Earthborne Rangers

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1. Executive Summary

Earthborne Games is a tabletop game company that desires assistance in producing a completely sustainable and biodegradable card game. The team did an analysis of all materials to determine both their environmental impacts and their quality. The main point of contact on the Earthborne Games side is game creator Andrew Navaro whose goal is to revolutionize the tabletop gaming industry by demonstrating how games can be manufactured sustainably. During the past three months, the ENVS 492 project team confirmed the specified materials are realistic with respect to quality and environmental impacts, identified domestic manufacturing facilities capable of sourcing and producing using these materials, and contacted these facilities.

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3. Project Description, Objectives, and Scope

As someone with a strong love for the environment who spent 18 years within the tabletop gaming industry in a multitude of roles, Andrew Navaro wants nothing more than to combine his love for both tabletop games and environment. By addressing the reusability and sustainability of the components used in the product, greenhouse gas emissions involved in the process of manufacturing and distributing, to even the degradability of the materials in all parts of the process, he hopes to create one of the best games as sustainably as possible.

During our partnership, we had aimed to aid in research and development in a few areas that include but were not limited to:

1. Researching and contacting different manufacturing facilities, and their capacity for producing with sustainable materials. Finding these groups will provide Earthborne Games with an idea of where he is able to begin his production, as well as to what extent he needs to split up the manufacturing of the game.
2. Forest Stewardship Council (FSC) certification requirements, the process in which one becomes certified, and its environmental benefits for wood and paper components. In doing so, we verify validity in the FSC certification to ensure resources such as time and money are concentrated into environmental movements that are effective and productive.
3. Potential toxicity the game may have, more specifically, adhesives that are used within the components used to manufacture the board game. Given that a majority of the game is paper and paper by-products, this adhesive research will isolate one of the last impediments to a green, uncontaminated, biodegradable game.
4. Overall environmental impact of materials, practices, or processes while maintaining quality and replay value of the game. It has been stated by Earthborne Games that if the game does not adhere to a higher standard, it will not be bought regardless, and in-turn produce less of an impact and fall short of the industry standards.

In doing so, we hope to provide Earthborne Games with innovative opportunities to create a transparent and revolutionary movement into more sustainable practices within the tabletop game industry.

Our group researched the materials and manufacturing of the card game Earthborne Rangers, along with answering any questions our partner, Earthborne Games, might have. Our research will specifically address the materials that have already been selected by our partner in order to determine if they are truly sustainable options. Selected materials range from recycled paper to certain coatings and adhesives. As an end result, our partner will receive a report that will cover what could possibly be the best materials and options available in order to produce Earthborne Rangers sustainably. Revolutionizing the card game industry is crucial in order to set a good foundation for other tabletop publishers and their manufacturing partners to follow.

Research completed includes the following: best form of paper or alternative, water based versus UV coating, and bioplastic versus wood materials; all as it applies to the card game. These selected materials that are being researched for the card game need to be transported to different regions when being manufactured and distributed. Specifically, the transportation and production of the games generates a carbon footprint, adhesive in the cards has potential to be toxic, and the use of trees to create the game will only lead to more climate changes. But playing tabletop games does not have nearly as large of an environmental impact as producing them (Sargeantson 2020). Reducing the impact of production and transportation is crucial to making a positive change. Furthermore, plastics from disposable packaging and single use items, along with nonrecyclable paper are crucial contributors to the global waste problems that arise in a majority of tabletop gaming products. There is an opportunity to make tabletop games more sustainable, not just for Earthborne Games, but for the industry.

4. Barriers and Scope Adjustment

Throughout our time working on the project our team experienced a few barriers that halted some parts of our research. When researching the different materials that make up the cards of the game, like inks and coatings, our group decided to do more research upon the environmental impact of commonly used adhesives in playing cards. However finding this information proved to be difficult since most information like safety data sheets for the adhesives were proprietary and companies would not give out this information to us. With several hours spent researching our team was only able to find general information regarding possible adhesives that are used for playing cards but could not get any specific information regarding their toxicities.

Another part during our research in which we experienced another barrier is when we dealt with responses from printers. A good portion of our time working on this project was spent emailing and calling printing and some recycling companies. Printing companies were contacted with hopes of finding an environmentally friendly company that our partner could work with. When emailing companies we would be lucky to get a response from them, and most responses we did receive were not helpful in progressing our research. Then we would try to send a follow up email to companies who did not respond in a timely manner.

Finally, everything that was listed in our scope within our project proposal was examined and researched; our research addresses the materials that our partner selected in order to determine if they are truly sustainable options. Selected materials we examined ranged from recycled paper to certain coatings and adhesives. Overall, our scope from our project proposal had little change and we spent more time trying to overcome any barriers that were mentioned previously, or we had to go about another way to find at least a general sense of information.

5. Research Methods

During our project with Earthborne Games, there were multiple stages within the project that required research. In order to ensure Earthborne Games was using the most relevant and pertinent information, we used only the most credible sources we could find.

A major component of our research was committed to finding companies that were able to produce the final product using the materials that we had researched, in addition to keeping those companies as centralized as possible. Our idea behind this followed two trains of thought; find companies working within the Midwest that utilized the acreage set aside specifically for FSC, and minimize any distribution or transportation of material in order to maximize the sustainability of the game during its manufacturing. This means that being central was an integral part to the companies we would be working with. In order to satisfy these requirements, we began our search at fsc.org, where we downloaded their list of printers that have already been certified. After this, we filtered our list and narrowed it down to the states we believed would be most beneficial to the goal of minimizing the time of travel and came up with Minnesota, Wisconsin, and Michigan. After cross referencing all the requirements for our printers, we began to reach out to these companies with the sample bill of materials. Our outreach consisted of email, phone calls, and requesting assistance through their ‘contact us’ page. Given we didn’t receive any responses, we reached out an additional one to two times, given about a week's difference between each attempt.

Some of our key resources used included Google Scholar, published journal articles, a LCIA database, as well as receiving information directly from companies in the industries we searched in. Google Scholar was used, for example, in the research done on bioplastics early on within the project. When doing research on bioplastics, the search would just include ‘energy use in bioplastics’ and a plethora of research would be presented. Then, it would be up to us as researchers to read the given articles in search of the information we were looking for, in this case, energy consumption and the requirements to produce bioplastics. Another primary research tool used was published journal articles, found on sites such as *jstor.org* or *pnas.org*. These sites are dedicated to publishing academic journal articles and primary sources that can be credited and then used within research. This research process looked almost identical to that of Google Scholar, as the databases work very similarly and prove to both be very useful when looking into information such as carbon credits or the coatings and their toxicity. Ecoinvent 3.8 cutoff cumulative LCIA was used in order to find information upon the chemical compositions of aqueous and UV coatings. We were able to search directly for the specific chemicals used in each coating to then compare the effects they have towards specific parts of the environment and human health. Lastly, one of our most reliable sources was calling companies that were working directly with the information we needed. Sara’s main root for data on the FSC and its chain of custody process was sourced directly from calling companies and passing through multiple extensions in order to get the full grasp and picture on the chain of custody and what it entailed.

6. Analysis of Research

6.1 Forest Stewardship Council (FSC)

6.1.1 What Does it Mean?

The Forest Stewardship Council provides certifications for proper and responsible forest management. The intention of this is to provide a system for consumers and businesses to be able to make a conscious effort to support products that are ethically sourced and more environmentally friendly. FSC certification is also a way to encourage forest managers to have more responsible forest management practices.[1]

The management plan required by the forest managers must provide:

a) Management objectives.
b) Description of the forest resources to be managed, environmental limitations, land use and ownership status, socio-economic conditions, and a profile of adjacent lands.
c) Description of silvicultural and/or other management system, based on the ecology of the forest in question and information gathered through resource inventories.
d) Rationale for rate of annual harvest and species selection.
e) Provisions for monitoring of forest growth and dynamics.
f) Environmental safeguards based on environmental assessments.
g) Plans for the identification and protection of rare, threatened and endangered species.
h) Maps describing the forest resource base including protected areas, planned management activities and land ownership.
i) Description and justification of harvesting techniques and equipment to be used"[2]

These nine items explore topics such as justified harvest rates to prevent overharvesting and having a detailed description of the forest and how exactly they will be managed. Because these management plans must be fully revised every 10 years, FSC is able to maintain a relationship with the managers. There is also monitoring in place to make sure that the forest managers are following their plans. The frequency of this monitoring depends on the scale of the operation and also the complexity and fragility of the environment this is occurring in.[3]

