SOLAR POWER UTILIZATION AS AN ALTERNATIVE ENERGY RESOURCE FOR DISASTER RELIEF

by

Wael W. Manqerios

A Thesis Submitted to the Faculty of the

COLLEGE OF ARCHITECTURE, PLANNING & LANDSCAPE ARCHITECTURE

In Partial Fulfillment of the Requirements

For the Degree of

Master of Science
Architecture
Design and Energy Conservation

THE UNIVERSITY OF ARIZONA

2017

STATEMENT BY AUTHOR

The thesis titled Solar Power Utilization as an Alternative Energy Resource for Disaster Relief prepared by Wael Manqerios has been submitted in partial fulfillment of requirements for a master's degree at the University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that an accurate acknowledgement of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: *Wael Manqerios*

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Prof. Nader Chalfoun PhD. Date Signed

Chair: Master of Science in Architecture program

Acknowledgements

I am indebted to the people whom I have learned from and to those who assisted me, this is not limited to those named hereafter. First, I would like to acknowledge the impact of all faculty members and colleagues in the College of Architecture at the University of Arizona. I learned invaluable lessons from them.

I must convey my genuine gratitude to the members of my committee for their guidance and support throughout this thesis. I am indebted to my thesis advisor, the committee chairman, and personal mentor, Prof. Nader Chalfoun, for the substantial time, effort spent, and the crucial advice given. I am grateful to Prof. Colby Moeller, for revising the presentation of my thesis, and for the essential knowledge I acquired from him on the subject of renewable energy. And to Prof. Valerie A. Lane, for her constructive assistance and consultations throughout this study. My special thanks to my friend and colleague Rishabh Parmar for his valuable discussions and advice. My friend and colleague Osama Imam whom I learned much from in regards to Photovoltaic systems.

I would like to express my most sincere, genuine gratitude for my wife for the encouragement, support, understanding, and partnership throughout my study and this Thesis. I also wish to extend my appreciation to my entire family. Last but not least, I am grateful to God. Through Him all things are possible. He carried my family and me through this labor amidst a difficult time but carried none the less. Thank you!

Dedication

First and foremost, I would like to dedicate this thesis to my wife, who provides me with all the support I need. To my family; my Mother, my Father and my two sisters who have supported me in every possible way.

Lastly to my newborn daughter, Audrey, who was a big motivation for me to work on this thesis, primarily to establish a better future for her and the next generations.

Thank you all!

Table of Contents

List of Figures

List of Tables

Abstract

The world is facing a significant energy crisis, and it differs from one country to another. Many industries strive to achieve a better greener solution for energy production by using non-depleting sources like the Sun, the wind, hydroelectricity, and geothermal power plants. We find that the most common resource around the world is the sun. And the most common way to collect solar radiation is PV panels, as they are available around the world, relatively easy to install, and many people are already familiar with them.

Global warming, ozone layer depletion, ocean acidification, droughts and heat waves are often associated with climate changing and temperature rising. All of which is playing a significant factor in the new danger we are facing, the natural disasters frequency occurrence hitting several areas simultaneously. The primary challenge happens after a disaster strike is losing electricity because of power lines cut. Loss of electricity leads to many needs going unmet.

Can solar power, along with other environmental strategies, be utilized to replace the use of traditional generators in long-term disaster relief? This research looks at environmental strategies (passive & active) which can make a big difference in the long-term recovery process for people who lost their homes.

The strategies that are discussed can be applied to many long-term structures to help reduce the energy needs in a green environmental way. Energy needs, conservation, and use are the primary focus here as we compare traditional approaches to available innovative environmental approaches in the disaster relief process, mainly in long-term housing. The ultimate goal is to meet people's energy needs after a disaster without harming the environment.

Severe Energy Crisis.

It is recognized, that the world has been facing a severe energy crisis for many years now. Many countries acknowledge the energy crisis, but they have different ways of coping with it. Despite these differences, the world is in need of more green solutions that rely on non-depleting resources for energy use. Even though there are many countries that are considered frontrunners in the clean green energy field, they only represent a small percentage in contrast to the total energy utilization around the world.

In the past ten to fifteen years, natural disasters used to be less frequent and not as aggressive in comparison to the last few years, the question is, Why? The way our global climate has changed is mostly due to greenhouse gas emissions, which are produced day after day by human activities and industries. The increased frequency of natural disasters has been linked to the way modern industries pollute the environment by using non-renewable energy resources. In general, burning any fossil fuel results in toxic gas emissions that are harmful to humanity and the environment.

In the year 2014, the total U.S. greenhouse gas emissions have reached 6,870.5 MMT. (million metric tons) Of carbon monoxide (CO) Eq from fossil fuel combustion. From 1990 to 2014, total U.S. gas emissions have been raised by 7.4

percent, and from 2013 to 2014 emissions increased by 1.0 percent[1]. We have been excessively using fossil fuels in almost all industries, which produce many types of fumes and exhaust that pollute the air. Also, acids and toxins are getting dumped in the ocean as a by-product of using those fuels. Eighty percent of marine pollution comes from "dumping". The scientific predictions of the past became true. The predicted impacts on the environment and the climate that would happen as a result of pollution and waste have arisen beyond levels initially anticipated[2]. As a result, marine pollution, global warming, ozone layer depletion, ocean acidification, droughts and heat waves are all competing factors in the rapid disaster phenomena we are currently suffering from.

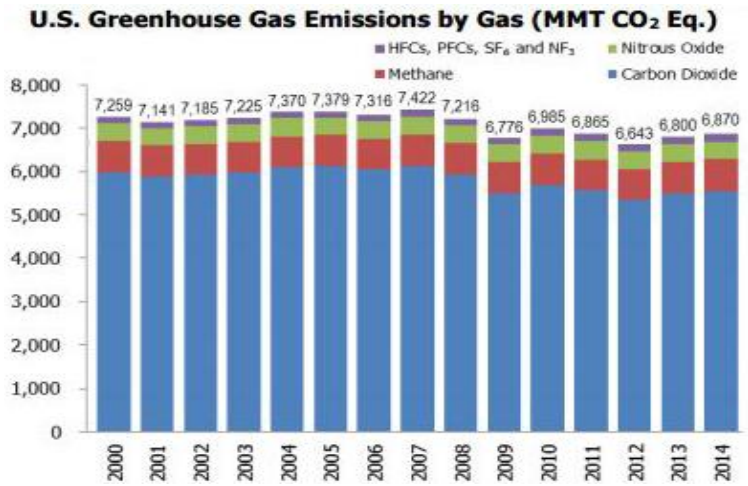


Figure 1: US Greenhouse Gas Emissions by Gas 2000-2014

[1] US Environmental Protection Agency. US Greenhouse Gas Inventory Report 1990-2014. EPA. GOV 16 Nov. 2017. https://19january2017snapshot.epa.gov/sites/production/files/2016-04/documents/us-ghg-inventory-2016-chapter-2-trends.pdf

[2] Krisberg, Kim. "Scientists: 2016 Was Hottest Year Ever Recorded." Nation's Health, vol. 47, no. 8, Oct. 2017, p.11.EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=125529742&site=ehost-liv

Disasters are predicted to be graver, and they are projected to increase in frequency as the climate continues to change globally[3]. Some individuals deny that climate change has occurred and there is global warming affecting our atmosphere. However, it is unrealistic to deny that climatic disasters like tropical cyclones, droughts, heat waves, storms, and hurricanes are clearly related to climatic changes. Changes in temperature, pressure, and humidity are the direct causes of these "natural" events, but man's ignorance of the consequences of industrialization has escalated these climatic changes. Global warming, the loss of sea ice, the accelerated rise in sea level and longer more intense heat waves magnify these changes. The fact that we have a surge in geophysical disasters like earthquakes is irrefutable. The movement of Earth's crustal plates is believed to be escalated by the increase of man's drilling for crude oil[4]. According to NASA, the published evidence shows that the cost to the environment due to climate change is likely to be severe and to increase in the future. Scientists are highly confident about the rising global temperatures, and they predict that it will continue to rise for decades unless global action is taken[5].

[3] Hayden, Thomas. "Super Storms." National Geographic, vol. 210, no. 2, Aug. 2006, pp. 66-77. EBSCOhost, ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=21584330&site=ehost-live.

[4] Richardson, Sarah. "Black Gold from Shaky Ground." American History, vol. 52, no. 1, Apr. 2017, p. 9. EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=120663377&site=ehost-liv

[5] Callery, Susan. Global Climate Change: Vital signs of the Planet. Earth Science Communications Team NASA, 21 Nov. 2017. https://climate.nasa.gov/effects/. Accessed 11 October 2017

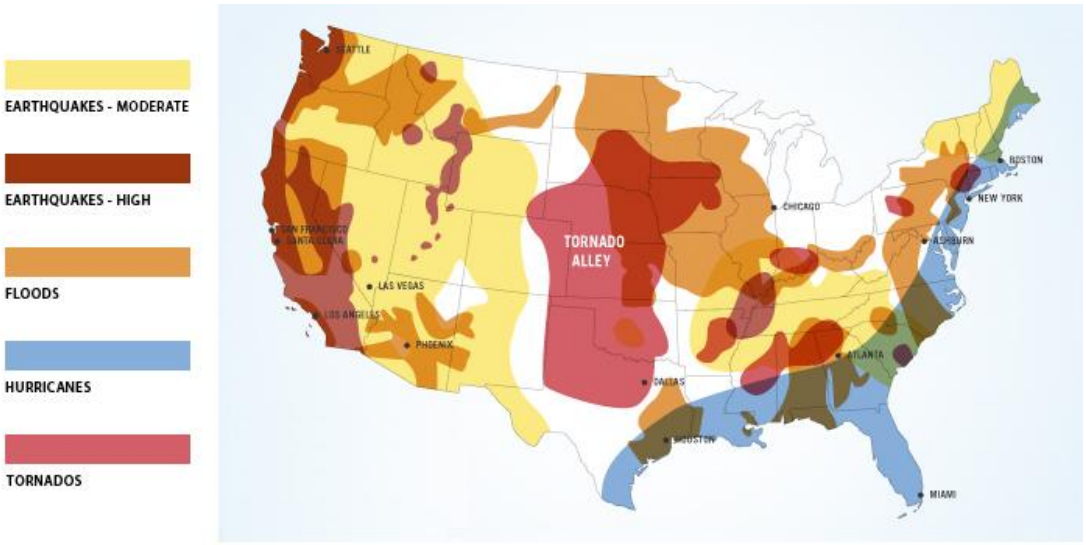


Figure 2: The map overlays Earthquake (both moderate and high risk), Flood, Tornado, and Hurricane risks in the continental United States

We need to reorient our thinking. Part of our mission is to accommodate people's needs after a disaster. The American Red Cross is a renowned First Responders agency. As soon as disaster strikes, they are the first on the scene after local responders. Though their efforts are much appreciated by the community affected and applauded by the rest of the world, the American red cross and other agencies alike have unintended consequences. In the rescue efforts, they unknowingly contribute passively to what caused the disaster initially[6]. When we use depleting resources like gas fuel to aid people's needs for electricity after a disaster, we coextend the negative effect on the environment due to the carbon gas emission that electric generators produce. Based on expert's findings, one way to

[6] American Red Cross. Safe Generator Use. Redcross.org 2017.http://www.redcross.org/get-help/how-to-prepare-for-emergencies/types-of-emergencies/power-outage/safe-generator-use. Accessed Oct. 28 2017.

solve this problem is to reduce the use of fossil fuels, particularly those used in disaster relief such as electric generators, etc. We must take into consideration the long-term savings to the environment despite short-term costs.

Renewable energy resources are available, and they are getting more and more available. Between solar PV panels, wind turbines and other natural resources like geothermal, hydraulic power and underwater current-turbines, the easiest to implement are PV panels. It is becoming increasingly feasible and reliable every day. The PV system is relatively easy to find and install. Using renewable resources will potentially help in two ways. Firstly, it will help stop depleting our natural resources and secondly, it will help reduce the impact on the environment by reducing the carbon gas footprint. Ultimately, this should reduce the frequency and the severity of these disasters.

Natural Disasters and Effects.

Revista Internacional de Direitos Humanos, international humanitarian magazine states, "changing weather patterns and extreme meteorological events mean that an increasing number of communities around the globe are unable to enjoy the full protection of various human rights guarantees including the right to life, food, water, and housing"[7]. Many underdeveloped communities with a minimal carbon footprint, end up suffering the consequences of others more culpable disproportionally. We are going to identify the different types of natural disasters and how they affect the areas and communities they strike.

Earthquakes

An earthquake is caused by an abrupt slide on a fault. The tectonic plates are always slowly moving, but they get jammed at their perimeters due to friction. When the strain on the perimeter overpowers the friction, there is an earthquake that discharges energy in waves that causes the rapid shaking of the earth. Earthquakes are known to be catastrophic and devastating disasters. Not only responsible for the death and displacement of millions of people, but they also may

[7] Salam, Jashim and Khaled Hasan. "The Impact of Climate Change on Humans." Sur: Revista Internacional De Direitos Humanos, vol. 14, no. 25, July 2017, pp. 137-153.EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=126256614&site=ehost-live.

lead to subsequent disasters like aftershocks, tsunamis, landslides, floods, volcanic eruptions, droughts, and wildfires. The majority of deaths by earthquakes are mainly caused because of structure collapse, depleting the affected area from shelter and community buildings[8].

Figure 3: Earthquake Sichuan, China, May 2008 7.9 Richter

Tsunamis

Tidal waves, aka Tsunamis, are very high ocean waves caused by an underwater earthquake, a volcanic eruption, or coastal landslide. Tsunamis start deep in the ocean as a series of waves called the Tsunami wave train. It could last from 5 to 60 minutes, reaching up to the speed of a flying jet and a wave as high as 100 ft. Tsunamis can travel hundreds of miles over the open sea and cause widespread wreckage as soon as it meets land. The record tsunami wave was 1722

[8] US Department of Homeland Security. Earthquakes. Ready.Gov 2017.https://www.ready.gov/earthquakes. Acssessed 8 Nov. 2017.

ft. above sea level occurred in Lituya Bay, Alaska in 1958[9]. Approximately two tsunamis occur every year, and a destructive, wide tsunami occurs every 15 years.

Figure 4: Tsunami Northeastern Japan, Mar 2011. 700 km/hr speed. 125 feet tall.

Floods

Flooding is an overflow of a large amount of water beyond its usual limits, especially over what is typically dry land, most commonly occurring when rivers or streams overflow their banks. Excessive rain, a ruptured dam or levee, rapid ice melting in the mountains, or even a misplaced dam can engulf a river and send it spreading over the neighboring land, called a floodplain. Floods are among the earth's most common and most destructive natural disasters[10].

[9] Geology.com. World's tallest tsunami. Geology.com 2005-2017.http://geology.com/records/biggest-tsunami.shtml. Accessed 8 Nov.17.
[10] National Geographic. Floods information and facts. National Geographic Society 2017. https://www.nationalgeographic.com/environment/

Figure 5: West Yorkshire - Dec/2015 over 16,000 homes in England destroyed

Cyclones

Cyclones are atmospheric vortices with diameters up to hundreds of kilometers and are formed from multiple convective storms. They are Tropical storms that have a maximum sustained wind speed more than 63 km/hr. Depending on the ocean basins, it could be either a hurricane, typhoon, severe tropical cyclone, severe cyclonic storm or tropical cyclone when the maximum sustained wind speed is more than 119 km/hr[11].

natural-disasters/floods/. Accessed 8 Nov 2017.

[11] NOAA. Cyclones, Hurricanes, Typhoons. National Ocean Service 2017. https://oceanservice.noaa.gov/facts/cyclone.html. Accessed 8 Nov. 2017.

Hurricanes

Hurricanes are also tropical cyclones with winds of 74 mph, 119 km/h or higher that occur mainly in the western Atlantic. Hurricanes typically start near the Tropic of Capricorn or Tropic of Cancer. Hurricanes are usually accompanied by rain, thunder, lightning, and sometimes moves into temperate latitudes.

