Homesteading in a Modern Society

A Design Thesis Submitted to the
Department of Architecture
North Dakota State University

By
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In Partial Fulfillment of the Requirements
for the Degree of
Master of Architecture

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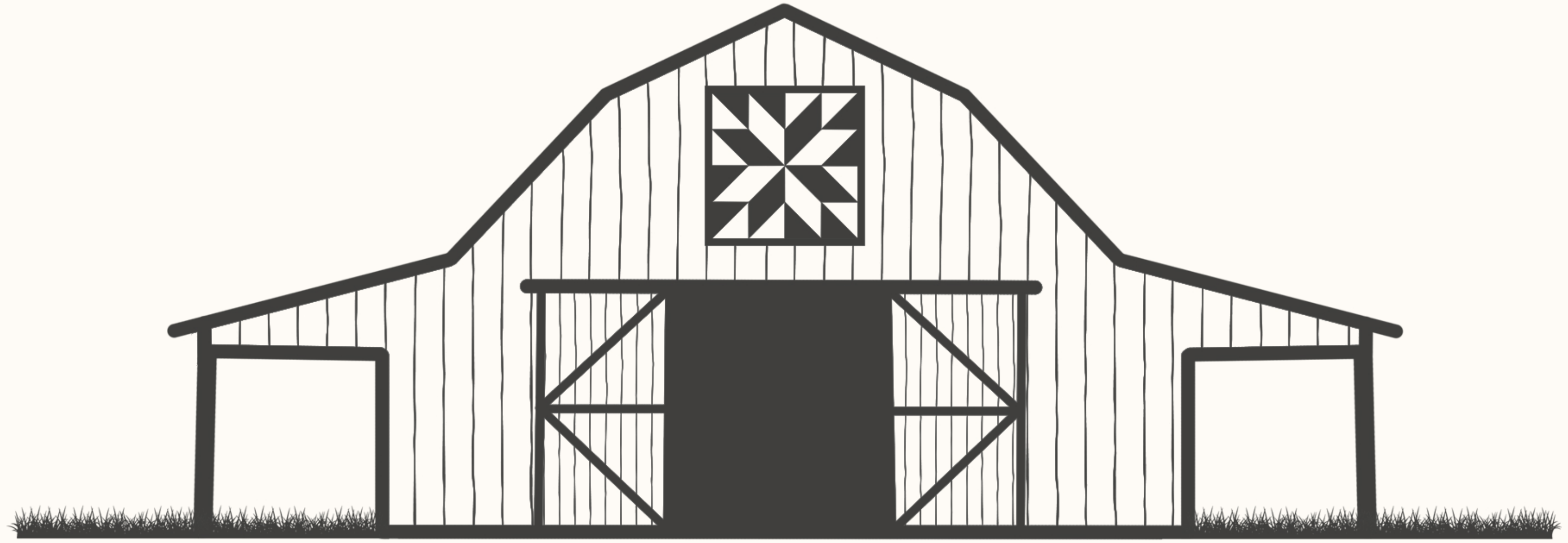

HOMESTEADING IN A MODERN SOCIETY

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Thesis Abstract

The ability to homestead has had a diminishing importance as the world becomes more modernized. There is no longer a need to understand what we eat and how it got to our dinner plate. In today's society, people would rather work 9 to 5, 5 days a week, then drive to the grocery store to purchase packaged food shipped from all over the world. Another reason people may be turned away from the idea of homesteading, is the amount of work that is involved with running a homestead. I would like to provide a solution that makes homesteading affordable and minimizes the amount of work needed to maintain it. This thesis research looks at how a homestead can function efficiently in a modern society to allow the residents to become self-sufficient.

Narrative of the Theoretical Aspect

In today's society people have become disconnected from how and where they get their food. It is simpler for food to be processed and packaged at large plants, then have the food shipped across the county to grocery stores. This way of mass producing and distributing food results in food that is less nutritious, less fresh, and contains more chemicals and preservatives. Producing your own food leads to a healthier diet and lifestyle. The reason many people have turned away from the homesteading lifestyle is because of the amount of money needed to establish a homestead and the amount of labor needed to maintain it. If there was an affordable and simple solution to having a homestead, people may be drawn back to the homesteading lifestyle.

Project Typology

The space occupied by the family/owners would have a residential building typology. The house would provide living spaces for the residents and some storage spaces such as a pantry, mechanical space, and storage space for personal belongings. The remainder of the buildings would have a storage building typology. Most of these spaces would be used to house livestock, and storing feed and equipment.

Figure 01

Precedent Research | Tiny Houses

Tiny SMART House is a company in Albany, Oregon that is committed to building affordably, durable, and sustainable tiny houses. These houses are built affordable by designing a house that has an efficient floor plan, prefabricating the house in a warehouse, then transporting it on a trailer to the lot. To lower energy costs, walls have an r-value from R-13 to R-21, roofs and ceiling have an r-value from R-13 to R-38. LED lighting also helps lower the energy consumption. Tiny SMART Houses are designed to have a lower carbon footprint by having lower energy needs to maintain, construct, and air condition. Much of the waste in the construction process is reused for other projects.

Research Findings

Like most tiny houses, Tiny SMART Houses are built on a trailer and are easily transported from the build site to a residential lot, or from the original lot to a new lot. This allows the user to take their home with them wherever they choose to live and avoid the hassle of selling and buying a house. They are also more affordable and have lower energy needs due to their compact floor plans as is common in tiny houses. Unlike other tiny houses, Tiny SMART Houses offer financing for their homes. Most lenders want to have comps to estimate the value of the house being purchased. Tiny house comps are harder to find because they are not as abundant, making getting a loan more difficult than a traditional house. Tiny SMART Houses also have the option for a composting toilet or an RV toilet. Most tiny houses opt for a composting toilet to lower its footprint and make moving easier. Tiny SMART Houses allow the client to start with a cheaper composting toilet, then install an RV toilet, which will then increase the value of the house.


Figure 02 - 03






Analysis & Conclusion

Using an efficient floor plan will help lower the cost to construct, maintenance needs, and heating and cooling load of the house. Using efficient appliances and lighting options will reduce the homeowners' energy needs and in turn save them money. Providing opportunities to "upgrade" finishes and fixtures will lower the initial cost and allow the homeowners to increase the value of their home as they can afford it.

Figure 04 - 09

Monterey Villa

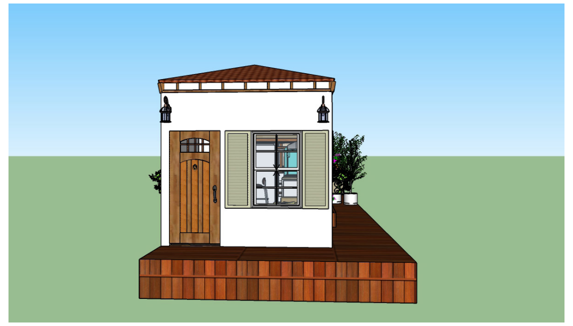
Prices starting at $57,475

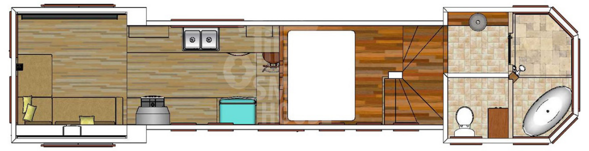
Shells starting at $28,738

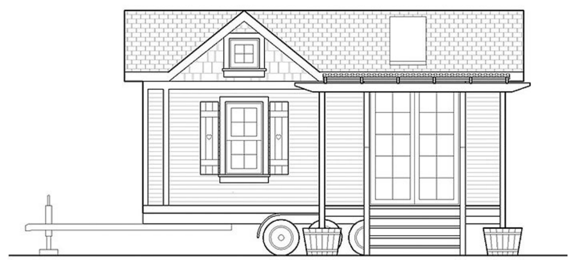
Lengths available: From 16' - 44'

Standard trailer width: 8' (8'6" outside edge to outside edge), 10' - 12' widths available

Roof: Spanish







Washington Craftsman

Prices starting at $54,975

Shells starting at $27,488

Lengths available: From 16' - 44'

Standard trailer width: 8' (8'6" outside edge to outside edge), 10' - 12' widths available

Roof: Double-Gable

Exterior: Lap Siding & Shake

Figure 10 - 17

California Cabin

Prices starting at $52,475

Shells starting at $26,238

Lengths available: From 16' - 44'

Standard trailer width: 8' (8'6" outside edge to outside edge), 10' - 12' widths available

Roof: Single Gable Roof

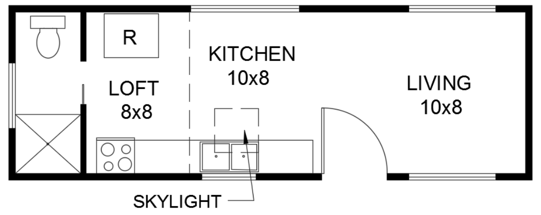
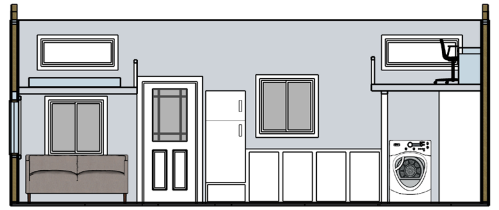
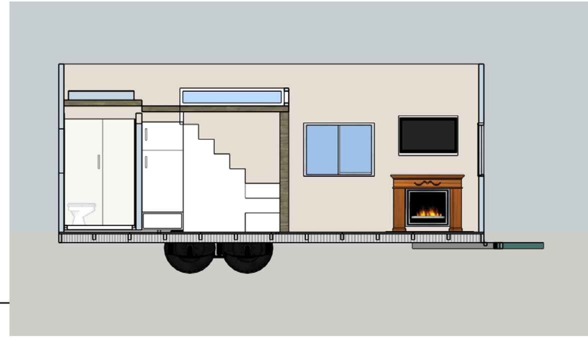


Figure 19





Oregon Trail

Prices starting at $53,975

Shells starting at $26,988

Lengths available: From 16' - 44'

Standard trailer width: 8' (8'6" outside edge to outside edge), 10' - 12' widths available

Roof: Double-Gable

Figure 18 - 25

84 Lumber Tiny Houses is headquartered in Eighty Four, Pennsylvania. They build 3 permanent tiny homes and 4 THOWs (tiny homes on wheels). Their permanent houses range from 448 square feet to 540 square feet, and THOWs range from 150 square feet to 200 square feet. These tiny houses allow homeowners to live an affordable and sustainable lifestyle. In addition to being affordable and sustainable, THOWs provide homeowners the ability to travel and take their tiny houses with them. 84 Lumber offers three package options. The first package is Build Your Own and includes the trailer and plans. This DIY option allows the homeowner to eliminate labor costs, making the house more affordable. The second option is a Semi-DIY option and includes the trailer, plans, and finished shell. The last option is a Move-in Ready option that is fully finished. 84 Lumber Tiny Houses emphasize energy efficiency, water conservation, responsible forestry, and recycling in their designs.

Research Findings

84 Lumber Tiny houses focus on energy efficiency, water conservation, responsible forestry, and recycling in their designs. They use energy efficient products to lower energy bills and the carbon footprint. Lumber is responsibly sourced. Sustainable bamboo and cork is used wherever possible. Recycled products are used to prevent waste from going into landfills.

Figure 26 - 28

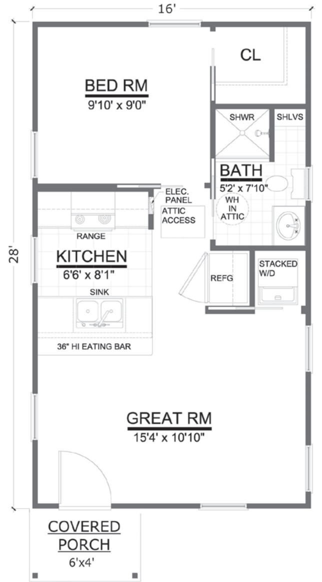
Analysis & Conclusion

By providing homeowners with 3 different packages, homeowners are able to purchase the package that is best for them based on their skill level and saves them money on labor costs. Choosing energy efficient and water conserving appliances will lower the energy needs, also saving the homeowner money. Using responsibly sourced lumber and recycling will lower the footprint of the tiny house.

Figure 29 - 33

Salmon Creek

448 square foot permanent home. It features a spacious great room, galley kitchen, and a front porch. Large windows provide plenty of natural light and opportunity for passive heat gains. At the back of the house, there is a master bedroom with a full sized bathroom and a walk in closet.



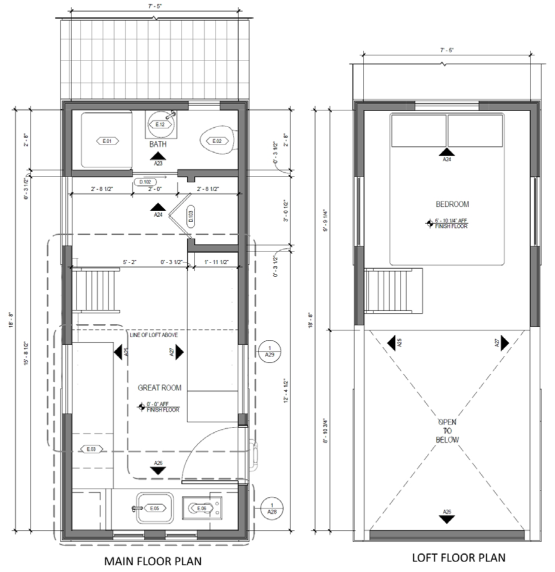
Hearts Content

448 square foot permanent home with a full length porch. This house includes a great room with a fireplace and a galley kitchen. Large windows provide plenty of natural light and opportunity for passive heat gains. It has a master bedroom with a full sized bathroom and a walk-in closet.

Figure 34 - 37

Ross Run

This is 84 Lumber's largest permanent tiny house with 540 square feet. It includes a great room with a fireplace and a galley kitchen. At the back of the house, there is a master bedroom, guest bedroom, and a full sized bathroom.



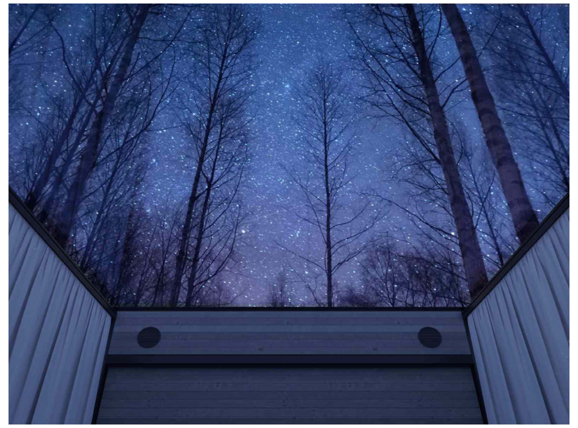
Countryside

This is 84 Lumber's largest tiny house built on a trailer. It features stained cedar siding, bamboo flooring, permanent staircase, and a loft. The kitchen includes custom butcher block counter tops, dining area, refrigerator, and electric cook-top. The bathroom is designed with low-e windows and a composting toilet.

Figure 38 - 41

DISAPPEAR RETREAT

Disappear Retreat is designed to have triple-zero performance; zero energy, zero waste, zero water. The design is light and transparent allowing it to blend into the surrounding landscape. It uses passive heating and cooling systems, and can withstand extreme cold climates. It is a certified Passive House and Living Building. The first prototype was tested near Grand Marais, Minnesota. Disappear Retreat is 83 square feet (8'x10'x9') and has a peak heating load of 100 watts.



Research Findings

To achieve triple-zero performance, Disappear Retreat is designed to create its own energy, reduce its energy needs, and recycle waste. Photovoltaic glass generates all the energy needs from solar energy. Winter passive heating and summer shading lower the heating and cooling loads of the house. The ideal site of a Disappear Retreat is near the edge of a tree clearing to maximize passive systems. Factory-assembly allows the house to be super-insulated and air tight. Glass walls are built with triple-pane insulated glass and have an r-value of 32. The roof and floors are built with VIPs (vacuum insulated panels) and have an r-value of 87. Insulated fabric shades on the ceiling and windows reduces summer heat gain. The compact floor plan minimizes the exterior surface area to reduce heat loss and gain. Disappear Retreat utilizes a portable water tank, a greywater tank, and a blackwater tank. The Shed is 5'x 7'x20' and allows for waste composting, rainwater harvesting, and storage for things such as bikes, kayaks, and tools. Disappear Retreat gets its name for being a peaceful place that blends seamlessly with the surrounding landscape. Its mirrored glass walls reflect the surrounding landscape and works as camouflage.

Figure 42 - 44

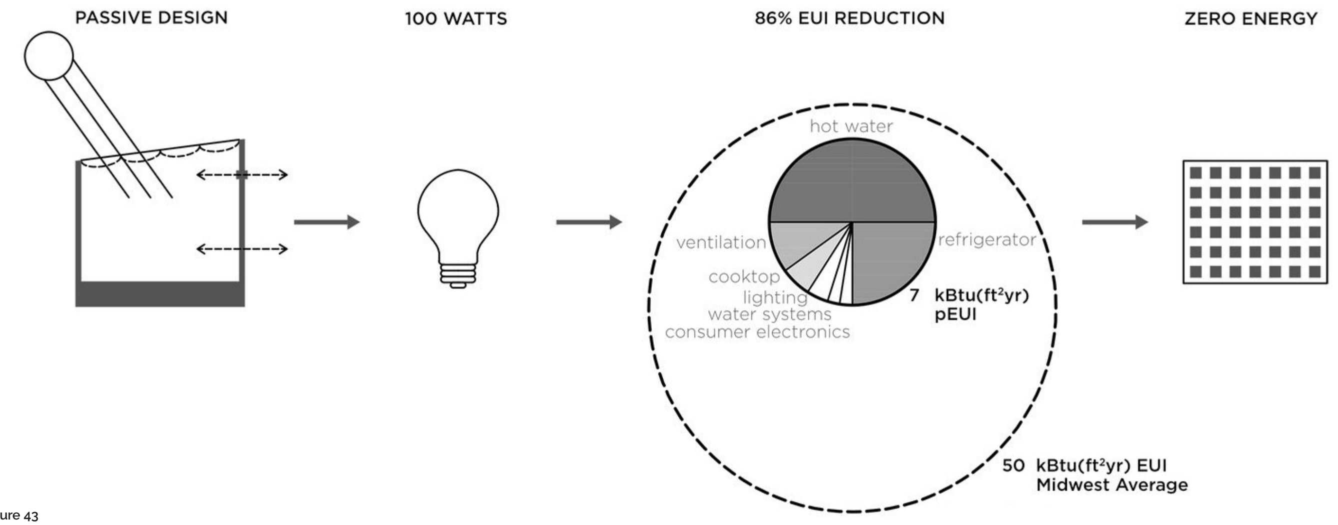
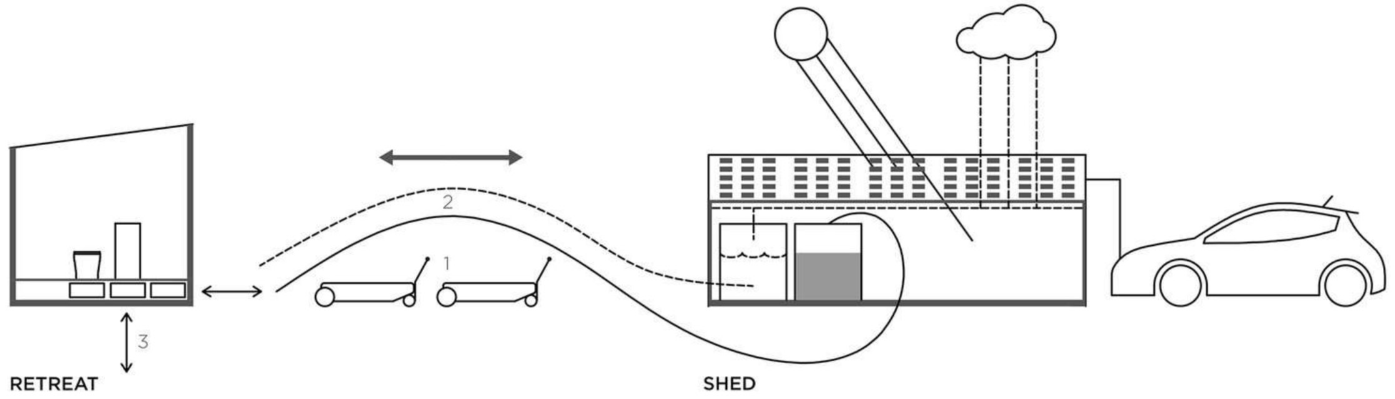


Figure 43

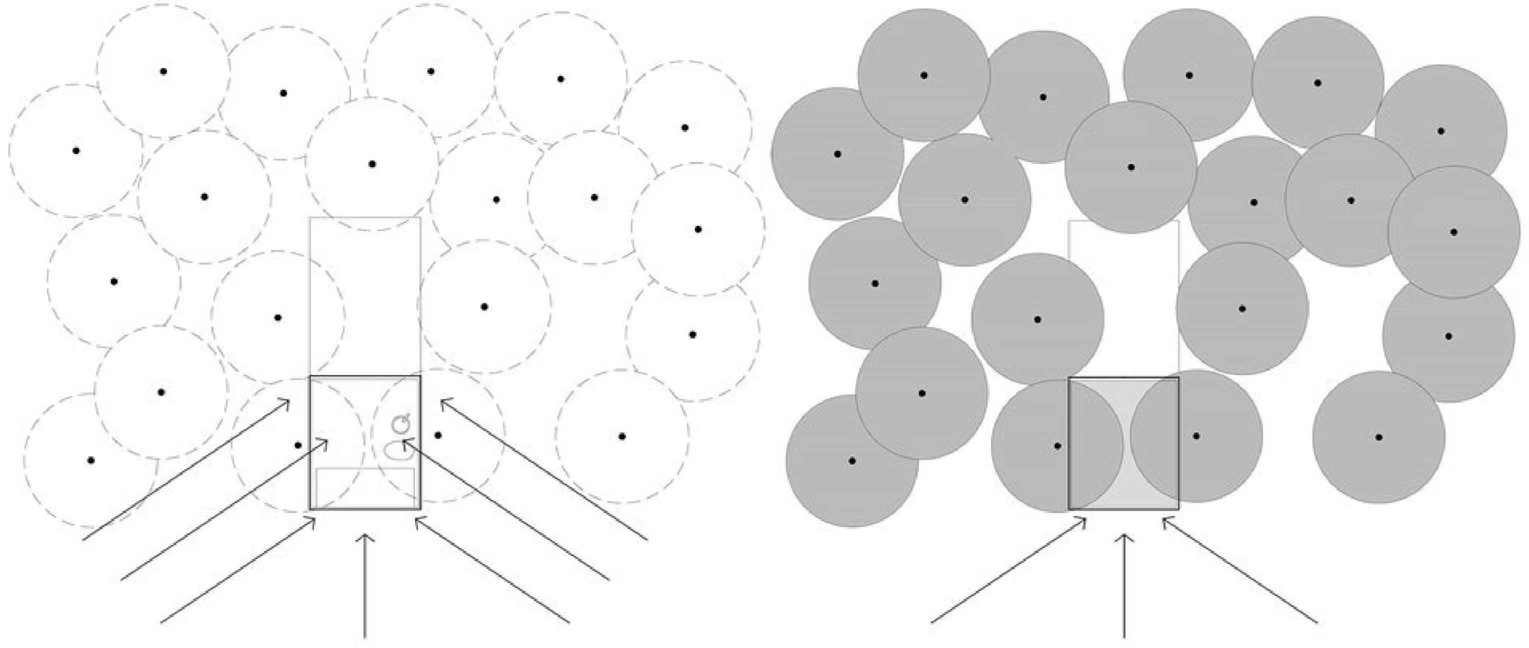


Analysis & Conclusion

If prioritized, passive systems can be designed to drastically lower the homeowners' energy needs and costs. Every aspect of the design can contribute to a sustainable house. By analyzing every need of the user the design can maximize its efficiency. Disappear Retreat's innovative design requires a minimalist lifestyle. Its compact and efficient design does not allow for excessive belongings, even for a tiny house standard. The homeowner also needs to be aware of how the passive systems function to maximize their benefit.

