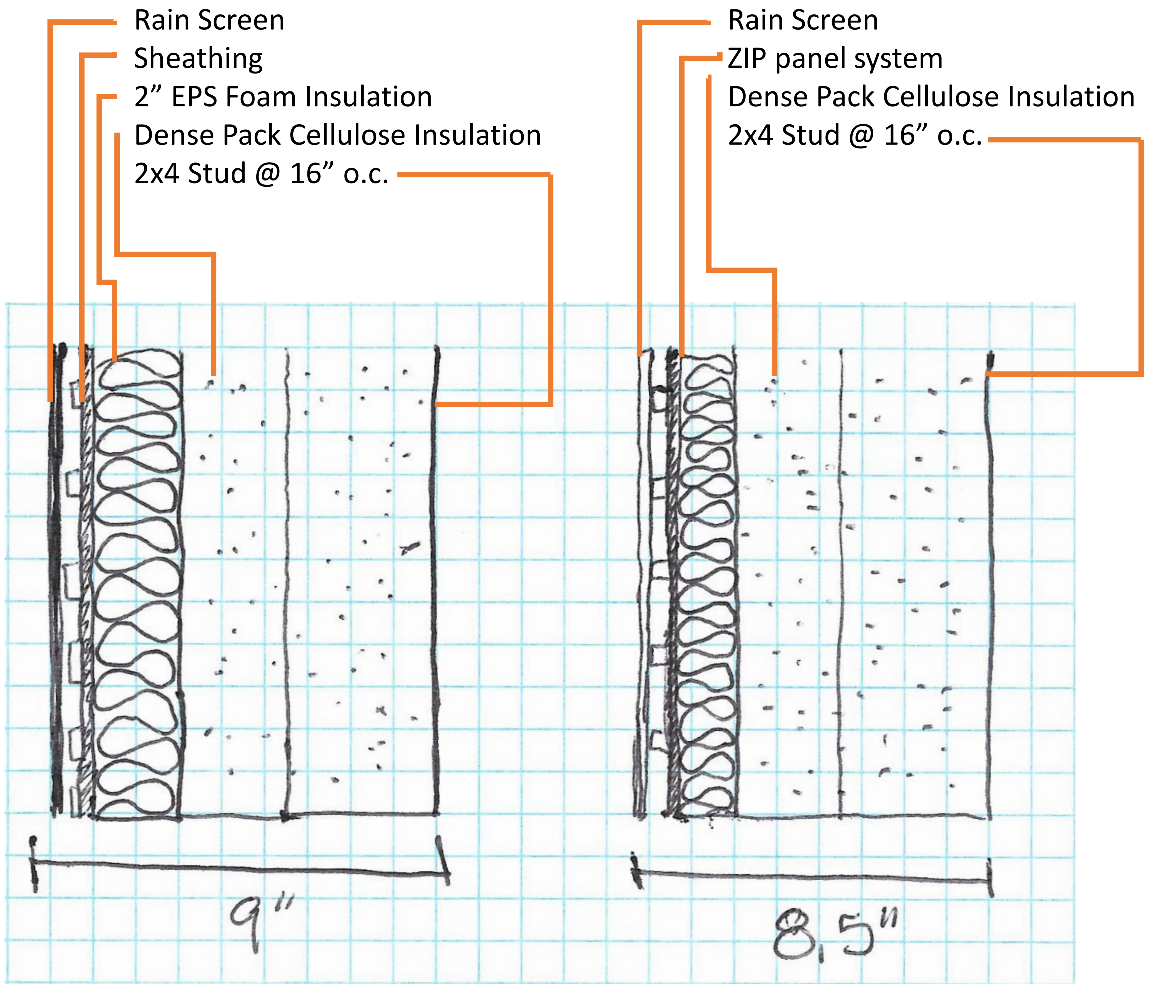
While constructing the wall section, it was crucial to find the highest ratio of R-value to wall thickness to leave maximum room available for manipulating the floor plan.

Proposed wall section design:

INTERIOR SIDE

Gypsum Wall Board
2x4 Studs @ 16” O.C.
Dense Pack Cellulose Insulation
EPS insulation
Sheathing
Air Gap
Rain Screen

EXTERIOR SIDE



Total R-Value: 30
Ratio of R-value to wall thickness: 3.33

Total R-Value: 30.6
Ratio of R-value to wall thickness: 3.6

Additional Design Constraints

Transportation

Another key factor in this problem is the distribution of the units. The FEMA trailer was distributed using the railroad system and highways. The goal of the new design in relation to distribution is to relocate as many units as possible in the minimum amount of space.

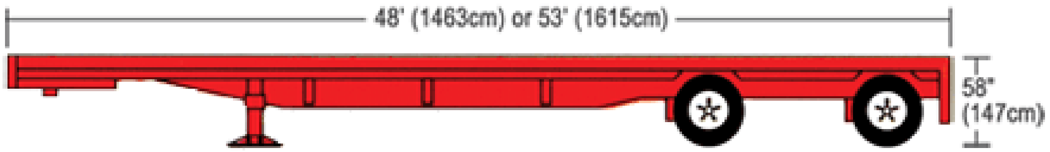
Between the two methods of distribution, the highway system has a much stricter code when it comes to size limits. The standard flatbed dimensions are 8'-6" x 48'-0." Each state has their own specific requirements for maximum widths and heights for loads, but there are some similarities amongst the regularly issued permits. The most restrictive permits allow for a 10' wide load and a 12' high load (not including the height of the trailer bed). These are the maximum design dimensions for the shipping of the proposed housing strategy (Department of Transportation, 2016).

Additionally, when shipping a FEMA trailer, only one can be pulled per truck. The project will also attempt to put two homes in the space that one FEMA trailer would occupy. This would double the amount of homes shipped at once to place more people faster.

The final design size constraint of the project in regards to shipping is 20' x 10' x 12.'

(Stuckey, 2005)

(Stuckey, 2005)



(Anderson, 2013)

