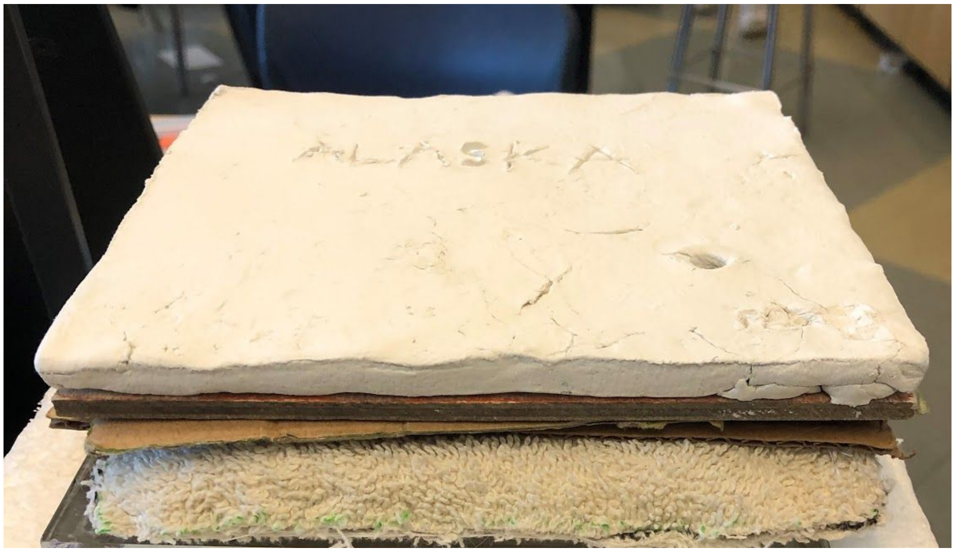
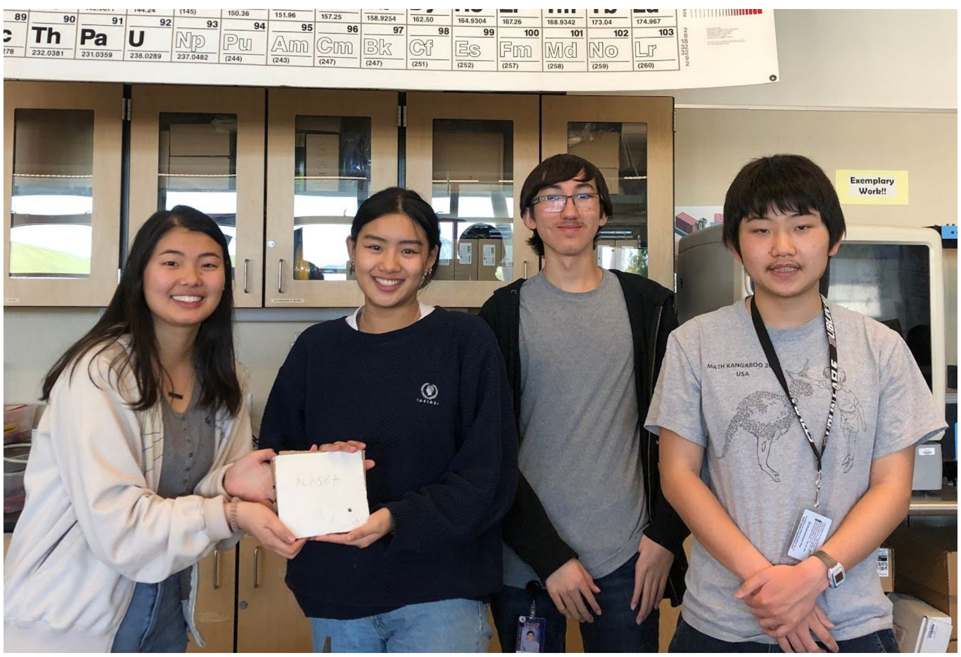
P2.2.3 Renewable Insulation

Alaskan Insulators Co.





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Principles of Engineering, Period 7
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Design Brief

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Client
Alaskan Construction Co.