Figure 45 - 46

Winter **Summer**



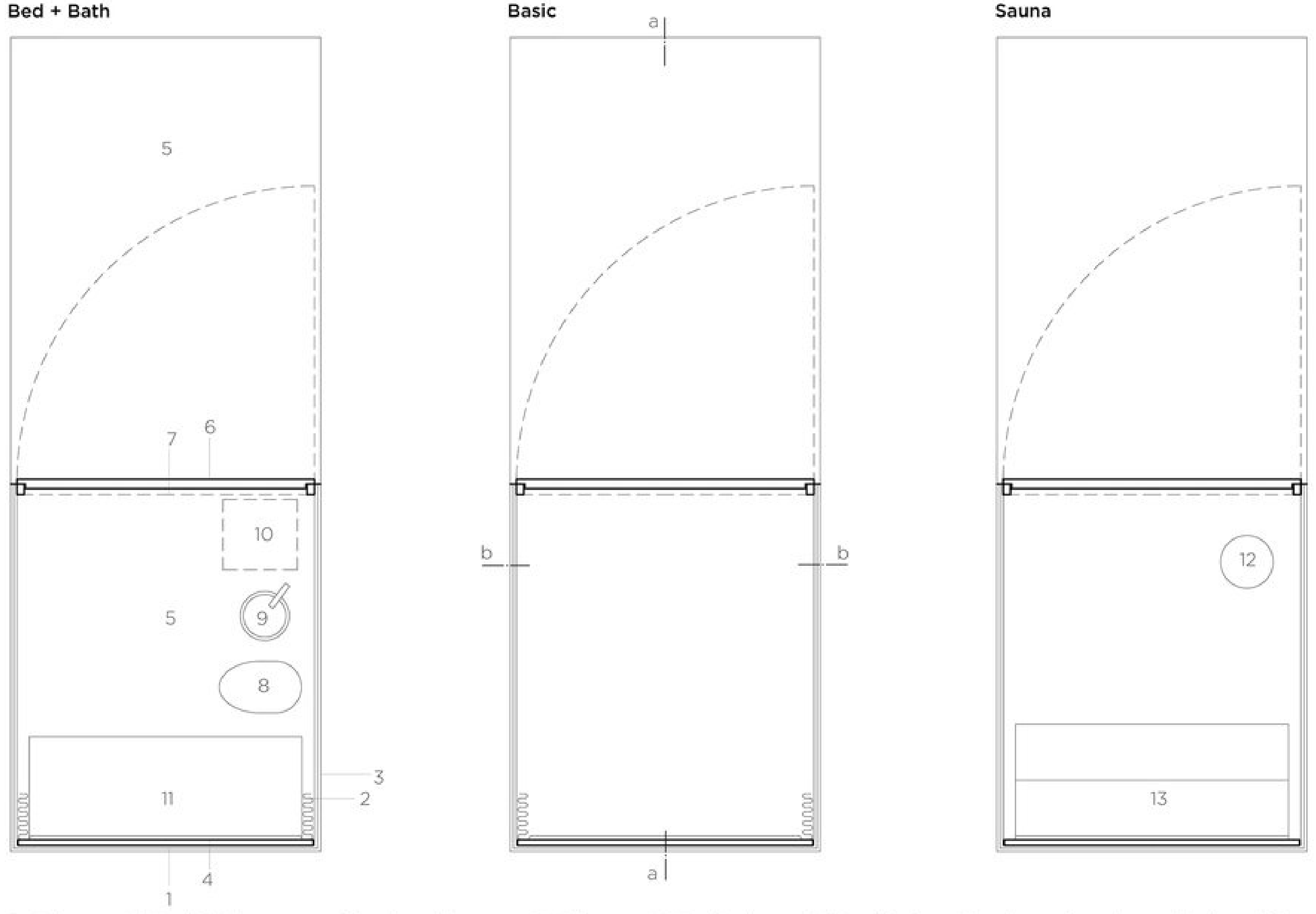
Bare deciduous trees with minimal shading
Passive solar heating and natural lighting thru roof and windows
Unobstructed solar access to south PV wall
View of night sky thru roof
Insulated shades at roof and windows to modulate heat loss/gains

Full deciduous trees with maximum shading
Natural lighting
Unobstructed solar access to south PV wall
Partial view of night sky thru roof
Insulated shades at roof and windows to modulate heat gains

Site Sun Shade

Figure 47

Bed + Bath **Basic** **Sauna**



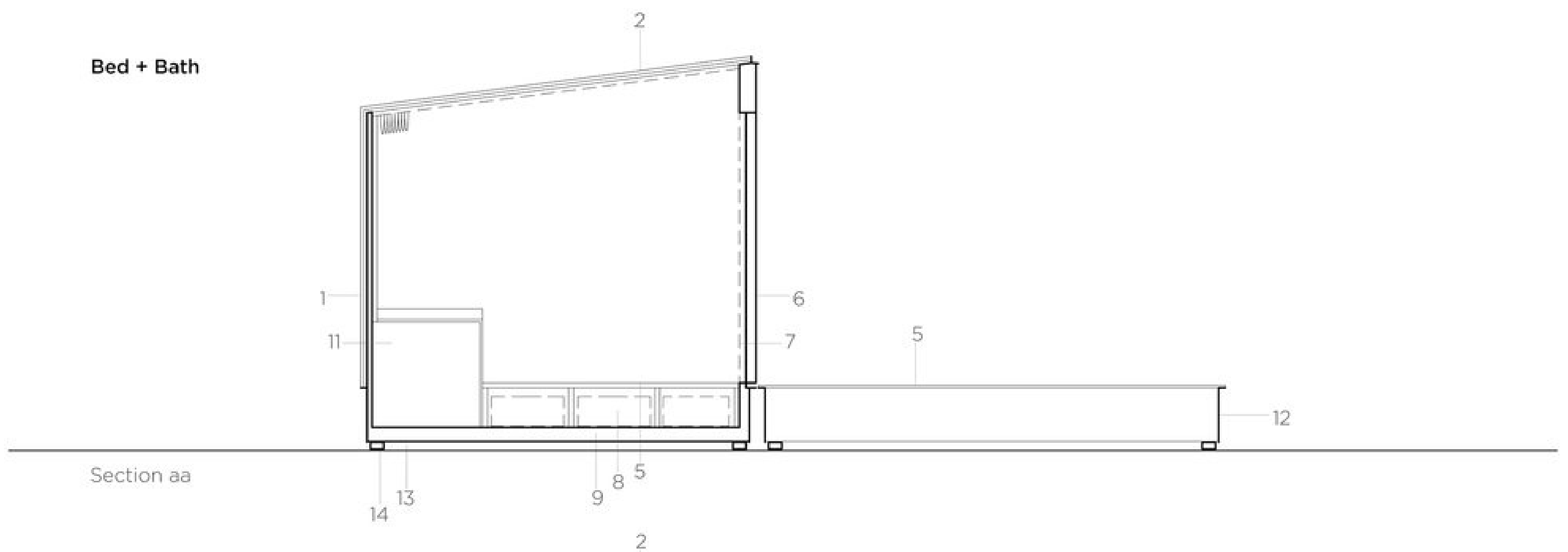
1 triple-pane IGU w/ BIPV opaque 2 insulated drapery 3 triple-pane IGU reflective 4 VIP wall 5 reclaimed weathered wood deck and floor
6 reclaimed weathered wood door w/ VIP core 7 retractable insect screen 8 toilet 9 sink w/ hand shower 10 concealed shower pan
11 built-in bed/sofa uplift w/ storage under + optional integrated refrigerator drawer 12 elec sauna heater 13 built-in wood sauna benches

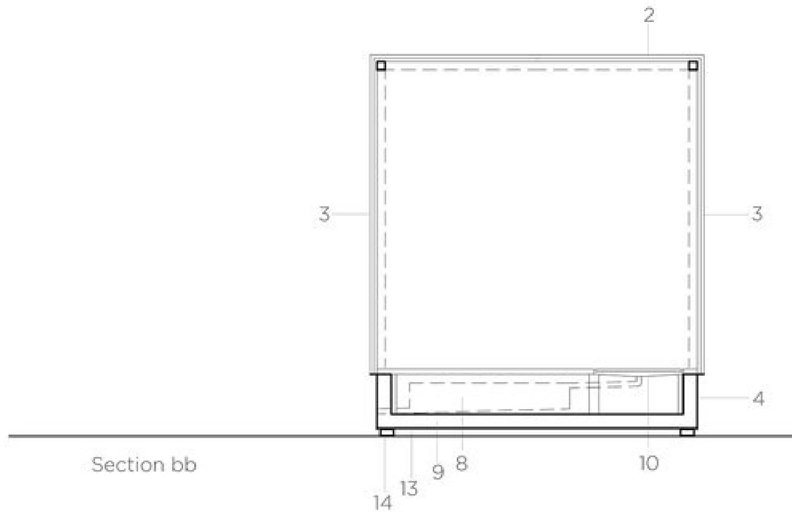
5ft 1.5m

Floor Plans

Figure 48

Bed + Bath



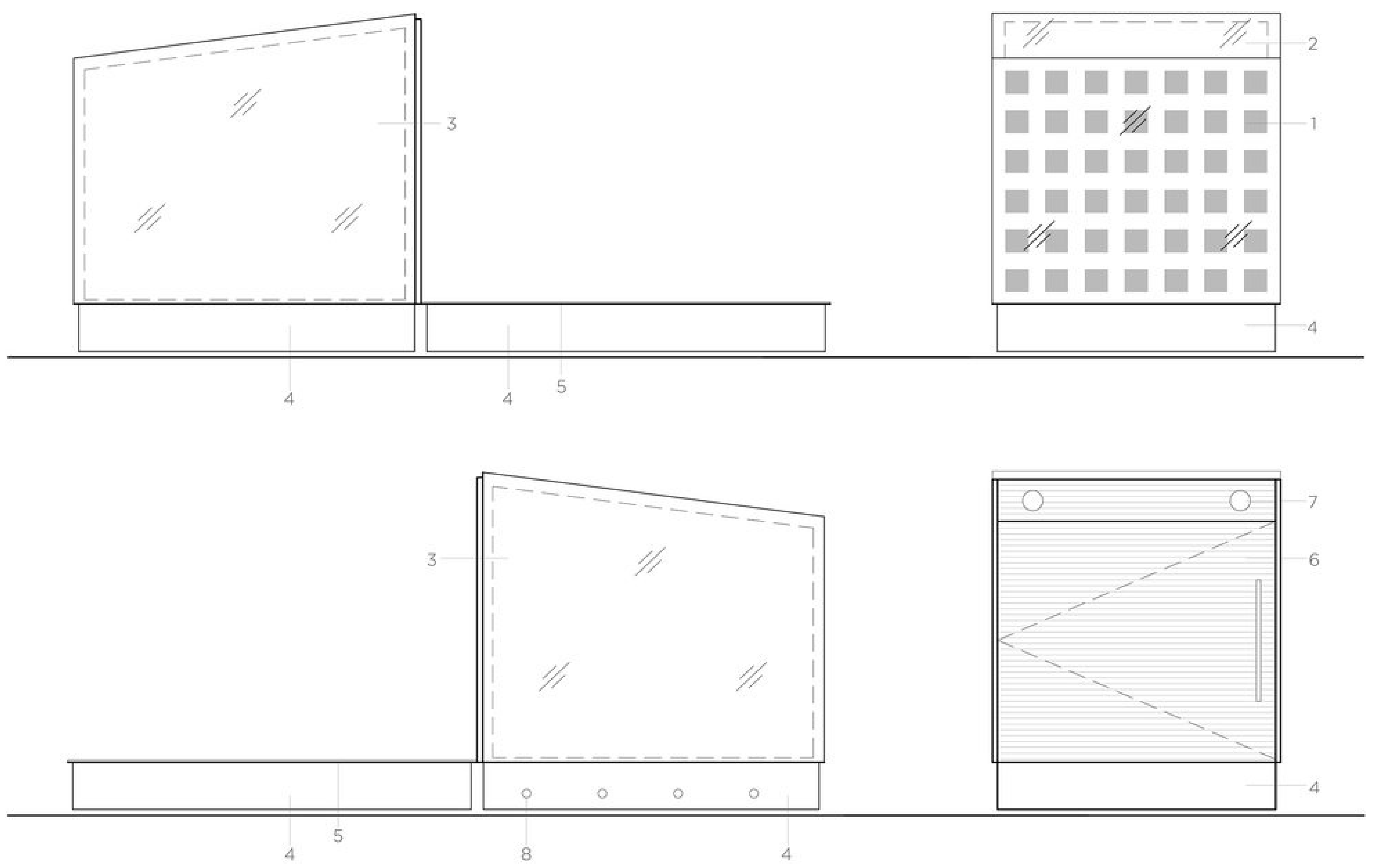


1 triple-pane IGU w/ BIPV opaque + VIP wall R-54
2 triple-pane IGU clear + insulated shade R-32
3 triple-pane IGU reflective + insulated shade R-32
4 perimeter beam + rigid insulation R-32
5 reclaimed weathered wood deck and floor
6 reclaimed weathered wood door w/ VIP core R-59
7 retractable insect screen
8 greywater tank under accessible floor
9 VIP floor R-87
10 concealed shower pan
11 built-in bed/sofa uplifts w/ storage under + optional integrated refrigerator drawer
12 perimeter beam
13 open
14 adjustable leveling foot w/ retractable wheel

5ft 1.5m

Building Sections

Figure 49



1 triple-pane IGU w/ BIPV opaque 2 triple-pane IGU clear 3 triple-pane IGU reflective 4 perimeter beam 5 reclaimed weathered wood deck 6 reclaimed weathered wood door 7 ERV thru-wall pair 8 exterior access ports for potable, grey, and black water systems and PV system

5ft 1.5m

Exterior Elevations

Figure 50

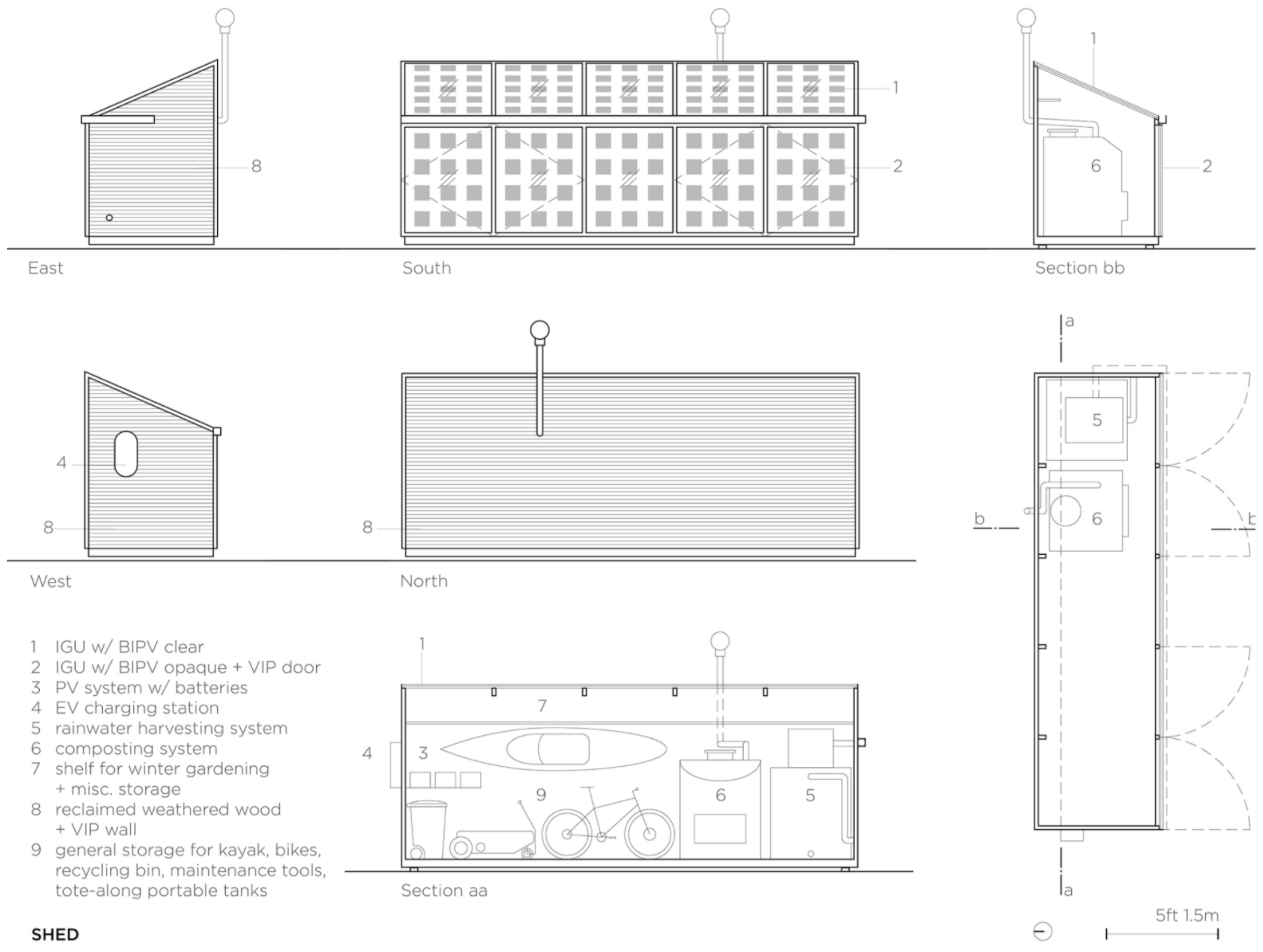


Figure 51

TINY HOUSE CASE STUDY CONCLUSION

These case studies were chosen based on their focus to be affordable and sustainable.

Tiny SMART Houses goal is to provide affordable luxury. By creating a compact design, luxurious finishes can be installed while still keeping them affordable. Luxurious finishes are not practical on a homestead. On a homestead, durable and easy to clean finishes are a better option. Choosing durable finishes can also further lower the price of the home. Tiny SMART Homes are also built on a trailer for easy transportation. These houses can easily be moved from one site to the next if the homeowner ever decides to change locations. I do not foresee this being a need in my thesis design. It is not likely or practical to move an entire homestead to a new location. Homesteaders prefer to grow their roots instead of changing locations.

84 Lumber Tiny Houses provides 4 designs built on a trailer, and 3 designs without a trailer. These designs range from 150 to 200 square feet, with one to two bedrooms. The options allow homeowners to choose the design best suited for their needs. By choosing a design that is not mobile, design challenges associated with building on a trailer can be avoided. The ability for homeowners to purchase tiny house in one of the DIY packages allows them to save money on construction cost.

Disappear Retreat pushes sustainability to the limit. Its compact design requires a minimalist lifestyle. Storage for personal items is stripped away to make room for passive systems. A house for a family of four will require more private spaces than that offered by Disappear Retreat. I would like to integrate Disappear Retreat's passive systems into a more traditional tiny house. Disappear Retreat also offers the homeowner to be completely off grid. Triple-zero performance can be achieved but at the cost of practicality. I would like to expand on the passive systems used in this house and find a low energy solution that is more suited for a homestead.

The research conducted in these case studies will help me create a design that can balance sustainability, affordability, and practicality.

Precedent Research | Greenhouses

HOOP HOUSE / HIGH TUNNEL

Hoop houses and high tunnels are used to moderately extend the growing season of the crops being grown. It is constructed by anchoring PVC or metal pipes at each end to create a half circle, then covering it with a clear plastic sheet. Solar energy is trapped inside the hoop house to raise the interior temperature. Hoop Houses will also protect against frost. During hot summer months the sides can be rolled up to let excessive heat escape. A drip system is often used to water crops as they will be sheltered from any rainfall. Hoop houses are fairly cheap to construct and maintain.

CONVENTIONAL

Traditional greenhouses use heaters and solar energy to extend the growing season to nearly year round. Greenhouses are typically built with walls and a roof, and often require electrical services. Like hoop houses, greenhouses require an irrigation system to water crops. Greenhouses can be time consuming and costly to build, but are typically more durable.

COLD FRAME / HOT BED

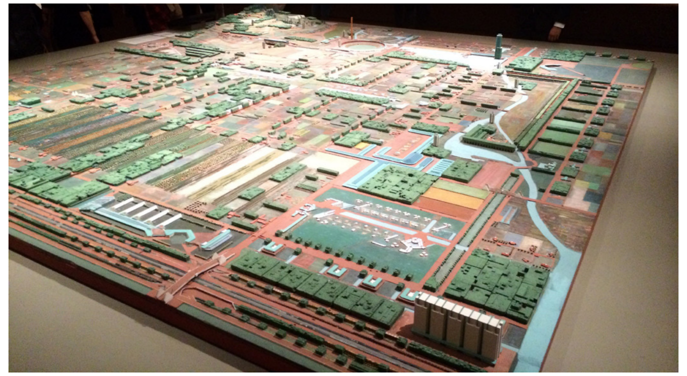
Cold frames and hotbeds are very small versions of a hoop house. They are small boxes covered in clear plastic, and placed over the garden bed. Like hoop houses, they use solar energy to extend the growing season and can be used to protect against frost. They do not require an irrigation system as they can be easily removed. Cold frames and hotbeds can be very cheap and easy to construct.

GREENHOUSE CONCLUSION

Hoop houses, high tunnels, cold frames, and hotbeds provide a passive solution to extending the growing season compared to greenhouses. They are also much cheaper to construct and maintain. Hoop houses and high tunnels allow for a larger growing area than cold frames and hotbeds. In conclusion, hoop houses and high tunnels are able to provide a passive solution while maximizing the amount of crops that can be grown.

Figure 52 - 54

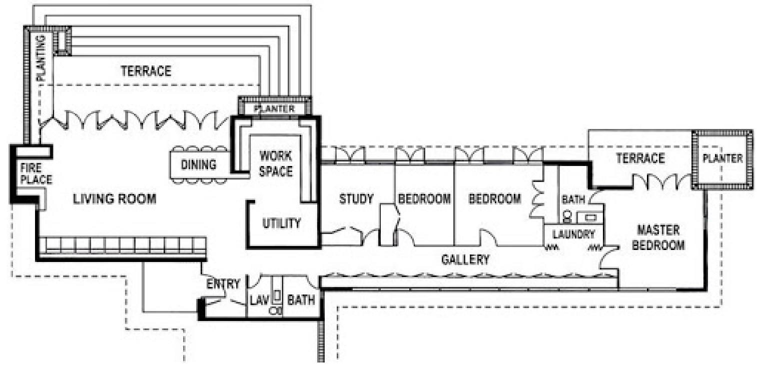
Precedent Research | Broadacre City



Broadacre City is an urban design created by Frank Loyd Wright. He first presented his design in The Disappearing City in 1932. The city was part of the garden city movement created by Ebenezer Howard in 1898 and written about in his book, To-morrow: A Peaceful Path to Real Reform. Wright and several interns built a 12' x 12' model, representing 4 square miles, to be displayed at an Industrial Arts Exposition in New York City. The model continued to be exhibited throughout the United States until 1939. It was then toured around Europe through 1950. The city was never built and probably never will be.

Research Findings

Through his design, Wright hoped to give residents freedoms that could not be gained in crowded cities. This would be achieved by utilizing the car, electrical inter-communication, and standardized machine-shop production. He planned on decentralizing the city by placing hubs along a highway system. Located in these hubs were gas stations, neighborhood distribution centers, meeting places, and restaurants. Separate lanes were provided for cars, trucks, and a monorail. With the city decentralized, Wright predicted a need for electrical inter-communication such as radio, telephone, and telegraph. Wright's plan provided houses for factory workers above the factory and thought professionals should work from home. Each childless family would be given one acre of land and larger families would get even more land. Each family would live in a 'minimum house" to lower the cost of living.



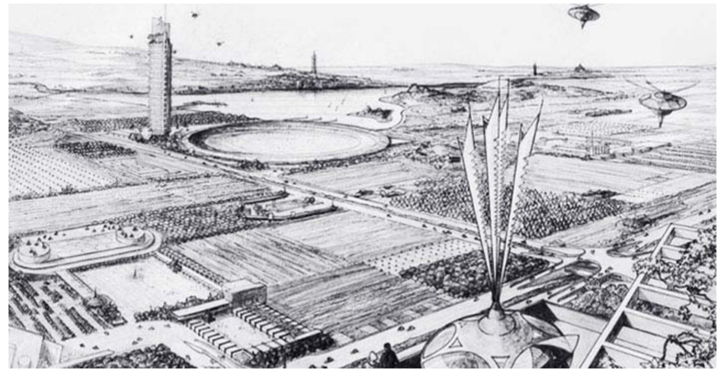


Figure 55 - 57

Analysis & Conclusion

Although planned on a much larger scale, Wright's hope for residence of Broadacre City is very closely aligned with my hope to create a design for a family of four. By providing families with plenty of land, they will be able to grow their own food. Residents will be able to lead a healthier lifestyle because they will be active outside and eating healthier food. Land ownership will give residents a sense of pride in their community. "Minimum houses" or tiny houses will also make homesteading more affordable. Efficient floor plans lower energy needs and will free up more land.

Figure 58

Figure 59

Major Project Elements

Residential House

- Provides sleeping and living spaces for the family
- Sustainable design to lower energy needs and costs
- Pantry to store one year's worth of food harvested from the homestead

Livestock Barns

- Stalls and pens for livestock
- Storage spaces for feed and equipment
- Milking stanchion
- Sustainable design to lower energy needs and costs

High tunnel / Garden Spaces

- Greenhouse to increase the growing season
- Raised garden beds to provide a year worth of food
- Irrigation system

User / Client Description

Residential

The house will need to accommodate a family of four. It will need to be compact to be affordable and sustainable, but also provide privacy and personal space for each of the family members.

Homestead Livestock

The barn will need to provide shelter for all the livestock needed on the homestead. Animals will vary in size and needs. Possible species include: poultry, cattle, swine, sheep, and goats.

Botanical

The garden will need to be big enough to grow a year's worth of food. Some crops can be grown in raised beds, but some may need an extended growing season and will need to be grown in a greenhouse.

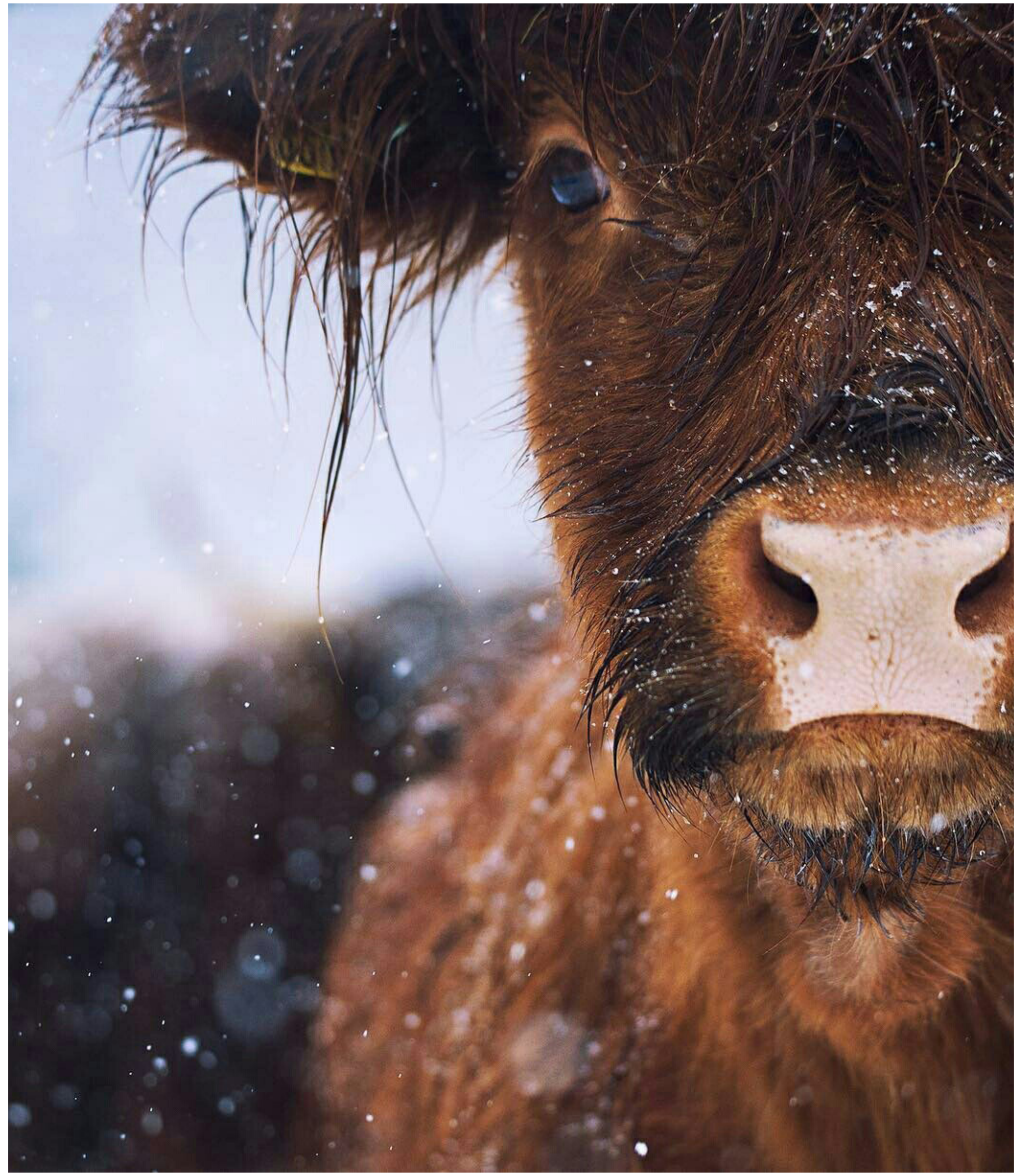


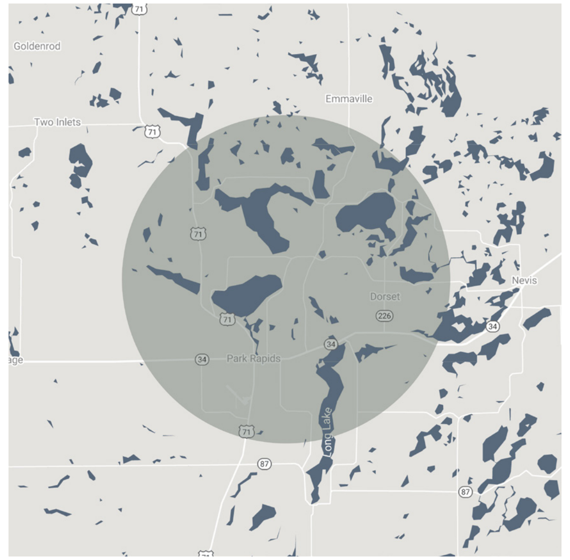
Figure 60

Site Information

PARCEL ID: 13.06.00400

This site is located in Northern Minnesota on 5.09 acres of land. The primary reason for choosing this site is for its size. It is just over five acres of land, resulting in an affordable price of $21,600. I also chose this site for its proximity to town and easy access to a bike trail. In the summer months, residents could bike to town instead of driving, reducing their cost on gas and car maintenance. This lot is also fairly clear of trees, reducing the cost of removing trees. There is a local farmers market 4 miles away in Park Rapids for the homesteaders to sell any of their surplus produce. This site is located in growing zone 3. The growing zone is important because it will have an impact on which plants can be grown. Plants that will not be able to grow in zone 3 may be grown in a high tunnel or greenhouse.