According to NOAA, approximately 85 hurricanes occur worldwide each year. Throughout the Atlantic basin, hurricane Charley caused $16.3 billion. Total damage in the U.S was estimated to be $15.4B and was responsible for 15 deaths[12].

Figure 6: Hurricane Matthew, Category 4, The Caribbean, Oct 2016

Typhoons

Typhoons are developed tropical cyclones that mature in the Northwestern Pacific Ocean. It is a non-frontal storm system that is categorized by a low-

[12] NOAA. Cyclones, Hurricanes, Typhoons. National Ocean Service 2017. https://oceanservice.noaa.gov/facts/cyclone.html. Accessed 8 Nov. 2017.

pressure center, spiral rain bands, and heavy winds. The Northwestern Pacific Basin is the most active tropical cyclone basin on Earth, accounting for nearly one-third of the world's annual tropical cyclones, 25 yearly. Highest wind speed: 215 mph[13].

Twisters & Tornados

Tornados or Twisters are atmospheric vortices with diameters that are hundreds of meters wide constructed by a single convective storm that occurs almost entirely over land. They are a strong column of air that revolves and travels over land at devastating speeds. Their sizes can range from few yards to several hundred meters in diameter. Tornadoes are downward spirals curtailing from a cumulonimbus cloud and are often adjunct to rain or hail[14].

Figure 7: Tornado in City of Wray, Colorado May 7, 2016

[13]NOAA. Cyclones, Hurricanes, Typhoons. National Ocean Service 2017. https://oceanservice.noaa.gov/facts/cyclone.html. Accessed 8 Nov. 2017.
[14] Department of Homeland Security. Tornadoes. Ready.Gov 2017. https://www.ready.gov/tornadoes. Accessed 8 Nov 2017.

Landslides

Mudslides, Rockslides, Avalanche are all types of landslides. Landslides are masses of rocks and other earthy material that is falling or has fallen down a hillside or other slope. Landslides are caused by the rock becoming unstable and unable to support their current position. Heavy rainfall, snowfall, and earthquakes are common causes of landslides. It is estimated that in the United States, they cause damages passing $1 billion and also cause from about 25 to 50 deaths each year[15].

Figure 8: Bluebird Canyon, Laguna Beach, June - 2005

[15] Department of Homeland Security. Landslides. Ready.Gov 2017. https://www.ready.gov/landslides-debris-flow. Accessed 8 Nov 2017.

Wild Fire

Wild Fires are uncontrolled fires in areas of bushes, shrubs, or brush, similar to a forest fire and it consumes dry plants, shrubs, and bushes very rapidly and with unchecked force. These uncontrolled fires can gain entry to residential areas causing hundreds or thousands to be displaced temporally or permanently from their homes. The US Department of Homeland Security announced that wildfire-fighting costs for 2017 are projected to run roughly $2 billion nationwide[16]. All disasters will be treated equally; as the recovery response comes at a late stage when people are removed away from hazard to a safer zone.

Figure 9: Northern California wildfires - Oct 2017 burned at least 245,000 acres.

[16] Department of Homeland Security. Wildfires. Ready.Gov 2017. https://www.ready.gov/wildfires. Accessed 8 Nov 2017

Focus Effect: Prolonged Power Outage

All of these disasters are devastating to humanity and the communities that they affect. When disaster hits, electricity is usually the first imperative service lost. High winds or unstable ground, break down power lines. Weeks or sometimes even months can go by before a reliable electrical connection is reestablished, depending on the amount of destruction the power company has to weed through. None the less, the effects are overwhelming.

As a result, lights go out and all electric appliances stop working causing exposure to extreme heat or cold. Lack of refrigerators creates a scarcity of food. Electric pumps that aid in delivering drinking water fail. Contaminated water goes untreated, causing outbreaks of diseases. Crucial needs go unmet without electricity for homes, hospitals, food stores and vital municipal services[17]. The absence of electricity also creates a loss of communication, leaving many in dangerous or helpless situations. Traditional responses offer fuel generators to aid people during their recovery period. But in this study, the energy needs will be addressed using environmental approaches, during the recovery phase which could last between 6 to 9 months and up to 12 months sometimes. To implement those solutions, we need a basic shelter to apply the environmental strategies to. There are several factors to be considered in order to build and deploy this shelter. The

[17] National Renewable Energy Laboratory. Counting on solar power for disaster relief. US department of Energy, 1999. https://www1.eere.energy.gov/femp/pdfs/26042.pdf. Accessed 8, Nov 2017.

period of residency, type of building, climate and region that the shelter will be deployed to are all factors that need to be defined in order to design the shelter efficiently.

Factors of the Recovery Response

Climate & Region:

According to the Köppen Climate Classification System, the earth is divided into diverse climate zones; Cold Climate, Dry Climate, Tropical Climate and Temperate Climate[18]. It is imperative that we establish what climate zone the disaster took place in, in order to determine the environmental strategies that will be used to passively cool or heat the shelter. These strategies will significantly reduce the need for energy that would usually be designated for cooling or heating.

Climate Zones	environmental strategies	Orientation	Building Shape	Natural Ventilation	Rainwater Harvesting	Hot Water Solar System	Raised Floor	Green house effect	PV
Cold		X	X	_	X	X	_	X	X
Dry		X	X	X	_	X	X	_	X
Tropical		X	X	X	X	X	X	_	X
Temperate		X	X	X	X	X	X	X	X

Table 1: Climate zone in relation to environmental strategies.

[18] ISC Audubon. The Köppen climate classification system. The Sustainability Council Org 2017. www.thesustainabilitycouncil.org/resources/the-koppen-climate-classification-system/. Accessed 10 September 2017.

Cold Climate

The Cold Climate zone has three sub-climates; Tundra, Boreal Forest and Highland Sub-climates. The Tundra sub-climate has freezing temperatures all year long due to the little or absent daylight in winter. The snow and atmosphere in this area reflect insolation back to space. This area also tends to be covered by permafrost and puddles due to poor absorption after rain.

The Boreal Forest climate areas are always cold and dry with short summers. For six months, the average temperature drops below freezing. Vegetation is scarce in the Boreal forest climate because of the harsh conditions. There are some shrubs, but most plants are evergreen trees like pine, white spruce, hemlock and douglas fir. The summers are warm, rainy and humid.

The Highland sub-climate is primarily made up of areas like the highest elevation of the Sierra Nevada Mountain Range with temperatures that vary depending on latitude, elevation, and direction of exposed areas. Winter can last from October to May in these regions and summer may last from June to September. The temperatures in the Highland sub-climate can also change from warm to freezing in one day.

Dry Climate

The Dry Climate zone is composed of two sub-climates; Dry Tropical and Dry Midlatitude climates. The Desert sub-climate has typically hot days; however, there are significant fluctuations in the temperature during the day and the temperature at night. Also, this sub-climate has only less than 10 inches of rain per year. In the desert sub-climate, many animals are nocturnal, and the vegetation has protections against dehydration. Dry Mid-latitude sub-climate is usually found between the desert and the forest. This sub-climate has hot to moderate temperatures but only gets between 10 and 30 inches of rain per year. Evaporation in that area exceeds the precipitation. However, there isn't much humidity in the air because this area is located away from the ocean and close to mountain barriers.

Tropical Climate

The Humid Tropical climate zone is made up of three sub-climates; Tropical Moist, Wet-dry Tropical, and Mediterranean sub-climates. The Tropical Moist sub-climate is the closest to the equator and contains the tropical rainforests. This sub-climate is hot and rainy throughout the entire year. Scientists estimate that more than 50% of all the world's flora and fauna species live in tropical rain forests. Tropical rainforests produce 40% of Earth's oxygen.

The Wet-dry Tropical sub-climate borders The Inter-Tropical Convergence Zone and includes the savannas around the world. This climate is hot with wet and dry seasons throughout the year. There are numerous kinds of savannas worldwide.

The Mediterranean sub-climate is portrayed as being very hot and mid-humid. The terrain in these areas is commonly flat plains, rocky hills, and mountain slopes. The area around the Mediterranean ocean is an excellent example of this sub-climate.

Temperate Climate

The Temperate climate zone has two sub-climates; Continental and Dry Midlatitude Climates. In the Continental climate, the average annual temperature is 50° F. The average rainfall is 30 to 60 inches a year. This sub-climate has four distinct seasons, spring, summer, autumn, and winter. An excellent example of this sub-climate is the eastern half of the United States.

The vast grassy plains of the mid-western United States are a great example of the Dry Midlatitude Climates. In the winter, temperatures can be as low as -40° F, and in the summer it can be as high, 70° F. The rainfall is so inconsistent that drought and fire thwart large forests from developing. Rainfall average per year spans from 10-30 inches or 25-60 inches depending on the particular area.

Climate & Region impact

The design of any shelter should always reflect the type of climate that the shelter is in. For example building orientation, building shape, envelope area and materials should be factors mainly depending on what climate and region the shelter will be sent to. These environmental strategies are most effective when they all work together to heat or cool the building passively.

In this study, we will see examples of the immense effect of climate on how the environmental strategies can be employed to naturally optimize the human thermal comfort in the shelter. Which in turn significantly reduce the need for any artificial methods people would normally use to stay cool or warm interiorly.

Building Type & Community Space

The community's needs are not just for housing shelters. For example, classes for school, churches and clinics are all vital buildings for any community. Environmental strategies can still be implemented in all these spaces, but the main focus here will be on housing and shared community space.

Period of Residency

Based on the need, whether it is temporary or permanent, the period of residency should be evident in the assembly and material of the building. Period of Residency is decided by discerning the amount of time we have to provide aid and how provisional the shelter should be. Based on that, the new shelters and buildings will be designed and executed.

Period of Residency	Environmental strategies	Orientation	Building Shape	Natural Ventilation	Rainwater Harvesting	Hot Water Solar System	Raised Floor	Green house effect	PV
Temporary		_	_	_	_	_	_	_	_
Long-Term		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Permanent		X	X	X	X	X	X	X	X

Table 2: Period of residency relation to environmental strategies.

Temporary

After a natural disaster occurs, people and families who are affected are left in great need of essentials in order to survive. Whether it's an earthquake, flood, tsunami, tornado, or hurricane; shelter is always the number one priority after a disaster. It is also understood that in the midst of a disaster the need for a quick, reliable, and durable temporary shelter is a necessity, which can be in the form of a tent or any structure built with the understanding that it will be used only for a limited short time.

Figure 10:A temporary quick ready-to-assemble Disaster Shelter.

Long-term

A long-term shelter is one that will be utilized for a longer significant period with more amenities than a tent or a purely provisional structure. This shelter will provide housing during the time that a permanent residence is being built or repaired. Unlike temporary shelters, long-term shelters should have more integrity to their structure, yet have some flexibility and adaptability to different environments. The goal of this research is to raise awareness of available environmental means and strategies that can be implemented in the long-term disaster relief which should lead to developing innovative environmentally enhanced prototypes. These strategies will address the critical issue of energy need, conservation, and use. Climate, building type and period of residency in correlation to other aspects will contribute to providing an environmental approach to the disaster relief.

Figure 11: Emergency wooden habitat.

Traditional Disaster Response

Governmental and NGO Responses

Since World War II, Governmental agencies like the Department of Homeland Security have established emergency management plans to prepare for and manage all types of emergencies. Emergency management concentrates mainly on preparedness. Non-Governmental Organizations (NGO) follow the same basic principles. However, they have a belief system that sets them apart from the government response, and that difference varies per organization. NGOs receive funding from private donors and organizations and could even receive funding from the government. When they receive funding from the government, they are not government controlled. Community preparedness for all disasters requires developing expertise and identifying resources in advance and organizing how

these can be used in a disaster. However, preparation is only one of the four phases of emergency management. Present-day thought defines the four phases of emergency management as mitigation, preparedness, response, and recovery[19].

A. Mitigation

Mitigation is preventing hazards from progressing into more prominent disasters by eradicating or diminishing risks and preventing emergencies and lessening their effects, which includes any activities that prevent an emergency, reduce the chance of an emergency happening, or reduce the damaging effects of unavoidable emergencies. Mitigation activities should occur before and after emergencies, but mainly should be contemplated long before an emergency arises.

B. Preparedness

Preparing to manage an emergency includes making plans or preparations to save lives. These measures include emergency plans and chain of command. There should be coordination of all agencies involved to help response and rescue operations. Preparedness activities take place prior to an emergency. This includes developing plans for what to do, where to go, and whom to call for help.

[19] Department of Homeland Security. Emergency Management. Fema.gov 2017https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjVn4Lap93XAhVR-2MKHf_iAL4QFggtMAA&url=http%3A%2F%2Fema.ohio.gov%2FDocuments%2FCOP%2FThe%2520Four%2520Phases%2520of%2520Emergency%2520Management.pdf&usg=AOvVaw16KHo6AUSPM8BZIUVqTXNR. Accessed 22 Oct, 2017.

Displaying emergency phone numbers, arranging emergency drills and preparing evacuation strategies are all examples of preparedness measures.

C. Response

The Response is the first round of basic emergency services, like firefighters, medical squads, and police. Responding to an emergency includes actions taken to save lives and prevent further property damage. The Response is not limited to waiting for the first responders to help. The Response is also putting preparedness plans into action. Standing in a door frame during an earthquake and seeking shelter from a tornado are both examples of response activities. These actions can save lives. The ability to act responsibly and safely will determine the outcome for the individual, their respective families, and their community.

D. Recovery

The goal of a recovery plan is to help restore the affected area to its original state. Recovering from a disaster includes measures taken to revert to a normal or an even safer situation. Recovery also includes securing financial assistance to help pay for the repairs or rebuild. All recovery activities take place after an emergency. During this phase, the individual is charged with rearranging their life and environment which can take anywhere from 6 - 9 months or sometimes a year, depending on the amount of damage, insurance, and income. A focus in this study will be on using available environmental strategies passively and actively by

implementing them into variable designs to accommodate people needs during the recovery phase.

Some of the leading NGOs

- International Red Cross
- Direct Relief International
- MAP International
- The United Nations Foundation
- OXFAM
- Americares
- All Hands

Have any of the governmental disaster relief agencies completely switched over to utilizing solar power in their disaster relief shelters? Unfortunately, there is no governmental organization that has entirely turned to solar power. On the other hand, there are few NGOs who are experimenting with solar panels, but still on a small scale. Not enough precedents have been documented and analyzed. One of the reasons is that very few organizations utilize the long-term recovery. They are busy focusing on the short-term/ immediate relief to aid as quickly and as many people efficiently as possible and make the situation safe. The few organizations that do aid in the recovery stage do so in the traditional ways because they believe it is the most cost-effective and fast way to provide assistance. Long-term planning may actually be more helpful and economically desirable.

Example of Traditional Responses

Department of Florida Disaster Preparedness and Relief

Program Overview

The program lists a group of procedures and protocols in case of a disaster. There is a local commander who assigns a relief officer and a relief coordinator. The components of their Emergency management plan are as follows; Planning for portable housing with beds, providing Emergency Power and first-aid equipment, deploying on-call trained emergency personnel, communication equipment, and vehicles. These are all activated during the response and recovery phases of their management plan. Out of the whole Emergency Management plan, the focus is on two main components; Planning for portable housing with beds and Providing Emergency Power. As part of their statewide recovery phase, Florida Disaster Preparedness and Relief Program promises to provide financial relief of $500.00 to people who lost their homes in a disaster. They also offer a 50% rebate of the cost of a Power Generator. With this allowance, the generator can only cost between $500.00 and $1000.00 maximum. Considering the theory that a generator with a rating below 5000 running watts (approx. $500 retail) will be too small and a generator about 8000 running watts (approx. $1000 retail) would be more than enough power. The actual expected cost according to the program would be around

$1000. Any generator above this will lead to a costly commercial category of generators and the use of more energy than would be needed. The following is a list of suggested equipment for the shelter provided by the Department[20].