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[1] *What is the Forest Stewardship Council*. (n.d.). Forest Stewardship Council Canada. Retrieved November 14, 2021, from https://ca.fsc.org/preview.introduction-to-the-forest-stewardship-council.a-1844.pdf
[2] *FSC-US Forest Management Standard (v1.1) [Excluding the Family Forest Indicators and Guidance]*. (n.d.). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/preview.fsc-us-forest-management-standard-v1-1-with-only-usfs-requirements.a-717.pdf
[3] *FSC-US Forest Management Standard (v1.0) (w/o FF Indicators and Guidance)*. (2010, May 25). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/download.fsc-us-forest-management-standard-v1-0.95.html

6.1.2 Harvest Rates

Forest management standard C5.6 discusses how the rate of harvest of products in the forest must be at a sustainable level. Criteria that are considered when determining this sustainable level are forest growth rates, factors that affect net growth, any harvest restrictions, silvicultural practices, and management practices. This level is not determined just according to one growth cycle, but also considers future growth cycles as well.[4]

6.1.3 Regeneration Rules

In FSC's forest management standards in Indicator 10.2e, it states, "In all regions except the Southeast, before an area is harvested, regeneration in adjacent forested areas (either natural forest or plantation) on the FMU must be of the subsequent advanced successional habitat stage, or exceed ten feet in height, or achieve canopy closure along at least 50% of its perimeter.[4]"

This suggests that there must be an adjacent forest to the one that is being harvested, that meets certain standards.

6.1.4 Locations

FSC is an international organization, but for the sake of Earthborne Games and the scope of the project, the United States will be the main focus. FSC is in the process of developing a map to pinpoint all of the FSC forests across the world. But this information must be submitted voluntarily by the forest managers, so there has not been a large response. For the United States specifically, there are no responses. But, another way to document FSC forests in the United States is acreage per state.[5]

Although this does not pinpoint exact locations of forests, it helps get an idea of where the most FSC certified forests are. Using this data, and data of total acreage for every state, we were able to standardize that data and decide which states truly had the highest density of FSC forests. Figure 1 demonstrates which states have the highest acreage of FSC certified forests, while Figure 2 demonstrates which states have the highest density of FSC certified forests through standardization.

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[4] *FSC-US Forest Management Standard (v1.1) [Excluding the Family Forest Indicators and Guidance]*. (n.d.). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/preview.fsc-us-forest-management-standard-v1-1-with-only-usfs-requirements.a-717.pdf

[5] *FSC Acreage Per State*. (2019). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/preview.fsc-acres-by-state-map.a-344.pdf

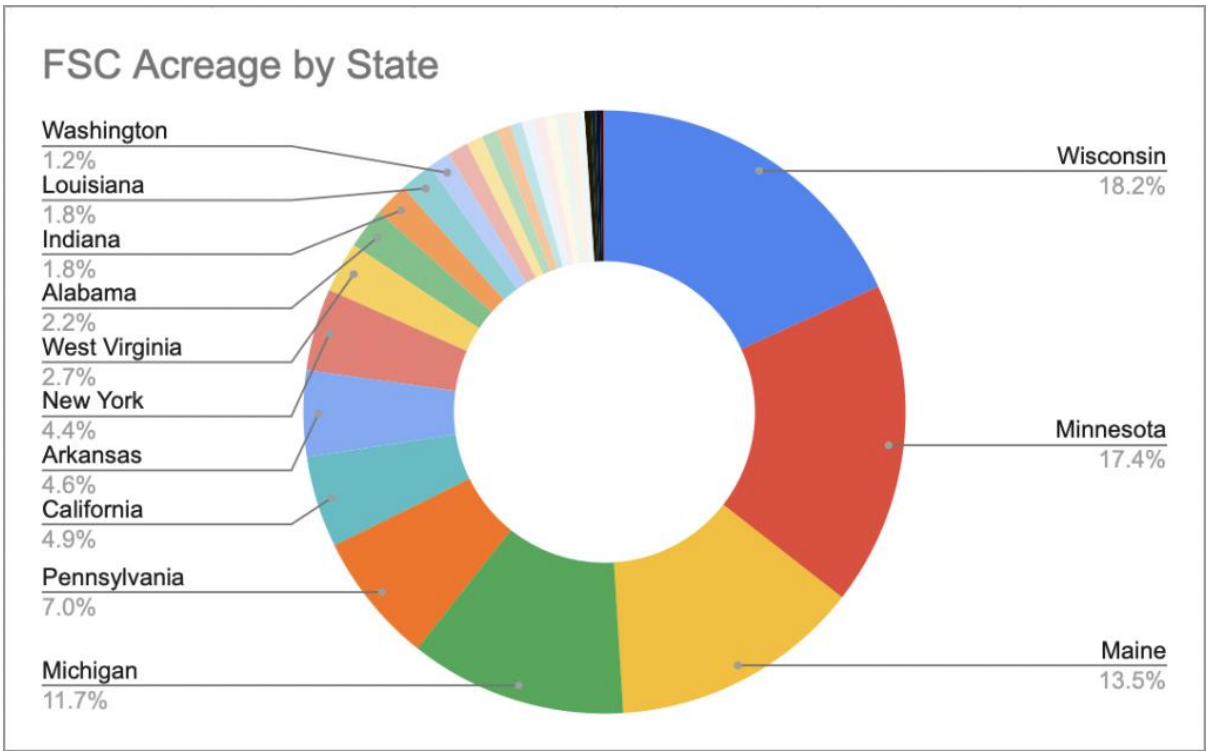

Figure 1: FSC Acreage by State

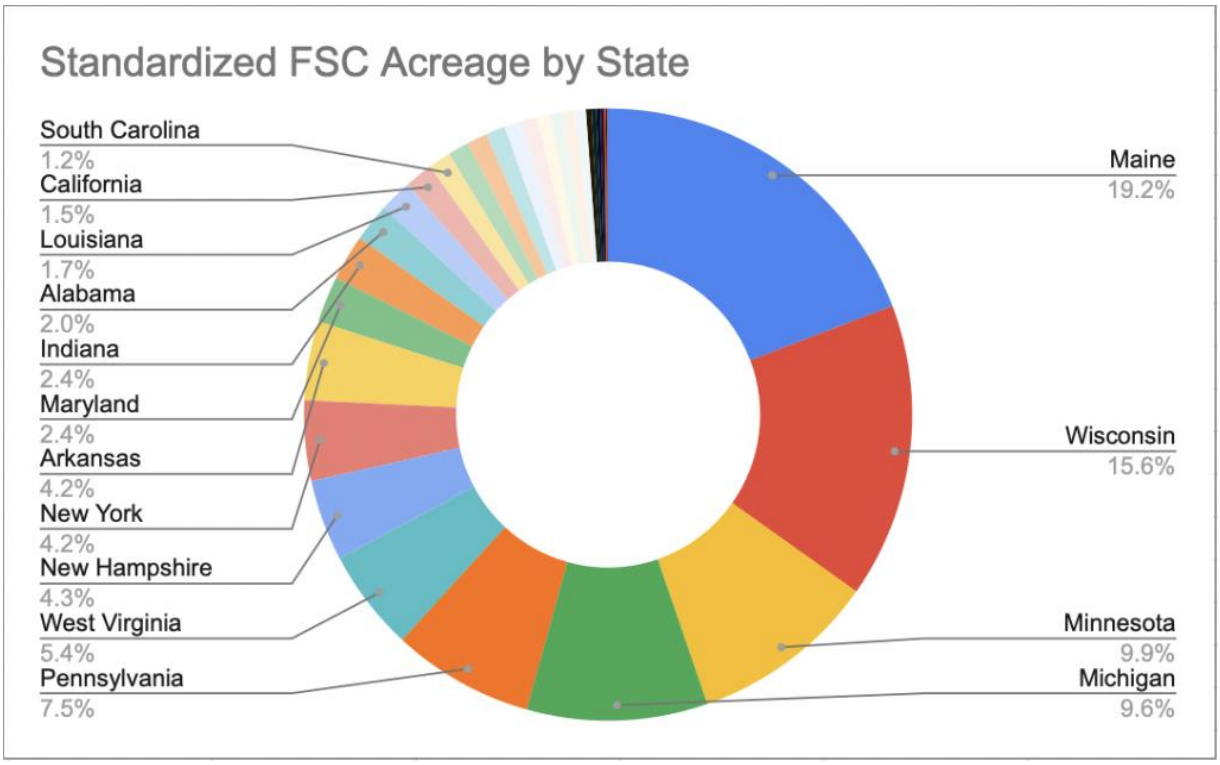

Figure 2: Standardized FSC Acreage by State

Understanding this and understanding that having production as central in the U.S. as possible to help limit transportation, the group decided to focus on the states of Michigan, Minnesota, and Wisconsin.