Problem Statement
The cold, subarctic temperatures of Alaska require buildings with extreme insulation yet is unobtrusive to Alaska's prominent wildlife. A new cabin resort for tourists requires insulation that will hold heat within the cabins without harming Alaska's natural environment. The Alaskan Construction Co. needs to create entirely biodegradable and environmentally friendly insulations.

Design Statement
Design a renewable composite insulation material that will hold in the most heat radiated from a heat box.

Constraints
- Composite insulation material must have an overall uniform thickness of less than or equal to two inches.
- Composite insulation material must have consistent internal composition.
- Individual insulation material(s) must be environmentally friendly.
- Individual insulation material(s) must be recyclable.
- Individual insulation material(s) must be economical (cost-effective).
- Composite insulation material dimensions must not exceed the overall dimensions of heat box apparatus top and have a hole to allow attachment to heatbox & temperature gauges (the screw).

Deliverables
- Spreadsheet with the following: team norms, consequences, Gantt chart, individual project logs/conclusion questions, and the team scatterplot
- Document with the following:
  - Title page with image of the material, team member names, class, date, and project title
  - Table of Contents denoting page numbers of each section
  - Full design brief fitted onto a single page
  - Material Description/Lifecycle: Describe the composition of the final insulation, describing every material and its lifecycle to prove that the design constraints were met, with in-text APA citations for external sources
  - Data Summary with scatterplot describing test data, neatly typed calculations, performance summary/comparison to other insulators, and final recommendation
  - Works cited with APA citations for external sources

Material Description and Life Cycle

Cardboard

Lifecycle (EZOP)

1. Collecting:
    - Cardboards that are put out for recycling are collected to be sent to the recycling center.
2. Shredded & Cleaned:
    - Special machines are used to mass shred cardboard and then be placed in chemicals for de-inking in order for later use.
3. Rebuilt:
    - The cardboard then gets added together with new fibers in order to make it as strong as it was before for reuse.
4. Reuse
    - The newly rebuilt cardboard is then sent out again to be used in companies that require cardboard again.

Description

Cardboard, also known as corrugated fiberboard when used with boxes, is a material that is made out of paper and has 3 layers, it has 2 layers of flat paper and sandwiched in between the two is a wavy-like layer in order to have a stronger structure (Science Direct, 2007). Cardboard is regularly found in a lot of common places, such as post offices, stores, and schools for boxes and other projects involving cardboard. Cardboard is a highly recyclable material and is one of the most recycled materials out there, because of this lots of places have a very common process for recycling cardboard. The process usually ends up very similar to how paper is recycled, with collecting, sorting, shredding, filtering & de-inking, and then finishing up for reuse (Conserve Energy Future, 2017).

Cost Effectiveness

The cost of cardboard can be free at post offices and recycling centers so the cost per effectiveness is essentially always positive. While cardboard is a weaker insulator, the price allows us to use however much we want. Essentially, this means that we just need more layers of cardboard in order to insulate more effectively.

Air Dry Clay

Lifecycle (Williams, 2014)

1. Mining of clay
2. Purification of clay
3. Manufacture of clay as products
4. Distribution
5. Recycle/ disposal of clay
6. Clay can be broken down to be turned into new clay

Description

Air dry clay is a modelling material made of paper, water, vegetable bindings and natural earth materials (Malaysia Clay Art, 2017). It requires no baking since it hardens to a stiff structure with exposure to air. Air dry clay can be easily made at home using regular household products including glue, cornstarch, and baking soda. Regular, school liquid glue is made of various chemicals and is not easily recyclable (Bennett, 2015). However, substituting liquid glue with biodegradable glue can also work. Cornstarch and baking soda are biodegradable and do not pollute the environment since it is made from natural resources. Cornstarch is made of corn grains (Moncel, 2019) and baking soda is a crystalline salt (University of Wisconsin-Madison 2017).