Exploration of Designs | Floor Plans & Section

Loft Space

Small windows along wall

Accessible by ladder

Open to Below

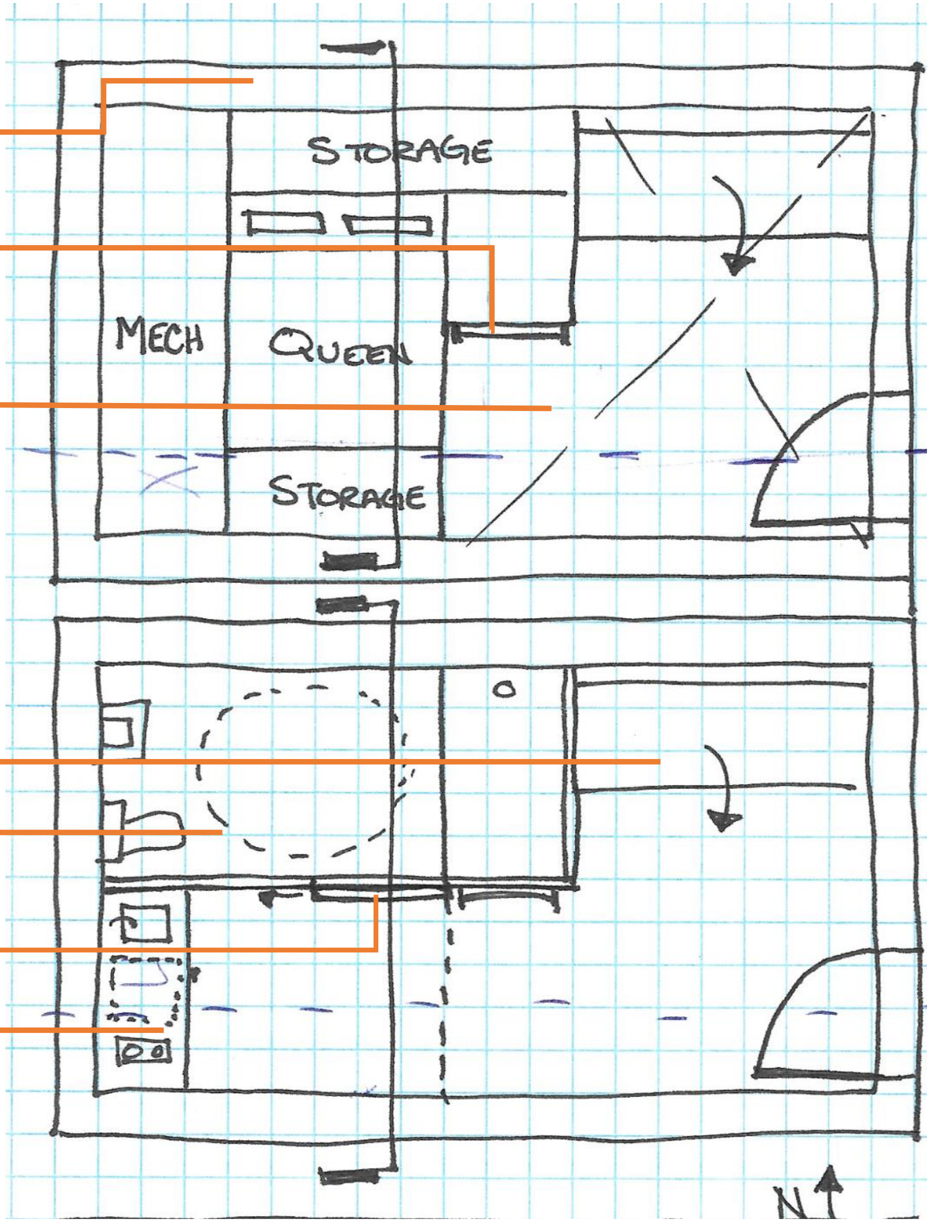
First Floor

Fold out couch

5’ circle for ADA Accessibility

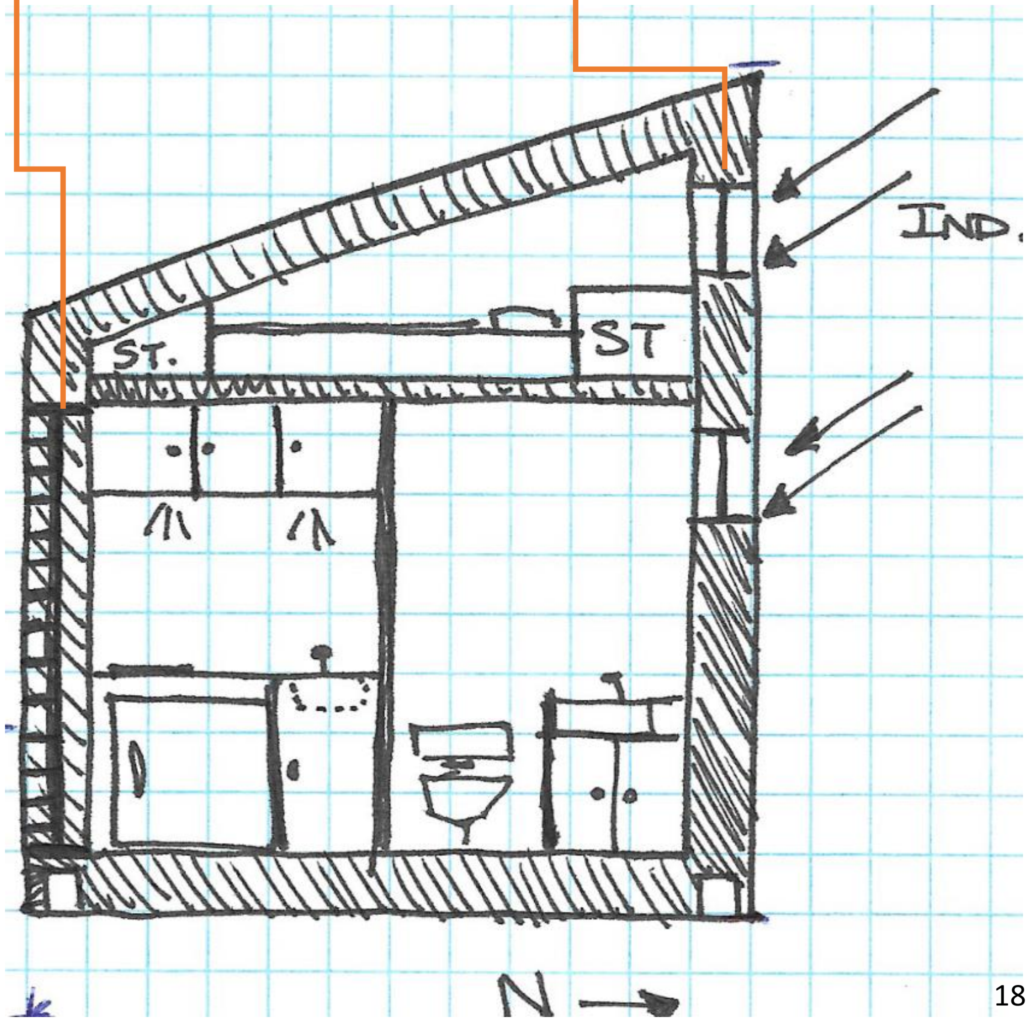
Sliding door

Kitchenette



Section

Horizontal louvers and operable windows
Small windows for indirect northern light



