Creating a Sustainable House for Klong Toey

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Abstract

This capstone looked at a housing problem in Klong Toey which is a slum in Bangkok, Thailand. Currently 100,000 people live in Klong Toey which is only on a 1 square mile plot of land. (Sapsuwan, Peewara, n.d.) The goal was to come up with a new sustainable housing design that could not only solve their housing issue, but also solve power and water shortages and health issues that arise due to their current living situation. The capstone looks at a resource called “Community Action for Sustainable Housing: Building a Low-Carbon Future” to help understand what goes into making a sustainable home. Two case studies were looked at to take ideas that had previously worked. There is also a cost benefit analysis to compare the design of just a simple house to one with more sustainable features added on. In the end it was concluded that there is not enough money to build the most sustainable home so it would be better to just go with the simple design.

Introduction

The earth consists of 7 billion people(7billionworld.com, n.d.) and 1 billion of those people currently live in slums that are in developing countries.(Murphy, Jarret n.d.) A slum is a place that was created by squatters who had no other place to live. They tend to build their houses and use materials that they find locally. Slums are filled with crime, diseases, and poor sanitations. Basically for the people that live in these slums life is back to the way it used to be before society as we know it began. One of these slums is located in Bangkok, Thailand and the name of this slum is Khlong Toey. Currently, 100,000 people ranging in all different ages call Khlong Toey home. (Sapsuwan, Peewara, n.d.) By changing the housing in Khlong Toey would we see Bangkok gain any type of benefit? Also some other questions that this essay will answer are how we could create the most sustainable house for these people? What types of materials will work best and how sustainable should it be?

Klong Toey was officially started in the 1950's by a group of poor people looking for a place that they could call home in the overcrowded city of Bangkok.(Sapsuwan, Peewara, n.d.) The slum is located near the center of Bangkok on a plot of land that is owned by the port authority of Thailand. Thailand is home to over 5,500 slums and Klong Toey is one of the oldest and well known slums. .(Sapsuwan, Peewara, n.d.) The 100,000 people who live there are compacted into a space that is only a square mile plot of land. The houses are built on top of a 3 meter deep swamp like ground that and

are makeshift tin homes. The swamp like ground is due to the garbage and sewage that are poorly handled and is just stored in the streets. Both electricity and water are scarce to have per household in the slum. The average household income is half of the national average and one-third of the citizens of Bangkoks. .(Sapsuwan, Peewara, n.d.) This is due to things like the fact that most of Klong Toey's residents lack skill and education. Drug addiction is common with the most common drug being meth and crime happens daily varying in crimes from murder to theft. .(Sapsuwan, Peewara, n.d.) Another thing that Klong Toey has to deal with is that it commonly floods which is only another reason that it is in need of development.

This capstone sets out to explore solutions to issues that Klong Toey faces. The goal is to determine and design an affordable sustainable housing model for this slum. To do so will require a case study of other affordable housing efforts in slums to draw upon successful examples and avoid the pitfalls of others.

Lit review

From the source Community Action for Sustainable Housing: Building a low-carbon future you find out what sustainable construction is and the strategies that go into cutting back on our ecological footprint. New buildings need to be built to handle mitigating climate change and adapting to it. A sustainable house can be anything from a high-tech smart house which can use things like modern construction methods and daily controlled energy use to low-tech solution house that can be as simple as off grid dwellings. Using Off the Grid Re-Assembling Domestic life you learn that off grid dwellings are residences that run without remote infrastructure. Examples would be

without an electrical grid, water supply, sewer, and natural gas. (Phillip, 2014) The dwellers create an alternative source of electricity by using sources like solar power and wind power. “Solar energy is the most prominent among renewable sources, as it is an inexhaustible resource and its exploitation has thus far been ecologically friendly.” (Akikur, 2013) We can collect more solar energy than the world currently needs to run everyday life. Solar power is advancing faster and gaining interest more than other renewable energy source. Solar panels collect solar energy through photovoltaic technology. It can also be used to bring in more electricity to the slum which is one of the things that Klong Toey needs the most. Solar panels can be used to power one house or even a small community. Solar panels should last 25 to 30 years. (Sharma, 2013) One bad thing about solar panels is that weather can affect them. When solar radiation is too high like in some places around the world you must use a hybrid solar PV panel. Wind power is electricity that is created by wind. The electricity is created by “Using the air flows that occur naturally in the earth’s atmosphere. Wind turbine blades capture kinetic energy from the wind and turn it into mechanical energy, spinning a generator that creates electricity.” (AWEA, 2017) There are two types of systems that create wind power which are windmills and wind turbines. Windmills are used to create mechanical energy whereas wind turbines are used to create electricity. There are 3 main types of wind that can be used to create energy: utility scale winds, distributed wind, and offshore wind. (AWEA 2017) “Wind turbines now provide the lowest cost of any renewable electrical energy.” (Cavallo, 2007) Which is why it would be possible to set up a wind farm to create and bring in enough energy for the slum.

To create a sustainable house you need to Harness the creative energies of community- led solutions and adapt them for wider mainstream settings. (Seyfang, 2010) Another reason residential housing needs to become more sustainable is to cut back on CO_2 emissions because like with the UK as an example they create a fraction of their carbon dioxide emissions from just running all the building in the country. (Seyfang, 2010) “The imperatives of climate change mean that our building technologies need to evolve to meet the demands of climate change predictions, while simultaneously reducing the contribution they made to CO_2 emissions.” (Seyfang, 2010) To solve water shortage in the slum we can install rainwater harvesting systems. Rainwater harvesting systems are a setup that use “The gathering and storage of water running off surfaces on which rain has directly fallen.” (Pacey, 1986) The rainwater harvesting system can be used as another source of water for communities like Klong Toey that don’t have large water resources. I was able to find a study about putting a rainwater harvesting system on a low income flat. The flat was located in Cengkareng, Jakarta which is a city that faces water crisis’s due to rapid population growth and building construction which a very similar situation to Klong Toey. This source was trying to find out how much rain water it would need to supply enough to be an alternative source. The city realized that they did not need to use this water for drinking or cooking and could still us the safe water and use the newly collected rainwater for toilets and gardens. The source started out by finding the size of water catching area that they would need and how much water it would collect. Rain water harvesting can be a daily alternative source if it rains in your location frequently. From this source I was able to find out how much water I would need to create for Klong Toey by taking the average

water consumption and multiplying it by 365 days. You can find the size of the water supply by multiplying the average rainfall by area by the runoff coefficient. You can also find out the size of the catchment are that you will need by multiplying average rainfall by .63 by the runoff coefficient than taking that number and dividing the supply with it. (Mydin, 2015)