Cost Effectiveness

Air dry clay costs around $10.00 for one package of a 2.2 lb block. The insulation design only used half of one package for the 7 x 7" size, meaning that the actual costs $5.00 when using 1.1 lb of clay. However, when making air dry clay, the cost is cheaper. If you were to buy 16 ounces of each main ingredient, cornstarch is $1.42, and baking soda is $0.82. Eco-friendly liquid glue is $2.49 for 4 ounces (about $9.96 for 16 ounces). Recycled paper scraps could be used to create the paper-like texture as well. This means that $12.2 to create at least 3 pounds of clay. This is more cost effective than buying ready made air dry clay. Although air dry clay is a more expensive material, it is one of the most effective materials for insulation when compared to the other materials used. Additionally, the other materials in the insulation are supposed to be from reusing materials which would practically be free so investing in clay is beneficial and economical.

Wood

Lifecycle (Pratt CSDS)

1. Raw materials
    - Forests or plantations are harvested and the logs are transferred to a sawmill
2. Material processing
    - Of the harvested wood, 35% - 45% is actually usable and can be converted to timber (the rest become sawdust or wood chips)
    - Kilns are used to dry timber (which can be sold raw or processed further)
    - Scraps can be repurposed
3. Distribution
    - The processed wood is sent to businesses and companies to be sold
4. Use
    - Wood is versatile and has many uses such as: buildings, furniture, jewelry, art, and other products
5. Recycled or distribution
    - Once the wood is run down, or unable to be used it can be recycled, composted or sent to the landfill

Description

Wood is one of the most common materials used in construction. It is an entirely organic and renewable material derived from trees, making it not only environmentally friendly, but also easily accessible. There are three main types of wood: timber, raw wood made into boards; engineering wood, natural wood combined with other materials; and veneer, wood that has been thinly sliced (Pratt CSDS). Byproducts of wood include: pulp, paper, reconstituted boards, energy, etc. The process in which wood is made usable does not negatively impact the environment. Additionally, commercial wood does not pose a risk to consumers, except for formaldehyde, a carcinogen commonly found in many surface finishes. To combat this, strict regulations have been placed to regulate formaldehyde emissions.

Cost Effectiveness

As stated above, wood is readily available. It is a relatively cheap material and although the price varies from supplier to supplier, it is on average pretty affordable, especially when purchased in bulk. However, for the most part, wood can be sourced for free. There are countless ways to obtain recycled timber. Free reclaimed lumber can be taken from old run-down buildings, excavators who have no use for the remaining wood, remodeling contractors looking for a way to recycle or dispose of leftover wood scraps. And since our insulation design does not require thick, hefty wood, it will be ten times easier to source free wood.

Cotton

Lifecycle

1. Planting & Harvesting
    - Cotton is planted and harvested
2. Spinning & Weaving
    - Cotton is then spun and weaved in order for processing for consumer goods,
3. Dying & Shipping
    - The processed cotton is dyed if needed and then shipped out to be sold
4. Selling
    - Cotton products are sold and distributed as intended
5. Recycling
    - Cotton products are sent to be recycled and turned into scrap pieces to be a different product in the cycle.

Description

Cotton is a naturally grown plant that is very renewable and recyclable in its lifecycle. Cotton is generally grown in 130-160 days and has a threshold temperature of 60 degrees fahrenheit for growing (ACE). Cotton does require some work to be turned into a good insulator as it is harvested as what is called a boll from the cotton plant and comes out as white fluff. From there is it most commonly used as fabric for clothing, towels, etc for consumers and other items. A very common use of cotton with insulation can be seen with cotton denim as a common alternative to fiberglass in homes (Home Advisor, 2019).

Cost Effectiveness

Cotton towels cost around $5-11 each for around a 10” x 10” square towel. The design only requires 7” by 7” so cutting it down helps use less of the cotton in case more is needed elsewhere. Although this material is a bit more expensive than others, it will still insulate a comparable amount to the rest as it has been seen dealing with in large house insulation with cotton denim. Cotton can also be taken from recycled old clothing to help cut down on costs as well.