Region



City

Site

Figure 61 - 63

Project Emphasis

Design an affordable and self-sufficient single family house

Create an affordable and cohesive space for raising livestock

Provide a suitable and efficient space for growing food

Goals of the Thesis Project

Demonstrate that homesteading can be accomplished in a modern society.

Understand how to efficiently and affordably run a homestead.

Provide an alternative to the traditional way of providing for one's family.

Understand how to create efficient and self-sufficient housing.

Understand how to create a space suitable for growing food efficiently.

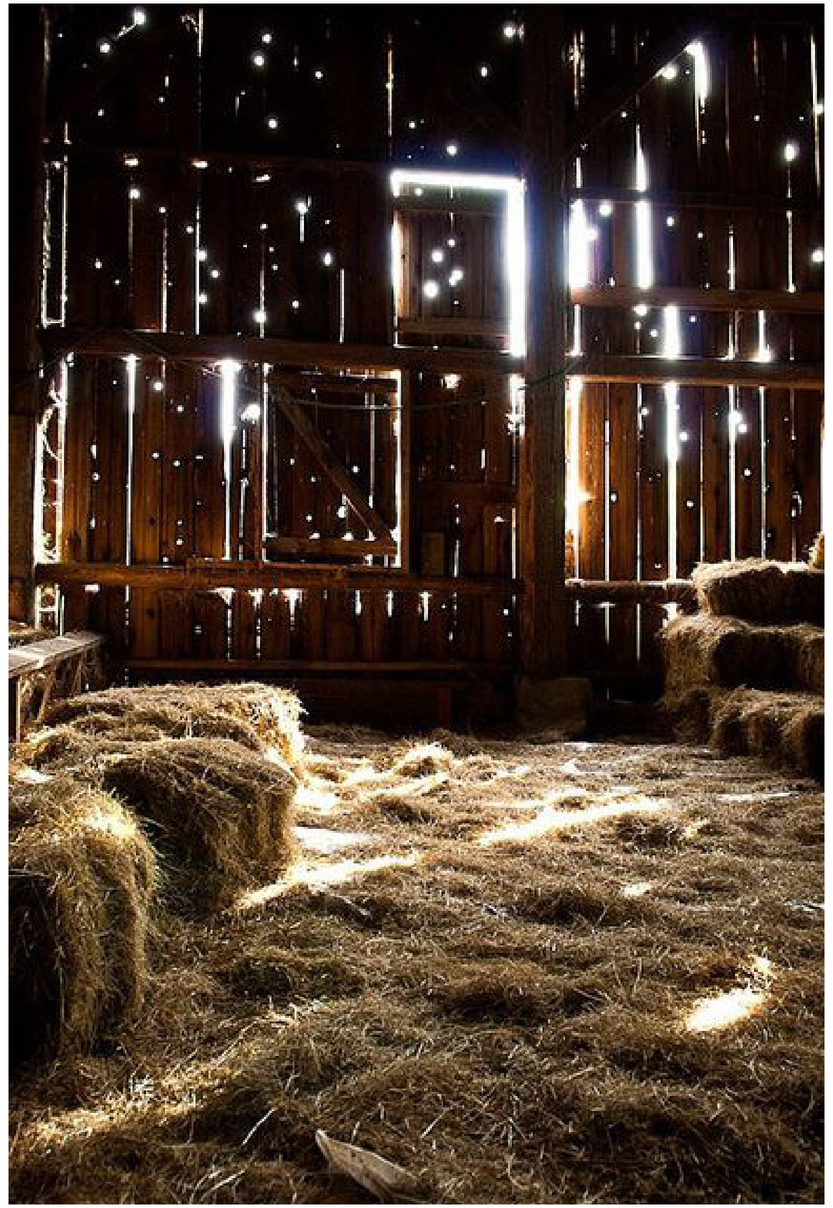


Figure 64

A Plan for Proceeding

DEFINITION OF RESEARCH DIRECTION

- Thesis Question
- Understand the project typology
- Research the historical context
- Understand the programmatic requirements

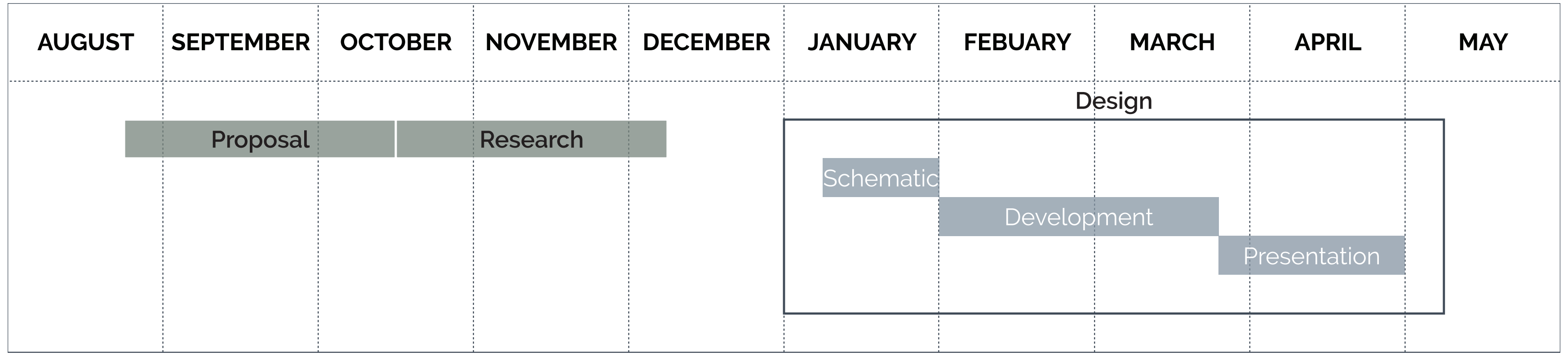
A PLAN FOR DESIGN METHODOLOGY

- Historical research
- Case studies
- Logical argumentation
- Correlational research

A PLAN FOR DOCUMENTING THE DESIGN PROCESS

Digital Analysis
- Revit
- Sketchup
- AutoCAD

Graphic Analysis
- Photoshop
- Illustrator
- Enscape
- Lumion



Schematic
- Site Plans
- Landscape Design
- Massing

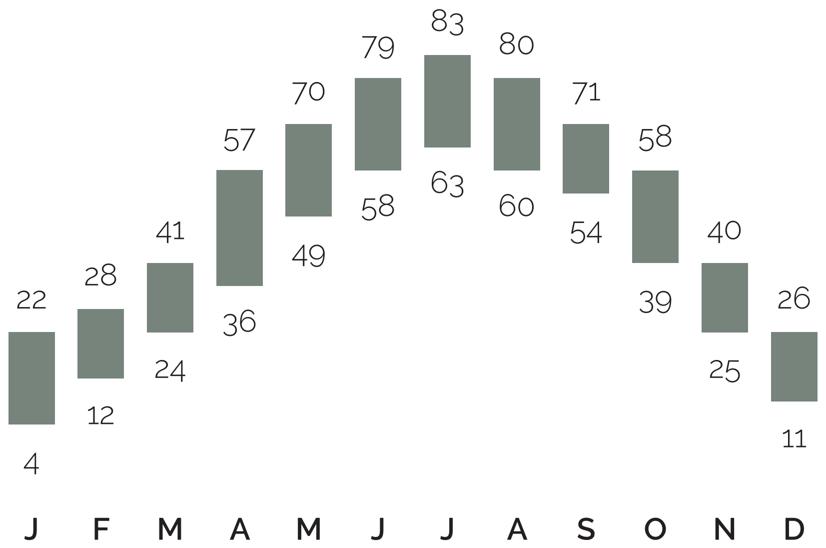
Development
- Parti Sketches
- Floor Plans
- Elevations
- Sections
- Passive Systems
- Analysis
- Materials
- Details

Presentation
- Renders
- Thesis Book
- Boards
- Models
- Reviews

Site Analysis

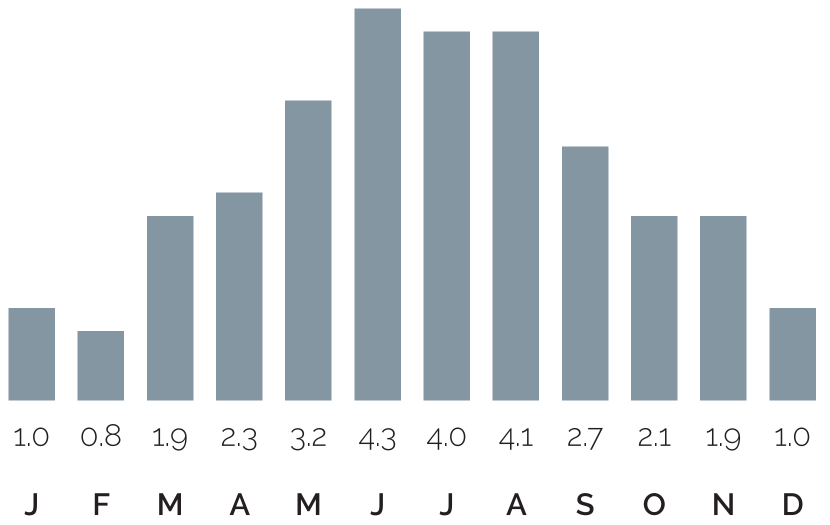
The site that I have chosen for this project is located 4 miles northeast of Park Rapids and 6 miles west of Dorset. The nearby communities have a "small town America" culture. Located in the heart of lake country, the site is surrounded by many lakes. Within 10 minutes of the site is Fishhook Lake, Potato Lake, and Big Sand Lake. The area is popular for farming, tourism, and summer retirement.

AVERAGE HIGH & LOW TEMPURATURE



AVERAGE PRECIPITATION

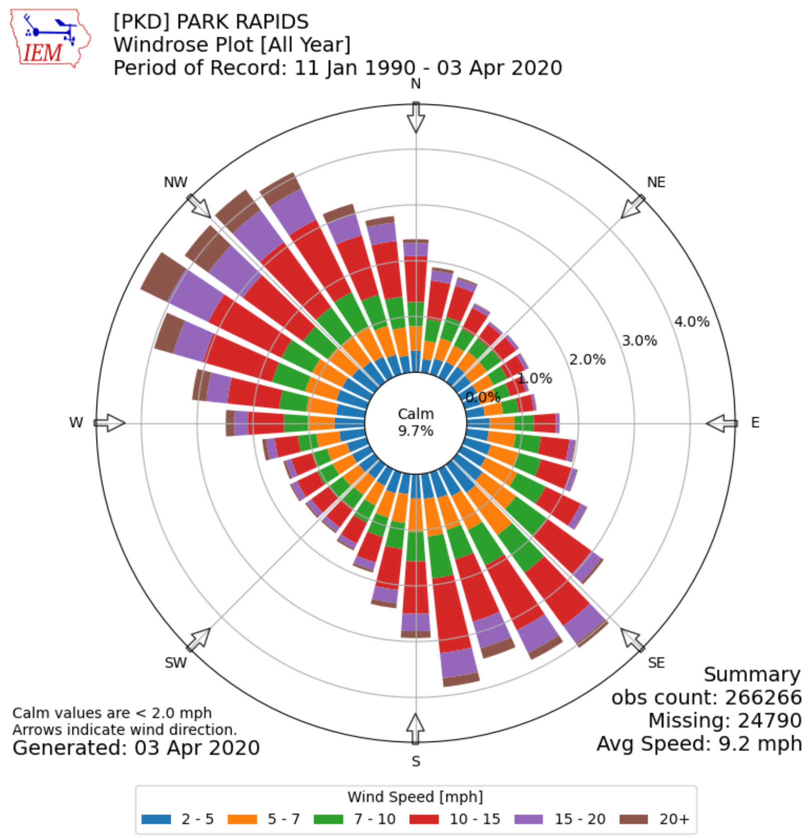
measured in inches



Northern Minnesota experiences all four seasons in full force. Summers can be as hot as 100 degrees with high humidity and winters can get below -30 with bitter winds. This wide range of temperatures creates interesting design challenges.

This site will receive most of its precipitation in the summer months, getting between 30" to 45" per year. In the winter months, the site can receive between 1" to 2" of precipitation in the form of snow. Most storms come from the west but may be diverted north or south by the Smokey Hills.

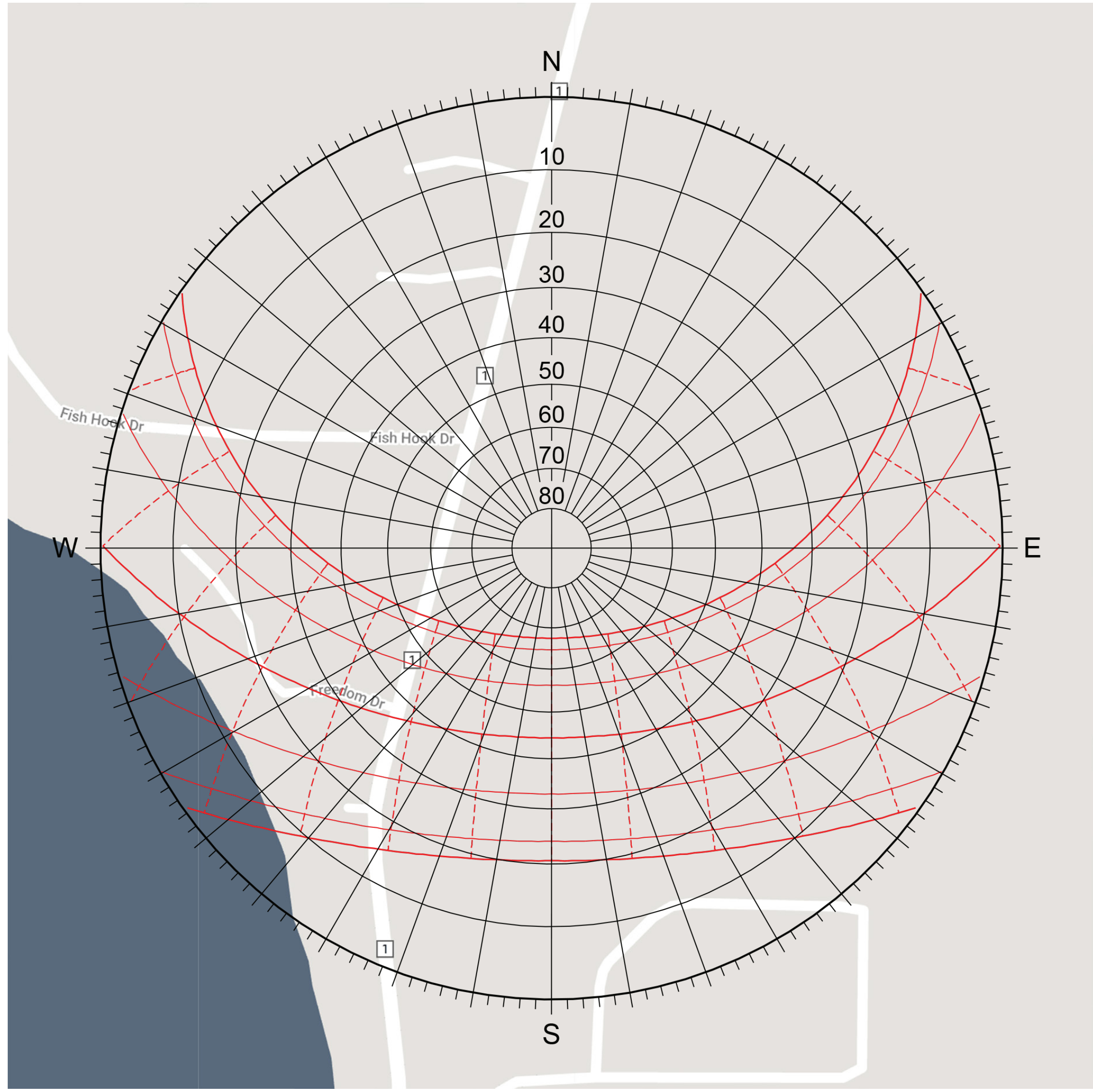
Figure 65 - 66



In the summer months, winds typically come from the south. In the winter, winds are usually out of the north or west. While summer winds should be utilized for passive cooling, winter winds should be sheltered.

During the summer, high winds can create straight line winds that may damage buildings and blow over trees. In the winter, high winds can create deadly wind chills and high snowdrifts.

Figure 67 - 68



On the summer solstice in northern Minnesota, there are 15 hours and 37 minutes of daylight with the sun rising at 5:26 am and setting at 9:03 pm. On the winter solstice, there are 8 hours and 46 minutes of daylight with the sun rising at 7:48 am and setting at 4:34 pm.

There is plenty of daylight to complete farm work in the summer. Work is sometimes best done in the morning and evening to avoid peak heat periods during the afternoon. Lack of daylight in the morning and evenings during the winter can make chores more difficult to complete.

Figure 69

Results from Theoretical Premise Research

RESIDENTIAL

Passive Lighting

Passive daylighting systems can be used to reduce energy needs. Well placed windows and light transport devices can provide enough natural light to eliminate the need for artificial light during the day. When natural light is not sufficient, artificial light can be used in addition. Lighting needs will change depending on the time of year.

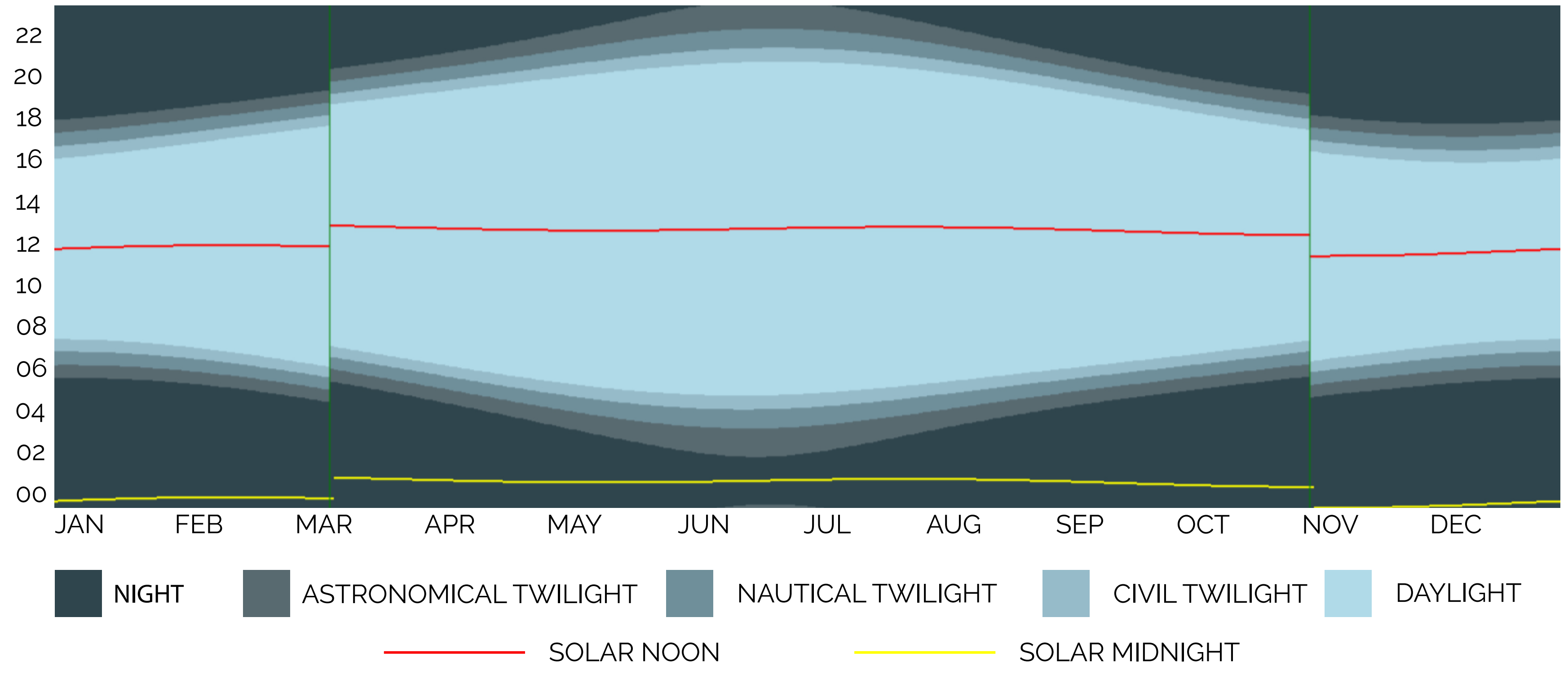
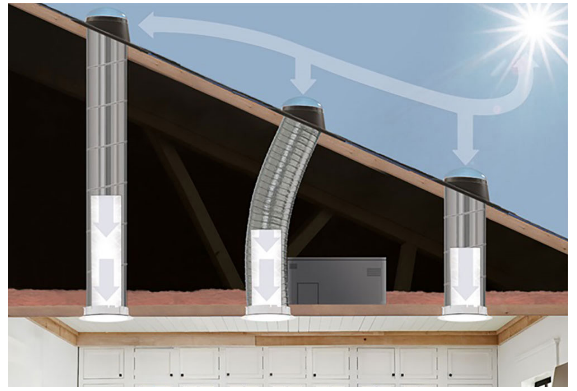


Figure 70

Light Tubes



Light tubes take sunlight and direct it a short distance to an interior space. Light tubes are most often used on roofs and ceilings to direct light downward from above.

Fiber Optics

Fiber optics capture light and focus it long distances in the most interior spaces of a building. Fiber optic lights are often supplemented with LED lights that respond to exterior light conditions.

Skylights

Skylights are a simple way of bringing light into an interior space. While sometimes considered a luxury in residential buildings, skylights are often used in barns and storage buildings. A benefit of using skylights in barns where animals are kept indoors is that it does not affect their circadian rhythm.

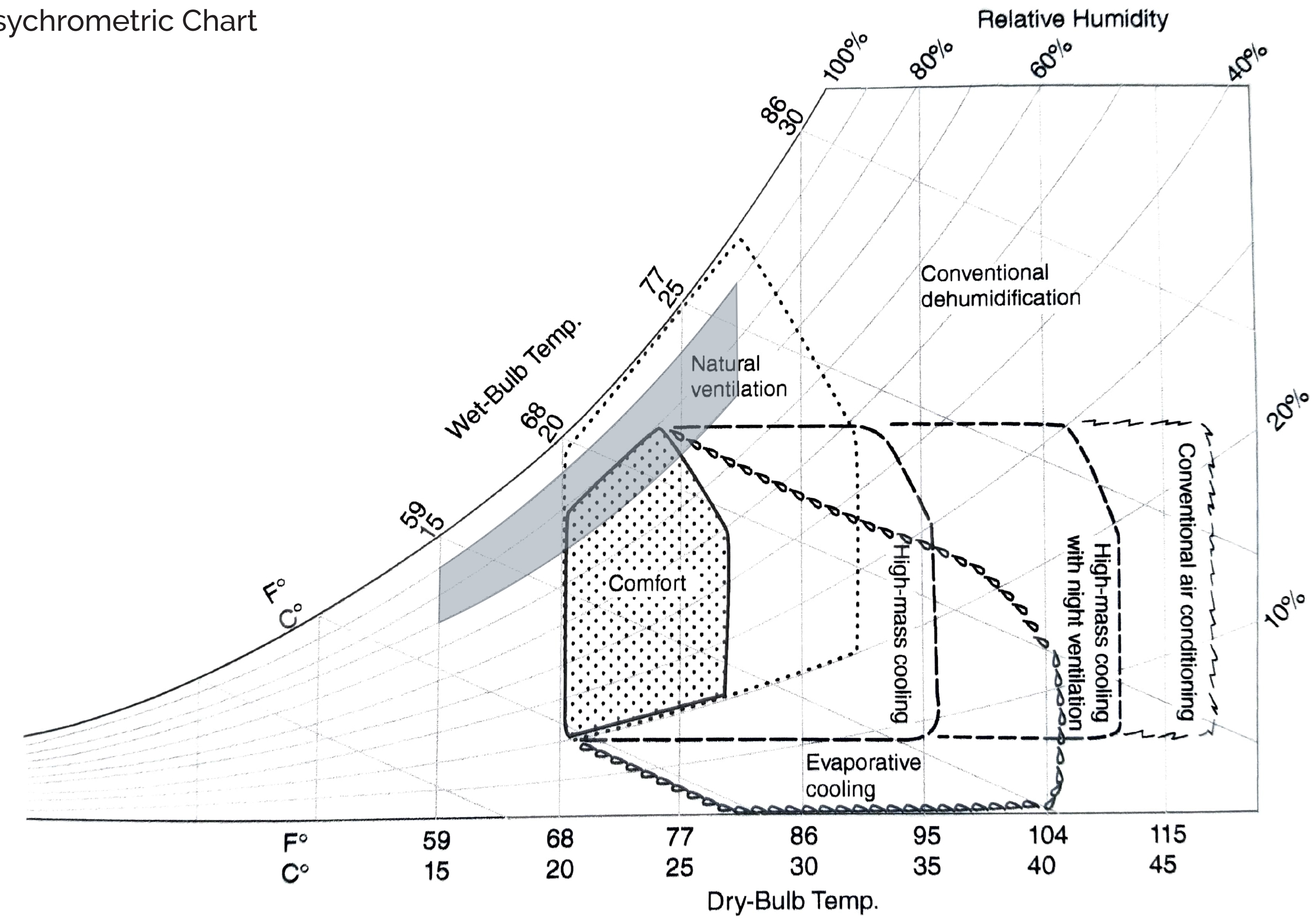
Passive Heating & Cooling

Cooling systems may be needed from June to August. Heating systems will be needed from October to April. No heating or cooling system may be needed from April to June and from August to October as their average temperatures often fall within the human comfort zone.