List of suggested equipment by the state:

Equipment	Running Watts	Count	Total watts /Day
Light bulbs	60 watts	10	3,600
Refrigerator/Freezer	700 watts	1	16,800
Micro Wave Oven	625 watts	1	1,875
Electric Stove	2100 watts	1	6,300
Coffee Maker	1000 watts	1	2,000
Color TV 27"	500 watts	1	3,000
Copy Machine	1600 watts	1	1600
Central A/C	3800 watts	1	68,400
Furnace Blower	800 Watts	1	103,575 Watts/Day
	11,125 W	**11,725 W**	

Table 3: Suggested shelter equipment provided by sate of Florida.

Generator Fuel Consumption

A typical 5,000-watt generator engine will burn about a gallon/ hour. Assuming that the average gasoline price is $2.623 per gallon

24 hours x $2.623 gal = $62.952 per day.

[20] Florida Division of emergency management. Recovery. Floridadisaster.org 2017. https://www.floridadisaster.org/recovery/. Accessed Oct. 17 2017.

The average cost will be around $63 per day to keep this generator running. Which means $63 x 30 days = $1,890 per month for fuel alone.

Not taking into consideration the rise and fluctuation in fuel prices.

Assuming the recovery period takes 6 to 9 months, it will cost between $11,340 to $17,010 NOT including maintenance or repairs which could vary between $235 and $600 for each time. These calculations are all based on a 5k watt generator.

Generator Hazards

Fuel Generators are dangerous for human health. During combustion, a generator produces Carbon Monoxide. Carbon monoxide (CO), is an odorless, colorless gas, which may cause sudden illness and death, is produced any time a fossil fuel is burned. CO can build up indoors and poison people and animals who breathe it[21]. *Fox news wrote: "In Central Florida, three people were found dead inside an Orlando home from apparent carbon monoxide poisoning… Further north in Daytona Beach, police said one person died, and three others were being treated at a hospital for carbon monoxide poisoning from an electric generator"*[22]. These occurrences were reported after Hurricane Irma and regretfully have started

[21] National Center for Environmental Health. Carbon Monoxide Poisoning. Center for Disease Control and Prevention 2017.https://www.cdc.gov/co/faqs.htm. Accessed 27, Nov. 2017.
[22] Travis Fedschun, Nicole Darrah. 8 dead due to intense heat, loss of power at Florida nursing home after Irma.Fox News 2017. http://www.foxnews.com/us/2017/09/13/5-dead-120-evacuated-from-florida-nursing-home-due-to-intense-heat-loss-power.html

to become a routine, due to the frequency that fossil fuel appliances are used in everyday life. The CDC reports an average of 400 accidental carbon monoxide deaths per year[23].This is a trend that is not only hazardous to humanity but to the environment as well. Electric generators need periodical maintenance and they can be hard to fix when they break down. Another problem, it is necessary to shut down the engine every time to refill the tank, change the lubricating oils or any parts of the generator. If the fuel becomes unavailable or too pricey, the generator becomes useless. Electric generators are big, heavy and noisy. All in all, Fuel Electric Generators are not safe, they are not environmentally friendly and very costly to keep running for long periods of time.

The Negative Revolving Cycle

It seems that we have a negative environmental revolving cycle and not much is being done to resolve or even alleviate the issue. This cycle shows carbon footprint/pollution along with greenhouse gas emissions leads to an increase in global warming and thus an increased rate of mega-disasters. The electric generators used in the traditional response to disasters emit greenhouse gases, which enlarge the carbon footprint, leading to the global warming effect.

[23] *QuickStats*: Number of Deaths Resulting from Unintentional Carbon Monoxide Poisoning, by Month and Year — National Vital Statistics System, United States, 2010–2015. MMWR Morb Mortal Wkly Rep 2017;66:234. DOI: http://dx.doi.org/10.15585/mmwr.mm6608a9

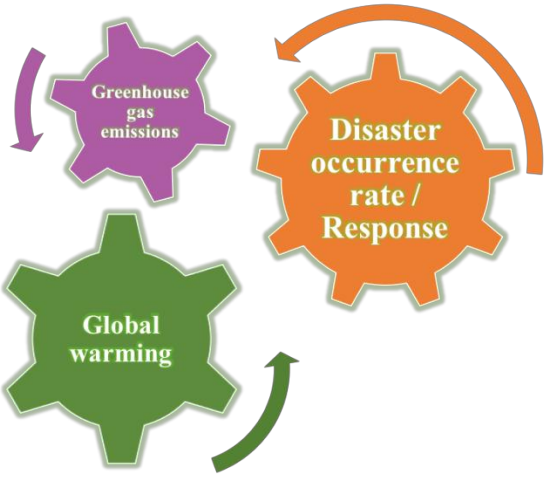


Figure 12: Negative Environmental Cycle.

Efforts must be made to break this chain. Even though the direct impact may seem small at the beginning, but it's the small changes that create a snowball effect that adds up to something substantial. We must find a way to help humanity without harming the environment further. Can solar power, *along with other environmental strategies*, be utilized to replace traditional generators in long-term disaster relief?

Solar Energy Components

"In 2017, most homeowners are paying between $2.87 and $3.85 per watt to install solar, and the average gross cost of solar panels before tax credits is $16,800. Using the U.S. average for system size at 5 kW, solar panel cost will range from $10,045 to $13,475 (after tax credits)[24].

[24] news.energysage.com. How much do solar panels cost in 2017? Energysage.com 2017.

In comparison to fuel generators, Solar Panels are:

1. More efficient as they don't use fossil fuel that needs constant refilling and frequent maintenance.

2. Environmentally friendly because they use a renewable energy resource, the sun.

3. Some of them can still function even without direct solar radiation.

4. Less expensive in the long run for the purpose of long-term recovery, which may inspire more people to use it in their permanent repaired homes after the recovery period is over.

5. Solar panels function better for extended periods without the need to shut down the solar system down even for regular maintenance, which could be done partially to individual panels or batteries.

PV Panels Types

Crystalline Silicon Cell Vs. Thin-Film, Quick comparison:

Monocrystalline Silicon:

Monocrystalline solar cells are constructed of cylindrical silicon ingots. To make silicon wafers, four sides are cut out of the ingots. This maximizes performance and lowers costs of a single solar cell. Monocrystalline solar panels are made of the highest grade silicon making them have the highest efficiency

news.energysage.com/how-much-does-the-average-solar-panel-installation-cost-in-the-u-s. Accessed Nov 3,2017.

rates. They can have up to an efficiency rate of 21.5%[25]. These solar panels are space-efficient by yielding the highest power outputs with the least amount of space. These panels can produce up to 4 times the amount of electricity than a thin-film solar panel. Most solar manufacturers have at least a 25-year warranty on their monocrystalline panels because they tend to live and function the longest. These panels perform better than polycrystalline solar panels under low-light conditions.

Though Monocrystalline panels are considered to be some of the best on the market, there are some downsides to these panels as well. Monocrystalline panels are expensive as they are made using the Czochralski process[26]. In this process, a lot of silicon is wasted to cut the silicon into the shape needed. Other downfalls are that the panels do not work correctly in extreme weather and can malfunction if covered partially by dust, snow or shade.

Polycrystalline Silicon:

Polycrystalline silicon was the first type of solar panels, also known as polysilicon (p-Si) and multi-crystalline silicon (mc-Si), that was launched in 1981.

[25] Mathias Aarre Maehlum. Which solar panel type is the best?. Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.
[26] Mathias Aarre Maehlum. Which solar panel type is the best?. Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

Polycrystalline solar panels are not made using the Czochralski process. In this process silicon is poured into a square mold, then cooled and cut into square wafers wasting minimal silicon, making them more affordable. These panels are robust and withstand harsh weather and circumstances. They are also available and widely manufactured in many countries around the globe. These panels could function better than the Monocrystalline type if they got partially covered with dust, snow, or shade. Polycrystalline solar panels efficiency rate is typically 13-16%. This is due to an inferior silicon purity. Polycrystalline solar panels have a lower space-efficiency. A more substantial surface area is needed to output the same amount of electrical power as monocrystalline silicon panels.

Thin-Film Solar Cells (TFSC):

Thin film solar cells are made by layering thin layers of photovoltaic material. They are easily made which makes them more affordable and simple to mass-produce. They have an appealing homogenous appearance. Thin film solar cells can be made flexible, which enables many possible applications. Their solar panel performance is not as affected by high temperatures and shading as the aforementioned two.

Thin-film solar panels require a lot of space to deploy. These are not practical in most residential situations. Monocrystalline solar panels can produce

four times the amount of electricity as thin-film solar panels for the same amount of space[27]. Thin-film solar panels are not as durable as their counterparts, mono- and polycrystalline solar panels. Most solar companies provide a lesser warranty on Thin film panels because of their short lifespan.

Monocrystalline, polycrystalline, and thin film solar cells are all excellent choices for a reliable solar system. If the budget is available, with limited roof space, in a sunny region and there is a need for a bigger battery system; monocrystalline panels are recommended because they are the best efficiency available in the market. Polycrystalline is good with an average budget and if the panels are at risk of getting partially covered by dust, shade or snow and possibly withstand harsh weather condition. If the budget is limited and/or a flexible roof system is needed as in fabric roofs, thin film panels are a good option as they offer an affordable and durable system that does not only need direct sun to function. Thin-film panels have a unique capability to function under daylight or skylight conditions providing the adequate space for an extensive panel system.
In this study, we will employ polycrystalline solar panels mainly because of their global availability.

[27] Mathias Aarre Maehlum. Which solar panel type is the best?. Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

Sizing a Deep Cycle Battery System

Deep cycle batteries have a high capacity to charge and discharge slowly. Batteries categorized in two ways, how they are used and how they are made. The primary uses are automotive, marine, and deep-cycle. Deep-cycle batteries are commonly used in Photovoltaic systems as well as other high capacity systems. If given the proper maintenance and care, a deep cycle battery has the lifespan of 4-8 years.

Envisioned Equipment in Basic Shelter:

Equipment	Running Watts	Starting Watts	Count	Outlet Type
Light bulbs	6 watts	6 - 9 Watts	10	Socket Adapter
High-Velocity Fan	62 watts	75 watts	3	Socket Adapter
Fridge Freezer	150 watts	650 watts	1	Tamper Proof
Micro Wave Oven	600 watts	600 watts	1	Tamper Proof
Smart Phone Charger	10 watts	15 watts	4	USB Outlets
Table Fan	10 watts	25 watts	2	USB Outlets
Laptop Computer	50 watts	100 watts	2	USB Outlets
	1,156 W			

Table 4: Suggested shelter equipment by this study.

Calculating amp-hour needs

A comparable equipment list was chosen based on the Florida disaster relief program's suggested list. Although the list was reduced significantly by choosing only the most basic equipment that may be needed during a disaster recovery phase[28]. The equipment was chosen based on its energy efficiency. To optimize the use of the battery system in the shelter this equipment should be used in turns instead of simultaneously. The equipment is strongly suggested to be used for the average time listed in the previous calculations.

1. Inverter size: By adding up the wattage of all devices, appliances, and plugins which will be running simultaneously in the shelter, we can estimate the needed inverter size. Inverters come in certain capacities like (1000W-2000W) and so on, the nearest wattage number for this case "1385 W" would be between (1000W-2000W)[29]. It is better to get a slightly higher capacity of the inverter than needed because some energy gets lost in the wiring.

2. Daily energy use: Is calculating the total energy used by all devices for 24 hours.

[28] Jon Solar. How to Calculate amp-hour needs. Instructibles 2017. http://www.instructables.com/id/How-to-Size-Your-Off-Grid-Solar-Batteries-1/. Accessed July 10 2017.

[29] Solar Power Talk. Inverter size vs. battery size tutorial.Solarpowertalk.com 2013. https://www.solarpaneltalk.com/forum/off-grid-solar/off-grid-solar-panel-systems/10394-inverter-size-vs-battery-size-tutorial. Accessed Sep. 9 2017.

Assuming that the shelter will have a certain schedule* to use electrical devices, it is recommended to follow the formula: 10 light bulbs for 5 hours +Fans for 12 hours +Fridge for 24 +microwave 3 hours +laptop and cell phone chargers 6 hrs. All= 7,200 w/h *(The schedule is subject to change and along with it the rest of all the calculations)

3. Days of autonomy: It is the energy stored in the battery bank for when there is no sun. Usually, it is between 2 to 5 days. Most cases people choose the average of 3 days. 7,200 x 3 days = 21,600 w/h

4. Battery bank capacity: 21,600 / 24 V = 900 Amps/h

Assuming it's a 24 V battery system with a charge controller of 92% efficiency and we're getting 250 Amp 12 V batteries. Where six batteries are connected in parallel and two sets are connected in series. (12 AGM batteries recommended)

For "50 Watt 12 Volt Polycrystalline Solar Panel" 20 Panels 5x3 should be enough to power up the chosen devices with the aforementioned schedule. If more devices are needed and/or change of schedule might increase the use of electricity, more batteries can provide that support along with a matching number or efficiency of PV panels. It is known that the better efficiency the panels, the less number of them needed. Same can be applied to batteries.

Envisioned Model

The model suggested here is a **gray box** architecturally speaking. The dimensions listed are not to be taken literally. It is merely an example to demonstrate how simple environmental strategies can be utilized to improve the interior human thermal comfort needs instead of using artificial methods that call for electric generators which cause many harming hazards to human health and the environment. These environmental strategies can be implemented in differently sized shelters to aid in disaster relief efforts. This particular unit is 8′ x 12′, to make it easy to build with commonly found materials in most countries which usually comes in 4′ x 8′. It is easier to install since it is relatively small. Also, it is easier to store and transport in most common trucks and vehicles.

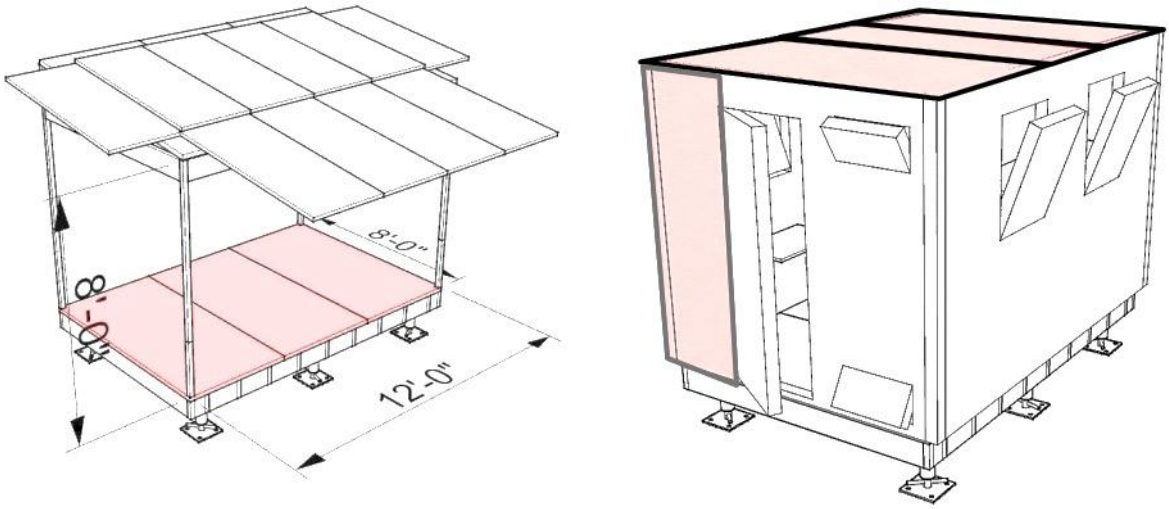


Figure 13: Using 4' x 8' materials in the grey box module.