Paper

Lifecycle (Pratt CSDS, SlidePlayer)

1. First, logs are cut from chopped trees and then used to create smaller wood pieces
2. Pieces are made into pulp that gets dried
3. The resulting fibers are flattened out and heated, and cut to make paper
4. Paper can be bought and distributed in forms such as newspaper, books, and printing paper, which are sold to consumers
5. The first step to paper recycling is washing ink off the paper.
6. Paper is then screened and remade into pulp
7. Pulp is remade into paper in the method described above

Description

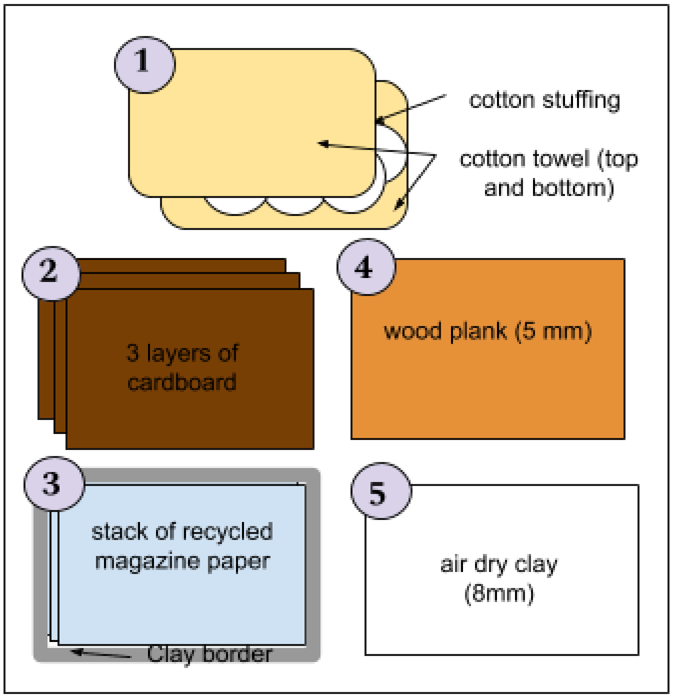
Wood used for paper is acquired from forests, which may cause various problems, from problems about the habitat and social problems with nearby peoples. Even though paper is typically recycled, it sometimes still proceeds to landfills, which causes paper to create methane. As an industry, paper production is a significant producer of greenhouse gases, and both chemicals in the air and water. Papermaking also uses a significant amount of electricity in America, and it is also the most water-consuming industry in the industrialized world. Areas close to paper factories often have unclean water and air. (Pratt CSDS)

Cost Effectiveness

Paper is made from wood, which is a renewable material that is easy to obtain. Also, the process of making paper is not expensive either, which makes paper a very cheap material. A piece of paper costs only $0.03. (Sustainable Roadmap for Hospitals) Assuming this cost is for a 8.5”x11” paper, a 7” by 7” paper would cost $0.02. Since we used several sheets of paper in our insulator, the total cost of paper in our insulator will be rather low. Still, paper is extremely thin, and may not capture heat very well. Even though paper is very cheap, the effectiveness of paper as an insulator may not make it extremely cost effective. This can only make paper have at most average cost effectiveness, since paper is cheap while it may not be a very good insulator.

Insulator Images

Diagram of Insulation Layers



Images of Insulator Composite

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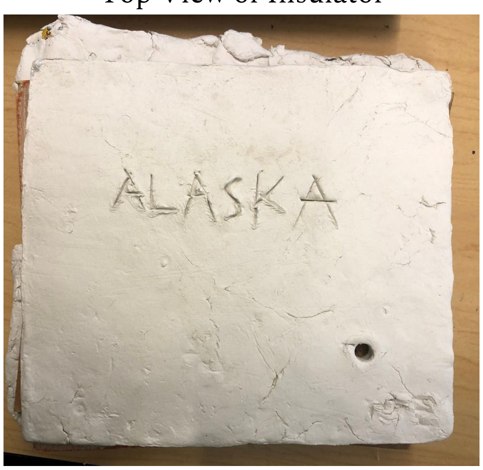
</td><td>Side View of Insulator's Layers
</td><td>Isometric View of Insulator

