REGENERATIVE ARCHITECTURE
Plastic Biodegradation & Bioplastic Production Algae Farm

by

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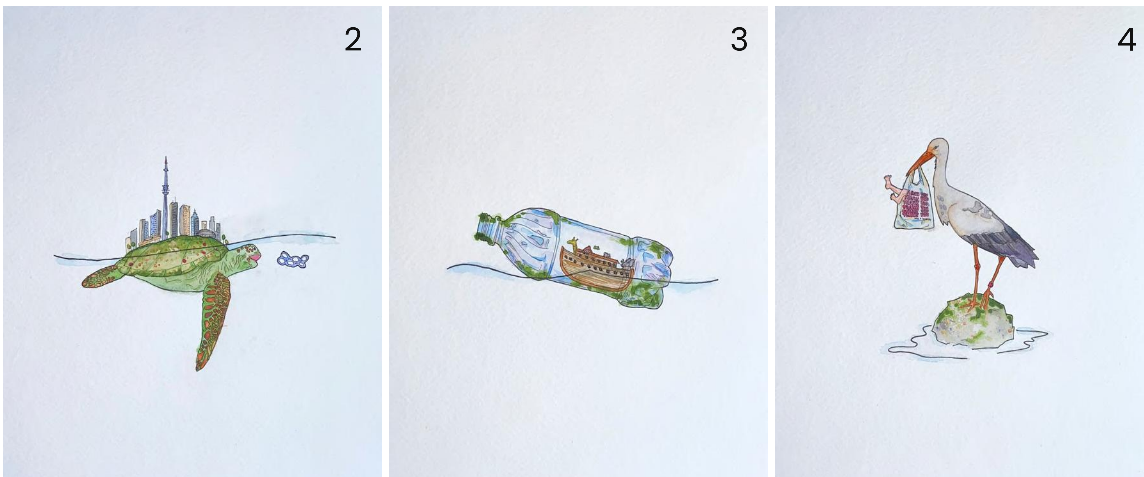
FIGURE 1
Marine plastic pollution, (2020, November)

Note: Steffen, A. D. (2020, November). *The EPA Marks Marine Plastic Pollution As A Top Priority*. Intelligent Living. Retrieved from https://www.intelligentliving.co/epa-plastic-pollution-top-priority/

FIGURE 2-4

Watercolour paintings, (2022, March)



Creation myths have been shared for thousands of years across many different regions and cultures. They are oral and illustrated stories that describe and explain the origin of life and speak universal truths central to the human experience. The symbolic narratives of Turtle Island, Noah's ark, and the stork and baby myth reveal cross-cultural inquiries into our origins and what it means to be human. These stories share a common framework built around conflict, the passage of time, and regeneration. The crises depicted in these myths serve as a cautionary tales while the new beginnings can be seen to represent rebirth and the persistence of hope.

Note: McMurtry, M. M. (2022, March). *Plastic Storytelling*.

STORYTELLING

TURTLE ISLAND

As with most myths, the Aboriginal story of ‘Turtle Island’ has many variations but with the same central narrative. In it, the Creator placed Anishinaabe (indigenous people) on the earth. Over time, the people began to fight one another and so the Creator decided to purify the earth with a great flood. The Creator sent an angel, Nanabush, down from the heavens to carry out the purge. Only Nanabush and some animals survived. Nanabush then worked with the animals to re-create the world. In one version of the story, the Sky-woman (the original human) survives and comes to rest on the back of a great turtle. In both stories, the message is clear: the earth (the turtle) is our Mother and we are a part of a greater whole. As with many nature myths, it compels us to recognize our connection with the land and protect all of creation from harm.

NOAH’S ARK

In the story of Noah’s ark, God washes away all signs of life with a great flood. Only Noah and his ark filled with animals survive. The rains eventually stop and the sun begins to shine. Noah and the animals emerge on dry land as a rainbow stretches across the sky. A message in a (plastic) bottle cast at sea carries Noah and his animals to safety. The water bottle is a message to the world: we must acknowledge that we do not have the climate crisis under control.

THE STORK

Storks are considered a symbol of fidelity due to their propensity to return to the same nest and mate with the same partner. The relationship between stork and baby differs depending on the region. The Greeks spoke of a stork stealing babies due to a tale involving Hera. The Egyptians and some Slavic peoples spoke of storks bringing souls into the world. It is German folk tales that bring us the version that most of us are familiar with today. This myth is likely based on the migration habits of the stork; with them leaving mid-summer and returning nine months later. Instead of the customary cloth or basket, the baby in this delivery is being carried in a plastic bag. Now we know where both babies and plastic bags come from.

FIGURE 5
Decomposing Albatross chick with a stomach full of plastic, (2017, September)

Note: Ortego, N. (2017, September). *This albatross full of plastic should change the way you think about litter*. Wildlife. Retrieved from https://enjoythesilence.today/2017/09/28/this-albatross-full-of-plastic-should-change-the-way-you-think%E2%80%8B-about-litter/

Abstract

REGENERATE
Verb [re•gen•er•at•e]
To re-create, reconstitute, or makeover, especially in a better form or condition. To come into existence or be formed again.[1]

The current plastic recycling system burdens the environment with harmful CO² emissions. Its operations mislead consumers to believe their duties of sorting waste according to material type will guarantee proper handling thereafter. However, this is not the case as less than 10% of all plastic ever produced has been recycled.[2] Most of it has either been incinerated for energy, buried in landfills, or littered in the land or seas. Emerging technologies and government incentives are slowly changing this. One promising development is the use of genetically modified algae to biodegrade plastics and create bioplastic production. Algae has the potential to reduce land use, save water and improve the recycling economy to combat plastic pollution and climate crisis. By understanding algae, its environment, applications, benefits and risks, I have designed a space that requires no land in order to produce an algae farm.

Keywords:
Plastic pollution, climate crisis, renewable energy, algae.

[1] Dictionary.com. (n.d.). *Regenerate definition & meaning*. Dictionary.com.
[2] *Visual feature*: *Beat plastic pollution*. UNEP. (n.d.).

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To my cousin, Keith Murphy and my aunt, Deb Murphy, for their encouragement and support.

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Lastly, to my mom and dad for their constant love and support throughout my entire academic journey, and life as a whole.

FIGURE 6

A study published by Science Magazine estimate that 24-35 million tonnes of plastic enter the aquatic environment yearly, (2022, September)

Note: The Ocean Cleanup. (2020, September). Twitter. Retrieved from https://twitter.com/TheOceanCleanup/status/1306971687406260225

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Introduction

In the brief time I had to research a topic for my thesis, I realized my educational background and interests influence my approach to the creative process. I developed drafting skills in the Architectural Technology program at Algonquin College (2014-2017). My passion for renewable technologies and strategies originated from my experience in Algonquin College's Bachelor of Building Science program (2017-2019). Thereafter, I pursued the Master of Architecture program at Carleton University to develop a creative narrative for my design approach (2019-2022). Combined, the programs have challenged and equipped me with a wide array of knowledge and skills. This shaped my purpose in the architectural realm and helped define how I would make a difference. I struggled with turning off and on my technical way of thinking and letting the creative side of my brain be free. For this reason, my thesis explores a predominant issue of my era and how I tackle it will be both creative and technical.

At the beginning of my research, I studied human connections and environments. This led me to explore spirituality, aboriginal histories, food relationships, and bonds to Mother Nature. For the remainder of the year, my thesis research focused on agricultural practices, human well-being, and climate crisis. I investigated deforestation, sustainable technologies, and social liabilities. It was not until recently that I discovered what I had been searching for all along.

Naturally, I gravitated toward a current and pressing topic of the era: the plastic crisis. This topic gave me the freedom to connect all areas of my research, from the issues of the agriculture sector to water scarcity and greenhouse gas (GHG) emissions. It addressed the health of the earth, its wildlife and human beings. I realized how important this topic was to me when I had to make the decision of tossing certain items in the recycling bin and wondering if they belonged there. I always wanted to learn more about the plastic industry as well as what happens to our garbage once disposed of. I could see how much plastic pervaded my everyday life. I only wondered what becomes of it afterwards.

FIGURE 7
Water Bottle Floating At Sea, (2018, December)

I might not be able to solve the climate crisis; nevertheless, my research and design may change the way the general public views plastics as a disposable commodity. I strove to develop a sustainable recycling system that can help clean cities, rivers, and potentially oceans and rid them of plastic pollution. I will strive to do so by understanding the properties of plastic, the plastic industry, and designing an alternative to current plastic recycling processes. My goal is to increase awareness of the plastic crisis and introduce a solution that protects all living things from the negative long-term effects of human activity.

Note: Hoffman, S. (2018, December). ***The Great Pacific Garbage Patch - 25 Things That Will Make Us Question Humanity.*** The Travel. Retrieved from https://www.thetravel.com/the-great-pacific-garbage-patch/222/

CHAPTER ONE

PLASTICS

Climate change affects rising temperatures, climatic shocks, surface ozone (affecting agricultural output), sea surface temperature, coral bleaching (affecting marine food security) and much more. These effects will largely impact countries and populations that already face poverty, malnutrition and existing inequalities.

FIGURE 8
Balinese surfer Dede Suryana is engulfed in rubbish while surfing off of a remote island near Java, Indonesia, (n.d.)

Note: Noyle. Z. (n.d.). *Balinese surfer Dede Suryana is engulfed in rubbish while surfing off of a remote island near Java, Indonesia*. A-Frame [Magazine]. Retrieved from http://www.aframephoto.com/portfolios/noyle.cfm#

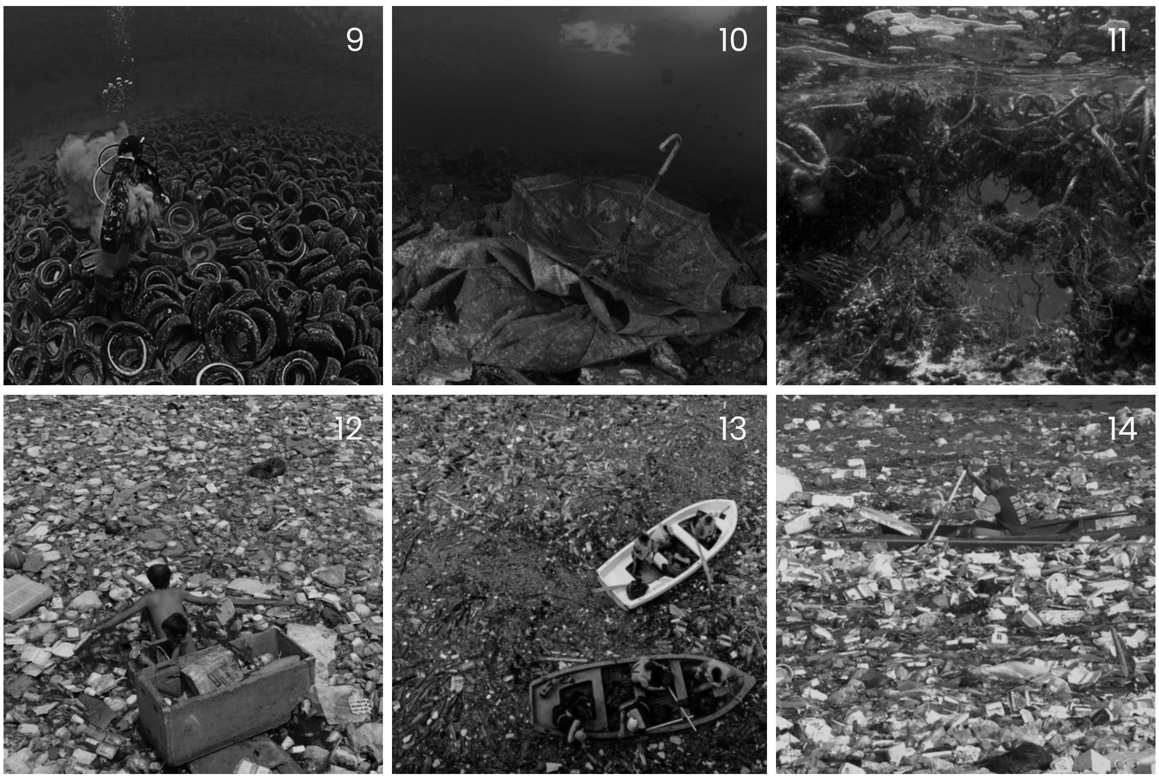
The Plastic Crisis

The solution to the plastic crisis involves addressing the scale of plastic production, introducing new plastic recycling technologies, and reducing waste. Due to inexpensive fossil fuel stocks, lack of regulation, and general mismanagement of waste, the amount of single-use plastic waste continues to escalate.

ENVIRONMENTAL EFFECTS

Regardless of the rise of the electric car, and transportation fuel dwindling, oil as fuel will most likely continue to be extracted for several decades in order to produce virgin plastic, until such time as polymer alternatives can be competitive on a global market scale. Establishing responsibility for cleaning up the waste remains a persistent issue as plastic is nearly indestructible. Recycling faces many challenges and delays, such as the declining quality of plastic as it decreases when diced, melted, and redesigned into a new product. The technologies that exist today can separate and preserve each material from an item made of various plastics and fibres.

FIGURE 9–14
Plastic pollution in rivers and seas, (n.d.)



Note: Brown, A. (n.d.). *The Great Pacific Garbage Patch - A New Continent Emerging on the Surface of the Earth*. Motmag. Retrieved from https://www.motmag.com/cultural-issues/the-great-pacific-garbage-patch-a-brand-new-continent-thats-emerging-on-the-surface-of-the-earth

THE PLASTIC CRISIS

Every year, more than 350 million tonnes of plastic are produced. According to research published by Science Magazine (2017), nearly 80% of all plastic waste ever made ends up in landfills or as litter in the natural environment.[3] This includes oceans, rivers, land, and the atmosphere. According to another study, in 2019 alone, roughly 850 million metric tonnes see above of GHG emissions penetrated the atmosphere during the production and incineration of plastic. Equivalent to the pollution levels from 189 new coal-fired power plants.[4] When comparing material production and other environmental impacts, such as risks to human health and wildlife, what must be considered apart from energy and carbon emissions. Additionally, as climate change continued to worsen with severe weather events, ocean warming contributes to 30-40% of global mean sea level rises. Low-lying areas are hit with catastrophic flooding, affecting every aspect of human life on earth from land and ocean ecosystems.[5] Plastic pollution is often found in regions with high rainfalls and rising sea levels.

EFFECTS ON MARINE LIFE

Human activity, including over-exploitation of ocean resources, is facilitating natural variation, provoking unusual changes in the composition of water, ecosystems, and coastlines. In September 2021, the Copernicus Marine Service issued its most recent annual report that uses ocean monitoring information to describe and calculate the state of the ocean and relevant changes.[6] They discovered an increasing amount of microplastics, (plastic measuring less than 5 mm in size), threaten marine species.[7, 8] Plastic is toxic for sea filter feeders and entangles marine life.

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[3] Geyer, R., Jambeck, J. R., & Law, K. L. (2017, July 19). *Production, use, and fate of all plastics ever made*. Science Advances, Vol 3, Issue 7.

[4] Center for International Environmental Law (CIEL). (2019). Executive Summary. In *Plastic & Climate*: *The Hidden Costs of a Plastic Planet* (p. 2).

[5] IPCC. (2022, February 27). *Climate Change 2022*: *Impacts, Adaptation and Vulnerability.* Intergovernmental Panel On Climate Change.

FIGURE 15
A sea turtle entangled in a ghost net, (2017)

The presence of plastic waste has become a universal concern in the ocean. Animals confuse plastic for food, contributing to malnutrition. Additionally, plastic can negatively impact their general behavior, health, and existence.

[6] Informa UK Limited, & Taylor & Francis Group. (2021). Copernicus Marine Service Ocean Report. *Journal of Operational Oceanography*, 14(5).
[7] Rogers, K. (2020, September 8). *microplastics. Encyclopedia Britannica*.
[8] Chatterjee, S., & Sharma, S. (2019, March 1). *Microplastics in our oceans and marine health*. Field Actions Science Reports, Special Issue 19.

Note: Perez, F. (2017). ***Caretta Caretta Trapped.*** The Ocean Cleanup. Retrieved from https://theoceancleanup.com/great-pacific-garbage-patch/

FIGURE 16
Boy on a boat in a river of plastic, (2019, January)

A 2015 study by the Marine Pollution Bulletin indicates 693 species have encountered marine waste. Of those animal-waste encounters, 92% of the waste is with plastic. The International Union for Conservation of Nature (IUCN) concludes 17% of the species affected by plastic on their Red List of Threatened Species.[9]

Note: Crooked, E. (2019, January). ***Lush To Open Their First Packaging-free Store In the UK.*** Dazed Digital. Retrieved from https://www.dazeddigital.com/beauty/soul/article/42895/1/lush-packaging-free-store

THE PLASTIC CRISIS

An article published by Environmental Science and Technology discovered 180 times more plastic floats on the North Pacific zone (NPAC) surface, a portion of the Great Pacific Garbage Patch (GPGP), than biomass. It is likely that animals migrating to or inhabiting these areas consume plastic. The article examined the digestive tract of sea turtles caught by nearby fisheries and found 74% (by dry weight) of their diet contained plastic. Additionally, the article suggests 45% of the wet mass in stomachs of Laysan albatross chicks from Kure Atoll and Oahu Island is composed of plastics. Their findings also indicated 84% of plastic samples contained at least one Bioaccumulative Toxic (PBT) chemical. Therefore, animals consuming plastic waste are ingesting additional hazards.[10] According to The Ocean Cleanup, "fishing nets account for 46% of the mass in the GPGP." These discarded nets, referred to as ghost nets, can be dangerous or even fatal when sea life swims in or collides with them, unable to free themselves.[11]

EFFECTS ON HUMAN HEALTH & WELLBEING

Impacts on humans and society include both the food chain and economy. The Ocean Cleanup claims plastic pollution costs $13 billion annually. Significant financial resource are expended in an effort to clean and eliminate water-bound plastics. The Ocean Cleanup collaborated with Deloitte in a study that suggested economic costs due to marine plastic is between $6 to $19 billion USD annually. The cost is said to "stem from its impact on tourism, fisheries and aquaculture, and (government) cleanups." Due to the lack of available research, these costs neglect the effects on human health and marine ecosystems.

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9 Gall, S., Thompson, Richard C. (2015, March). "The impact of debris on marine life," Marine Pollution Bulletin, Vol. 92, Is 1-2, p. 172.

10 Chen, Q., Reisser, J., Cunsolo, S., Kwadijk, C., Kotterman, M., Proietti, M., Slat, B., Ferrari, F. F., Schwarz, A., Levivier, A., Yin, D., Hollert, H., & Koelmans, A. A. (2017). Pollutants in Plastics within the North Pacific Subtropical Gyre. *Environmental Science & Technology*, 52(2), 446–456.

11 The Ocean Cleanup. (2022, February 21). *The Great Pacific Garbage Patch*. The Ocean Cleanup.

“There is no such thing as ‘away’. When we throw anything away, it must go somewhere.”

- ANNIE LEONARD
Executive director of Greenpeace USA

It is possible for marine sustenance to be contaminated with plastic and carried forward through the food chain resulting in human consumption. When chemicals found in plastics enter the body of an animal, the chemicals are passed on to predators, ultimately making their way up the food chain. This is a process known as bioaccumulation. Preventing plastic in rivers from leaking into oceans is a cost-effective way of handling severe consequences downstream.[12]

[13] Ibid, [11a].
[12] American Chemistry Council. (n.d.). *life cycle of a plastic product*. americanchemistry.
[14] Andrady, A. L., & Neal, M. A. (2009). Applications and societal benefits of plastics. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 364(1526), 1977–1984.
[15] Theclassics Us. (1857). And Other Waterproof Fabrics. In *Patents for inventions. Abridgments of specifications* (pp. 80–255).

History of Plastics

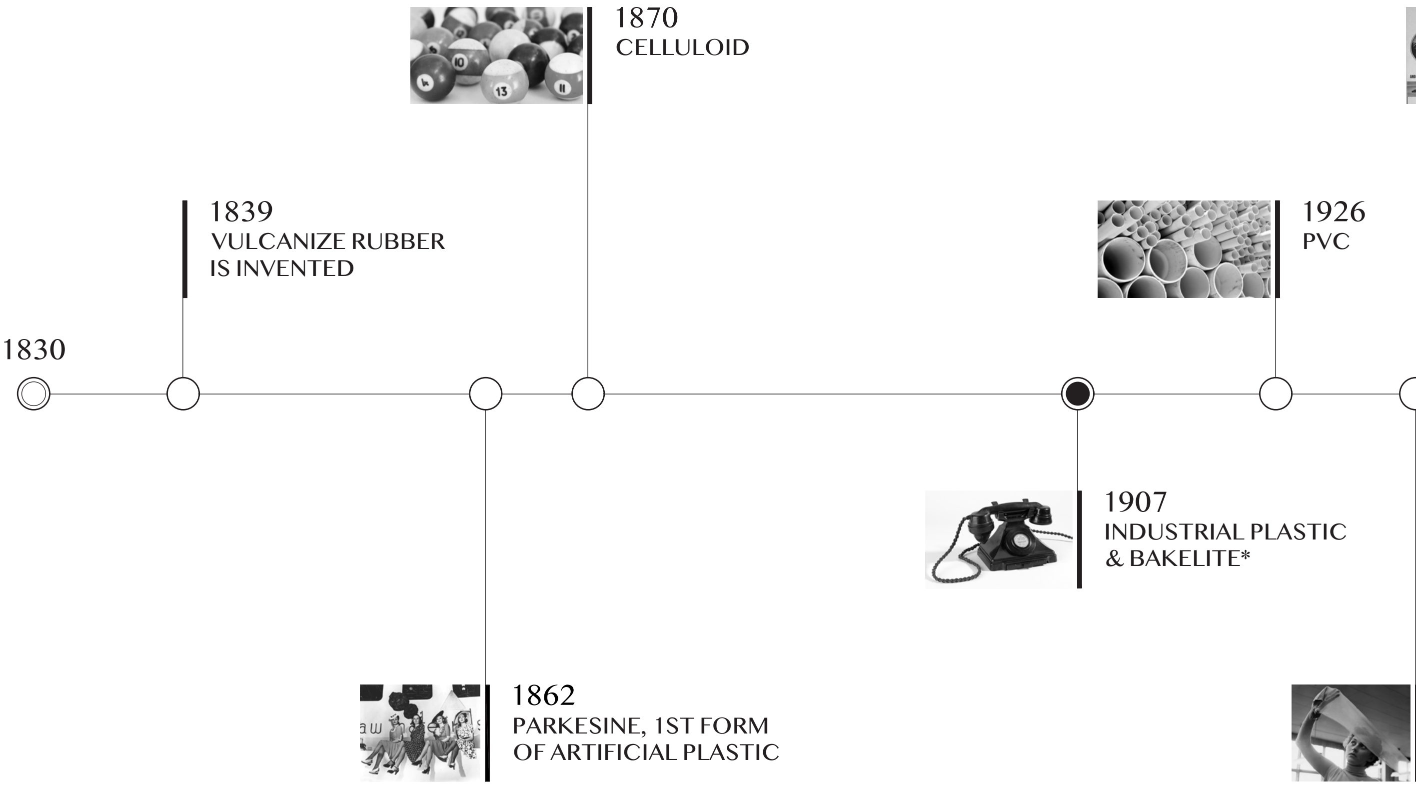
Plastics are a wide range of synthetic or semi-synthetic materials that use polymers as the main ingredient. Plasticity allows for plastics to be molded, extruded or pressed into various shapes and objects. Its many benefits include adaptability, lightweight, durability, flexibility, and inexpensive production. Due to these factors, plastic is the choice of material for a wide selection of products. Most plastic derives from fossil fuel-based chemicals like natural gas or petroleum. However, in recent years, renewable materials such as corn or cotton derivatives have begun to be used to make plastics.[13]

THE INVENTION OF PLASTICS

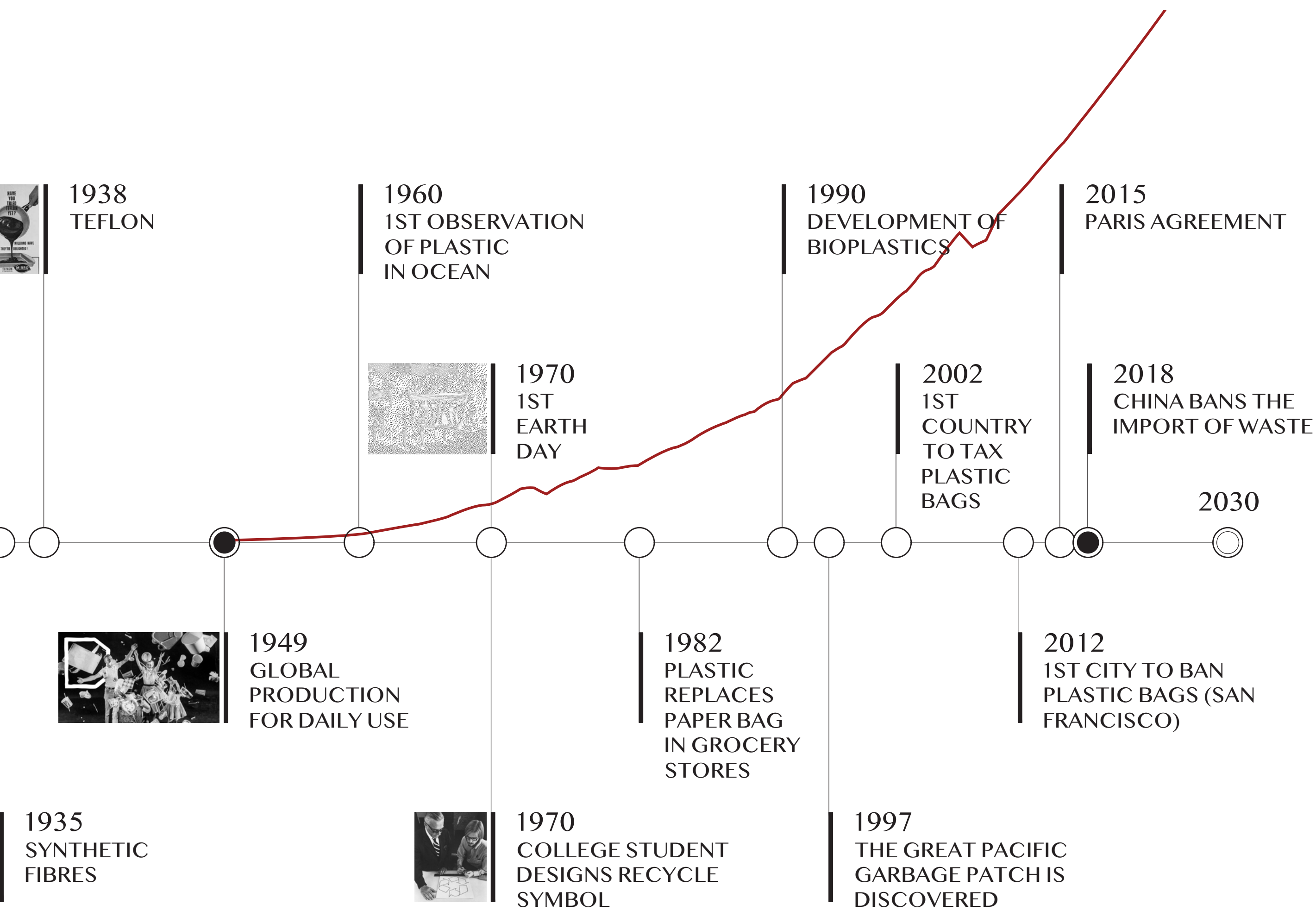
As far back as 1,600 BC, Mesoamericans used plastic (natural rubber) for balls, bands, and figurines. In 1839, Eduard Siman, a German apothecary discovered polystyrene (PS).[14] In 1856, Alexander Parkes patented for Celluloid (considered the first man-made plastic).[15] Some years later, Polyvinyl Chloride (PVC) was accidentally synthesized by Eugene

FIGURE 17

Timeline of major events in the history of plastics, (2022, February)



Note: McMurtry, M. M. (2022, February). *History of Plastics*.


1935
SYNTHETIC FIBRES
1938
TEFLON
1949
GLOBAL PRODUCTION FOR DAILY USE
1960
1ST OBSERVATION OF PLASTIC IN OCEAN
1970
1ST EARTH DAY
1970
COLLEGE STUDENT DESIGNS RECYCLE SYMBOL
1982
PLASTIC REPLACES PAPER BAG IN GROCERY STORES
1990
DEVELOPMENT OF BIOPLASTICS
1997
THE GREAT PACIFIC GARBAGE PATCH IS DISCOVERED
2002
1ST COUNTRY TO TAX PLASTIC BAGS
2012
1ST CITY TO BAN PLASTIC BAGS (SAN FRANCISCO)
2015
PARIS AGREEMENT
2018
CHINA BANS THE IMPORT OF WASTE
2030

Baumann.[16] In 1898, German chemist Hans von Pechmann invented the first synthesized Polyethylene (PE). In 1907, Belgian chemist Leo Baekeland invented Bakelite, the first entirely synthetic thermosetting polymer.[17] Plastic quickly gained popularity with new inventions such as vinyl, nylon, Teflon, polyethylene terephthalate (PET) and polyester. Today, there are seven different types of plastic that are categorized by material. Each type is tagged with a number, known as resin identification codes (RIC), ranging from one to seven (see Table 1). Additionally, RICs indicate general ease of recycling (thus, cost-effectiveness). The lower the RIC, the easier it is to recycle. RICs six and seven are much more difficult.[18]

Figure 16 (right) shows a case study I conducted over one week of collected plastic waste for a household of two people. I then sorted the waste according to its resin identification code (see Figure #). This case study is a visual example of how much waste is unrecyclable.

Figure 17-23 shows the collected waste for the case study organized into RIC groups. It is estimated that 70% of global production is concentrated in six major polymer types. The remaining 30% falls in the seventh category of mixed materials (unrecyclable). The first image (right) is unidentified plastics with no RICs.

[16] Hameed, S. A., Ibraheem, H. H., & Yousif, E. (2021). The use of new pyridine derivatives as effective photostabilizers for poly (vinyl chloride). *Journal of Physics: Conference Series*, 1795(1).

[17] Mercelis, J. (2014, May 29). *Leo Baekeland's Transatlantic Struggle for Bakelite: Patenting Inside and Outside of America*. Technology and Culture. p. 366-400.

[18] Hopewell, J., Dvorak, R., & Kosior, E. (2009, July 27). Review of *Plastics recycling: challenges and opportunities. Philosophical Transactions of the Royal Society*, 364(1526), 2121.

FIGURE 18-25
Plastic Waste Case Study, (2022, January)

 Note: McMurtry, M. M. (2022). *Plastic Waste Case Study.*

TABLE 1
Polymer types, (n.d.)

RIC	Name	Abbr.	Example
1	Polyethylene terephthalate	PET	beverage bottles, cups, other packaging, etc.
2	High-density polyethylene	HDPE	bottles, cups, milk jugs, etc.
3	Polyvinyl chloride	PVC	pipes, siding, flooring, etc.
4	Low-density polyethylene	LDPE	plastic bags, six-pack rings, tubing, etc.
5	Polypropylene	PP	auto parts, industrial fibers, food containers, etc.
6	Polystyrene	PS	plastic utensils, styrofoam, cafeteria trays, etc.
7	Other	O	acrylic, nylon, polycarbonate, polylactic acid (PLA)

Table 1 shows the categorization of polymers by Resin Identification Code (RIC), material makeup, abbreviation, and examples of such types.