Foundation

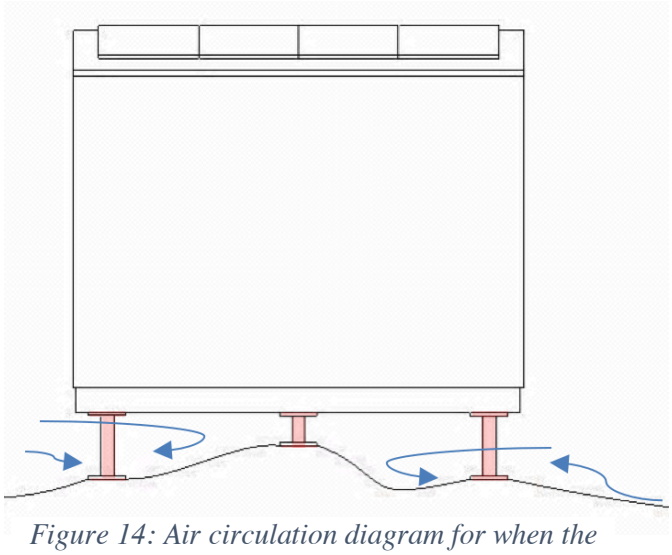


Figure 14: Air circulation diagram for when the unit is elevated

It is envisioned that the unit is elevated using adjustable foundation columns to give the shelter several advantages. For instance, it provides flexibility with topography as it can be leveled evenly on many types of land and uneven surfaces. This feature will provide the ability to assemble this shelter in most areas even if the surface area is less than ideal for setting up a shelter which makes this shelter more adaptable than the majority of other traditional shelters like tents. As a result, this feature can help reduce the need to search or travel the extra distance to find an optimal flat area to build tents.

Additionally, in certain climates when cross ventilation is needed like hot humid or even hot arid, the elevated unit will allow for fresh air to speed across the unit's corners which in turn will cool the surface of the unit's walls and floor. Also in heavy rain areas, the elevated unit will provide distance from the wet, muddy ground which is a privilege we don't find in most deployed shelters like tents.

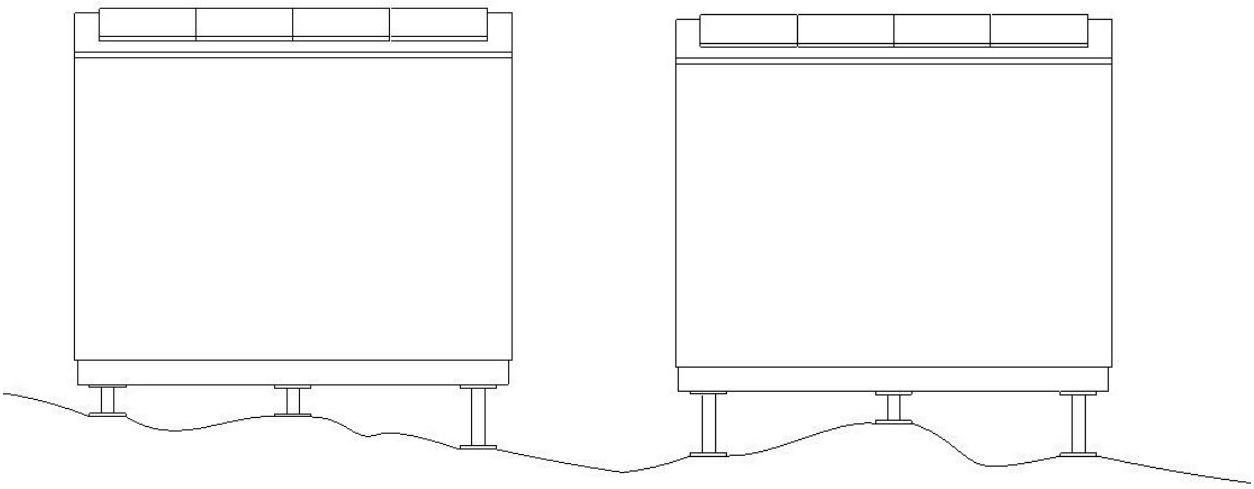


Figure 15: Demonstration of elevated unit strategy in relation to topography.

Flooring

To further with flooring, a braced framing made out of treated lumber is suggested to help the continuity of supporting the weight that the shelter should withstand. This is just to establish that there must be some type of flooring in conjunction with lifting the unit and for the unit to be able to bear the weight that it is to support, the actual design and implemented strategies are to be determined by the designer or constructor. The floor material should be biodegradable material and preferably treated lumber[30]. Examples of biodegradable materials that could be used for flooring (Cork - Bamboo - Reclaimed Hardwood - Terrazzo - Earthen - Rammed Earth Floor - Adobe Floor)[31].

[30] Kelly Hart. Using Local Materials. Greenhomebuilding.com 2001.http://www.greenhomebuilding.com/localmaterials.htm. Accessed Oct 17, 2017.
[31] Tony Serna. Dancing Rabbit Ecovillage. Dancingrabbit.org 2017.http://www.dancingrabbit.org/about-dancing-rabbit-ecovillage/eco-living/building/natural-building/earthen-floor. Accessed Oct 10, 2017.

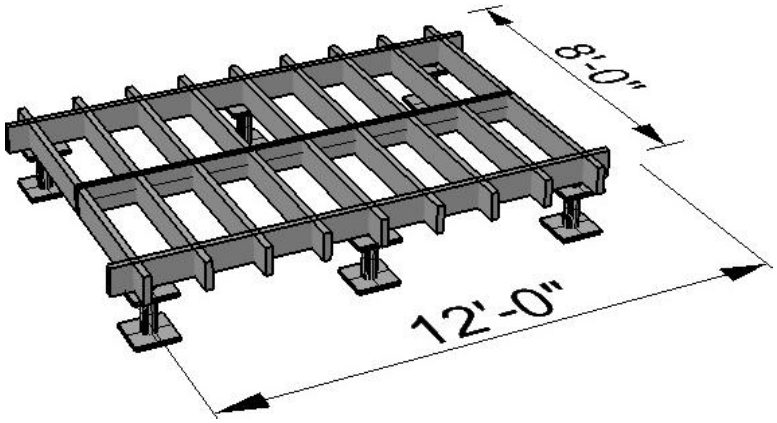


Figure 16: Example of envisioned framing for shelter floor.

Again, the form here is merely suggested to have grounds for our strategies and not to be taken literally or judged architecturally.

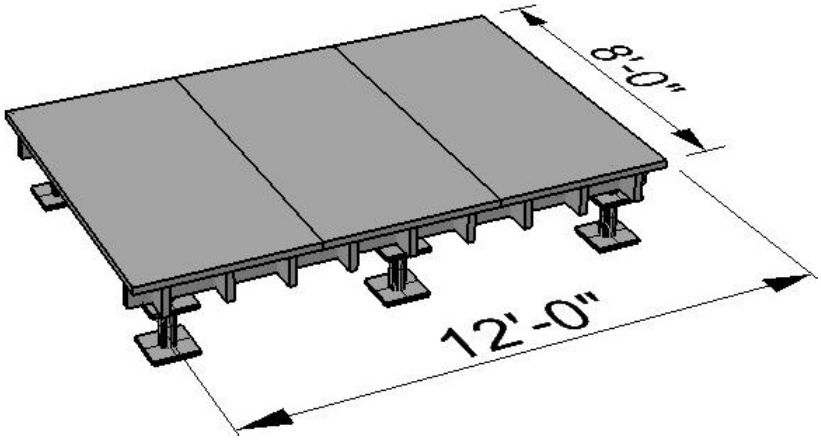


Figure 17: Biodegradable hardwood, preferably treated & finished.

Framing and Adjustable Pillars

The main frame parts should be adjustable starting with the main pillars, beams to other bracings and struts, to provide flexibility on site. The main four pillars should be adjustable so that they can be extended to tilt the roof towards the

direction of the most solar radiation exposure to help acquire that energy through the PV panels on the roof. It is envisioned that the pillars would have multiple settings that can easily be adjusted. This again is promoting the user-friendly theme carried throughout this project. The pillars should be able to accommodate different angles in either direction to tilt the roof to provide the fullest exposure of direct sun radiation for the PV panels to be able to produce the needed electricity.

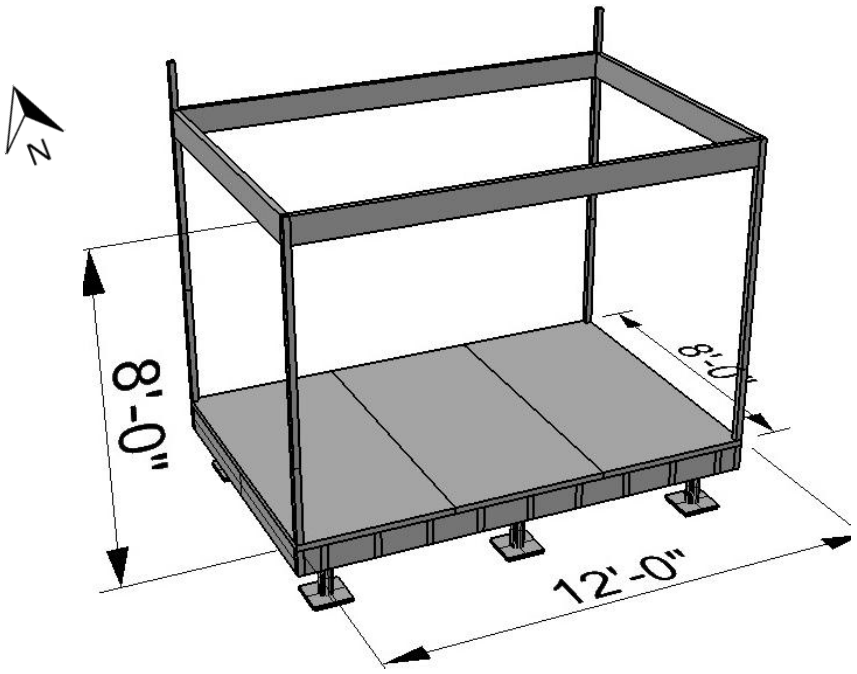


Figure 18: Envisioned framing and adjustable pillars to tilt the roof

Walls

The walls are made of two fabrics sewn together (Light color side & Dark color side). The fabric that we used in this model is 600 denier PVC backed polyester. This fabric is durable, water-resistant and lightweight. A pocket is made from the two fabrics and is filled with pool noodles as an affordable example of

foam insulation in-between, plus a single radiant barrier sheet or multiple barrier sheets. This wall has the flexibility to move, rotate, and be reinstalled between seasons. This easy to install low-cost wall has great potential to be made from all recyclable items. This wall design is foldable, easy to store and also doesn't take much space in transportation. This wall has a high-performance R-Value in relation to its cost with other valuable characteristics such as water resistance and breathability.

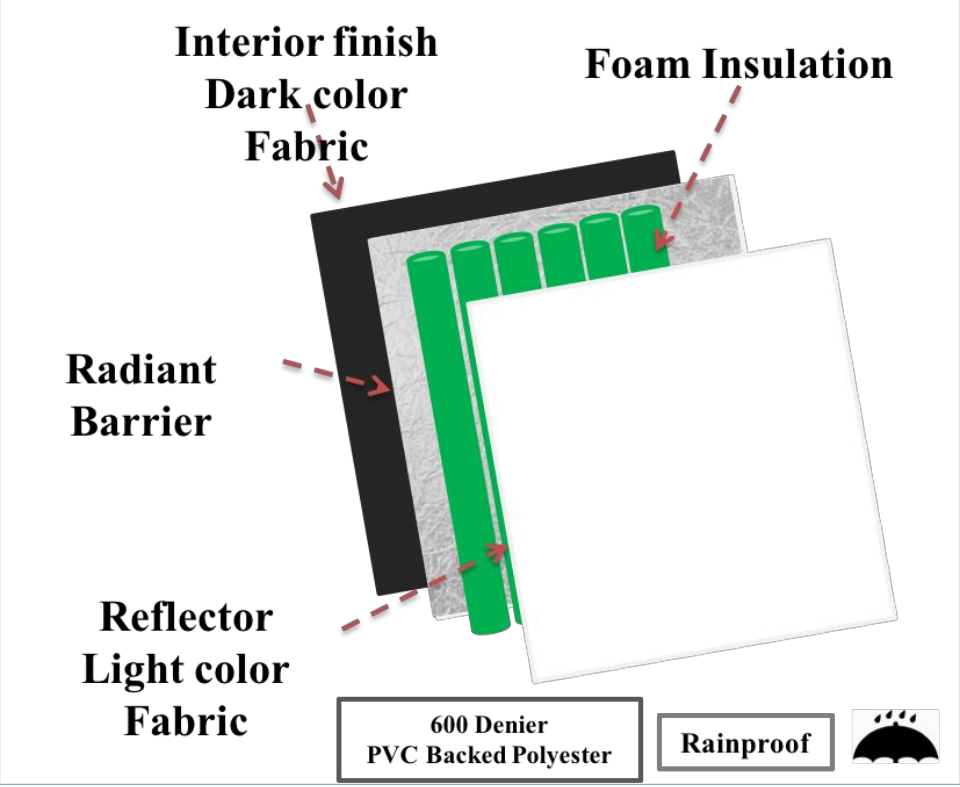


Figure 19: Envisioned wall components.

Wall design R-Value

	Actual.	Performance
Outside air film.	0.15	0.17
Fabric Light Color	0.5	1.5 clo.
Foam. (closed cell	2	3
Air. (still air)	0.75	0.75
Foam. (closed cell)	2	3
Radiant shield.	1.5	5
Fabric Dark color.	0.5	1.5 clo.
Inside air film	0.68	0.68

Table 5 R-Value Wall Components

In total, this fabric wall should provide the R-Value performance of 15.58 ft²·°F·h/Btu. If we were to add another layer of radiant barrier, we could reach the performance of 20 R-Value and more. Though R-Values are important to measure insulative qualities, yet most R-Values of materials are measured in a lab with certain conditions. It is important to realize that materials have more to them than just R-Values numbers. For example, other factors need to be considered: color, reflectivity, absorptivity, emissivity, breathability, and moisture resistance. The projected total R-Value of this wall is estimated to be 15 - 20 ft²·°F·h/Btu., but it is yet to be tested in a lab as we are mainly relying on the inherent environmental qualities of the light and dark colors to reflect or absorb solar radiation between seasons, as desired. Also the dead air inside the foam isolation will help vent the hot air as the radiant barrier reflect the heat radiation.

Wall Cost

The approximate cost of this fabric wall, one single four-sided unit 8 ft. by 12 ft., is $586. The following demonstrates how this was calculated:

The total length of the unit is 40 ft. by 8 ft. of height equal 320 ft^2. Rolls of fabrics usually come in 5 ft. width & 66 ft. length which means 330 ft^2. The retail price of a yard of fabric is $7.90, but at a wholesale price can go down to $3.95 a yard[32]. Traditional foam insulation could be expensive for most people, but choosing pool noodles as equal quality insulation, has a great potential of reducing the cost significantly as they can probably be acquired/donated for free after pool seasons or even purchased at a wholesale where they are $ 1- 2 per noodle. Total number to cover the unit is estimated to be 137 noodles for a single four-sided unit. The radiant barrier comes in rolls of 4ft. by 250 ft. The market price is $168.51 per roll. Since we only need around 80 ft. of the 250 ft. to insulate the unit, the price per unit is approximately $56. Additionally, the wall is assembled by sewing. In doing this research, we priced a few different local upholstery shops and were able to find a very reasonable quote for the wall. Due to the simple stitching required the price was set at $0.75 per yard[33].