When talking about new sustainable construction Hacker et al said “That we need to design new ways in which we do not rely on air conditioning to maintain thermal comfort, but rather draw on cooling socio-technologies traditionally employed in warmer climates, such as shading from the sun, thermal mass to stabilize temperature, passive heating and cooling systems and afternoon siestas.” (Hacker et al 2005,SDC,2006) Thermal comfort is the level at which people are comfortable in a room or space. Thermal mass is a technique that is used to store heat within a building. Thermal mass slows the release process of heat from a material. Thermal mass is ideal for locations that have large temperature swings from day to night. The materials that work best are: concrete floors and walls, sandstone, brick, tiles, and adobe. (Shaviv, 2001) The solar gain that is collected from thermal mass materials can help also with passive strategies. Passive strategies can be described as “A building that is heated by the sun directly through south facing windows.” (Chiras, 2002) Passive strategies work best when the house is compactly designed. Use of a trombe wall is a good passive heating strategy and also a good thermal mass material. In order to collect as much solar gain as possible “Passive solar homes should be oriented to the south.” (Chiras, 2002) The main 2 strategies are cooling and heating. Cooling is done by using openable windows

and a cool breeze (Chiras, 2002). Another passive strategy is natural ventilation which is cooling or heating a building or space without a mechanical unit. Another way of cooling by way of natural ventilation is by creating a cool tower. “Wind towers maintain natural ventilation through buildings due to wind or buoyancy effects.” (Bahadori ,1994) It works by cooling air from outside by taking it through wet pads that help condense the air and slows it down so that it has a longer time period to cool down and this all works through evaporation. There are two main modern designs for cool towers. “One design incorporates one-way dampers in the tower head and a wetted column in the tower.” (Bahadori, 1994) This design works best in areas that frequently have good winds. “The other design incorporates evaporative cooling pads at the tower entrance.” (Bahadori, 1994) This design works best in areas that typically have little to no wind. You can also modify old existing towers to perform these tasks. The only bad thing about cool towers is that they can generate and bring in a lot of dust to your building. I believe this could be a unique way to bring natural ventilation into the design of the new sustainable slum homes.

Some major things that go into creating a sustainable house are: renewable materials and energy resources, low-polluting materials, a concern with the overall lifetime impacts of the house and autonomy. (Seyfang, 2010) Some steps that could help with creating a more sustainable house come from the Centre for Alternative Technology. These steps are using renewable energy, appropriate technologies, community living, and self-sufficiency. (Seyfang, 2010) Green architecture is defined as “A design which: conserves energy, works with climate, minimizes use of new

resources, respects its users and its site and is holistic. (Vale and Vale, 2000) From this source I have also learned that you can benefit from solar gain by having large south facing windows to heat the house and then use high mass walls and floors so that the heat can be collected and stored during the day and released at night. This helps with cutting back on mechanical use to cool or heat a building. Another important part of creating a sustainable building is the materials that you use. When trying to create a sustainable building you should look to use renewable and recycled materials. Some examples of renewable materials are: are straw bale, wood, cob, reed and thatch, and other forms concrete such as papercrete and hempcrete. (Seyfang, 2010) Some examples of recycled building materials are: newspaper wood, nappy roofing, recy blocks, blood bricks, bottle bricks, mushroom walls, plasphalt, and wine cork pads. (Jeffery, 2015) Also an important way to keep the buildings in good shape and running is by educating the people who will be uses them so that they truly know what they are using, how the strategies work, and how they can fix them. The goal of sustainable housing is about technology-intensive “smart” housing which requires no change in householders’ behavior to deliver energy saving.” (Lovell, 2004) Examples of these technologies are: movement sensor lights, energy-efficient appliances and networked devices. (Seyfang, 2010)

Another way to create sustainable housing is by using low-impact development which minimizes the ecological footprint. Low impact development is a type of construction “In which we look at evolving approaches to ecological design, many of which are based on the use of locally sourced, traditional, natural and benign materials,

often used in innovative ways, and the construction techniques that follow from them. (Halliday, 2008) Low-impact development is used more for small scale projects and has really cheap materials. A way to use low-impact development is “Through the use of unconventional technical and contractual frameworks, can deliver improvements and efficiencies measured in orders of magnitude. (Halliday, 2008) Some low impact materials include mud, straw bale, hemp, lime construction, and timber. (Halliday, 2008) By using these materials for your building you can cut the cost of construction in half. This is done “With improved environmental performance and markedly lower running costs.” (Halliday, 2008) From this sources I hope to learn how to create the most sustainable house for the people of Klong Toey and use more sustainable materials. I feel like these sources have helped me get a better understanding of the strategies and materials that are out there and has taught ways to use those strategies and materials.

Methodologies

This capstone will incorporate both qualitative and quantitative research. The qualitative will consist of a case study on two previously done projects that dealt with similar circumstances. The case studies will focus on sustainable designs created in different ways one in Mexico and one for a competition. The goal will be to analyze what worked in both design strategies. The success from the case studies will be applied to a separate location in Klong Toey, Thailand. A cost benefit analysis will be applied. The CBA will focus on creating two types of sustainable buildings: one being an all-out sustainable house compared to a house that just focuses on some sustainable features.

These houses will be designed with appropriate materials and products for the weather in Klong Toey, Thailand.

Data

Case Study 1

Figure 1; Sandy (n.d.)

The first case study that I looked at was a design that was created for a $300 house competition for the Ingersoll Rand Center for Energy Efficiency and Sustainability and the Harvard Business Review Blog. The house needed to be simple and affordable. Joseph Sandy came up with a design that included low cost recycled materials. The house starts with walls made of earth block that vary in height based on the climate zone you live in. Sandy uses earth blocks to add thermal mass to the house. Then placed on top of the earth block is a wooden frame that has operable wooden shutters

to regulate the temperature of the house. By using the operable window shutters the design is able to use cross breezes to change the temperature inside of the home. (Sandy,n.d.) To heat the home the use a stove that is also used for cooking. The design uses a shed roof that is constructed of corrugated metal. The house uses LED lights to light the inside and outside. They then placed the house around a communal courtyard that is also surrounded by more of the homes. The homes all share facilities like “Solar panels, solar cooker, solar water purifier, cistern and a washing station.” (Sandy,n.d.) The houses come in four different designs based on what climate zone you are in.