GLOBAL SCALE

The process of polymerization forms a polymer chain and involves reacting monomer molecules together in a chemical effect. For this reason, plastics are produced in chemical plants (see Figure 18). It is said that 100 companies account for 90% of the global production of plastics. Major international producers, including American-owned Dow Chemical, Exxon Mobil and Sinopec in China.[19] Currently, the plastic

Note: McMurtry, M. M. (2022). *Polymer Types.*

FIGURE 26

The five-tier waste hierarchy pyramid, (2017)

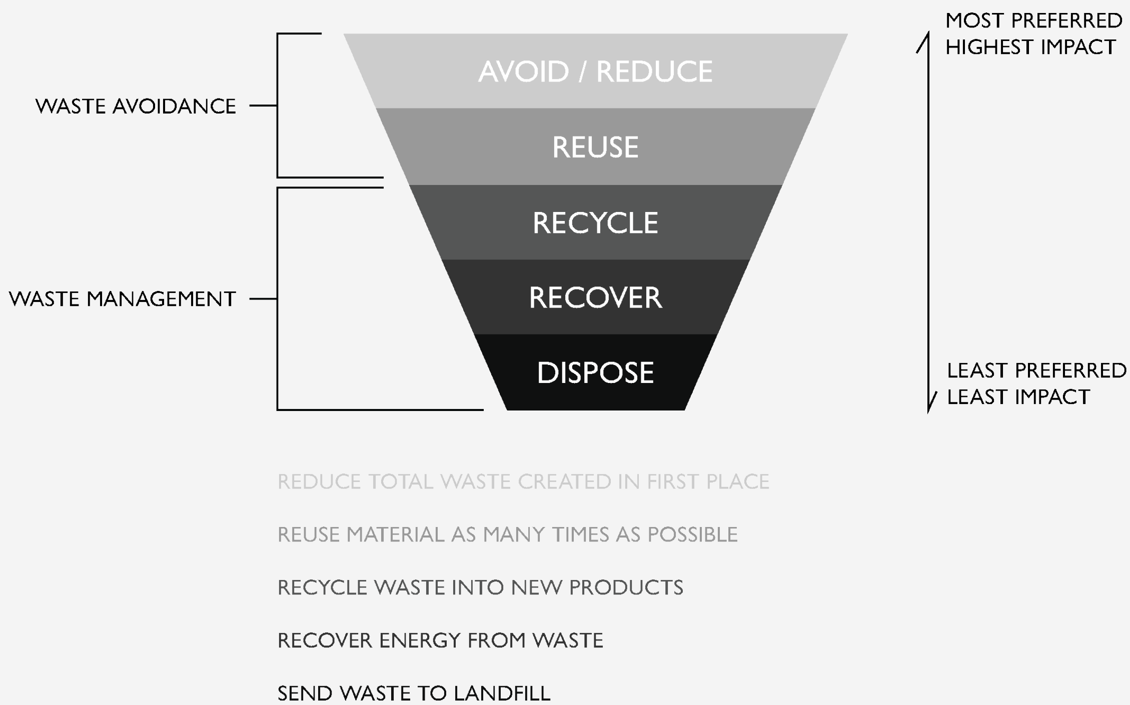


Figure # shows...

recycling industry operates on a linear economy model type. A small proportion of Material Recovery Facilities (MRF) operate on a reuse economy (see Figure 11). However, for the recycling industry to become a green and renewable sector, it must operate on a circular economy (see Figure 12). A circular economy designs products to be reusable from recycled sources and produce fewer products and eliminates the use of virgin materials (oil).

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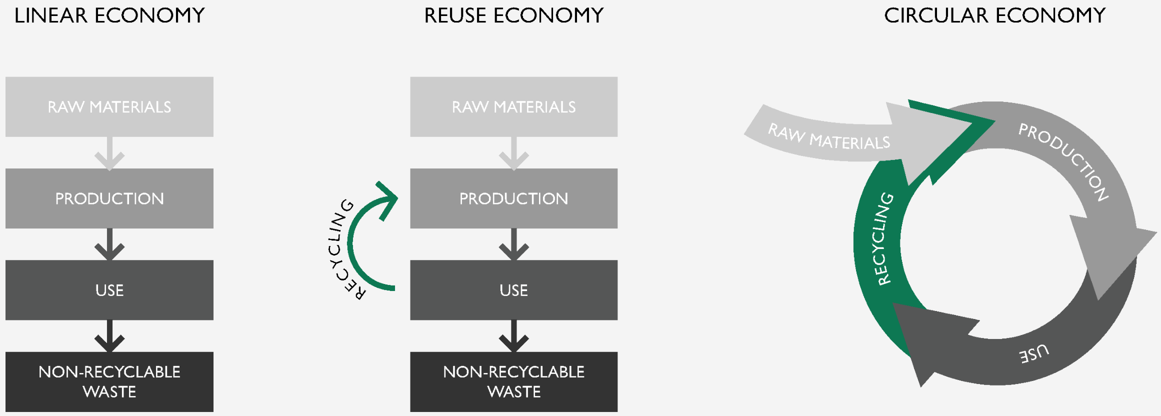
[19] Minderoo Foundation. (2021, November 22). *Top 100 Polymer Producers*. Plastic Waste Makers Index.

Note: Downes. (2017). *The Waste Hierarchy*.

FIGURE 27
Main differences among linear economy, reuse economy, and circular economy, (n.d.)



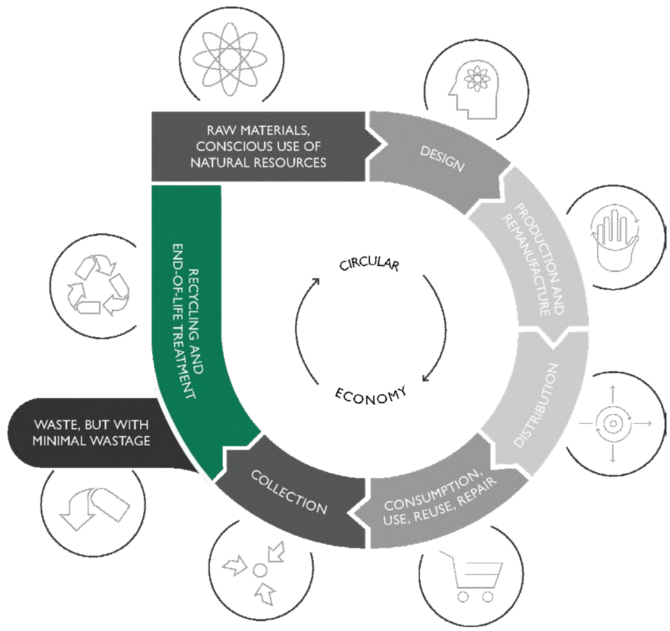
PLASTIC INDUSTRY

A key issue with the recycling industry is the lack of infrastructure and Material Recovery Facilities (MRF). However, China has the infrastructure to process plastic waste. In 2016, China imported 60% of global plastic waste. Therefore, most plastic waste was sent to landfills or shipped to China.[20] In 2017, the Government of China initiated the "Operation National Sword" policy which banned the import of most plastic waste. As a result, China saw a 99% reduction in imported plastic waste.[21] Although the import of waste was a profitable business on the surface, the associated environmental and social costs were increasing to the extent that the

[20] Improving Plastics Management: Trends, policy responses, and the role of international co-operation and trade. (2018). *OECD Environment Policy Papers,* (12).
[21] Katz, C. (2019, March 7). Piling Up: *How China's Ban on Importing Waste Has Stalled Global Recycling*. Yale Environment 360.

Note: Government of the Netherlands. (n.d.). *Circular economy*. Government of the Netherlands. Retrieved from https://www.government.nl/topics/circular-economy

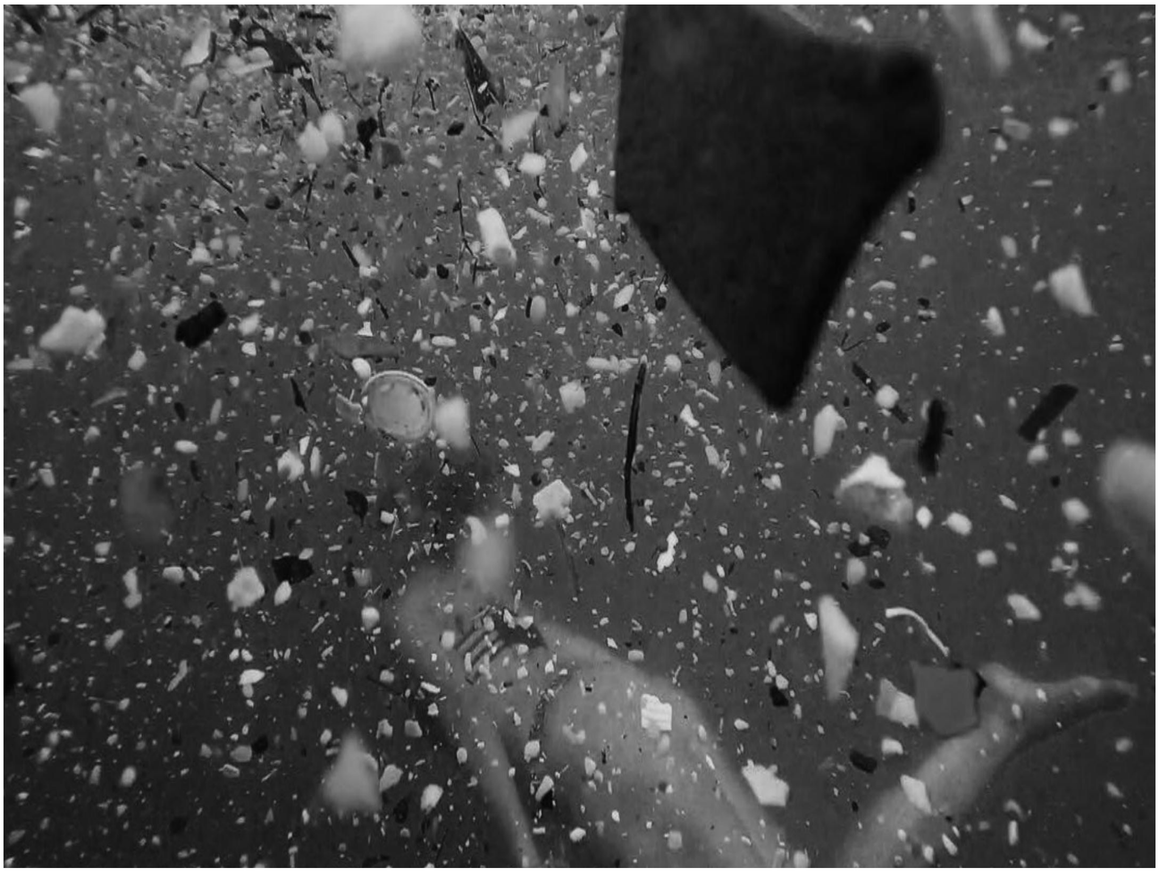
FIGURE 28
Circular economy model, (n.d.)



business was no longer profitable. The European Union (EU) and the United States have invested substantially in the recycling industry since the release of the policy. Similarly global policy changes have driven significant investment in recycling research and infrastructure.
The entire plastic process is a poisonous life cycle, from its manufacturing with harsh chemicals to how it is dealt with at the end of its life span. The general public view most plastics as disposable goods. Due to the low cost of oil, virgin plastic is relatively inexpensive to produce yet it is expensive to recycle. Government incentives now urge innovations on a global scale. For the recycling industry to be truly green, it must shift its operations from the current linear economy to a circular economy. The current recycling system is a linear economy with minor reuse economy practices. The current recycling system diverts public awareness of its true intentions of benefiting from its funding from the fossil fuel industry.

Note: Bluevision. (n.d.). *Infographic: Circular economy in one image*. Bluevisionbraskem.com. Retrieved from https://bluevisionbraskem.com/en/innovation/infographic-circular-economy-in-one-image/

FIGURE 29
A giant swirl of microplastics, (2018, August)



Note: Plastic Ocean Project. (2018, August). *Plastic Ocean Project Inc*. Instagram. Retrieved from https://www.instagram.com/p/Bm8jdqzBnq9/

“It cannot be right to manufacture billions of objects that are used for a matter of minutes, and then are with us for centuries”.

- ROZ SAVAGE
English ocean rower, environmental advocate, writer and speaker

Handling of Plastics

Every minute, two garbage trucks' worth of plastic is dumped into the ocean.[22] Plastic never truly disappears and it can take years to break down into smaller particles.[23] As it breaks down, it enters the food chain through marine life. However, solving the plastic crisis does not begin or end in the oceans. Rather, it starts with the process of making plastic itself.

CURRENT PRACTICES
& TECHNOLOGIES

The majority of mass recycling processes fall under one of three categories: mechanical, chemical, and energy recycling. On an industrial scale, Mechanical Recycling is the most commonly practiced system. The process involves municipal collection that transports the waste to a MRF. There, the plastic is sorted by machinery or hand according to its RIC. The sorted plastic is then pressed or milled (ground), washed and dried. Next, the plastic goes through reprocessing steps

HANDLING OF PLASTICS

(agglutination, extrusion, and cooling) to form pellets or nurdles (beads). Finally, the pellets are transformed into raw materials for new plastics.[24]

The second, less common process, is known as "Chemical Recycling." This process is uncommon due to the expense of machinery and limited technology; however, this process produces very little waste. After being delivered to an MRF, plastic waste is heated through one of three processes: hydrogenation (fuel), gasification (gas) or pyrolysis (oil). In the hydrogenation process, polymers break down from hydrogen and heat. In the gasification process, oxygen heats the plastic, generating gas used for synthesis hydrocarbon derivatives. In the pyrolysis process, plastic is heated without oxygen and generates hydrocarbons to be used either as fuel for power generation or processed by refineries. The products of these three processes are then transformed into raw materials or fuel and sent to a refinery.[25]

In the third process, energy recycling, plastic waste is delivered to an MRF where it is burned. While it is burning, the plastic is converted into solid, gas and energy waste. Solid waste is disposed of in landfill or made into building materials or aggregate. Gas waste goes through a filtering process to remove pollutants then through a heat exchanger to recover waste energy. Ultimately, the gas is released into the atmosphere. Meanwhile, the energy waste is used for heating water to generate steam for power turbines to produce electricity.[26] This recycling process works well in areas with existing infrastructure, such as Sweden, where the country runs on an integrated underground electrical grid. However, this process involves carbon emissions and waste byproducts that are harmful to both the atmosphere and the environment.

[22] Oceana USA. (2022, February 3). *Tackling the Plastics Crisis At the Source*. Plastic Pollution.

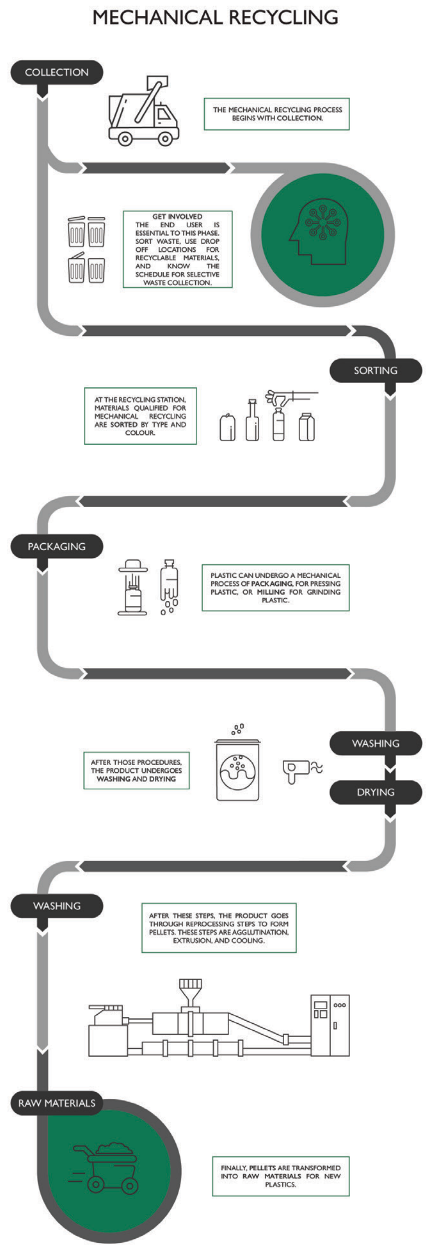
[23] Harris, W. (2010, December 15). How Long Does It Take for Plastics to Biodegrade? HowStuffWorks.com.

[24] Bluevision Braskem. (2018, May 25). *Infographic: How does the process of Mechanical Recycling work?* Intelligence.

[25] Bluevision Braskem. (2018, May 28). *Infographic: How does the process of Chemical Recycling work?* Intelligence.

[26] Bluevision Braskem. (2018, June 7). *Infographic: How does the process of Energy Recycling Work?* Intelligence.

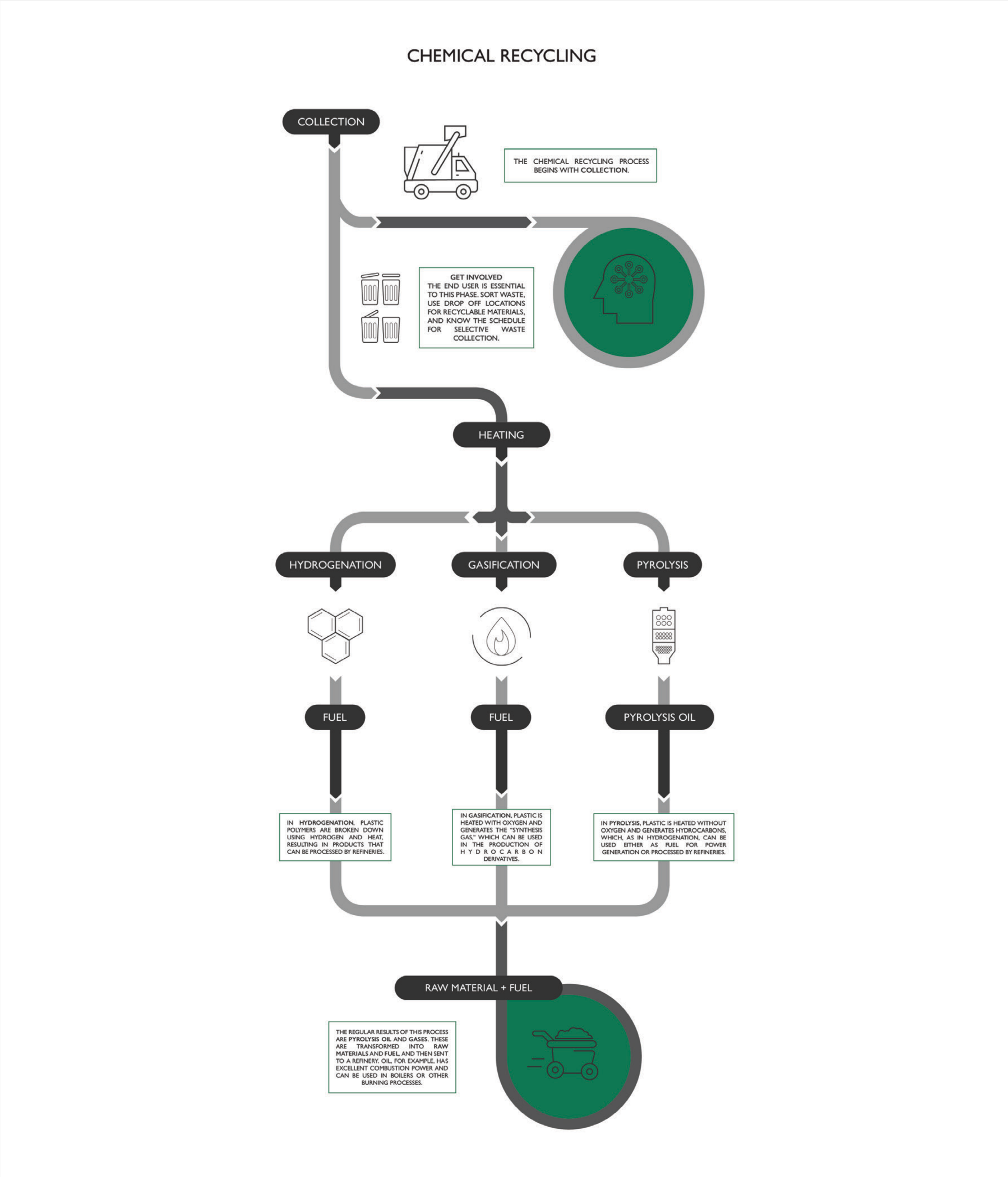
FIGURE 30
The mechanical recycling process, (n.d.)



Note: Bluevision. (n.d.). *Mechanical, energy or chemical? How the different types of recycling work*. Bluevisionbraskem.com. Retrieved from https://bluevisionbraskem.com/en/intelligence/mechanical-energy-or-chemical-the-different-types-of-recycling-work/

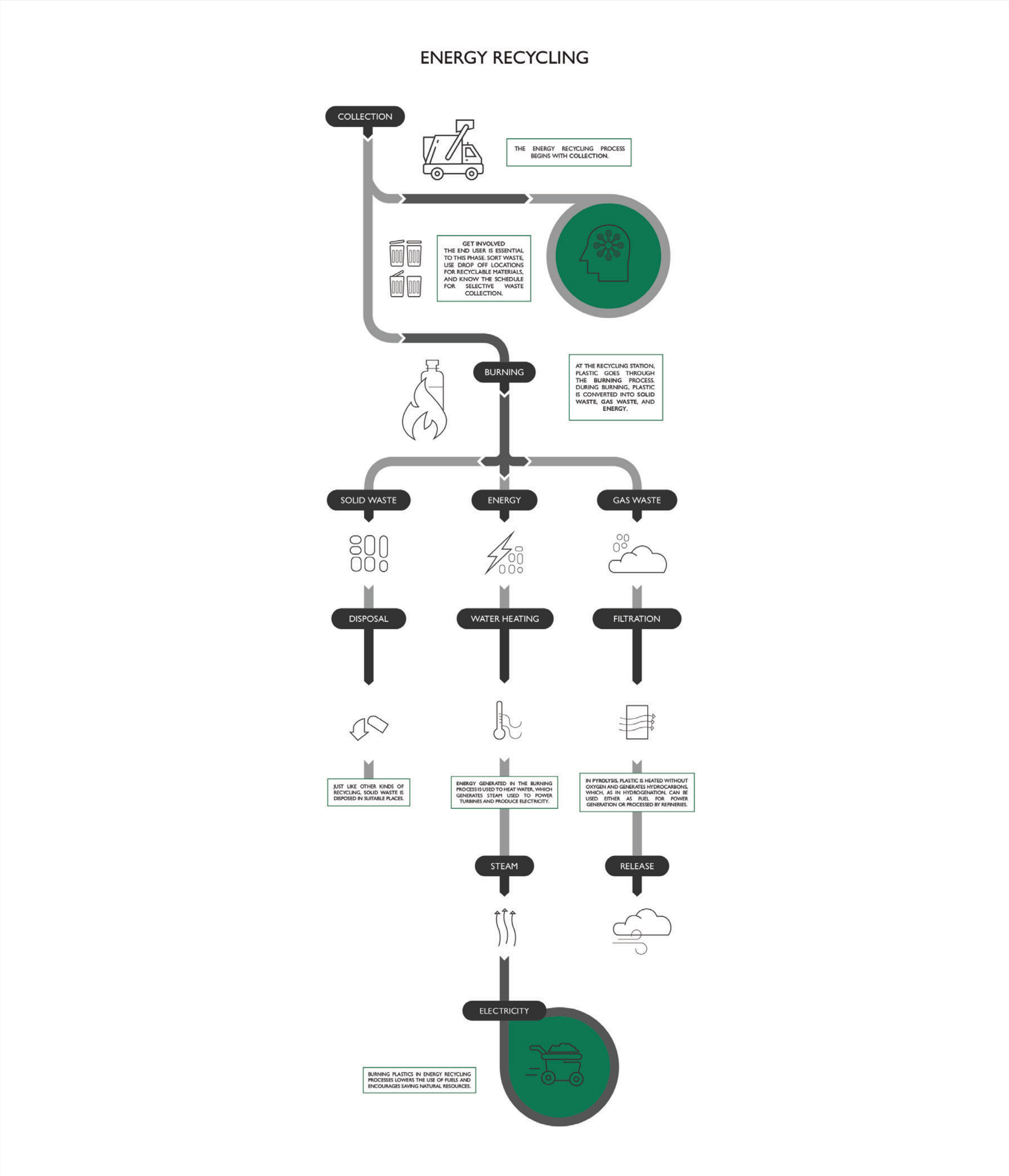
FIGURE 31

The chemical recycling process, (n.d.)



Note: Bluevision. (n.d.). *Mechanical, energy or chemical? How the different types of recycling work*. Bluevisionbraskem.com. Retrieved from https://bluevisionbraskem.com/en/intelligence/mechanical-energy-or-chemical-the-different-types-of-recycling-work/

FIGURE 32
The energy recycling process, (n.d.)



Note: Bluevision. (n.d.). ***Mechanical, energy or chemical? How the different types of recycling work***. Bluevisionbraskem.com. Retrieved from https://bluevisionbraskem.com/en/intelligence/mechanical-energy-or-chemical-the-different-types-of-recycling-work/

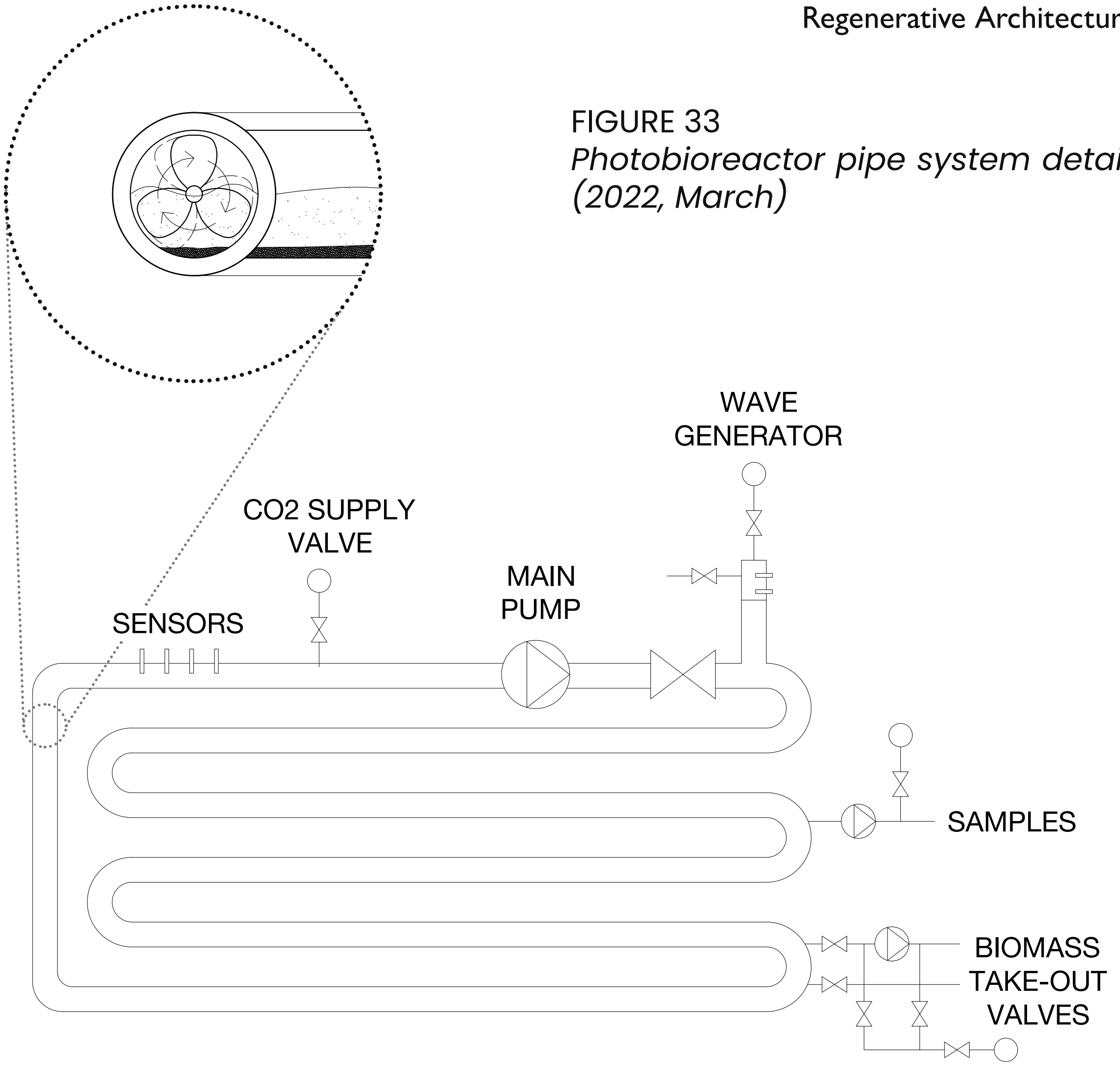


FIGURE 33
Photobioreactor pipe system detail, (2022, March)

EMERGING TECHNOLOGIES
With the advancements in technology moving quickly, different business sectors are applying new technologies in ways never seen before. Currently, testing is underway using artificial intelligence (AI) to identify RICs by density, colour, and flexibility which could greatly improve plastic sorting, achieve higher efficiency, and the purity of plastics when recycled.[27] Another invention is the use of digital watermarks printed on

[27] Pahl, C. (2020, October 29). *How Machine Learning and Robotics are Solving the Plastic Sorting Crisis*. Sustainability.

Note: McMurtry, M. M. (2022, March). *Photobioreactor Detail.*

HANDLING OF PLASTICS

the side of plastic products. When scanned with a smartphone camera, the watermark shares proper disposal instructions of the product. It works similarly to a QR code and is invisible to the human eye.[28] Additionally, 3D printing is making it's way into the recycling industry with printing material made of recycled plastic and wood.[29, 30] These are just a few of the many inventions, if properly executed, can transform the plastic industry.

In more recent years, the term Bioplastic has made an impression. Bioplastics are 100% biodegradable plastic materials produced from renewable biomass sources.[31] They are produced with the natural biopolymers (starch, cellulose, etc.), proteins (gluten, gelatin, etc.), sugars (lactic acids) and lipids (oils and fats) found in certain crops such as corn, wheat, sugar cane or potatoes.[32] Bioplastics are a renewable source. As they require large amounts of land and water for production, they are in direct competition with the agriculture and lumber industries, negatively impacting the environment and competes with land.[33]

POTENTIAL USES OF ALGAE

Another plastic alternative is certain bacteria species that can turn plastic into a biodegradable polyester (PHA).[34] Genetically modified algae have the potential to replace fossil fuels to produce virgin bioplastics. Algae contain a polymer known as Polyhydroxybutyrate (PHB) that

[28] *Pioneering Digital Watermarks for Smart Packaging Recycling In the Eu. (n.d.). Digital Watermarks Initiative HolyGrail 2.0.*

[29] Zhu, C., Li, T., Mohideen, M. M., Hu, P., Gupta, R., Ramakrishna, S., & Liu, Y. (2021). Realization of circular economy of 3D Printed Plastics: A Review. *Polymers*, 13(5), 1–16.

[30] Pringle, A. M., Rudnicki, M., & Pearce, J. M. (2017). Wood furniture waste–based recycled 3-D printing filament. *Forest Products Journal*, 68(1), 86–95.

[31] Ashter, S. A. (2016). New Developments. *Introduction to Bioplastics Engineering*, 251–274.

[32] Ibrahim, N. I., Shahar, F. S., Sultan, M. T., Shah, A. U., Safri, S. N., & Mat Yazik, M. H. (2021). Overview of Bioplastic Introduction and Its Applications in Product Packaging. *Coatings*, 11(11), 1–23.

[33] Khan, N., Sudhakar, K., & Mamat, R. (2021). Role of Biofuels in Energy Transition, Green Economy and Carbon Neutrality. *Sustainability*, 13(22), 1–30.

[34] Surendran, A., Lakshmanan, M., Chee, J. Y., Sulaiman, A. M., Thuoc, D. V., & Sudesh, K. (2020). Can Polyhydroxyalkanoates Be Produced Efficiently From Waste Plant and Animal Oils? *Frontiers in Bioengineering and Biotechnology*, 8, 1–15.