From the end of spring, through summer, and into fall, cooling systems may be needed. According to the psychrometric chart, natural ventilation is the only passive cooling option for the climate of the site. Natural ventilation can be achieved in two ways: cross ventilation and stack ventilation. Cross ventilation uses breezes to bring in cool, fresh air through windows and vents warm air through windows on the opposite facade. Stack ventilation uses low openings to bring in cool, fresh air and vent rising warm air through high openings. When natural ventilation does not provide enough cooling, active air conditioning will be needed.

Figure 71 - 73

Psychrometric Chart

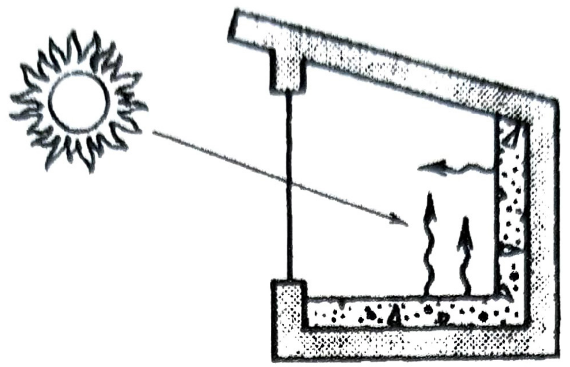


Average climate conditions for the site between June and August are highlighted in blue.

Figure 74

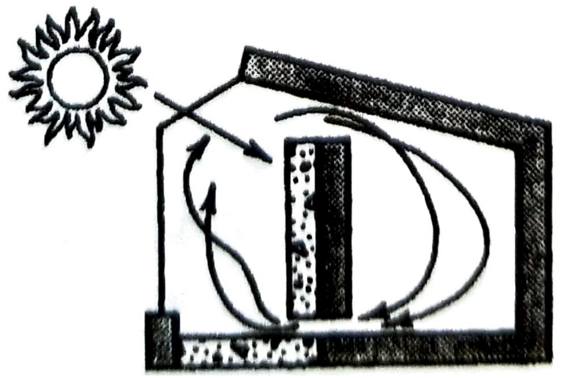
From mid fall, through winter, and until the end of spring, heating systems will be needed. There are three options of passive heating: direct gain, isolated gain, and thermal massing. Active heating solutions may be needed to supplement passive heating systems.

Direct Gain



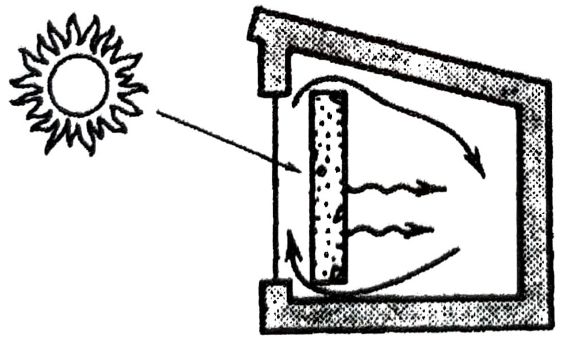
Direct gain uses heat from the sun that comes directly in to heat a space. This is most commonly achieved by placing large windows on the south facade.

Isolated Gain



Isolated gain traps heat from the sun in an intermediate space. Sunlight enters a space through a south facing window, heat is trapped within the space, then distributed throughout the rest of the building. A sun room is a great example of isolated gain.

Thermal Mass



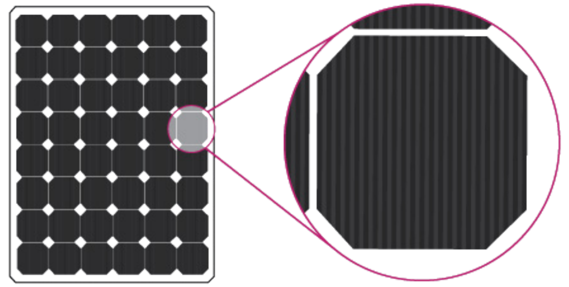
Thermal mass uses a large mass, such as concrete walls and water, to capture heat during the day and radiate it into the space at night. Thermal masses can also be used during the summer to cool the space.

Solar Energy

Solar cells produce electricity from a semiconducting material that converts solar light into electricity. The electricity that is produced can then be used by the residence. Any extra energy that is produced can then be stored in batteries to be used later or may be bought by the local power company. There are three types of solar panels: monocrystalline, polycrystalline, and thin-film. The type of solar panel to be used should be selected based on the site, performance goals, and budget.

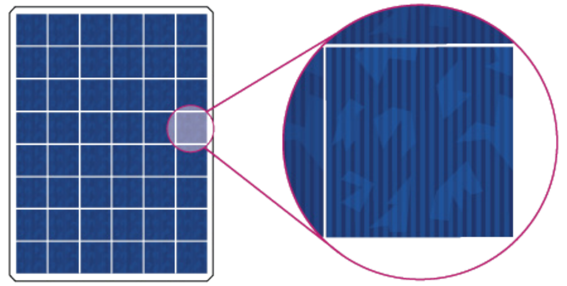
Figure 75 - 78

Monocrystalline



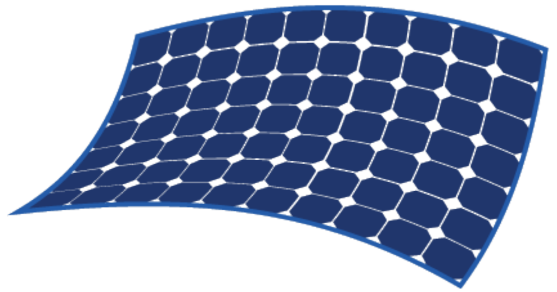
Mono panels have high efficiencies of 20% and higher. This makes them great for sites with limited space. One drawback of these panels is their high initial costs.

Polycrystalline



Poly panels have efficiencies between 15% and 17%. While they have lower efficiencies, they are more affordable than mono panels. Poly panels are typically used for large sites.

Thin-film



Thin-film panels are lightweight and flexible. They also have low efficiencies. These panels are often used on large roofs that cannot hold the weight of other panels and can afford to be less efficient.

The number of panels needed can be calculated using the predicted daily kWh (27 kWh) needed and the daily kWh produced by the solar panels. The kWh produced by the solar panels can be calculated using the following equation.

Watt hours produced daily by solar panels = hours of direct sunlight x watts per solar panel

Hours of direct sunlight during the winter = 4.5 hours, Predicted watts produced by one solar panel = 250 watts

4.5 hours x 250 watts = 1125 watt per hour or 1.125 kWh

Now the number of panels can be calculated:

Number of panels = Daily usage / solar panel daily kWh output

27 kWh / 1.125 kWh = 24 panels

24 solar panels will be needed to supply 100% of the predicted household electricity needs during the winter (period of lowest daily output).

Figure 79 - 81

Square Foot Gardening

Square foot gardening uses raised beds divided into square foot sections to maximize the yield of a garden space. Unlike row planting, soil stays friable in SFG because you do not need to walk along rows to maintain crops. It also uses much less water and requires less weeding compared to row planting.

1 plant per 2 square feet

squash, cucumber, melon

1 plant per square foot

tomato, pepper, eggplant, broccoli, cabbage, corn, asparagus, cilantro, oregano, rosemary, sage, thyme

4 plants per square foot

lettuce, basil, potatoes, strawberries

6 plants per square foot

vining plants such as pole beans, tomatoes, peas

9 plants per square foot

onions, beets, bush beans, bush peas, garlic, spinach

16 plants per square foot

carrots, radishes, chives

Plant Hardiness Zone

This site is located in growing zone 3a. The growing zone indicates which crops can be planted. Crops not within the growing zone can either not be planted or must be kept in a greenhouse. Most vegetables, including the ones listed above can be grown in zone 3. Many fruits, especially ones that grow on trees, will not be able to survive harsh Minnesota winters. The growing zone will be listed on the back of the seed packet or on the label.

Figure 82

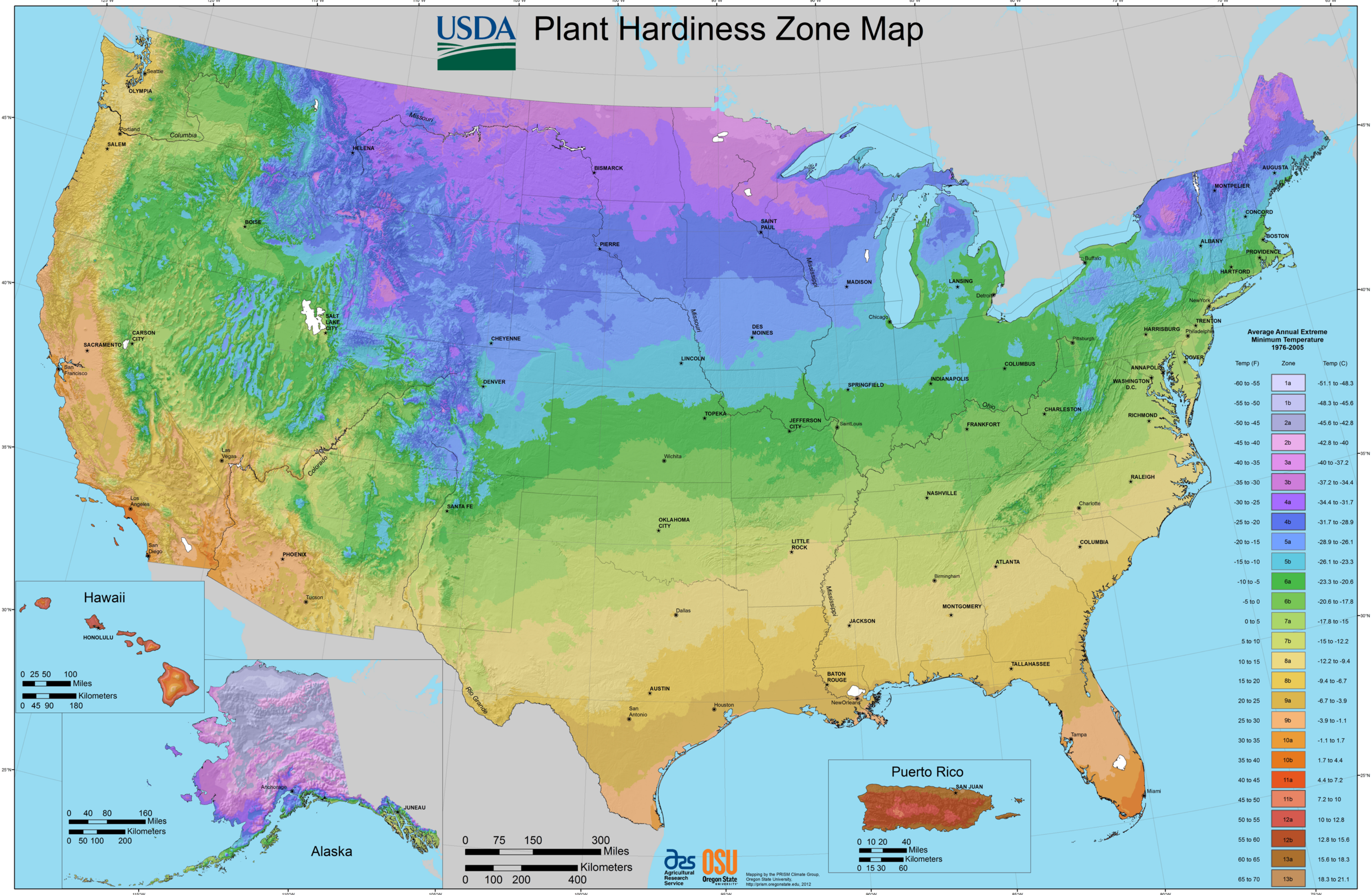


Figure 83

LIVESTOCK

General Care

Most animals do not need to be kept indoors or in a heated space. In some cases, it may be detrimental to animals as it can affect their natural cycles. In most cases, a shelter that protects animals from wind, rain, and summer sun is all that is needed. Barns used to house animals indoors should be well ventilated. Poor ventilation can cause health issues such as pneumonia.

Livestock can either be kept in a pasture or hay fed. Pasture feeding is more sustainable, but may result in animals that produce less than other animals. Animals raised in a feedlot require much less space, but need to be provided with hay. No matter if livestock is kept in a pasture or feedlot, hay will need to be provided in winter when snow covers the ground.

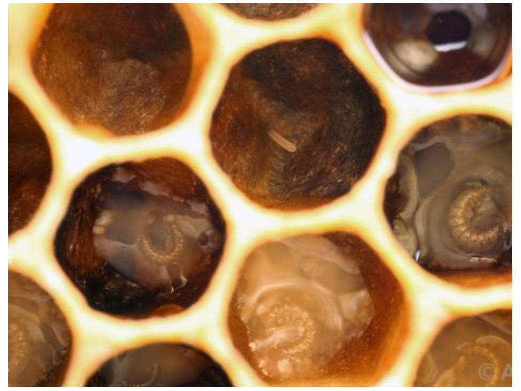
Water should be provided to livestock at all times. Lack of clean water can result in many health risks year round. Lastly, animals are most likely to drink water that is kept at 50 degrees.

Dual Purpose

Dual Purpose Animals are animals that provide more than one resource (meat, eggs, milk, wool, hide) or skill (protection, herding, transportation). It is important to use dual purpose animals on a homestead with limited space because they will produce twice as much as other species to maximize the efficiency of the resources. Dual purpose animals are often referred to as Heritage Animals because they were often historically used on farms and homesteads.

Bees

Bees are the only insect known to store food. Despite their reputation, bees are very docile. While bees require very little space, they do need regular maintenance to ensure the colony stays healthy and productive. Both honey and beeswax can be harvested from bee hives. Honey can be used as a sweetener, natural antibiotic, or flavoring. Beeswax can be used to make candles, salves, and in cooking.



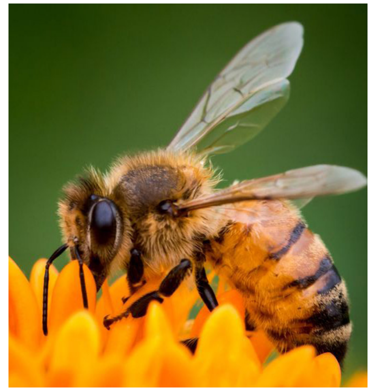


Figure 84 - 85

Chickens

Chickens require a shelter with nesting boxes and roosts, and outdoor space either as a run or free range. A minimum of 4 square feet of interior space and 10 square feet of exterior space must be provided per chicken. Chickens are very sensitive about nesting boxes. The recommended dimensions for a nesting box are 14" wide by 12" deep by 18" tall. One nesting box will need to be provided for every 4 hens. Lastly, 8" to 10" of roosting space must be provided per chicken. Some chicken breeds have a bantam version. Bantam chickens require half the feed and space as a typical chicken, but also produce half the amount of meat and half sized eggs

Dual purpose chickens provide eggs and meat.

Orpington	Wyandotte	Australorps	Rhode Island Reds	Plymouth Rocks
				
150 eggs per year	208 eggs per year	260 eggs per year	260 eggs per year	200 eggs per year
6.8 lbs - 7.9 lbs	6.8 lbs - 7.9 lbs	6.8 lbs - 7.9 lbs	6.8 lbs - 7.9 lbs	6.8 lbs - 7.9 lbs
Known for being cold hardy and very broody.	Known for its fancy colored feathers.	Known for being friendly and climate hardy.	Known for being cold hardy and friendly.	Known for being friendly, climate hardy, and broody.

Figure 86 - 91

Cattle

On average 1.5 to 2 acres of grassy pasture is needed per cow. If the pasture is not big enough or does not have good grass coverage, hay bales will be needed to supplement the cattle's diet. 20 to 30 square feet of shelter space is required per cow. In addition to exterior shelter, interior pens may be needed for sick or calving cows. To be kept indoors, 35 to 50 square feet of interior space should be provided for each cow. If being used for milking, a milking stanchion will be needed. A stanchion should be about 3' wide and 6' long; and a head gate or tie ring should be at the front of the stanchion to keep the cow in place. Side rails should be placed along both sides to keep the cow from moving and protect the milker from a kick.

Dual purpose cattle can be used for milk and beef production. If they are used as oxen or for fiber production they may be considered triple-purpose.

Irish Dexter

2.6 - 3.2 gallons daily

320 lbs - 485 lbs hanging weight

Know for being friendly, good mothers, and having high feed efficiency.

Scottish Highlander

About 2 gallons daily

500 lbs - 600 lbs hanging weight

Know for being friendly and having high feed efficiency.

British White

5 - 6 gallons daily

682 lbs - 768 lbs hanging weight

Know for being polled, good mothers, and having high feed efficiency.

Shorthorn

5 - 6 gallons daily

720 lbs - 840 lbs hanging weight

Know for having high feed efficiency, high fertility, and long lifespans.

Simmental

4 - 6 gallons daily

650 lbs - 800 lbs hanging weight

Know for having high feed efficiency, high fertility, and long lifespans.

Figure 92 - 97

Goats

A minimum of 200 square feet of grassy pasture should be provided per goat. If this can not be achieved supplemental hay will need to be fed. If hay is provided, a minimum of 25 square feet of exterior space is needed per goat. Exterior shelters should block wind rain and sun, but can be built inexpensively. Goats like to climb, so creating different levels can help combat boredom. If kept primarily indoors, 15 square feet per goat of interior space is required with 6 foot tall walls. A milking stanchion or shearing stand may be needed depending on the use of the goats. Lastly, as goats are herd animals, at least two goats should be kept together.

Although not as productive as cattle, goats can provide milk, meat, and fiber. Chevon contains less fat and more protein compared to beef, making a very healthy red meat. Goat milk contains more protein and calcium than cow milk and the cream will not rise to the top like cow milk.

Nubian

Dual Purpose

Known for their extended breeding season and tolerability to heat.

LaMancha

Dual Purpose

Known for their small ears, two year lactation period, and hardiness.

Alpine

Dairy Purpose

They are hardy with well shaped udders and teats.

Boer

Meat Purpose

Know for their high fertility and rapid growth rate.

Pygora

Fiber Purpose

Produces all three types of fiber.

Figure 98 - 103

Sheep

A minimum of 200 square feet of grassy pasture should be provided per sheep. If this can not be achieved supplemental hay will need to be fed. If hay is provided, a minimum of 20 square feet of exterior space is needed per sheep. Exterior shelters should allow for 10 square feet per sheep. Shelters should protect against wind and rain, but should not provide heat. When kept indoors, 12 square feet per sheep is required with 6 foot tall walls. A milking stanchion or shearing stand may be needed depending on the use of the sheep. Lastly, as sheep are herd animals at least two should be kept together.

For health and safety concerns, sheep almost always require a docked tail. They also need to be sheared at least twice a year.

Most sheep breeds are dual purpose as they can produce wool and mutton. Some breeds are considered triple purpose for their ability to be milked (although rare in the United States).

Icelandic Sheep

Triple Purpose

Known for being smart, rugged, and hardy.

East Friesian

Triple Purpose

Known for their ability to produce large amounts of milk.

Finnsheep

Triple Purpose

Adapt well to harsh climates and rough forage. Known for maturing early.

Romney

Dual Purpose

Known for its durable hooves and resilient coats.

Columbia

Dual Purpose

Known for being hardy and adapting well to many climates.

Figure 104 - 109

Swine

Unlike other livestock, pigs require very little space. If kept indoors, only 8 square feet is needed per pig. Pigs can either be raised in pastures or feed lots. If pastured, pigs will need to be rotated frequently to prevent the ground from being overworked, and need at least an ⅛ of an acre for grazing. If kept in a feedlot, they will need a minimum of 80 square feet per pig. A pool and shade must be provided as pigs cannot regulate their temperature.

Pigs are very territorial animals. A single pig should not be introduced to a new group of pigs.

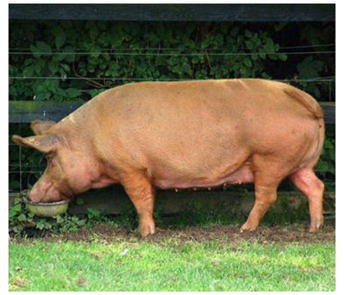
While pigs are not considered dual purpose animals, they can help till the ground for new garden spaces.

Old Spot

180 lbs average hanging weight

Know for being good mothers, friendly and good pasture hogs.

Tamworth



160 lbs average hanging weight

Know for high piglet survival rate, good foraging skills, and being active hogs.

Large Black

144 lbs average hanging weight

Know for being docile, good forager, and maternal instincts.

Hereford

153 lbs average hanging weight

Know for being very adaptable and maturing early.

Red Wattle

245 lbs average hanging weight

Know for its hardiness, rapid growth rate, and being good foragers.

Figure 110 - 115

HOMESTEADING ON MARGINAL LAND

Homesteading on Marginal land was written by a couple, Beth and Shawn Dougherty, about their experiences of finding and purchasing land, and starting a homestead. They wanted to find a farm away from the city where they could grow clean food. They wanted to live in a house that could be a retreat. This article describes how this couple turned an unusable piece of land into a successful homestead, and gives tips to beginners on how to start their journey into homesteading. I chose this article because it provides information on how to be resourceful and how to keep the homestead affordable.

Finding Property

Beth and Shawn began searching for a farm suitable for their needs and became increasingly frustrated with finding property that was within their price range. The couple was reluctant to raise their budget as they felt it was necessary to save money for any improvements that would be needed on the farm. Every ad they found was either well over their budget or too small for their needs. Eventually, they reevaluated their "must have" list. Things such as barns, fences, and watering systems were removed from the list. They settled on looking for something with accessible land and a house. Soon, they find a 17 acre piece of land with a house on a rocky hillside covered in trash and weeds. Although structurally sound, the small house located on the property needed many repairs. It was not their dream

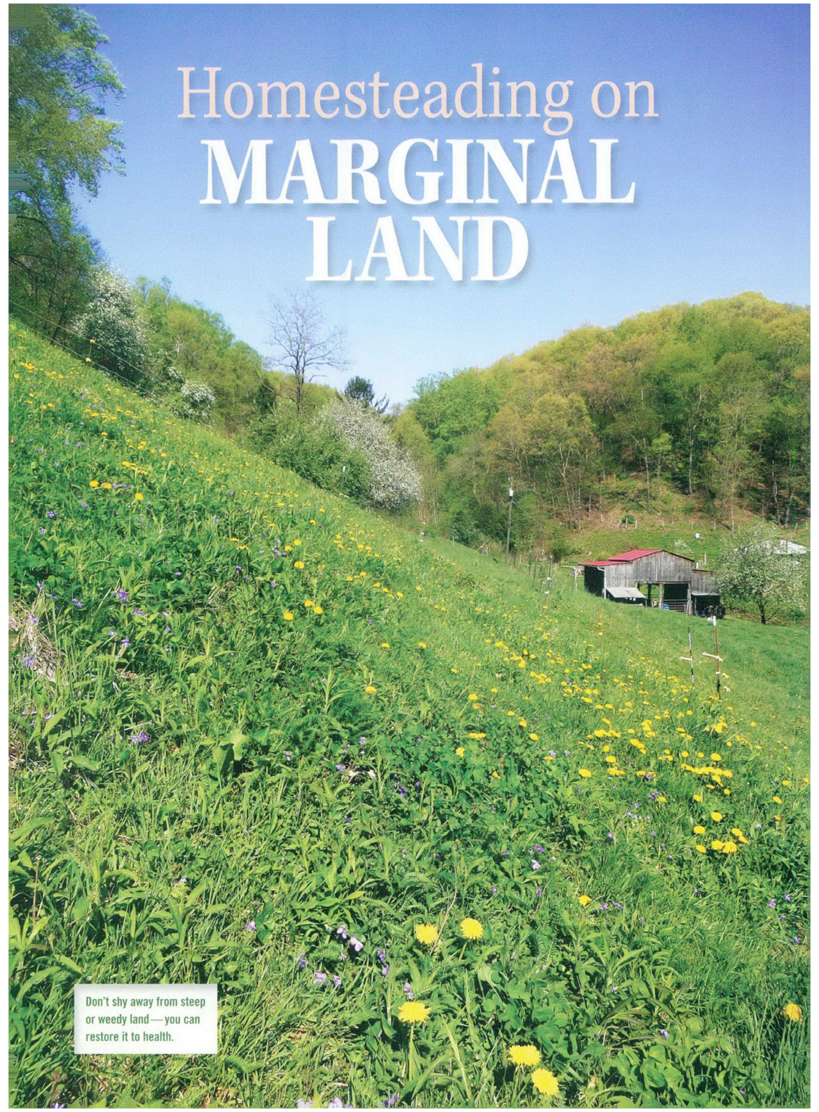


Figure 116

house, but it would provide them with everything they needed to start a homestead.

An important thing to keep in mind when buying a property is to be honest about what your needs are versus what your wants are. For example, while a master bathroom is nice to have, it is not a necessity. One bathroom shared by the entire household is cheaper and easier to maintain. The homesteading lifestyle does not put value on luxury items but on things that give back to the homestead as much as they take.

Improving the Land

Two creeks passed through the property and provided a source of water for livestock and crops. The hill ran east to west, giving them a south facing slope. They started by getting goats to clear the land. As brush was cleared the goats would be moved to a new section of land and the process repeated itself. This form of rotational grazing allowed overgrown brush to be cleared and more desirable grasses to come in. Manure fertilized the land, resting land grew lush grass, and hooves softened the soil.

Rotational grazing can become very important to maximizing the potential of the land or prevent damaging it. Besides clearing brush, rotational grazing can also ensure that the pasture is not over grazed and works as pest control. Over grazing is avoided by allowing grass to grow back and stay healthy. Livestock tend to prefer grazing on fresh grass over long stocky grass. This means that they are constantly grazing the same spots. The grass is unable to regrow and older grass is left uneaten. Pest control is achieved by allowing manure to compost. Animals are less likely to ingest manure where they can pick up internal parasites.

Figure 117 - 119

The couple also started a garden. Due to the rocky soil, raised gardens were needed. They composed the soil they would use from manure and sawdust. Eventually, they added pigs and added their used bedding to the compost mix. Using the compost, they were able to grow greens and vegetables year round. Chickens were eventually brought in to control weeds and insects.

Water

To provide water for their livestock, the couple installed a French-drain in damp areas of the pasture. The water was then directed to a used shipping container. The water was then gravity fed through garden hoses to half-barrels. Later, they were able to use this system to put running water in the barn.

Water is the most important resource to have. Without water, all other resources become redundant. Finding a reliable source of water year round is the first task that should be completed on any new homestead.

