MESM GROUP PROJECT PROPOSAL 2022 – 2023

Comparative Life Cycle Assessment of Flexible Film Packaging and Algae Bioplastics in the Apparel and Food Industries

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CLIENT

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OBJECTIVES

1. Complete a life cycle assessment of LDPE plastic film packaging.
2. Complete a life cycle assessment of an algal bioplastic alternative.
3. Compare LCAs to evaluate algal bioplastic as a potential replacement for LDPE packaging.
4. Conduct and report results of a community survey looking into the current effects of plastic pollution, perspectives on alternatives, and the likelihood of adopting plastic pollution prevention methods.

SIGNIFICANCE

Forbes called 2021 the Year of the Package. COVID-19 shut down in-person experiences, leading to increased online shopping, food delivery services, and virtual interactions. This shift in consumer demands highlighted a major environmental problem: waste from plastic packaging. The Center for International Environment law indicates that packaging accounts for 40% of the global demand for plastics[1]. Although the Covid-19 pandemic has raised the visibility of the plastics problem, these issues have been widespread since World War II. It has been estimated that 8,300 million metric tons (Mt) of virgin plastic has been produced to date and, if current trends continue, about 12,000 Mt of plastic waste will accumulate in our natural environment by 2050[2]. This Group Project will focus on how brands in the apparel and food industries have increasingly become more engaged with plastic and packaging solutions. Fashion e-commerce already makes up the largest segment of all e-commerce worldwide, and it is expected to grow 10% annually between 2021 and 2024[3]. With this growth, has come an increase in brand commitments. For example, The Ellen MacArthur Foundation's New Plastics Economy Global Commitment has grown from 280 to 500 organizations from 2017 to 2021[4]. The packaged food industry faces challenges between protecting consumers and operating sustainably. Since food packaging is unavoidable, the packaging industry is moving towards using more innovative packaging solutions. Consumers have become increasingly invested in waste solutions, driving the need for innovative packaging solutions. Packaging is also an opportunity for marketing sustainability commitments so, with more sustainable packaging, businesses can capitalize on brand engagement while lowering impact.

BACKGROUND

Historically, the apparel and food industries have relied on single-use plastics for packaging. Apparel must be packaged to stay clean, dry, and undamaged during shipping. Further, food products are frequently stored in containers throughout their lifetime in order to prevent spoiling and product loss. In

both industries, the integrity of the product is critically important to the maintenance of its economic value, and plastic has traditionally taken on the role of insulating the item from ambient conditions.

Low-density polyethylene (LDPE) forms a strong, flexible film, so it has become a common packaging product frequently seen in grocery bags, wrapping up our dry cleaning, and more[5]. Although recyclable, LDPE films are rarely accepted by curbside pickup recycling programs and instead require the user to bring them to designated plastic film collection facilities. As a result, LDPE film often ends up in landfills; consumers are unwilling or unable to bring the films to another location, or they are unaware it cannot go with the rest of their recycling so recycling facilities end up putting the LDPE they receive into the landfill anyway[6]. Some LDPEs can biodegrade under specific lab conditions but are unlikely to degrade fully (if at all) in the environment[7]. In fact, some LDPEs partially degrade in the environment, resulting in the breakdown of the film into harmful microplastics[8]. Because of this, plastic films accumulate in our oceans, on our beaches, in our food, and all around us.

Alternatively, algae-based plastic films offer the possibility of a fully biodegradable packaging product that is not derived from fossil fuels. Algae grow quickly, only requiring sunlight, CO2, water, nutrients, and significantly less area than conventional food crops to thrive. Algae sequester CO2 from the atmosphere and produce up to 70% of the oxygen in the atmosphere[8]. Algae also produce polyhydroxyalkanoates, a biopolymer that is naturally biodegradable, hydrophobic, and nontoxic and contributes these qualities to the viability of bioplastics as an alternative to flexible film plastics[9].