HANDLING OF PLASTICS

can substitute polypropylene (PP). In an article about new metabolic engineering strategies for the German Interfaculty of Institute of Microbiology and Infection Medicine, researchers used techniques to modify a microalgae (microscopic algae) strain to increase the amount of PHB found in its structure from 10% to 80%.[35] This single step creates a bioplastic product that is fully decomposable (converts to CO^2) within a year.[36] Decomposition is similar to that of natural algae as the carbon sinks to the seabed.[37] Although modified algae is a new process for producing and recycling plastics, it has an infrastructure that is well established. Currently, algae farms yield large quantities of algae for foods, medicines, and nutritional supplements like Spirulina at an industrial scale.[38]

The considerable benefits of algae go beyond a natural and renewable source for plastic alternatives, it also accelerates plastic decomposition (due to its high nitrogen concentration), serves as a protein alternative in diet and can absorb CO^2 emissions.[39, 40, 41, 42] Additionally, if algae were to replace the beef industry, it could significantly reduce CO^2 emissions from entering the atmosphere.

[35] Koch, M., Bruckmoser, J., Scholl, J., Hauf, W., Rieger, B., & Forchhammer, K. (2020). Maximizing PHB content in Synechocystis SP.. PCC 6803: A new metabolic engineering strategy based on the Regulator Pirc. *Microbial Cell Factories*, 19(1).

[36] Lott, C., Eich, A., Makarow, D., Unger, B., van Eekert, M., Schuman, E., Reinach, M. S., Lasut, M. T., & Weber, M. (2021). Half-life of biodegradable plastics in the marine environment depends on material, habitat, and climate zone. *Frontiers in Marine Science*, 8, pp. 8.

[37] Ibid, [36a].

[38] Araújo, R., Vázquez Calderón, F., Sánchez López, J., Azevedo, I. C., Bruhn, A., Fluch, S., Garcia Tasende, M., Ghaderiardakani, F., Ilmjärv, T., Laurans, M., Mac Monagail, M., Mangini, S., Peteiro, C., Rebours, C., Stefansson, T., & Ullmann, J. (2021). Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. *Frontiers in Marine Science*, 7, 1–24.

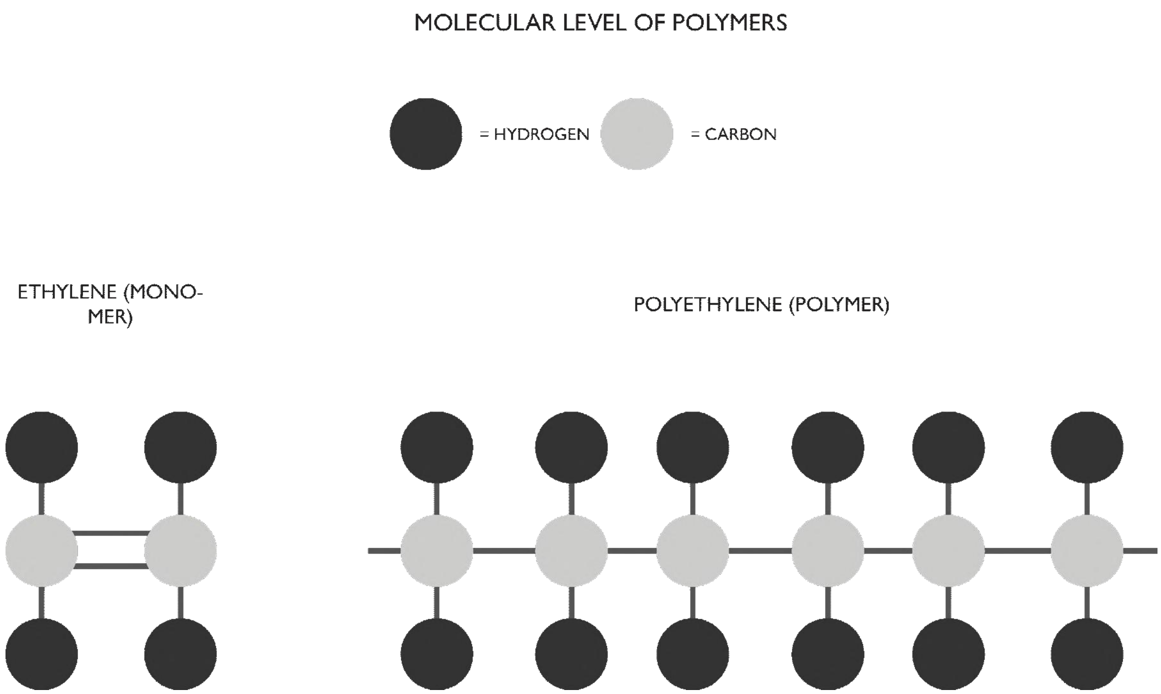
[39] Chia, W. Y., Ying Tang, D. Y., Khoo, K. S., Kay Lup, A. N., & Chew, K. W. (2020). Nature's fight against plastic pollution: Algae for plastic biodegradation and bioplastics production. *Environmental Science and Ecotechnology*, 4, 100065.

[40] Kalita, N. K., Damare, N. A., Hazarika, D., Bhagabati, P., Kalamdhad, A., & Katiyar, V. (2021). Biodegradation and characterization study of compostable PLA bioplastic containing algae biomass as potential degradation accelerator. *Environmental Challenges*, 3(6), 1–10.

[41] Tentu, R. D. (2021, June 23). *Algae to become alternative protein frontrunner*. Opinion.

[42] Lamm, B. (2019, October 1). *Algae might be a secret weapon to combatting climate change*. Seaweed Sequestration.

FIGURE 34
Molecular level of polymers, (n.d.)



According to SuSeWi, a UK-based algae farm startup, 100g of protein derived from algae removes 320g of CO^2.[43] SuSeWi dries and converts the algae into powdered protein. Ultimately, this could potentially compete with beef and poultry sales. Furthermore, algae farms require little land and can successfully operate in water. However, if grown in water, they must be monitored to prevent uncontrolled spread that could threaten other marine habitats and species. According to a study published by the Online Journal Science Direct (2019), approximately 48,000,000 km^2 of ocean suitable for algae aquaculture is available.

[43] Blakely, R. (2021, October 20). *Why algae is the food of the future*. The Sunday Times: Times Earth.

Note: McMurtry, M. M. (2022, February). *Molecular Level Of Polymers.*

HANDLING OF PLASTICS

The authors claim if algae aquaculture were to increase the total suitable area from its current 2,000 km² to 7,000,000 km² (or 15%), it would be enough to offset all greenhouse gas (GHG) emissions from current global agriculture.[44] With an unrealistic growth rate such as this, it is quite unlikely to occur with proper control. Regardless, the authors point to regions such as Asia and the United States having the potential to harvest seaweed farms at an industrial scale of expansion. This could have a significant impact on accomplishing the Intergovernmental Panel on Climate Change (IPCC) objective of maintaining global climatic warming to under 2 °C above pre-modern levels.[45]

THE FUTURE OF PLASTICS

Plastics may seem natural, given that oil is an organic substance but it was human ingenuity behind the creation of plastic. It was human inventiveness that discovered that when propylene, a component of petroleum, is heated sufficiently with a catalyst, molecules form an incredibly strong carbon-to-carbon chain link known as a polymer.[46] This is not a naturally occurring reaction. Nature, on the other hand, makes peptides, which are polymer-like molecules. Peptides are produced from nitrogen-to-carbon bonds and require significantly less energy to produce.[47] They occur naturally in proteins and other organic molecules. Peptides have evolved over millions of years in tandem with species that have perfected the art of decomposition. Organisms have never had to degrade carbon-to-carbon linked polymers, nor do they have the metabolic capability to do so. In short, this is the root of the global plastic pollution catastrophe, which has resulted in the production of more than eight billion metric tonnes of plastic since the mid-twentieth century.[48]

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[44] Froehlich, H. E., Afflerbach, J. C., Frazier, M., & Halpern, B. S. (2019). Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting. *Current Biology*, 29(18), 3087–3093.

[45] IPCC. (2022, February 27). Climate Change 2022: *Impacts, Adaptation and Vulnerability*. Intergovernmental Panel On Climate Change.

[46] Reusch, W. (2013, May 5). *Polymers*. MSU chemistry.

[47] Reusch, W. (2013, May 5). *Peptides & Proteins*. MSU chemistry.

[48] University of Georgia. (2017, July 19). *More than 8.3 billion tons of plastics made*: *Most has now been discarded*. Science News.

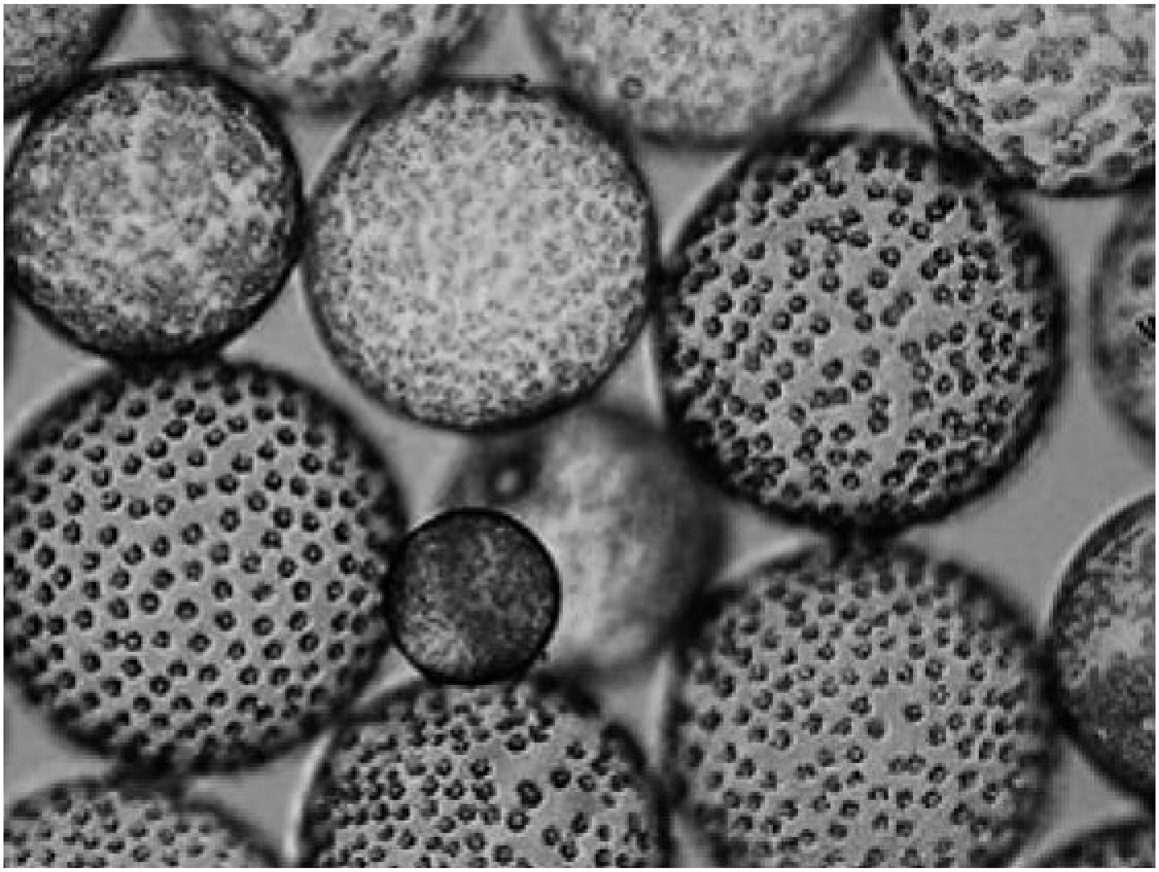
“The plastic pollution problem does not start at the middle of the ocean; [it] does not start on our shores or in our rivers: It starts on land. Solutions should be found on land, its source.”

- MERIJN TINGA
Dutch environmental activist and Plastic Soup Surfer

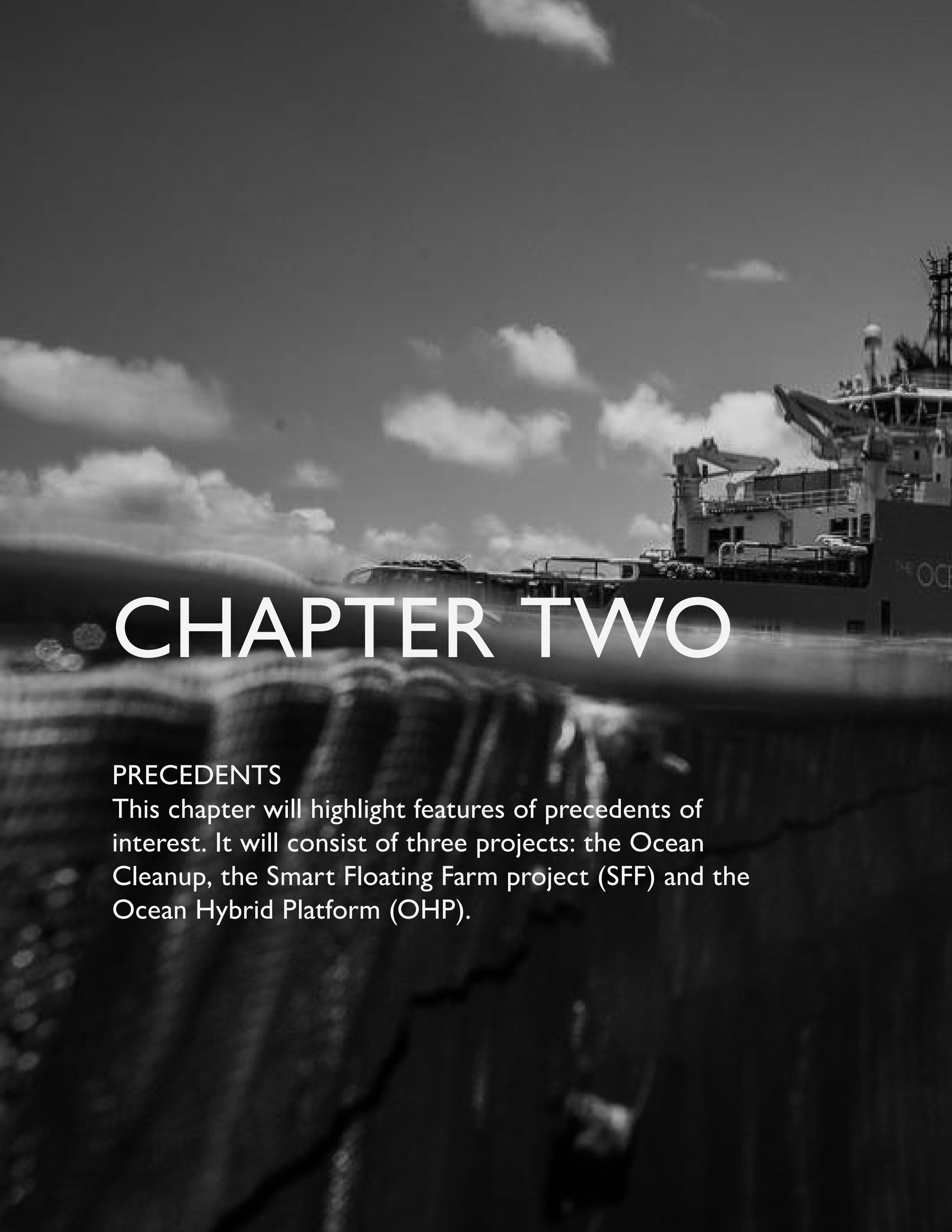
It makes sense to employ naturally occurring nitrogen-to-carbon bound peptides for polymers because they will decompose back to nature after use. However, they have a tendency to degrade almost immediately, which is not ideal. The challenge is to find materials that can compete with current plastics while also being environmentally friendly. The objective is to create recycled plastics of similar quality to that of virgin material. This can be difficult as plastics have different requirements; such as automotive parts, that require durability while plastics, say for foams, require longevity and resistance to deformation.

Emerging technologies can make a tremendous contribution toward a circular economy that our governments are beginning to work towards. It is clear the plastic problem is not going away, nor is our need for plastics. Plastics produced using genetically modified algae have the potential to prevent further environmental and damage to human health caused by virgin plastics.

FIGURE 35
Algae biofuel, (2020, January)



Note: Misra, A. (2020, January). *Changing climate by changing genes.* Medium.com. Retrieved from https://medium.com/@aryanmisra/changing-climate-changing-genes-3ae63a8a44a2



CHAPTER TWO

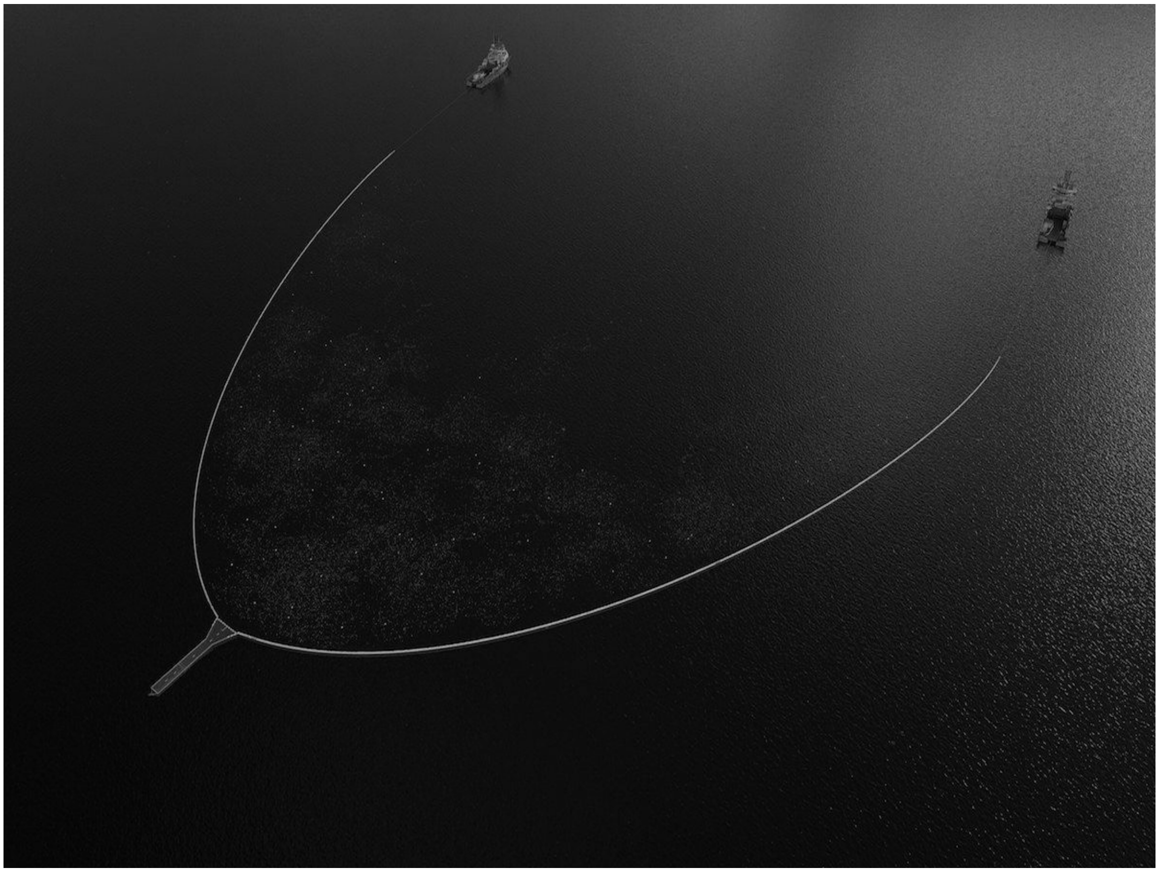
PRECEDENTS

This chapter will highlight features of precedents of interest. It will consist of three projects: the Ocean Cleanup, the Smart Floating Farm project (SFF) and the Ocean Hybrid Platform (OHP).

FIGURE 36
The Ocean Cleanup, (2021, January)

Note: OE. (2021, January). *Plastic Free Oceans: Maersk Supply Service, The Ocean Cleanup Extend Partnership*. Oedigital.com. Retrieved from https://www.oedigital.com/news/484503-plastic-free-oceans-maersk-supply-service-the-ocean-cleanup-extend-partnership

FIGURE 37
The Ocean Cleanup at sea, (2020, January)



Note: The Ocean Cleanup. (2022, March). ***TheOceanCleanup***. Twitter. Retrieved from https://twitter.com/TheOceanCleanup/status/1501601812117438464

The Ocean Cleanup

The Ocean Cleanup is a non-profit organization that conducts trips to clean the Great Pacific Garbage Patch (GPGP) and rivers around the world. After conducting hundreds of scale model experiments, the team developed “System 002” or “Jenny,” a system that collects plastic garbage using a long floating screen that connects two barges. It operates in harmony with nature, taking advantage of natural ocean currents. Another effort of the Ocean Cleanup is the “1,000 Rivers” project, which aims to clean up contaminated rivers that lead to the ocean. The “Interceptor” is the name of the system they developed for this project.

OVERVIEW

Two system concepts used by The Ocean Cleanup collect plastic garbage in the ocean and most polluted rivers. The garbage is targeted, captured, extracted and recycled by System 002. The waste patch’s circulating currents move the plastic about, creating natural hotspots of higher concentration that fluctuate over time.

THE OCEAN CLEANUP

The Ocean Cleanup's research uses computational modelling to anticipate where these hotspots are and where the cleanup system should be placed. The plastic can be captured in the cleanup system's retention zone by maintaining a relative speed differential with the screen. The vessels constantly correct and maintain the wingspan, speed and direction of the screening system. The back of the retention zone is carried aboard, closed off, separated from the system and unloaded on board the vessel once the system is full. The retention zone is then replaced and the cleanup process begins. The containers are carried ashore to be recycled once they are filled on board the vessels. The floating systems are intended to catch plastics ranging in size from millimeters to tens of meters, including enormous, abandoned fishing nets (ghost nets). The system's success is determined by four factors: speed, span, plastic density and efficiency.

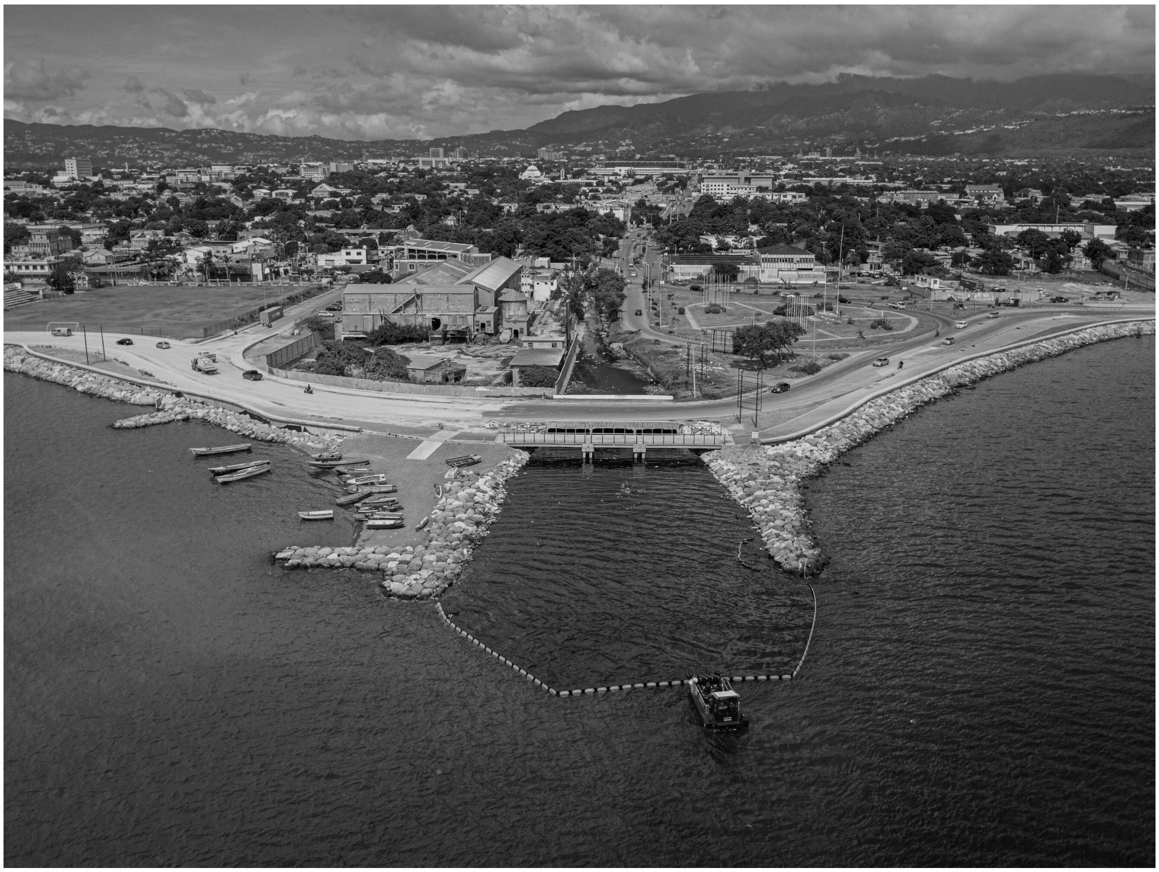
The Interceptor, the second system, is built for rivers. According to The Ocean Cleanup, 1,000 rivers account for 80% of ocean plastic. Rivers are the arteries that transport debris from land to the sea. The Interceptor is the first modular device to keep plastic out of rivers and avoid the world's oceans. Barriers, a conveyor belt, a shuttle and dumpsters are among the components of the system. The plastic waste travels with the current and is directed towards the Inceptor's entry by the floating barricades. Due to the Interceptor's catamaran form, the channel of water is adjusted to pass through the system, transferring the plastic onto the conveyor belt. The belt then removes the waste from the river and transports it to large containers on the shuttle. The garbage is mechanically distributed over six containers by the shuttle. The containers are filled evenly using sensor data until they reach their maximum capacity. Up to 50m³ of waste can be stored in the Interceptor before it needs to be serviced. When the Interceptor is nearly full, it sends a text message to the local operators, instructing them to come collect the waste. The barge is then disconnected from the Interceptor to the riverbank where the dumpsters are emptied and delivered to a local MRF. The barge is then returned in place.

FIGURE 38
The Ocean Cleanup Interceptor in operation, (n.d.)

Note: The Ocean Cleanup. (n.d.). *Media Gallery: High Quality Photos & Videos*. Theoceancleanup.com. Retrieved from https://theoceancleanup.com/media-gallery/

FIGURE 39

The Ocean Cleanup Interceptor Barriers and Interceptor Tender in Kingston, Jamaica, (2022, January)



Note: The Ocean Cleanup. (2022, January). *TheOceanCleanup*. Twitter. Retrieved from https://twitter.com/TheOceanCleanup/status/1480570822427353094

THE OCEAN CLEANUP

The Interceptor is powered entirely by solar energy, removes plastic on its own, and can operate in the majority of the world's most polluted rivers. The system is internet-connected, allowing it to collect data on its performance. When the dumpsters are full, it immediately alerts local operators. The Interceptor is placed in rivers on a case-by-case basis, taking into account flow velocity, river breadth, debris, river traffic, and other factors. Interceptor systems have been installed by The Ocean Cleanup in Indonesia, Malaysia, Vietnam, the Dominican Republic and Jamaica. The Interceptors in Jamaica use a system of barriers and tenders to keep plastic out of gullies that feed into the sea.

KEY FEATURES

The Ocean Cleanup carried out the world's largest ocean research expedition involving 30 vessels crossing the GPGP simultaneously, resulting in the first high-resolution mass map of plastic pollution. Other airborne expeditions included scanning the ocean's surface for items up to 10 m in length. The most difficult problem they faced was securing the system to the seabed. The Ocean Cleanup takes advantage of natural currents by cooperating with nature. Their first ocean model mimics plastic to trap plastic. The depth of the water and the velocity of the current have a relationship. On the surface, the stream is swift, but it slows down as it descends. The Ocean Cleanup system is attached to the lower depth beneath the surface rather than the seabed. The plastic can be captured if the mechanism moves more slowly. The system consists of a network of floating fenders with a screen and a dragging anchor. The Ocean Cleanup is expected to clear 42% of the GPGP in approximately ten years using a single 100 km screen. To allow sea life to swim freely, the screen is 3 m deep and entirely open on the base. The screen is attached to a vessel traveling at 1.5 knots (2 mph) on both ends. The plastic is transferred from the screen's wings to a central U-shape location (the retention

zone). The two vessels moor once a week and use a crane to unload the collected rubbish onto the other vessel. It is then manually divided into different RIC bins and bundled for delivery to a land based MRF for recycling.
With sophisticated steering and computer modelling, the system is completely scalable and carbon-neutral, allowing it to target plastic clusters. The Interceptor was made for large-scale production and can be deployed almost everywhere. All the electronics on The Interceptor are solar-powered, including the conveyor belt, shuttle, lighting, sensors, and data transmission.

TAKE-AWAY

The Ocean Cleanup concept is a stunning real-world system that is addressing the GPGP - the world's largest trash pile. There is an estimated 1.8 million tonnes of plastic in the GPGP. Ten percent of the 100 million tonnes of plastic produced each year ends up in rivers and 2% ends up in the ocean. The Ocean Cleanup has widened its scope and shifted its focus to rivers, which serve as entry points to the ocean and are the source of much of the plastic pollution. Tides, traffic, algae, depth, ecosystems, and other factors all contribute to the diversity of rivers. The "Global River Model" was developed by The Ocean Cleanup. According to the model's findings, land use, slope, distance from rivers, high rainfall rates, wind rates, and river volume are all factors that contribute to the largest sources of pollution. The goal of The Ocean Cleanup is to lessen the detrimental impact of plastics on marine life and to protect the ocean. The Interceptor system can work diligently, seven days a week to help achieve this goal.

FIGURE 40
The Ocean Cleanup Interceptor in operation, (n.d.)

Note: The Ocean Cleanup. (n.d.). *Media Gallery: High Quality Photos & Videos*. Theoceancleanup.com. Retrieved from https://theoceancleanup.com/media-gallery/

FIGURE 41
The Ocean Cleanup Interceptor in operation, (n.d.)

Note: The Ocean Cleanup. (n.d.). ***Media Gallery: High Quality Photos & Videos***.
Theoceancleanup.com. Retrieved from https://theoceancleanup.com/media-gallery/

“The greatest threat to our planet is the belief that someone else will save it.”

- ROBERT SWAN

Explorer, first person to walk to both the North and South poles

It makes sense to employ naturally occurring nitrogen-to-carbon bound peptides for polymers because they will decompose back to nature after use. However, they have a tendency to degrade almost immediately, which is not ideal. The challenge is to find materials that can compete with current plastics while also being environmentally friendly. The objective is to create recycled plastics of similar quality to that of virgin material. This can be difficult as plastics have different requirements; such as automotive parts, that require durability while plastics, say for foams, require longevity and resistance to deformation.

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The Smart Floating Farm

Population growth is on track to increase 21% by 2050. Scarcity of food and water is expected to worsen as the world's population grows. According to the design studio, Forward Thinking Architecture (Barcelona) the densest areas and cities are located close to large bodies of water.
In the United States, the average food product travels over 1,500 miles before reaching the table, many countries rely heavily on food imports and international markets, and potentially, land utilization can be reduced by growing produce in a floating vertical, indoor, controlled environment. These facts are what makes The Smart Floating Farm project (SFF) so compelling.

OVERVIEW

In 2015, the SFF project unveiled its plans for an aquaculture fish farm, hydroponic crops, and an aeroponic food production system. The objectives of this project are twofold; use sustainable energy to produce fresh food closer to home and potentially eliminate food related illness. The SFF project aspires to create a transparent food supply system that can be scaled to various areas throughout the world. Hydroponics is

FIGURE 42
Exterior view of The Smart Floating Farm project, (n.d.)