The Many Uses of Milk

Beth and Shawn milked several goats and a jersey cow. Having a surplus of milk, the couple discovered all the many uses of milk. In addition to drinking, milk can be used to make butter, hard and soft cheese, yogurt, and sour cream. Around the farm, milk can be used to feed calves, pigs, chickens, dogs, and cats. The whey can be used in the garden to add nutrients to the soil. With limited space, finding multiple uses for your resources is very important. Milk is one of many examples.

Achieving Self-Sufficiency

With the large amount of milk being produced by their cow, they were able to get their first pig. In addition to being fed extra milk, food waste was also fed to the pig instead of being added to the compost pile. Soiled bedding created by the pig was composed. Homegrown pork was added to the family's diet of fresh milk, vegetables, fruits, and eggs. By utilizing every resource, their grocery and feed bills were drastically reduced.

Advice for Beginners

Location: Understand where you want to homestead. Important factors to consider are family, employment, climate, and culture.

Accessibility: Be sure that whatever land you purchase has a reasonable amount of access for any equipment that may deliver supplies.

Water: It is very important to have access to clean water year round.

Residence: Although it is not necessary to live on your farm, the house should suit your needs. Know what your minimum requirements are.

Previous Use: Depending on what the site was previously used for may limit what you may be able to use it for. Diseases and pathogens can remain in the soil for many years and harm you or your livestock as it gets worked.

Neighbors: Neighbors can be a great source of knowledge and resources. They may have experience working in the same land condition that you will be encountering. It is also important to be respectful of neighbors. Issues may be avoided by clearly communicating with those that your decisions may affect.

Premiums: Understand the full potential of your land. Trees can provide shade and lumber. Water can provide irrigation, livestock water, and a way for livestock to cool down.

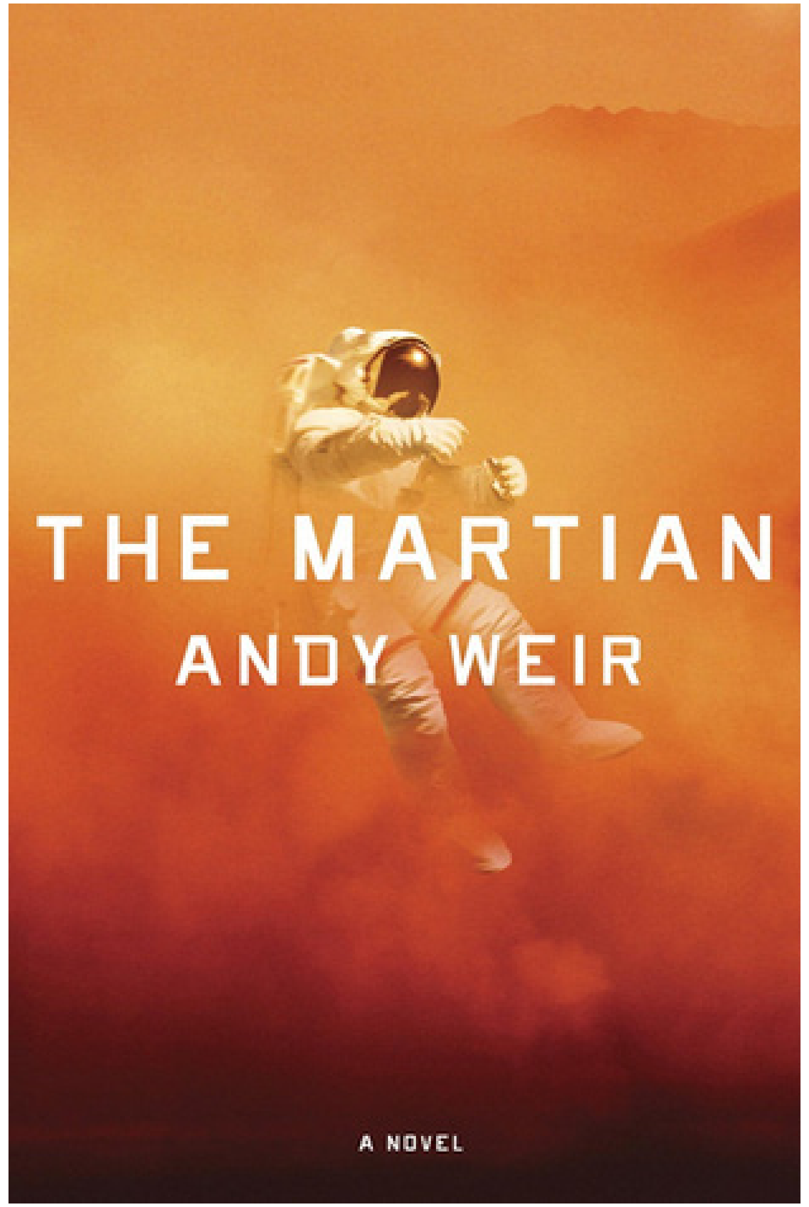


Figure 120

THE MARTIAN

After a Martian dust storm, the Ares 3 is forced to abort the mission and evacuated to the MAV (Mars Ascent Vehicle). On the way to the MAV, one of the six astronauts, Mark Watney, is struck by debris and lost in the storm. Forced to leave a crew member behind or risk the MAV tipping over, Commander Lewis makes the difficult decision to launch the MAV and leave Watney behind. Now stranded on Mars, Watney must find a way to survive until NASA can send a rescue mission.

I chose to include this book in my literature review because nothing is more self-sufficient than surviving on an entire planet by yourself. Although it's a science fiction novel, the Martian is considered to be very accurate. For this review, I will be focusing on how the food shortage was solved.

Food Supply

The first thing Watney does is take stock of his supplies. The original mission was to send 6 astronauts to Mars for 31 sols (sol is a Martian day). As a redundancy, NASA sent 56 sols worth of food. The mission was aborted after sol 6, so there are now 50 sols worth of food for 6 people or 300 sols worth of food for 1 person. He decides to ration his food to ¾ of a ration per sol, extending his food supply to approximately 400 sols. His initial plan is to create enough food to survive until the Ares 4 mission schedule in 4 years.

Fertilizing Martian Soil

Watney's only hope of extending his food supply, is to grow more food. Mars is known for its lifeless soil and inaccessible water. He will first need to tackle the problem of creating soil capable of supporting plant life. On Earth, soil is often supplemented with manure. The only source of manure available to Watney is his own solid waste and 6 sols worth of solid waste of the crew. The reason human manure isn't used is because it can carry pathogens that spread to anyone who consumes food grown in the soil. Watney is able to remedy this problem because up until sol 6 all waste was vacuum-dried and discarded to the surface, effectively killing all harmful pathogens the waste could be carrying. To create viable soil, Watney used his own untreated waste. Because he will be using his own waste, he will not have to worry about ingesting pathogens than what his body can't already handle. By mixing the solid waste with Martian soil, he is able to create 92 square meters of soil, 10 centimeters deep.

Watney starts with 5 square meters of soil to mix his solid waste in. Once the bacteria had a chance to breed and spread, he doubled the amount of soil by adding 5 more square meters on top of what he already had. He continued to double it, increasing the depth of his soil, until he had enough to start his crop. By starting with a small amount of soil, the bacteria was able to grow and spread quickly. This increased the amount of bacteria available to spread when the soil was double.

Finding Water

Watney's next problem is finding enough water to water his potato crop. Unlike Earth, Martian water is very inaccessible. For the soil to be moist enough to grow plants, it needs 40 liters of water per cubic meter. To water all 9.2 cubic meters of soil, he will need 368 liters of water.

Figure 121

NASA sent 50 liters of water per crew member, or 300 total liters of water. For emergency purposes, 50 liters are set aside. With 250 liters of water, Watney can water 62.5 square meters of his soil, about ⅔ of his goal area. To get enough water for his crops, Watney will need to create the water himself. In concept, water is fairly easy to make: "Take hydrogen. Add oxygen. Burn."

He started solving this problem by finding a source of oxygen. He had various sources of liquid oxygen but concluded it would be best to save those for EVAs (extravehicular activities or spacewalks) and emergencies. He decided to use the oxygenator that provides oxygen to astronauts living in the HAB (habitat). The oxygenator pulls CO_2 from the Martian atmosphere and separates out the oxygen.

The next thing he needed was hydrogen. With limited options for obtaining hydrogen. Watney settles on a dangerous plan to use leftover hydrazine (aka rocket fuel) from the MDV (Mars Descent Vehicle). Hydrazine is made up of nitrogen and hydrogen, that when burned becomes N_2 and H_2. The trick will be burning it slowly to not create an explosion.

Creating Calories

The average human needs at least 1,500 calories a day or risks starvation. Watney calculates that he will need 1,387 sols or 1,425 days of food to survive long enough for an Ares 4 rescue. He already has 400 days worth of food. After some calculations, Watney comes to the conclusion that he will need to create 1,100 calories a day. Potatoes have 770 calories per kilogram. He will need to grow 2,776 kilograms of potatoes to survive.

Colonizing Mars

After solving the soil and water problems, Watney can start growing. Unlike commercial farming on Earth, Watney will be able to tend to individual plants and plant more intensely to increase his yield. He also will not have to deal with weeds, insects, or weather conditions. Increasing the temperature of the HAB to 25 degrees celsius will help the plants grow faster.

To plant the potatoes, Watney cut them into quarters, ensuring each had two eyes, and placed them in the soil. Potatoes usually take 90 days to reach full yield, but he will need to harvest early to replant and increase the number of plants he has growing. When the first round

Figure 122

of potatoes is ready, he will harvest the potatoes, being careful not to disrupt the plant and replant the potatoes, effectively doubling his yield.

Homesteading on Earth

While a homestead would not face the same dilemma Watney did on Mars, many of the concepts can be applied to Earth.

Viable soil is important to grow anything. Although there are ways to make human solid waste a safe source of fertilizer, it is not a practical solution. Livestock manure and compost are better solutions to fertilize garden soil.

Finding a source of water will also be important for both irrigation and drinking. Unlike in The Martian, finding water on a homestead can be as simple as drilling a well or utilizing a creek.

Although on a homestead you will not starve to death, it is good to understand what you need to grow. To be completely self-sufficient, you will need to be able to produce enough food, plant or animal, to feed everyone in your family for a year.

Lastly, an important theme throughout the novel is being resourceful. You may not have exactly the right tools or equipment on a homestead, but being creative and resourceful can get you a long way.

BUMPS ALONG THE ROAD OF THE TINY HOUSE MOVEMENT: PRACTITIONER NOTES WITH CRITICAL REFLECTION

This article shares insights, construction methods, and practice-based reflections from experienced tiny house builders in Australia. This article is not intended to be used as a "how-to guilde" or give advice on code regulations, but to inform prospective builders about building issues and techniques. Findings and analysis of this article during my research stage of my thesis project will be useful to avoid issues early on in the design process.

Transportation

In regulatory terms, tiny houses are often viewed as a road vehicle because they often sit on trailers and can be moved from one site to another. As a road vehicle, tiny houses should be equipped with proper lighting, follow weight and size restrictions, and be properly registered. Since there are unclear regulations for tiny houses, homeowners often will park on leased land before acquiring council permission. Due to the uncertainty of whether you will be required to move or not can sometimes cause "housing stress".

For my thesis project, I anticipate that I will be designing a tiny house on a foundation and will be able to avoid many problems associated with THOWs. The only time the tiny house for my project may need to be transported is if it is constructed in a climate controlled warehouse. In this case, the house will need to be built on skids so that it can be placed on a trailer for transportation.

Figure 123

If your plan on building a THOW, be sure you select a trailer capable of transporting your house. Due to a house's weight distribution, you should select a trailer with load sharing suspension. Weight should be distributed with more weight toward the front of the trailer than the back. To avoid fishtailing while towing, 6% - 8% of the weight should be placed on the hitch. Side to side weight should be equal to minimize the potential for roll over. Although it may seem obvious, tiny houses should be securely fastened to the trailer.

Material Choice

A second consideration when preparing to build a tiny house is material choice. Recycled materials are very popular in tiny house builds and can help reduce costs. It is important to be aware of the quality of reused materials as they may not be in good enough condition to reuse or may cost almost as much as a new product. Recycled materials can also be more difficult to work with or require more prep time. Lastly, reused materials may have a shorter lifespan, decreasing the overall longevity to the tiny house.

The tiny house designed in my thesis project will not be designed with specific recycled materials, but every opportunity to substitute a new product for a quality recycled product should be utilized. Replacing materials with reused ones should not significantly affect the efficiency or longevity of the house.

Ventilation

Proper ventilation of a tiny house is important to avoid interior water issues. Cross ventilation or exhaust fans are good solutions to remove moisture from the inside of the house. Showers, sinks, and toilets should be properly drained and sealed.

Due to tiny houses' small volume, the smallest amount of moisture can have a dramatic effect on the indoor air quality. Simple tasks, such as boiling a pot of water or taking a shower, can increase the humidity level enough to create condensation throughout the house. With regular repetition, mold can begin to grow and create a toxic environment for humans and pets. Proper ventilation will ensure healthy air quality for the occupants.

Water Collection

Many tiny houses aim to be off-grid and finding ways to reduce water use is important. Tiny houses have a small roof arena, making rain water collection difficult. A large collection barrel may be necessary to store plenty of water and to top off when water is accessible. Reducing water usage will also help minimize the amount of water needed. Water usage can be reduced by water efficient appliances and a composting toilet.

One question that I would like to answer is: What is the cost difference between using a well and using a water collection system. As tiny houses have a small roof area, a water collection system may not be feasible. If the cost to collect, store, and filter rainwater is not lower than the cost of electricity needed to run a well, it will not be worth including a water collection system into my design.

Fireproofing

As with any house, fireproofing and egress should be carefully considered. Choosing fire resistant materials like metal or hardwood cladding, fire resistant paint, and proper windows and doors can prevent fires to tiny houses.

Many tiny houses are designed with a loft for sleeping. In the event of a fire, it may be difficult to exit the house if proper measures are not considered. Operable windows big enough for a person to comfortably fit through and a way to get to ground level safely will need to be provided for every sleeping space. Two means of egress should also be provided for other spaces within the house.

Insulation

Proper insulation is important to reduce a tiny house's heating and cooling loads. Passive cooling, such as cross ventilation, may be sufficient to keep the house cool in the summer months. To an extent, passive heating can be used but may need to be supplemented with active heating solutions depending on the climate of the site.

Proper insulation will increase the house's R-value and help to keep conditioned air from escaping. This will lower the amount of energy needed to heat and cool the house. Construction methods to consider for increasing the house's R-value include: SIPs, double stud wall, and continuous exterior insulation and stud wall.

Conclusion

Many issues that must be addressed when designing a THOW will be avoided in my project by making it a permanent structure built on a foundation. I am able to build the tiny house as a permanent structure because it is not likely that it will need to be transported once it is on the site. Certain lifestyle choices that often come with tiny house living will need to be solved in my design.

Figure 124

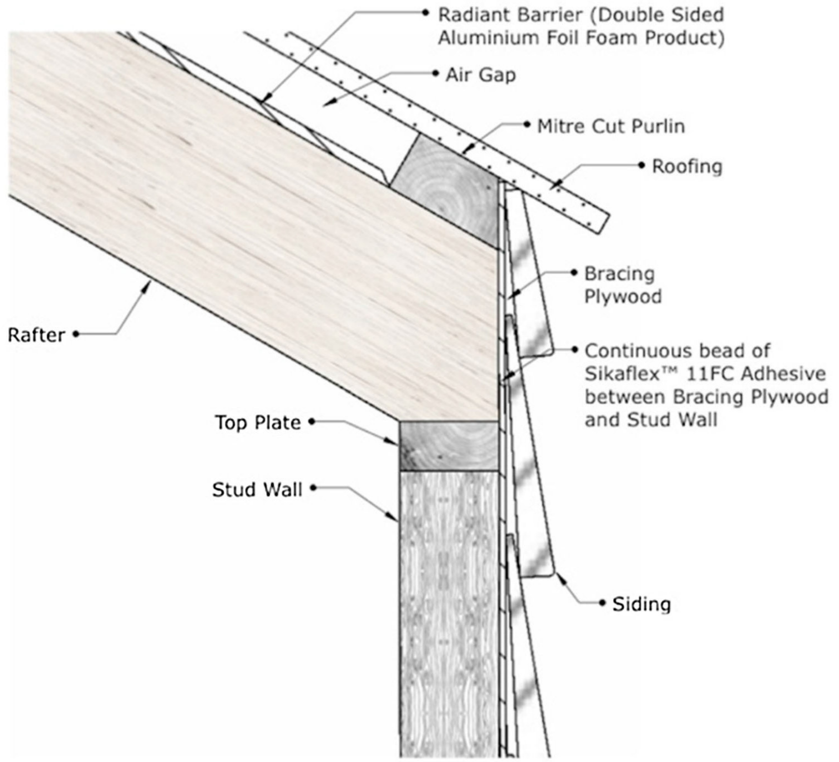


Figure 125

THE MINIMALIST BARN

The Minimalist Barn is written by two experienced barn builders to give prospective barn builders tips. This article covers strategies to maximize your budget, gives advice on what is worth skimping on, and provides ideas of what can be added later to save money on initial building costs. Although this article focuses on horses, the concepts can be translated to other species.

Where to Build

You should plan to build your barn on ground that is dry year round. Damp ground can cause moisture issues to the indoor air quality of the barn. The barn should be raised at least 12 inches above surrounding ground to make sure water runs away from your barn. If sloping the ground does not provide enough drainage, a drainage pipe will need to be installed.

In hot climates, barn aisles should be oriented to utilize summer breezes to maximize cross ventilation. This will help keep the barn cool and well ventilated. In cold climates, the barn aisles should be oriented perpendicular to prevailing winter winds. Based on the wind rose of my project site, the barn should run east and west to avoid cold north winds.

What to Build

Climate and aesthetics should be considered when designing the layout of the barn. The shape of the barn can increase its ability to properly circulate air and regulate interior temperature. In some cases, it may be important to match the materiality and design of the barn with surrounding buildings such as the house.

In hot climates, both shedrow barns and center-aisle barns are suitable solutions. Shedrow barns place stalls down the center of the barn and place aisles along the exterior of the building. This maximized cross ventilation while protecting the animals from rain and weather. A center aisle barn with clerestory windows allows for heat to escape and let light in. In most cases, storing hay in a loft can cause an increase in temperature and raises the chances of a hay fire.

For barns being built in cold climates, a center aisle is the best option. A center aisle with doors on either end provide more protection from winter weather than a shedrow barn. A loft for hay storage can work as insulation but should be well ventilated to prevent hay fires and control dust. A center-aisle barn will be the best solution for my thesis project.

Construction & Materials

Pole barns are a great option for building a basic barn. Pole barns do not require a foundation, helping to lower costs. Both wood and metal siding can be used. Wood may be more aesthetically pleasing but require maintenance. Metal is cheap, but can be loud and moisture can condense during cold weather.

Modular barns are very easy and cheap to construct. They are prefabricated and come as a kit. Modular barns are also very easy to remodel or add on to. They have a limited ability to match the design style of existing buildings.

Concrete blocks are fireproof and durable, but have increased labor costs. They are cool in hot climates, but may be cool and damp in cold climates.

A pole barn will be the best option for my thesis project. It will be cheap and easy to construct. It will also be easier to incorporate reused materials.

Size

Planning ahead is key to avoiding unnecessary costs in the future. Allow for room for additions to the building. Another suggestion provided was to build with space to grow, use the unused space as storage, and add stalls as needed.

Do not build less than the minimum. By skimping on a few feet, you may only save a little money, but will be stuck with the dimension. Center aisles should be a minimum of 10 feet, but 12 feet is preferable to allow for vehicles to pass and provide extra room for vet work.

Features

Proper flooring is important for any building used to house livestock. In some cases, a dirt floor will work. Cement can be poured to prevent animals from digging in the dirt and to keep bedding clean. Rubber mats can be used to provide cushion. All flooring should be slip proof to prevent animals from falling.

Stalls can be prefabricated or custom built. Custom stalls provide more opportunities to use recycled materials and lower costs. Stall walls should not be built the full height of the wall or should use a grill to allow for ventilation.

Water lines should be buried at least 3 feet deep in cold climates to avoid freezing. A single hydrant can be installed and water buckets manually filled or an automatic waterer can be installed in each stall.

Costs should not be cut when installing electrical services. Proper lighting and wiring should be used to create a healthy and safe space for livestock and people. LED lighting can provide plenty of light while using very little electricity.

Conclusion

Proper planning and material choice can significantly lower the cost of building a barn. Planning ahead can also save money when additions and upgrades are added.

Project Justification

My love of farm life started with horses at the age of 12 when I started doing yard work for my grandpa in exchange for horse riding lessons. Over the years I became a stronger and smarter rider. I began competing and eventually bought my own horse. I have learned that hard work doesn't always pay off but that doesn't mean you ever give up. I've learned how to communicate with an animal 5 times my size using cues that are often imperceivable to the average person. It is a thrilling experience to be so closely bonded with an animal that could so easily hurt you.

In high school I worked on a dairy farm. Working on a dairy farm is something very few people get to experience. They will never understand what it feels like to wake up very early in the morning, walk into a still and peaceful barn, watch the sun rise as you herd in the cattle, hear the rhythmic sound of the milking machines, wake up newborn calves with a fresh bottle of milk, and watch the cows line up when it's time for morning feeding. The physical and psychological process of milking is amazing and is something that cannot be understood by opening the refrigerator door at the grocery store to grab a plastic jug.

With the recent pandemic, I feel an even greater need to have the ability to provide for myself. I no longer want to depend on factories and big box stories for everything I need. I want to eat food that I know was produced by animals that are happy and healthy. I want

Figure 126 - 127

Figure 128 - 129

to eat fruits and vegetables that I know are not covered in chemicals. And I want to use products that do not pollute other resources. This research will give me the basic knowledge I need to begin my career and live the life I have always dreamed of. I know that I am not the only person with these desires.

Due to lock downs and boredom, many people are exploring old fashion skills such as baking bread, canning, and DIY projects. People are learning the value of slowing down and enjoying the process. They want to continue and expand on the opportunity to do things themselves. I believe with the newfound realization that they can provide for themselves, people will be drawn to the homestead lifestyle.

This project is important for my academic development and future professional career because I hope to homestead in the future and I will be better prepared when I graduate. The research that I conduct will expand my knowledge base of homesteading and architecture overall. I will also be more familiar with the lingo used by the homesteading community.

Finally, the design for my thesis project will provide solutions for the current housing shortage. In the United States, there is a housing shortage, especially in a price range that is affordable for middle and low income families. This project will find ways to provide affordable housing that take up less space than traditional houses.

Historical, Social, and Cultural Context

Nearly 10,000 years ago, on the fertile lands between the Tigris and Euphrates rivers, Mesopotamians began planting crops such as wheat, barley, lentils, and peas. Soon after, other civilizations began planting crops. Rice was planted in Asia and potatoes were planted in South America.

Animal domestication quickly followed the domestication of plants. Animals were domesticated for their meat, milk, and hides. Goats were most likely the first animals domesticated, followed by sheep. People began domesticating larger and larger animals. Oxen and horse were used for plowing and transportation.

Overtime plants and animals were selectively bred for certain qualities. Plants were bred for their ability to withstand droughts and diseases. Animals were bred for friendly temperaments and easy ability to reproduce.

With the domestication of plants and animals, humans began to create more and more permanent civilizations. As humans gained the ability to produce more food with less effort the population increased. Villages and cities began to form and the human race progressed.

During medieval times, peasants were often farmers. As part of the feudal system, peasant farmers often did not own the land, but borrowed it from the lord of the manor. Most farmers could not afford oxen or horses and had to do the work by hand using a hand plow. Farming in medieval times was not easy and peasants often worked together to ensure the work was completed. Livestock were often kept in houses to keep them safe and as a source of heat. Technology began to advance and humans began exploring new lands.

On May 20, 1862 Abraham Lincoln signed the Homestead Act. This granted Americans 160 acre plots of land for an $18 fee, 5 years of continuous residency, building a house, farming the land, making improvements, and proving that they had never bore arms against the US. The purpose of the Homestead Act was to encourage western expansion. President Lincoln said, "to elevate the condition of men, to lift artificial burdens from all shoulders and to give everyone an unfettered start and a fair chance in the race of life." This resulted in 4 million homesteads being claimed.

Starting with the Industrial Revolution, homesteading began to decline. By 1920, more Americans lived in cities than rural areas. Today, the majority of Americans live in cities or suburbs than in rural areas. Most Americans no longer wake up in the morning to feed their animals, spend days under the sun tending to crops, or work hard to know their animals are well taken care of. The homesteading lifestyle was replaced by city life.

Figure 130

Performance Criteria

Executive Summary

The first criteria that should be met for this project are psychological and behavioral. The project needs to work well for the user and be a place they enjoy being. The rest or the criteria won't matter if the user is unhappy with the spaces. Measuring the success of these criteria will be subjective to the users preferred lifestyle.

The next criterion that should be met is code compliance. This criterion will ensure the project is capable of meeting the minimum requirements of the project typologies.

Once a safe and enjoyable project has been created, space allocation, environmental performance, behavioral performance, and cost requirements can be met. Meeting these criteria will ensure that the project is well suited for the tasks that need to be completed in the spaces.

Lastly to be met are energy consumption and environmental impact criteria, This is where the project can go above and beyond the minimum standard set by all previous criteria.

1. Space Allocation

Space allocation will be determined by looking at case studies with a similar typology. Tiny house case studies and farmhouse case studies will be used to determine the allocation of space of the residence. The barn will be determined by the interior space requirements of the livestock it will house and greenhouse and garden spaces will be calculated based on how much food needs to be grown. In addition to case studies, I will use personal experiences to determine if the space allocations created by the case studies are suitable for my project.

2. Energy Consumption

One of the goals of my project is to minimize the energy consumption needed. I plan to achieve this by investigating solar energy, wind power, and passive heating and cooling strategies. I will need to determine which system has the greatest potential and the best return on investment.

3. Environmental Performance (luminous, thermal, acoustical environments, ecosystem balance)

This project aims to create environmental comfort by using a passive system. Buildings will be heated using solar gain, and cooled using natural ventilation. Lighting will be provided using natural daylight during the day.

4. Behavioral Performance (usage patterns)

Behavior patterns specific to the user must be used to ensure the design is suited for their needs. The daily activities of a homesteader are very different from people that live in an urban setting. Materials will need to be more durable and easy to clean. It will also be important to design livestock space to the animals' needs rather than human needs. For example, humans must have an external source of heat to stay warm during cold weather, many animals do not need a heated space to stay warm. In some cases heating a space could be detrimental to the health of the livestock.

5. Psychological Impact (aesthetics, sensory experiences)

The psychological impact of my project will be very important to the success of the project. Most people who want to start a homestead usually do it in part to escape the city. They want a slower simpler life than what can be achieved in urban areas. My project must be a relaxing place to be and lower the stress level of the user.

6. Environmental Impact

One of the goals of this project is to minimize the environmental impact. This may be achieved by using green energy sources, passive (heating, cooling, and lighting) systems, sustainable sourced materials, and energy efficient appliances.