Although these algal plastic films will not be derived from fossil fuel feedstocks, there are necessary elements of the production processes that, at this time, may necessitate the combustion of fossil fuels. This project will evaluate whether the inputs necessary to create the algal film outweigh the benefits. Additionally, we aim to explore the environmental justice implications of plastic pollution in Santa Barbara county via a community survey.

EQUITY

As with many environmental issues, the brunt of the effects and the volume of litter disproportionately impact marginalized communities, especially communities living near plastic production and disposal sites. Additionally, there is uneven access to composting and recycling programs that would allow communities to reduce impacts. This portion of our project will address issues surrounding the end-use of plastic and access to pollution prevention infrastructure in Santa Barbara county. Additionally, it will explore perspectives on the adoption of plastic alternatives.

Our survey aims to:

- Aggregate data for a representative sample of Santa Barbara County community members
- Evaluate impacts of plastic pollution, gauge current packaging disposal habits (landfill, recycling, composting, etc.), accessibility of plastic film recycling drop off facilities
- Evaluate willingness of Santa Barbara County residents to accept alternatives or alter habits to reduce plastic pollution
- Identify areas overburdened by the effects of plastic pollution in Santa Barbara county
- Receive a minimum of 100 respondents in order to analyze trends

AVAILABLE DATA

To complete our LCA of LDPE flexible film plastic, we will access publicly available data on cradle-to-grave processes, including the production of polymers, manufacturing of packaging, distribution of packaging, overall transportation, and the end-of-life treatments, with the functional unit of 1000 kg, using GaBi LCA software and TRACI 2.1 method[10]. We expect publicly available data to be sufficient for the scope of our project, and we are in the process of procuring student access to the Higg Index MSI,

which tool contains a catalog of LCA data relating to various types of plastic packagings, including LDPE. Finally, Dr. Masanet will be able to help with procuring any LCA data and energy and emissions modeling data that are needed.

The client PANGAIA and its partners are willing and able to provide the data necessary to complete an LCA for their partner's bioplastic solution. In the interest of protecting company secrets, the packaging partner will provide a biorefinery model systems diagram for their algae-based bioplastic as well as high-level data on cradle-to-grave processes. The data will allow us to measure the energy, water, and material inputs and any waste outputs of production without revealing the exact steps of their proprietary process (ex. algae cultivation, material extraction, raw materials processing, manufacturing, distribution, end of life disposal). The partner is already producing their algal-based packaging on a large scale and has launched to market, so the data will represent inputs and outputs at their full extent. In our literature review, we identified existing LCA research that similarly utilized broad categories with a zoomed-out view of production processes, so we are confident we will be able to conduct a scientifically rigorous assessment within the boundaries set by the packaging partner. We have not yet received this data, but Andrew Yip, Head of Materials & Process Innovation at PANGAIA, and Lori Bystrom, Senior Science Officer at PANGAIA, have been communicating the information we will need to the partner and are confident it will be available when projects launch.

In order to collect data for our survey, we will develop questions and distribute surveys based on equitable best practices. This may include providing online, telephone, and mail-in surveys. We will compile the responses and use R to analyze and evaluate survey data.

POSSIBLE APPROACHES

LCA:

1. Quantify the life-cycle environmental impacts of industry-standard LDPE flexible film plastics through completing a life cycle analysis in GaBi (or a similar tool) using existing literature and primary data for LDPE packaging products.
2. Quantify the life-cycle environmental impacts of an alternative biorefinery approach to algae-based bioplastics for flexible film packaging through completing a life cycle analysis in GaBi (or a similar tool) using data provided by PANGAIA's partners.

Survey:

3. Employ techniques learned in ESM 269 Survey Design & Environmental Public Opinion to develop effective survey questions and identify and execute best practices for equitable survey distribution
4. Collect survey responses and create data visualizations to represent trends and conclusions via a Shiny App that will be published on the internet

DELIVERABLES

Students will deliver:

1. A report containing results from the comparative life cycle analysis (LCA).
2. Survey results and interactive visualizations in the form of a Shiny App.