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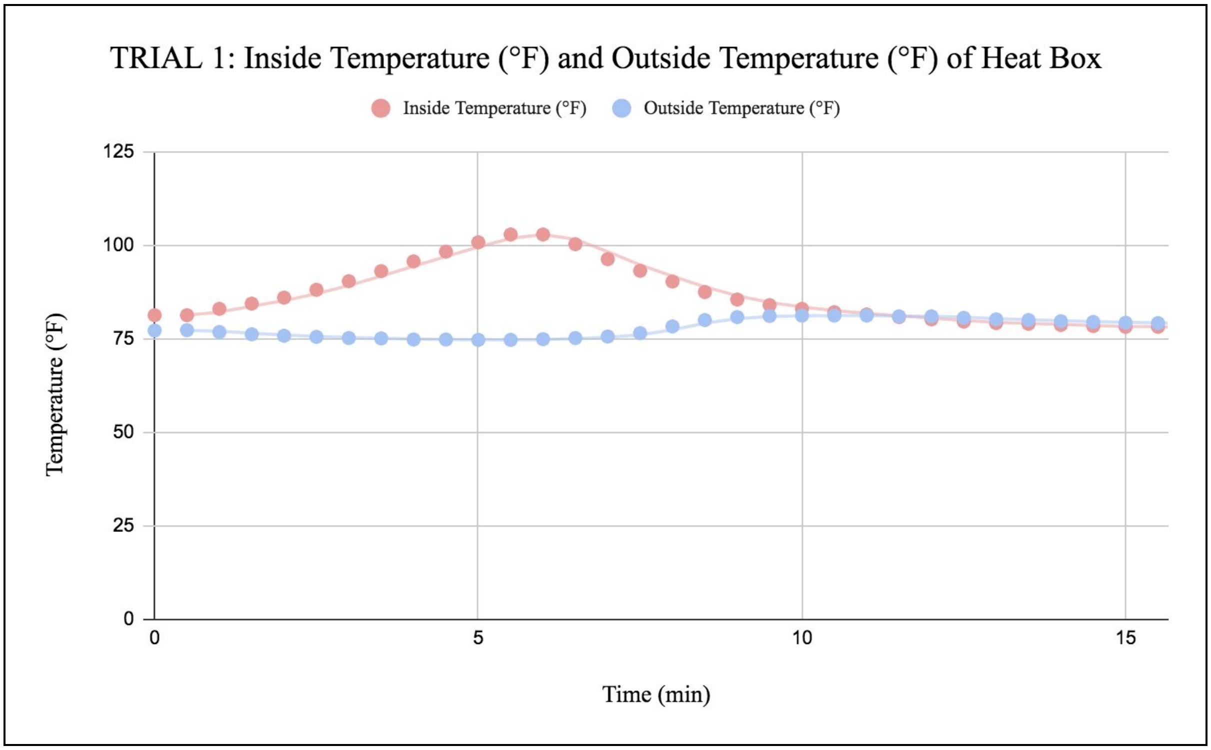
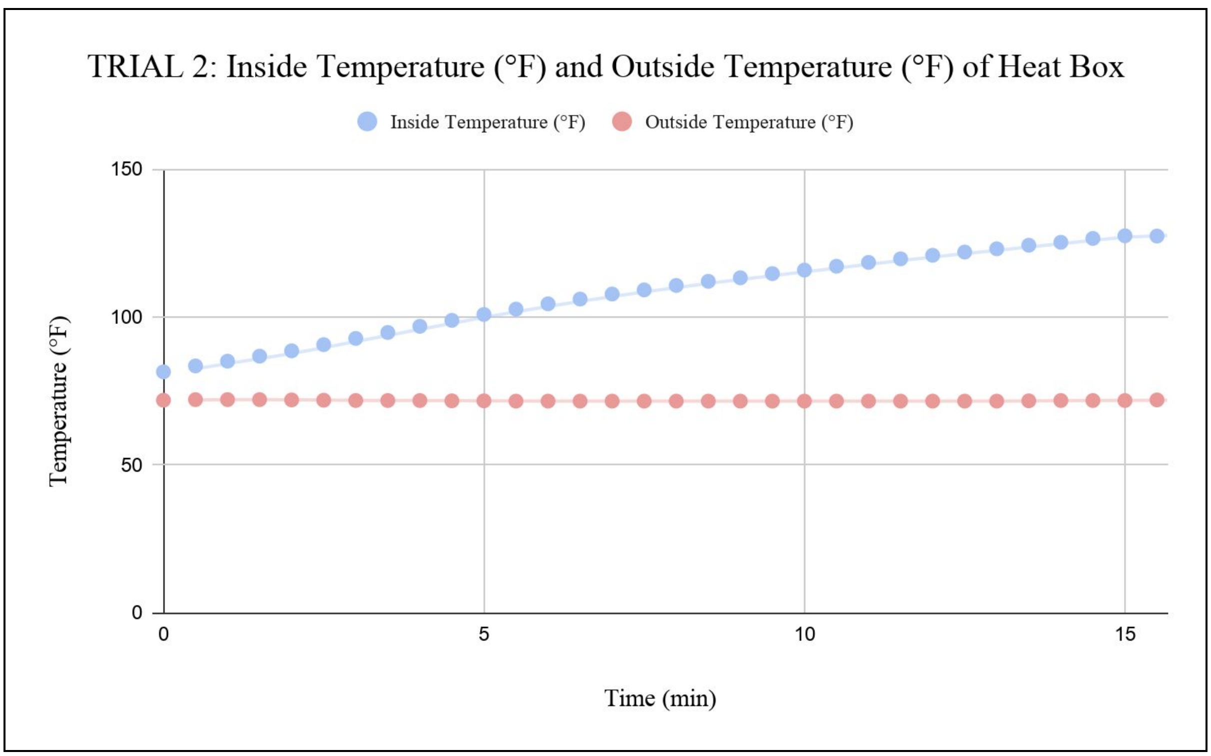
Haliun Enknyam 2/19/2020, Kellie Tai 2/19/2020, Alex Woods 2/19/2020, Derek Xu 2/19/2020