Exploration of Designs | Floor Plans & Section

Alternative First Floor Plan

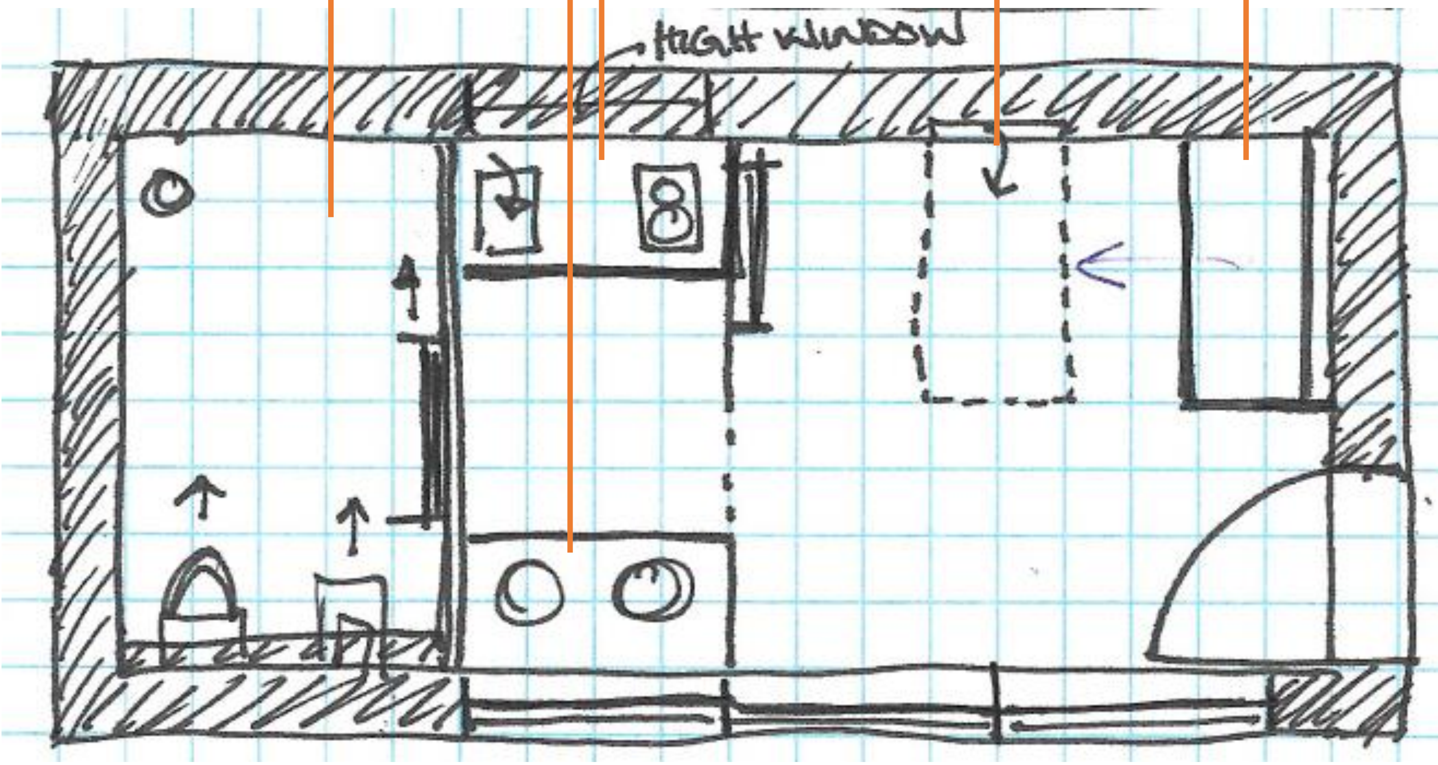
Fold out couch

Fold down table

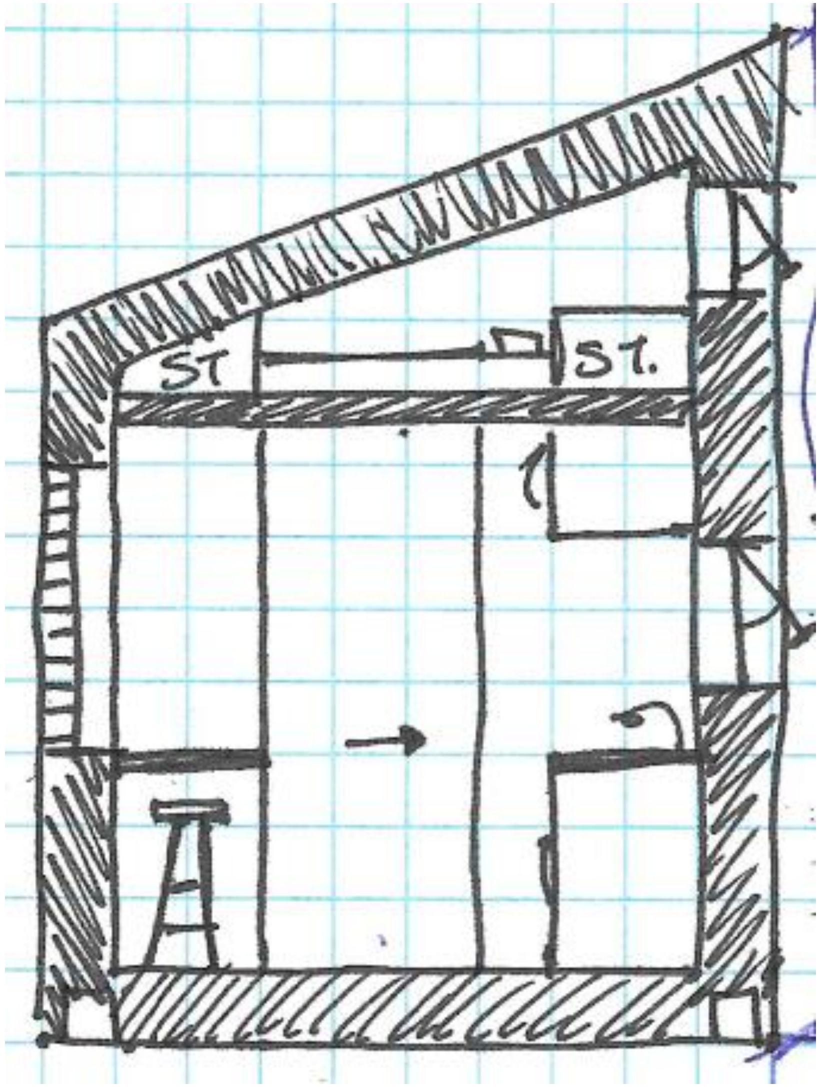
Kitchenette

Table and stools

Wet bathroom



Section



Exploration of Designs | Moving Pieces

Additional Space

In order to gain some additional space, a moving element was incorporated into the design. Two ways of motion were analyzed: moving one piece vertically above the first floor, or sliding horizontally out from one piece

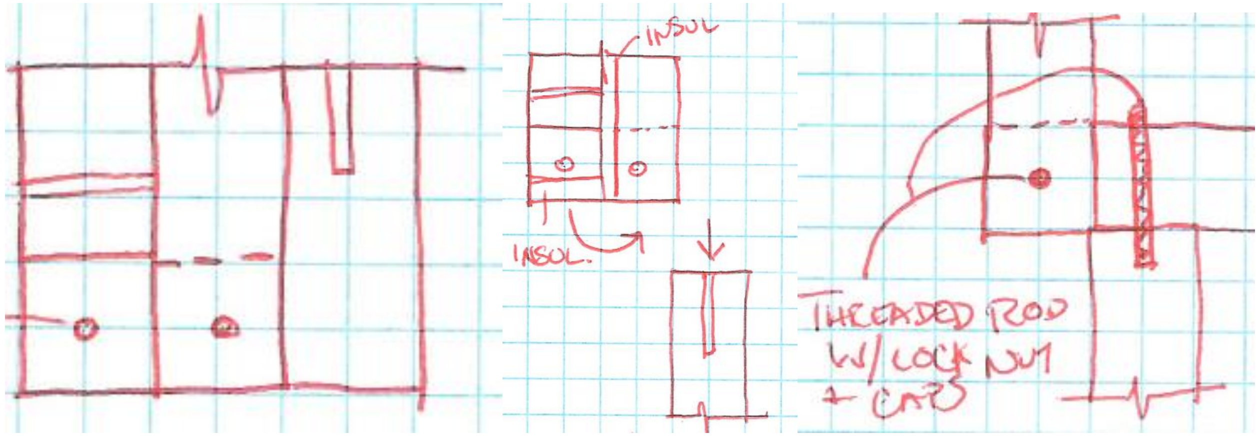
Vertical Movement

If the home was to open up vertically, there would be more head room on each story. The upper piece could sit inside the lower piece for transportation and then raised up above the first story, or the upper piece could rest outside of the first floor during transport. Having the upper story to the outside of the first story presented a simpler connection system. During installation, the second story floor would swing into place and be the main support for the second story walls and transferring it to the first story walls. The series of diagrams to the upper right show the steps to the connection.

Horizontal Movement

If horizontal movement was selected, it would make more sense for the home to be on one level with taller ceilings. The connection for the horizontal movement would be much easier to maneuver than the vertical transition. One half of the home would sit inside the other during transport and shift into place during installation. In addition to having a less complex connection, the single story unit could be made to be fully ADA accessible. In contrast, the initial design only has an accessible first floor.

Vertical Movement

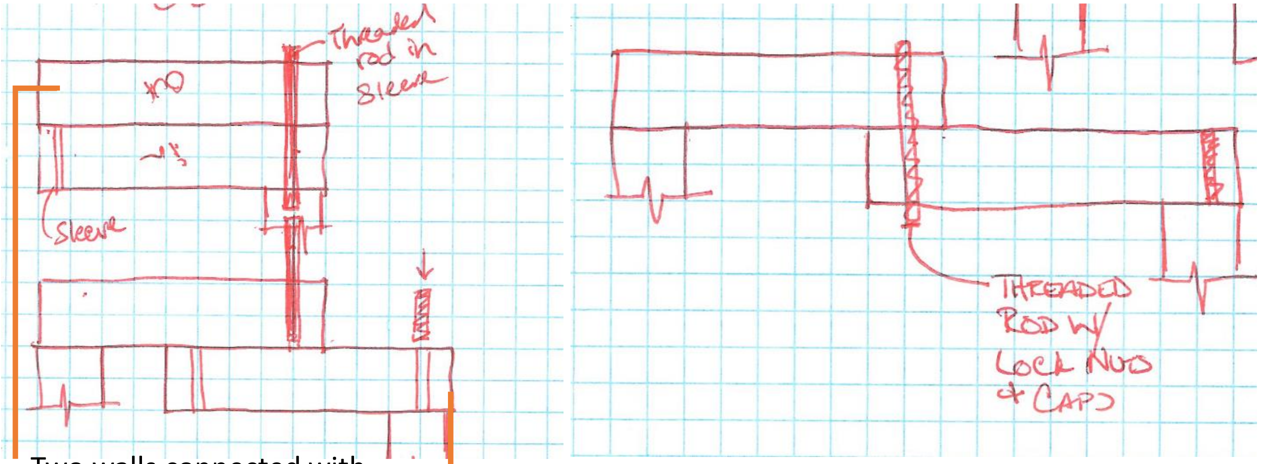


Second story floor edge followed by second story wall base then top of first story wall

Second story floor and wall are raised up and the floor rotates under the second story wall

Threaded rods are secured in the second story wall and floor as well as the floor and first story wall