4 Climate Designs

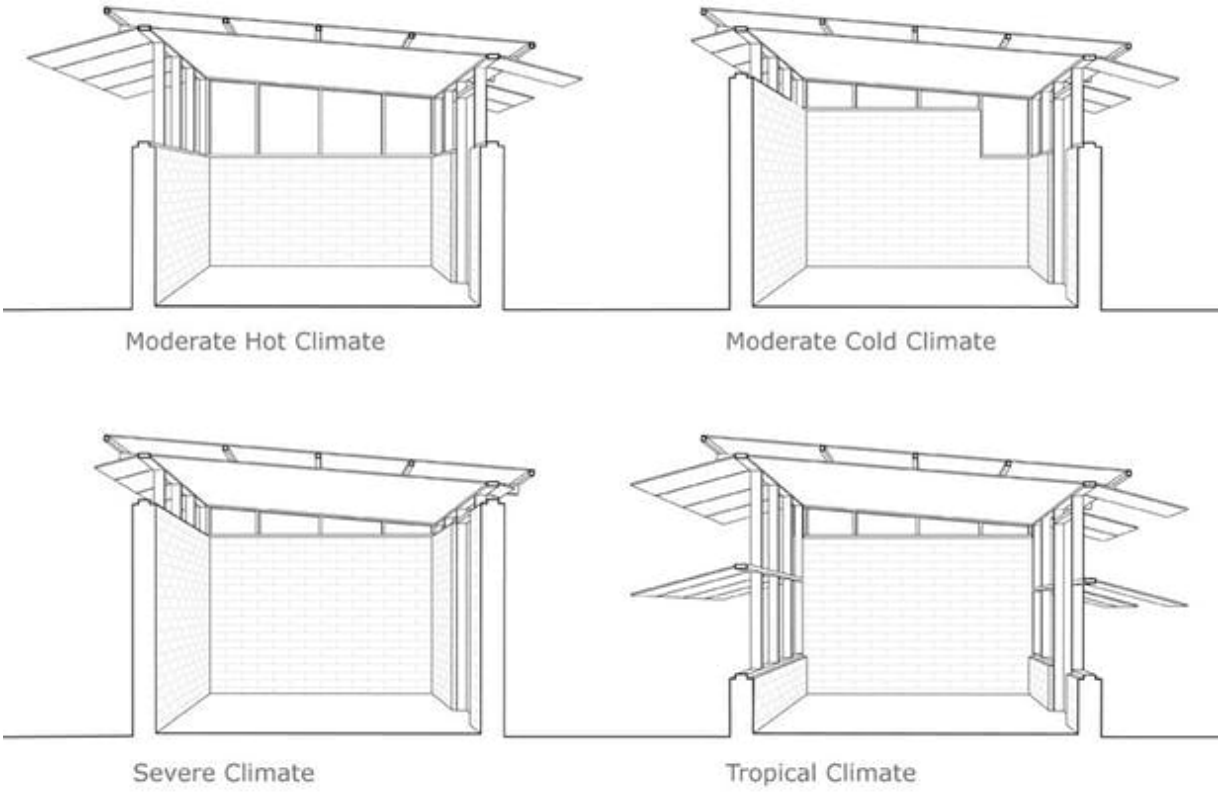

Figure 2; Sandy (n.d.)

Case study 2

Figure 3; Lane (2016)

The second case study that was looked at was done by a company in Mexico called EcoDomum. They noticed that Mexico had a lot of people living in poverty and wanted to come up with a design to solve that problem. Next they noticed that Mexico was the 12th Largest plastic consumer in the world and they wanted to find a way to use plastic waste to create the homes. (Lane, B. 2016) Plastic typically takes around 1,000 years to decompose and 10 -20 million tons of that plastic is ending up in the ocean. (Lane, B. 2016) The company came up with a way to use the recycled plastic to construct the walls and roof of the house. EcoDomum hires waste companies to pay the trash collectors more money so that the waste companies keep sending the plastic waste to EcoDomum. Which helps boost the economy in Mexico and means they have an endless supply. The trash collectors collect the plastic, it is then melted down, and then shaped in the large panels. (Lane, B. 2016) The company only uses plastics that don't burn into a harmful toxin. The panels are 8 feet by 4 feet and 1 inch thick. (Lane,

B. 2016) They chose to make the homes 430 to 460 square feet. (Lane, B. 2016) A 430 square foot home uses 80 panels. (Lane, B. 2016) The costs of the 430 square foot house would be $33 for the roof, $36 per exterior wall, and $28 per interior wall. (Lane, B. 2016) The house includes 2 bedrooms, 1 bathroom, 1 living room, and 1 kitchen. The house takes a total of 2 weeks for the company to complete. (Lane, B. 2016)

Plastic panels

Figure 4; Lane (2016)

Rainwater Harvesting

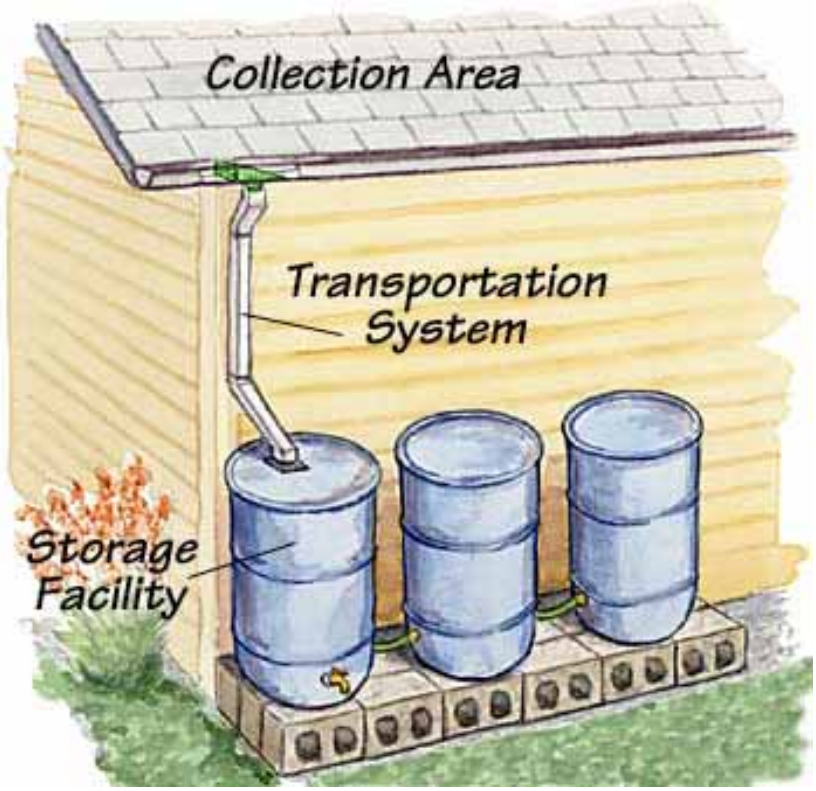

Figure 5; Garden Gate Magazine (2018)

A major problem that Klong Toey faces is water shortage and a great solution to that is rain water harvesting. A rain water harvesting system is made up of a collection area, the transportation system, and the storage facility. (Staff, G. G. 2018). The collection area is the area that collects all the water that hasn't already soaked in and is located on the roof. The size of your roof effects the amount of water collected. The next part is the gutter which is the transportation system. The gutters are placed along the edge of the roof where the roof is down sloped. The bigger the gutter the better and they can be made of aluminum or plastic. The average size gutters that are used are 5 to 6 inches. (Staff, G. G. 2018). The gutters have to have filters that are made up of a bunch of screens that catch the debris to keep it out of the water. The transportation system carries the water to the storage facility which is made of barrels. You can either

make or buy the barrels is does not matter. You need to have an overflow system like more barrels.

Weather

Average Minimum and Maximum Temperature Over the Year

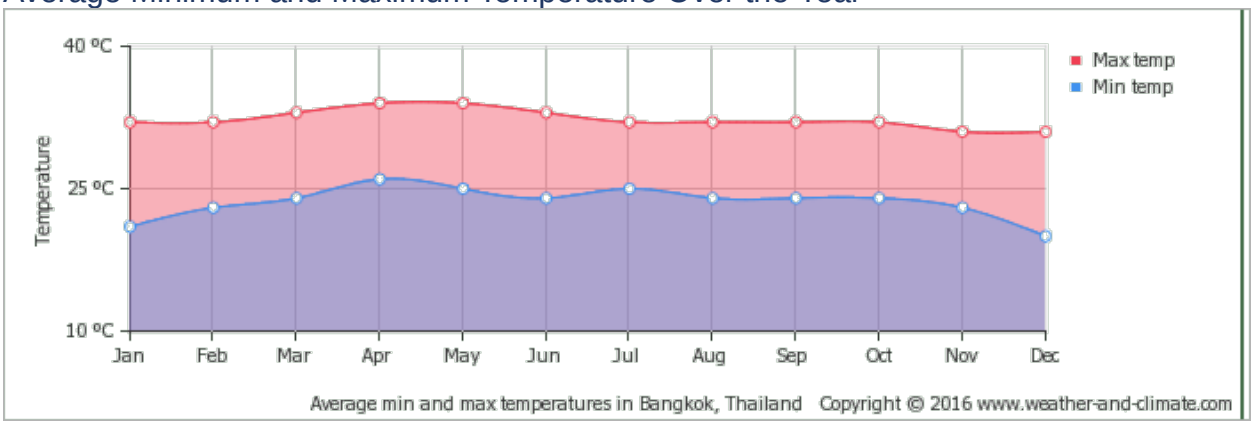

Figure 6; Weather and Climate (2016)