Data Summary

Graphs





Measurements

Thickness	Area
L = 0.04445 m	A = 1.2446 m^2
Power	**Time (sec)**
P = 29 W	t = 900 sec
Initial Temperature Inside	**Initial Temperature Outside**
27.5 °C	22.3 °C
Final Temperature Inside	**Final Temperature Outside**
53.1 °C	23.4 °C
Difference in Final Temperature	
29.7 °C	

Calculations

Energy Transferred (Q)	$Q = P\Delta T$ $= 29\frac{J}{s} \cdot 900s$ $= 26100J$
Thermal Conductivity Constant (k)	$k = \frac{PL}{A\Delta T}$ $= \frac{29W \cdot 0.04m}{0.03m^2 \cdot 29.67^{\circ}C}$ $\approx 1.30\frac{W}{m \cdot {}^{\circ}C}$
U-Value	$U = \frac{P}{A\Delta T}$ $= \frac{29W}{0.03m^2 \cdot 29.67^{\circ}C}$ $\approx 32.58\frac{W}{m^2 \cdot {}^{\circ}C}$
R-Value in SI Units	$R = \frac{1}{U}$ $= \frac{1}{32.58\frac{W}{m^2 \cdot {}^{\circ}C}}$ $\approx 0.03\frac{m^2 \cdot {}^{\circ}C}{W}$
R-Value in US Customary Units	$R = 0.03\frac{m^2 \cdot {}^{\circ}C}{W} \cdot \frac{\frac{ft^2 \cdot hr \cdot {}^{\circ}F}{Btu}}{\frac{m^2 \cdot {}^{\circ}C}{W}}$ $\approx 0.17\frac{ft^2 \cdot hr \cdot {}^{\circ}F}{Btu}$

Summary

Our measurements were initially in the US Customary system so we had to convert the units. With the measurements, we also calculated the energy transferred (Q), the thermal conductivity constant (k), U-Value, and the R-Value in SI Units. With the final measurements recorded from our second trial of the insulation composite, we calculated that the R-Value (US Customary) of our insulator is 0.17 $\frac{ft^2 \cdot hr \cdot {}^\circ F}{Btu}$. This R-Value is similar to real world construction materials like concrete mortar, stucco, and asphalt roll. These materials are used in roofing and masonry systems which make sense since our insulator's main layer was the air dry clay on top of the wooden plank. For the Alaskan Insulator Company, the best recommendation would be to add more cotton inside the towel layer and a thicker clay layer to get the maximum results from our materials selected.