Note: Smart Floating Farm. (n.d.). ***Information***. Smartfloatingfarms.com. Retrieved from https://smartfloatingfarms.com/%20

FIGURE 43
Interior view of the vertical farm in The Smart Floating Farm project, (2015, October)

Note: Calderone, J. (2015, October). *This futuristic floating farm may take a bite out of global hunger - or totally sink*. Businessinsider.com. Retrieved from https://smartfloatingfarms.com/%20

THE SMART FLOATING FARM

a method of growing plants without soil and feeding them nutrients like nitrogen, phosphate and potassium by immersing them in a liquid solution. Crops can be cultivated on trays and stacked vertically. The crops are monitored to ensure that optimal carbon dioxide levels are maintained in a controlled environment which guarantees that photosynthesis takes place. These regulated crops do not require hazardous pesticides because pests are not present in an environment without soil. When compared to traditional soil farming, hydroponic systems use 90% less water and require significantly less land to produce the same output. Hydroponic systems require specific blue and red LED lights that can be powered by renewable energy sources. Aeroponics is the practice of growing plants in an air or a mist environment using the same nutrients as in soil. The project was influenced by the network of corridors found in traditional Asian fish farm layouts and features a rectangular footprint that allows for maximum manufacturing space.

KEY FEATURES

By collecting food on-site and close to communities, the SFF lowers agricultural import transit and associated CO^2 emissions. It also frees up land for other purposes, while significantly reducing water consumption used in conventional crop irrigation systems. Through the use of photovoltaics (PV), the SFF generates 100% of sustainable energy required to function effectively and continuously. The stacked floating farm system combines solar energy and hydroponics for growing food and aquaculture. The farm uses a software system to automate operations and record data.

The rectangle grid is made up of a single 200 m x 350 m modular structure, resulting in a 70,000 m^2 footprint with a total size of approximately 210 m^2. The three story platform is sheltered with a roof that consists of skylights, apertures, and a PV system. The floor directly below is an area of 51,000 m^2 of hydroponic agriculture. The waste byproduct from the agricultural system can be utilized for feeding the fish nutrition while the waste from the fish can be recycled as fertilizer for the hydroponic farm. The bottom floor, which is submerged in the water, houses

THE SMART FLOATING FARM

the enclosed fish farm and service corridors with exterior perimeter wave barriers. The designers at Forward Thinking Architecture suggest the SFF project can generate up to 8.1 tonnes of vegetables and 1.7 tonnes of fish every year. The versatility of The SFF's also allows for future growth.

TAKE AWAY

Even though the SFF project is a conceptual design, its goals and features are relevant to meeting the growing demand for renewable agriculture. The multi-level platform is simple to assemble and can scale based on different projects and geography. It offers options to help decrease food hazards in communities and expanding cities, as well as make food production more transparent by using sustainable energy to cultivate fresh food closer to home. Many countries and nations rely heavily on imports and worldwide markets for their food, putting them at risk of food shortages. The SFF's success is due to its ability to link consumers directly with the localized food sector. Due to the better yield of hydroponic systems and the multi-level method, the SFF requires less space to grow crops. Another advantage of the SFF is that it uses less water than traditional farming. Because it is a complete and seamless platform, it also negates the need to construct new infrastructure such as pipes. Droughts, floods, pests and other natural occurrences do not affect this environment, therefore, the crops can be cultivated all year. As no machinery or transportation is required, agricultural runoff is appreciably minimized, as is fossil fuel usage. Further, as there is no need for storage or preservation, and CO^2 emissions and logistic expenses are minimized overall.

FIGURE 44
Interior view of the fish farm in The Smart Floating Farm project, (2015, October)

Note: Calderone, J. (2015, October). *This futuristic floating farm may take a bite out of global hunger - or totally sink*. Businessinsider.com. Retrieved from https://smartfloatingfarms.com/%20

"The most environmentally friendly product is the one you didn't buy."

- JOSHUA BECKER
Author of "The Minimalist Home"

It makes sense to employ naturally occurring nitrogen-to-carbon bound peptides for polymers because they will decompose back to nature after use. However, they have a tendency to degrade almost immediately, which is not ideal. The challenge is to find materials that can compete with current plastics while also being environmentally friendly. The objective is to create recycled plastics of similar quality to that of virgin material. This can be difficult as plastics have different requirements; such as automotive parts, that require durability while plastics, say for foams, require longevity and resistance to deformation.

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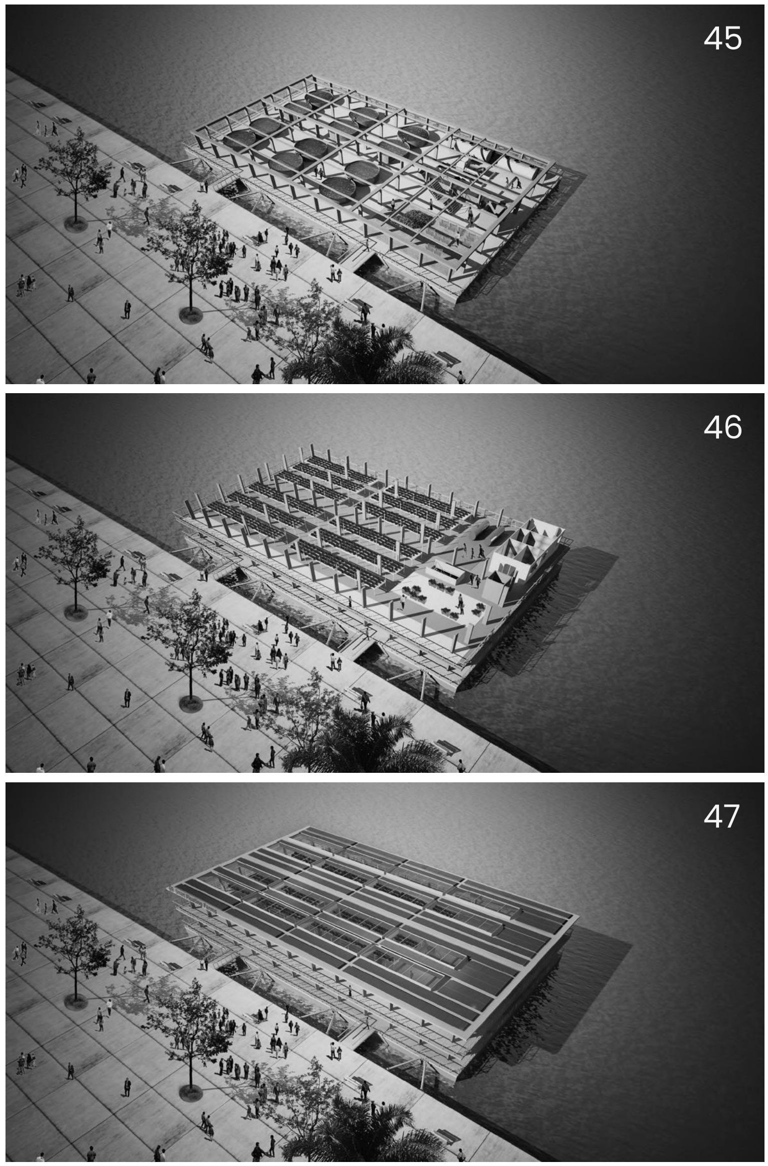
FIGURE 45-47

Solar plant level (clean energy), hydroponic level (crops production), aquaculture level (fish and other species production), (n.d.)



Note: Smart Floating Farm. (n.d.). ***Information***. Smartfloatingfarms.com. Retrieved from https://smartfloatingfarms.com/%20

FIGURE 48
An example of a clean fish farm using the Ocean Hybrid Platform system, (n.d.)

Note: SINN Power Gmbh. (n.d.). ***SOcean Hybrid Platform***. Sinnpower.com. Retrieved from https://www.sinnpower.com/platform

Ocean Hybrid Platform

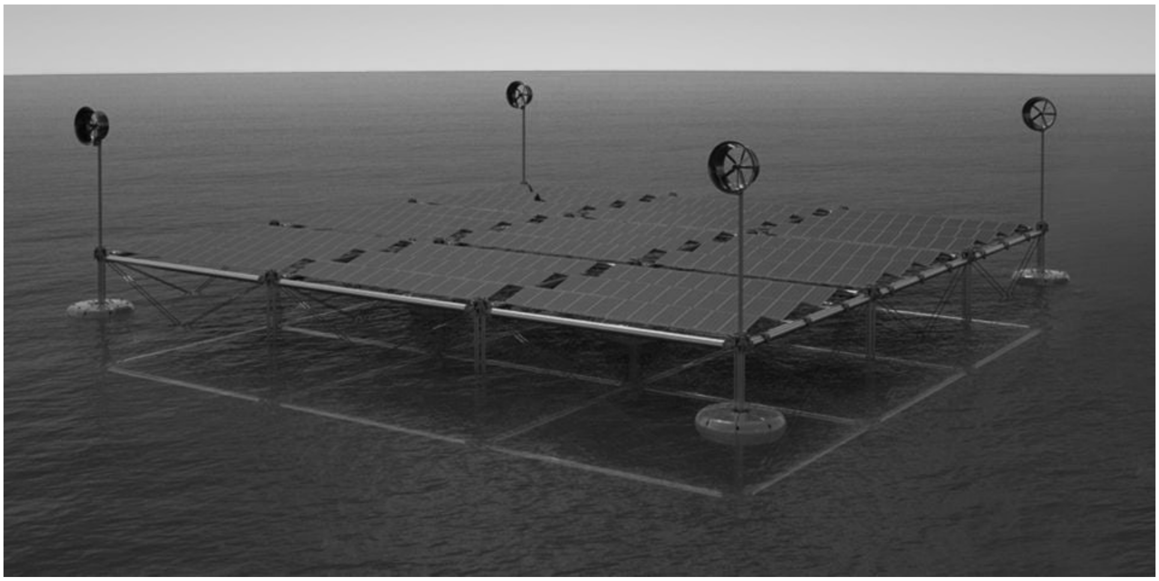
SINN Power, a German marine energy start-up, has developed a design they call the offshore hybrid platform. Dr. Philip Sinn, the inventor, and the company's founders created a modular grid system and platform layout that can readily target various environmental goals. The Ocean Hybrid Platform is a comprehensive off-grid energy solution that uses waves, wind and the sun to generate sustainable energy. The device is capable of withstanding waves of up to 6 m in height. Its versatility provides for a wide range of applications and flexibility. It has the potential to support offshore wind farms and provide energy to grids while being fully customizable. SINN Power has prepared and implemented renewable power production systems for difficult maritime settings, despite originally being designed for calm waters such as those found in lakes or reservoirs. Four wind turbines (each rated at 10 kWp), four wave-energy exchangers, and four wind generators with PV modules are included in each modular system (each rated at 390 Wp). A significant degree of customization is

OCEAN HYBRID PLATFORM

available in its maritime construction (size, buoyancy, layout of a variety of renewable energy sources, etc.). It can be used to supplement large offshore wind parks across the world or to supplement diesel power supplies on remote islands. The smallest unit measures 12m × 12m and has a 30kWp rated power. The largest unit is 120m × 120m and has a 5 MWp total power. Owing to its longevity and simplicity, the construction is flexible enough to adapt to various sizes and layout configurations and may also be enlarged later.
The ocean represents a massive untapped reserve of energy. Water covers around 70% of the globe and, because of its density, which is 830 times that of air, it can deliver significantly more energy per volume than wind. The up-and-down oscillations of the wave can be harnessed to access the ocean's limitless power.
When compared to solar and wind energy, ocean waves have the greatest energy density and provide the most consistent supply of energy. As a result, energy from ocean waves is far more dependable and may be used to meet base-load energy requirements. Additionally, ocean water can be used to generate power using oscillating water columns. SINN Power developed a wave energy converter (WEC) that is made up of various modules that are merged and joined into a stiff framework that allows it to drift on the ocean's surface like an anchored ship. These 12 m long oscillating lifting rods built of marine-grade aluminum link to IP68 bi-directional powertrain generators at the end of the rod. Each powertrain has a combined power rating of 5 kWp. The principle is based on wave motions, with each module's associated floating bodies turning a lifting rod. All of the associated generators produce power as a by-product of friction. Traverses are used to connect PV modules or flooring. The primary assemblage consists of structure fences made up of horizontal structural pressure pipes, vertical struts, pull rods and floating bodies.

FIGURE 49

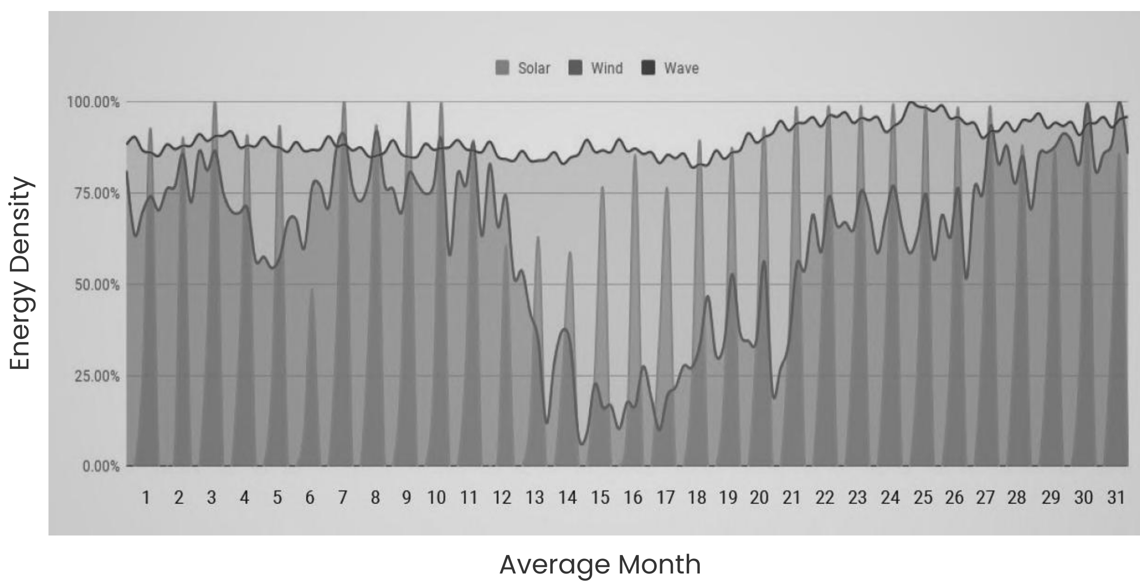
Unused ocean surface space for renewable energy production: Floating solar panels in combination with wave and wind energy, (2021, January)



Note: SINN Power Gmbh. (2021, January). *Wave, wind and PV: The world's first floating Ocean Hybrid Platform*. Sinnpower.com. Retrieved from https://www.sinnpower.com/post/the-world-s-first-floating-ocean-hybrid-platform

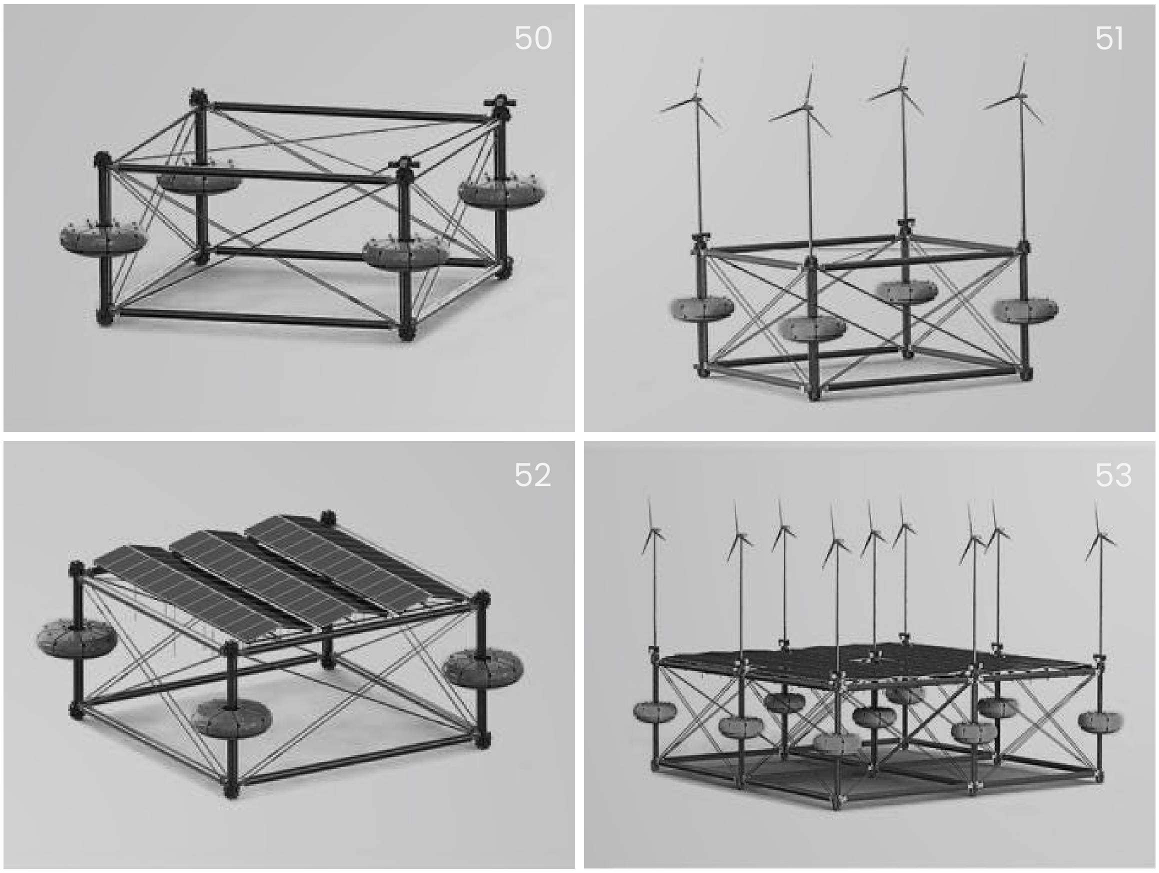
TABLE 2

Comparison to Solar PV and Wind, (n.d.)



Note: SINN Power Gmbh. (n.d.). *Wave Energy: Background, Potential & Solution*. Sinnpower.com. Retrieved from https://www.sinnpower.com/waveenergy

FIGURE 50-53
wave energy converter, small wind turbines, photovoltaics, complete grid system, (n.d.)



Note: SINN Power Gmbh. (n.d.). *SOcean Hybrid Platform*. Sinnpower.com. Retrieved from https://www.sinnpower.com/platform

OCEAN HYBRID PLATFORM

OVERVIEW

The platform is supported by a system of buoyant aluminum pipes loaded with oxygen that lie horizontally on the surface of the ocean. Each pipe is 6 m or 12 m long and weighs up to 470 kg. The subframe is supported by vertical supports that extend 6 m above the frame. These supports ensure the structure's lateral stability so it can survive coastal buffeting and saltwater off-splash corrosion. Attached to the base of the supports are three and a quarter meter diameter "floats" with a lifting capacity of 6 tonnes. A computer-controlled electronic bi-directional power generator (rated at 5 kW) is attached to the lifting rods.

Wind energy is the system's second processing component. A 12 m tall mast constructed of the same marine-grade aluminum can be connected to the top of the structure to accommodate a stormproof, continuous-duty wind turbine at any point when wave power is not being used. Finally, PVs are joined to the platform's surface. The platform has a total capacity of 10 MW. The full assemblage can be installed at any time, even after the framework is in place. Furthermore, all components can fit into a 40' shipping container, providing ease of transportation by both road and sea to their end destination. The system is currently undergoing intensive testing in Heraklion, Greece, and is fitted with 192 PV panels.

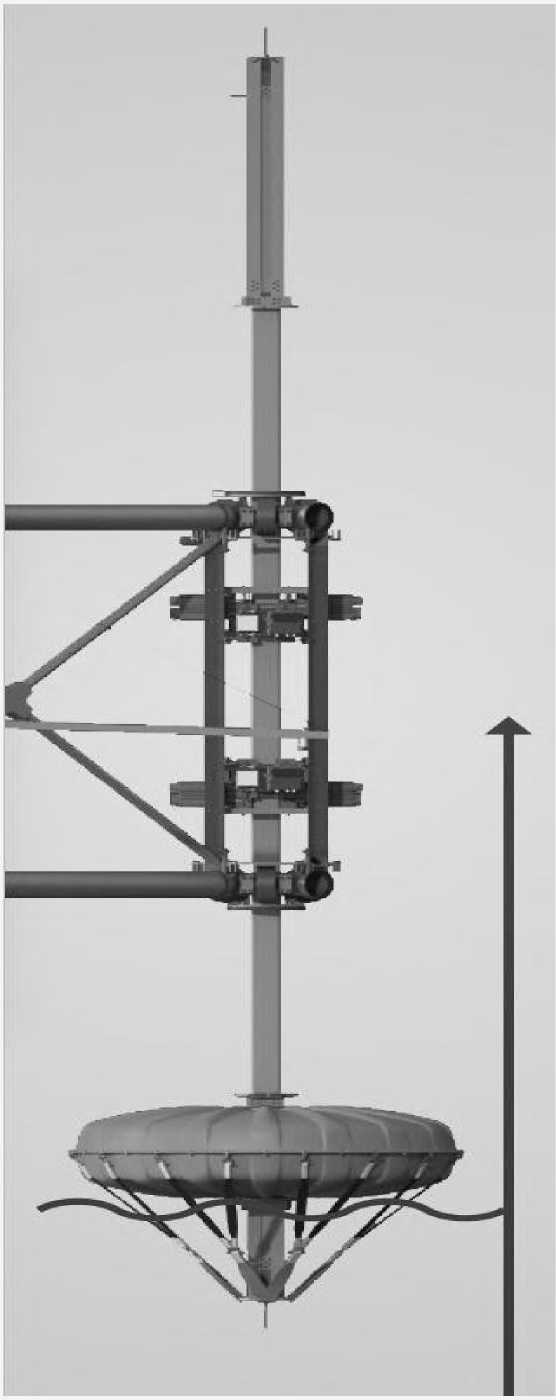
KEY FEATURES

The multifunctional platform can endure waves up to 12 m high and winds up to 27 m/sec without being damaged. It is appropriate for both on- and off-shore applications. It can operate independently as a system that stores wind-wave-solar energy and/or in conjunction with infrastructure that permits human activity. The smallest unit is 12 m × 12 m and has a 30 kWp total power, while the largest OHP is 120 m x 120 m and has a 5 MWp total power.

SINN Power's strategy is based on a modular, simple and dependable structure that can be tailored to the customer's energy needs. Hundreds of modules can be scaled up or down to build a large commercial power plant or a few dozen for an island settlement. Standard components

OCEAN HYBRID PLATFORM

FIGURE 54
Side elevation of The Ocean Hybrid Platform's oscillating column, (n.d.)



are mass-produced and are convenient for shipping and construction. All of the components are designed to be delivered in an ISO container, making them accessible to even the most remote locations with limited connectivity.

TAKE-AWAY
The OHP from SINN Power was created to be used in a maritime setting. SINN Power has now released two more versions of the platform, both of which are intended to be positioned in waters with very few waves. Although SINN Power's OHP is an electronic powerhouse solution to off-grid power, during development and testing it became clear the harsh maritime environment brings challenges to power electronics. Due to this, their design was revised for waters with little to no swell.

Note: SINN Power Gmbh. (n.d.). *Wave Energy: Background, Potential & Solution*. Sinnpower.com. Retrieved from https://www.sinnpower.com/waveenergy

“Plastic will be the main ingredient of all our grandchildren’s recipes.”

- ANTHONY T. HINCKS
Author of “An Author of Life”

The OHP’s integration of renewable energy sources provides unrivalled energy density, as well as the ability to optimize each project independently, taking into account the local environment and resources. SINN Power has been able to address and overcome several logistical, installation, and operational difficulties by using a modular design approach, all of which have a substantial economic impact.

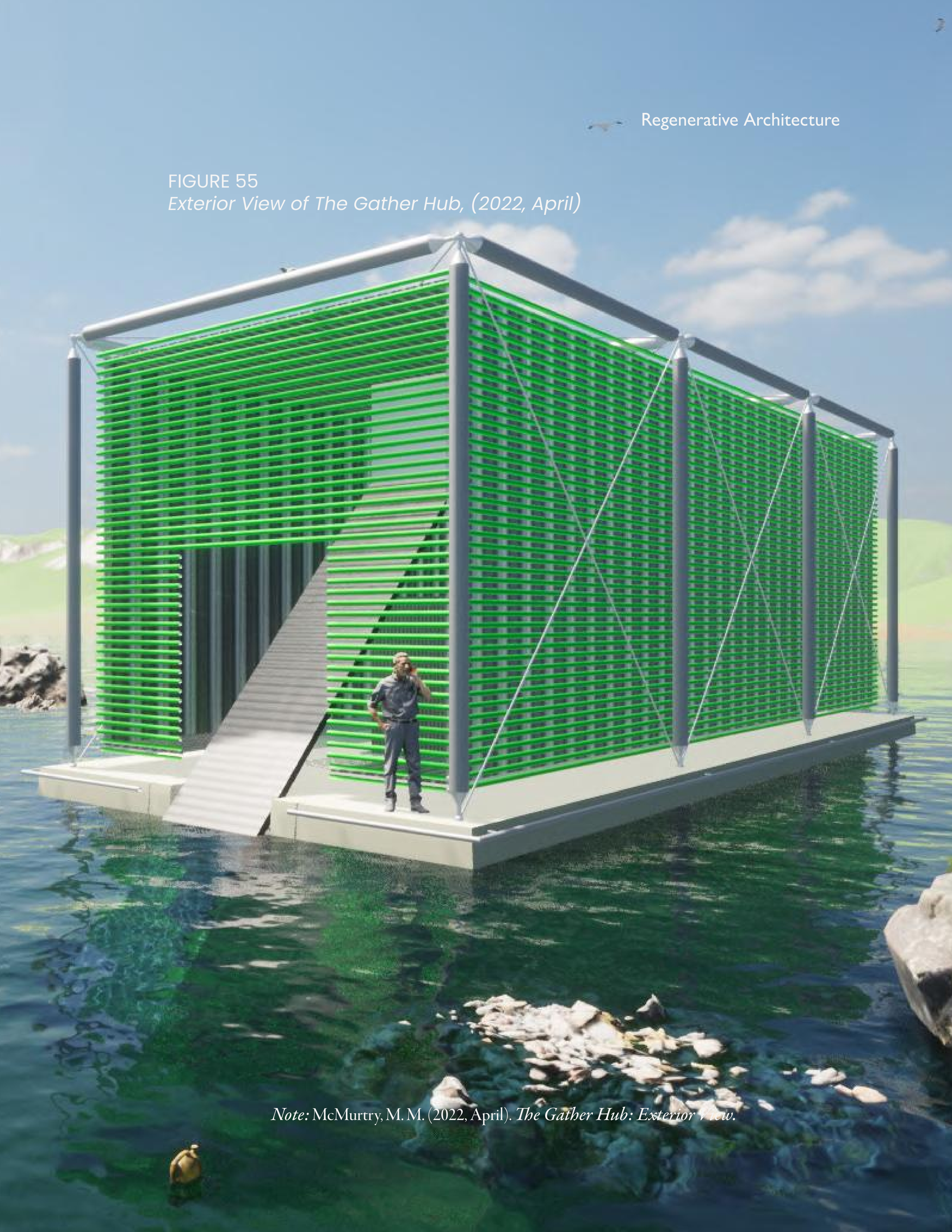
CHAPTER THREE

DESIGN PROPOSAL

The following section entails the design proposal for a floating algae recycling farm called the “Regenerative Hub.” Inspiration, including performance, design and overall concept, was taken from the precedents in Chapter Two. The goal of the Hub is to create a closed-loop, renewable recycling system that does not further harm marine life or the planet.

N.T.S.

FIGURE 55
Exterior View of The Gather Hub, (2022, April)



Note: McMurtry, M. M. (2022, April). *The Gather Hub: Exterior View.*

Site

The Hubs are a free-moving floating structure that can be scaled on a case-by-case basis. There are two applications, the Gather Hub (intended for River cleanup) and the Main Hub (intended for near-shore processing).

The Gather Hub can be integrated into the world's most polluted rivers such as the Ulhas in India, the Klang in Malaysia, and the Meycauyan/Pinagkabalian rivers in the Philippines. The Gather Hub will continue to digitally monitor environmental and surrounding factors that may impede its performance. Rivers are diverse bodies of water that are particular and require ongoing data collection to fully understand their unique qualities. The modular design of the Hub makes it scalable and applicable to a variety of scenarios. The Main Hub will be situated in rivers and at the edge of their arteries which connect to oceans and seas with the potential of it being scaled up to an ocean use case.

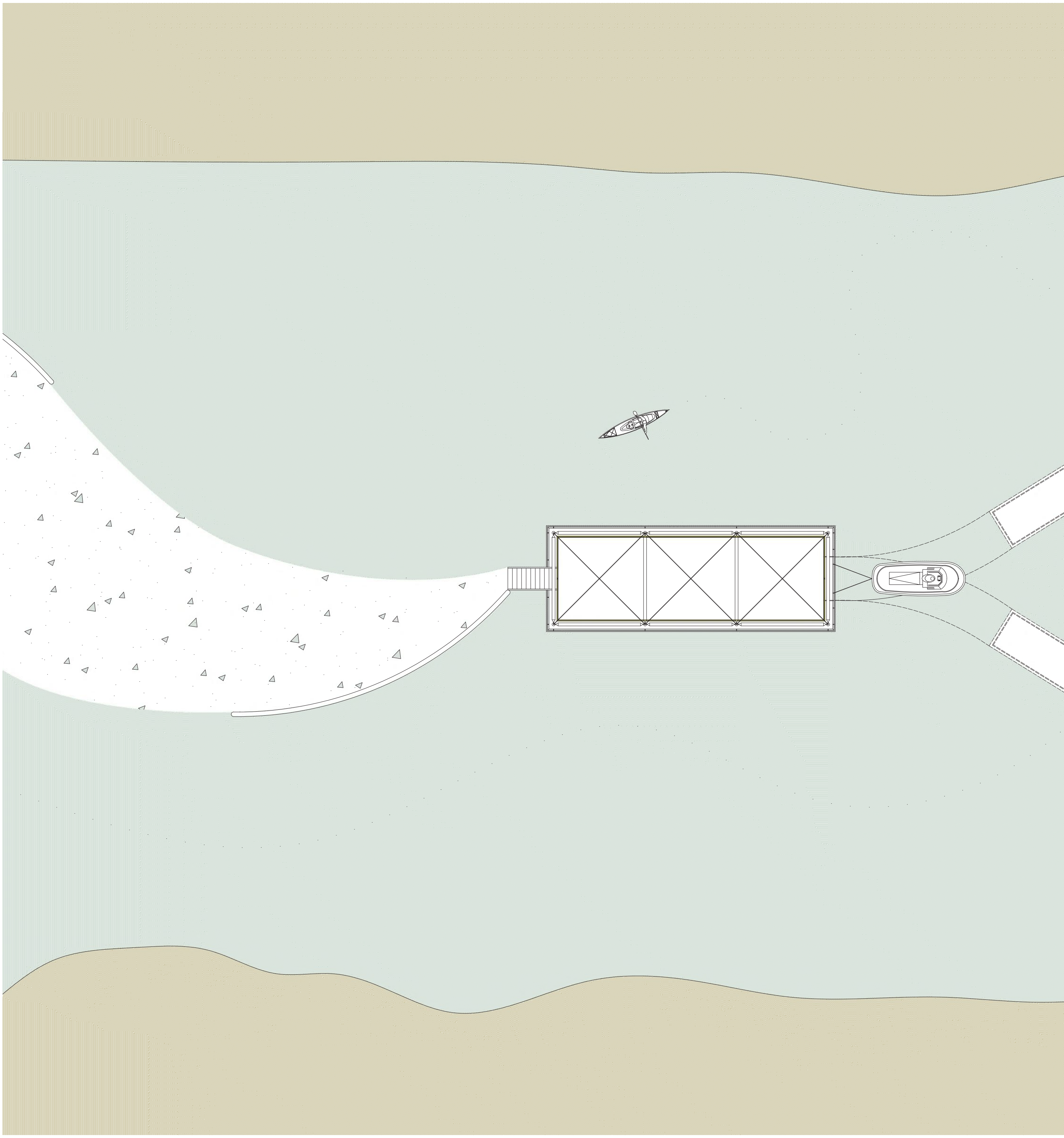
APPLICATIONS
The Gather Hub is intended for river

SITE

cleanup. However, it can be modified to include ocean applications with minor design adjustments such as more storage room, salt-resistant building materials, and a larger scale. The Gather Hub river system design stems from the functionality of The Ocean Cleanup's Inceptor, the concepts of the SFF, and the simplicity of the OHP. The Gather Hub will collect river waste pollution and repurpose the waste plastic into small plastic pellets intended to be further processed at the Main Hub into an algae bioplastic. At the Main Hub, the raw material can be distributed to local manufacturers to produce new, 100% biodegradable products. The Gather Hub requires very little human operation and is monitored using cloud services to record data and performance values. The digital system will also make recordings of its surroundings and map the effects of that specific area for further improvement to the design. The Gather Hub measures an overall dimension of 12 m x 6 m with an attached conveyor belt that extends and retracts 2 m below water. Its simple design allows the Gather Hub to follow the natural currents of the river. It can easily dock on the banks of the river using traditional boat fenders and ropes. It requires another vessel to remove the bins of plastic pellets once filled. As the full bins are being removed, empty bins are put in place to operate continuously at all hours.