INTERNSHIP

PANGAIA is able to sponsor one summer internship at the living wage rate for the intern's home office. The internship length will be determined with the clients closer to the summer. Under current COVID-19 restrictions and safety concerns, the internship will likely be remote. Please see the attached client letter of support for confirmation.

APPENDIX

BUDGET

It is not anticipated that the proposed project would require additional funding beyond the $1,300 contributed by the Bren School. The client is able to contribute an additional $1,000 as needed.

ACKNOWLEDGEMENTS

We would like to thank Roland Geyer for helping initially form our idea. We would like to thank Satie Airamé for reviewing our proposal. Lastly, we would like to thank Eric Masanet for meeting with us and the client, answering all of our questions, and reviewing our proposal. We truly appreciate all the support.

REFERENCES

1. Light, L. (2021, January 04). 2021: The Year of the package. Retrieved January 10, 2022, from https://www.forbes.com/sites/larrylight/2021/01/04/2021-the-year-of-the-package/?sh=4c3cb33b4cd1
2. Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7). doi:10.1126/sciadv.1700782
3. Hugill, R., Ley, K., & Rademan, K. (2021, April). *The Rise of Reusable Packaging* (Rep.). Retrieved from https://reports.fashionforgood.com/wp-content/uploads/2021/04/Reusable_Packaging_Report_April_2021.pdf
4. The global commitment 2021. (2021). Retrieved January 21, 2022, from https://ellenmacarthurfoundation.org
5. EPAgov. (no date). *How Do I Recycle?: Common Recyclables* Retrieved January 14, 2022 from https://www.epa.gov/recycle/how-do-i-recycle-common-recyclables
6. PlasticFilmRecycling. (2022). *Find a Drop Off Location.* Retrieved January 14, 2022 from https://www.plasticfilmrecycling.org/recycling-bags-and-wraps/find-drop-off-location/
7. Kyaw, B. et. al. (2021). *Biodegradation of Low Density Polythene (LDPE) by Pseudomonas Species*. NCBI. Retrieved January 14, 2022 from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3460136/
8. Devadas, V. et. a. (2021). *Algae biopolymer towards sustainable circular economy.* ScienceDirect. Retrieved January 14, 2022 from https://www.sciencedirect.com/science/article/pii/S0960852421000407?casa_token=ieChJ9KbU2YAAAAA:8_ybkdu5J5SoHS7FInwmSbWUHHx06eKeINBX1n6TV2ttPvo0PFb9rpR-UNX2rQSyCLXnKQwboPc
9. Masood, F. (2017). *Polyhydroxyalkanoates in the Food Packaging Industry*. Science Direct. Retrieved January 14, 2022 from https://www.sciencedirect.com/science/article/pii/B978012811942600008X
10. Izhar, T. (2020). *Life Cycle Analysis of Plastic Packaging.* Retrieved January 21, 2022 from https://www.researchgate.net/publication/348069754_Life_Cycle_Analysis_of_Plastic_Packaging

LETTER OF SUPPORT

Programs Manager
BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
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21 January 2022

Dear Group Project Coordinator

Letter of Support in respect of Project Proposal "Comparative Life Cycle Assessment of Flexible Film Packaging and Algae Bioplastics in the Apparel and Food Industries"

This is the client letter of support in respect of the above proposal, and it sets out our commitments in relation to the offer of an internship, funding and data output pursuant to the requirements of paragraph 5. c. of the Bren School Guidelines for Group Project Proposals.

Our Commitments:

If successful in the application Pangaia undertakes that it will honor the commitments stated below:

1. Internship

Pangaia will offer one remote internship through either of its offices in London or New York City; the location to be determined in accordance with and subject to guidance on travel restrictions, entry requirements, and visa obligations applicable during the Summer of 2022 in the UK and the USA.