Horizontal Movement



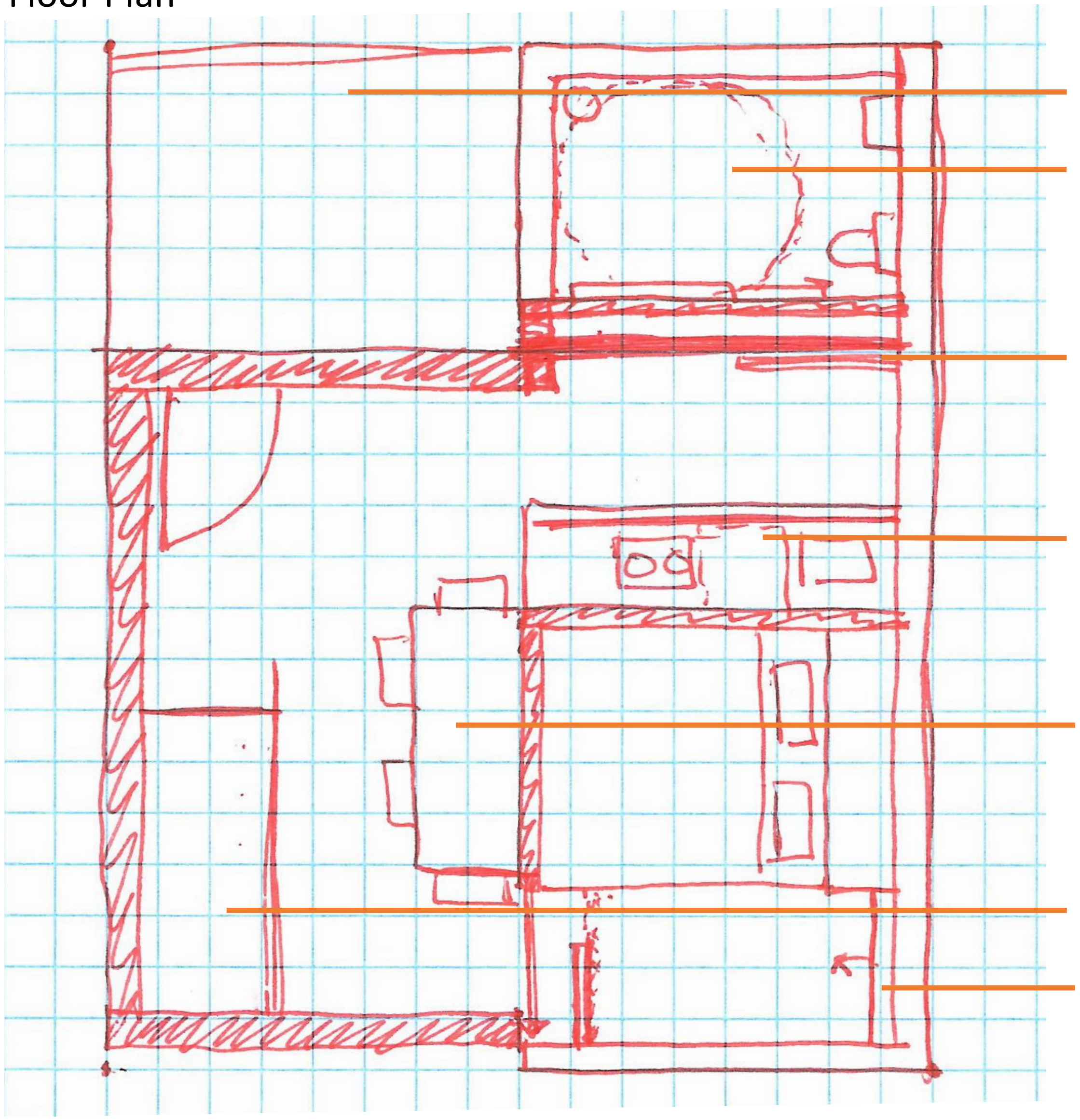
Two walls connected with threaded rod during transport

Rod pulled out to shift walls

The threaded rod is replaced in the wall, and a plug seals the other connection that was used during transport.