ASSEMBLY

Both the Gather Hub and the Main Hub are constructed from a system of buoys that connect to a structural grid of 6m x 6m. Structural rods vertically stiffen the structure while the system of buoys weighs the platform in place. The buoys are circular in size and have weights inside them to support the structure's top-heavy load. The structural columns on the Main Hub differ from that of the Gather Hub. The Main Hub's columns operate similarly to the OHP's tidal wave system by moving up and down with the power of waves. Both assemblies have steel floor trusses that support recycled plastic deck boards. All parts of the Gather Hub and Main Hub are no longer than 6m. This allows for ease of transportation to the desired location. Further, its modular design makes the installation simple and it can easily be retrofitted or dissembled.



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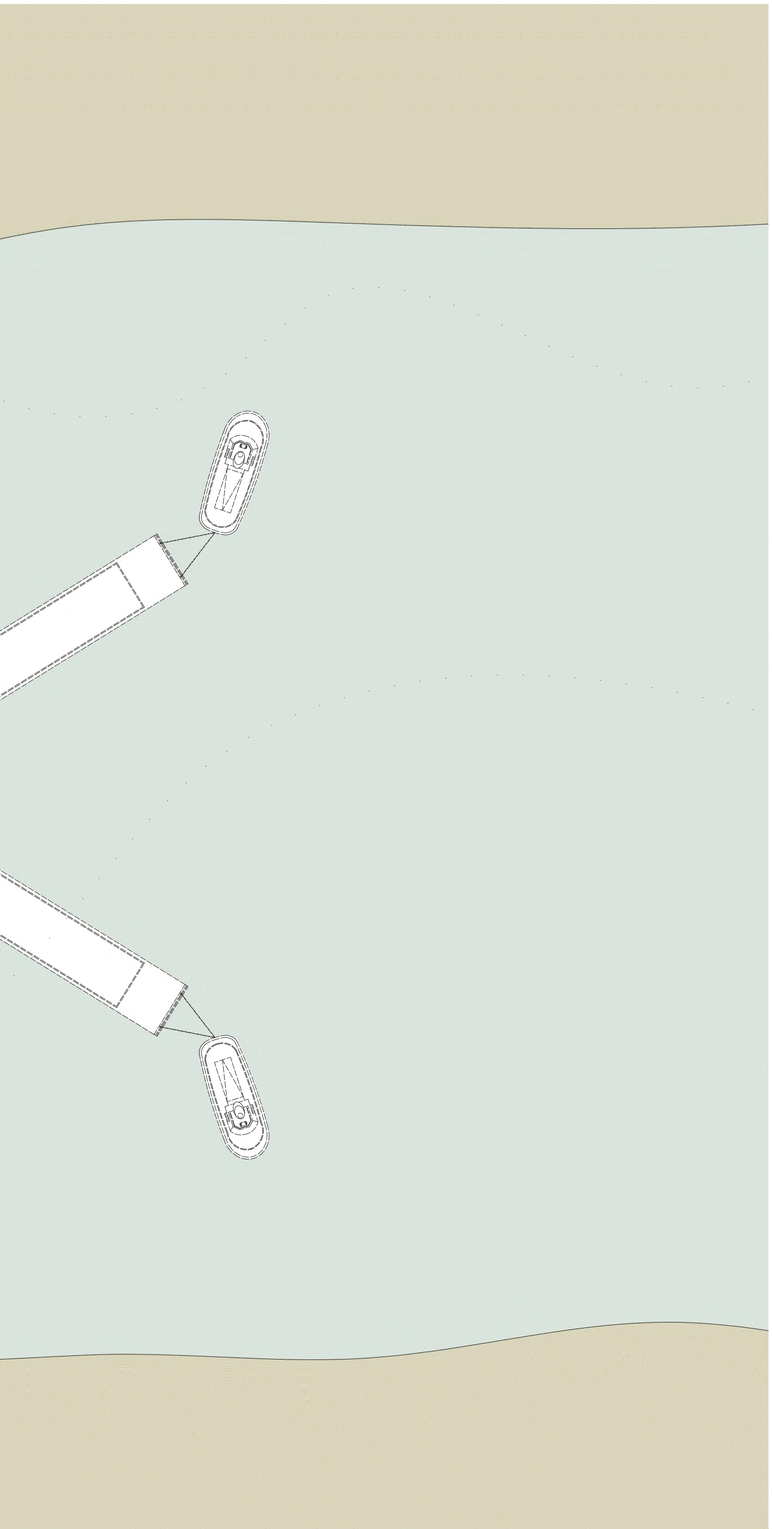
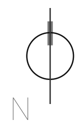


FIGURE 56
Roof/Site plan of The Gather Hub, (2022, April)



SCALE
The size of the Gather Hub will allow it to function effectively in narrow channels and bodies of water. It also occupies only the first few feet deep. The Main Hub will reside on the coastline of nearby ports, cities, and shores. It measures a maximum width of 92m x 92m and is intended for water with a minimum depth of 3m. The Main Hub can be scaled down depending on its purpose and application.

Note: McMurtry, M. M. (2022, April). *The Gather Hub: Roof/Site Plan.*

Program

The Gather Hub will consist of one level housing a miller machine attached to the ceiling and large bins for storage and transportation. The Gather Hub's purpose is to collect plastic river waste that floats downstream onto a sloped conveyor belt. The plastic is directed downstream using a system of floating buoys with a weighted screen that extends 1' below the waterline. The Gather Hub will collect and grind the plastic waste on-site. The flooring of the Gather Hub is rectangular with a U-shaped split. The split is to allow for the emptying and replacement of the storage bins once they are full. The bins lay on the middle portion of the U-shaped deck. Assistance from another vessel is required to tow away the middle portion of the platform from the shell of the Gather Hub. The assistant vessel then returns a deck with empty containers in its place. The assistant vessel then delivers the containers to the Main Hub for further processing. The vessel will occasionally return with a small package of algae powder that is used for topping off the photobioreactor (PBR) façade. The

PROGRAM

Gather Hub’s façade will be a miniature example of the algae recycling process housed on the Main Hub. The Gather Hub will have an intake valve to pour plastic pellets and dried algae into the PBR system.

The Gather Hub uses an extendable and retractable sloped conveyor belt to transport the collected waste to the miller. The miller then grinds the collected plastic into small pellets. It then continues through the machine to be rinsed and dried before being distributed by a horizontal conveyor belt into large bins. The large bins are covered with a felt cloth on an automatic system that covers the bins to prevent the pellets from blowing away from the wind.

The Main Hub processes the plastic pellets into a bioplastic using algae. Once the bins full of plastic pellets reach the Main Hub, they are unloaded using cranes to lift them onto the platform. From there, the pellets are distributed through a tube that connects to the bins. The tube carries the plastic pellets and feeds them into the algae-filled PBR. The PBR system is the harvesting stage of the algae where it spends an average of 90 days breaking down the plastic pellets into a bio sludge. The algae work to break down the plastic pellets using water, nitrogen, and sunlight. The PBR system lays flat in the center of the platform and expands 60m x 60m in width. The series of tubes are fed dried algae, water, and nitrogen and pumped with plastic pellets to the end of the system where it feeds into a heated press machine. This machine heats the sludge and presses out all the excess water. It then is fed through a form that creates circular strings of compressed bioplastic. A blade in the machine cuts the strings into pellets. Thus, the final product is a raw, renewable material that is packaged and stored for shipment to resin manufacturers.

PLASTIC FILTERING

The Gather Hub uses the river currents to collect plastic. With the aid of floating fenders, this plastic is directed toward the Hub’s sloped conveyor belt, and into the belly of the machine. This design allows boat traffic to pass freely by

PROGRAM

without interrupting the process by using openings in the fender system. The fender system directs plastic off the fenders and towards the Gather Hub. The fenders also have a screen that extends 1' below the water level to collect any plastics that might have sunk. This screen has to remain short as river depths vary and can be quite shallow.

MODIFIED ALGAE FARM

Biodegradation refers to any chemical or physical change in material resulting from biological activity. Generally, a biological agent utilizes organic polymers as a substrate for their energy and growth, resulting in microbial biomass as the end product of complete biodegradation. One potential way to mitigate plastic waste is by using algae and its toxins, which could effectively break down the polymeric materials biologically.

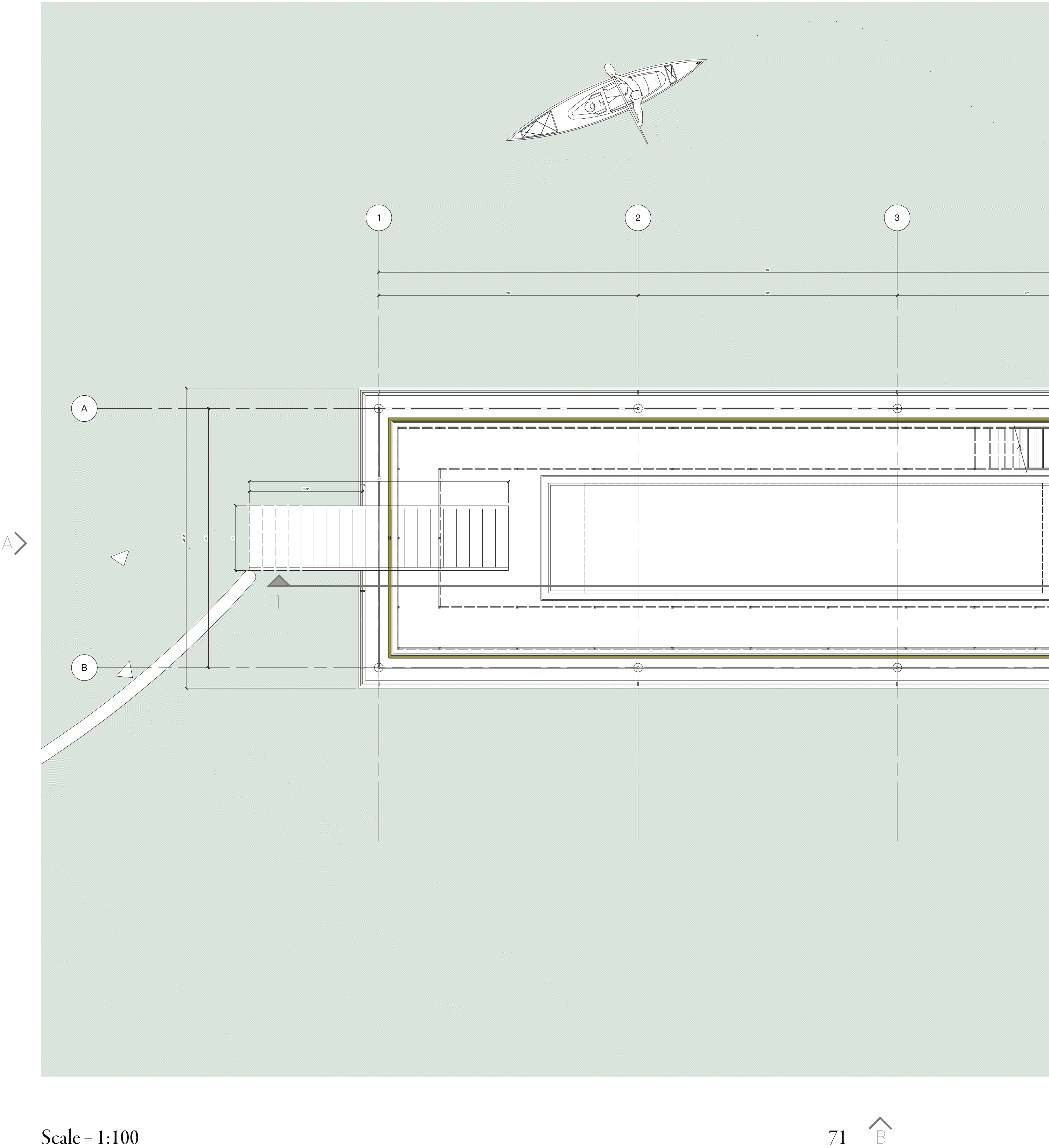
The algae recycling process to biodegrade plastic waste relies on using the algea's own enzymes to weaken the chemical bonds of plastic polymers. The plastics are thus converted into metabolites such as carbon dioxide, water, and new biomass. The algae bonds to the surface of plastics and initiate the biodegradation with their production of ligninolytic and exopolysaccharide enzymes. The algal enzymes present in the liquid media interact with macromolecules present at the plastic surface and trigger the biodegradation. The polymer is utilized by algae as a carbon source since the species growing on the PE surface were found to have higher cellular contents (protein and carbohydrates) and higher specific growth rate. Apart from that, microalgae can be genetically modified to a microbial cell factory which is capable of producing plastic degrading enzymes.

Bioplastics are defined as plastics that are made fully or partially from biomass or renewable sources, such as food crops, and serve the same function as the petroleum-based plastics. Bioplastics are generally categorized by their make-up of different materials and properties

PROGRAM

as bio-based but non-compostable, bio-based and degradable, or fossil resource-based that are biodegradable. There are numerous sources that can be used to manufacture bioplastics; mainly agricultural crops such as corn, wheat, soy, etc. This, however, raises the concern of the sustainability of these feedstocks, as competition between land and water resources for human consumption emerges. Additionally, the process of extracting compounds, especially polymers from plants for the synthesis of bioplastics is difficult. Algea can be a potential biomass source for the manufacture of bioplastics as it can be cultivated on non-arable lands and has short harvesting time. Microalgae biomass can be blended with petroleum plastics to produce bioplastic where possible. Genetic engineering offers another promising way to modify the algae strains to synthesize compounds for bioplastic production. The algae is cultivated in a closed photobioreactor system with less susceptibility to contamination and has a high productivity due to its high photosynthetic rate.
On average, PLA biodegrades in four to six weeks in industrial composting facilities. Microalgae biomass can be blended with petroleum plastics to produce bioplastic where possible. Genetic engineering offers another promising way to modify the algae strains to synthesize compounds for bioplastic production. The algae is cultivated in a closed photobioreactor system with less susceptibility to contamination and has a high productivity due to its high photosynthetic rate.
Microalgae contribute to the biodegradation of plastic waste with enzymes that weaken the chemical bonds of plastic polymers. The attempt to use microalgae to convert these plastics into metabolites such as carbon dioxide, water, and new biomass is of great interest.

CIRCULATION & ACCESSIBILITY
Both the Gather Hub and Main Hub will be accessible via boat and the



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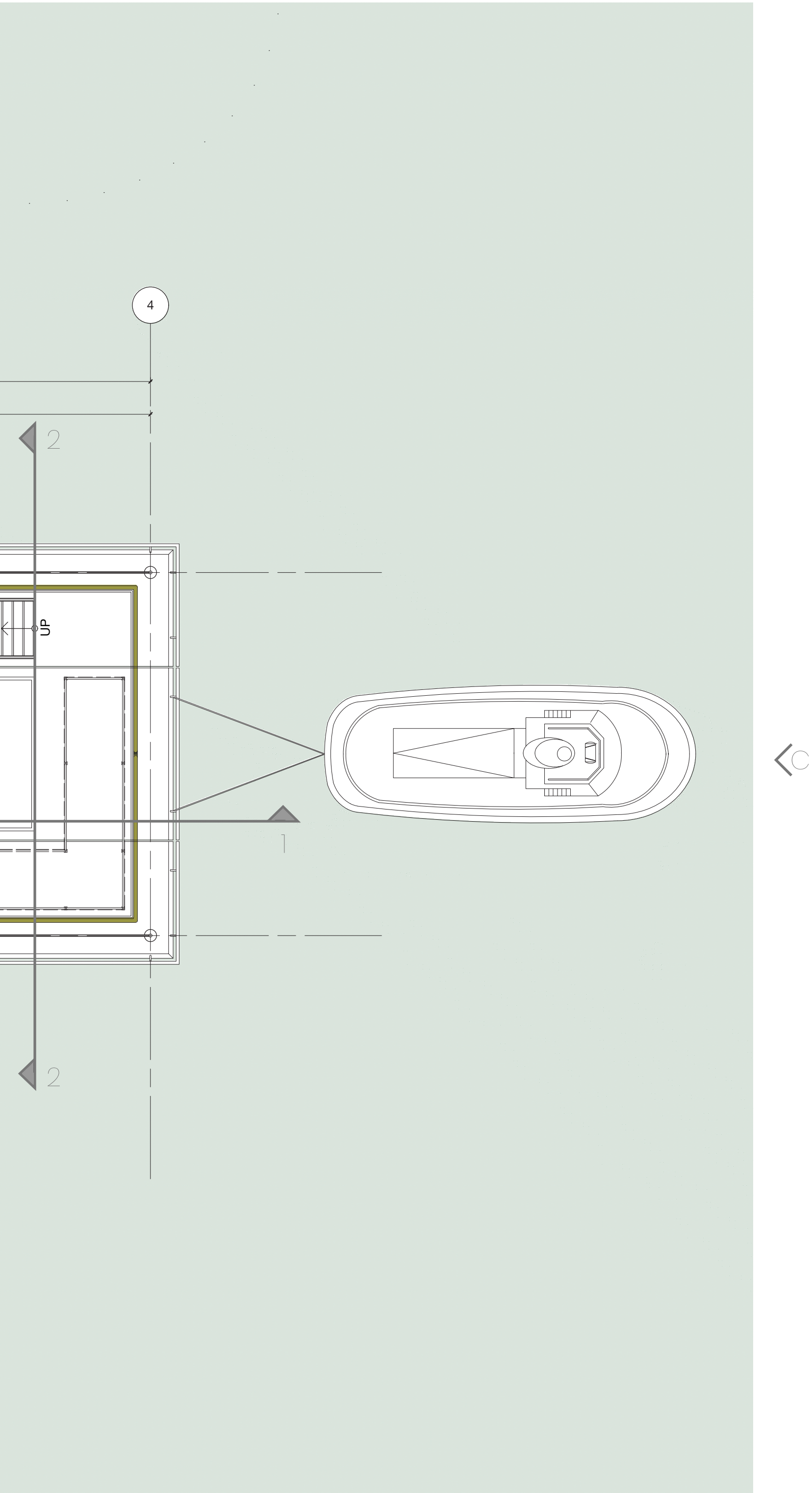
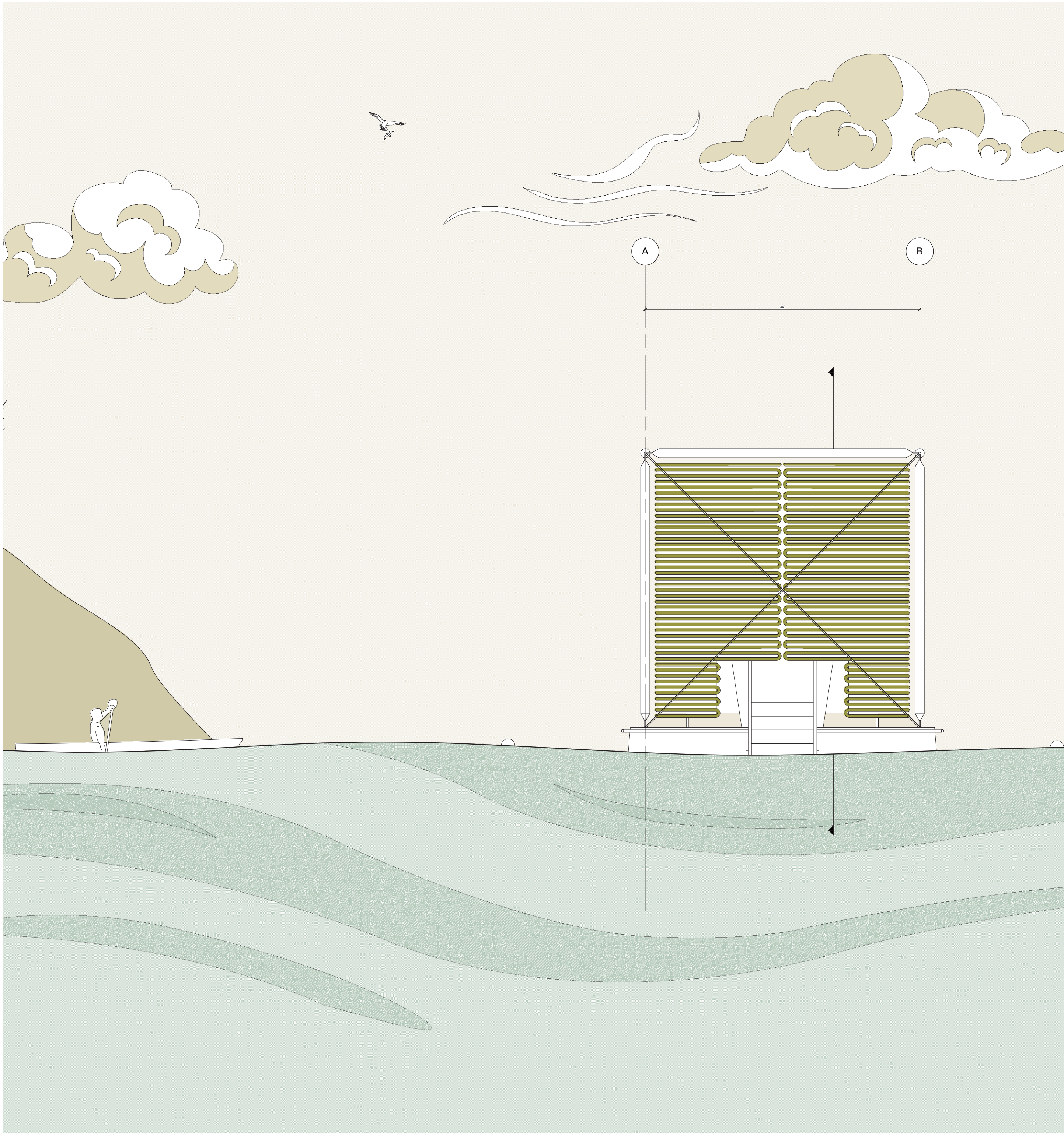


FIGURE 57
Floor plan of The Gather Hub, (2022, April)

Gather Hub by foot when docked in a harbour. The Gather Hub is accessible by boat and can dock using ropes that wrap around its continuous exterior rail along the 1’-0” wide perimeter fender. The Main Hub can be secured using ropes and cleats attached to the plastic deck flooring on the platform. The Gather Hub has a 5’-0” wide walkway on the interior shell of the platform. This walkway is intended to be used for maintenance, general surveillance of the system, and for removing and retrieving empty bins from an assistant vessel. The ground floor plan of the Gathering Hub is clear of any intrusions as the miller machine is hoisted to the ceiling of the shell.

Note: McMurtry, M. M. (2022, April). *The Gather Hub: Floor Plan*.



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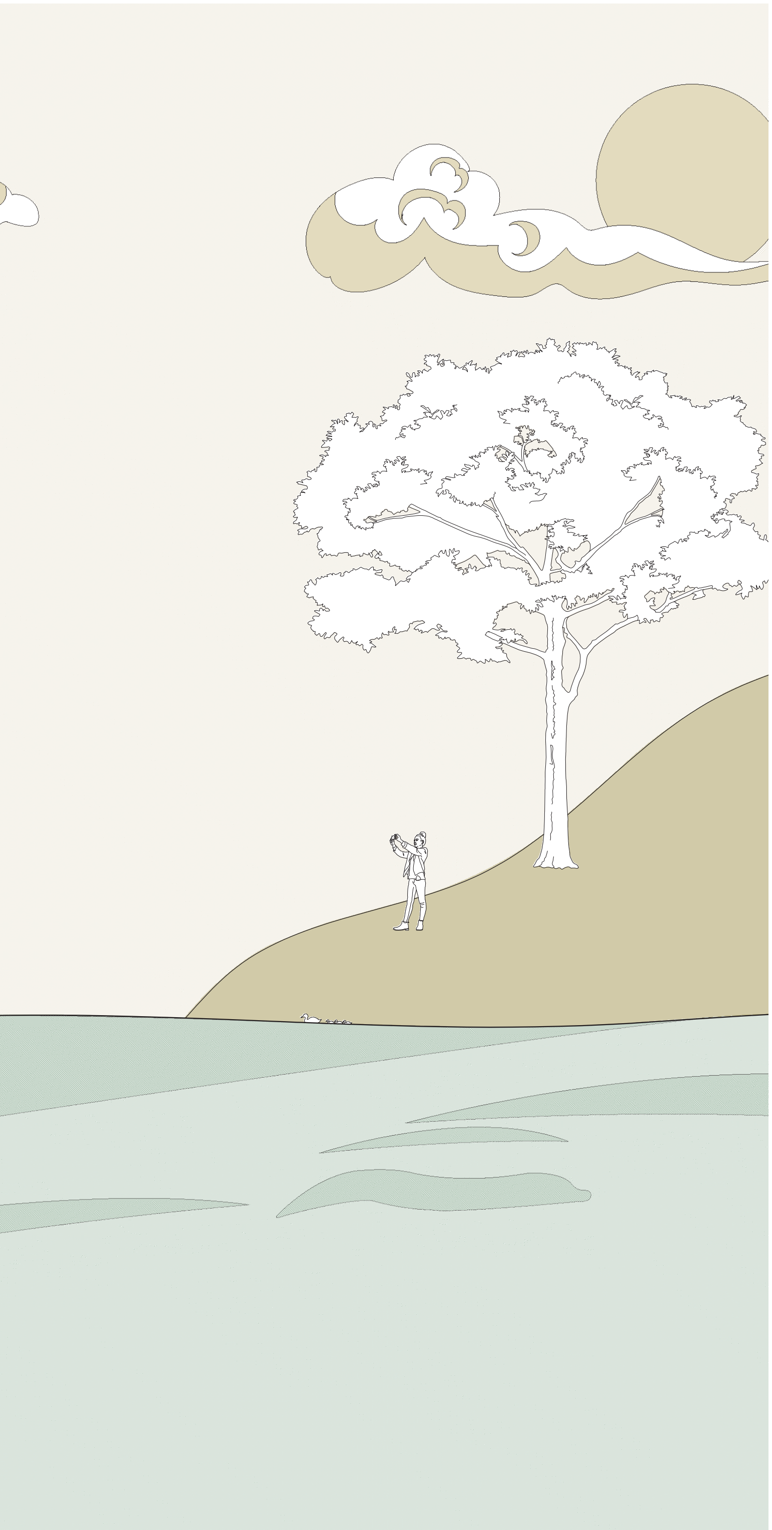
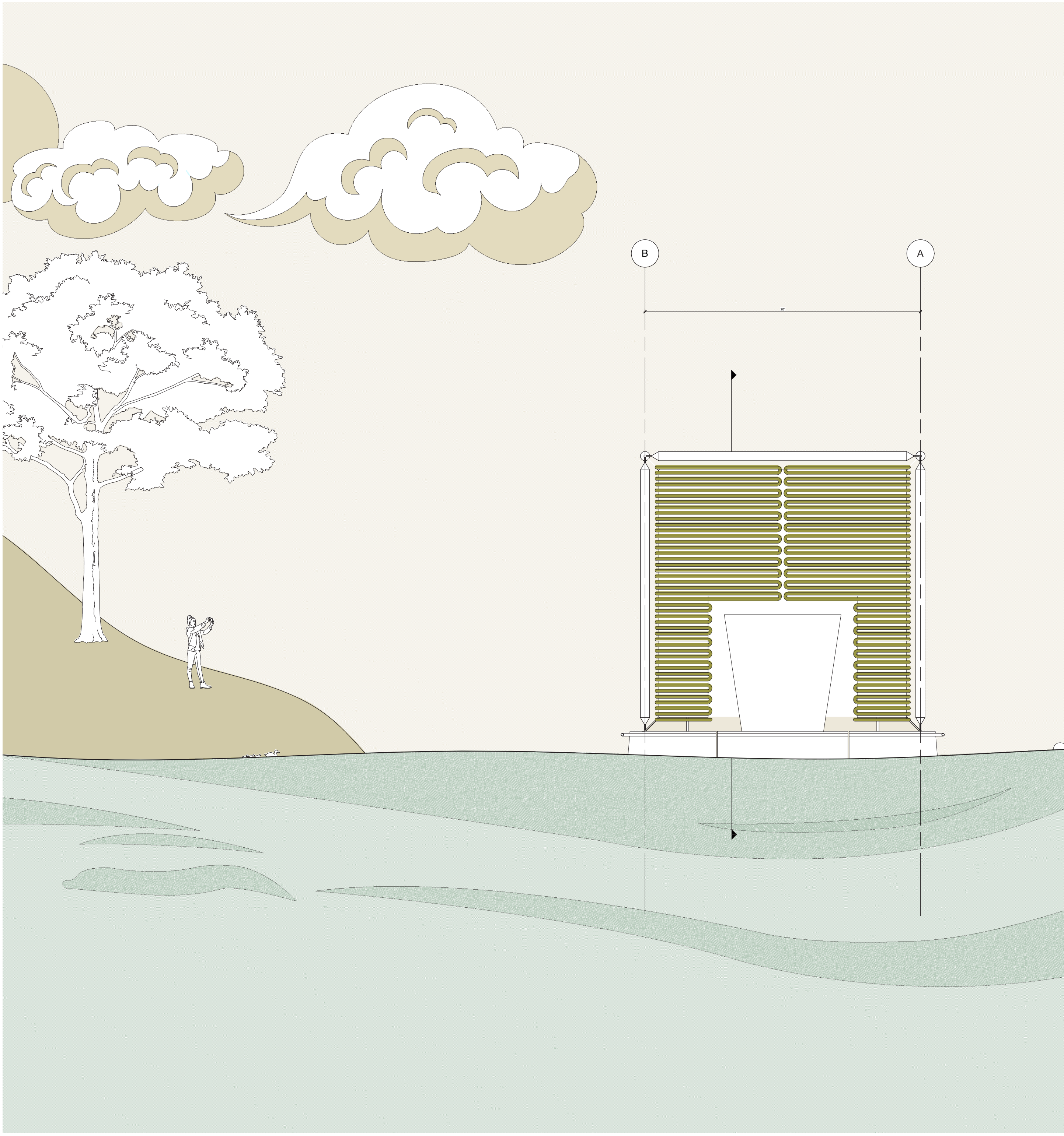


FIGURE 58
Front elevation of The Gather Hub, (2022, April)

The reason for hoisting the miller to the ceiling is to free the area below of walkability and to follow the natural gravity of the sloped conveyor belt to freely drop the plastic into the machine and then free falls from the machine to the horizontal conveyor belt, and then finally into the storage bins.

The Main Hub's circulation is broken down into five sections. The first section is the interior area where the algae PBR harvesting area stretches the majority of the platform. It is centralized and begins the process on one side of the platform and ends on the opposite side. On the side where the PBR is fed plastic pellets is where the shipment of plastic pellets and dried algae are brought on board close to where the PBR is fed plastic pellets.