Bangkok faces hot temperature averages for most of the year. The temperature ranges from 60 degrees Fahrenheit to 95 degrees Fahrenheit. (World Weather & Climate Information. 2016) The hottest months of the year are April and May. (World Weather & Climate Information. 2016) The coolest months of the year are December and January. (World Weather & Climate Information. 2016)

Average Monthly Hours of Sunshine Over the Year

Figure 7; Weather and Climate (2016)

Bangkok can get up 270 hours of sunshine or as little as 150 hours a month. (World Weather & Climate Information. 2016) The months that have the most sunshine are January, March, April, and December. (World Weather & Climate Information. 2016) The months the have the least amount of sunshine are June, July, August, and September. (World Weather & Climate Information. 2016)

Average Monthly Precipitation Over the Year

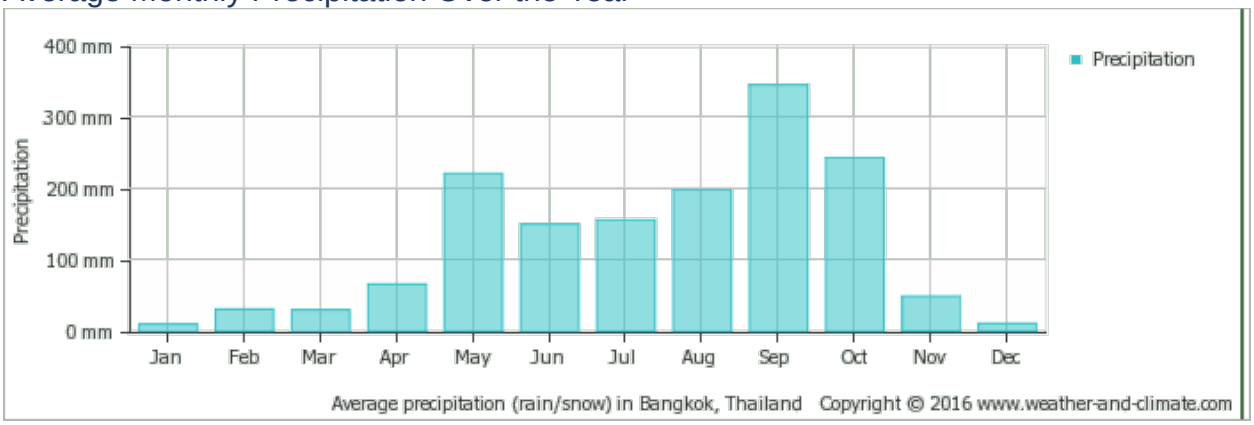

Figure 8; Weather and Climate (2016)

The city gets most of its precipitation for 6 months of the year, but still receives some in the other 6 months. (World Weather & Climate Information. 2016) The city can get up to 14 inches or as little as under an inch. (World Weather & Climate Information. 2016) The months with the most rain are May, September, and October. (World Weather & Climate Information. 2016) The months that receive the least amount of rain are January, February, and December. (World Weather & Climate Information. 2016)

Average Monthly Rainy Days Over the Year

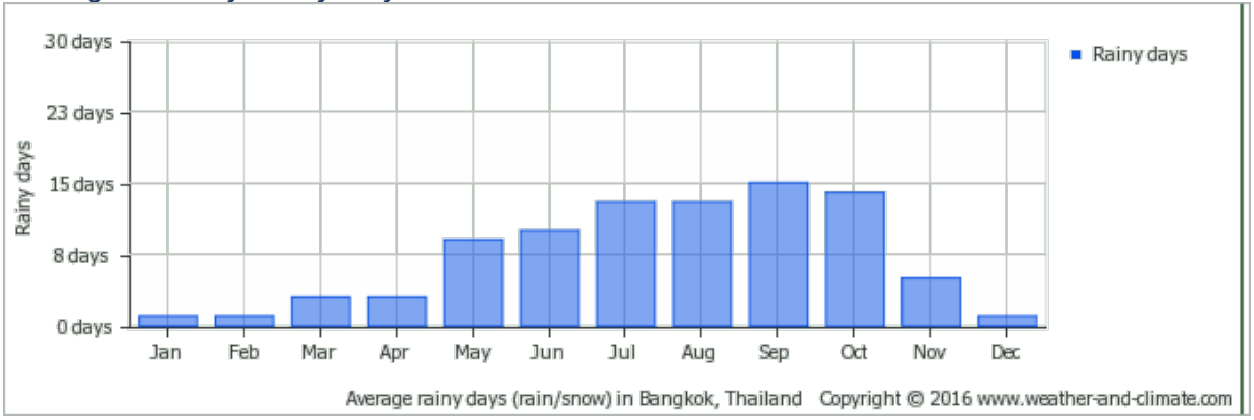

Figure 9; Weather and Climate (2016)

A month in Bangkok can have up to 15 rainy days or as little as 2 days. (World Weather & Climate Information. 2016) December, January, and February have the least amount of rainy days. (World Weather & Climate Information. 2016) The months with the most rainy days are July, August, September, and October. (World Weather & Climate Information. 2016)

Average Humidity Over the Year

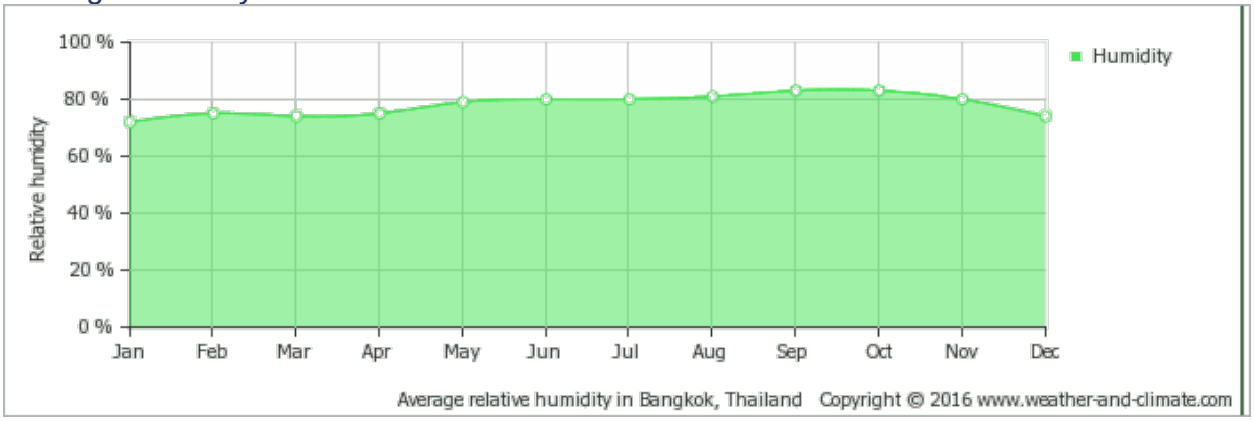

Figure 10; Weather and Climate (2016)