Exploration of Designs | Single Story Floor Plans

Floor Plan



Porch

Wet bathroom

Ladder to mechanical space

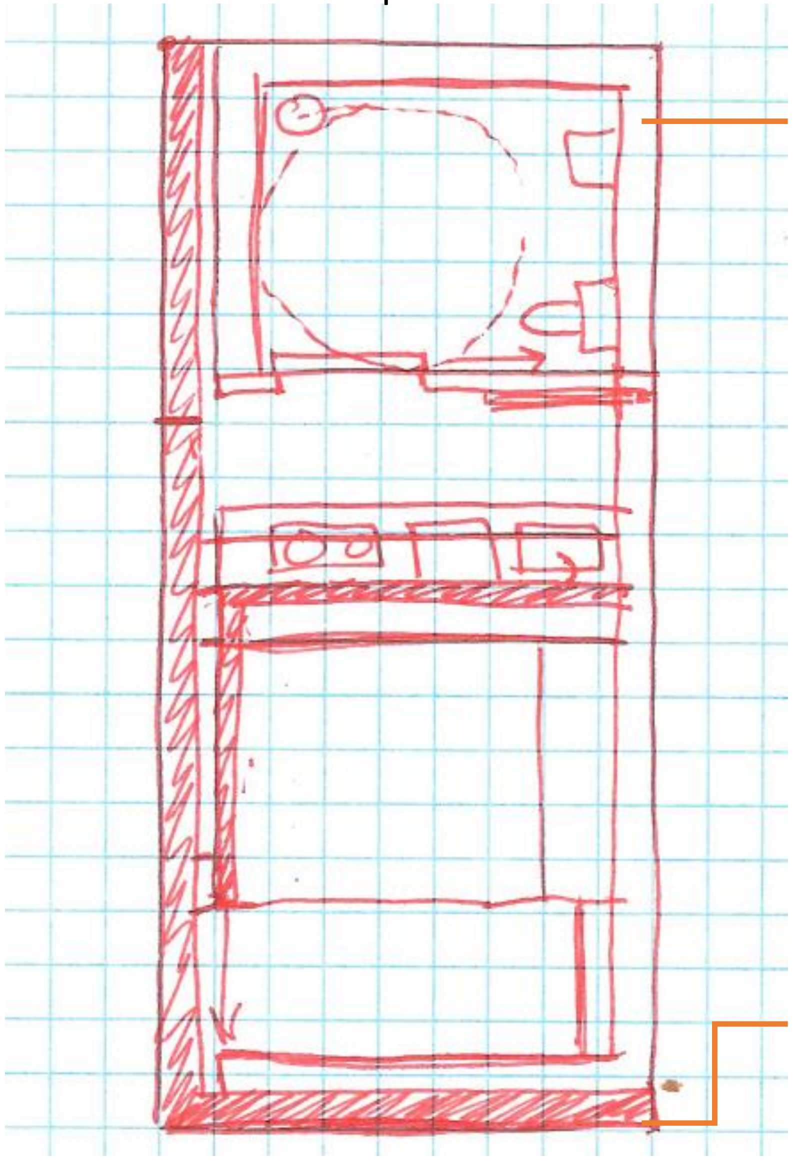
Kitchenette

Fold down table

Fold out couch

Fold down bed

Plan Closed for Transport



Outlined walls indicate stationary floor

Solid walls indicate sliding piece

Exploration of Designs | Section & Modifications

Modification | Footing

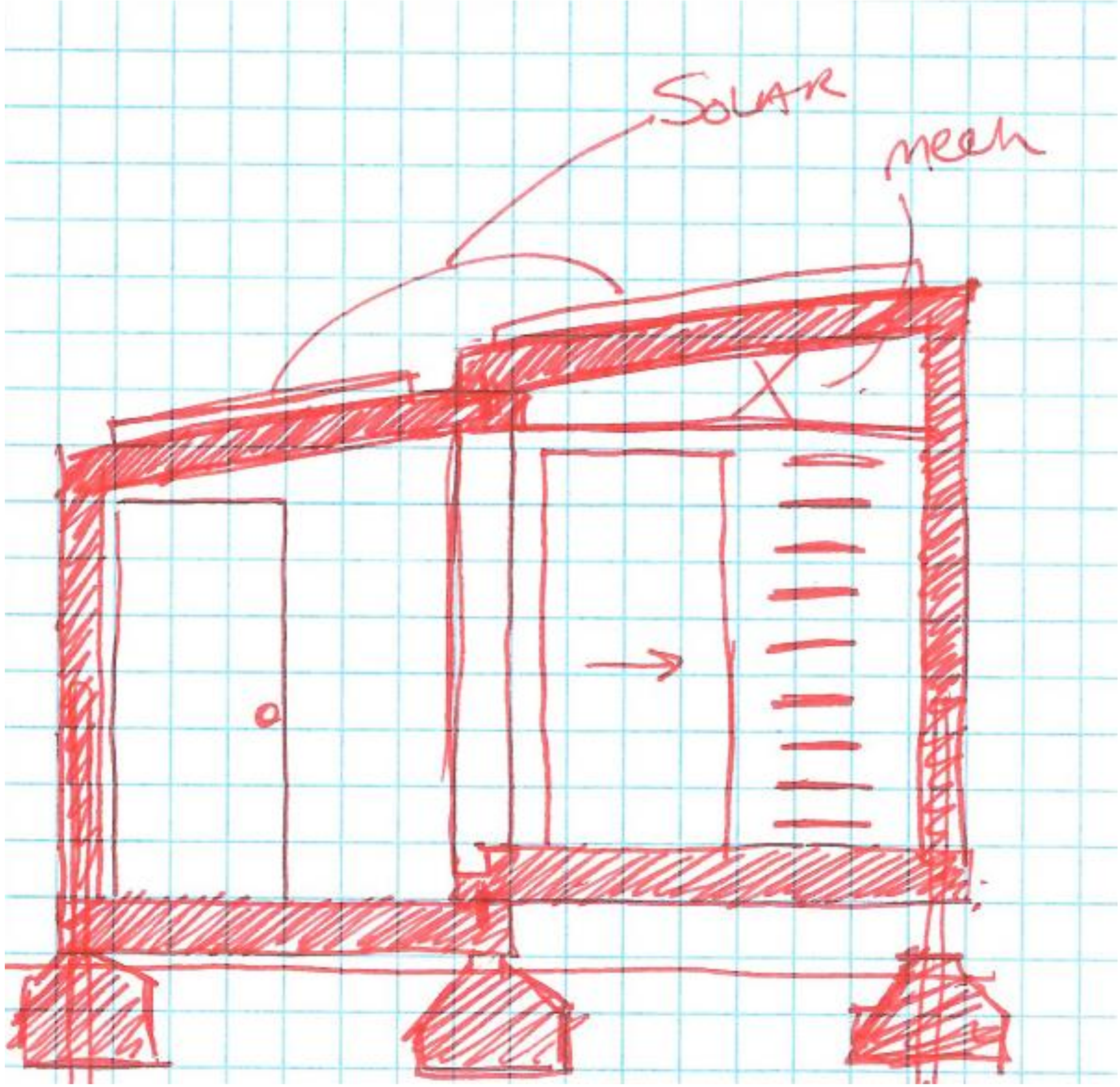
With manufactured housing, the footing conditions can be tricky. The footing needs to be quickly installed, and the builders cannot afford to wait for concrete to dry. Additionally, these small structures are susceptible to wind damage as they are lighter than normal buildings and do not have permanent footings. The proposed solution to the right uses a polygonal concrete footing with a pressure treated column embedded in it. These posts ship with the unit and slide into place in the corners and center of the structure. A hole is the only preparation required for this ground connection.

After more research was conducted on secure footings for manufactured homes, a new product was selected for the ground connection. Helical piers are corkscrew pieces that can be "drilled" into the ground using a hand tool. These will be attached to the ends of the wooden columns and twisted into the ground for a more secure connection.

Modification | Negotiating the change in level

In the sketch to the right, a step can be seen between the two halves. To make the entire home ADA accessible, a hinge that slides and raises the second half of the house will be installed. This hinge is similar to the one used in a fold out couch. The roof and floor would then be sealed by a worker on site.

Cross Section

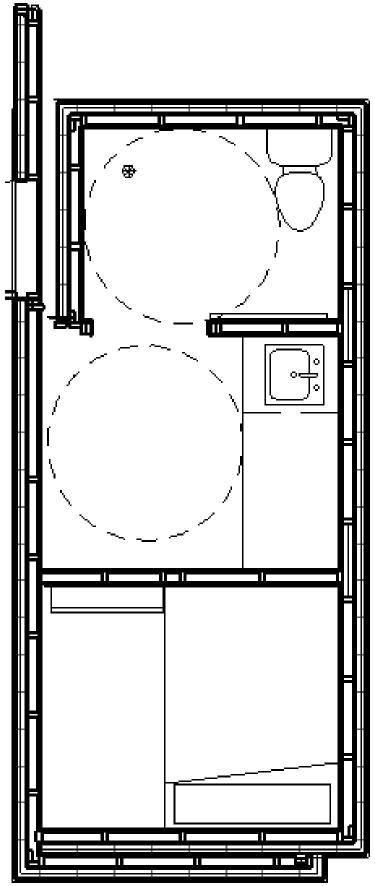


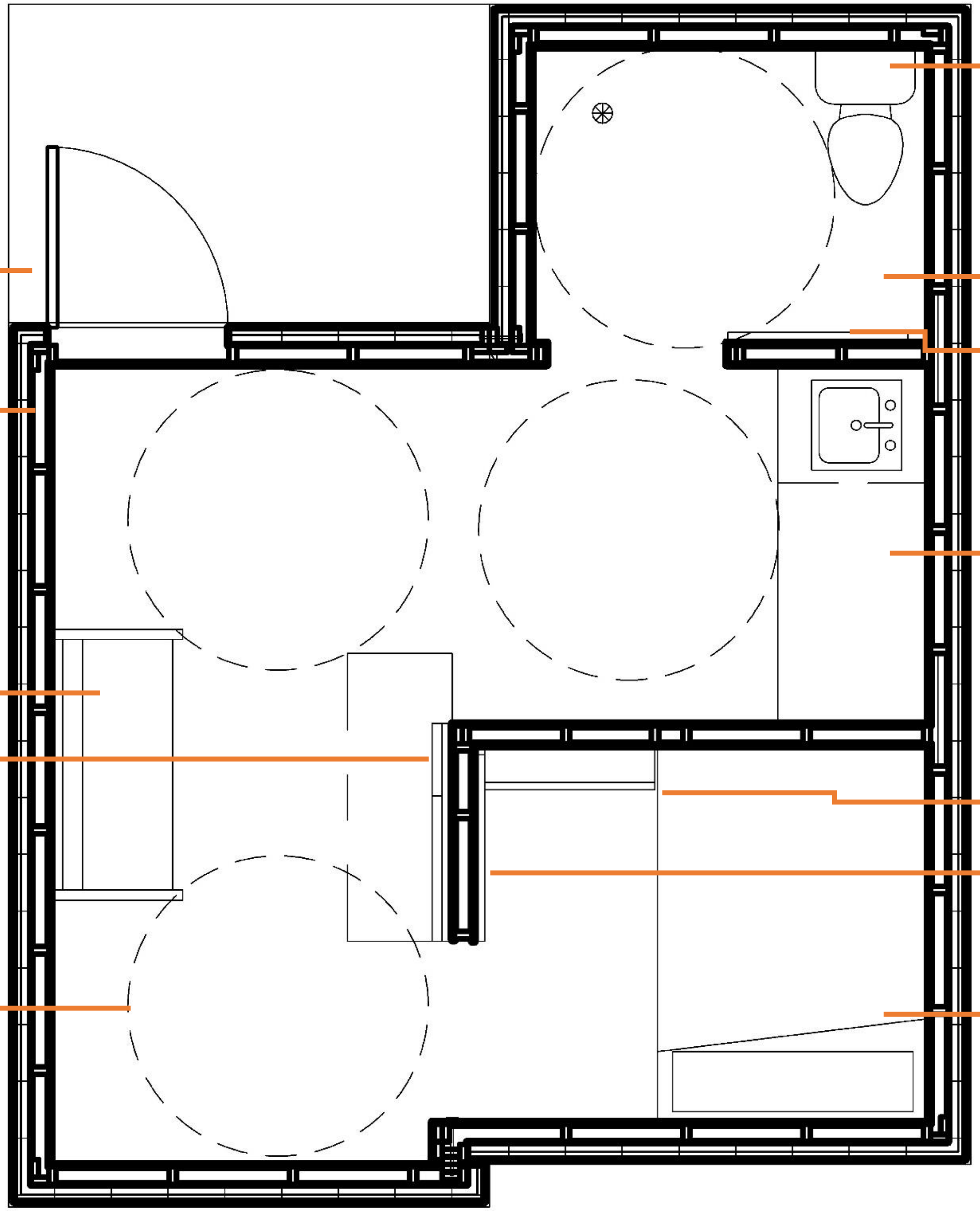
Final Design | Floor Plan

Closed: 9’ x 22’