Note: McMurtry, M. M. (2022, April). *The Gather Hub: Front Elevation 'A.'*



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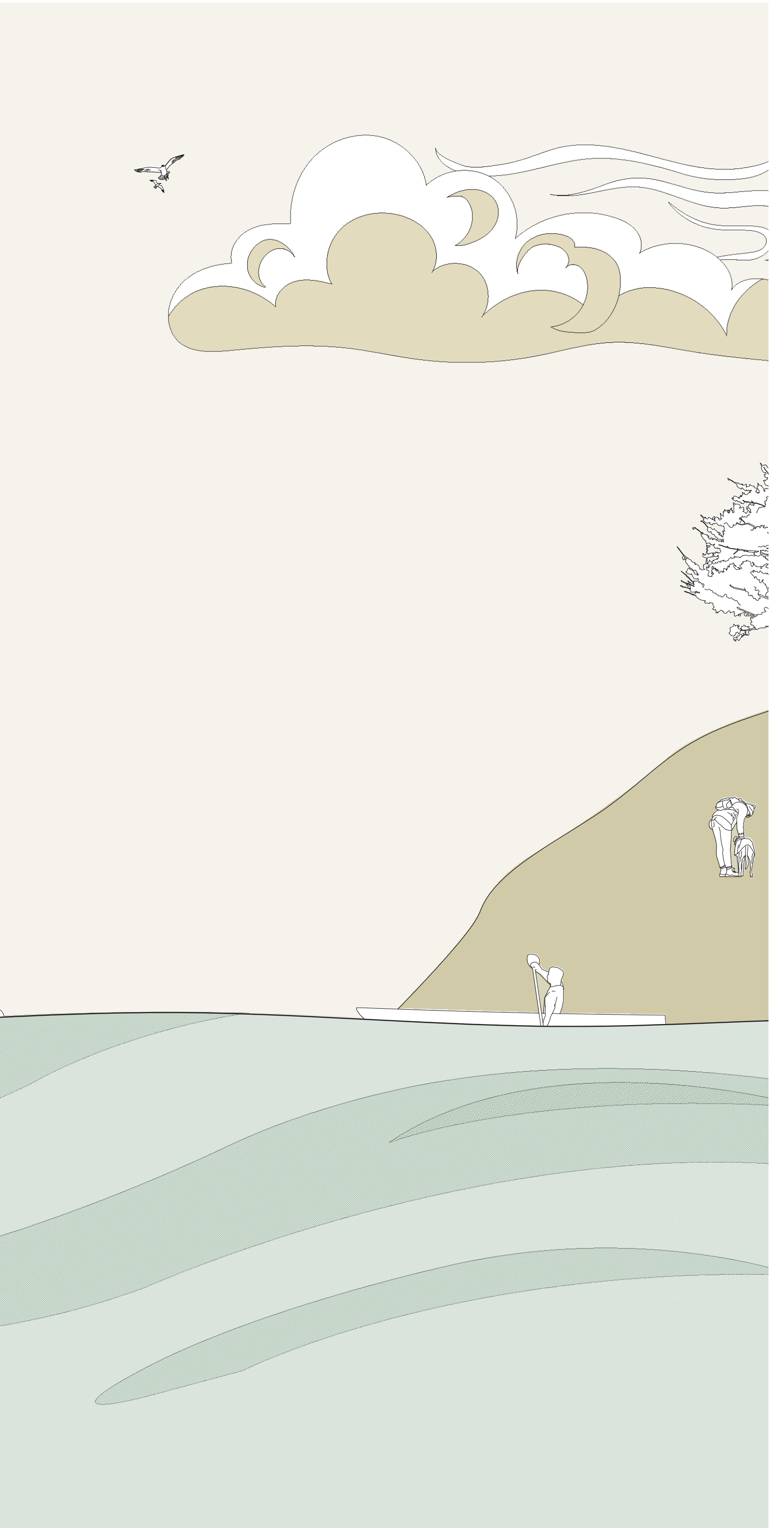
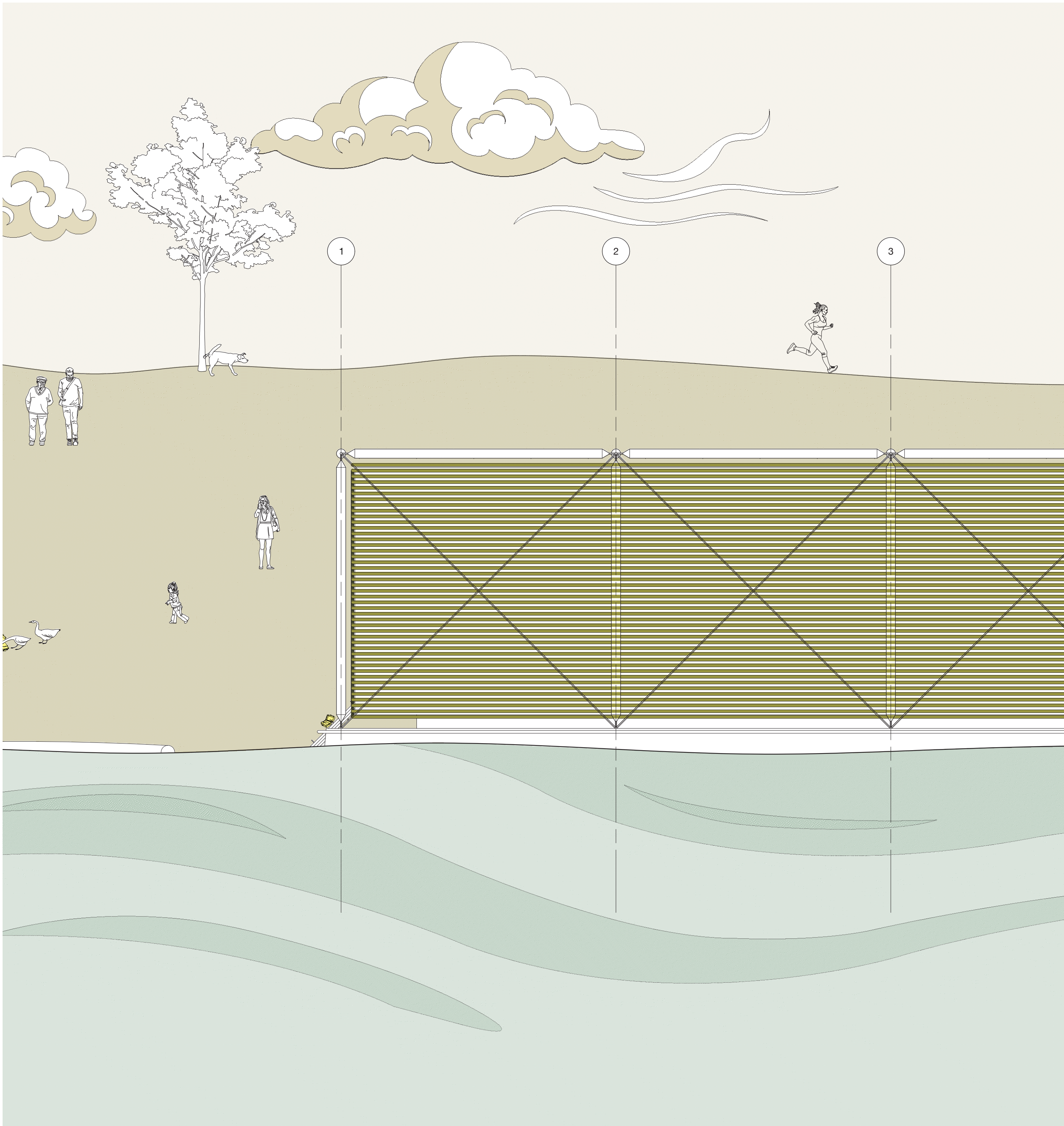


FIGURE 59
Side elevation of The Gather Hub, (2022, April)

This area of the platform is mainly an exposed storage system that is fed into the PBR using connectable pipes. On the opposite side of the platform is where the heating and pressing machine is fixed. This area processes the PBR byproduct into a finished product or raw material. It is also packaged in this area and then transported using forklifts to a designated storage area for the purpose of pick-up.

Note: McMurtry, M. M. (2022, April). *Gather Hub: Side Elevation 'B.'*



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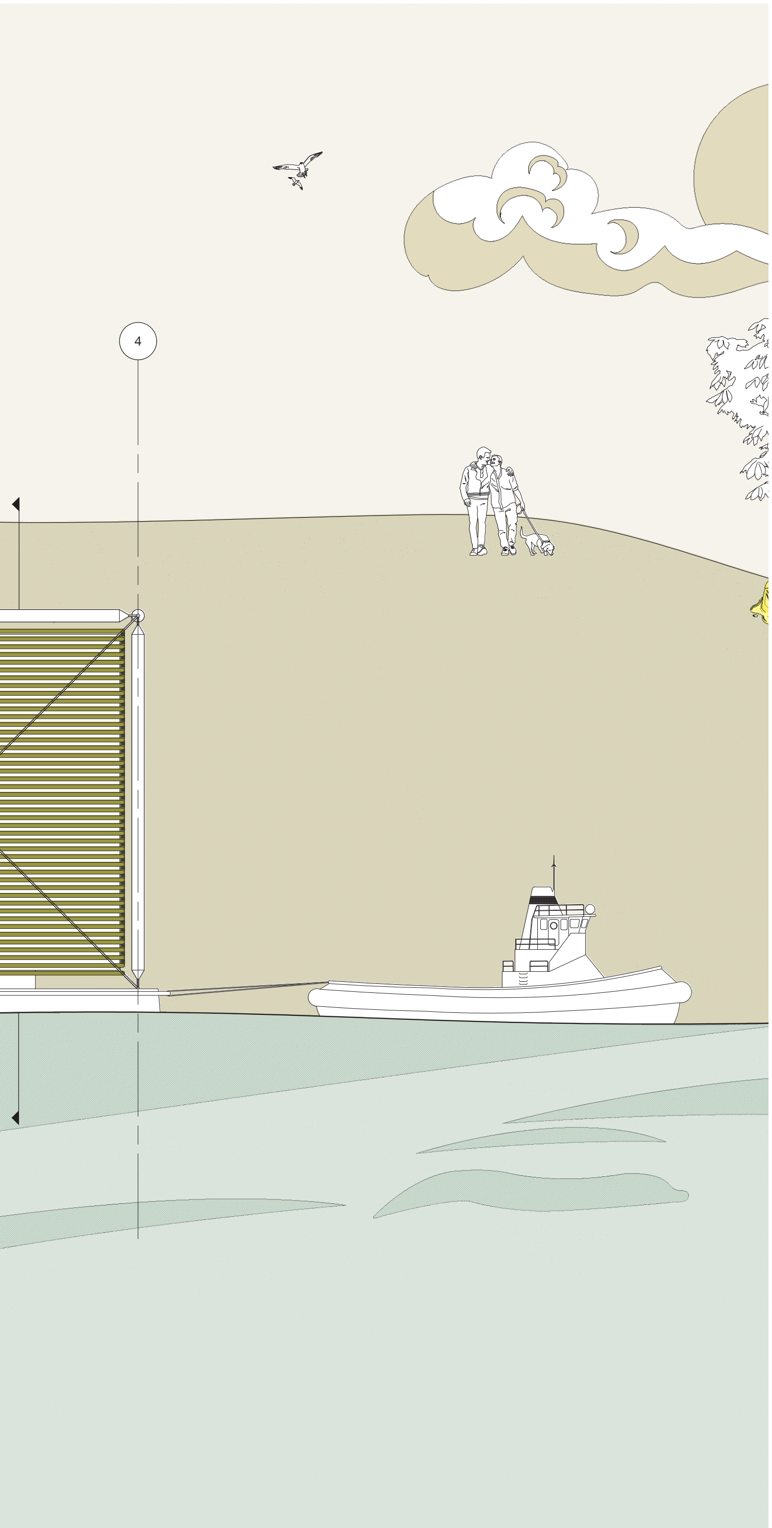
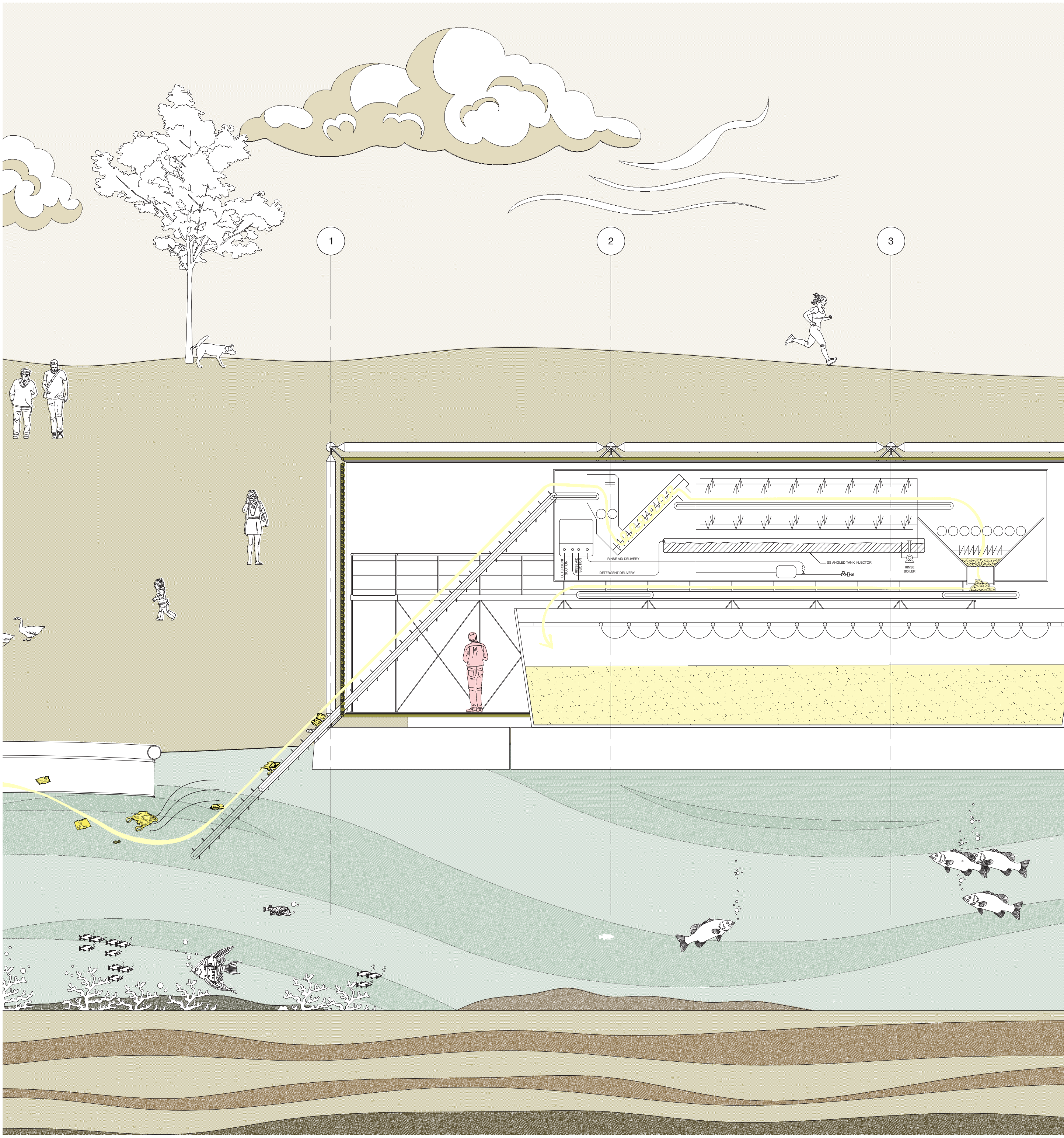


FIGURE 60
Back elevation of The Gather Hub, (2022, April)

Note: McMurtry, M. M. (2022, April). *The Gather Hub: Back Elevation 'C.'*


1
2
3
DETERGENT SUCTION
RINSE AID SUCTION
RINSE AID DELIVERY
DETERGENT DELIVERY
SS ANGLED TANK INJECTOR
RINSE BOILER

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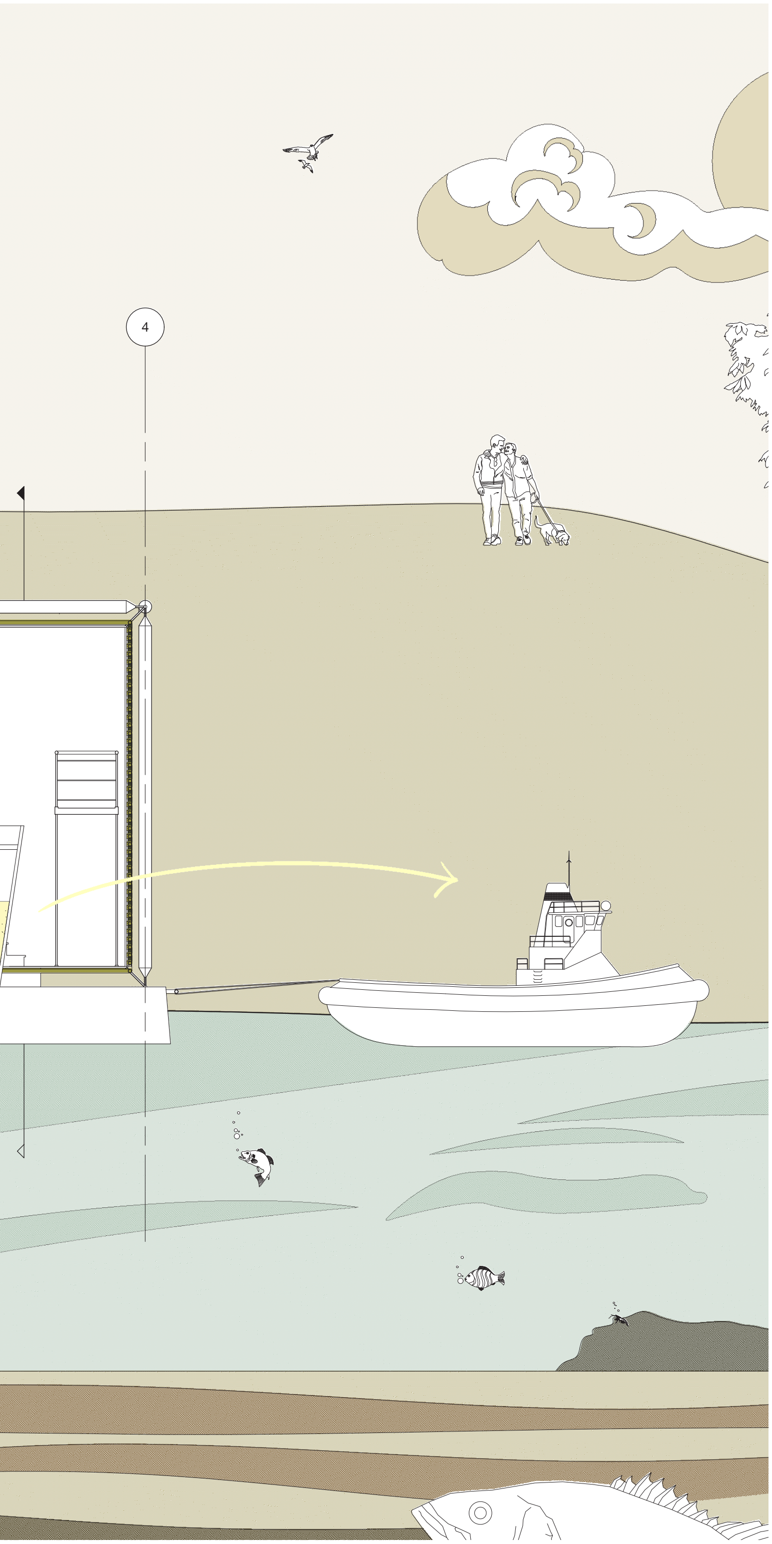
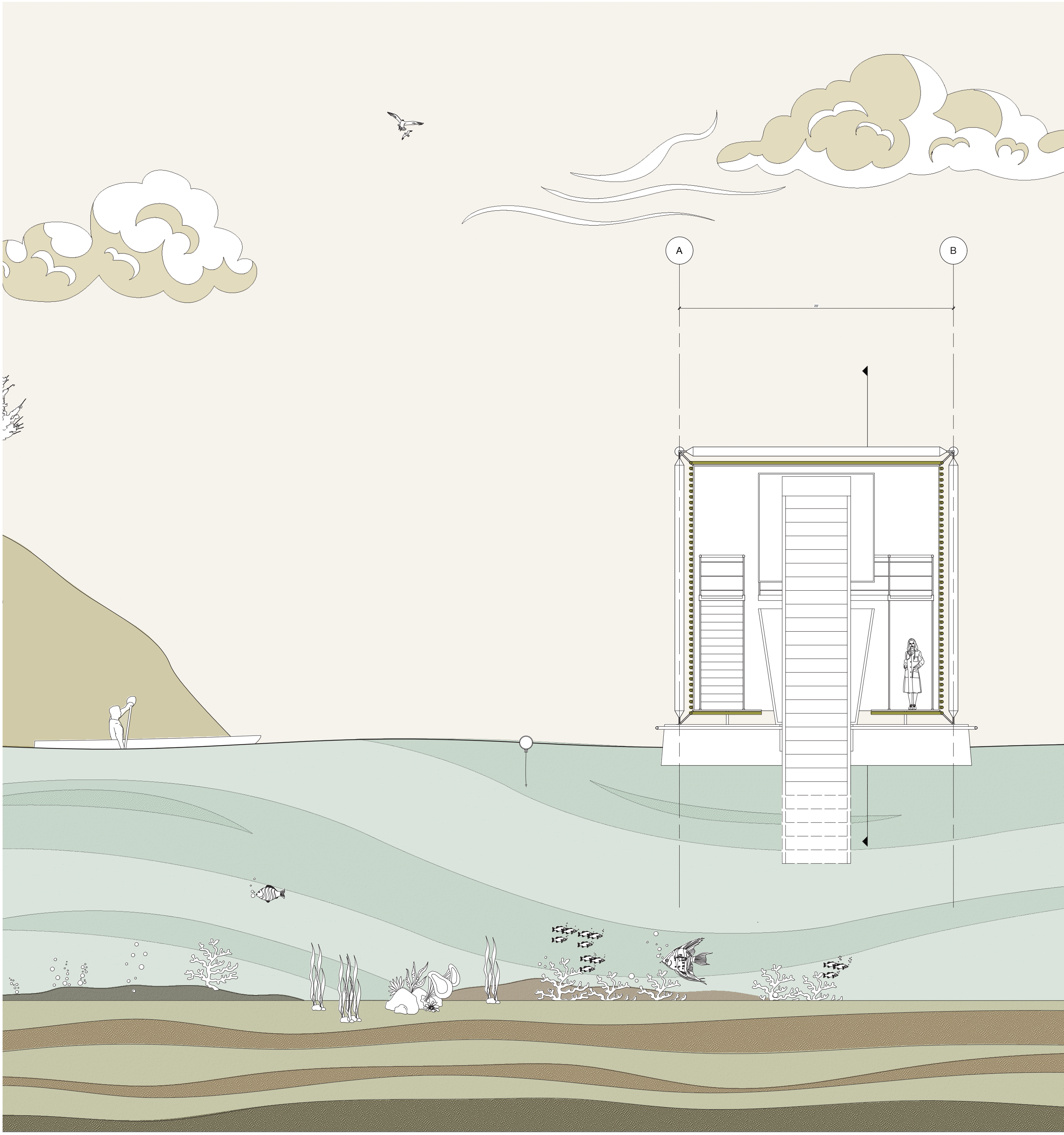


FIGURE 61
Long section of The Gather Hub, (2022, April)

Note: McMurtry, M. M. (2022, April). *The Gather Hub: Long Section '1.'*



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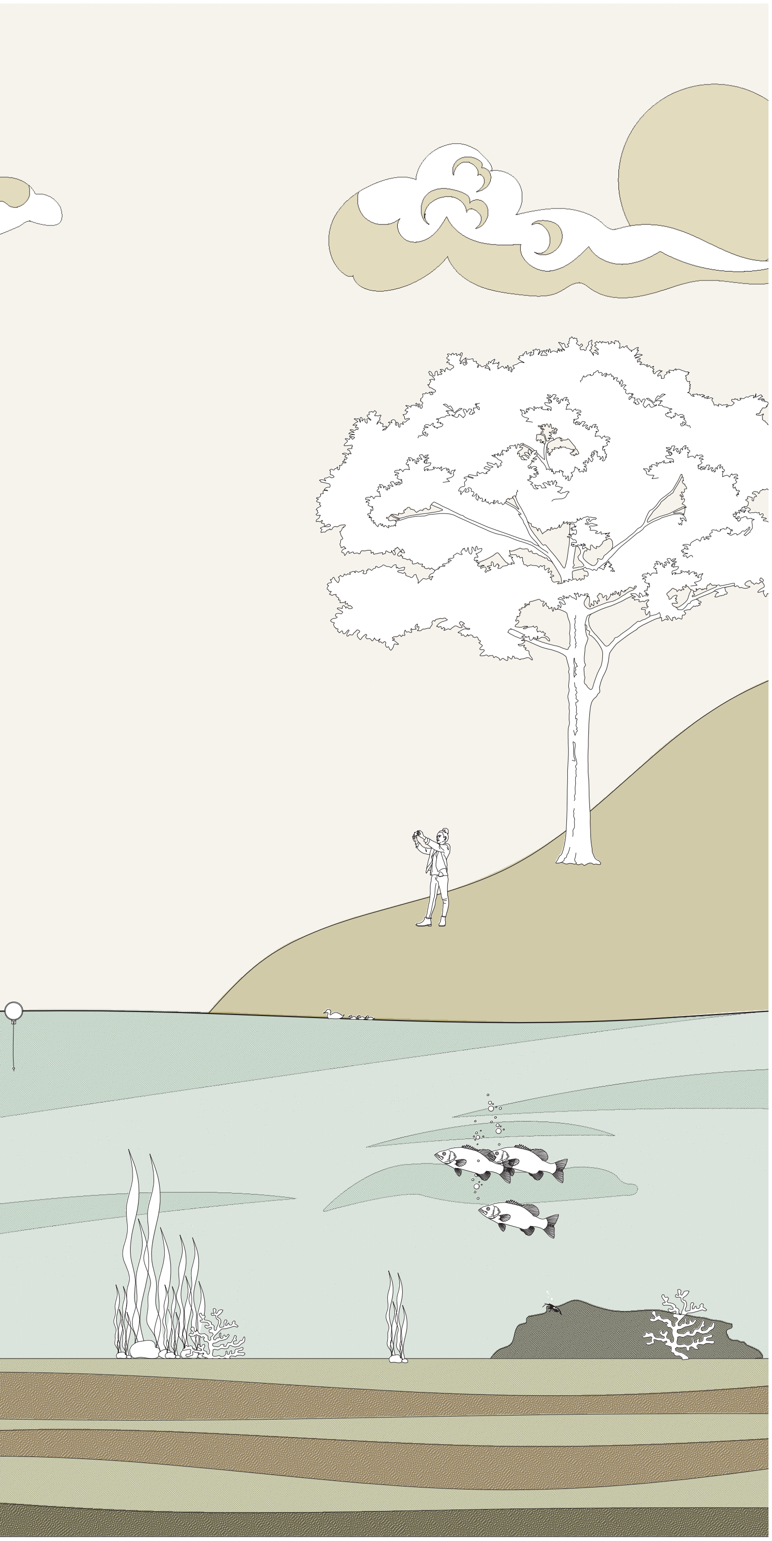
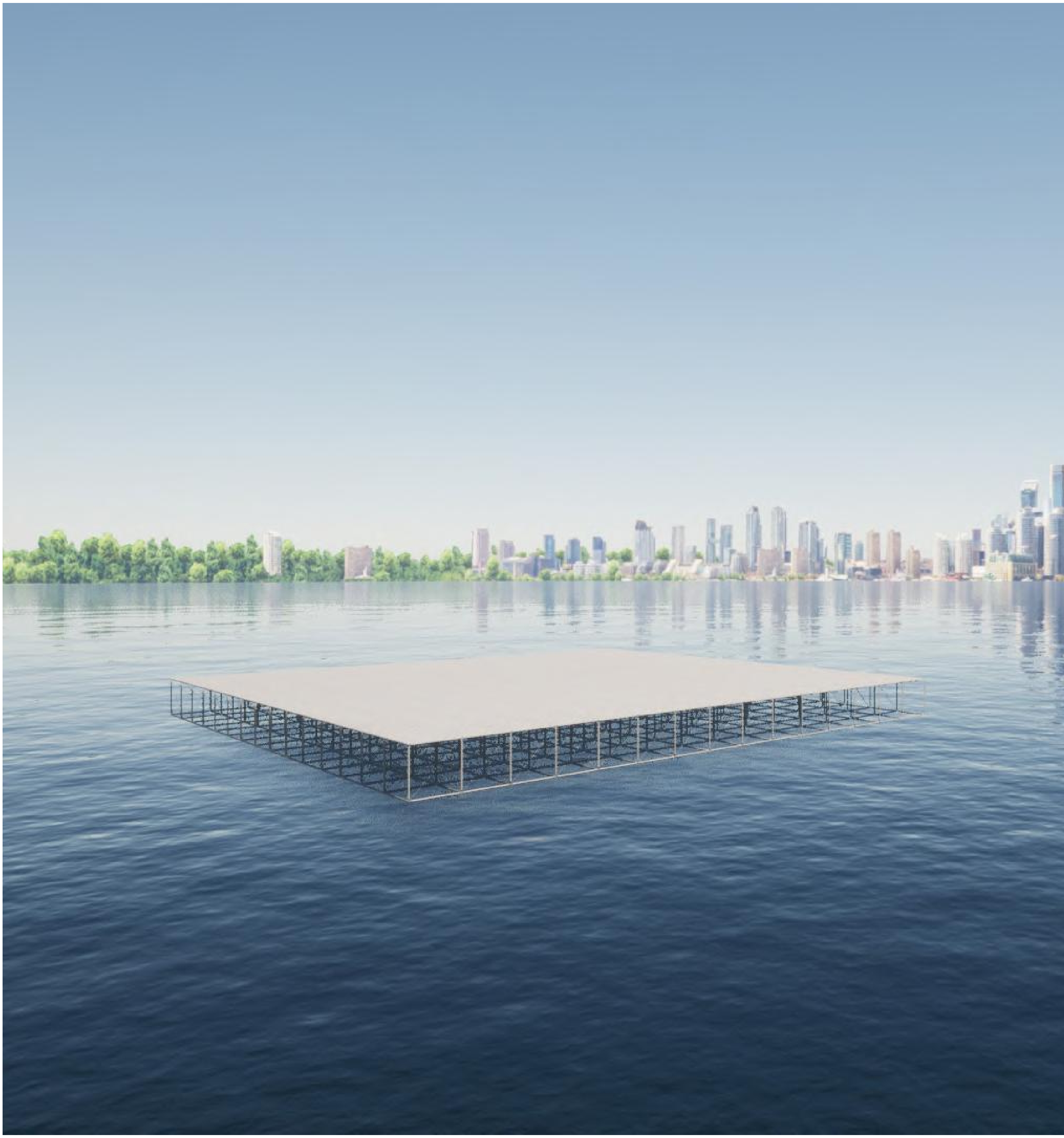


FIGURE 62
Short section of The Gather Hub, (2022, April)

Note: McMurtry, M. M. (2022, April). *The Gather Hub: Short Section '2.'*

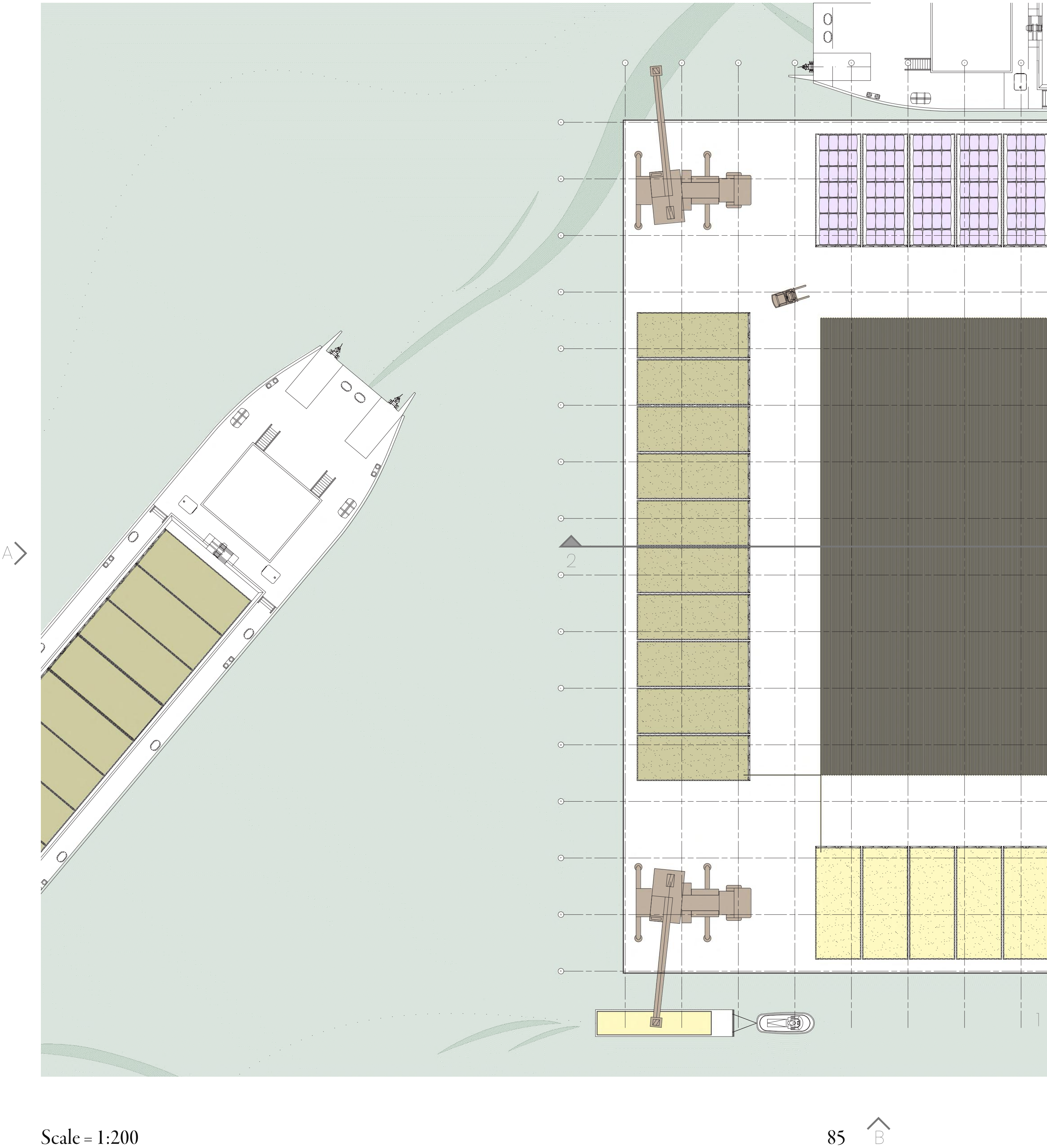


N.T.S.