Bangkok is a very humid climate year round. The humidity can get up to 85% or be as low as 70%. (World Weather & Climate Information. 2016) Bangkok experiences the most humidity in September and October and the least humidity in January and December. (World Weather & Climate Information. 2016)

Average Wind Speed Over the Yea

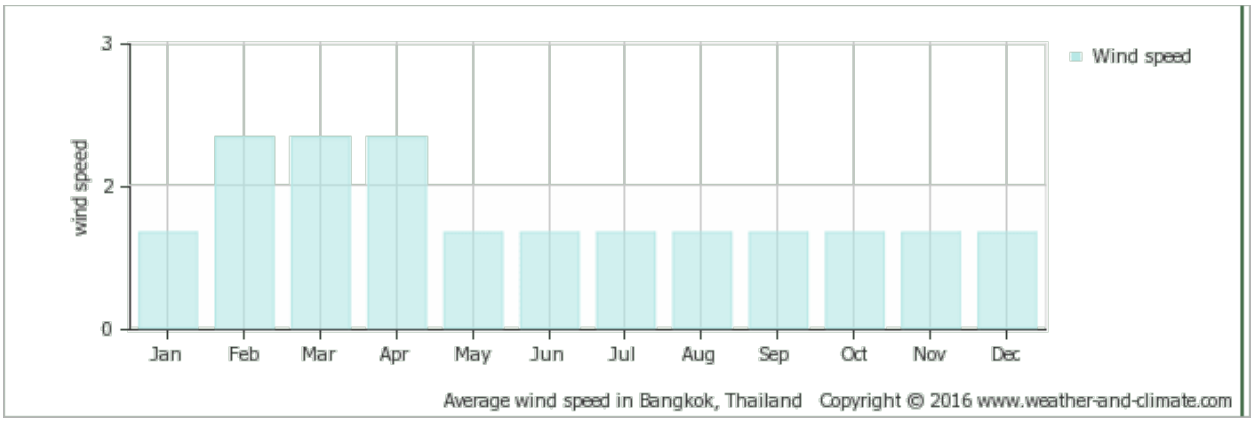

Figure 11; Weather and Climate (2016)

The city of Bangkok does experience a lot of wind throughout the year. The windiest months are February, march, and April which can see speeds of 2.5 meters per second. (World Weather & Climate Information. 2016). The rest of the months are the same and see wind speeds of 1.6 meters per second. (World Weather & Climate Information. 2016)

Homes in Thailand

The typical house in Bangkok is raised off the ground be beams or post to protect against floods and animals. The roofs are constructed in different types of ways like with corrugated iron, woven bamboo, palm leaves, and tiles. (Hays, J. 2013) The floor can be a planked floor, but some are on the ground and just have an earthen floor. Most houses use bamboo for the walls or other types of wood. Most houses take a

resemblance to a gazebo rather than your western style homes you are used too. (Hays, J. 2013) The houses are designed in a way to catch breezes from all directions because it is usually really hot. (Hays, J. 2013) The kitchen is usually located in a separate structure that is more open than the house to keep all of the steam out of the house and to keep the smells away. People in Thailand use a tub and a cup or hose to hand wash themselves because they do not use bathtubs or showers. Their houses also have squat toilets instead of the normal sit down toilet. Also most slums and rural house use an outhouse rather than an inside bathroom. Most houses are around 728 square feet and include two bedrooms and a living room. (Hays, J. 2013)

Plastic Use

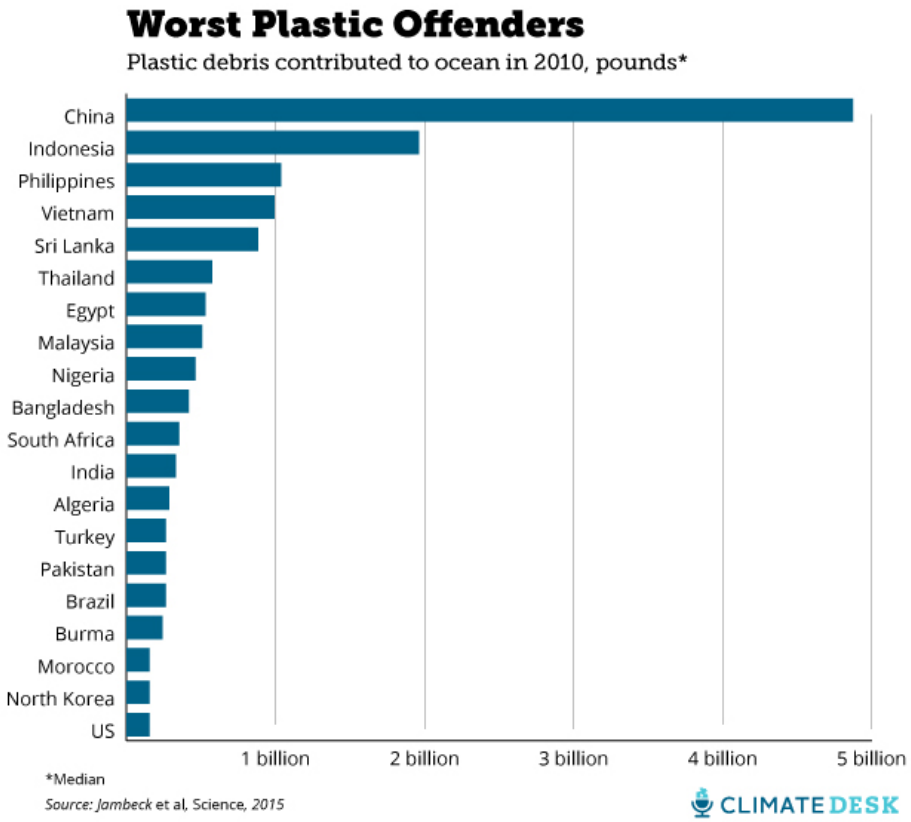

Figure 12; Jambeck et al, Science (2015)

On average “1 ton of plastic is used daily” and that is being increased by 10% per year. (Linnenkoper, 2016) For the average person in Bangkok recycling is not a priority and they don’t go out of their way to recycle leading to most of it ending up on the streets and the ocean. On average a person in Bangkok uses 8 plastic bags a day. (Linnenkoper, K. 2016) This graph shows that Thailand was number 6 in countries that contribute to plastics in the ocean, since then they have moved into the 5th spot. In 2015 Thailand used 2.33 million tons of plastic and only recycled and reused 1.57 million. (Ocharoenchai, 2017) Bangkok went from 23.93 million tons of waste in 2008 to 27.04 million tons in 2018. (Karnjanatawe, 2018) Only 21% of the 27.04 million tons is recycled and reused. (Karnjanatawe, 2018) Bangkok produces the most plastic waste in all of Thailand. (Karnjanatawe, 2018).