Should a work or travel visa be necessary for the intern to travel to the UK, Pangaia will procure and fund such application.

a. Mentorship:

The intern will work within the Research & Development department at Pangaia. This department is responsible for application of Pangaia's research and development in new materials across the fashion and retail sector. The intern will be supervised by a qualified and experienced team who work in R&D placement. The intern will be expected to actively participate in discussions concerning the business and to contribute learnings from the Project to those discussions.

Supervision of the intern's work will be undertaken by active engagement with the above-mentioned team and by a single 'supervisor' who will guide the intern in relation to the business ethos, practices, working environment and application of Project knowledge in the business.

The Pangaia staff engagement and human resource team will provide pastoral oversight and support for the intern.

Given the sensitive and intellectual property rich environment that Pangaia operates in, the intern will be required to sign a non-disclosure agreement with Pangaia to ensure Pangaia's patents (registered and pending), trade marks and other intellectual property rights; internal information relating to operation of the business; supplier information and trade secrets are protected. Such NDA is not expected to extend to the information which is the subject of the Project.

b. Living Wage:

Pangaia is a B Corp and is committed to treating all staff with respect, dignity and to quip them on a journey of learning for life in the workplace irrespective of the length of their engagement with Pangaia.

Should the intern choose or be requested to work in the UK, the intern will receive a "living wage" direct from Pangaia during their internship in accordance with local laws and good practice. In the event that the intern works from our New York City offices, Pangaia will similarly provide a "living wage" to the intern during the period of their work with Pangaia in line with New York City Wage Orders and good practice.

In each instance, the Intern will enter into an "Internship Contract" setting out their rights during the period of their engagement, as well as the skills it is anticipated they will develop during their time with Pangaia and the obligations that Pangaia has to that intern in respect of achieve those skills and providing experience for them of the work environment and the practical applications of the Project.

In addition to payment being made to the intern for their work with Pangaia, Pangaia will contribute to the BREN Summer Internship Funding scheme to ensure that a stipend, living and travel expenses can be covered if applied for by the intern.

2. Data

a. Type and Content of Data:

Data will encompass inputs and outputs to the processes and systems used to create flexible film packaging in order for a comparison to be made across different processing routes.

Pangaia will facilitate the acquisition of data from partner companies for the Project, from businesses it works with in the industry, from its collaborators and businesses which it incubates and operates with.

The format of the data will be secured by Pangaia in discussion with the Project Coordinator and according to that needed by the students on an ongoing collaborative and iterative basis. It is anticipated that to facilitate this, the students would create a standardized data template for Pangaia to use when requesting data from these aforementioned partners to ensure parity of data quality, quantity and to provide contextualization across the data resources that Pangaia will draw on for the Project.

b. Confidentiality and Non-Disclosure:

We anticipate that using a collaborative approach with our industry partners, data will be provided to the extent that trade secrets and/or intellectual property will not be compromised by that supply, and that in most cases, data will be supplied for analysis anonymously without identification of the source to avoid data bias in any event.

Where it is necessary for Pangaia to secure data from third party data sources who require NDAs in relation to that data, Pangaia undertakes to secure those NDAs at a corporate level (i.e. without the need for student or BREN involvement) as part of its commitment to the Project.

Should the need arise for Non-Disclosure Agreements in circumstances where the disclosing party wishes to have final rights of refusal in regards to anonymizing certain information prior to publication, these will be secured at a corporate level by Pangaia, but Pangaia will use its best efforts to ensure those will not reserve rights of veto or censorship to those data sources, to ensure the integrity of the outputs.

3. Funding

Pangaia will be able to provide funding for the project up to an additional $1000, but we do not however currently expect the needs of the project to exceed the $1300 provided by the university.

We remain happy to discuss any elements of the above at your convenience.

Yours sincerely,

Andrew Yip, Head of Materials and Process Innovation

BREN Project Sponsor

For PANGAIA MATERIALS SCIENCE LIMITED