6.2 What Type of Paper is Best?

6.2.1 Recycled Paper

Recycled paper requires fewer resources, and it also decreases the demand for wood. If the paper is being recycled, that means there will be less waste in landfills. Although the term recycled may make it seem like this is the most sustainable solution, some claim that if recycled paper is normalized, there will be a decrease in demand for well-planted forests. Thus, potentially causing greater damage to the environment since the forests will no longer be available as carbon sinks.[6]

6.2.2 Alternative Fiber Paper

In North America, paper made from wood is common because there is a large amount of forest area. Non-wood paper alternatives are more common in places that do not have this available, such as China or India. In these areas, they use fibers that are more readily available. When reading an article from Two Sides NA, the author posed some interesting questions when it comes to the sustainability of alternative fiber paper:

"Does it remove incentives to keep the landscape forested? Do the environmental advantages persist when the production expands to the necessary scale to economically produce paper, or does it result in more negative environmental impacts (i.e. consider water use, chemical inputs, energy requirements, climate effects, etc.)? What is the risk that forest land will be converted to agriculture? What effects, both positive and negative, would this have on local communities and indigenous peoples? Is independent, third-party certification available to ensure environmental, social and economic baselines are being met?[7]"

Although using an alternative fiber may be sustainable on a small scale because it is limiting deforestation, if it is extrapolated to a larger scale, is it still sustainable? Framing these questions in this way really brings the focus back to the goals of sustainability- living and producing in a way that does not bring harm to the environment over an extended period of time.

[6] Carter, B., Mathews, B., Hanson, K., & Hyson, P. (2020). *Which eco friendly paper is best - recycled or FSC certified?*Eco & Beyond. Retrieved November 9, 2021, from https://www.ecoandbeyond.co/articles/eco-friendly-paper/

[7] *Wood-based Paper and Alternative Fiber-based Paper*. (n.d.). Two Sides North America. Retrieved November 14, 2021, from https://twosidesna.org/wp-content/uploads/sites/16/2020/11/TSNA-Alternative-Fibres.pdf

6.2.3 FSC Paper

Overharvesting and forest mismanagement are currently issues that the world is facing. Because of the forest management standards that FSC holds, there is a way to identify forests that are using the most sustainable and ethical practices. By committing to these practices, forest managers are able to replace their forests naturally and consistently. When paper is labeled as FSC, it means that the sourcing of the material is in line with those standards. It is a way for the consumer to have more control over what they choose to consume.

There are three different types of FSC paper: FSC 100%, FSC MIX, FSC Recycled. FSC 100% means that it comes from 100% virgin fibers from well-managed forests. FSC MIX means it may be a mix of virgin fibers and/or recycled fibers with controlled fibers. Lastly, FSC Recycled means that it comes from 100% recycled fibers.[8]

FSC also provides documentation on what printers and suppliers are already FSC certified. The list of printers in North America is from 2019[9] and the list of suppliers and what FSC paper they offer in North America is from 2018.[10]

6.3 Logo Use and Chain of Custody Certification

The only entities that may use the FSC logo on their products are those that have chain of custody certification.[11] This certification is for companies that take ownership of a FSC certified forest product along the supply chain.

In order to achieve the FSC chain of custody certification, the entity must first contact a certification body or group manager and submit an application.[12] Our team contacted two certifying bodies, Advanced Certification Solution and Bureau Veritas Certification. Advanced Certification Solution said the mandatory FSC audit for chain of custody certification would total about $3500. Bureau Veritas Certification said it would cost between $3000 - $4000. Then, the entity must complete an on-site or virtual assessment to make sure that the entity is compliant with the FSC Chain of Custody standard. Next, the entity will receive the approval and can start

[8] *Paper & Printing*. (n.d.). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/en-us/market/paper-printing
[9] *Printers with FSC Chain of Custody Certification*. (2019). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/preview.fsc-certified-printers.a-560.pdf
[10] *FSC-Certified Papers*. (2018). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/preview.fsc-certified-papers-north-america.a-671.pdf
[11] *FSC Trademark Use Guide For Promotional Licence Holders*. (n.d.). Forest Stewardship Council. Retrieved November 14, 2021, from https://fsc.org/en/document-centre/documents/resource/165
[12] *Chain of Custody Certification*. (n.d.). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/preview.fsc-chain-of-custody-101.a-774.pdf

producing and selling FSC products. This certification will last five years.[13] In order to maintain the FSC certification, the entity must undergo annual audits.

Another way to get chain of custody certified would be through a group certification. Group certification is a way to get smaller companies involved in the FSC chain of custody by splitting the certification cost amongst other companies.[14] This can reduce the certification cost by about one third of the original price.

In Earthborne Games' situation, the printer is the one who requires this chain of custody certification. After calling the FSC office in Minnesota, we came to the conclusion that Earthborne Games does not need the chain of custody certification because they are not altering the product in any way. In order to confirm this information, the team reached out to Greener Printer. This is a printer that we knew early on would be able to produce the tabletop game, so we asked about the process that is required when the FSC logo is used. Greener Printer responded saying that they present the logo use claim to FSC for approval. Knowing this, it makes sense that the printer's chain of custody certification is the one that is necessary for logo use.

6.4 Bioplastic vs. Wood

Earthborne Games raised that given they would be providing some additional tokens or figures to a game, there should be an alternative ready aside from producing them from plastic. Thus began the research for a plastic alternative, and the question as to whether we used bioplastics, or wood?

Due to a lack of research published about direct correlation between bioplastics and wood, the information was synthesized between separate researches. First, research on energy usage was conducted for bioplastics vs petroplastics, and then afterwards compared with that of wood.

Energy usage itself is not easy to compare, however, in *Assessment of the Impacts of Bioplastics* written by Brian Laith Momani, we are provided some insight into the energy usage statistics associated with plastics.

Keynotes that were pulled from this article state that ethylene, propylene, and styrene, which are used to produce petroplastics, are extracted directly from crude oil, as a result they are directly correlated with oil. Quick facts include 4% of the world's total oil usage went to plastics in 2008 and that was discounting heat, energy, or transportation to produce and distribute. Additionally, in 2008, the plastics industry in the United States consumed about 6% of all the energy used by American industries. Bioplastics, on the other hand, require a lot less energy. The fermentation

[13] *FSC® Chain of Custody*. (n.d.). SCS Global Services. Retrieved November 15, 2021, from https://www.scsglobalservices.com/services/fsc-chain-of-custody

[14] *Chain-of-Custody Group Certification*. (n.d.). Forest Stewardship Council. Retrieved November 14, 2021, from https://us.fsc.org/en-us/certification/chain-of-custody-certification/coc-group-certification

process that is used to cultivate and produce the materials such as yeast and bacteria in PHAs, while expensive in cost, only require electricity production. Again, this does not consider other factors including transportation and distribution. [15] [16]

Taken from the study above entitled *Bioplastics as Better Alternative to Petroplastics and Their Role in National Sustainability: A Review*, we quote "Do not use scarce crude oil: In contrast, each kilogram of plastic typically requires 20 kilowatt hours of energy to manufacture, more than the amount needed to make the same weight of steel. Almost all this comes from fossil sources." 20 kwH of energy consumption is put up against that of bioplastics, which doesn't delve into extremely large amounts of energy requirements. As stated before, PHA plastic is produced in bacteria and yeast. Using plant systems for a vast majority, however, means it is considerably less expensive as PHA bioplastics rely on soil nutrients, atmospheric CO_2 and sunlight.[16]

From the research article *Study of Bio-plastics As Green & Sustainable Alternative to Plastics*, "Bioplastics have the same cycle time as traditional plastics but because the process requires significantly lower processing temperatures, bioplastic products can save up to 35% energy. In addition to saving energy during its processing, bio-plastics have two thirds less harmful greenhouse gas emissions as compared to conventional plastics, during the production process." And so given this, it is clear that our bioplastic research has been deemed to be better than petroplastics in regard to energy consumption. [17]

Now, when discussing wood and its sustainability, we specifically talk about wood as itself and disregard the treatment of wood as it wouldn't apply to the game. This is because treated wood, as it stands, specifically uses chemicals as a treatment to be used outside. These additional chemicals need not to be considered as none of the materials are being used outdoors.