Results

Low cost proposal

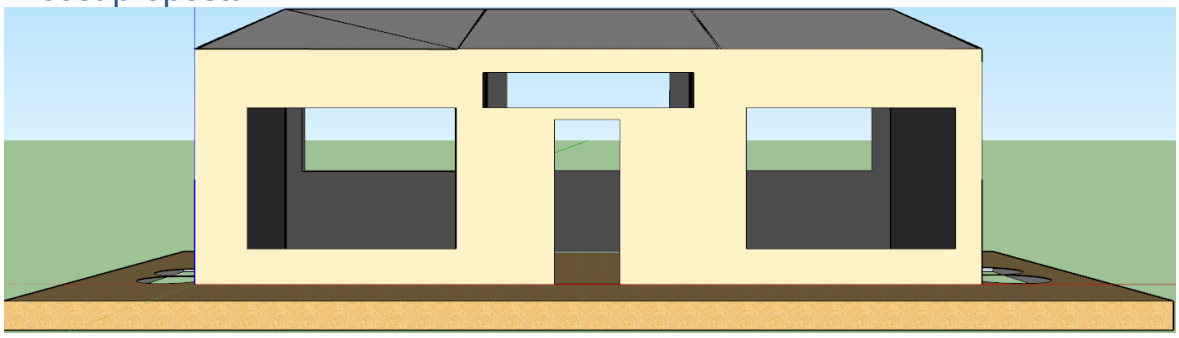

Figure 13; Lastine (2018)

The proposed house is designed for the Klong Toey slum in Bangkok, Thailand and is addressed to fit their needs and weather. The house is 430 square feet and is 30 feet in length and 14.33 feet in width. The south wall is 9 feet high and the north wall is 12 feet. For the structure of the house we will be using the recycled plastic panels that

EcoDomum created. The house will be constructed out of the recycled plastic panels that will be shaped to fit the house allowing for an easy setup. This is to help reuse some of the plastic that is usually left in the street or that ended up in the ocean. These plastic panels will have cutouts in them to allow air flow. The cutouts will take up most of the surface areas on the north and south sides of the house. This is take advantage of the sunlight that comes from the south to have more daylight brought into the house which will help cut back on electricity that is used on lighting the interior. The cutout idea comes from the Joseph Sandy design which allows the house to use cross breezes to ventilate and regulate the temperature inside the home.

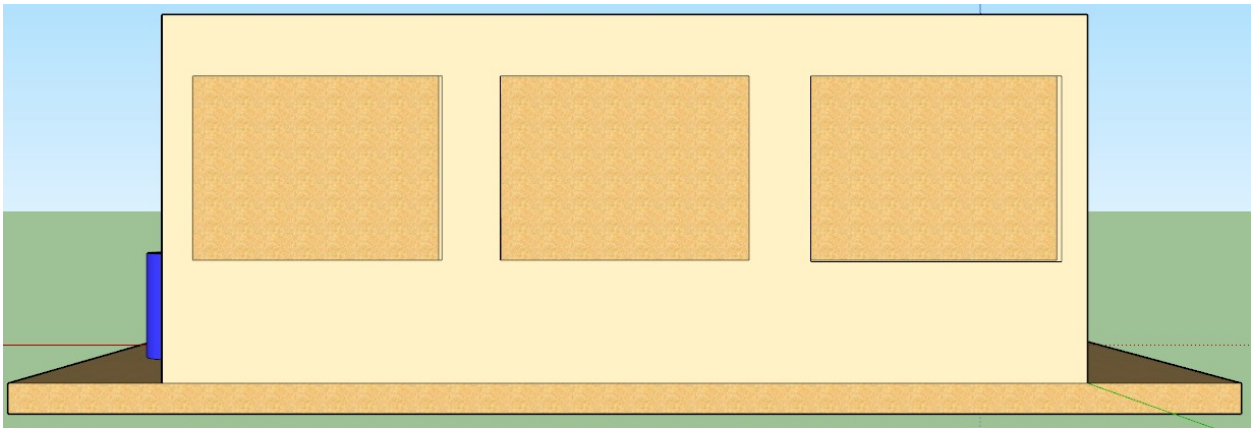

Figure 14; Lastine (2018)

The cutouts will have blinds that are made of woven bamboo to allow ways of block the sunlight and to protect against weather. In total the house will have 6 cutouts and 1 door with 3 cutouts and the door on the south side and the 3 cutouts on the south side. The door is 7 feet by 2.5 feet, 2 of the cutouts on the south side and 3 of the cutouts on the north side are 8 feet by 6 feet, and the last cutout on the southside is 8 feet by 1 foot. The roof will be made of the same recycled plastic panels as the walls. On top of the roof will be corrugated metal to allow the rain to slide down easily and because to is a common material found in Bangkok. The roof will be at an angle with the

highest point being at the north wall and slanted down towards the south. The exterior of the house will be painted a tan color to help against the harsh sun. The interior will be broken into 3 rooms 2 bedrooms and a living room. The house will not include a bathroom or a kitchen because typically those are in different structures. The two bedrooms are on the end with the living room located in the middle. The cutouts are placed so that the breeze will come through each of the rooms. The interior walls will be made of bamboo to help cut back on the cost. There are also two interior doors that are also 7 feet by 2.5 feet. All three of the doors are made of bamboo. The whole house will be placed on top of a bamboo platform that will be raised be beams to help protect from floods and animals. The platform is 450 square feet giving the sides an extra 5 feet and the front an extra 5 feet as well. The bamboo platform will serve as the floor as well.

Sustainable Add-ons

That design was just a low cost proposal to make a sustainable house, but I also wanted to look at adding more sustainable features to that design. 4 sustainable add-ons were look at and they were solar panels, wind turbines, rainwater harvesting, and cork floors.

Figure 15; Renogy (n.d.)

Solar panels were chosen because they can help bring more power to the home and because there is sunlight a lot of the year. The solar panels that were chosen was the Renogy 200 watt 12 volt solar starter kit with MPPT charge controller. This a basic starter kit that is easy to use and setup and is usually used to go off grid. It is made of both monocrystalline and polycrystalline. (Renogy 200 Watt 12 Volt Solar Starter Kit w/ MPPT Charge Controller. n.d.) The 20A MPPT charge controller is created to use the maximum power point tracking technology. (Renogy 200 Watt 12 Volt Solar Starter Kit w/ MPPT Charge Controller. n.d.) The solar panels are guaranteed to have no hot spots. The panels are made to last a long time and are constructed out of an aluminum frame and have a IP65 junction box. (Renogy 200 Watt 12 Volt Solar Starter Kit w/ MPPT Charge Controller. n.d.) The system is made up of 2 panels that will be placed on top of the roof.

Figure 16; Aliexpress (n.d.)

The wind turbine will also help bring power to the home and was chosen because of the amount of wind Bangkok receives. The wind turbine that was selected was the Mars Rock DC Hawt. The turbine is used to turn natural power into electricity. The wind turbine generates 3 phases of AC power and turns it into DC power. The turbine comes with a built in controller which makes it really easy to use as well. The generator only needs winds that reach speeds of 2 m/s to start so that falls into the wind speeds that Bangkok is common too. (12V or 24VDC 5 blades 400W wind turbine generator with built-in rectifier module , 2m/s small start wind speed windmill. n.d.) This wind turbine is a 5 blade system and would also be placed on the roof.