FIGURE 63
Exterior view of The Main Hub, (2022, April)

CONTEXT
According to The Ocean Cleanup's 1000 Rivers project, one percent of rivers worldwide represent the largest contributors of ocean plastics. The study examines 1,000 rivers responsible for nearly 80% of plastic emissions. According to The Ocean Cleanup, rivers are the primary source of plastic in the oceans. Plastic waste is determined by various factors such as population concentration, economic development, waste management quality, and plastic waste transportation via water. Precipitation, wind, land use, terrain slope, and distance to nearby water are additional factors that have been noted.

Note: McMurtry, M. M. (2022, April). *The Main Hub: Exterior View.*



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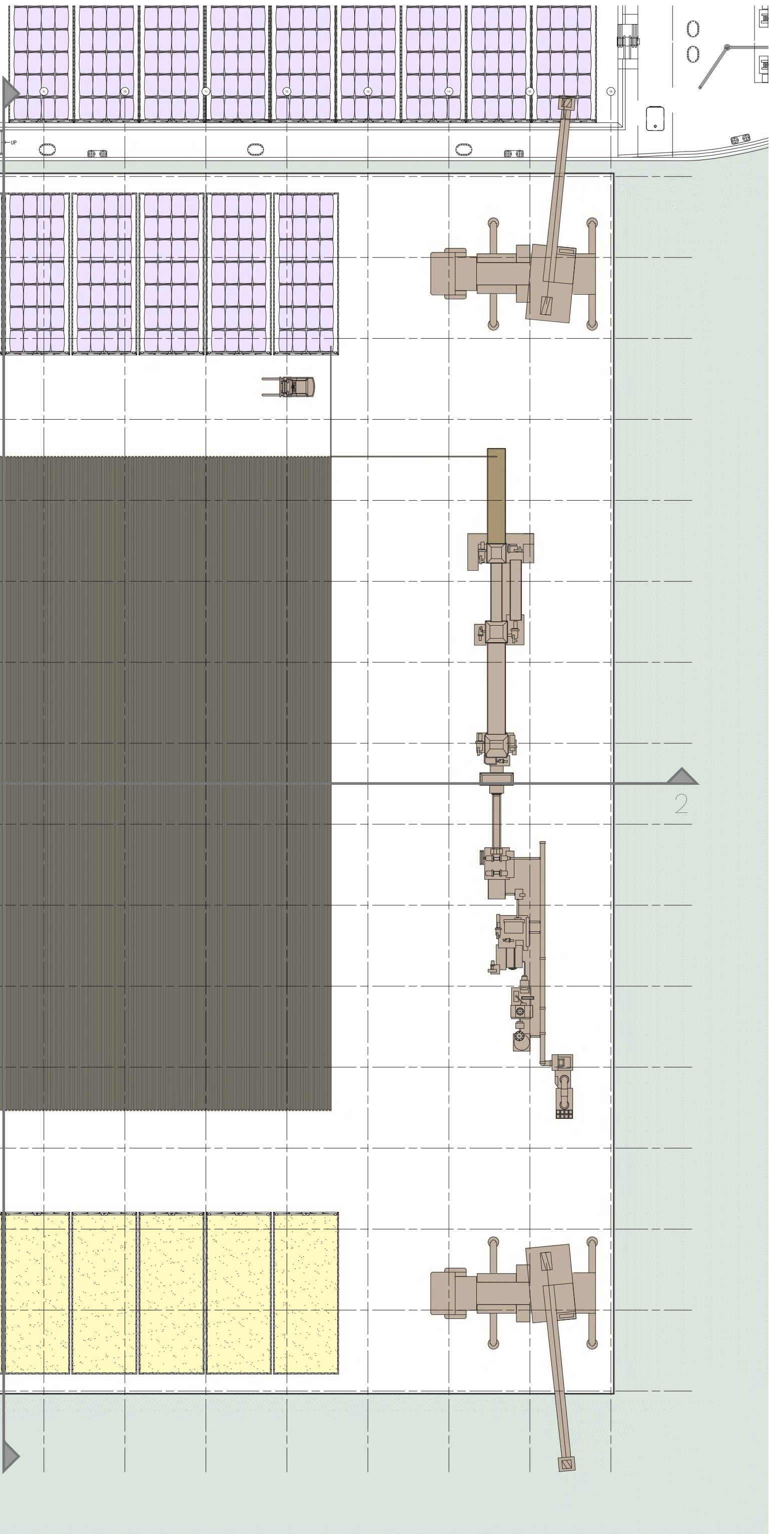
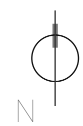


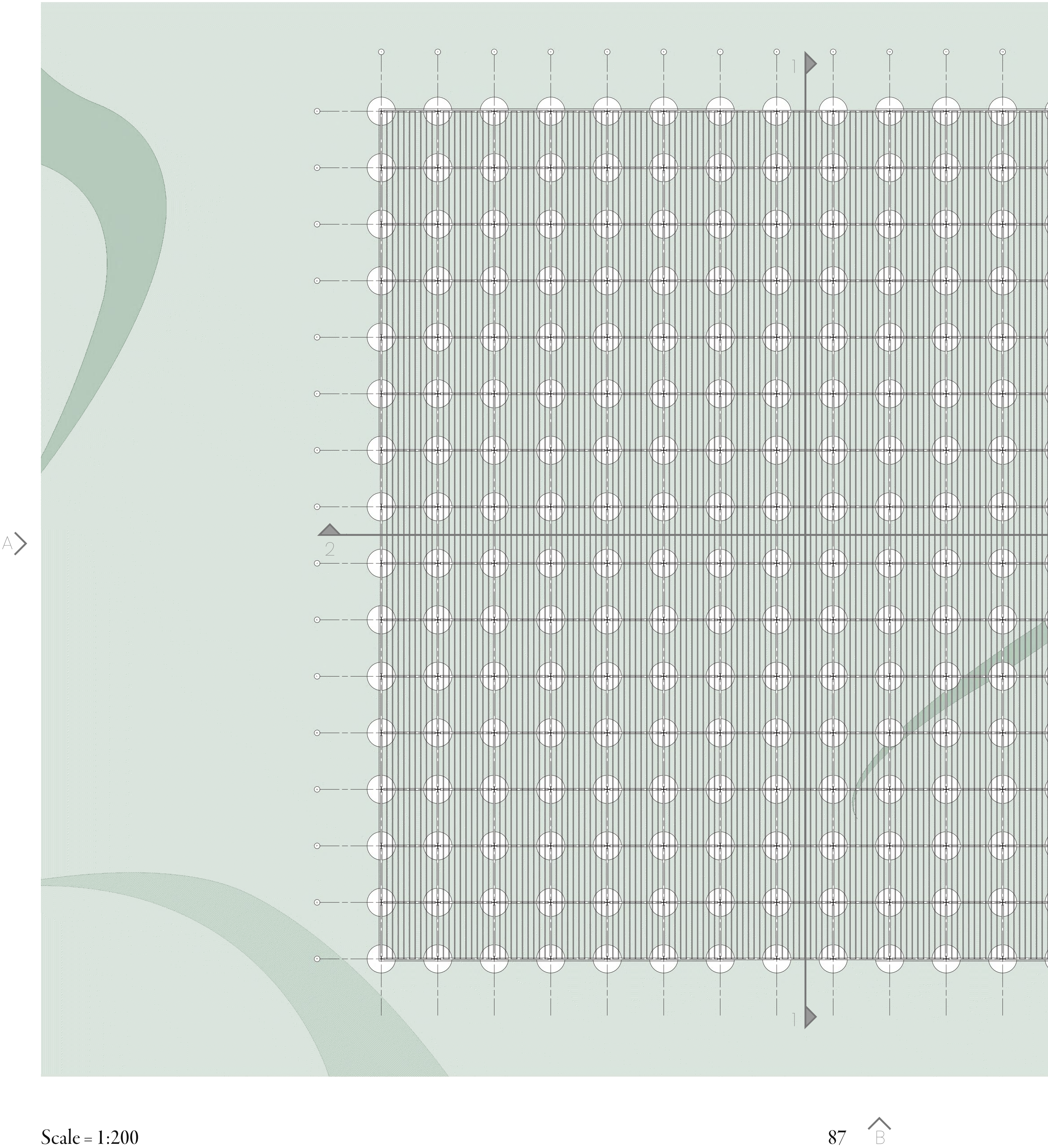
FIGURE 64
Roof/site plan of The Main Hub, (2022, April)



CONTEXT (CONT.)
In North America, the worst plastic polluting river arteries are located in the provinces of British Columbia and Quebec. The South Arm of the Fraiser River in Vancouver emits 42,000 kg of plastic per year. The mouth of the St.Lawrence River in Quebec emits 15,100 kg of plastic per year. Lastly, the St.Charles River in Quebec emits 14,300 kg of plastic per year.

? *Meijer, L. J., van Emmerik, T., van der Ent, R., Schmidt, C., & Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the Ocean. Science Advances, 7(18), 1–13.*

Note: McMurtry, M. M. (2022, April). *The Main Hub: Roof/Site Plan.*



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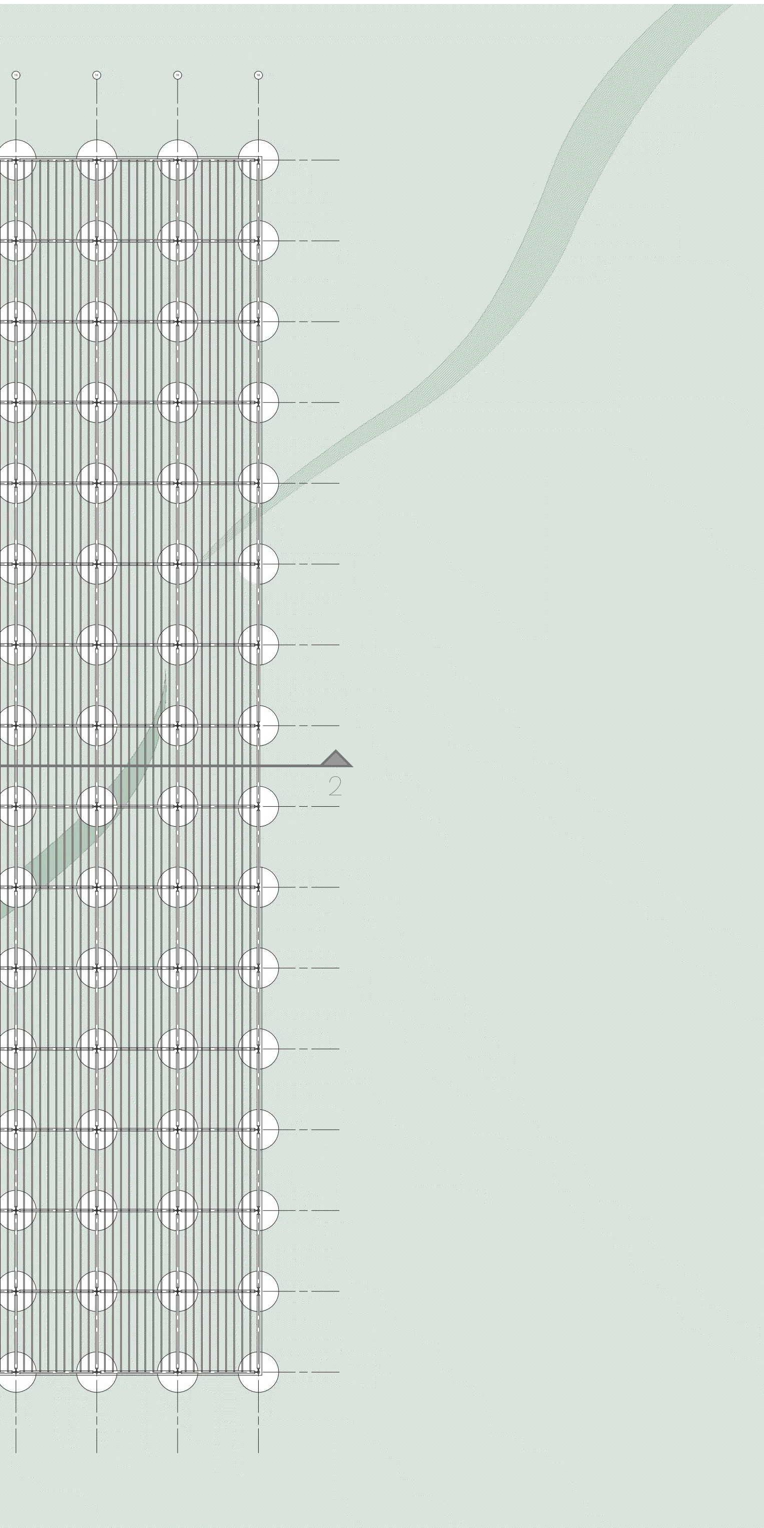
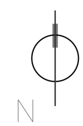


FIGURE 65
Structural plan of The Main Hub, (2022, April)



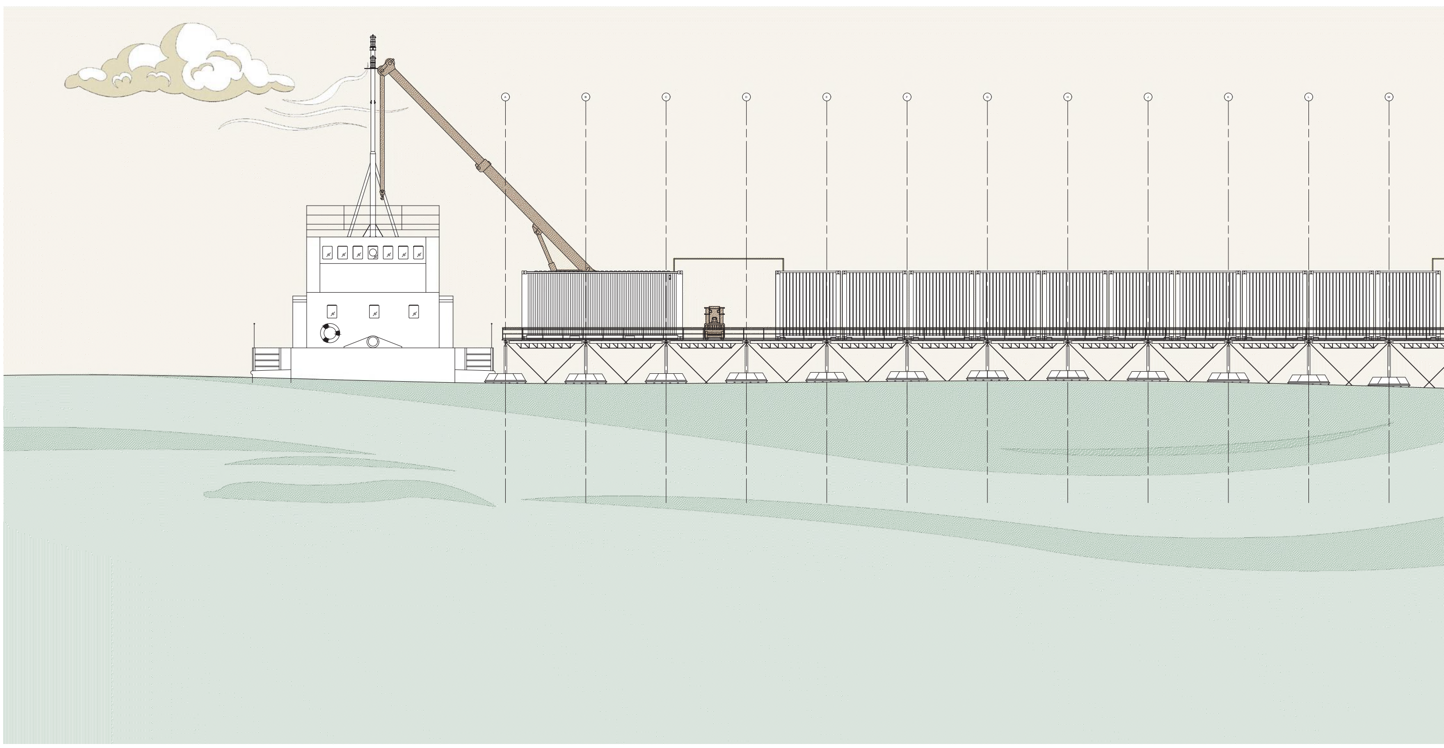
CONTEXT (CONT.)
These numbers are low when compared to The Ocean Cleanup's world data. The urgent locations globally for riverine plastic pollution are as follows:

1. The Tullahan River, Philippines, emits 13,450,200 kg of plastic per year into the Manila Bay and then to the South China Sea.

2. The Ulhas River, India, emits 13,432,900 kg of plastic per year into the Arabian Sea and then to the Indian Ocean.

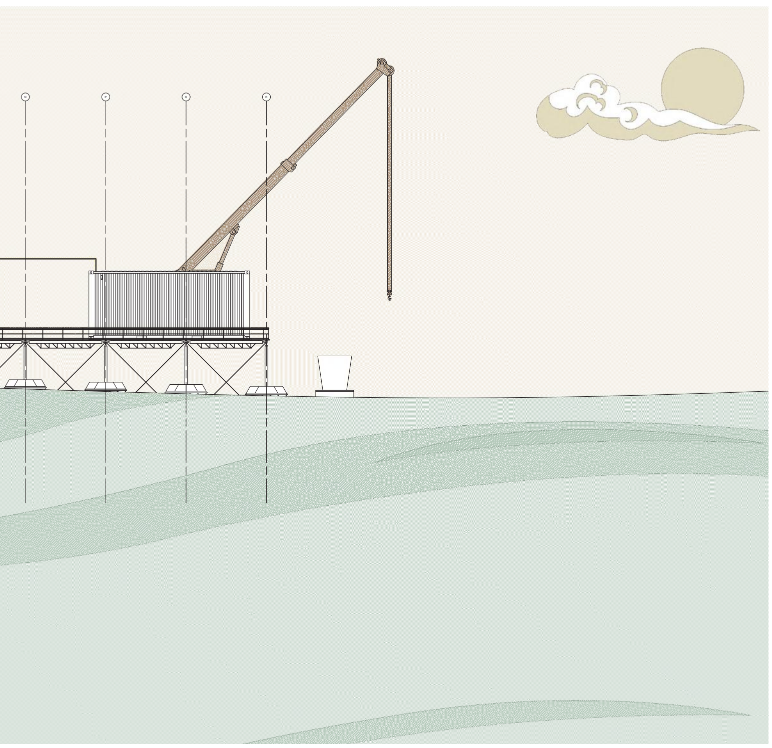
3. The Klang River, Malaysia, emits 12,816,000 kg of plastic per year into the Indian Ocean.

Note: McMurtry, M. M. (2022, April). *The Main Hub: Structural Plan.*



Scale = 1:200

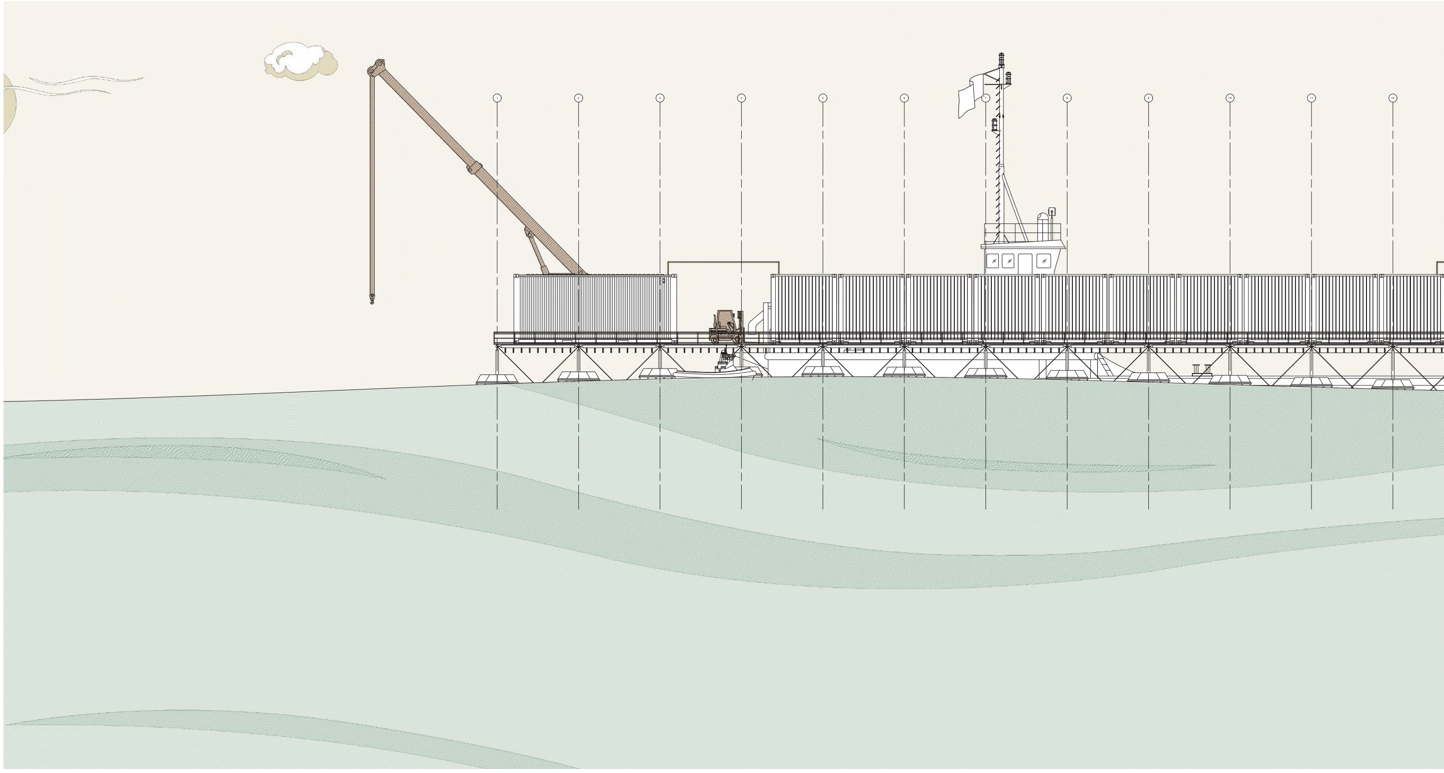
FIGURE 66
Elevation 'A' of The Main Hub, (2022, April)



OBSTACLES

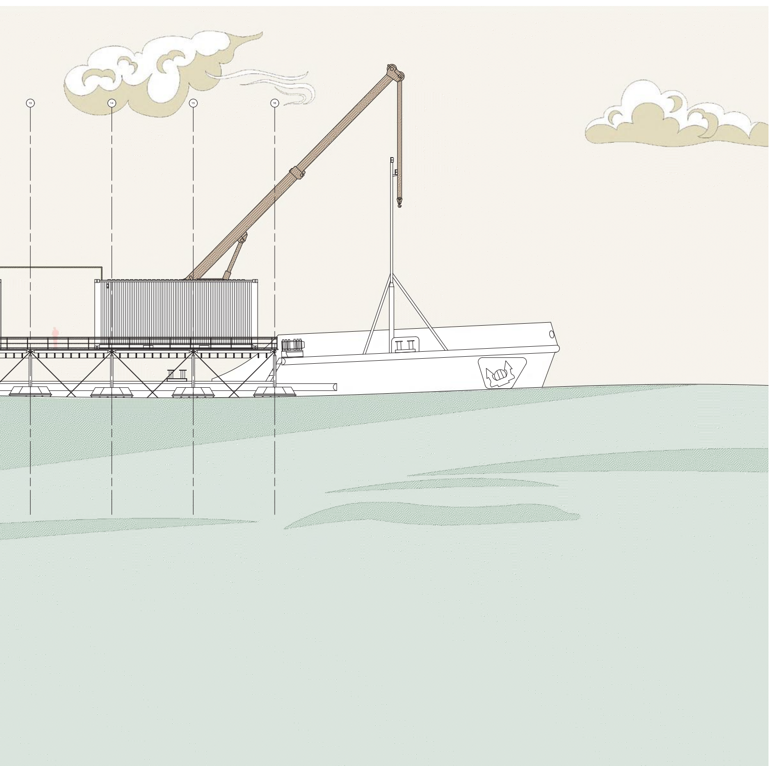
Although algae bioplastics can ensure a circular economy, it comes with certain obstacles. Harvesting algae must be done in a controlled environment. Algae can quickly spread and destroy other species and habitats. Additionally, algae's many potentials (food supplement, oil alternative, raw material potentials) can compete with the agriculture industry, lumber industry, and oil industry. This can become a potential drawback as it can strain the global economy of its high demand.