It has been found that much of the energy used in wood processing is within thermal energy used for drying, for which wood processing residues are commonly used. In this link, it is also mentioned that wood proves to be a sustainable storage for carbon, as about 50% of dried wood is considered to be carbon absorbed during its growth process. Found a bit later within the published article *Meta-analysis of greenhouse gas displacement factors of wood product substitution*, it is

[15] Worcester Polytechnic Institute, & Momani, B. L. (2009, March). *Assessment of the Impacts of Bioplastics: Energy Usage, Fossil Fuel Usage, Pollution, Health Effects, Effects on the Food Supply, and Economic Effects Compared to Petroleum Based Plastics.* Interactive Qualifying Projects. https://core.ac.uk/download/pdf/212988946.pdf

[16] Muhammad Shamsuddin, I. (2017). Bioplastics as Better Alternative to Petroplastics and Their Role in National Sustainability: A Review. *Advances in Bioscience and Bioengineering*, *5*(4), 63. https://doi.org/10.11648/j.abb.20170504.13

[17] Reddy, R. L., Reddy, V. S., & Gupta, G. A. (2013). Study of Bio-plastics As Green & Sustainable Alternative to Plastics. *International Journal of Emerging Technology and Advanced Engineering*, *3*(5). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.413.3777&rep=rep1&type=pdf

written that sustainability eventually will increase along with the increase in the production of wood and its forestries, thus, supporting sustainable management in the future.[18]

And under our research, very likely the most valuable and important information to digest is quoted as follows: "The quantification of GHG benefits due to the use of residues from the wood product value chain is not straightforward; issues include the allocation of benefits to the different biomass fractions, varying carbon intensity of the fossil fuel replaced, leakage (i.e., a unit of additional biofuel does not necessarily lead to a unit reduction of fossil fuel use), potential soil carbon stock change due to removal of harvesting residues, and uncertainties about how post-use wood products will be handled by future waste management systems." When finished and its purpose has been served, there is no exact number to be placed on its carbon intensity or residues that are left behind as it differs greatly. While, with bioplastics, it is generally accepted that under a vast majority of conditions they decompose naturally.[18]

Bioplastics versus wood, we decide on wood. While the disadvantages of wood such as the initial cost upfront and its disruption of the carbon cycle seem to be bigger issues, they are easily mitigated when doing a bit more research on the advantages. These include an ultimate reduction in overall CO_2 emissions as a result of the carbon cycle, more durable and higher quality pieces, a lack in overall processing which means mitigation of health concerns, etc., etc..

6.5 Adhesives

Finding information about black core adhesive is very tough because it is not used very often, and companies generally do not like sharing information about this material. However, we did find some promising information. Printninja is a website that sells a variety of cardstock types including black core and also has information about the material. Black core is the highest quality core since it is the strongest. It also is the most desired by casinos because the core doesn't allow players to see through the cards. If the playing cards are being used a lot, then black core adhesive should be used as it will be able to withstand the wear and tear.[19] We reached out to Printninja but unfortunately were not able to get a response by phone or email.

We did find a limited amount of information from a company called LD Davis, which manufactures glues and gelatins. We came across a safety data sheet for a water-based adhesive that has properties similar to black core adhesive. This adhesive is black in color and light blocking, which are two characteristics of black core adhesive. It has good adhesion, a high level of stiffness, and is used for laminating. It was too late in the semester to reach out to them to inquire about price quotes.

[18] Sathre, R., & O'Connor, J. (2010). Meta-analysis of greenhouse gas displacement factors of wood product substitution. *Environmental Science & Policy*, *13*(2), 104–114. https://doi.org/10.1016/j.envsci.2009.12.005

[19] *Playing Card Stock*. (2021). PrintNinja. Retrieved December 1, 2021, from https://printninja.com/printing-resource-center/printing-options/custom-game-printing/playing-card-material/card-stock/

Eric Benson is an associate professor at the University of Illinois and has some knowledge about different types of adhesives. He suggested water-based cold-melt adhesives, mainly due to the fact that they are low in volatile organic compounds (VOCs). He also mentioned bio-based glues which are more environmentally friendly. Unfortunately, he did not have any experience with black core adhesive and thus could not provide any information.

Finally, we found information from LD Davis, an adhesives company and they use an adhesive called block out glue that is sometimes used in manufacturing playing cards. Block out glue is made from a water based polymer emulsion. Additionally, an alternative to this block out glue is to use jelly glue, also known as protein glue. Protein glue is an "entirely biodegradable alternative to starch-based liquid glue. Jelly glue is 100% non-toxic, recyclable, and decomposable, making it one of the most environmentally-friendly adhesives available to manufacturers."[20] Jelly glue is another name to call protein glue. Jelly glue may be a problem for the manufacturing company that we are looking at since they may not offer this type of adhesive as an option for card production. Overall, adhesives are a crucial material in the composition of a card game.

6.6 Inks

Finding specific inks that are used in playing cards is nearly impossible since companies tend to keep this information private, however an article was found that describes the LCA of playing cards which provided crucial information towards the environmental impact of inks used in the cards. In the article it is stated that "inks used in card production are oil-based… the oil base of the ink is combined with organic compounds, which are the salts of nitrogenous compounds to produce color."[21]

Another type of ink that is widely used is vegetable and soy based inks, which are the most environmentally friendly that can be recycled. According to printing company Green Printing "soy-based inks do have a smaller environmental impact than traditional, petroleum-based inks. Soy ink produces about 1/3 of VOC than conventional printing inks. Plus when it comes time to recycle, paper printed with soy ink is a lot easier to de-ink, resulting in less energy-intensive and more cost effective."[22] If possible, printing companies should try to use vegetable and soy based inks in order to be the most environmentally friendly when it comes to recycling.

[20] LD Davis. (2019, September 24). Natural Glues for Industrial Applications. LD Davis Glue and Adhesives. Retrieved November 29, 2021, from https://blog.lddavis.com/natural-glues-for-industrial-applications
[21] Frassi, D. F. (2018, December 6). Playing Cards. Design Life-Cycle. Retrieved November 29, 2021, from http://www.designlife-cycle.com/playing-cards
[22] Green Printing. (n.d.). Green Printing. Green Printer. Retrieved November 29, 2021, from http://www.unicorngraphics.com/printing/green%20printing.asp

6.7 Coatings

Coatings are an important material when manufacturing playing cards; the coatings help keep the artwork and inks safe from any scratches or blemishes. There is a large array of coatings that can be applied to playing cards and paper in general. Throughout our research we looked at two types of coatings, Aqueous and Ultraviolet (UV) coating, and we will discuss the benefits of each one and ultimately decide which one is the better choice, environmentally for our partner, Earthborne Games, while maintaining the best quality.

Aqueous coatings are made from several chemicals that give it its properties of repealing water and giving it a sleek appearance. This coating is composed of these "basic ingredients: water, polymers, ammonium hydroxide, wetting agents, and wax, or a slip agent… the key ingredient is the polymer." Most of the composition of aqueous coatings that companies use is similar but the key ingredient being that of the polymer is actually a "co-polymer (two polymers) system of styrene and acrylate."[23] It is also important to note that these polymers are what give the chemical it's clear film, however aqueous coating has a high amount of water in it as well, hence its name. Research was conducted in order to determine the sustainability of the chemical composition.

As noted above, the chemical composition of aqueous coating is mostly composed of "water, and contains a copolymer containing styrene and acrylates,"[24] whereas UV Coating is mostly composed of "polyethylene, calcium carbonate and kaolinite."[25] A European company, SigmaKalon Services, had a patent for an aqueous coating that could be compared to the aqueous coating for paper; they state "when the styrene acrylic copolymer is in the form of an aqueous mixture as defined herein, the aqueous mixture comprising 20 wt% of the styrene acrylic copolymer, 20% plasticiser, 45 wt% water and 15 wt% organic solvent."[26] These specific percentages help determine the exact amounts of each chemical compound needed to make an aqueous coating. The specific percentages of the chemical makeup of UV coating could not be found so an average was taken between the chemicals that comprise it. Now we can compare the two coatings since we have an understanding of the specific chemical percentages.