The calculations are as follows:

[32] http://www.nukshbundtraders.grpofcompanies.org/thread%20%20PRICES%20LIST.pdf

[33] A foam and Fabric Place, Tucson Az https://www.fourthavenuetucson.com/retail-shops/a-foam-and-fabric-place/

40' total unit length x 8' height = 320 ft²

320 ft² */ 5 ft. width of a roll = 64 ft. which is equal to 21 yards.*

21 yards x $3.95 wholesale = $84 x 2 sides = $168

480" total unit length / 3.5" pool noddle thickness = 137 noodles x $2 wholesale = $274 + $168 = $442

21 yards x $0.75 sewing per yard = $15.75 + $442 + $56 (Radiant Barrier) = estimate of $514 for 4 sided single unit 8 ft. by 12 ft

Compared to Drywall

Cost: The current installation price is estimated to be $40.00 to $60.00 per panel of drywall. Assuming there are 12 panels needed for an 8' by 12' four-sided room, then the total price for those 12 panels would be $480.00 - $720.00. This price does not include any additional costs. Other factors that influence the price are like paint and other finishes, insulation, labor, the location of the job site, and environment. Some laborers charge more on smaller jobs to offset the cost of transportation, insurance, etc. Weight: A standard drywall 4' x 8' x ½' is 52 Lbs. per panel. For one room, 12 Panels = 624 Lbs. which is very heavy and needs heavyweight transportations to deliver enough amounts for prominent structures.

The Roof

The roof is recommended to be a light but sturdy material to support the PV panels system and potentially collect rainwater if needed. Structural insulated panels (SIPs) are a good example of a light sturdy and well-insulated material. R-Value 14

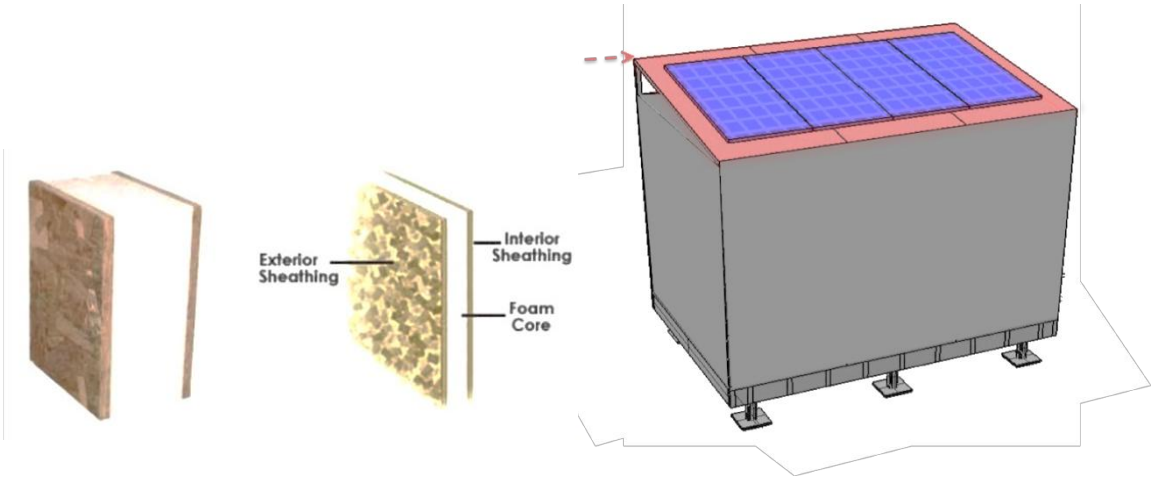


Figure 20: Sample boards of sips panels and example of roof structure.

Compared to other Shelters, i.e., "Tents."

Tents shortcomings:

Tents have less insulation to the outside weather & temperature due to the nature of the tent use. They are geared more towards short-term, temporary housing. And even if the tent claimed to be insulated, most likely, it will be one separate isolated small room and it works only for cold climates.

Tents rarely come with flooring. Sleeping on the floor is a problem when it's uneven floor. As tent residents could search for a long time to find a semi-even floor that can accommodate their sleeping needs. Tents hardly provide enough separation from moisture, when it's wet and rainy. With traditional tents there are fewer opportunities for energy conservation principles or strategies to be implemented; because of the lack of reliable structural integrity and proper envelope insulation. In this study, the envisioned unit has comparable erection time with better structural integrity and adequate envelope insulation. When combined with other environmental strategies the unit can provide adequate thermal comfort which reduce the need for artificial heating or cooling allowing the energy use to be kept only for different survival needs like cooking, refrigerating, etc.

Passive and Active Strategies Utilized

Orientation

The orientation of the building controls the building's gain of solar radiation. This allows a better handle of the indoor temperature swing. For example, if the structure is oriented towards east and west we are maximizing the solar radiation gain which could be beneficial in winter and cold climates. In hot arid climates, it is better to orient the building towards north and south where you can gain more

control over the solar radiation exposure of the building. Orientation involves maximizing or minimizing the façade area exposed to the sun, along with the window area rate to the wall. When we maximize the east and west façade, we will gain more solar radiation. When we optimize the east and west façade exposure and maximize the north and south façade, we have more control over the amount of solar radiation infiltrating the interior space. The last is a strategy geared towards reducing the solar radiation gain which is more appropriate in hot climates and overheated periods. In this design by using the orientation strategy for the shelter, we will reduce the need for air conditioning, thus saving energy for other uses. The unit has the additional flexibility to be restructured and reformed to maximize or minimize the total radiation gain by grouping single modular units or rotating it to different directions as needed in specific climates.

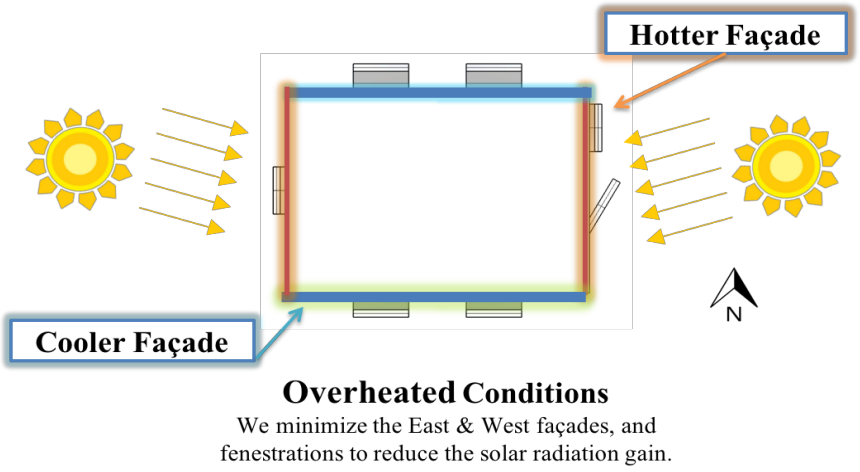
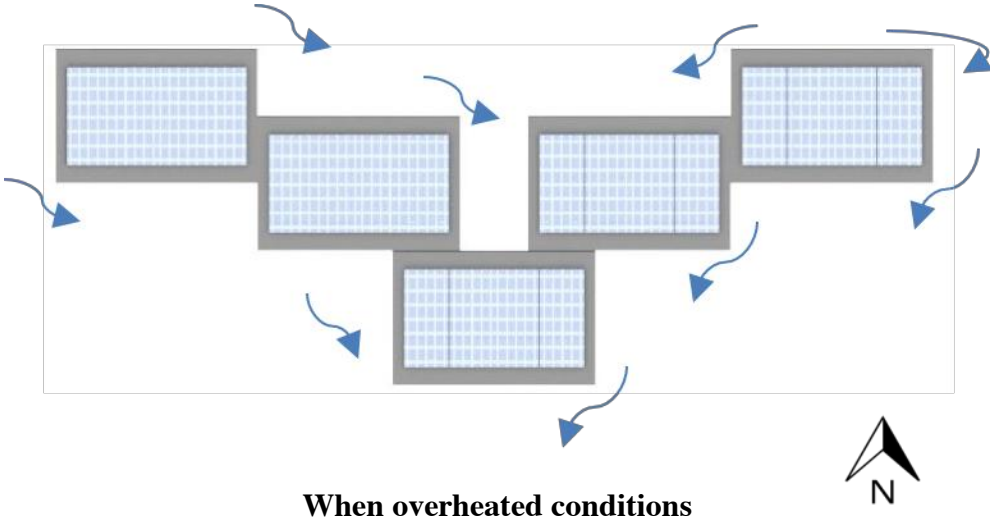


Figure 21: Example of overheated conditions (orientation).

Building Shape

Building shape works in conjunction with the building orientation. By applying specific shapes, we can have control over solar radiation and prevailing wind exposure. Prevailing wind tends to speed around corners, consequently creating natural ventilation in hot humid areas by creating more corners in the building. Exposing more façade surface area to the prevailing wind, will not only cool off the wall surfaces but also reduce the relative humidity around and across the building. Building shape works not only on the outside but also works interiorly in combination with operable windows creating successful cross ventilation.



When overheated conditions prevail with humidity
By maximizing the exposed area to prevailing wind and opening fenestrations, we provide adequate cross ventilation

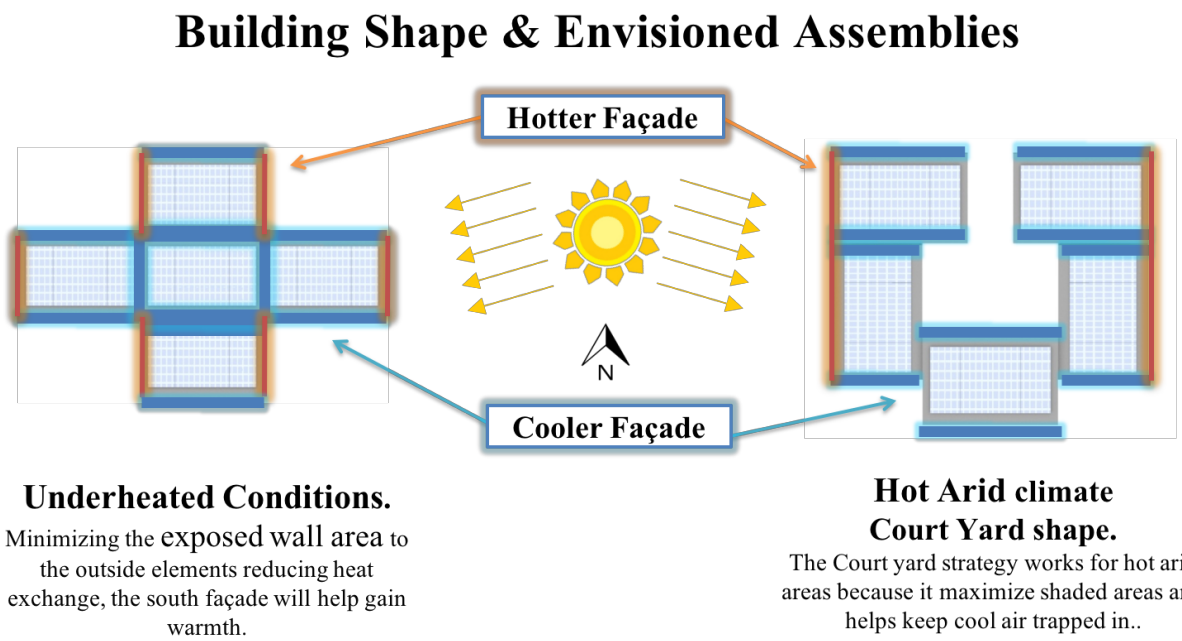


Figure 22: Examples of structure shapes in response to climate.

Natural Ventilation

Natural Ventilation happens as a result of a difference in air pressure. Air tends to float from high-pressure areas to low-pressure areas. By creating operable windows in different spots, we can control the air flow. Creating a window low on the structure's wall, we control the gain of cooler air, as colder air sinks. Creating higher windows, controls the gain and loss of hot air, as hot air tends to rise. Applying this strategy all across the unit in different directions using operable windows can help in controlling the pervading wind flow across the unit interiorly. This strategy works in conjunction with operable windows, building shape and orientation.

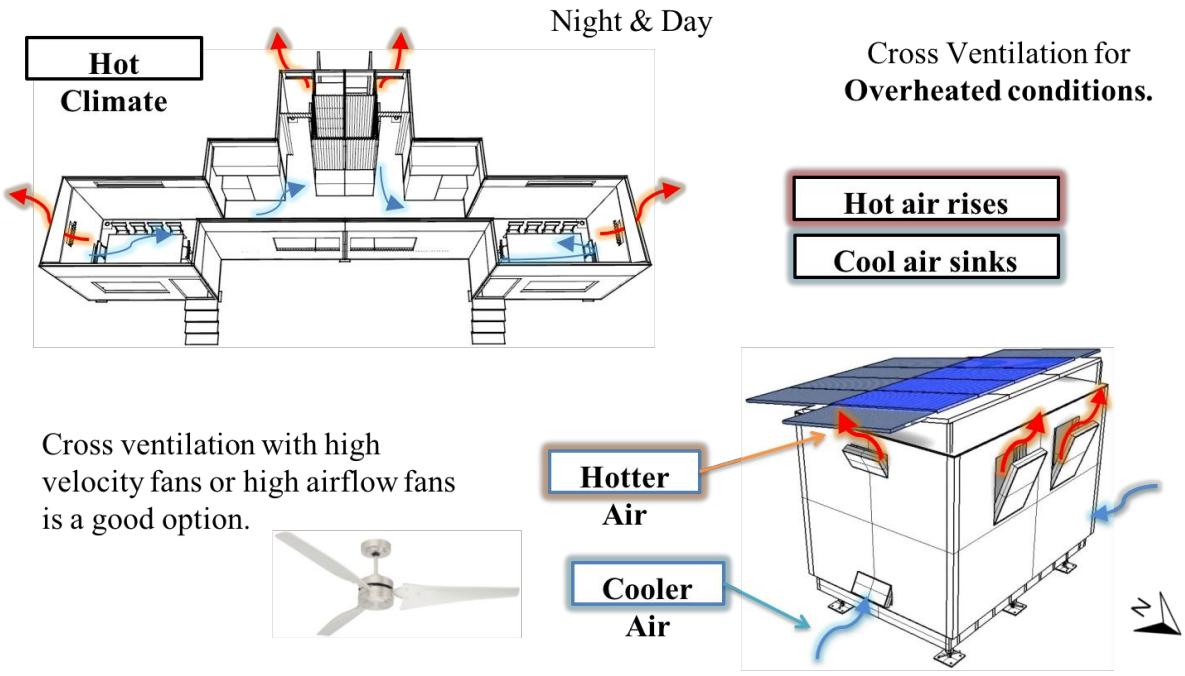


Figure 23: Natural ventilation diagram

By researching the wind rose in a particular region, we can determine the direction of the predicted prevailing wind. Alternatively, this can also be done just by standing outside in that area and feeling the direction of the wind at different times of the day. Whether employing the wind rose as a scientific method, or using simple primitive instincts, the operable windows can be used to let air in or air out according to the direction of the wind. Operable windows can be used to control how long we want to keep the airflow inside the building. For example, to naturally cool off the space, assuming that the prevailing wind is from the South East towards the North West, we can open the lower windows on the East and South sides to let fresh cooler air into space. Then opening the higher windows on the North and West to let the hot air out, will help cool the space naturally.