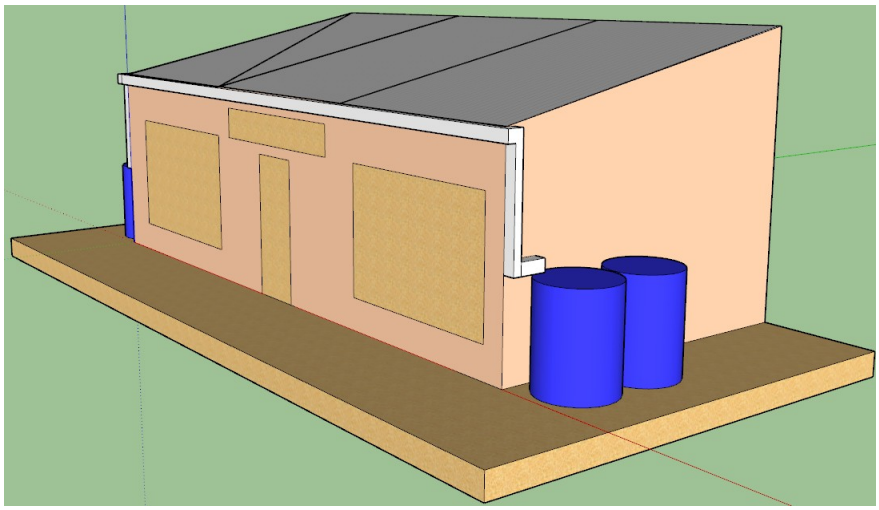

Figure 17; Lastine (2018)

The rainwater harvesting system will also be added to help bring the people of Klong Toey water because it is so scarce currently. It also rains enough in Bangkok to get enough water to supply the house for parts of the year. I have chosen to use a 4 barrel system the uses the roof to catch the water which is also why it is corrugated metal. It uses aluminum gutters that have a pitch in the middle to have them slope down towards the ends to help that transport the water to the barrels. There will be two barrels on each side of the house. 1 is the storage tank and the other is to store the overflow from the first.

Figure 18; House Energy (2013)

The last add on is cork floors which would be taken from the Indian cork trees that are found in Thailand. The cork floors will help with heat loss and gain. It also adds comfort because it is common to sit on the ground in Thailand. The cork floors are water resistant, fire proof, and doesn't mold. (Cork flooring for thermal and acoustic insulation. 2013)

Cost benefit analysis

The cost benefit analysis will be looking at the cost to just build the simple house compared to what it would cost to add the other sustainable features. First what goes into the simple house: bamboo, corrugated metal, recycled plastic panels, and paint. Broken down that would be $131 for the bamboo because the platform would cost $79, the doors would cost $10, and the blinds would cost $42. (Bamboo Canes/ Bamboo Poles - Buy Bamboo Canes Product on Alibaba.com. n.d.).The plastic panels would cost in total $233 having the exterior walls cost $144, the interior walls would be $56, and the roof would cost $33. (Lane, B. 2016) The corrugated metal would be $159 and the paint would cost $60. (Thailand roofing sheet. n.d.) (Learn how much it costs to Paint a Home Interior. n.d.). That makes the total of the simple house $583. Now what the price would look like with the sustainable add-ons. The solar power setup would cost $398.99 and the wind turbine would cost $144.50. (12V or 24VDC 5 blades 400W wind turbine generator with built-in rectifier module , 2m/s small start wind speed windmill. n.d.) (Renogy 200 Watt 12 Volt Solar Starter Kit w/ MPPT Charge Controller. n.d.) Also the rainwater harvesting system would cost $213 while the cork floor would cost $54. (K Style Aluminum Rain Gutters, n.d.) (Comfort Flooring in Shoreline by Cali Bamboo, Wide Sample. n.d.) (SpringSaver Rainbarrel, Home Gardening Supplies at

Burpee.com. n.d.)This would bring the total of the simple house and the sustainable add-on features to $1,393.49. This shows that it still isn't that expensive to add-on all the feature, but is a safer and cheaper route to go with the simple house.

Conclusion

The goal of this capstone was to create a sustainable house for the people of Klong Toey who are in desperate need of a new homes that will last for many years to come. They face harsh environments, having to rebuild their homes frequently, and health problems. With this new design the people get a low-cost sustainable healthy home. The homes will also make the people happier with the clean looks and feels. One thing I found out during my research is that the people of the slums aren't always nice and pick fights with the port authority saying they will not leave. My solution to this is that the port authority should build my homes and charge the people of Klong Toey rent because they already have to pay rent for these tiny shack's they call homes. My other solution was to build the homes in another location and the people of Klong Toey will want to move because they will be getting a new home. Another thing that was brought to my attention doing research was that EcoDomum was looking to expand its company into other countries and since Bangkok and Thailand have so much plastic waste I feel that here would be a perfect fit. This would help the design because we wouldn't have to ship the panels from Mexico. This would help Bangkok in 2 ways. First by bringing more jobs for the people of Thailand because the company will factory workers and more trash collectors. The second way it helps is that it will increase the amount of reused plastics and decrease the amount of plastics found on the streets and in the ocean. From the research done I believe that it would be better to build the simple low-cost

design without the add-ons because nobody wants to donate enough money to build these homes. If you were to add at least one of the wrongs it should be the rainwater harvesting system because it can be built very inexpensively and would help the people of the slums the most. The design could be built in other locations as well with modifications for the locations climate. Overall this goal of building a more sustainable home for the people of Klong Toey Will probably never happen because truthfully not enough people care in the world to help these people. Some further research that could be done is finding a way to get enough money to build these homes. Also coming up with designs for the kitchens in the out houses which were not included in my design. In conclusion the people of Klong Toey deserve better homes and lives and we need to find a way to make that possible.

Bibliography

12V or 24VDC 5 blades 400W wind turbine generator with built-in rectifier module , 2m/s small start wind speed windmill. (n.d.). Retrieved April 21, 2018, from https://m.aliexpress.com/item/32791810537.html?trace=wwwdetail2mobilesitedetail&productId=32791810537&productSubject=400W-12V-or-24V-DC-5-blades-Built-in-controller-module-wind-turbine-generator-only-2m&src=google&albslr=6772457&isdl=y&aff_short_key=UneMJZVf&source={ifdyn:dyn}{ifpla:pla}{ifdbm:DBM&albch=shopping&acnt=708-803-3821&albcp=653482935&albag=32646801963&slnk=&trgt=61865531738&plac=&crea=en32791810537&netw=g&device=c&mtctp=&gclid=EAIaIQobChMIpubQlerB2gIVRVcMCh3lugJvEAQYAyABEgJZ8vD_BwE&gclsrc=aw.ds

23 Awesome DIY Rainwater Harvesting Systems You Can Build at Home. (2016, August 30). Retrieved April 19, 2018, from https://morningchores.com/rainwater-harvesting/

Bahadori, M. (2003, July 02). Viability of wind towers in achieving summer comfort in the hot arid regions of the middle east. Retrieved December 5, 2017, from https://www.sciencedirect.com/science/article/pii/0960148194901082

Bamboo Canes/ Bamboo Poles - Buy Bamboo Canes Product on Alibaba.com. (n.d.). Retrieved April 23, 2018, from https://www.alibaba.com/product-detail/BAMBOO-CANES-BAMBOO-POLES_50036246417.html?spm=a2700.7724857.main07.40.9454348dnBJZSJ

Cavallo, A. (2007). Controllable and affordable utility-scale electricity from intermittent wind resources and compressed air energy storage (CAES). Energy, 32(2), 120-127. doi:10.1016/j.energy.2006.03.018

Chiras, D. D. (2005). The solar house: passive heating and cooling. White River Junction, Vt: Chelsea Green Publ.