7. Code Compliance

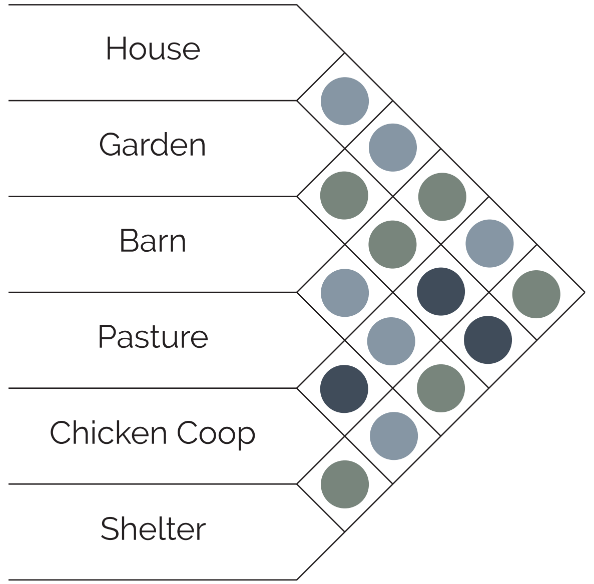
I will need to be aware of several different standards. The house will need to comply with residential building codes. The outbuildings will need to follow storage typology building codes. Other considerations will need to be addressed to ensure the livestock are kept in a safe environment.

8. Cost

Between the housing shortage and lack of affordable housing, it will be important to keep this project affordable. One goal of this project is to minimize the monthly expenses of the user and use products that have a high return on investment. I will also plan for opportunities to upgrade systems so that a temporary product that is cheaper can be used until a more durable and efficient product can be installed. This will offset the initial expense of the project.

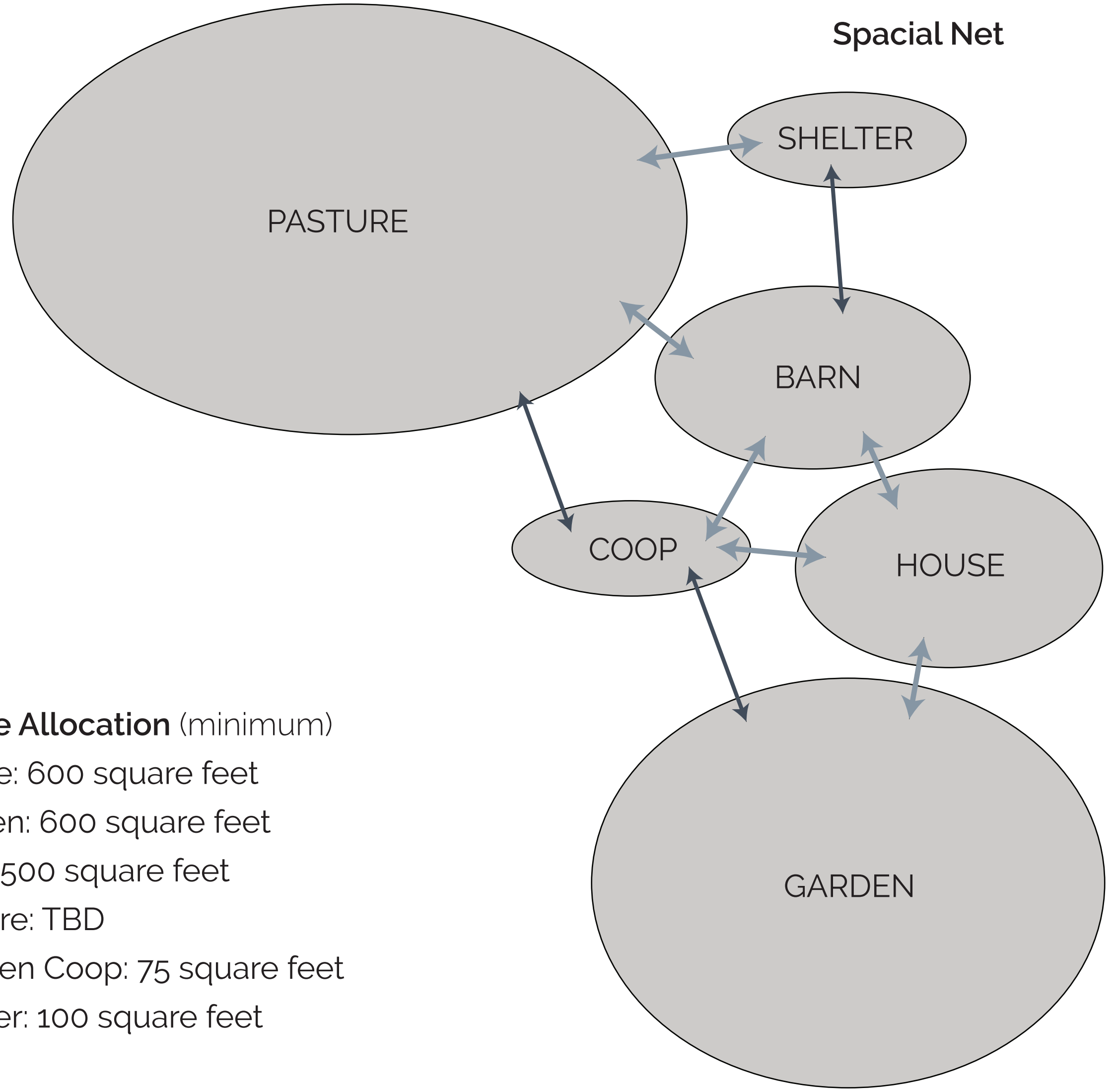
THE SITE

Adjacency Matrix



- ADJACENT
- NEARBY
- NOT ADJACENT

Spacial Net

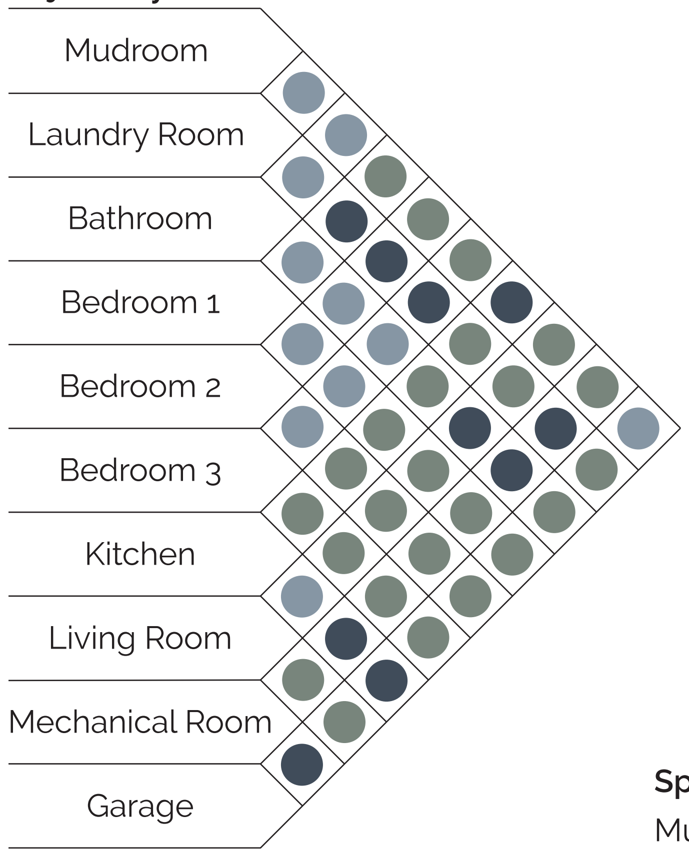


Space Allocation (minimum)
House: 600 square feet
Garden: 600 square feet
Barn: 500 square feet
Pasture: TBD
Chicken Coop: 75 square feet
Shelter: 100 square feet

Figure 131

THE HOUSE

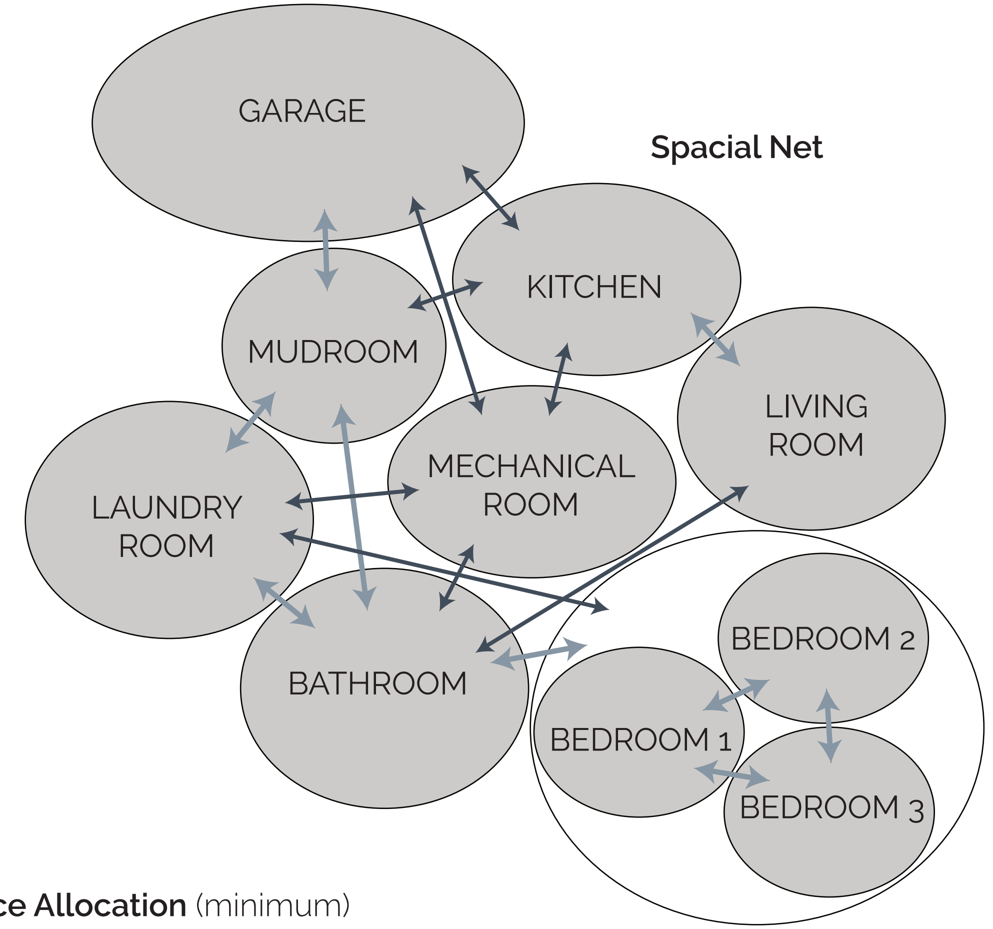
Adjacency Matrix



- ADJACENT
- NEARBY
- NOT ADJACENT

Figure 132

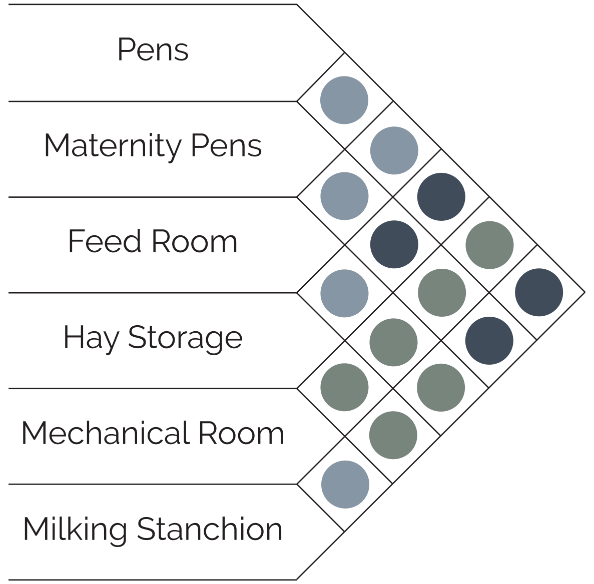
Spacial Net



Space Allocation (minimum)
Mudroom: 25 sqaure feet
Laundry Room: 10 square feet
Bathroom: 50 square feet
Bedroom 1: 100 square feet
Bedroom 2: 80 square feet
Garage: 288 square feet
Bedroom 3: 80 square feet
Kitchen: 80 square feet
Living Room: 100 square feet
Mechanical Room: 50 sqaure feet

THE BARN

Adjacency Matrix



ADJACENT
NEARBY
NOT ADJACENT

Space Allocation (minimum)
Pens: TBD
Maternity Pens: 60 square feet
Feed Room: 25 square feet
Hay Storage: TBD
Mechanical Room: 25 square feet
Milking Stanchion: 20 sqare feet

Spacial Net

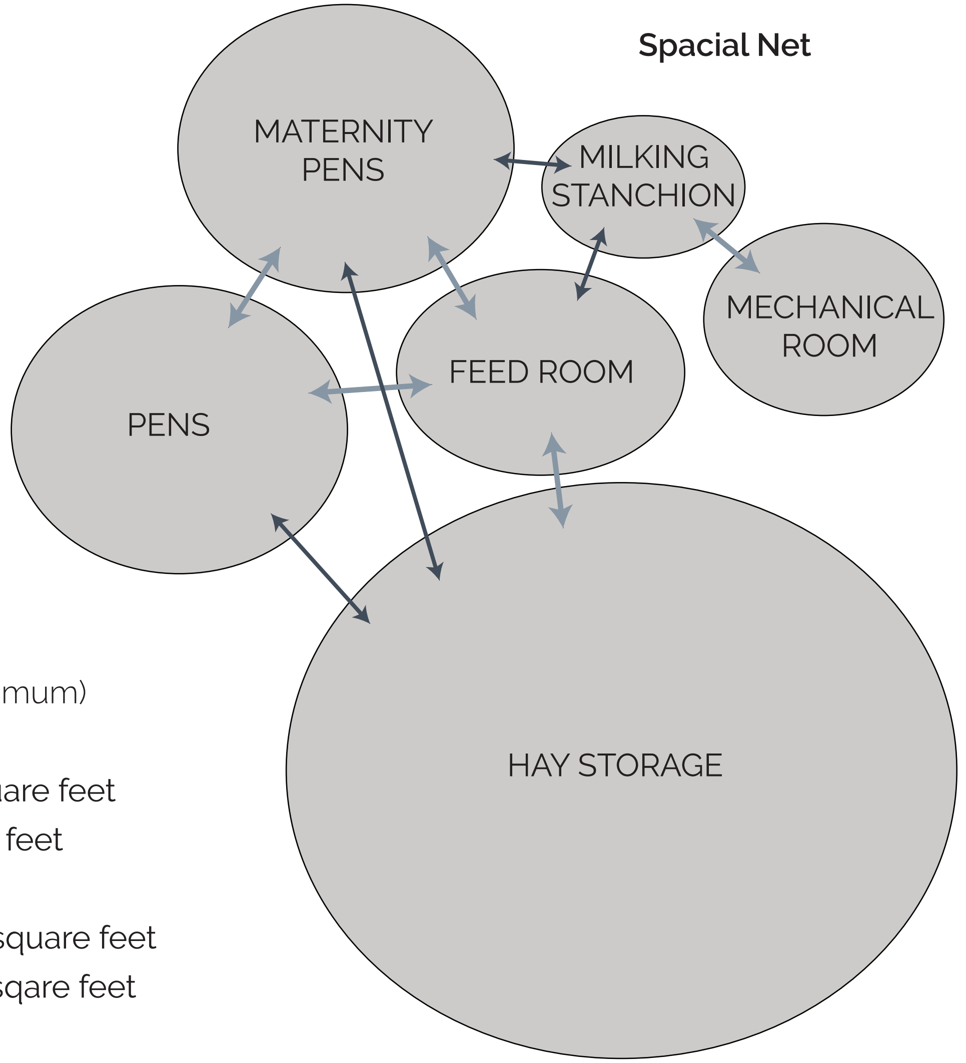
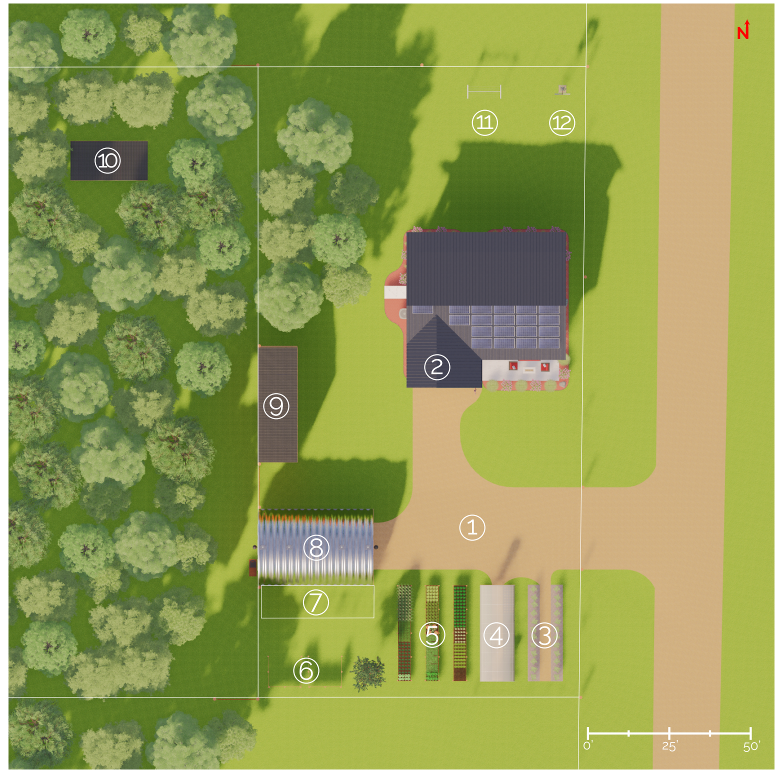


Figure 133

Site Plan

1. Sacrifice Pen
2. Rotation Pasture
3. Yard



1. Driveway
2. House
3. Berry Bushes
4. Hoop House
5. Raised Garden Beds
6. Compost Pits
7. Chicken Run
8. Barn
9. Hay & Storage Shed
10. Livestock Shelter
11. Cloths Line
12. Windmill

Figure 134 - 135

RENDERS

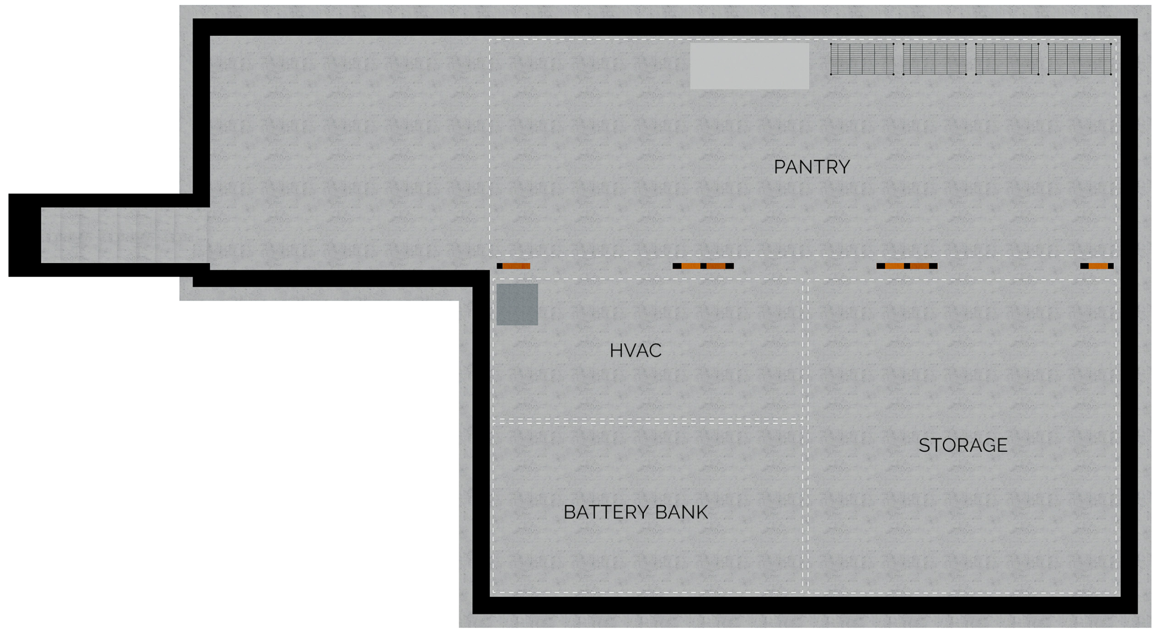
Figure 136 - 139

RESIDENTIAL HOUSE

PLANS

Main Level Plan

Figure 140



Cellar Plan

Figure 141

STRUCTURE

Buck & Beam Straw Bale Construction

Wood framing supports the weight of the roof (opposed to the straw bales carrying the load)

The wood framing is built first, then walls are infilled with straw bales

This method reduces settling issues

R-Value of 36

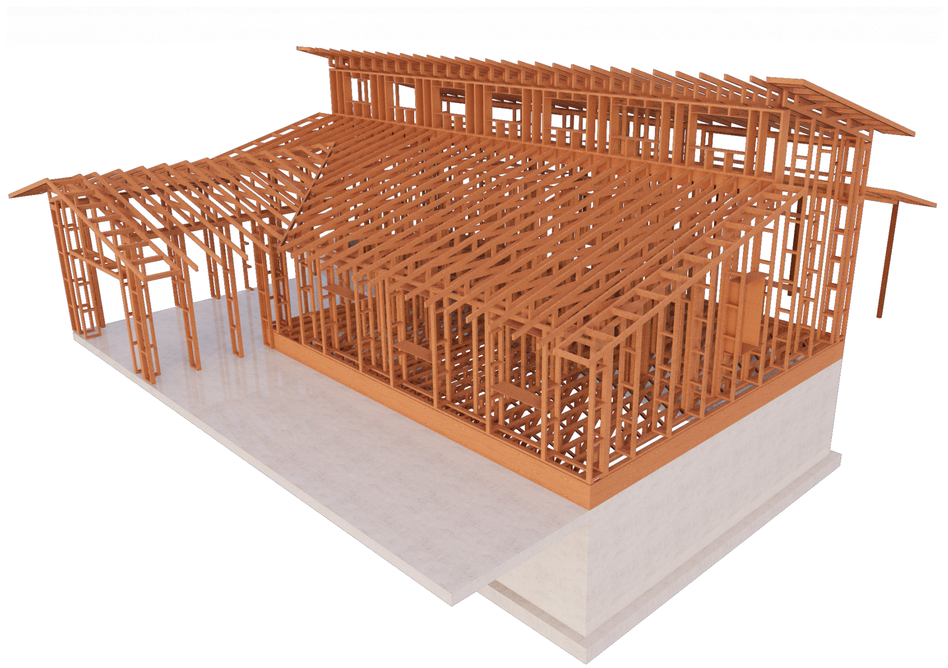
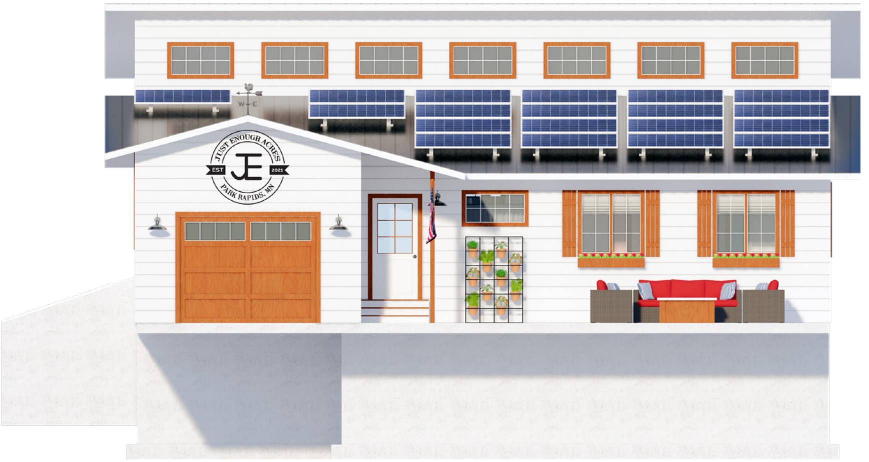


Figure 142 - 145

ELEVATIONS



South Elevation

East Elevation

North Elevation

West Elevation

Figure 146 - 149

SECTIONS

Transverse Section

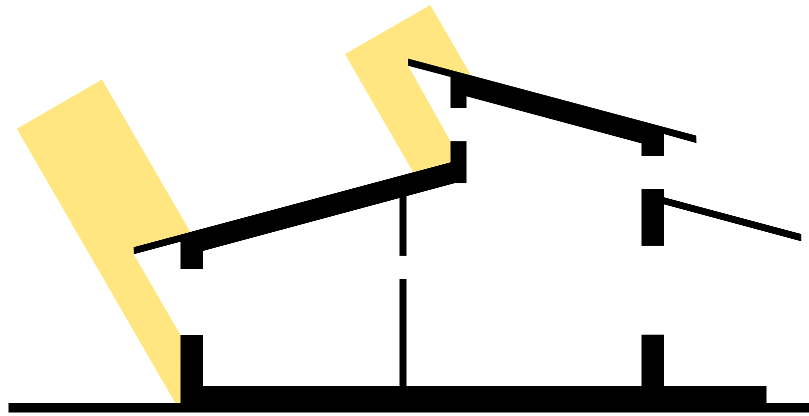
Longitudinal Section

Figure 150 - 151

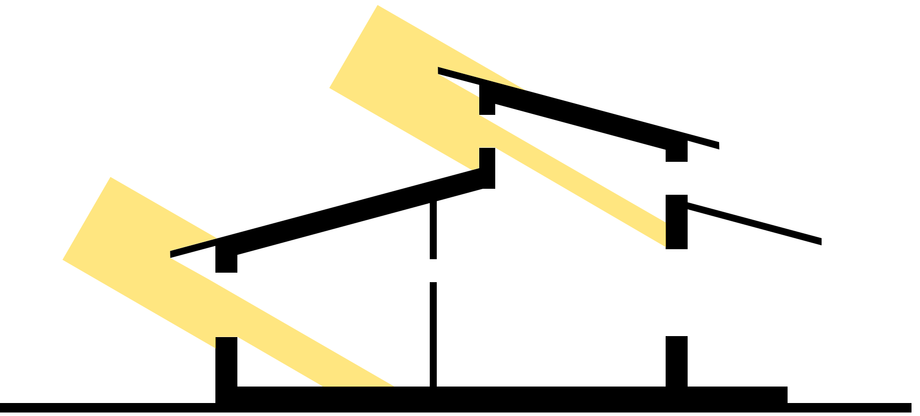
HVAC Solution

PASSIVE HEATING

Summer Sun - Higher than 60˚, April to September



Winter Sun - Lower than 60˚, September to April



PASSIVE COOLING

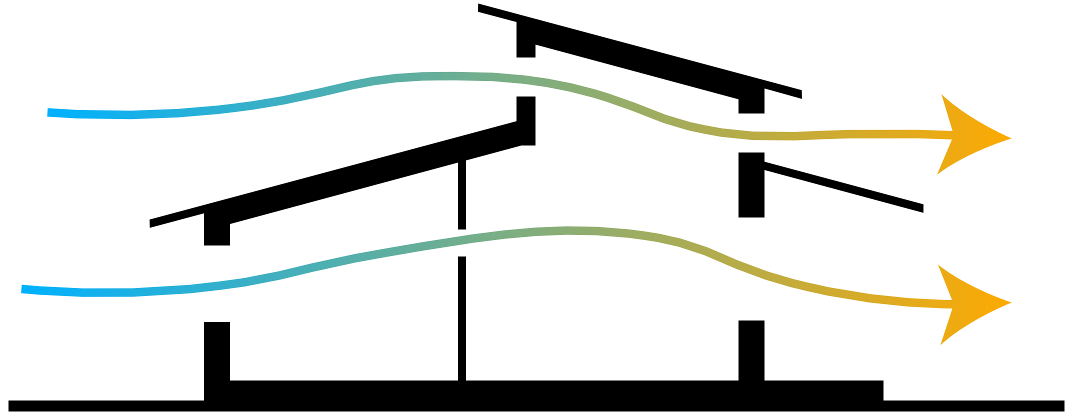


Figure 152 - 154

ACTIVE SYSTEM

Package Unit - Air handling unit will be located in the cellar, and the compressor will be located on the west side of the house next to the exterior cellar door.