Raised Floor

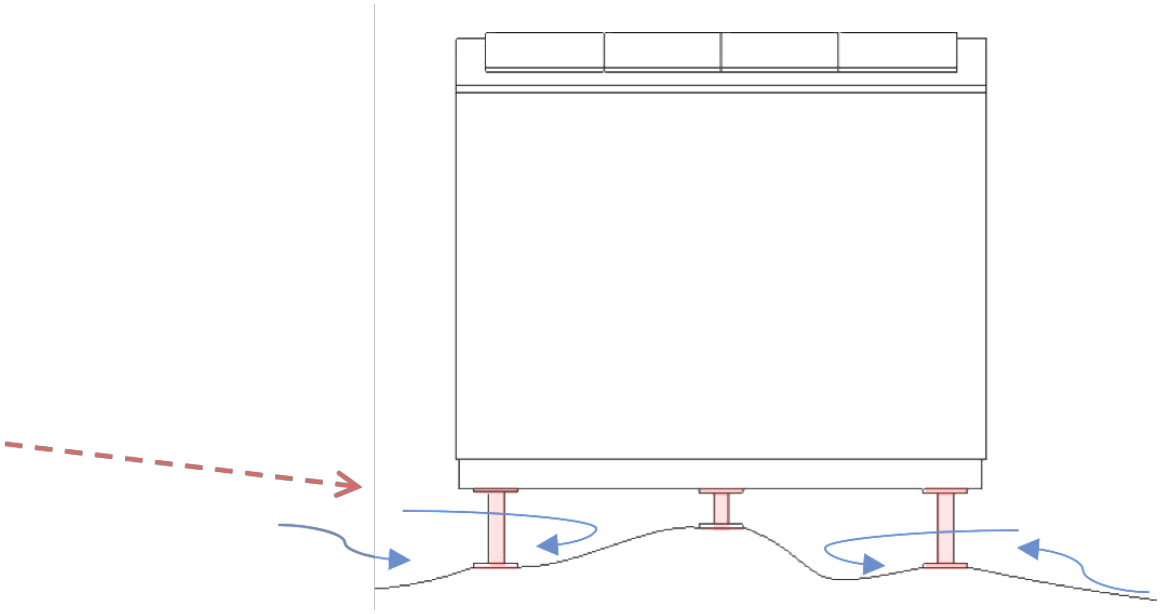


Figure 24: Raised floor benefits

Raising the floor is a beneficial strategy, especially in the following conditions: A) When the topography is hilly or uneven. B) To keep out moisture in a rainy area. C) To increase cross ventilation and reduce relative humidity. By using adjustable posts, we can keep the shelter floor leveled evenly as well as keeping the shelter floor well above the muddy or rocky surface. These are both places a tent would not be able to be placed. The adjustable posts are another easily applied strategy that does not require prior knowledge. Occupants can rely on a simple method of adjusting the height of the post according to need. In humid areas

bringing the unit off the ground helps ventilate the area and reduces the relative humidity. By leveling up the unit, space is provided for any desired drainage.

Natural Light

Natural light or Skylight, is having light without direct sun radiation. Having enough natural light during the day can save energy. The best ways to have natural light is through fenestrations that are oriented towards the North. The rotation of the sun starts from the East and ends at the West, crossing mostly in the South. Thus it spends the minimum time in the North, especially during the winter if in the northern hemisphere and vice versa if in the southern hemisphere. There are other ways to get daylight or skylight without direct sun radiation within the three other sides of the building using a distinctive design for fenestration and/or shading is needed. The design should include an appropriate method of shading or blocking direct sun radiation, like having a deep window that stops the suns direct radiation but allows indirect sunlight to come in. There are other ways to acquire daylight without exposing the interior space to the sun heat like sun tubes. These tubes are installed on the roof to collect daylight as its interior parts are made of reflective materials. When the direct sunlight infiltrates the top exposed part on the roof, these light beams get through some reflective surfaces and out of a lens that distributes reflected light that does not heat up space because it is not direct

radiation. In general daylight usually is preferred over artificial light because it saves energy during the day and it has positive effects on the environment and people. People tend to receive daylight with positivity and enthusiasm as daylight has a better aesthetic.

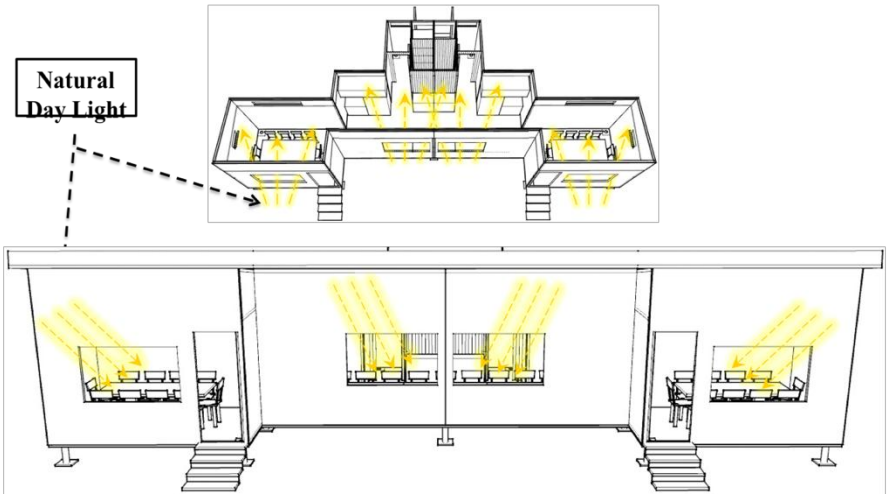


Figure 25: North façade fenestrations are bigger and wider to allow the maximum gain of daylight.

Operable fenestrations

Operable fenestrations are operable windows and doors. They can be opened and closed at the user's convenience. The benefit of controlling the ability to close or open a window is to control wind ventilation, light, and solar radiation gain. Operable fenestrations are usually recommended when the occupants are aware of the best way to use them. The modern building industry has taken away the operability of fenestrations in most of the modern buildings. Where the users

frequently have minimum control of when, where and how to open a window thus preventing the users from gaining the control of their surrounding environment.

To naturally cool, heat or light space the occupants should have the control of when and where to open or close a window. Fenestrations or windows are recommended to be installed with a screen to prevent dust, insects and other elements from entering the space. Another benefit could be gained during under-heated periods is by installing a separate layer of transparent vinyl on windows that can be attached via Velcro to allow natural light and direct sun radiation to infiltrate the space and heat up the space naturally. This is done to warm up the space without losing the heat in under-heated periods. This phenomenon called the greenhouse effect. This is a natural passive way to warm up a space without using electricity. This is to be done primarily in under-heated periods by using the south façade fenestrations where the solar path spends most of its time during the day.

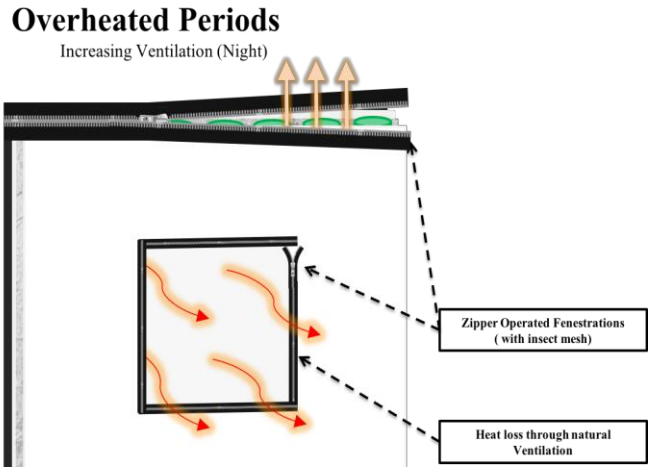


Figure 26: Example of night ventilation in overheated conditions.

Shading

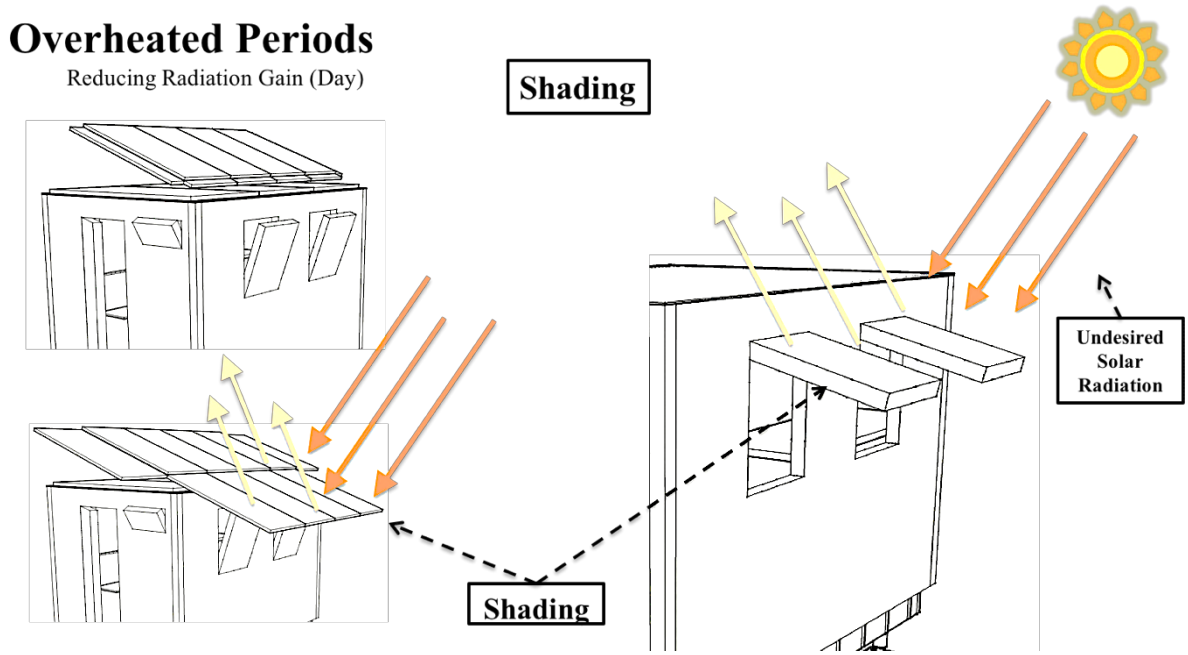


Figure 27: Shading techniques during overheated conditions

One of the most common and vital strategies, especially in hot climates, is shading. Once the solar radiation has already crossed into space, it heats that space. The goal is to block the solar radiation before it infiltrates into space. The best way to avoid the sun radiation is to shade the fenestrations externally. In this study, the operable fenestration themselves can be used to shade by using the operable part of the window positioned up, on the outside. This gives two benefits. First, we shaded the window from the outside preventing solar radiation gain. Second, the open window will ventilate the room to cool off the heated space.

Another method employed to shade in this study is expanding the PV panels. The panels would not only cover the windows, but also the majority of the Southern façade. This will help keep the space's temperature swing at the minimum, thus naturally reducing the need to reach human thermal comfort artificially. There are many other ways to shade using the natural landscape of an area. It is recommended to use such shading in any overheated conditions if available. If not available, a simple tensile structure can be put up in minimum time and could provide adequate shading. It is especially important to shade the southern façade which would get the most solar radiation exposure throughout the day.

Envelope material & insulation

There are so many modern materials that are used for building and insulating the building. These materials have different capacities to resist heat flow. These capacities are measured by R-values and thermal lag. Different materials have different characteristics, like color, reflectivity, absorptivity and emissivity that also affect its resistant to heat flow beside R-value. In this study, the proposed shelter introduces the best of both worlds: insulative quality and lower cost. The envisioned shelter envelope will be made out of a very affordable material that

provides a decent R-value, a successful thermal lag, and a high potential to be vented during overheated conditions.

The wall will be made out of two sides of fabric, one side is a dark color, and the other side is a light color. The dark side should face the exterior during under-heated conditions, while the light color side will be facing the exterior during summer or an overheated period. This practice is mainly based on the theory of dark colors have a higher absorptivity than light colors. Thus, the exterior color should absorb or reflect the solar radiation heat based on the color. When employing the dark color side exteriorly, we are passively reducing the heat exchange between the interior and the exterior temperature which in turn minimize the heat loss inside the unit. On the other hand, we know that light colors mostly reflect most of the solar radiation, thus blocking most of the heat. Applying this during overheated periods will aid in reducing the radiation absorbed by the exterior envelope and cooling the interior.

In between the two sides of the fabric (dark and light colors), we will place insulative foam material that is mostly made out of closed cell polyethylene. These polyethylene foams are commonly found in many forms and products like (pool noodles). There are positive aspects of using pool noodles as insulation inside the wall in this type of long-term housing. First, pool noodles are made out of light foam, the same foam that many building insulation industries use as an

expensive method of insulation. Additionally, pool noodles come hollow, with a hole in the middle that has a great potential to be used to ventilate the wall during overheated conditions and perform as an extra layer of dead air, which has the highest R-value and is considered a great way to insulate.

Theoretically, if the wall absorbed heat from the outside during the summer the top part of the wall, which will have a zipper, can be left open to ventilate the hot air (chimney effect). This would leave the inside of the wall cooler consequently the interior space of the unit. To add another layer of thermal protection, a radiant barrier can be installed with the reflective face right behind the noodles, to prevent any radiant heat from crossing into the interior space. Additional radiant barriers can be installed, as needed, depending on the budget allowed and the severity of climate where the unit will be deployed.

For example, if the unit will be deployed to an extremely hot arid region during the summer it is recommended to at least double the radiant barrier and possibly add another layer of pool noodles to the wall. This would affect the cost, but it will save on energy and will provide better thermal comfort for the occupants. The wall also should be relatively easy to install and may require basic knowledge about setup, equal to putting up a tent or easier. All windows and doors should be operable with sturdy, durable double zippers, a similar concept to a tent. Fenestrations also should be insulated the same way as the rest of the wall.

The wall installation is reversible between the dark and light color sides to facilitate switching between the two colors between seasons. The wall is made out of a very light, yet durable, material allowing for easy install and inexpensive transportation. The wall has the ability to be folded into smaller sections as pool noodles are flexible, and they can rebound to their original shape. The preferred way is to pre-manufacture the wall into sections attachable upon arrival to the site where the affected people can install it quickly without the need to wait for experts.

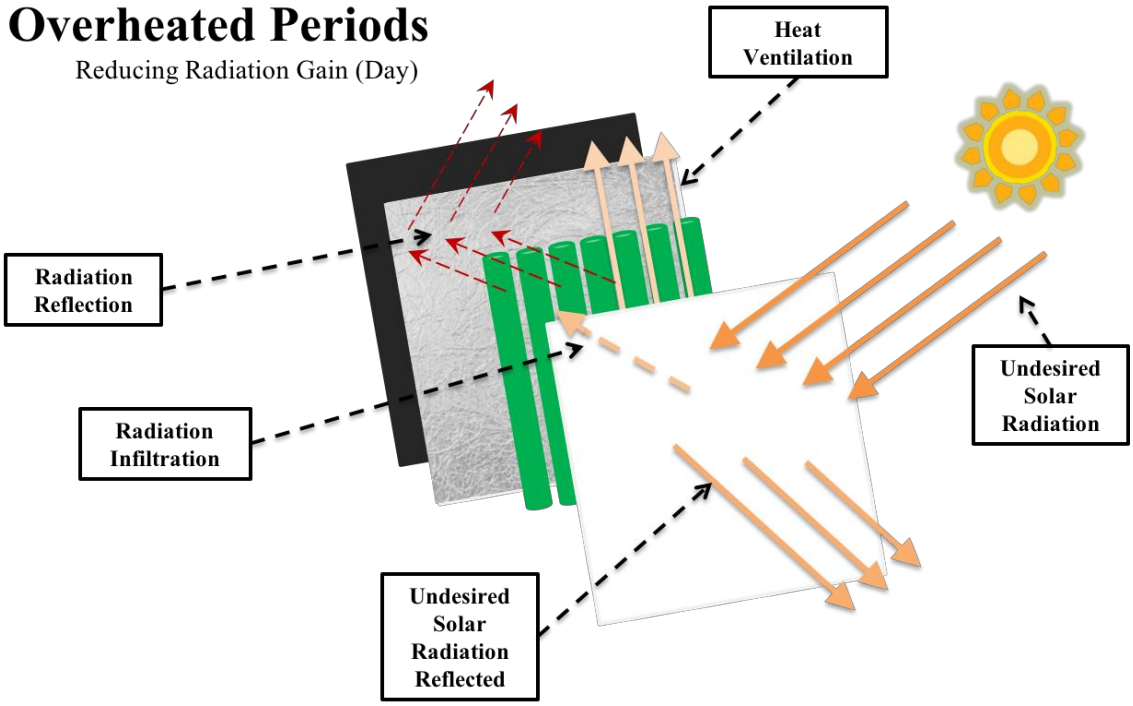


Figure 28: Envisioned wall performance during overheated conditions.