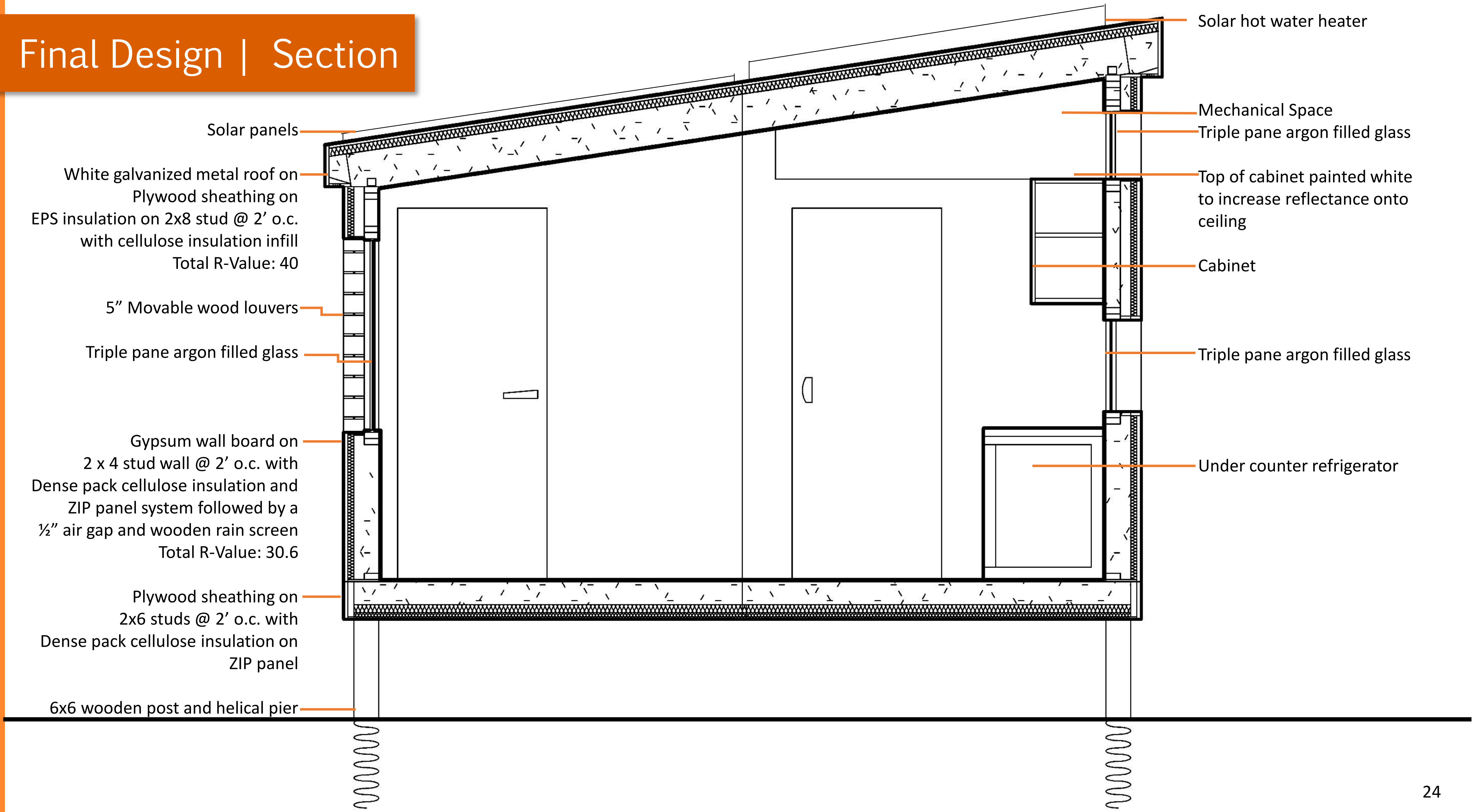
Open: 16’ x 20’

Total Sq. Ft.: 280 sq. ft.