[23] NANCY PLOWMAN ASSOCIATES, INC. (n.d.). Are Aqueous Coatings Permeable? Nancy Plowman Associates. Retrieved November 17, 2021, from http://www.npatest.com/pdf_docs/Are_Aqueous_Coatings_Permeable.pdf

[24] NANCY PLOWMAN ASSOCIATES, INC. (n.d.). Are Aqueous Coatings Permeable? Nancy Plowman Associates. Retrieved November 17, 2021, from http://www.npatest.com/pdf_docs/Are_Aqueous_Coatings_Permeable.pdf

[25] What is UV Coating (and Why Do You Need It?). (n.d.). PsPrint. Retrieved November 17, 2021, from https://www.psprint.com/resources/what-is-uv-coating/

[26] SigmaKalon Services. (2003, September 19). EUROPEAN PATENT APPLICATION. Retrieved November 8, 2021, from https://patentimages.storage.googleapis.com/05/40/15/e1b8346eef689d/EP1518904A1.pdf

Table 1: Environmental Impacts

	Global Warming (kg CO2-Eq)	Eutrophication (kg N)	Acidification (moles of.)	Ozone Depletion (kg CFC-11)	Ecotoxicity (kg 2,4-D-)	Photochemical Oxidation (kg NOx-Eq)
Aqueous Coating	0.951	0.000235	0.215	$8*10^{-8}$	0.390	0.00219
UV Coating	2.745	0.000624	0.487	$1.1*10^{-7}$	0.597	0.00546

Table 2: Human Health Impacts

	Respiratory Effects (kg pm2.5-)	Carcinogenic (kg benzen.)	Non-carcinogens (kg toluen)
Aqueous Coating	0.00110	0.00485	6.19
UV Coating	0.00237	0.00523	9.67

Table 3: Chemical Environmental and Human Health Impacts

		TRACI	TRACI	TRACI	TRACI	TRACI	TRACI	TRACI	TRACI	TRACI
		environmental impact	environmental impact	environmental impact	environmental impact	environmental impact	environmental impact	human health	human health	human health
		global warming	eutrophication	acidification	ozone depletion	ecotoxicity	photochemical oxidation	respiratory effects, average	carcinogenics	non-carcinogenics
Reference Product Name	Reference Product Unit	kg CO2-Eq	kg N	moles of .	kg CFC-11.	kg 2,4-D-.	kg NOx-Eq	kg PM2.5-.	kg benzen.	kg toluen.
styrene	kg	2.8118815	0.00031628	0.54591818	0.00000014	0.86009312	0.00496157	0.00280219	0.00683604	7.7161802
acrylic binder, without water, in 34% solution state	kg	1.3243017	0.00052688	0.31418592	0.00000011	0.70201521	0.00359467	0.00164185	0.00856389	12.032411
acrylic filler	kg	0.40502862	0.00017013	0.16670001	0.00000003	0.32872448	0.00113289	0.00080134	0.00382768	62.677666
acrylic varnish, without water, in 87.5% solution state	kg	1.8990276	0.00083312	1.1448753	0.00000016	2.3196332	0.00487738	0.00544834	0.03046597	607.13263
packaging film, low density polyethylene	kg	2.8178993	0.00045549	0.57329632	0.00000006	0.911946	0.00791970	0.00299704	0.00677646	15.262327
xylene	kg	1.6114371	0.00012601	0.23711685	0.00000000	0.09979840	0.00244037	0.00089179	0.00049564	1.2341161
isobutanol	kg	2.2495062	0.00098841	0.47991537	0.00000025	0.81185559	0.00726109	0.00209944	0.00727285	10.950624
plasticiser, for concrete, based on sulfonated melamine formaldehyde	kg	1.2379753	0.00033571	0.37829066	0.00000019	0.82772786	0.00303910	0.00214531	0.01363389	16.50404
tap water	kg	0.00030984	0.00000004	0.00007054	0	0.00012238	0.00000072	0.00000062	0.00000060	0.00104564
calcium carbonate, precipitated	kg	0.33853269	0.00005835	0.09510794	0.00000002	0.34116906	0.00099465	0.00048511	0.00410045	4.5173118
ene acrylic copolymer, 20% plasticiser, 45 wt% water and 15 wt% organic solvent		0.95092355	0.00023506	0.21547770	0.00000008	0.39018552	0.00219138	0.00109809	0.00484968	6.18999316
16% calcium carbonate, 16% layered sodium silicate, 33% acrylonitrile-butadiene-styre		2.74515824	0.00062370	0.48681453	0.00000011	0.59745106	0.00546451	0.00237371	0.00523244	9.66557068
layered sodium silicate, SKS-6, powder	kg	1.8656876	0.00028377	0.3430113	0.00000041	0.89942612	0.00360243	0.00217195	0.01195139	17.433214
acrylonitrile-butadiene-styrene copolymer	kg	4.3466583	0.00125484	0.67210517	0.00000006	0.26937636	0.00617054	0.00281693	0.00109137	2.9221072

Data comes from a database supplied from class Ecoinvent 3.8 cutoff cumulative LCIA

Weighted and Average values were used respectfully for the chemical composition of Aqueous and UV coating to determine overall numbers

The spreadsheet seen in Table 3 highlights the comparison of the various environmental impacts the production of 1 kg of said chemical will have against the environmental and human health categories listed in the table. Overall, it seems that UV coating has a chemical composition that has a larger negative impact on the environment in terms of Global Warming, Eutrophication, Acidification, Ozone Depletion, Ecotoxicity, and Photochemical Oxidation. In addition UV coatings are more harmful towards human health in terms of respiratory effects, carcinogens, and non-carcinogens. It is important to note that specific weighted values were found for aqueous coating composition, however an assumption had to be made in order to use an average weight composition for UV coating. These numbers can be compared in the highlighted rows in Table 3, seen above. In addition, aqueous and UV coatings each have their own amount of volatile organic compounds (VOCs) they produce when they are being processed that can be seen in Figure 3. High volatile organic compounds are not favorable for the environment nor human health since they "react to our room temps and light which then produce low level ozone which leads to smog."[27] An overall tradeoff can be seen in Table 4 that highlights the benefits and drawbacks of each coating.

[27] ChemMasters. (n.d.). Seal the Deal : What Are VOCs. Chemmasters.Net/Newsletters/2013-05/Article2.Php. Retrieved November 17, 2021, from https://www.chemmasters.net/newsletters/2013-05/article2.php

Sheetfed Printing Inks	VOC Levels
Conventional Process Inks	< 30%
Conventional Overprint Varnishes	< 30%
Soy-based Inks	< 10%
Aqueous Coatings	< 7%
UV Coatings	< 5%
UV Overprint Varnishes	< 5%
UV Process Inks	< 1%

Figure 3: VOC Comparison[28]

Table 4: Coating Tradeoff

Paper Coating Tradeoff	
Aqueous Coating	UV Coating
● Can be recycled easily ● Less than 7% VOC ○ VOC are released when curing ● Does not require energy to cure	● Difficult recycling process ○ Can be recycled in mixed pulp ○ May vary depending on recycling plant ● Less than 5% VOC ○ Little to none VOC are released when curing ● Has more of an impact towards: Global Warming, Eutrophication, Acidification, Ozone Depletion, Ecotoxicity, and Photochemical Oxidation ● Requires high amount of energy to cure ● Higher gloss finish

6.8 Recycling

Finally it is important to consider recycling as such this is a crucial step in the life cycle for the card game; once the card game has reached the end of its use it may be disposed of, but exactly how it will be disposed of will be discussed. We contacted a recycling company, International Paper, and according to Ryan, a sales manager, aqueous and water based coatings can be recycled, whereas UV and any other poly or plastic based coating cannot be recycled easily.

[28] Green Printing. (n.d.). Green Printing. Green Printer. Retrieved November 29, 2021, from http://www.unicorngraphics.com/printing/green%20printing.asp

Furthermore, “the ability to recycle paper with heavy UV coverage may be limited. Too much of this coating in a batch may contaminate the pulp which prevents the paper from being used to make recycled paper products.” It is also important to note that several recycling companies were contacted (International Paper, Illini Recycling, American Eagle Paper Mills, etc.) and an overall consensus was reached that these recycling companies tell the difference between a water and UV based coated paper by either feeling the paper, wetting it, or by tearing it. For example a UV coated paper will tend to show the film itself on the paper when ripped, whereas it is difficult to see a water based film.