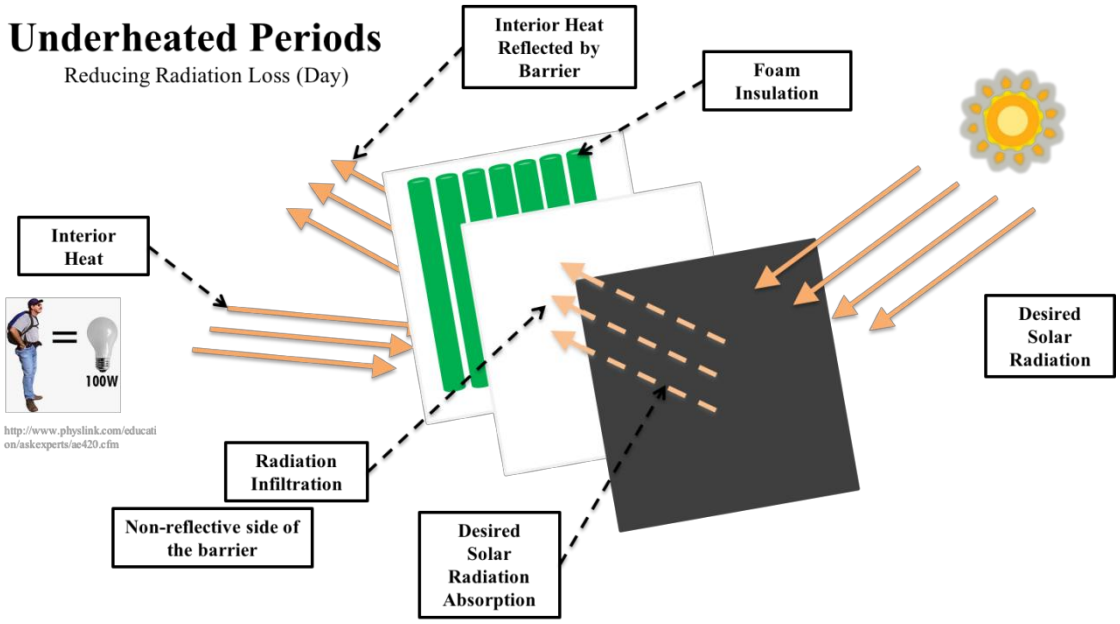


Figure 29: Envisioned wall performance during under-heated conditions.

Double wall / Cavity wall concept

The double wall is usually a wall made out of two sides of bricks separated by an empty dead air in the middle. Foam insulation or other forms of insulation can be added to that space. It is also knowing as (cavity wall), which is a great method for insulation in permanent buildings, but unfortunately when disaster strikes and people get displaced the downside of such a technique is affordability and waiting for labor, making it an inadequate alternative. Thus, the need for

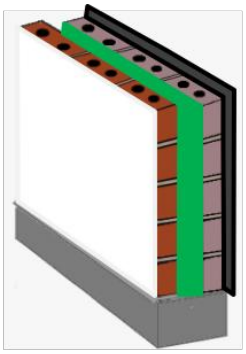


Figure 30: Cavity wall concept

a quick, inexpensive and light material arises. Usually, the government and many NGOs fulfill this need by sending tents and blankets to everyone regardless of what climate the people at. The concept of cavity wall is the main inspirational concept in this wall design to use cheaper materials in comparison to actual insulation. By providing high R-value materials and using passive techniques, like color, we offer an innovative way to thermally stabilize a space and reduce the temperature swing. Additionally, by using the appropriate adjacent passive strategies such as cross ventilation, orientation, building shape and other strategies we can pave the road to the use of PV Panels as they will provide energy to vital devices and equipment only chosen for certain use and periods of use, leaving the shelter in a good standalone energy net zero need.

Tilted Roof

In addition to orienting the building in the right direction, the roof needs to be tilted in the right direction as well. The sun spends most of its time during the day in the south, which leaves the south façade with the maximum solar radiation exposure during the day. Therefore, to maximize the solar radiation gain, on the provided PV panels that come intergraded on the roof, the unit's roof needs to be tilted facing south. When PV panels are exposed to the maximum direct solar

radiation, they generate the maximum electricity possible that gets stored in a deep cycle battery system later.

The number of degrees the roof needs to be tilted will be determined by the location of the deployment. Prior to deploying the shelter, necessary information about the location should provide us with the degrees that the roof needs to be tilted towards the south. The degree of the tilt differs per location. The further the location from the equator, the wider the angle of the tilt. In the northern hemisphere the roof would need to be tilted south; the opposite is true for the southern hemisphere.

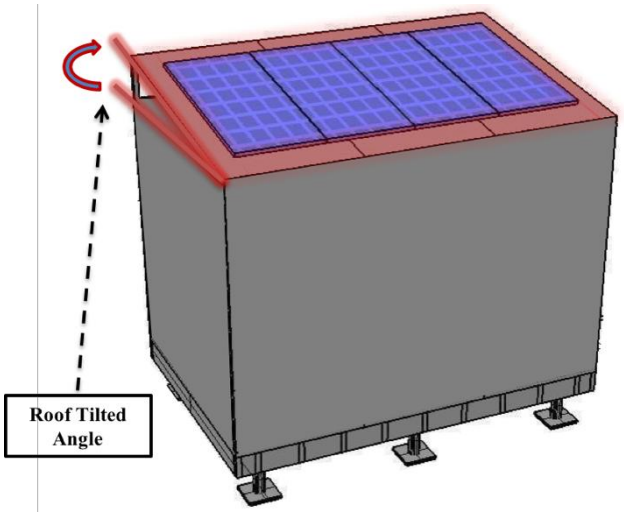


Figure 31: Roof tilting angle

Photovoltaic Panels

Photovoltaic Panels, or PV panels, are light sensitive panels made out of material that reacts to direct sun radiation by creating electricity. There are several types of PV panels that are currently on the market[34]. There is crystalline silicon

[34] Mathias Aarre Maehlum. Which solar panel type is the best? Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

cell and thin film solar cell. The crystalline silicon cell has two subcategory types, monocrystalline silicon cell, which is considered to be the highest efficiency rate among the others, but it comes at a high cost. Also, there is the polycrystalline silicon cell which is less efficient than those as mentioned above but also comes at a cheaper cost.

The third type, thin film solar cell, is the least efficient. However, it provides a unique feature, such as flexibility, which allows it to be attached to flexible materials like fabrics. This panel also has a high-temperature tolerance, where the previous two types fail to operate at high temperature. The thin film panels also have the ability to work in indirect sunlight. It has better adaptability to extreme weather and circumstances. The Thin Film solar cell is one of the cheapest PV cells that are available on the market, at the same time, it also produces less electricity than the types mentioned above.

There are other types of PV panels that are available, though they are not as common around the world such as those already cited. These include but are not limited to; organic photovoltaic cells, copper indium gallium selenide,

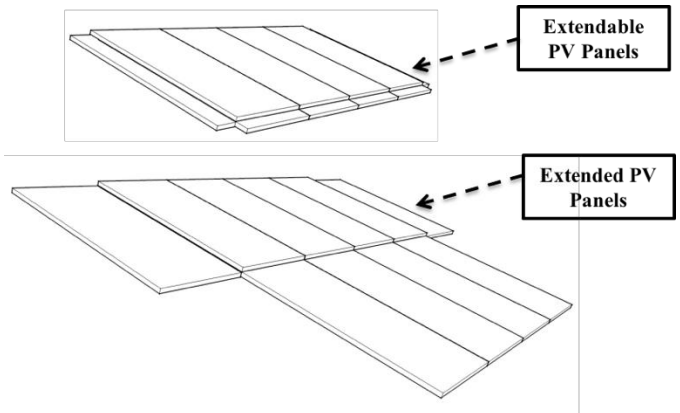


Figure 32: Example of how PV panels can be expandable on a roof

cadmium telluride, amorphous silicon cells, and other types.

The shelter's allotted budget, the deployment location and the condition of the area; whether it is dusty, cloudy, or clear skies will determine the type of PV panels needed. Since different regions have variable cost for the same type of PV panels, the cost of the system will vary per location.

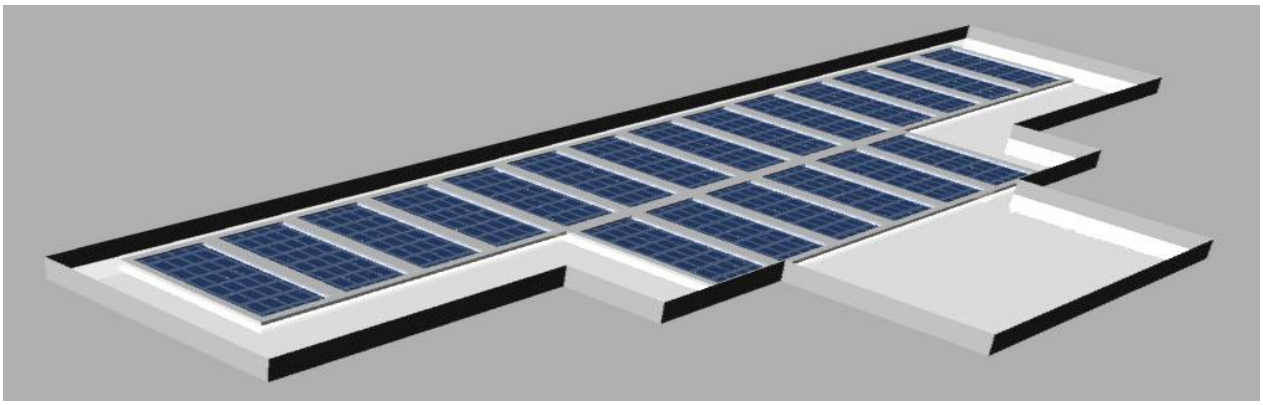


Figure 33: Integrated PV panels on the roof of the unit

Rainwater Harvesting

Rainwater harvesting is an essential strategy for survival, as water is necessary for life. The roof of the unit can collect rainwater to be stored and used as needed by merely insulating the roof under the PV panels to prevent leaking. The collected rainwater is contingent on the rain rate in the region the unit will be deployed to. A simple calculation for the rainfall rate of the deployment area should be done prior to sending the unit to the deployment location. Thus an appropriate tank should also be provided to store the collected water. For example, if the shelter will be sent to Florida, this given area we know receives 1200 cubic

liters of rainwater per year an appropriate tank of 150 litters should be provided assuming the daily use would be around 50 litters[35].

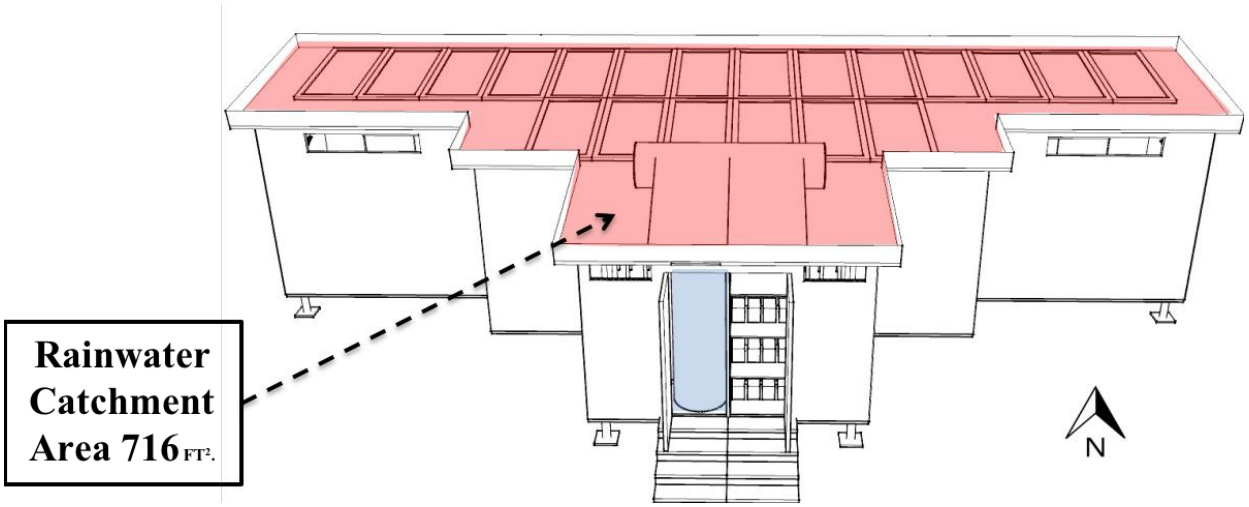


Figure 34: Example of Rainwater catchment area.

The tank can be a stand-alone structure if the atmospheric conditions do not risk the integrity of the tank. If the conditions are too extreme, the tank should be kept safely within the unit to reduce temperature fluctuations, possibly causing freezing or evaporation. A filtration system is recommended if drinking water is scarce.

The United States government and the American red cross, recommends some very straightforward methods to purify any suspected contaminated water[36]. One of the most convenient and recommended ways to purify any contaminated water, including but not limited to harvested rainwater, is to add bleach, using a

[35] Texas A&M Agrilife Institute. Rainwater Harvesting. TAMU.edu 2017. https://rainwaterharvesting.tamu.edu/catchment-area. Accessed Dec 1, 2017.

[36] https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water

6% bleach you add eight drops to one gallon of suspected contaminated water, repeating until the water has a slight smell of bleach[37]. The government states this method is safe to convert dirty water into potable water for humans and animals. However, this is only to be used when no other alternative is available, and until clean water is brought to the affected area.

Tensile

Tensile is a light fabric structurally tensioned on a structure made of a light material to provide a stand-alone shading device to block any solar radiation gain in the building. The tensile strategy is often used where no traditional shading methods are available. The advantages of using tensile shading are their flexibility and movability from one spot to another. The best place to use tensile is on the south facade of the unit, especially in overheated conditions. This will limit solar radiation access to the building independently from the structure.

[37] https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water

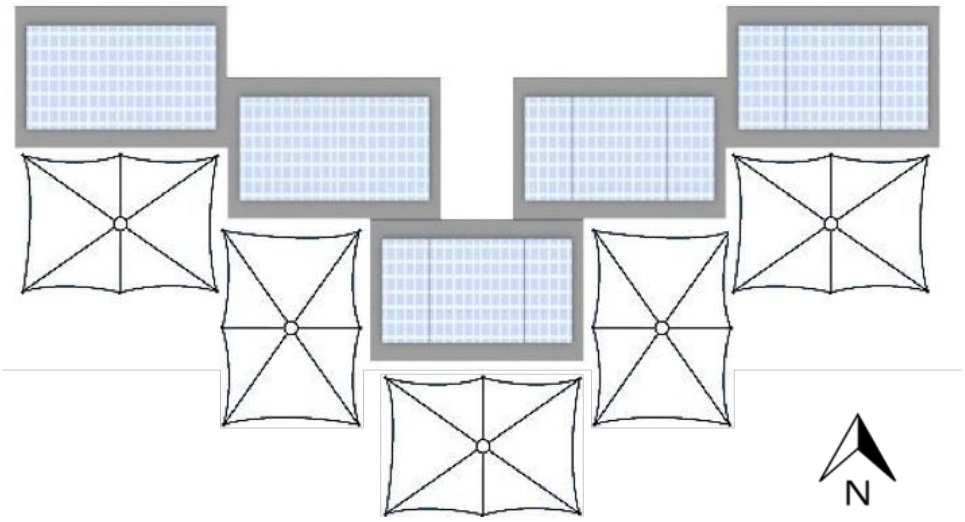


Figure 35: Example of tensile structure shading.