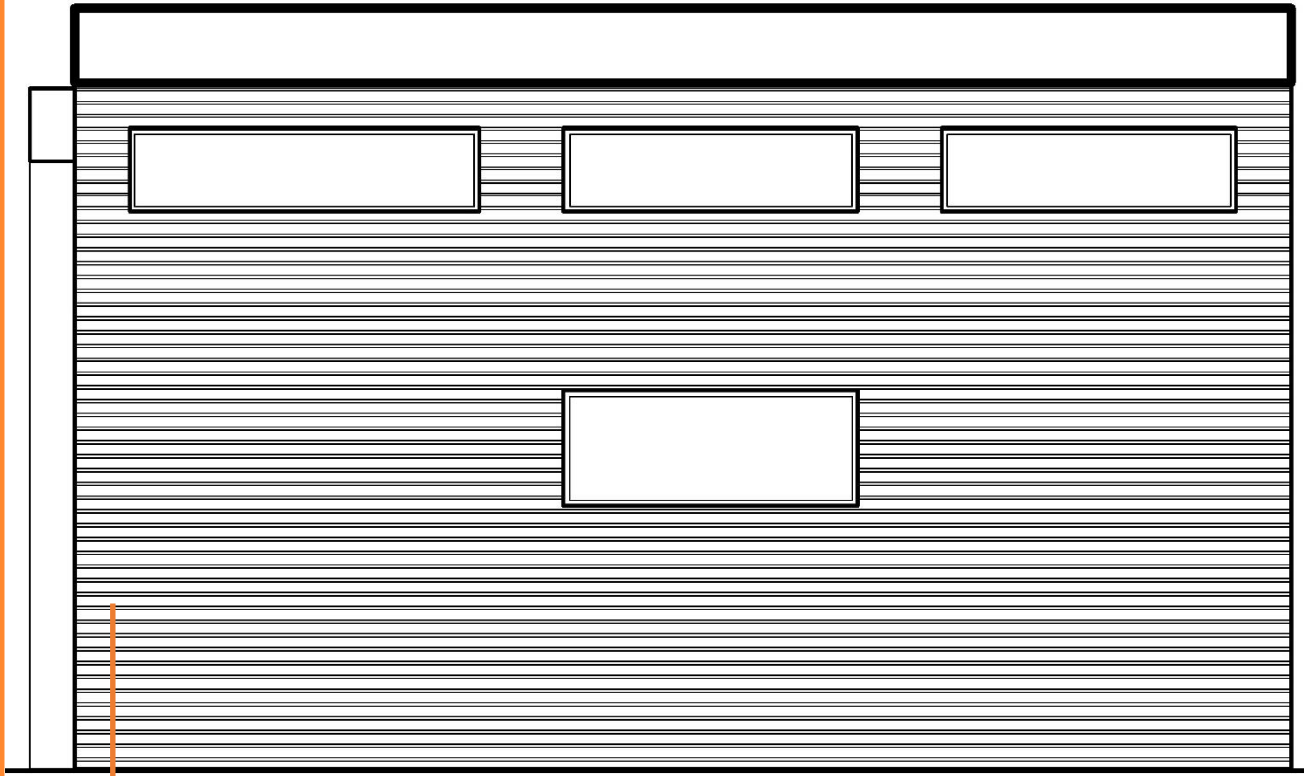


Final Design | Section



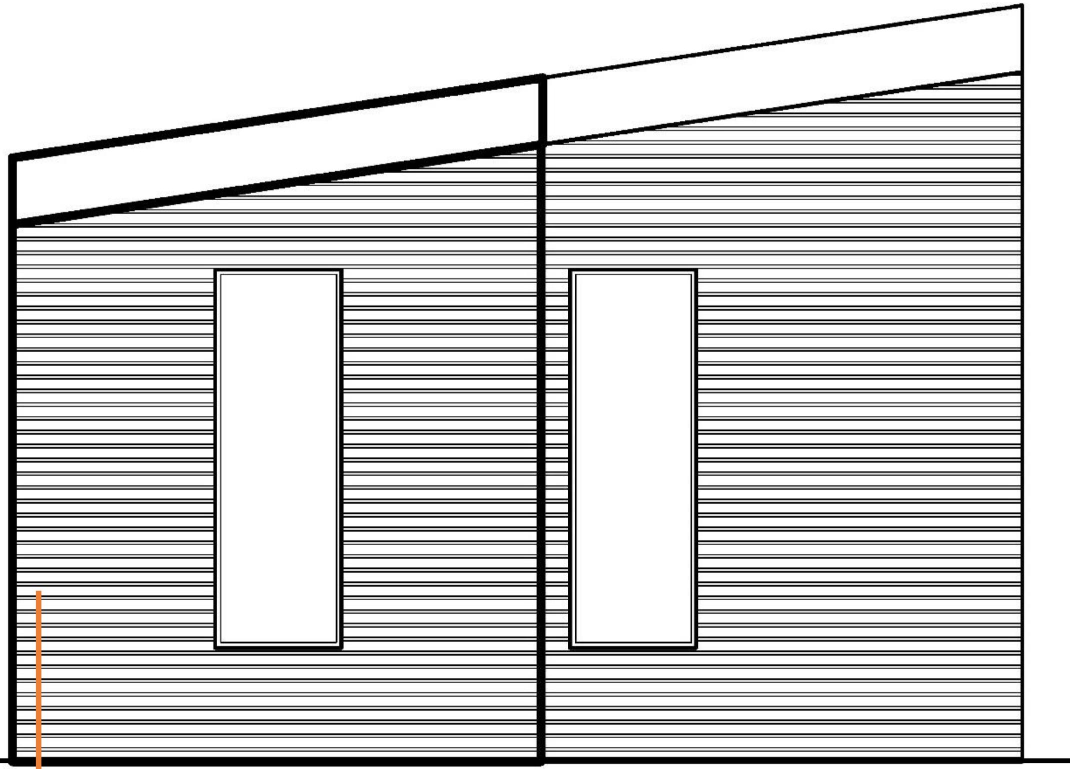
Final Design | Elevations

North Elevation



Sealed wooden rain screen and
Triple pane argon filled awning windows

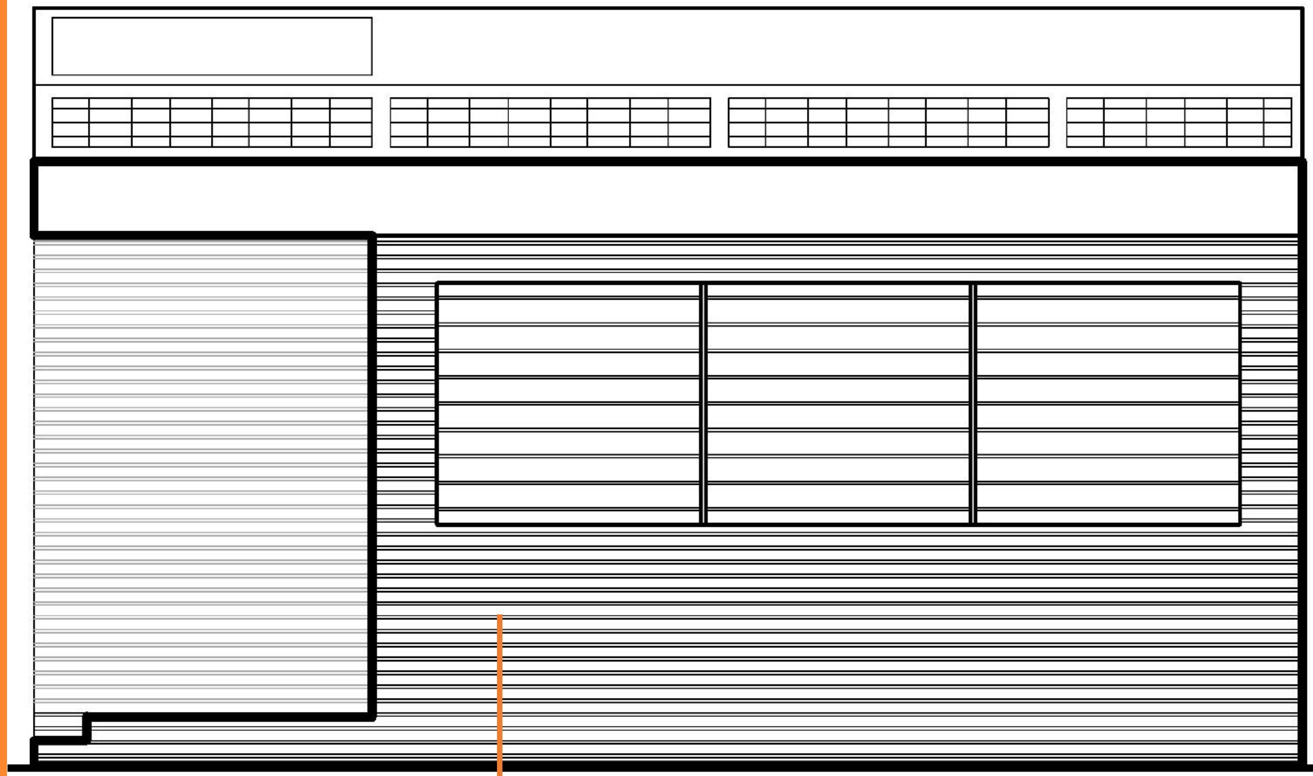
East Elevation



Sealed wooden rain screen and
Triple pane argon filled pivot windows

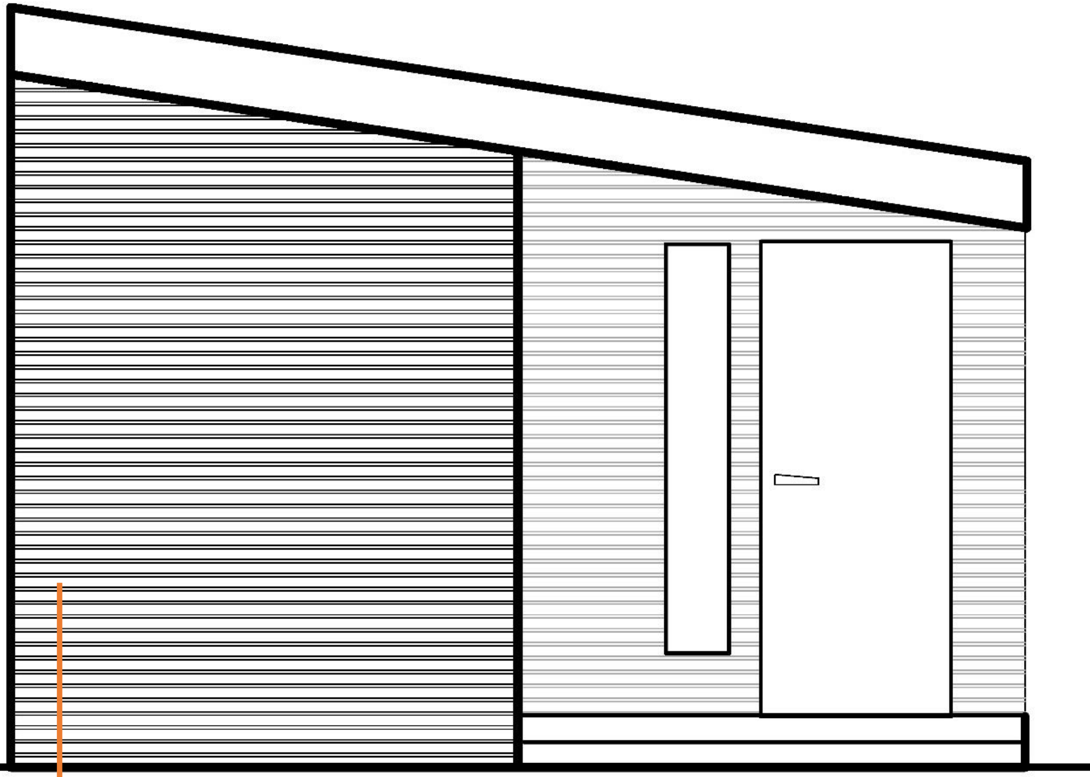
Final Design | Elevations

South Elevation



Sealed wooden rain screen and
Triple pane argon filled hopper windows with
Movable louvers

West Elevation



Sealed wooden rain screen

Final Design | IESVE

The goal of the 2030 Challenge is to meet net zero energy use for a building. The results below are for the proposed structure in each climate zone. These results were taken directly from the energy modeling program Integrated Environmental Solutions-Virtual Environment

Temperate

Calculation data:

Results file "c:\..\KANSAS3\vista\KANSAS3.aps"
Calculated 10/May/2016 on 09:28
Calc. Period: 01/Jan - 31/Dec

Weather:

Climate file KansasCityTMY2.fwt

Architecture 2030 Challenge:

Current design 113 % Reduction

Meets 2030 target

Single-Family Detached (National Average)

Design Building Energy Use Intensity:
-5kBTU/ft^2
(Design EUI = Energy / Building Area)

Average Building Energy Use Intensity:
44kBTU/ft^2
(Used to generate 2030 Challenge Targets)

Summary:

The building uses 113% less energy than a traditional single family residence. It has achieved net zero energy.