Cork Floor - Comfort Flooring in Shoreline by Cali Bamboo, Wide Sample. (n.d.). Retrieved April 25, 2018, from https://www.calibamboo.com/product-shoreline-greenclaimed-plank-cork-flooring-7808005601.html?gacstm_source=google&gacstm_medium=cpc&gacstm_term=7808005601&gacstm_adgroup=cork flooring&gacstm_campaign=193072446&gclid=EAIaIQobChMIh6vOxsDT2gIVFzyBCh2y2AQ1EAYYASABEgJpd_D_BwE

Cork flooring for thermal and acoustic insulation. (2013). Retrieved April 20, 2018, from http://www.house-energy.com/Floors/Cork.htm

DiStasio, C. (2016, January 25). Eco Domum recycles tons of plastic waste from Mexico into low-income homes. Retrieved April 18, 2018, from https://inhabitat.com/eco-domum-recycles-tons-of-plastic-waste-from-mexico-into-low-income-homes/

Gill Seyfang, Community action for sustainable housing: Building a low-carbon future, In Energy Policy, Volume 38, Issue 12, 2010, Pages 7624-7633, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2009.10.027.
(http://www.sciencedirect.com/science/article/pii/S0301421509007745)

Hays, J. (2013). HOMES IN THAILAND: BAMBOO HOUSES, TEAK HOUSES, RAFT HOMES, CONDOMINIUMS AND SUBURBAN CONCRETE TOWN HOUSES. Retrieved April 19, 2018, from http://factsanddetails.com/southeast-asia/Thailand/sub5_8c/entry-3230.html

K Style Aluminum Rain Gutters - Aluminum Gutters - Rain Gutter,Rain Gutter Supplies. (n.d.). Retrieved April 20, 2018, from https://www.guttersupply.com/m-aluminum-gutters-k-

style.gstml?utm_medium=cpc&utm_term=|412|335&utm_campaign=2-Shopping-PLAs&utm_content={AdId}&kclickid=5eb13900-ef1c-4198-80e5-b3cda11e3583&gclid=EAIaIQobChMInq2BvsLT2gIVlsDICh0FBQTSEAYYBCABEgJrC_D_BwE

Lane, B. (2016, January 14). This Startup Turns Plastic Waste into Affordable Housing. Retrieved April 18, 2018, from https://unreasonable.is/ecodomum-story/

Learn how much it costs to Paint a Home Interior. (n.d.). Retrieved April 25, 2018, from https://www.homeadvisor.com/cost/painting/paint-a-home-interior/

Linnenkoper, K. (2016, September 9). Bangkok locked in 'constant battle' with plastics. Retrieved April 20, 2018, from https://www.recyclinginternational.com/recycling-news/9918/plastic-and-rubber/thailand/bangkok-locked-039-constant-battle-039-plastics

Khlong Toei District. (2018, May 03). Retrieved from https://en.wikipedia.org/wiki/Khlong_Toei_District

Markham, D. (2018, February 05). This company turns plastic waste into affordable housing in Mexico. Retrieved April 18, 2018, from https://www.treehugger.com/tiny-houses/company-turns-plastic-waste-affordable-housing-mexico.html

Morgan, H. (2011, July 26). Hybrid House: Extraordinary Green Home Can be Built for Under $300. Retrieved April 20, 2018, from https://inhabitat.com/joseph-sandys-amazing-hybrid-house-is-winner-of-300-house-competition/

Ocharoenchai, N. (2017, June 14). Producer responsibility: The key to solving Thailand's plastic crisis. Retrieved April 20, 2018, from http://www.greenpeace.org/seasia/blog/producer-responsibility-the-key-to-solving-th/blog/59748/

Pacey, A. (n.d.). Rainwater harvesting: the collection of rainfall and runoff in rural areas. London: Intermediate technology publications.

Renogy 200 Watt 12 Volt Solar Starter Kit w/ MPPT Charge Controller. (n.d.). Retrieved April 21, 2018, from https://www.renogy.com/renogy-200-watt-12-volt-solar-starter-kit-w-mppt-charge-controller/

R.K. Akikur, R. Saidur, H.W. Ping, K.R. Ullah, Comparative study of stand-alone and hybrid solar energy systems suitable for off-grid rural electrification: A review, In Renewable and Sustainable Energy Reviews, Volume 27, 2013, Pages 738-752, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2013.06.043.

(http://www.sciencedirect.com/science/article/pii/S1364032113004346)

Sandy, J. (Ed.). (n.d.). $300 House | Joseph Sandy. Retrieved April 20, 2018, from https://archinect.com/people/project/47305553/300-house/47306761

Seyfang, G. (2010). Community action for sustainable housing: Building a low-carbon future.Energy Policy, 38(12), 7624-7633. doi:10.1016/j.enpol.2009.10.027

SpringSaver Rainbarrel, Home Gardening Supplies at Burpee.com. (n.d.). Retrieved April 20, 2018, from https://www.google.com/aclk?sa=l&ai=DChcSEwjUwLi3y9baAhUXxGQKHZ9cALEYABAUGgJwag&sig=AOD64_0oGIbWnXzbpgg56OUb6mpGr3hqDg&ctype=5&q=&ved=0ahUKEwiEpbO3y9baAhUH3mMKHbdWDAQQ9aACCDs&adurl=

Staff, C., & Jeffrey, S. (n.d.). 9 building materials made entirely from waste products. Retrieved December 08, 2017, from http://www.citymetric.com/skylines/9-building-materials-made-entirely-waste-products-932

Staff, G. G. (2018). How to Harvest Rainwater. Retrieved April 20, 2018, from https://www.gardengatemagazine.com/articles/web-extras/all/52droughttolerant/

Thailand roofing sheet. (n.d.). Retrieved April 20, 2018, from https://www.alibaba.com/countrysearch/TH/roofing-sheet.html

Vannini, P., & Taggart, J. (2015). Off the grid: re-assembling domestic life. New York: Routledge Taylor & Francis Group.

Vikrant Sharma, S.S. Chandel, Performance and degradation analysis for long term reliability of solar photovoltaic systems: A review, In Renewable and Sustainable Energy Reviews, Volume 27, 2013, Pages 753-767, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2013.07.046. (http://www.sciencedirect.com/science/article/pii/S1364032113004917)

Wind 101: The basics of wind energy - AWEA - American Wind ... (2013). Retrieved April 20, 2018, from https://www.bing.com/cr?IG=26B4E2E6729043F68842D49230ABB59F&CID=29AC8AFC95BF6AD633E0812194106B38&rd=1&h=f0BZ1bbQwGjqdnMLjkmAjP4p2CS-SzCaylzGr_-nsRc&v=1&r=https://www.awea.org/wind-power-101&p=DevEx.LB.1,5070.1

World Weather & Climate Information. (2016). Retrieved April 20, 2018, from https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Bangkok,Thailand