Diverse Unit Utilizations

Envisioned Singular Module

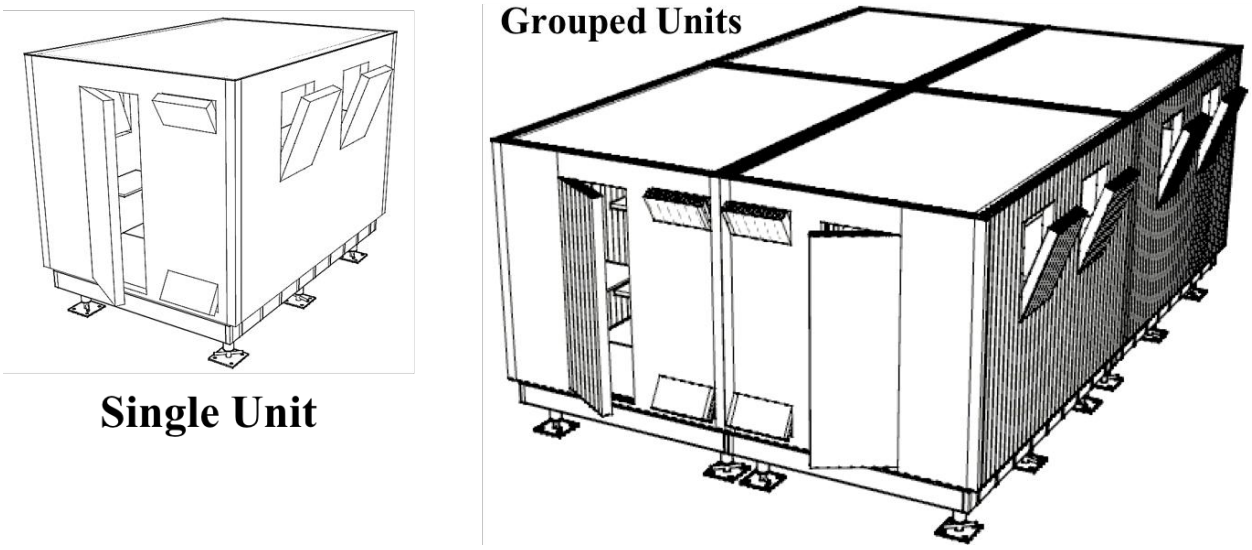


Figure 36: Singular module and grouped singular module.

These modular units can be gathered in many forms and shapes. In the singular unit, the space provided can accommodate a small family for sleeping with minimum activities, like reading or relaxing in the unit. The unit is 8′ x 12′ and can be multiplied to form a larger mother unit which can accommodate more people as a shared space. It is assembled of 5 or 6 of the single units, based on the needed space. It is a shared community space that can function as a bigger housing unit, a gathering place or even a classroom for students who lost their school.

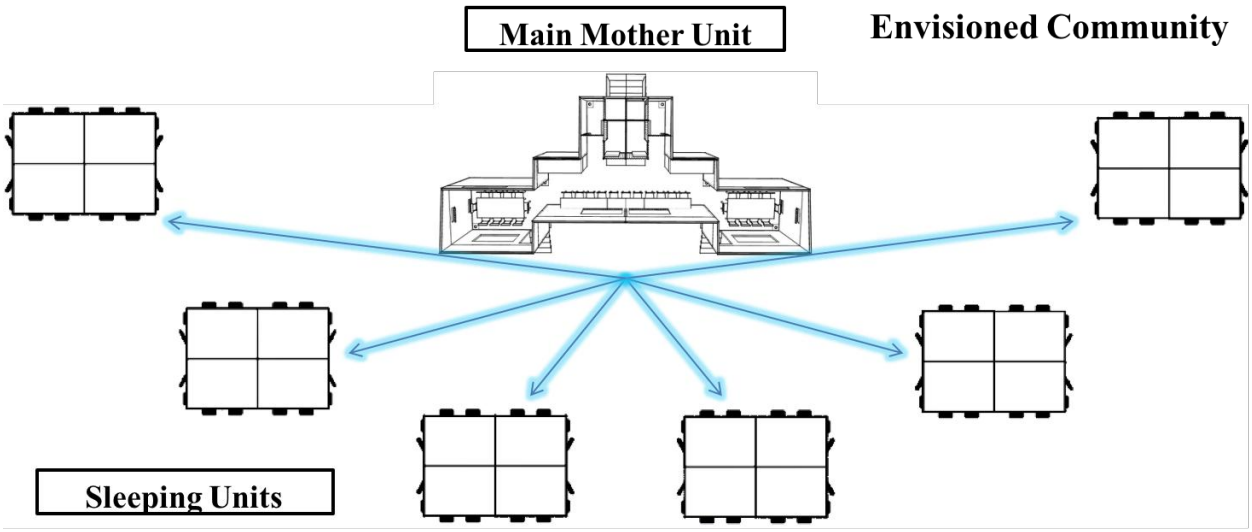


Figure 37:Electricity distributed from the main mother unit to the sleeping units

The mother unit is where the gathering, eating, storing food, water and electricity will be. By putting 5 units together, this space can hold up to 22 people at once. If people are willing to eat by taking turns, the space can accommodate up to three or four times that number. The mother unit will be gathering rainwater, solar energy through the PV panels and storing them for reusing. It's also where all

the appliances, devices and outlets will be. Even if the mother unit is a stand-alone structure among a group of tents, it should sustain that group for a very long time.

The mother unit can also be surrounded by grouped single units. These can accommodate bigger families. These individual grouped units can be connected to the mother unit to receive electricity. It is better for the mother unit to generate and collect electricity into a battery bank. Then distribute the electricity when needed versus each unit collecting electricity individually that may or may not be used, causing an electricity loss and possible overcharge to the battery (reduces battery life). The mother unit can take a wide variety of shapes to improve thermal comfort and expand the roof area for PV panel installment. The shape of the structure can be chosen based on the location and season of the deployment.

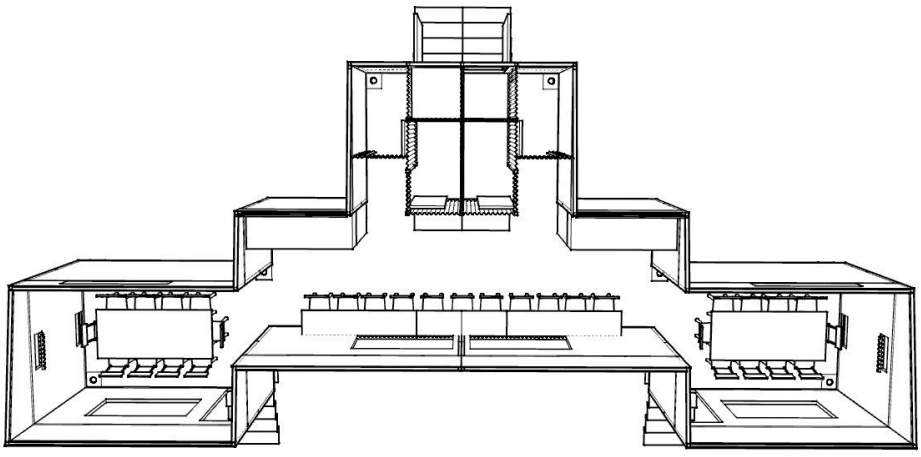


Figure 38: One possible layout of the envisioned mother unit

Conclusion

In conclusion, it is evident that there is a desperate need for energy. Man's reaction has not always been the kindest to the environment. It is clear that humanity needs to make changes for the earth to continue to be the hospitable planet we have known. Though today we will not see the changes take effect, future generations will be grateful for our efforts. In all our actions, even the smallest, we must realize the impact on our surroundings and environment. Can solar power, *along with other environmental strategies*, be utilized to replace the use of traditional electric generators in long-term disaster relief? Yes, solar power along with other supplemental environmental strategies should replace the use of traditional electric generators especially in long-term housing and shared community space.

This study proposes creating net-zero shelters that are self-sustainable and conserve energy with the help of passive and active environmental strategies. The prototype module is yet to be tested. Though many strategies were discussed, not all of them can be applied simultaneously. Some strategies are better for certain regions and climates with taking into consideration the needed space. In combination with Solar Powered Energy, these strategies can provide a great alternative to traditional responses as the PV panels produce no carbon footprint and are environmentally friendly.

This response is geared towards NGO's and Governmental organizations who help people with limited resources, who can not afford to pay for additional accommodations like hotels. Also, people who want to do the right thing for the environment and save their money, energy and their health. This response will require time, effort and money from people to have a better long-term recovery after a disaster. First responders can benefit from such a shelter when they want to establish their services in the affected area. Other social services can benefit from a shared community space, where the need arises for a gathering place, a class for kids and a clinic that can stand alone off the grid.

In the proposed shelter, the people affected, will have their primary energy needs met. During their stay in this long-term recovery shelter, they will be rebuilding their permanent residence. It is anticipated that these people will learn about the effectiveness of green energy. They will also learn some of the impacts of passive environmental strategies on the energy conservation and use. It is the goal of this thesis to bring awareness of available environmental strategies to society so that more people learn about them and implement these strategies in their permanent housing and everyday lives. In conclusion, solar power potentially holds the solution to, not only, long-term recovery phase, but also, to put an end to creating more frequent disasters.

List of References

1. US Environmental Protection Agency. US Greenhouse Gas Inventory Report 1990-2014. EPA. GOV 16 Nov. 2017. https://19january2017snapshot.epa.gov/sites/production/files/2016-04/documents/us-ghg-inventory-2016-chapter-2-trends.pdf
2. Krisberg, Kim. "Scientists: 2016 Was Hottest Year Ever Recorded." Nation's Health, vol. 47, no. 8, Oct. 2017,p.11.EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=125529742&site=ehost-liv
3. Hayden, Thomas. "Super Storms." National Geographic, vol. 210, no. 2, Aug. 2006, pp. 66-77. EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=21584330&site=ehost-live.
4. Richardson, Sarah. "Black Gold from Shaky Ground." American History, vol. 52, no. 1, Apr. 2017, p. 9. EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=120663377&site=ehost-liv
5. Callery, Susan. Global Climate Change: Vital signs of the Planet. Earth Science Communications Team NASA, 21 Nov. 2017. https://climate.nasa.gov/effects/. Accessed 11 October 2017
6. American Red Cross. Safe Generator Use. Redcross.org2017.http://www.redcross.org/get-help/how-to-prepare-for-emergencies/types-of-emergencies/power-outage/safe-generator-use. Accessed Oct. 28 2017.
7. Salam, Jashim and Khaled Hasan. "The Impact of Climate Change on Humans." Sur: Revista Internacional De Direitos Humanos, vol. 14, no. 25, July 2017, pp. 137-153.EBSCOhost,ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=asn&AN=126256614&site=ehost-live.
8. US Department of Homeland Security.Earthquakes.Ready.Gov2017. https://www.ready.gov/earthquakes.Acssessed 8 Nov. 2017.
9. Geology.com. World's tallest tsunami. Geology.com 2005-2017.http://geology.com/records/biggest-tsunami.shtml. Accessed 8 Nov.17.

10. National Geographic. Floods information and facts. National Geographic Society 2017. https://www.nationalgeographic.com/environment/natural-disasters/floods/. Accessed 8 Nov 2017.

11. NOAA. Cyclones, Hurricanes, Typhoons. National Ocean Service 2017. https://oceanservice.noaa.gov/facts/cyclone.html. Accessed 8 Nov. 2017.

12. NOAA. Cyclones, Hurricanes, Typhoons. National Ocean Service 2017. https://oceanservice.noaa.gov/facts/cyclone.html. Accessed 8 Nov. 2017.

13. NOAA. Cyclones, Hurricanes, Typhoons. National Ocean Service 2017. https://oceanservice.noaa.gov/facts/cyclone.html. Accessed 8 Nov. 2017.

14. Department of Homeland Security. Tornadoes. Ready.Gov 2017. https://www.ready.gov/tornadoes. Accessed 8 Nov 2017.

15. Department of Homeland Security. Landslides. Ready.Gov 2017. https://www.ready.gov/landslides-debris-flow. Accessed 8 Nov 2017.

16. Department of Homeland Security. Wildfires. Ready.Gov 2017. https://www.ready.gov/wildfires. Accessed 8 Nov 2017.

17. National Renewable Energy Laboratory. Counting on solar power for disaster relief. US department of Energy, 1999. https://www1.eere.energy.gov/femp/pdfs/26042.pdf. Accessed 8, Nov 2017.

18. ISC Audubon. The Köppen climate classification system. The Sustainability Council Org 2017. www.thesustainabilitycouncil.org/resources/the-koppen-climate-classification-system/. Accessed 10 September 2017.

19. Department of Homeland Security. Emergency Management. Fema.gov 2017https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjVn4Lap93XAhVR2MKHf_iAL4QFggtMAA&url=http%3A%2F%2Fema.ohio.gov%2FDocuments%2FCOP%2FThe%2520Four%2520Phases%2520of%2520Emergency%2520Management.pdf&usg=AOvVaw16KHo6AUSPM8BZIUVqTXNR. Accessed 22 Oct, 2017.

20. Florida Division of emergency management. Recovery. Floridadisaster.org 2017. https://www.floridadisaster.org/recovery/. Accessed Oct. 17 2017.

21. National Center for Environmental Health. Carbon Monoxide Poisoning. Center for Disease Control and Prevention 2017.https://www.cdc.gov/co/faqs.htm. Accessed 27, Nov. 2017.

22. Travis Fedschun, Nicole Darrah. 8 dead due to intense heat, loss of power at Florida nursing home after Irma. Fox News 2017. http://www.foxnews.com/us/2017/09/13/5-dead-120-evacuated-from-florida-nursing-home-due-to-intense-heat-loss-power.html

23. *QuickStats*: Number of Deaths Resulting from Unintentional Carbon Monoxide Poisoning, by Month and Year — National Vital Statistics System, United States, 2010–2015. MMWR Morb Mortal Wkly Rep 2017;66:234. DOI: http://dx.doi.org/10.15585/mmwr.mm6608a9

24. News.energysage.com. How much do solar panels cost in 2017? Energysage.com 2017.news.energysage.com/how-much-does-the-average-solar-panel-installation-cost-in-the-u-s. Accessed Nov 3,2017.

25. Mathias Aarre Maehlum. Which solar panel type is the best?. Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

26. Mathias Aarre Maehlum. Which solar panel type is the best?. Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

27. Mathias Aarre Maehlum. Which solar panel type is the best?. Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

28. Jon Solar. How to Calculate amp-hour needs. Instructibles 2017. http://www.instructables.com/id/How-to-Size-Your-Off-Grid-Solar-Batteries-1/. Accessed July 10 2017.

29. Solar Power Talk. Inverter size vs. battery size tutorial.Solarpowertalk.com 2013. https://www.solarpaneltalk.com/forum/off-grid-solar/off-grid-solar-panel-systems/10394-inverter-size-vs-battery-size-tutorial. Accessed Sep. 9 2017.

30. Kelly Hart. Using Local Materials. Greenhomebuilding.com 2001.http://www.greenhomebuilding.com/localmaterials.htm. Accessed Oct 17, 2017.

31. Tony Serna. Dancing Rabbit Ecovillage. Dancingrabbit.org 2017.http://www.dancingrabbit.org/about-dancing-rabbit-ecovillage/eco-living/building/natural-building/earthen-floor. Accessed Oct 10, 2017.

32. http://www.nukshbundtraders.grpofcompanies.org/thread%20%20PRICES%20LIST.pdf

33. A foam and Fabric Place, Tucson Az https://www.fourthavenuetucson.com/retail-shops/a-foam-and-fabric-place/

34. Mathias Aarre Maehlum. Which solar panel type is the best? Energy informative.org 2017.http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/. Accessed Oct 11, 2017.

35. Texas A&M Agrilife Institute. Rainwater Harvesting. TAMU.edu 2017. https://rainwaterharvesting.tamu.edu/catchment-area. Accessed Dec 1, 2017.

36. United States Environmental Protection Agency. Emergency Disinfection of Drinking water. www.epa.gov 2017. https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water. Accessed Dec 1, 2017.

37. United States Environmental Protection Agency. Emergency Disinfection of Drinking water. www.epa.gov 2017. https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water. Accessed Dec 1, 2017.