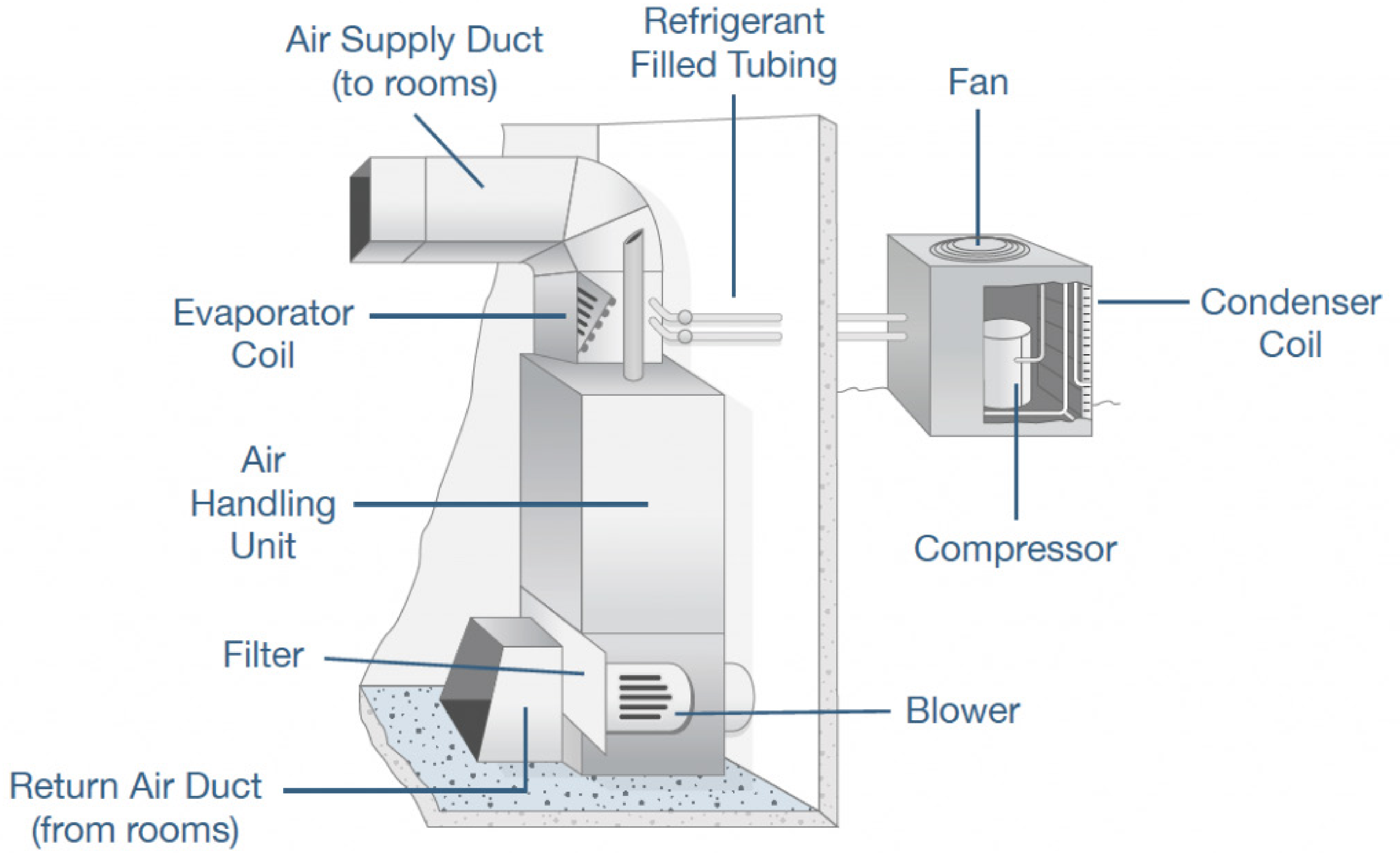


Figure 155

RENDERS

Figure 156 - 161

Livestock Barn

PLAN

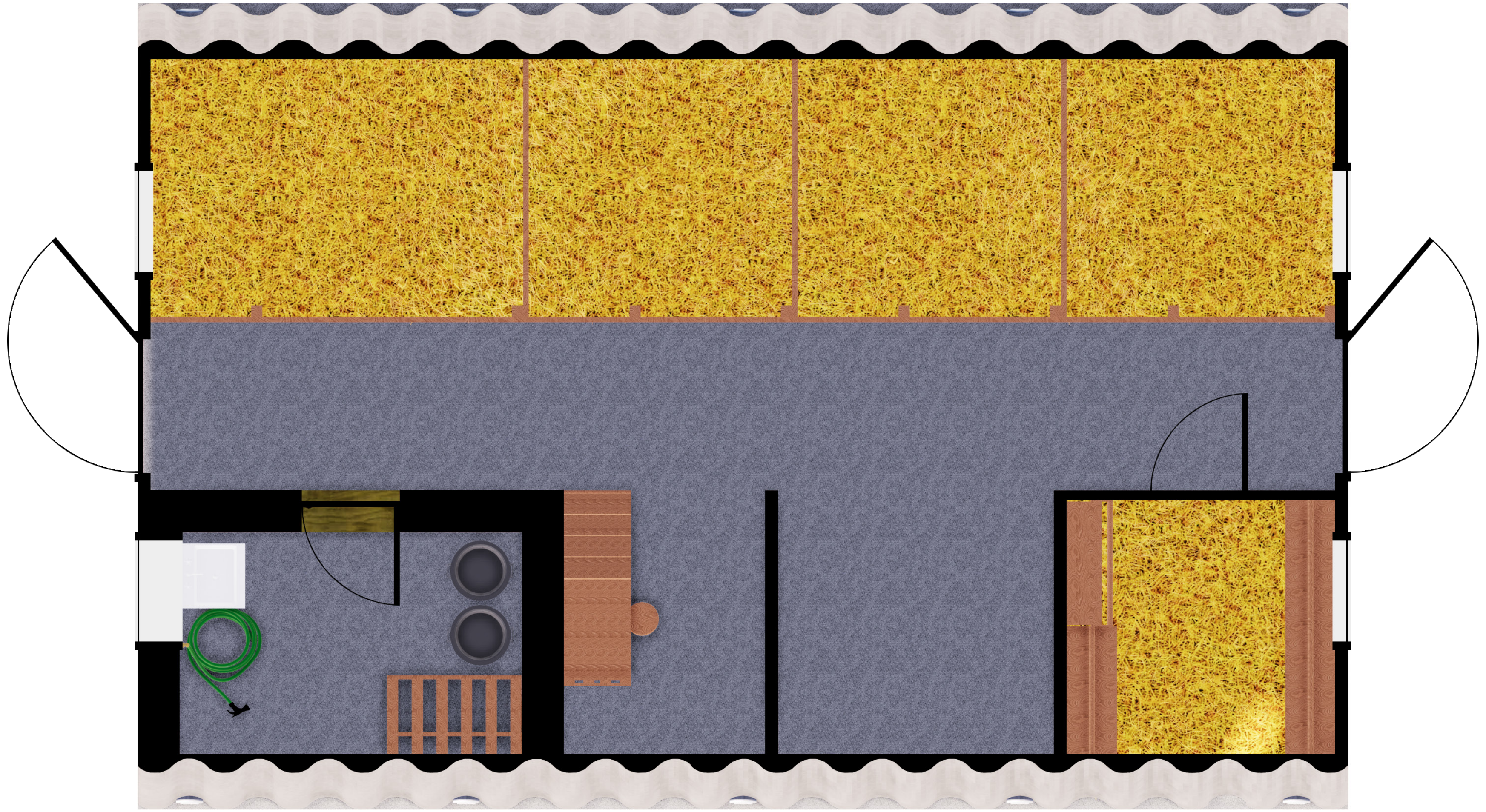


Figure 162

STRUCTURE

Quonset Hut - Double skin system to keep cool in summer months

Traditional Wood Framing - Used to constructed the end walls, uninsulated

Buck & Beam Straw Bale Construction - Used to insulate the feed room, non load bearing

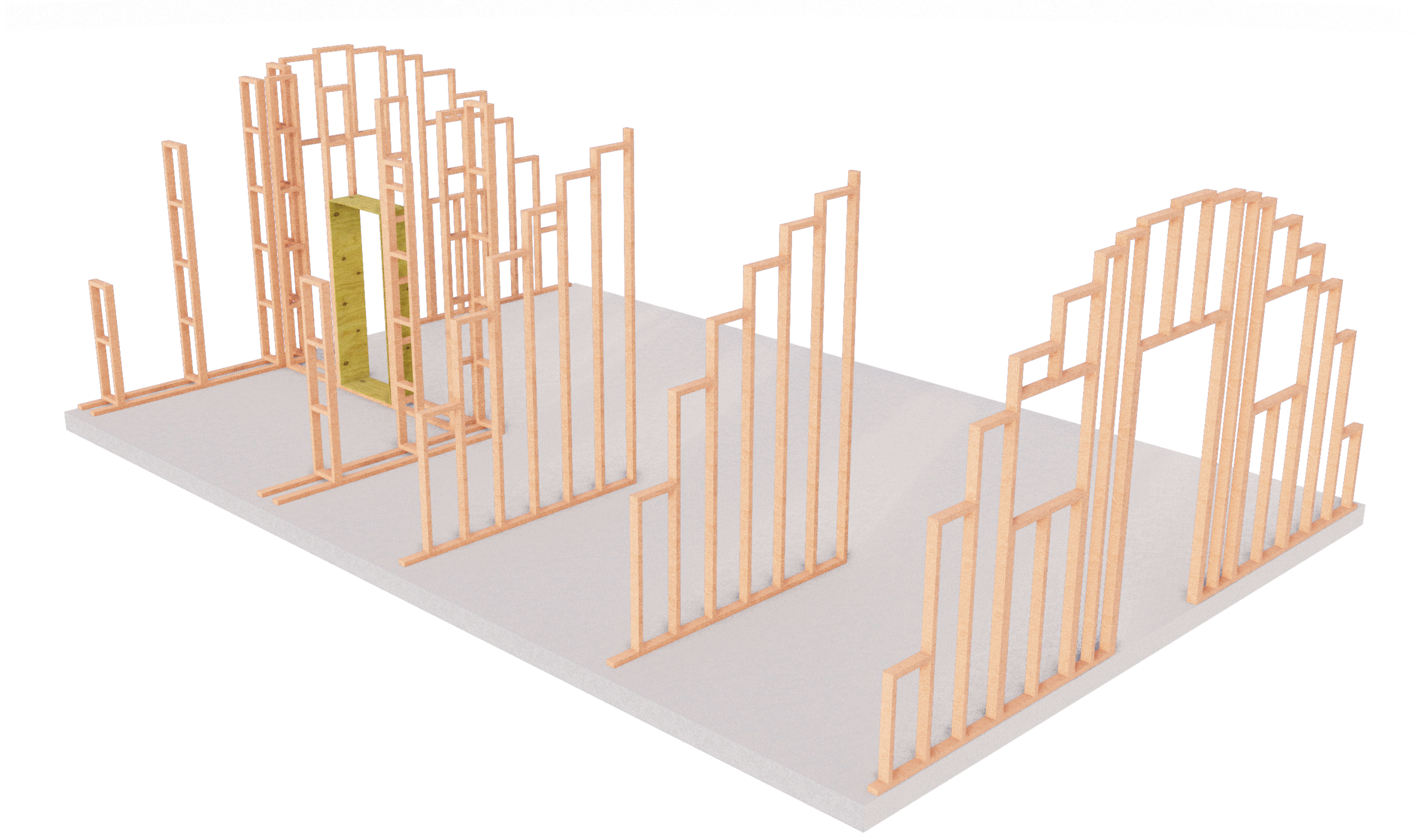
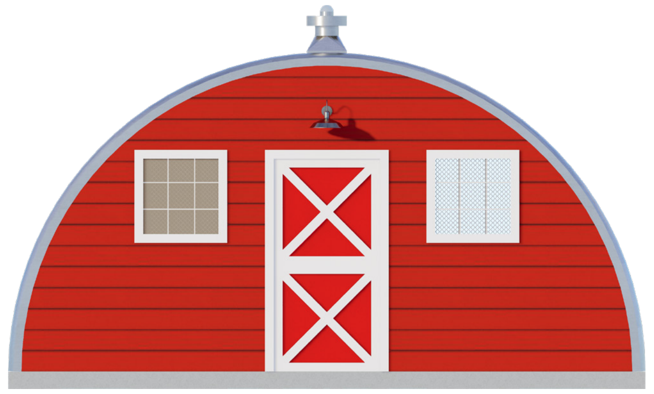
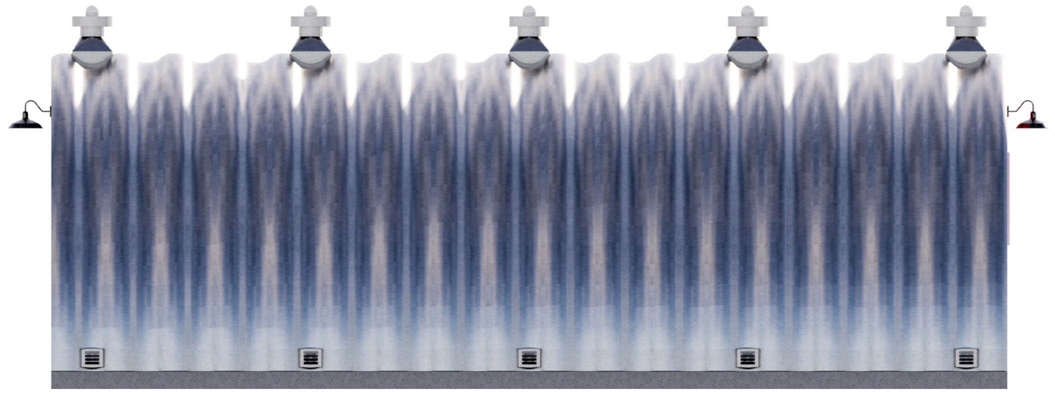


Figure 163

ELEVATIONS

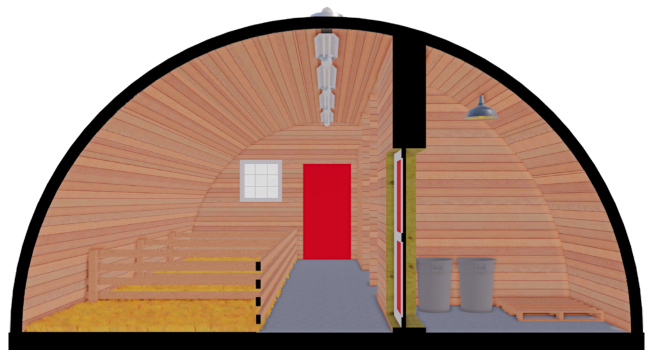


Front Elevation



Side Elevation

SECTIONS



Transverse Section

Longitudinal Section

Figure 164 - 167

PASSIVE COOLING & DAYLIGHTING SYSTEM

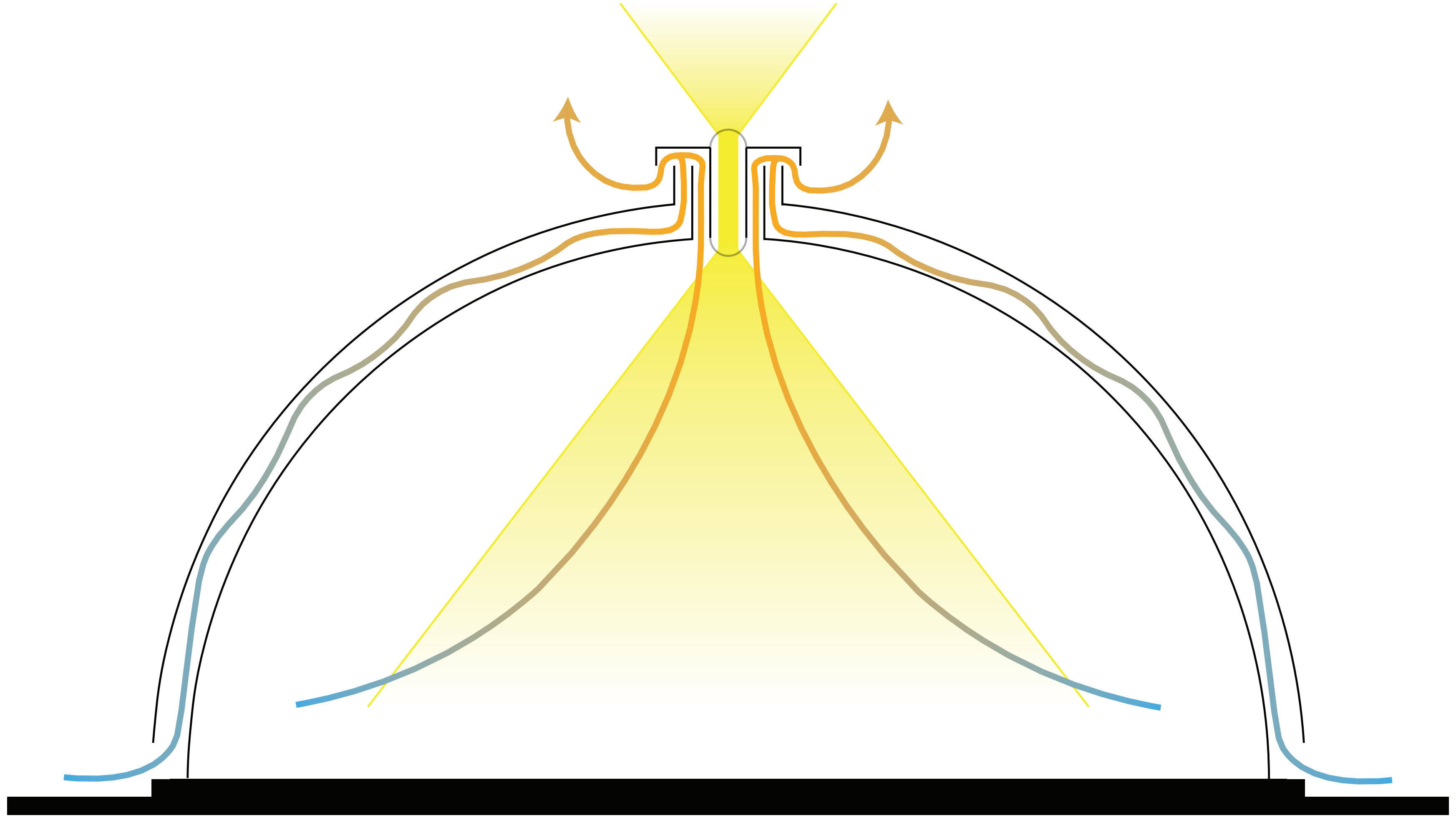


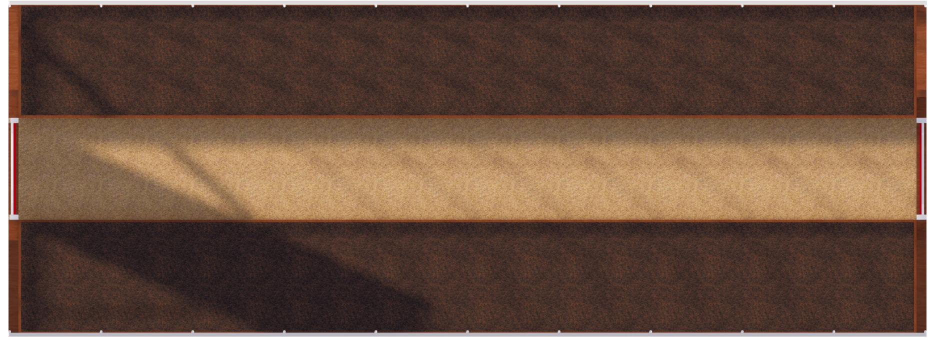
Figure 168

RENDERS

Figure 169 - 173

High Tunnel / Garden Spaces

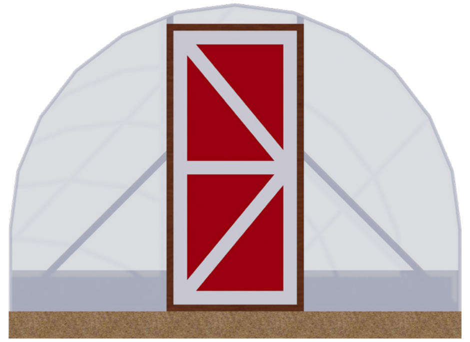
PLAN



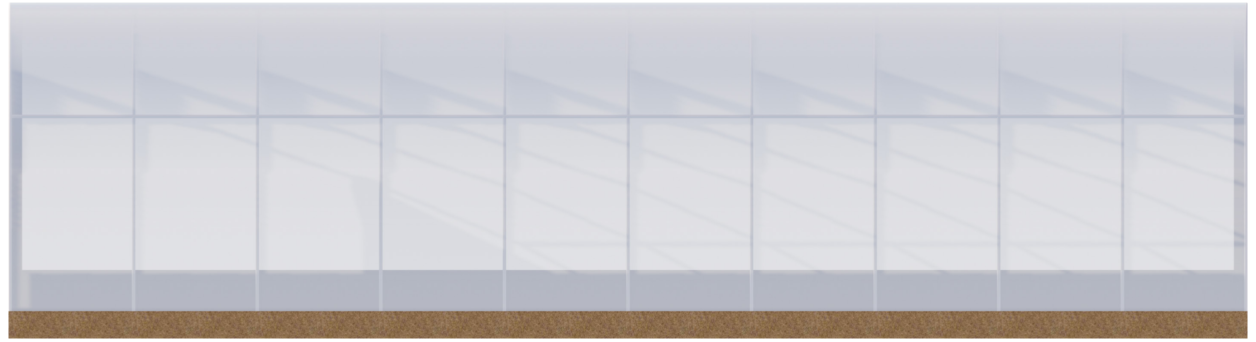
STRUCTURE

Figure 174 - 175

ELEVATIONS

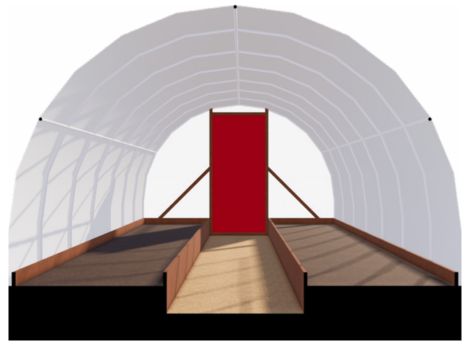


Front Elevation

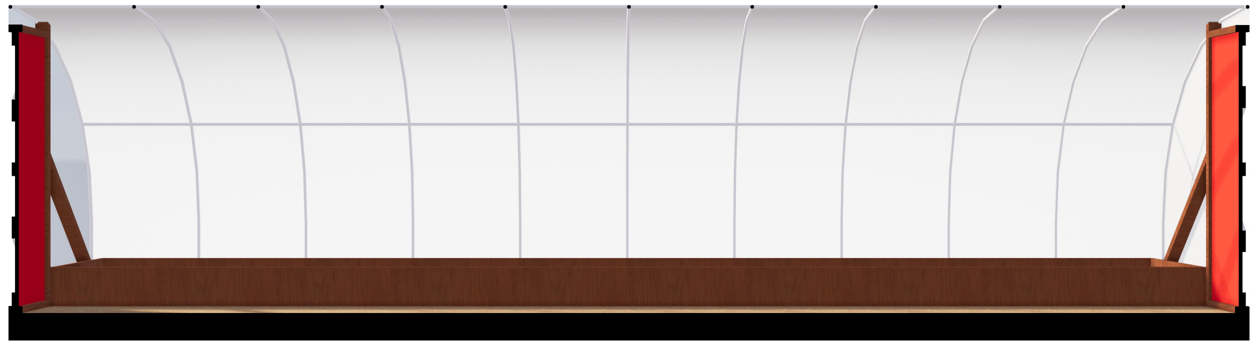


Side Elevation

SECTIONS



Transverse Section



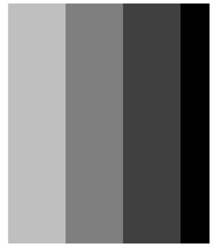
Longitudinal Section

Figure 176 - 179

RENDERS

Figure 180 - 182

Color & Material Palette

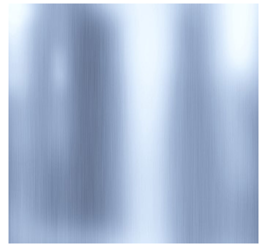


Gray Color Scheme

Used throughout the house

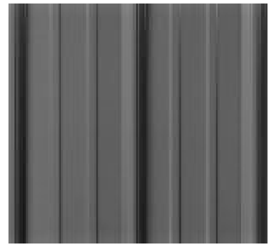
Straw

Used to insulate the house and feed room



Corrugated Galvanized Steel

Used to sheath the quonset hut



Grey Steel Roofing

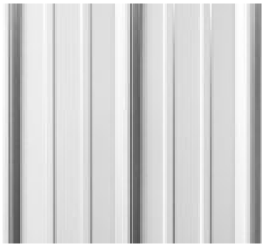
Used to roof the house

Stained wood

Used on trim and wood furniture

Red Painted Wood

Used to side the end walls of the barn



White Steel Siding

Used to side the house

White Hexagon Tile

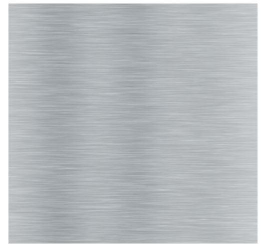
Use in the mudroom, kitchen, and bathroom

Wood Planking

Used on the interior of the barn

Concrete

Used for the house foundation and other on grade slabs



Brushed Silver Metal

Used for fixtures in the house

Figure 183 - 193

Specifications

TWO-WAY SELF-CLOSING GATE LATCH

Two-way self-closing gate latches allow for gates to swing both directions and can be latched by simply swinging the gate shut. This makes opening and closing gates quick and easy with also ensuring that they are secure.