Note: McMurtry, M. M. (2022, April). *The Main Hub: Elevation 'A.'*

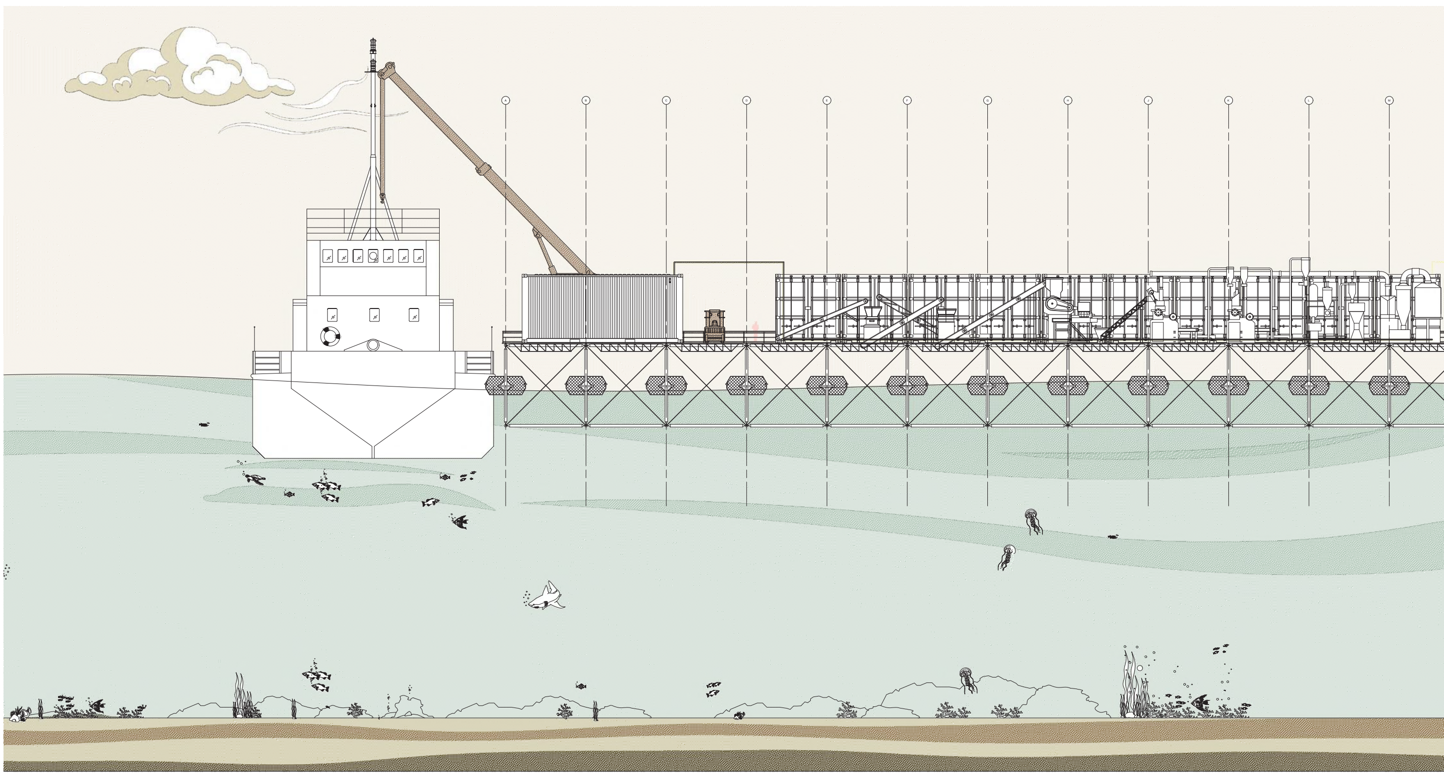


Scale = 1:200

FIGURE 67
Elevation ‘B’ of The Main Hub, (2022, April)

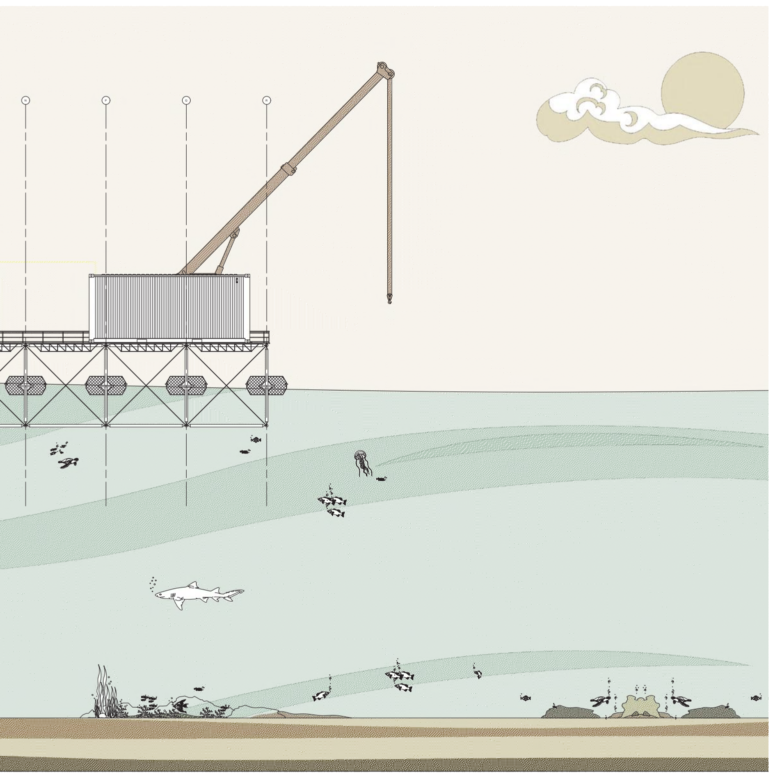


Note: McMurtry, M. M. (2022, April). *The Main Hub: Elevation ‘B.’*

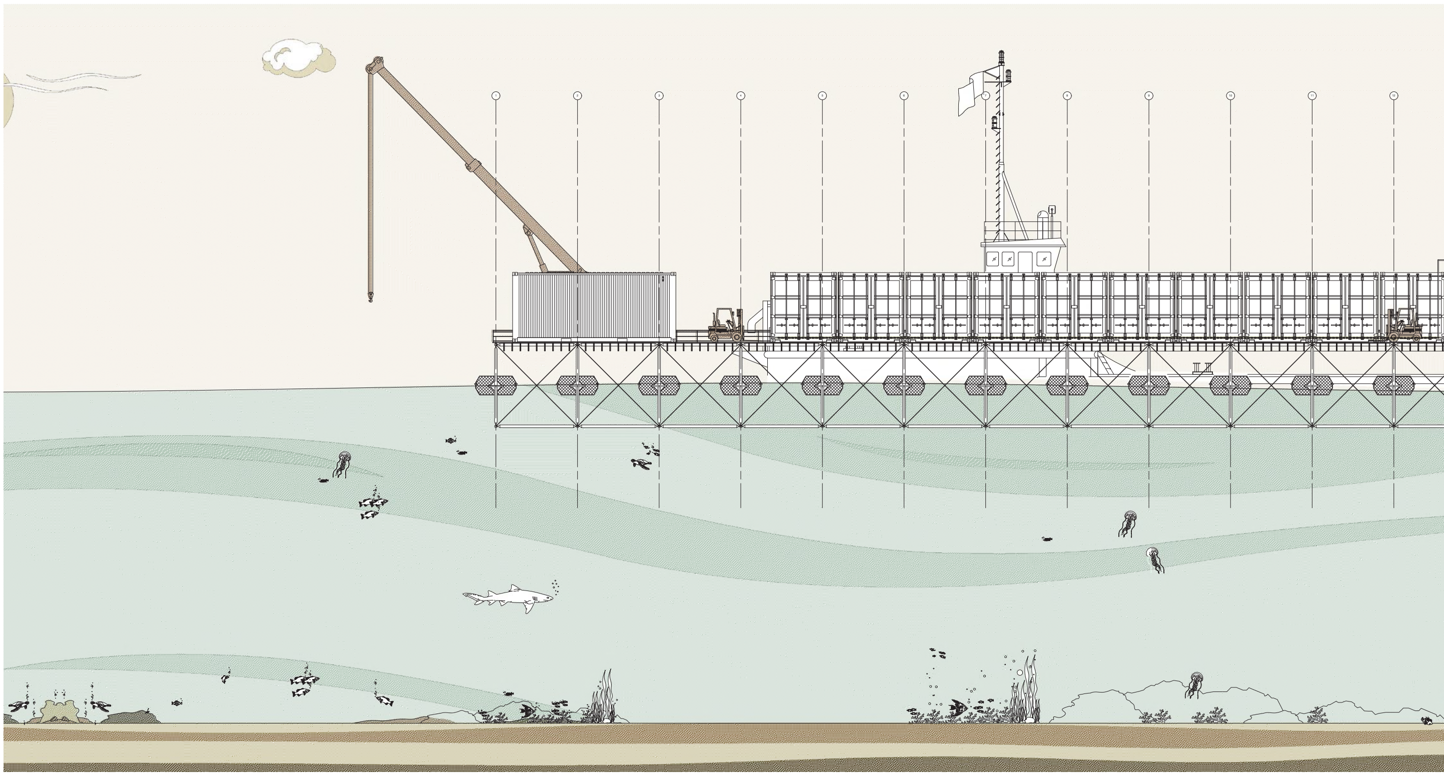


Scale = 1:200

FIGURE 68
Section '1' of The Main Hub, (2022, April)

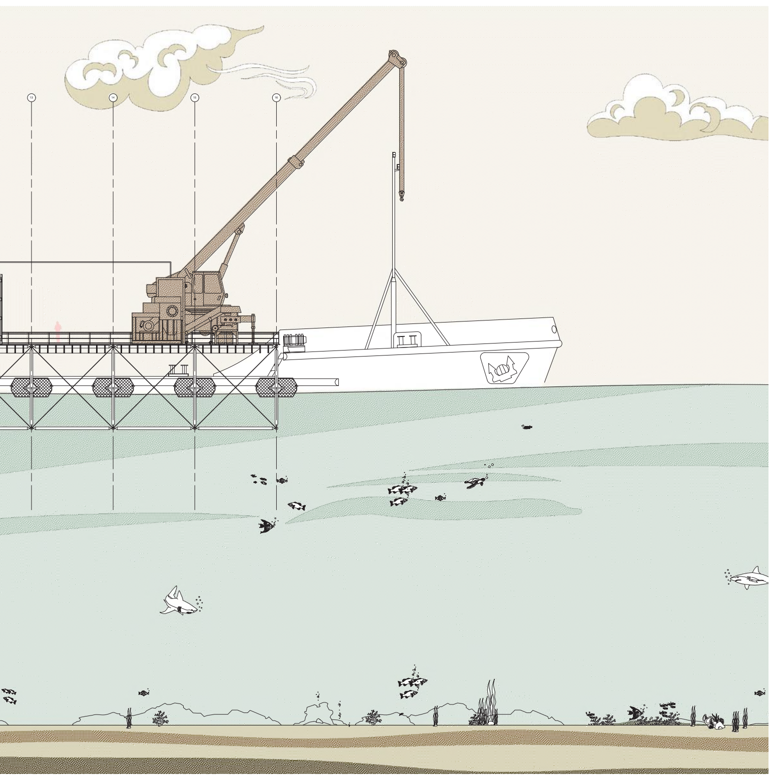


Note: McMurtry, M. M. (2022, April). *The Main Hub: Section '1.'*



Scale = 1:200

FIGURE 69
Section '2' of The Main Hub, (2022, April)



Note: McMurtry, M. M. (2022, April). *The Main Hub: Section '2.'*

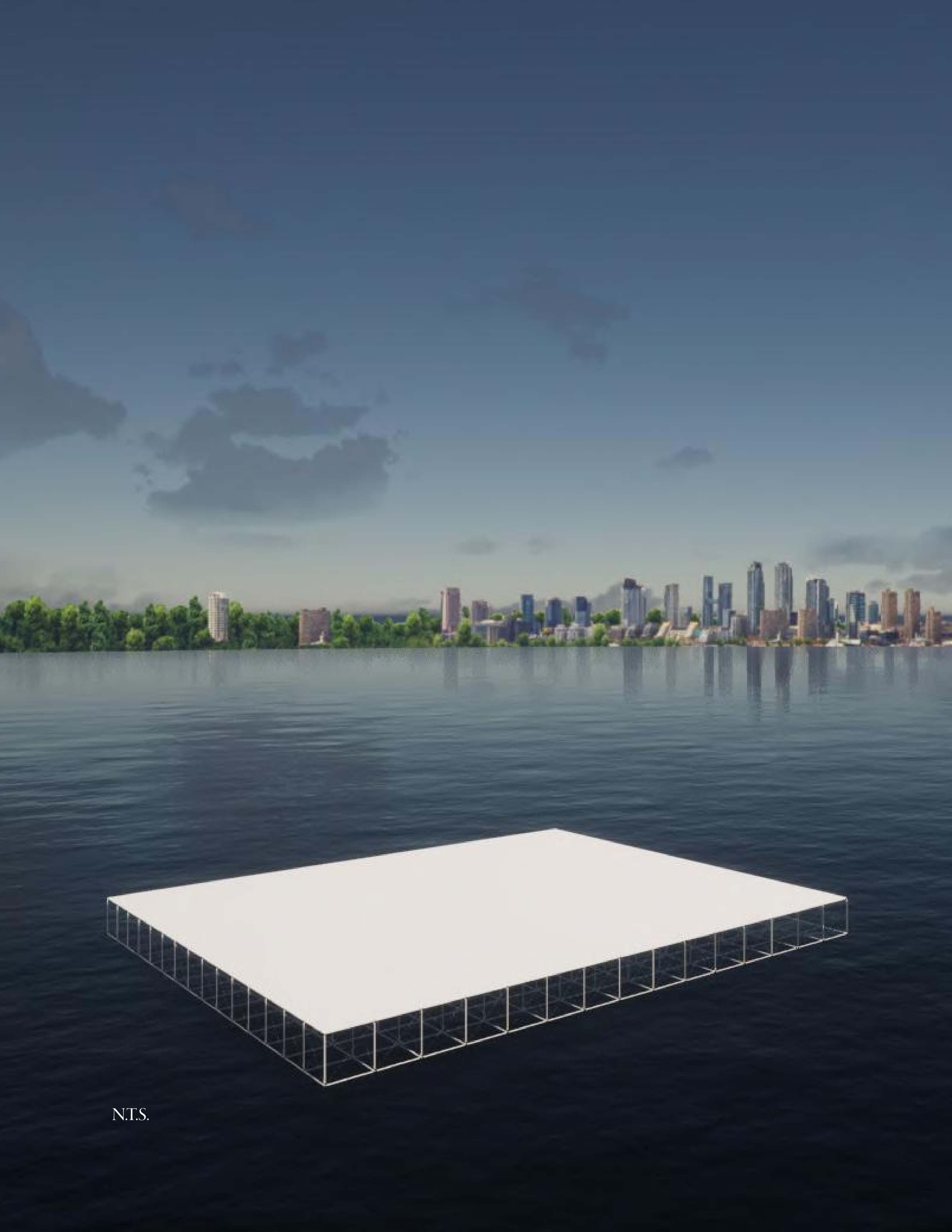

N.T.S.

FIGURE 70
Both the Gather Hub and Main Hub together, (2022, April)

Note: McMurtry, M. M. (2022, April). *Both Hubs: Exterior View.*

Design Scope

The design of the Hubs are simple yet complicated due to its many details that allow for it to perform efficiently in a wide variety of potential uses. The overall concept is simple: collect plastic and recycle it into a bioplastic. The structure of both the Gather Hub and Main Hub reflects simplicity in its modular design and complexity in its process to recycle the plastic waste.

APPROACH

The modular design of both Hubs is intended to maximize space, natural energy resources, and ease of deployment into rivers and oceans. The rectangular shape of the Gather Hub maximizes the efficiency of the space required to house the operations of the collection storage, recycling machinery, and packaging. Its narrow design allows for it to be launched into rivers with narrow channels. The rectangular grid creates a stiff structure that can withstand the forces of strong winds and waves. Its stackability allows for vertical expansion and limits its footprint of the water.

DESIGN SCOPE

SUSTAINABLE FEATURES

The Hub will be fully powered using 100% renewable energy sources such as wind, wave, and solar energy. The Gather Hub will harness enough sunlight using PV film wrapped on the PBR system to power all electric loads. It will also use skylight openings to allow for natural daylight. The Main Hub will also use flexible PV film to wrap around the encasing of the PBR system. This will maximize the sunlight and act as an extra barrier of defence for accidental damage or leakage as the film is quite resistant to tear. Additionally, the Main Hub will have columns that move up and down using the power of waves. This will generate power that can be used for the operation of machinery on-site. These columns will also be equipped with wind turbines to collect additional power if necessary.

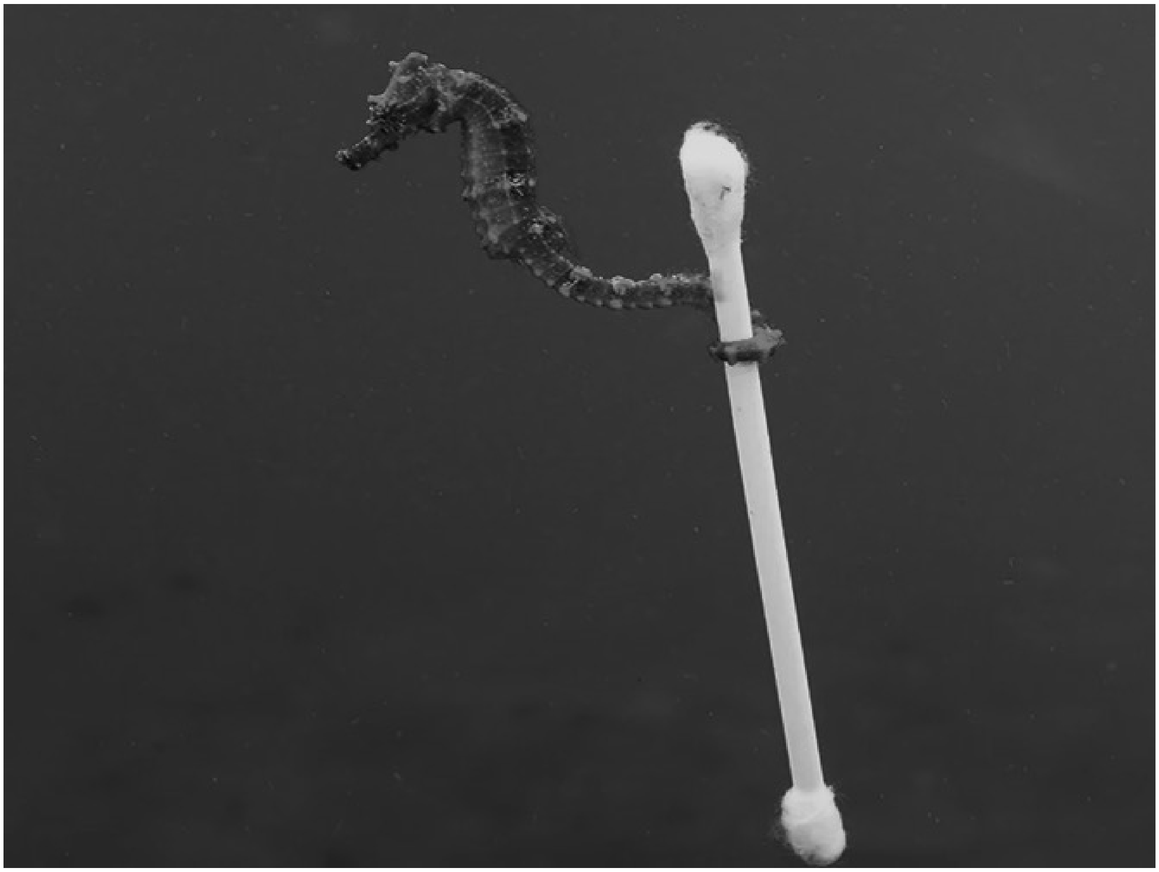
PURPOSE

The purpose of the Gather Hub is to clean plastic pollution in rivers and for the Main Hub to further recycle the collected plastic sustainably, all while creating awareness of the plastic problem. The vision of the Hub is to actively engage in the plastic pollution crisis by cleaning rivers of the debris that threatens habitats, health, and the environment. The Hub's exposed process of recycling will help start the conversation about alternative and emerging technologies that can be scaled for mass recycling. Similar to The Ocean Cleanup, it is a simple idea that can grow into many practical applications.

The design of the Gather Hub is simple yet elegant. The façade celebrates the circular process of microalgae. It is visible from the exterior and provides a positive impression when navigating a river. The interior is just as exposed, creating a transparent learning environment for the overall recycling process.

The Hub is a floating space with a meaningful impact. It can be retrofitted depending on the location and requirements of the area. It can be used in a fleet of Hubs to clean up a large area of mishandled plastics in the water. Its presence also raises awareness of the plastic recycling industry and the plastic pollution crisis in a tangible and compelling way.

FIGURE 71
Seahorse holding onto a cotton swab, (n.d.)



Note: [Photograph of Seahorse Holding Onto A Cotton Swab]. (n.d.).
Retrieved from https://www.thetravel.com/the-great-pacific-garbage-patch/222/

CONCLUSION

The global recycling system currently in place is not sustainable. Immediate action is required as the climate crisis continues to worsen. Only one-tenth of what is disposed of in a recycling bin makes its way into a circular economy and returns in another form of lesser quality. When China banned the import of waste in 2018, it was an alarming wake-up call. We simply do not have the infrastructure to deal with the amount of plastic waste that we produce. The technologies are there, but many of them are too expensive, such as the promising Chemical Recycling process. This is where recycling using genetically modified algae can help fill the void.

Algae can grow ten times more quickly than land-based plants and requires only a tenth of the space to produce an equivalent amount of biomass. In addition, some algae contain a substance called polyhydroxy-butyrate (PHB), which is a polymer that can be used to replace polypropylene. This can greatly improve the recycling system and the amount of time it takes for bioplastics to decompose.

The purpose of the Hub is to collect plastic waste from waterways and to safely recycle it in a way that does not harm human health, sea life or ecosystems. The Hub aims to clean up the existing pollution in areas with the highest concentration of plastic waste. It is a floating mechanical structure that consumes, digests, and excretes raw, renewable plastic material. From there, the bioplastics can be sent to plastic distributors and factories to replace virgin plastic materials for manufacturing goods.

The design of the Hub is made to allow it to work in conjunction with nature using the natural currents of a river. It is powered using PV film, wind turbines, and wave turbines. The natural energy is used to keep the internal operations of the Hub functioning at optimal performance. The Hub can easily be situated in the majority of rivers, lakes, and along city shorelines.

Glossary

Term	Definition
CO^2	Carbon dioxide
GHG	Greenhouse gas
GMO	Genetically modified organism
GPGP	Great Pacific Garbage Patch
HDPE	High-density polyethylene
IPCC	Intergovernmental Panel on Climate Change
kWp	Kilowatt-peak
LDPE	Low-density polyethylene
NTS	Not to scale
MWp	Megawatts-peak
O^2	Dioxygen
PBR	Photobioreactor
PET or PETE	Polyethylene terephthalate
PHB	Polyhydroxybutyrate
PP	Polypropylene
PS	Polystyrene
PV	Photovoltaics
PVC	Polyvinyl chloride
RIC	Resin identification code
WTO	World Trade Organization

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FIGURE 72
Recycled plastic made into raw microplastic pellets, (2021, July)

Note: The Ocean Cleanup. (2021, July). *How it started vs. how it's going*. Twitter. Retrieved from https://twitter.com/TheOceanCleanup/status/1410620225540837376

APPENDIX A
FALL 2021 RESEARCH

SUZANNE SIMAR

- Networks of forests characterized by fungi and roots facilitate co communication and interaction between trees and plants of an ecosystem.
- Within the communication between trees and plants is the exchange of carbon, water, nutrients and defence signals between trees.
- Birch and Douglas fir share carbon. Birch receives extra carbon from Douglas firs when the birch trees lose their leaves. Birch trees supply carbon to Douglas fir trees that are in the shade.
- Mother trees (Hub trees) are the largest trees in forests that act as central hubs for vast below-ground mycorrhizal networks.
- A mother tree supports seedlings by infecting them with fungi and supplying them with the nutrients they need to grow.
- What role do Mother Trees play in forest regeneration?
- What seedling mixes work best for forest regeneration?
- How does the size, number and distribution of trees retained (left uncut) at a harvesting site impact forest regeneration?
- How is the forest carbon budget affected by various harvesting and
- regeneration treatments?
- How is biodiversity (animals, plants, fungi, bacteria) affected by various?
- harvesting and regeneration treatments?
- What are the ecological processes that drive these responses?

KISS THE GROUND (NETFLIX DOCUMENTARY)

- Erosion from plowing and tilling.
- Reduce tilling and spraying of pesticides and other chemicals.
- Carbon is key for regeneration.
- Carbon dioxide is absorbed by plants and goes into the ground.
- Glyphosate (RoundUp) is used most heavily in corn and water to kill microbes in the soil but it also kills them in the body.
- Moisture must leave through the plants to cause humidification and more rain.
- Cover the land with plants and the temperature fluctuates are very mild when compared to bare soil (high and low temps).

APPENDIX A
FALL 2021 RESEARCH

- Drawdown means reducing carbon emotions per year using no-tilling machinery, cover crops, animal grazing on plants, and crop/animal grazing rotation.
- Free-roaming cattle, goats, and chickens can richen the soil and stomp down the plants to pack the carbon into the soil.
- Three days of grazing followed by 6-9 months of no animals on the land to regenerate it.
- Grass-fed land birds will be attracted.
- Regeneration Agriculture has 4 practices:
    1. No-till
    2. Cover crops
    3. Perennials + trees
    4. Compost/mob grazing

DIRT! THE MOVIE (NETFLIX DOCUMENTARY)

- Mud-made homes (reduce transporting mud off-site).
- Earth structures (processed straw adding an enzyme to the manure and it dries with incredible hardness).
- Mud compared to cement is warm in the winter and cool in the summer
- Vandana Shiva (Indian activist).
- The first 5” of dirt (the thinner the soil, the more important it is to have perineal roots to protect that soil).
- Mountain tops filled with heavy metals and lead are now exposed due to mining and explosions these metals are now free to get out into the watershed.
- Microbial fuel cells powered by soil to turn landscape lights on.

TYPES OF PLASTIC

- Toxic, Commonly Recycled, 36% recycled annually, 5-10 years decompose under perfect conditions: Polyethylene terephthalate (1: PET or PETE). Commonly used in commercially sold water bottles, soft drinks, sports drinks, and condiment bottles.
- Low Toxicity, Commonly Recycled, 30-35% recycled annually, 100 years decompose under perfect conditions: Polyethylene (high density) (2: PE-HD or HDPE). Commonly used in milk and juice bottles, detergent bottles, shampoo, grocery bags, and cereal box liners.

APPENDIX B
WINTER 2022 RESEARCH

- **High Toxicity, Sometimes Recycled, <1% recycled annually, never decomposes:** Polyvinyl Chloride (3: PVC). Can be flexible or rigid and used for plumbing pipes, clear food packaging, shrink wrap, children's toys, tablecloths, vinyl flooring, mats, and bandages.
- **Low Toxicity, Sometimes Recycled, 6%, 500-1000 years: Polyethylene (low density) (4: PE-LD or LDPE).** Dry cleaning bags, bread bags, produce bags, garbage bags, "paper" milk cartons, and hot/cold beverage cups.
- **Low Toxicity, Occasionally Recycled, 3%, 20-30 years:** Polypropylene (5: PP). Yogurt containers, deli food containers, furniture, luggage, winter clothing insulation.
- **High Toxicity, Commonly Recycled but difficult to do, 34%, 50 years:** Polystyrene (6: PS). Also known as Styrofoam, take-out containers, supermarket meat trays, and packaging.
- **High Toxicity, Difficult to Recycle, low, majority of these plastics never, polylactic acid: 6 months:** Bisphenol A and others (7: O). Any plastic item not made from the above six gets lumped together as #7 plastic. Things like fibreglass, acrylic, nylon, polylactic acid, BPA, BPS, CDs, baby bottles, headlight lenses, etc.

QUESTIONS TO ASK
- How does plastic need to be re-framed (though of)?
- Why does the plastic industry promote beach cleaning and recycling and what real difference can they make?
- What should governments do and what should be left to the market?
- What role for lifestyle campaigns?

RETHINKING PLASTIC
1. **Reduce plastic production & consumption** (to cut plastic pollution at source).
   - Rethinking our relationship with plastics
   - Cut down on virgin plastics
   - Think about our plastic footprint
2. **Redesign plastic products** (to make the circular economy come true).
   - Disposability is a design flaw
   - Fully recyclable

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- Producer accountability
- Toxic-free
- Better traceability
- Ownership service
- Incorporate recycled plastics

3. Improve plastic waste management (to end landfill, incineration and leakages of plastics into the environment).

- Incentives
- Technologies
- Re-purpose
- Re-use
- Deposit schemes
- Sorting
- Collecting

JAPAN'S RECYCLING SYSTEM

- Container and Packaging Recycling Act.
- Manufacturers and businesses entities using containers and packages have to pay a recycling fee to the JCPRA (Japanese Container and Package Recycling Association), in accordance with the volume they manufacture or sell.
- Each year, recycling business entities are selected by public bidding in every local municipality where a waste storage site is located. They are assigned to collect and transport the waste from storage sites to recycling facilities. To make sure the waste is getting recycled, these recycling business entities receive payment only after showing a delivery report, signed by the recipients of the recycled products.
- If an item was disposed of improperly, a large red warning sticker is put on the offending rubbish bag to shame the person responsible. It is then sent back to that person's house.
- Recycling organization:
  - Glass bottles, no colour
  - Glass bottles, brown
  - Glass bottles, other
  - PET bottles
  - Paper

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  - Plastics
  - Aluminum
  - Steel
- Thermal recycling and a charging system.
- Strict compliance and scheduled collection calendar (ex: plastic must be cleaned with all labels removed, cartons folded to minimize space, and labels of household data to ensure that individuals assume full responsibility and comply with all rules. Furthermore, no garbage cans on the city streets because each individual is responsible for processing their waste at home).

Source: https://cen.acs.org/environment/recycling/years-dabbling-Japan-serious-plastics/99/i38

GERMANY’S RECYCLING SYSTEM
- The Green Dot creates the first duel recycling system in the world for collecting waste from households and businesses.
- It is funded by industry and waste costs are dependent on the weight of a product that companies make. This collab has led to the recycling rate increasing from 3% to 56%.
- Retailers are responsible for promoting the use of eco-friendly products.
- Sorting: plastics (yellow bin), paper and cardboard (blue), clear glass (white), coloured glass (brown), green glass (green), and the sixth bin is for food waste or organic waste.
- Bottled drinks have a deposit and it is refunded once the empty bottle is returned to the food store or automated machines.

AUSTRIA’S RECYCLING SYSTEM
- The country has a blanket ban on certain waste types going to landfills.
- Any product that has a total carbon emission rate of more than 5% is banned, which ends any packaging from ending the landfill.
- Like Germany, Austria Operates a producer responsibility model.

SOUTH KOREA’S RECYCLING SYSTEMA
- Previously, privately-run companies collect the waste and sell it for profit until China, the economic superpower, banned the import of plastic waste.

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- Ban of both coloured plastic bottles and PVC.
- Phase-out of disposable cups and plastic screws.
- Reduction of waste paper imports.
- Bags have prices for recycling certain wastes.
- Just as in Switzerland, bags for recycling organic waste have a special price that is used to fund the recycling process, they are biodegradable.
- The bags are deposited in automated bins that weigh food waste.
- To use the bins, residents are required to identify themselves using an ID card.
- The bins then charge the residents based on the amount of weight they deposit. The more you deposit, the more you pay. Thus, the country has managed to cut food waste from 130 kilos per person per year to less than 11.
- The organic waste collected is used to produce biogas to fuel power plants, crop fertilizers and livestock feed.

Source: https://www.bbva.com/en/sustainability/5-best-recycling-practices-from-aro und-the-world/

WALES RECYCLING SYSTEM

- Both people and businesses have similar rules on what can and can't be recycled.
- Ban on a range of single-use plastic items.
- Its a success is from the structure of 3 strategies: provide citizens with easy access to a simple and efficient recycling systems, a comprehensive awareness-raising campaign focusing on the 3Rs (Reduce, reuse, recycle) approach and a policy agenda envisaging incentives and taxation measures.

SWITZERLAND'S RECYCLING SYSTEM

- Households and businesses pay for any non-recycling waste they produce.
- Bin bags for landfill waste are also taxed.
- Recycling points are set up across the country and typically found at supermarkets to recycle aluminum cans, light bulbs, paper, and electronic products.
- Extremely successful for sorting and reusing waste.

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2022 RECYCLING STATISTICS

- Canadian’s throw out around 3.3 million tonnes of plastic each year.
- Over 2 million tonnes of plastic end up in landfills.
- Mechanical recycling is prevalent in Canada. This type of recycling consists of shredding the plastic, melting it down, and then using it to create new products. However, this technique is difficult to implement because the materials must first be sorted and cleaned.
- Canadian’s generate 673 kilograms of waste per year per person which makes us the largest producers of waste in annual waste per capita.
- 12% gets shipped from Canada to overseas, mainly to Southeast Asian countries where most of it is burned or reenters the environment.
- Over 2 million tonnes of Canadian plastic waste ends up in landfills according to Oceana data from 2019.
- Nestle, Tim Hortons, Starbucks, McDonald’s and The Coca-Cola Company (in order) are the top 5 companies that claim 39% of the plastic pollution according to Greenpeace.

Source: https://reviewmoose.ca/blog/recycling-statistics/#:~:text=Top%2010%20Recycling%20Statistics%20for%202022&text=Canadians%20throw%20out%20around%203.3,plastic%20end%20up%20in%20landfills

STATISTICS PUBLISHED BY THE GOVERNMENT OF CANADA

- 80-90% of marine litter is plastic (source).
- Microplastics are small plastic particles less than or equal to 5mm in size.
- In 2016, about 29,000 tonnes of plastic waste was littered into our environment in Canada (equivalent to the weight of 300 Blue Whales).
- Close to 10,000 tonnes of plastics enter the Great Lakes every year from Canada to the US.
- Over the last 25 years, nearly 800,000 volunteers have removed over 1.3 million kilograms of trash across Canada’s shorelines through the Great Canadian Shoreline Cleanup.
- Canada is managing plastics is based on a “take-make-waste” model. We extract resources, make products and then throw them away.

Source: https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/reduce-plastic-waste/need-action.html

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3D PRINTERS FOR MRFs

- 3D printers can make recycling materials more efficiently and decentralize the production of large industrial plants with cleaner energy consumption.
- The circular economy revolution. The symbol of this new era is the 3D printer.
- With a 3D printer, the technology can reuse materials that would traditionally end up in a bin and promote the non-linear economy.
- Example, the traditional method of manufacturing a car involves hundreds of raw materials. Today, a 3D printer can make up to 80% of a car with recycled plastic.

Source: https://bluevisionbraskem.com/en/innovation/3d-printers-can-drive-economic-sustainability/

AI REYCYCLING FOR MRFs

- Humans can sort between 30-40 recyclable items per minute whereas a robot can sort between 70-80 recyclable items per minute.
- What other environmental impacts can be considered apart from energy and carbon emissions when comparing primary and secondary material production?
- In July 2017, China changed the rules of the international recycling game. In a meeting held by the World Trade Organization (WTO), in Geneva, the Chinese government announced that it would drastically reduce the import of solid waste, especially plastic and paper. Importing waste was a good business, but with environmental and social costs getting increasingly higher.
- Southeastern Asian countries such as Malaysia, Thailand, Vietnam, Indonesia and India received part of the waste, but China's message spread over the entire continent: no one else wanted to be the world's landfill.
- The United States faced the biggest challenge: they have a population of about 330 million people with an average generation of nearly 1,200 kilos of waste annually per person.
- 75% of this waste is recyclable: it is an economic opportunity.
- RoCycle developed by MIT and Cortex created by AI company AMP Robotics announced precision rates of about 90% at screening.
- A machine developed by the Canadian company Machinex, uses an optical mixer and infrared light and a system of chains and magnets is able to sort up to 3,000 recyclable objects per minute but fails when it comes to precision.

Source: https://bluevisionbraskem.com/en/innovation/artificial-intelligence-and-robots-may-solve-recycling-crisis/

REGENERATIVE ARCHITECTURE

Plastic Biodegradation & Bioplastic Production Algae Farm

by

Montana Morand McMurtry