6.9 Environmental Impacts: Greenhouse Gases

Playing cards typically have four main components, which are coating, ink, adhesive, and paper. Starting with coating, there are many impacts that this component has on the environment as it relates to greenhouse gases. The environmental impacts depend on the types of coatings that are commonly used, which include solvent borne coatings, water borne coatings, and powder coatings. The solvent borne coatings averaged .58 kg CO_2/m^2 emitted, powder coatings averaged .4 kg CO_2/m^2 emitted, water borne coatings averaged .41 kg CO_2/m^2 emitted. This data reveals that water based coatings and powder coatings have the lowest carbon footprint.[29]

Inks also have a significant environmental impact on greenhouse gas emissions. In 2009, ink manufacturing contributed to 212 kg of NMVOC (non-methane volatile organic compound) emissions. NMVOC emissions are emitted from a variety of sources, including production processes, activities involving combustion, and usage of solvents. Amounts of NMVOC emissions depend on the temperature and species of the emission source but are typically emitted by a variety of vegetation. NMVOCs can have a negative effect on the health of certain species because they can add to tropospheric ozone formation.[30] Also, in 2009, manufacturing of coating preparations, varnishes, inks and adhesives contributed to 480 kg of NMVOC emissions.[31]

[29] *Carbon Footprint Study for Industrial Coatings Applied on a Metal Substrate*. (2011). DSM. https://www.dsm.com/content/dam/dsm/furniture/en_US/documents/20.-dsm-carbon-footprint-%20-disclaimer.pdf

[30] “Non-Methane Volatile Organic Compounds (NMVOC) Emissions.” *European Environment Agency*, EEA Web Team, 6 Dec. 2021, https://www.eea.europa.eu/data-and-maps/indicators/eea-32-non-methane-volatile-1/assessment-4.

[31] National Environmental Research Institute, & Nielsen, O. N. (2011, September). *Projection of Greenhouse Gas Emissions 2010 to 2030*. National Environmental Research Institute. https://www.osti.gov/etdeweb/servlets/purl/1032901

Table 5: Carbon Footprint Results

	System	Raw Materials	Manufacturing	Application			Total (Individuals)	Total (System)
				Substrate Heating	Substrate Coating	Solvent Incineration		
Solvent	Primer	0.189	0.002	0.019	0.118	0.162	0.49	1.01
	Adhesive	0.210	0.008	0.019	0.118	0.167	0.52	
Aqueous	Primer	0.104	0.002	0.025	0.118	0.005	0.25	0.52
	Adhesive	0.090	0.026	0.025	0.118	0.004	0.26	

(Units of Analysis: Kg CO_2e/m^2 of coated substrate)

The third component of playing cards, adhesives, also have an impact on greenhouse gases. Table 5 shows carbon emissions for two main types of adhesives, which are solvent-based and aqueous-based. Carbon is released during different parts of the adhesive construction process. This process includes raw materials, manufacturing, and application. The application process includes substrate heating, substrate coating, and solvent incineration. For solvent adhesives, raw materials make up the majority of carbon emissions, and substrate coating makes up the majority of carbon emissions for aqueous adhesives. In total, solvent adhesives make up the majority of greenhouse gas emissions.[32]

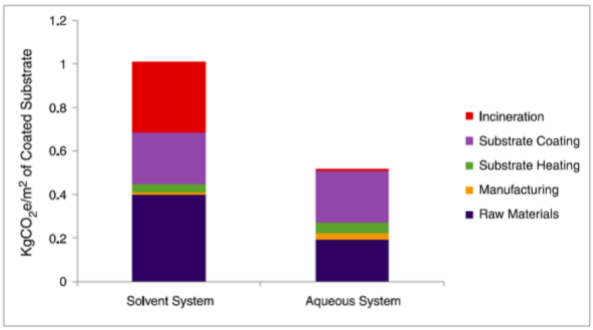

Figure 4: Components of the Life Cycle Analysis of the Systems

Figure 4 compares the amount of carbon emissions released for solvent and aqueous systems. This graph shows that solvent systems release almost twice as many carbon emissions as aqueous systems. One major difference between these two systems is the incineration process. For aqueous systems, carbon released from the incineration process is negligible, while it makes up a significant

[32] *Carbon Footprint: Water Based vs. Solvent Based Adhesives*. (2020). LORD Corp. Retrieved December 1, 2021, from https://www.lord.com/products-and-solutions/adhesives/rubber-bonding/carbon-footprint-comparison-rubber-bonding-adhesives

portion of the solvent system. Solvent-based adhesives also have other adverse effects on the environment, and can lead to air, water, and soil pollution.[33]

Finally, paper also has a significant impact on greenhouse gas emissions. Greenhouse gases are released during raw material sourcing in forests as well as production of the paper itself. The biggest source of emissions, 40%, comes from burning trees for energy used for pulping. Harvesting trees also destroys peatlands, which are a type of wetland. The destruction of peatlands releases carbon into the atmosphere, which oxidizes the peat and makes it more susceptible to burning. Annually, peat oxidation releases 88 million tons of CO_2 per year into the atmosphere. Methane is also emitted from paper discarded in landfills, and a significant source of emissions is land use change related to pulp fiber production. Despite these adverse effects of greenhouse gases, there is hope that the situation could be improved. Annual emissions of CO_2 could be reduced by 75% if we protected current forests, stopped deforestation, and restored and expanded degraded forests.

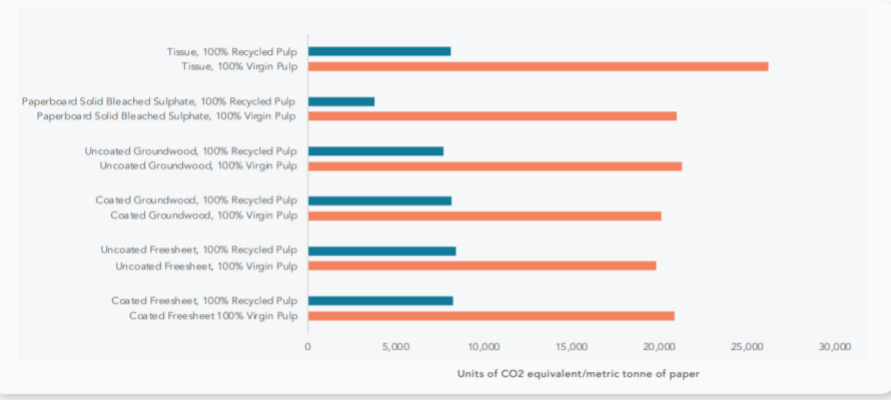

Figure 5: Greenhouse Gases/Climate Change Impacts (units of CO2 equivalent/metric ton of paper)

Figure 5 shows the amount of CO_2 released for different types of paper. We can see that for every type of paper, 100% virgin pulp releases over twice as much CO_2 as 100% recycled pulp.[34]

[33] *How Bad are Solvent-Based Adhesives for the Environment?* (2016, November 25). Sure Tack Systems. Retrieved December 1, 2021, from https://suretacksystems.com/2016/11/are-solvent-based-adhesives-bad-for-environment/#:%7E:text=Soil%20Pollution,comes%20into%20contact%20with%20it.

[34] Haggith, M. (2018). StateOfTheGlobalPaperIndustry2018_FullReport-Final.pdf. Environmental Paper Network.

6.10 Printing Companies Contacted

Using the FSC certified printers list and our understanding that the states of Minnesota, Wisconsin, and Michigan have the most desirable printing location for Earthborne Games due to limited transportation, we contacted the printers we previously had selected. As seen in Figure 6, we contacted the most companies in those three states. A more detailed spread of the companies contacted, their responses, and their locations are documented in Figure A.1 in the Appendix. In total we contacted 77 different companies, focusing mainly on the United States.

Figure 6: Locations of Printing Companies Contacted

Of the 77 companies we contacted, eight total seemed interested, as seen in Table 6. Of those eight, one did not align with Earthborne Games' mission, and one is still asking questions about the Bill of Materials. The other six companies have now moved onto the quoting process.