LOW IMPEDANCE FENCE CHARGER

A low impedance fence charge is ideal for pastures with overgrown weeds, large animals such as cows and horses, and animals that have this or woolly coats.

SLOW FEED HAY NET

Slow feed hay nets use small holes in the net to force livestock to eat slowly and prevent hay from being stepped on to minimize waste.

ELECTROBRAID FENCE

An Elecrobraid fence should be used because it has a much higher strength and requires less fence posts than wire fencing. This makes it ideal for pastures with cattle and wooded areas, and reduced to cost of fence posts.

Figure 194 - 197

Analysis

CALCULATING HEATING & COOLING ENERGY CONSUMPTION

The total thermal conductivity (Btu/h ˚F) of the residential house can be calculated by using the equation Q = U x A; where U is the u-value, and A is the area in square feet. Each part of the envelope must be calculated separately then added together to find the overall thermal conductivity. South facing windows should not be included in this calculation.

ASSEMBLY TYPE	U-FACTOR	AREA	Q VALUE
WALLS	0.028	1,630 sf	45.64 Btu/h ˚F
WINDOWS	0.125	232 sf	29 Btu/h ˚F
DOORS	0.167	60 sf	10.02 Btu/h ˚F
ROOF	0.028	948 sf	26.544 Btu/h ˚F
		Q TOTAL:	111.204 Btu/h ˚F

Table 01

Now that the thermal conductivity of the envelope has been calculated to be 111.204 Btu/h ˚F, the heat loss and cooling load (Btu) of the envelope can be calculated by month using the equation E = ((UA)(DD)(24h)) / ((AFUE)(V)); where UA is the total thermal conductivity, DD is the difference between the daily temperature mean and the base temperature of each month, AFUE is the heating method efficiency, and V is the unit conversion from Btu to kWh.

MONTH	HDD65	HEATING ENERGY
January	1,703	1,331.711 kWh
February	1,465	1,145.600 kWh
March	1,134	886.765 kWh
April	752	588.049 kWh
May	339	265.091 kWh
June	96	0 kWh
July	45	0 kWh
August	85	0 kWh
September	247	193.149 kWh
October	720	563.025 kWh
November	1,082	846.101 kWh
December	1,538	1,202.684 kWh
	YEARLY:	7,022.176 kWh

MONTH	CDD75	COOLING ENERGY
January	0	0 kWh
February	0	0 kWh
March	0	0 kWh
April	0	0 kWh
May	10	7.820 kWh
June	28	21.900 kWh
July	51	39.881 kWh
August	25	19.550 kWh
September	6	4.692 kWh
October	0	0 kWh
November	0	0 kWh
December	0	0 kWh
	YEARLY:	93.838 kWh

June, July, and August heat loss set to 0, because although there are HDD in those months, it is unlikely that energy will be needed for heating.

Table 02 - 03

The thermal conductivity and heat loss of the barn can be calculated the same way as the envelope of the house.

Feed Room

ASSEMBLY TYPE	U-FACTOR	AREA	Q VALUE
WALLS	0.028	350 sf	9.80 Btu/h ˚F
WINDOWS	0.125	8 sf	1.00 Btu/h ˚F
DOORS	0.167	20 sf	3.34 Btu/h ˚F
		Q TOTAL:	14.14 Btu/h ˚F

Stock Tank

ASSEMBLY TYPE	U-FACTOR	AREA	Q VALUE
SIDES	0.100	22 sf	2.175 Btu/h ˚F
OPENING	0.990	7 sf	6.435 Btu/h ˚F
		Q TOTAL:	8.610 Btu/h ˚F

Table 04 - 05

Feed Room

MONTH	HDD40	HEATING ENERGY
January	928	92.273 kWh
February	758	75.369 kWh
March	394	39.176 kWh
April	162	16.108 kWh
May	13	0 kWh
June	0	0 kWh
July	0	0 kWh
August	0	0 kWh
September	5	0 kWh
October	113	11.236 kWh
November	374	37.187 kWh
December	764	75.966 kWh
	YEARLY:	347.315 kWh

Stock Tank

MONTH	HDD50	HEATING ENERGY
January	1238	74.955 kWh
February	1039	62.906 kWh
March	676	40.928 kWh
April	355	21.493 kWh
May	78	0 kWh
June	4	0 kWh
July	0	0 kWh
August	1	0 kWh
September	34	0 kWh
October	306	18.527 kWh
November	646	39.112 kWh
December	1074	65.025 kWh
	YEARLY:	322.947 kWh

Some values have been set to 0, because although there are HDD in those months, it is unlikely that energy will be needed for heating.

Table 06 - 07

ESTIMATED ELECTRICAL CONSUMPTION

The overall electrical consumption of the homestead can be calculated by adding the monthly heating and cooling energy consumption with the monthly electrical consumption of appliances used in the house. The appliance electrical consumption can be calculated by using the equation E = (P x t)/1000; where E is the electrical consumption in kWh, P is the power needed by the appliance in watts, and t is the estimated length of time the appliance is used for in hours

Appliance Energy Consumption | House

APPLIANCE	POWER	TIME	ENERGY	COST
Outside Lights (10 watt, x3)	30 W	60.833 h	1.825 kWh	$0.22
Garage Lights (10 watt, x4)	40 W	7.604 h	.304 kWh	$0.04
Garage door opener	400 W	3.802 h	1.520 kWh	$0.18
Mudroom Lights (10 watt, x2)	20 W	7.604 h	0.152 kWh	$0.02
Washer	255 W	21.667 h	5.525 kWh	$0.66
Dryer	2,790 W	7.500 h	20.925 kWh	$2.51
Kitchen Lights (10 watt, x4)	40 W	60.833 h	2.433 kWh	$0.29
Refrigerator	255 W	121.667 h	31.025 kWh	$3.72
Range	3,000 W	15.208 h	45.625 kWh	$5.48
Microwave	1,500 W	3.125 h	4.688 kWh	$0.56
Toaster	1,100 W	3.125 h	3.438 kWh	$0.41
Dishwasher	330 W	60.000 h	19.800 kWh	$2.38
Coffee Maker	1,000 W	6.250 h	6.250 kWh	$0.75
Living Room Lights (10 watt, x4)	40 W	60.833 h	2.433 kWh	$0.29
TV	234 W	50.000 h	11.700 kWh	$1.40
Bathroom Lights (10 watt, x5)	50 W	60.833 h	3.042 kWh	$0.37

Table 08

APPLIANCE	POWER	TIME	ENERGY	COST
Hairdryer	710 W	6.250 h	4.438 kWh	$0.53
Master Bedroom Lights (10 watt, x2)	20 W	15.208 h	0.304 kWh	$0.04
Bedroom 1 Lights (10 watt, x3)	30 W	60.833 h	1.825 kWh	$0.22
Laptop 1	25 W	50.000 h	1.250 kWh	$0.15
Bedroom 2Lights (10 watt, x3)	30 W	60.833 h	1.825 kWh	$0.22
Laptop 2	25 W	50.000 h	1.250 kWh	$0.15
Office Nook Lights (10 watt, x4)	40 W	8.667 h	.0347 kWh	$0.04
Laptop 3	25 W	50.000 h	1.250 kWh	$0.15
Internet Modem	6 W	730 h	4.380 kWh	$0.53
Cellar Lights (10 watt, x8)	80 W	3.802 h	0.304 kWh	$0.04
Freezer	255 W	121.667 h	31.025 kWh	$3.72
Tankless Water Heater	4500 W	30.417 h	136.875 kWh	$16.43
Well Pump	725 W	45.625 h	33.078 kWh	$3.97
		YEARLY:	378.836 kWh	$45.46

Appliance Energy Consumption | Barn

APPLIANCE	POWER	TIME	ENERGY	COST
Outside Lights (10 watt, x2)	20 W	365.000 h	7.300 kWh	$0.88
Lights (10 watt, x8)	80 W	30.417 h	2.433 kWh	$0.29
Coop Lights (10 watt, x1)	10 W	45 h	0.450 kWh	$0.05
Nesting Box Heater	18 W	60 h	1.080 kWh	$0.13
Electric Fence	5 W	730 h	3.650 kWh	$0.44
		YEARLY:	14.913 kWh	$1.79

Table 09

TOTAL ENERGY CONSUMPTION

The energy needed for heating, cooling, and appliances can be added together to find the total monthly energy consumption for the entire homestead.

MONTH	HEATING	COOLING	APPLIANCES (HOUSE)	BARN CONSUMPTION	TOTAL	COST
January	1,331.711 kWh	0 kWh	378.836 kWh	182.141 kWh	1,892.688 kWh	$227.12
February	1,145.600 kWh	0 kWh	378.836 kWh	153.189 kWh	1,677.625 kWh	$201.31
March	886.765 kWh	0 kWh	378.836 kWh	95.018 kWh	1,360.619 kWh	$163.27
April	588.049 kWh	0 kWh	378.836 kWh	52.513 kWh	1,019.399 kWh	$122.33
May	265.091 kWh	7.820 kWh	378.836 kWh	14.913 kWh	666.660 kWh	$80.00
June	0 kWh	21.895 kWh	378.836 kWh	14.913 kWh	415.645 kWh	$49.88
July	0 kWh	39.881 kWh	378.836 kWh	14.913 kWh	433.630 kWh	$52.04
August	0 kWh	19.549 kWh	378.836 kWh	14.913 kWh	413.299 kWh	$49.60
September	193.149 kWh	4.692 kWh	378.836 kWh	14.913 kWh	591.590 kWh	$70.99
October	563.025 kWh	0 kWh	378.836 kWh	44.676 kWh	986.537 kWh	$118.38
November	846.102 kWh	0 kWh	378.836 kWh	91.213 kWh	1,316.151 kWh	$157.94
December	1,202.684 kWh	0 kWh	378.836 kWh	155.904 kWh	1,737.425 kWh	$208.49
				YEARLY:	12,511.267 kWh	$1,501.35

Table 10

SOLAR ENERGY PRODUCTION

To calculate the electricity produced (kWh) by the solar panels the equation E = r x A x t; where r is the solar radiation, A is the total area of the solar panels, and t is the number of days per month.

MONTH	SOLAR RADIATION	AREA	DAYS	TOTAL	VALUE
January	2.36	32 sqm	31	2,341.12 kWh	$280.93
February	3.47	32 sqm	30	3,331.20 kWh	$399.74
March	4.65	32 sqm	28	4,166.40 kWh	$499.97
April	4.70	32 sqm	30	4,512.00 kWh	$541.44
May	4.74	32 sqm	31	4,702.08 kWh	$564.25
June	6.29	32 sqm	30	6,038.40 kWh	$724.61
July	6.52	32 sqm	31	6,467.84 kWh	$776.14
August	6.11	32 sqm	31	6,061.12 kWh	$727.33
September	4.72	32 sqm	30	4,531.20 kWh	$543.74
October	3.11	32 sqm	31	3,085.12 kWh	$370.21
November	2.24	32 sqm	30	2,150.40 kWh	$258.05
December	2.07	32 sqm	31	2,053.44 kWh	$246.41
			YEARLY:	49,440.32 kWh	$5,932.84

Table 11

NET ENERGY BALANCE

The table below compares the energy consumption of the homestead vs the energy produced by the solar panels. For this project, it was important to see if the minimum solar energy produced was greater than the maximum energy consumption to prove that the homestead could be self-sufficient in energy.

MONTH	ENERGY CONSUMPTION	SOLAR ENERGY	DIFFERENCE	PROFIT
January	1,892.688 kWh	2,341.12 kWh	448.432 kWh	$53.81
February	1,677.625 kWh	3,331.20 kWh	1,653.575 kWh	$198.43
March	1,360.619 kWh	4,166.40 kWh	2,805.781 kWh	$336.69
April	1,019.399 kWh	4,512.00 kWh	3,492.600 kWh	$419.11
May	666.660 kWh	4,702.08 kWh	4,035.420 kWh	$484.25
June	415.645 kWh	6,038.40 kWh	5,622.755 kWh	$674.73
July	433.630 kWh	6,467.84 kWh	6,034.210 kWh	$724.11
August	413.299 kWh	6,061.12 kWh	5,647.821 kWh	$677.74
September	591.590 kWh	4,531.20 kWh	3,939.610 kWh	$472.75
October	986.537 kWh	3,085.12 kWh	2,098.583 kWh	$251.83
November	1,316.151 kWh	2,150.40 kWh	834.249 kWh	$100.11
December	1,737.425 kWh	2,053.44 kWh	316.015 kWh	$37.92
YEARLY:	12,511.267 kWh	49,440.32 kWh	36,929.053 kWh	$4,431.49

Table 12

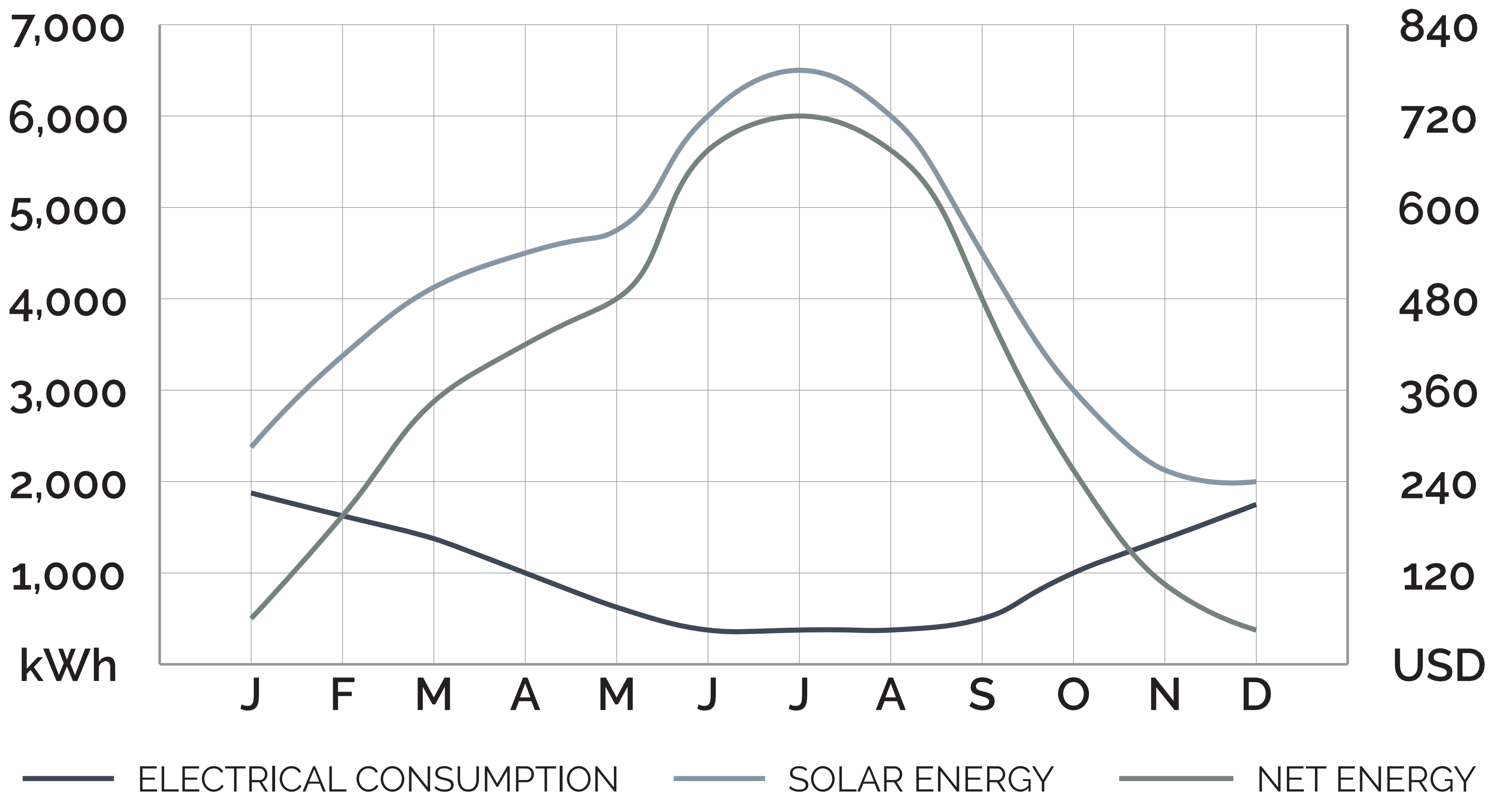


Figure 188

RESOURCE FLOWCHART

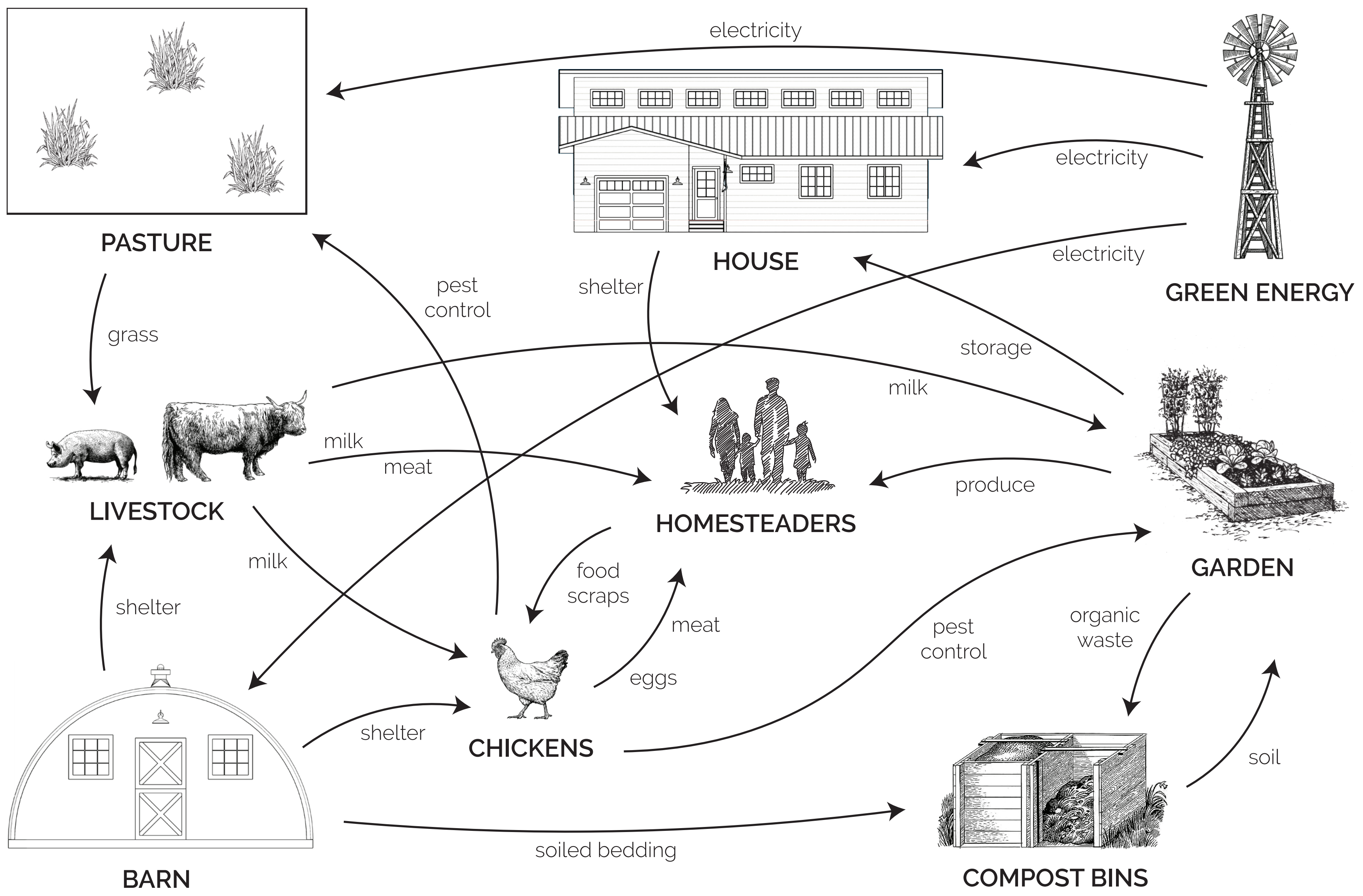


Figure 199

GARDEN INVENTORY

The garden will provide all the fruits and vegetables needed for a year for a family of four. It is a total of 600 square feet; 240 square feet in the high tunnel and 360 square feet in the raised garden beds. The chart above estimates home many plants of each crop should be planted and how much space each crop needs. The estimated total space needed to plant these crops is 587 square feet. As a rule of thumb, you should only plant as much food as you are able to eat within a year. For example, if you can 52 jars of peas, you will need to eat about 1 jar a week. The number of plants per crop can be adjusted to fit the diet of the residence.

CROP	# OF PLANTS	AREA PER PLANT (sf)	AREA PER CROP (sf)
Asparagus	50	1	50
Basil	4	4	1
Bush Beans	198	9	22
Pole Beans	30	6	5
Beets	81	9	9
Broccoli	20	1	20
Cauliflower	20	1	20
Cucumber	15	0.5	30
Pickles	20	1	20
Carrots	96	16	6
Celery	8	4	2
Corn	80	1	80
Chives	9	9	1
Cilantro	5	5	1
Cabbage	24	1	24
Dill	20	1	20
Garlic	72	9	8
Leaf Lettuce	50	2	25

CROP	# OF PLANTS	AREA PER PLANT (sf)	AREA PER CROP (sf)
Melon*	9	0.5	18
Onions	64	4	16
Oregano	1	1	1
Peas	90	6	15
Pepper*	40	1	40
Potato	80	4	20
Pumpkin	4	1	4
Parsley	10	2	5
Rhubarb	4	0.5	8
Rosemary	1	1	1
Strawberries	20	1	20
Summer Squash	3	0.5	6
Winter Squash	10	0.5	20
Sweet Potato*	14	1	14
Thyme	4	4	1
Tomato*	50	1	50
Watermelon*	4	1	4

** should be planted in the high tunnel*

Table 13

TOTAL PRODUCTION

The table below estimates the resources produced on the homestead. To make the homestead more efficient, resources produced on the homestead can be used by the homesteaders or in other parts of the homestead. For example, milk produced by the cows can be used by the homesteaders for drinking and making cheeses, yogurt and other dairy products. Leftover milk and dairy byproducts can be used to fertilize the garden and supplement feed for the hogs and chickens. Some additional resources were needed to support the homestead such as hay, pig feed, chicken feed, and meat bird chicks. These expenses are paid for by the surplus electricity produced by the solar panels.

PRODUCT	SOURCE	YEARLY PRODUCTION	WEEKLY PRODUCTION
Eggs	Chickens (16-18)	3,500 eggs	48 eggs
Poultry	Meat Birds (25)	125 lbs	2 lbs
Milk	Cow (1 Highlander)	730 gal	14 gal
Beef	Cow (1 Highlander)	220 lbs	4 lbs
Pork	Pig (1)	175 lbs	3 lbs
Produce	Garden	587 lbs	11 lbs
Electricity	Solar Panel (342 sf)	49,440 kWh	950 kWh

Table 14

CHORE SCHEDULE

The site was designed so that the garden and barn are close to the house, reducing the amount of time and energy needed to complete chores. The chore schedule changes based on time of year and how often the chore must be done. For example, the stock tank must be filled daily but only during the winter months as an automatic waterer can be used during the summer. The homesteaders can also invest in a heated automatic waterer that can be used year round but is more expensive than a stock tank. Another way to reduce the amount of time spent doing chores is to allow a calf to nurse for half the day and separate the calf from the mother for the other half to reduce the number of milking times per day from 2 to 1.

TASK	LOCATION	SEASON	REPETITION	DURATION
Feed Chickens	Barn	Year Round	Daily	2 min
Water Chickens	Barn	Year Round	Daily	2 min
Collect Eggs	Barn	Year Round	Daily	1 min
Milk Cow	Barn	Year Round	Bi-daily	30 min
Fill Stock Tank	Barn	Winter	Daily	5 min
Feed Pigs	Barn	Year Round	Daily	4 min
Weed Garden	Garden	Summer	Weekly	90 min
Clean Stock Tank	Barn	Summer	Weekly	10 min
Clean Coop	Barn	Year Round	Biweekly	15 min
Hay	Sacrifice Pen	Winter	Biweekly	15 min
Hay	Sacrifice Pen	Summer	Monthly	15 min
Canning/Freezing	House	Fall	Yearly	na

Table 15

EXPENSES

The table to the right estimates the expenses of the resources that can not be produced by the homestead. These expenses can be covered using the profit produced by the solar panels.

PRODUCT	COST
Hay	$1,200
Pig Feed	$750
Chicken Feed	$400
Meat Bird Chicks	$75
Straw	$200
TOTAL:	$2,625

BUILDING COST

The table to the right estimates the costs of the project. Items are listed in order of construction. The site will need to be the first item purchased, followed by the house and barn. The high tunnel and hay shed should be built last as they are less important to the overall function of the homestead.

DESCRIPTION	COST
Site	$21,600
House	$170,000
Barn	$15,000
High Tunnel	$1,000
Hay Shed	$4,000
TOTAL:	$211,600

Table 16 - 17

Conclusion

Just Enough Acres is successful in providing a family of four a sustainable house that is affordable and provides privacy for all members, an efficient barn for caring for livestock, and garden space to provide a year's worth of food for the homesteaders. The estimated building cost of this project is $211,600. Its energy production exceeds its energy consumption, which provides a profit to cover expenses. It takes an estimated 12 hours per week to maintain the homestead, and allows residents to live lives in a modern society. In conclusion, Just Enough Acres meets all of the project goals while making a profit of an estimated $1,800 a year.

Figure 200

The Appendix

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Personal Identification

Macy Miller

Hometown | Park Rapids, MN

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Previous Studio Experience

2ND YEAR

Fall 2017: Milton Yergens
Tea House | Moorhead, MN
Boat House | Minneapolis, MN

Spring 2018: Cindy Urness
Dwelling | Crippled Creek, CO
Birdhouse | Fargo, ND
Mixed Use Building | Fargo, ND

3RD YEAR

Fall 2018: Regin Schwaen
Oscar-Zero Minuteman Missile Visitor's Center | Cooperstown, ND
View Point of the Fjords Competition | Seven Sisters Waterfall, Norway

Spring 2019: Ron Ramsey
Boutique Hotel | Chicago, IL
Native American Art & Cultural Center | Moorhead, MN

4TH YEAR

Fall 2019: Davide Crutchfield
Miami Highrise Capstone Project | Miami, FL

Spring 2020: Paul Gleye
Term Abroad | Brussels, Belgium