Works Cited

Advancing Cotton EducationGrowth and Development of a Cotton Plant, www.cotton.org/tech/ace/growth-and-development.cfm.

Building with Wood Is Cost-Effective, www.forestfoundation.org/building-with-wood-is-cost-effective.

Bennett/ RecycleNation, S. (2015, July 10). How to Recycle Glue Bottles. Retrieved February 18, 2020, from https://recyclenation.com/2015/07/how-to-recycle-glue-bottles/

Dahlia James-Williams, D. (2014, July 1). PDF. Retrieved February 19, 2020, from https://www.researchgate.net/figure/Life-cycle-of-a-clay-pot-See-Dahlia-James-Williams-Representations-of-Cosmology-A_fig1_265539878

EFFECT OF ADDITIVES ON THE THERMAL CONDUCTIVITY, ljs.academicdirect.org/A14/074_077.htm.

Glossy Paper, www.orau.org/ptp/collection/consumer products/magazines.htm.
"Cardboard." Cardboard - an Overview | ScienceDirect Topics, www.sciencedirect.com/topics/engineering/cardboard.

Green, Simon. "The Best Insulators to Keep Water Hot." Sciencing, 2 Mar. 2019, sciencing.com/insulators-keep-hot-water-10027507.html.

"Liquid Glue And Eco-Friendly Adhesives: Water-Based Glue." LD Davis, www.lddavis.com/products/liquid-glue/.

Malaysia Clay Art. (2017, October 6). What Is The Difference Between Polymer Clay And Air Dry Clay? Retrieved February 15, 2020, from https://www.malaysiaclayart.com/blogs/news/what-is-the-difference-between-polymer-clay-and-air-dry-clay

Moncel, B. (2019, November 12). Do You Know How to Properly Use Cornstarch? Retrieved February 18, 2020, from https://www.thespruceeats.com/what-is-corn-starch-1328466

"Paper: Life Cycle." Pratt CSDS, csds.pratt.edu/resource-center/materials-research/material-life-cycles/paper/.

Paper: Life Cycle. (n.d.). Retrieved February 19, 2020, from http://csds.pratt.edu/resource-center/materials-research/material-life-cycles/paper/

Plantation to Paper and Paper to Paper. (n.d.). Retrieved February 19, 2020, from https://slideplayer.com/slide/3861146/13/images/3/Plantation to paper and paper to paper:.jpg

Reduce Paper and Cut Costs: A Guide for Businesses. (n.d.). Retrieved February 19, 2020, from http://www.sustainabilityroadmap.org/resources/pdfs/18_institute_sustainable_paper_Metro_Paper_Reduction_Guide.pdf

“Recycled Cotton: CottonWorks™.” CottonWorks, www.cottonworks.com/topics/sustainability/cotton-sustainability/recycled-cotton/#.

Roxana. “Cotton Insulation - Cost, R-Value & Benefits: HomeAdvisor.” Home Improvement Tips & Advice from HomeAdvisor, 30 Nov. 2016, www.homeadvisor.com/r/cotton-insulation/.

Roxana. “Cotton Insulation - Cost, R-Value & Benefits: HomeAdvisor.” Home Improvement Tips & Advice from HomeAdvisor, 30 Nov. 2016, www.homeadvisor.com/r/cotton-insulation/.

“The Recurring Life Cycle of a Recycled Cardboard Box.” The Life Cycle of a Cardboard Box Madison Wisconsin, www.ezop.com/blog/water-cooler-talk/life-cycle-of-a-cardboard-box-infographic-madison-wisconsin.

University of Wisconsin-Madison. (2017). Baking Soda - The Everyday Miracle. Retrieved February 18, 2020, from PDF.

Wood: Life Cycle. (n.d.). Retrieved February 18, 2020, from http://csds.pratt.edu/resource-center/materials-research/material-life-cycles/wood/