Hot Humid

Calculation data:

Results file "c:\..\vista\New Mexico.aps"
Calculated 10/May/2016 on 09:51
Calc. Period: 01/Jan - 31/Dec

Weather:

Climate file LaredoTMY.fwt

Architecture 2030 Challenge:

Current design 155 % Reduction

Meets 2030 target

Single-Family Detached (National Average)

Design Building Energy Use Intensity:
-24kBTU/ft^2
(Design EUI = Energy / Building Area)

Average Building Energy Use Intensity:
44kBTU/ft^2
(Used to generate 2030 Challenge Targets)

Summary:

The building uses 155% less energy than a traditional single family residence. It has achieved net zero energy. The number is greater than in the temperate zone because the building’s weak area is heating. A hot humid area requires less heating.

Hot Arid

Calculation data:

Results file "c:\..\vista\New Mexico.aps"
Calculated 10/May/2016 on 09:48
Calc. Period: 01/Jan - 31/Dec

Weather:

Climate file AlbuquerqueTMY2.fwt

Architecture 2030 Challenge:

Current design 197 % Reduction

Meets 2030 target

Single-Family Detached (National Average)

Design Building Energy Use Intensity:
-42kBTU/ft^2
(Design EUI = Energy / Building Area)

Average Building Energy Use Intensity:
44kBTU/ft^2
(Used to generate 2030 Challenge Targets)

Summary:

The building uses 195% less energy than a traditional single family residence. It has achieved net zero energy. Like the hot humid zone, it requires less heating, but it also requires less air conditioning as there is reduced humidity values in this zone.

Cold

Calculation data:

Results file "c:\..\vista\Wisconsin.aps"
Calculated 10/May/2016 on 09:45
Calc. Period: 01/Jan - 31/Dec

Weather:

Climate file MadisonTMY2.fwt

Architecture 2030 Challenge:

Current design 73 % Reduction

Meets Current target

Single-Family Detached (National Average)

Design Building Energy Use Intensity:
12kBTU/ft^2
(Design EUI = Energy / Building Area)

Average Building Energy Use Intensity:
44kBTU/ft^2
(Used to generate 2030 Challenge Targets)

Summary:

The building uses 73% less energy than a traditional single family residence. More work is needed for the structure to achieve net zero energy in this climate zone. Options to achieve the goal could include: more insulation, higher efficiency heating system, or an increase in solar panels.

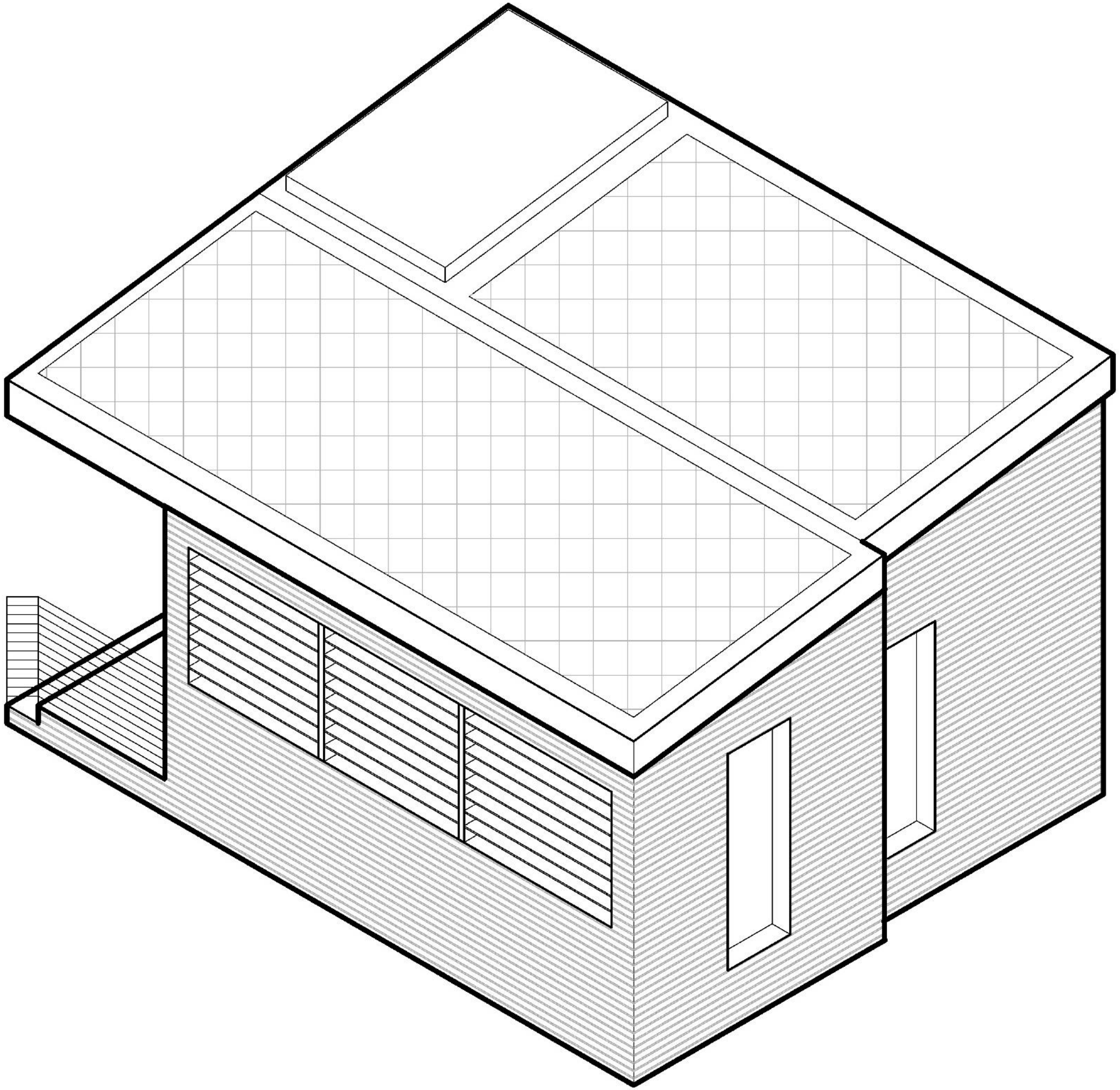
Final Design | Moving Forward

The initial phase of this project is complete. A disaster relief structure has been designed and tested for being passive in each climate zone. Based on the results, the model still needs additional analysis on passive and mechanical heating systems. This is shown in the energy modeling results where the most efficient application is in a hot arid climate, and the least efficient is in a cold climate. The next step is to continue manipulating materials and systems to achieve net zero energy in each climate zone. Efforts to reduce the cost of the structure will also be analyzed at that stage.

Once that goal is achieved, connections will be looked at in depth to create a flat pack version of the structure that can be easily assembled on site. By creating a prefabricated kit, more homes are able to be shipped at once. This would allow for an initial wave of pre-constructed homes (as currently proposed) for immediate shelter, and a secondary wave of simple to assemble housing kits to accommodate the entire population in need of shelter.

The prefabrication also presents new opportunities for combining one or more homes into larger structures for bigger families. Additionally, several units could be combined without the interior features for gathering spaces.

This project presents a design for disaster relief housing that is more pleasant than the current solutions. It also incorporates the sustainable lifestyle that the architectural community has shifted towards to reduce energy consumption. Although further development will continue, the initial phase of the project is complete.



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