Table 6: Count of Printing Company Responses

Response	Company Count
No Response	45
Doesn't Fit Production	20
Quoting	6
Unfavorable Timing	2
Email Error	2
Questions	1
Doesn't Align With Mission	1
TOTAL	**77**

6.11 Carbon Offsetting

Carbon offsets are vouchers to help pay towards environmentally friendly and sustainable projects that will help offset our pollution. Carbon offsets can be purchased on energy and its production process, in order to counteract emissions that have already been made. Purchasing offsets on production means subsidizing work in order to encourage production. Some things these carbon offsets help with include allowing businesses to take near-term action to meet carbon reduction goals as they take steps to become more carbon-neutral. Money from these offsets is put towards emission reduction projects (solar farm, planting new forests, wind farms, etc.).

Offsets are measured in tons of carbon dioxide-equivalent (CO_2e). For every metric ton (2,204 lbs) a project or set of activities reduces, one carbon credit is generated. This is a problem, take methane for example (25 times more potent than carbon) If someone's primary goal is to offset methane emissions they may not be achieving the responsibility they're looking to take and may be in the wrong market entirely. The two types of carbon-offset markets that are open to the public consist of what are known as the *voluntary* and *compliance* carbon markets. Both the voluntary and compliance markets were originally established in the Kyoto Protocol, carried on in the Paris Accords.

Compliance markets are where government regulations require firms to reduce their carbon emissions. Failure to meet these carbon caps result in fines and legal issues, and so carbon offsets

are bought to stay within compliance. Some different variations of these compliance markets include California and various countries in Europe, where technical numbers on emissions and purchasing and contractual agreements become more ambiguous.[35]

Voluntary is where non-regulated organizations participate according to their own carbon neutrality goals. Biggest participants are government entities, food and beverage companies, airlines, etc.. Certification programs (done through Verified Carbon Standard, Gold Standard, Climate Action Reserve) determine and generate carbon offset credits based off of projects where the activities meet all the requirements to be considered offsetting. After this, carbon credits are generated and can be bought by anyone/any entity that aims to neutralize their carbon footprint.[35]

We find some information in regard to different types of carbon offsets, often referred to in research as GHG offsetting. First, we look at voluntary RECs (Renewable Energy Certificates). Initially, the most criticism within this field comes during an "overwhelming environmental integrity issues." These do not effectively reduce emissions, and therefore are seen as a non-reliable form of reducing your emissions, as their integrity to reducing emissions is fragile and tracking of the REC isn't as reliable as with compliance markets. Compliance RECs (Renewable Energy Certificates), on the other hand, are believed to have high confidence in carbon reduction, and the long-term contracts that are required by the carbon-neutral supplier (renewable energy source) strengthen their assurance. Renewable Energy Offsets, one of the more reliable forms of carbon reduction, is known to add a lot of complexity with additional levels of tracking the validity of the renewable carbon voucher but still lacks return that completely outweighs its negatives. This includes the complexity mentioned, as well as no guarantee to a tangible reduction in carbon emissions, given that the chain of custody of these renewable energy offsets aren't tracked the same way they are within the compliance market.[35]

In their entirety, most carbon offsets are considered to be good when the renewable project that produces them has validity in its production and numbers and doesn't come from an oversupplied market.

Some other common issues that are seen in these markets are as follows; fluctuation in prices as carbon may not cost the same in all areas due to different projects having different costs which results in some markets getting flooded with buyers for cheaper carbon offsets. There is also the issue that emissions of methane and or nitrous oxide don't have the same weight as carbon for example methane is 25 times more potent than carbon and isn't equivalently offset, carbon offsetting may promote pollution as people believe they are 'un-doing', for example 50,000 new oil wells are drilled every year and that doesn't change with offsetting which can also be described as the indulgence controversy. This indulgence controversy talked about, references those that

[35] *Offset Project Entities*. (2019, November 15). Carbon Offset Guide. https://www.offsetguide.org/understanding-carbon-offsets/carbon-offset-projects/offset-project-entities/

begin to ramp up their consumption under the belief that there is someone undoing their actions, such as when oil companies drill new wells as we offset. Additionally, indigenous land is not necessarily always considered. While there are not high amounts of reports of this, this has been an issue in the past and occurred in Kenya and Uganda, where companies that aimed to contribute to FSC certified land and ended up displacing 20,000 farmers.[35]

Earthborne Games was curious about carbon sequestration, the terrestrial storage of CO_2 and so some research was conducted to understand its current state. Underground storage of CO_2 has taken place for many years as a consequence of injecting CO_2 into oil fields to enhance recovery.

Work to develop many of these options for carbon sequestration are in progress, but so far we have a few. Major reservoirs, suitable for storage, have been identified under the earth's surface. CO_2 needs to be stored securely for hundreds or even thousands of years, in order to avoid it reaching the atmosphere and so deep aquifers are generally our best bet as long as they remain impermeable. The potential capacity for underground storage is large but not well documented. Other geological storage schemes are under development and plans to monitor them are well-advanced. Deep ocean could be used to store large quantities of CO_2. but this would exacerbate ocean acidification and has been made illegal under the London and OSPAR (Oslo/Paris Convention) conventions. As a result, ocean storage is no longer considered feasible.

The goal for the development of CO_2 capture technology is to reduce its cost. The ultimate goal is to develop sequestration technologies that cost $10 or less per ton of carbon sequestered, equivalent to adding only 0.2 cents per kWh of electricity that we currently use. For reference, DAC (Direct Air Capture), regarded as one of the best technologies within the field as of now, can cost anywhere from $94-$232. For CO_2 storage the priority is to establish its credibility and acceptability as a safe, reliable, long-term storage.

Only time will tell if this will be opened publicly, allowing others to purchase credits for carbon they've sequestered or intend to sequester but for now, CO_2 has been naturally stored for long geological time-scales and so it enhances the credibility of many of the storage options.

6.11.1 Regulation Involved in Compliance RECs (Renewable Energy Certificate)

Renewable Energy Certificates are extremely complex, complexity is exacerbated by regulation for these renewable energy certificates, since they take place at a national, regional, and provincial level along with mandated emission sources and no central set of rules to follow.

Information taken from a few articles show that typically, because compliance program offset credits are generated and traded for regulatory compliance, they under-go what is known as commodity pricing. In this, all offset credits in a particular program are priced similarly based on the dynamics of supply-and-demand, and this is not affected by project type, nor other

characteristics. All RECs have serial numbers, though, and it is used as a system to track ownership. This system is intended to track the liveness or status of credit, which means finding out whether it has been used and where or what it is allotted for.[36] [37]

When discussing the clean development mechanism (CDM), also known as certified emission reduction (CER), we find that they arose during the Kyoto Protocols which ran valid from 1997 to 2016. The goal of the clean development mechanism aimed to provide clean energy to purchase these carbon credits from. Of course due to aforementioned complexity, the experience with these included some problems which involved issuance as an average time of 500 days long. Also the need to include permanence and additionality, projects must be additional in what energy would be saved versus what would occur without the project.

To give an idea into the usage of the compliance market, generally used for public image, it is noted that the compliance market was 150 times larger than the voluntary market in 2008. When purchasing within the compliance market, you can find these RECs from any jurisdiction that follows RPS (Renewable Portfolio Standard), the Clean Development Mechanism, or RGGI (Regional Greenhouse Gas Initiative). These guidelines found in these standards mean these RECs are actively tracking your emissions, purchased from a certified production through special jurisdictions, and consider proper baseline and measurement. Additionally, there should be a clear goal that is obtainable given research and evidence, the goal should also clearly progress and have an increase in its impact and should have a long-term contract for financing and planning to be considered beneficial. These goals all need to be aimed at reducing carbon emissions in their totality. These goals all need to be in line with meeting the equivalent of carbon reduction in metric tons.[38]

7. Research Implications/Product Transfer and Maintenance

Ideally, Earthborne Games would want to go with 330gsm black core or 350gsm coreless as far as the adhesives are concerned. GSM stands for grams per square meter and refers to the weight of the paper, and the core refers to the material holding the two sides of the card together. Black core is the strongest type of core and highest quality and is typically used in casinos. Coreless cards can be used if the cards don't need to be handled a lot. Additionally, if given the choice between solvent and aqueous adhesives, we would recommend aqueous because they release less carbon dioxide into the atmosphere.

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[36] *Renewable Energy Certificates: Background & Resources*. (2008, October). EPA Clean Energy-Environment Technical Forum. https://epa.gov/sites/default/files/2016-03/documents/background_paper_3.pdf

[37] Kizzier, K. (2020, December 17). Carbon Offsets – When Done Right – Can Reduce Emissions and Support the Paris Agreement: EDF and ENGIE Impact. Environmental Defense Fund. https://www.edf.org/media/carbon-offsets-when-done-right-can-reduce-emissions-and-support-paris-agreement-edf-and-engie

[38] *RECs: Making Green Power Possible*. (2015, March 27). [Video]. YouTube. https://www.youtube.com/watch?v=_12VYXms6-c&ab_channel=U.S.EnvironmentalProtectionAgency

There are two main types of coatings that can be used for playing cards, which are aqueous and UV. To determine which is ideal, the environmental impacts and the volatile organic compounds (VOCs) released from each material need to be taken into consideration. When considering environmental impacts, Aqueous coatings can be recycled easily and thus have a lower impact on the environment. UV coatings, however, are more difficult to recycle and have a larger impact on global warming, acidification, eutrophication, ozone depletion, and other harmful processes. When considering VOCs, aqueous coatings release more than UV coatings (<7% compared to <5%, respectively). If the main concern is VOCs, we recommend going with UV coatings. Otherwise, we recommend aqueous coatings.

As far as the paper is concerned, FSC paper is ideal because that would mean that the game would get the FSC seal on the box. There are three types of FSC certified paper: FSC virgin paper, FSC recycled paper, and FSC mixed paper which has components of both. From our analysis, FSC virgin paper is the best, because it promotes sustainable forest management while also providing high quality paper. The other two FSC papers are still great options, but they may have a slight decrease in quality. The second option is to use recycled paper that isn't FSC certified, but in this scenario the game would not get the FSC seal on the box.

When deciding between bioplastics and wood, we came to the conclusion that wood would be a better option. Wood provides the quality and durability while being one of the cleanest materials to work with. When working with wood, a vast majority of health concerns are removed, the concerns of food resources are negated, and energy is used more efficiently to name a few of the benefits.

If Earthborne Games was interested in purchasing carbon offsets, we recommend doing business with companies that purchase RECs. These offsets come in the form of renewable energy certificates (RECs), and RECs are proven to have an impact on carbon reduction. Faith in these compliance RECs comes from long-term contracts that are mandated by the carbon-neutral supplier.

8. Recommendations

If we were to replicate this process, we would start contacting printers sooner and more vastly. The team broadened the type of printers we would contact, so we reached out to companies who on surface may seem as if they didn't have the capabilities to produce, but after looking at the Bill of Materials, they were either able to completely do it or just had problems with the cradle tray, which was adjusted.

With respect to materials for the game, our team recommends using FSC paper. FSC paper promotes well managed forests and is recognized as high quality paper. With respect to wood vs. bioplastics, wood is recommended by our team because of its durability and quality. As far as adhesives, our team recommends using black core adhesive because of its accessibility. A coreless

stock would be preferred, but it would be more important to have access to a reliable and quality stock than using a coreless stock. Therefore, our team recommends black core stock despite the increase in toxicity. Additionally, we recommend using aqueous coating for the cards since they are able to be recycled easily and are more environmentally friendly than UV coatings.

Moving forward, we encourage Earthborne Games to keep working with the companies that are giving him quotes. For his first production run quality should be the top priority, but cost is still a significant factor. We know these printers all have FSC capabilities since they were on the FSC certified printer list, so there are no concerns there. We also suggest that Earthborne Games works with a company with a more central location- specifically in the states of Minnesota, Michigan, or Wisconsin. This will limit carbon emissions by reducing overall transportation of goods. Since Earthborne Games will not need to be Chain of Custody certified, we also suggest that Earthborne Games use the FSC logo on their finished goods.

9. Appendix

Budget

No other money or resources are needed to complete this project. Cash should not be a major concern since our group is not responsible for traveling or purchasing anything for our partner. Our only resource that is crucial is time, hence why our group has developed an in depth Gantt chart for planning and scheduling. Our Gantt chart that our group has made has been designed in order to spread out our time resources fairly.

In terms of labor hours, hypothetically speaking, our team would expect to get paid twenty dollars an hour for our academic research, our group will put about five hours into research a week for about ten weeks. A total group cost associated with this labor comes out to a total of $4,000 for all four members of our team. See the list below to see total overall costs.

Information

- No paid databases needed
    - $0

Travel

- No travel needed
    - $0

Software

- LCA database
    - $1,000 - 3,000

Labor

- $20 per hour
    - $1,000 per person for the entire course of the semester

Total Cost

- $5,000

Figure A.1: Companies Contacted and Responses

Companies Contacted	Responses	Location
Cartimundi	Doesn't Align With Mission	Belgium
Franklin Press Inc.	Quoting	Minnesota
Gilson Graphics	Quoting	Michigan
Greener Printer	Quoting	California
J-C Press	Questions	Minnesota
Quantum Graphics	Quoting	Minnesota
The First Impression Group	Quoting	Minnesota
Viridiam	Quoting	Wisconsin
Arandell Corporation	Doesn't fit production	Wisconsin
Aura Printing	Doesn't fit production	United Kingdom
Badger Press, Inc.	Unfavorable timing	Wisconsin
Barefoot Press	Doesn't fit production	North Carolina
Bolger LLC	Unfavorable timing	Minnesota
Broudy Printing	Doesn't fit production	Pennsylvania
Conquest Graphics	Doesn't fit production	Virginia
Dekker Bookbinding	Doesn't fit production	Michigan
Fresh Color Press	Doesn't fit production	Minnesota
Greenhaven Printing	Doesn't fit production	Minnesota
Ideal Printers	Doesn't fit production	Minnesota
Impressions Inc	Doesn't fit production	Minnesota
Jakprints	Doesn't fit production	Ohio
Johnson Printing & Packaging	Doesn't fit production	Minnesota
Modern Press, Inc	Doesn't fit production	Minnesota
New Leaf Printer	Doesn't fit production	Wisconsin
Premier Printing	Doesn't fit production	Illinois
Print Authority	Doesn't fit production	Tennessee
Quad Graphics	Doesn't fit production	Wisconsin
Suttle-Straus, Inc.	Doesn't fit production	Wisconsin
Swift Printing & Communications	Doesn't fit production	Michigan
Tepel Brothers Printing Company	Email Error	Michigan
Thomson-Shore, Inc	Email Error	Michigan
Visions Inc	Doesn't fit production	Minnesota

Advertisers Press, Inc.		Wisconsin
American Printing Co.		Wisconsin
American Spirit Graphics Corp.		Minnesota
Arbor Oakland Group		Michigan
Burton & Mayer, Inc.		Wisconsin
Catapult Me		Minnesota
Circle Incorporated		Wisconsin
Color Ink, Inc.		Wisconsin
Crossmark Graphics, Inc.		Wisconsin
Daily Printing, Inc.		Minnesota
Dedicated Converting Group		Michigan
Dolan Printing, Inc.		Minnesota
EPI Marketing Services		Michigan
F.P. Horak		Michigan
Foremost Communications		Michigan
Foresight Group, Inc. - Ann Arbor		Michigan
Grandville Printing Company		Michigan
Graphicolor Printing		Wisconsin
Hatteras Printing, Inc.		Michigan
Heinn Chapman		Wisconsin
Holland Litho Printing Service, Inc		Michigan
Imagine Print Solutions		Minnesota
Imperial Lithographing Corporation		Wisconsin
Independent Printing Company, Inc		Wisconsin
Lawson Printer, Inc.		Michigan
McAdams Graphics Inc.		Wisconsin
McNaughton & Gunn, Inc.		Michigan
Meyers Printing Company Inc		Minnesota
MTI Connect		Wisconsin
Multi Packaging Solutions		Michigan
OneTouchPoint-CCI		Wisconsin
Philipp Lithographing Co.		Wisconsin
Print Craft, Inc.		North Carolina

Printwell Acquisitions, Inc.		Michigan
Reindl Printing		Wisconsin
Rogers Printing Inc.		Michigan
Rooney Printing Co. Inc.		Wisconsin
Royle Printing Co.		Wisconsin
Seven Corners Printing		Minnesota
The John Roberts Company		Minnesota
Times Printing Company		Wisconsin
Travel Tags		Minnesota
Tweddle Group		Michigan
University Lithoprinters		Michigan
Zimmermann Printing		Wisconsin