circulate

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Group 12: Climate Change and Pollution

Executive Summary

Climate-induced flooding is causing a huge displacement of people in developing countries. In 2041, people will need to adapt to life on water due to insufficient habitable landmass. This report uses foresight techniques such as STEEP to discuss social, technological, economic, environmental, and political factors that in turn contribute to this projected 20-year scenario.

The most significant findings from the initial literature review showed that there will be no infrastructure to deal with future waste. Furthermore, the isolation of communities on water only worsens the communities' problems regarding access to clean drinkable water, food security and energy supply. It was important to define what the future of waste would be, and possible emerging techniques that could utilise waste as a resource in the scope of a 20-year timeline. The research found that communities in NICs and LEDCs would be mainly outputting organic waste by 2041.

Following on from the research section, fieldwork, expert interviews and evaluation techniques were conducted to validate concepts in more depth. A service system is proposed to address the unique design engineering opportunity of designing a new waste management system on the water. Furthermore, for the scope of this project, the place in which this system would be implemented first would be Thailand with the prediction to next expand to similar climates in south-East Asia and a projection to be globally adaptable in the future beyond 2041.

This portfolio presents that a product service system, called Circulate, to address the circularity of waste management in this community must also address the water, food, and energy scarcity using organic waste as a resource.

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Special Thanks

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The Problem

Climate Change

Even if climate change mitigation is successfully implemented now, in 2021, sea levels will continue to rise. Under a high emission projection, it is indicated that up to 630 M people will live on land below the projected annual flood levels for 2100 (1). This means by 2041 people will need to start adapting to life on the water.

The overarching topic of this project is the effect of global climate change and its implications on the circular economy of waste in 2041. More specifically looking at future scenarios in less economically developed countries. This is crucial as studies reveal that tens of millions of people in the developing world are likely to be displaced by sea levels rising within this century (2).

What will be addressed?

How a circular economy of waste is successfully implemented in developing communities that are vulnerable due to flooding. Discussed are contextual analyses of the predicted environment for 2041, the main problems that these communities will face in 2041, what a circular system design will need to solve in this scenario and finally how such a system will work and be integrated into a community.

The diagram below outlines the predicted timeline from 2021 to 2041 in which our product service system will be implemented.

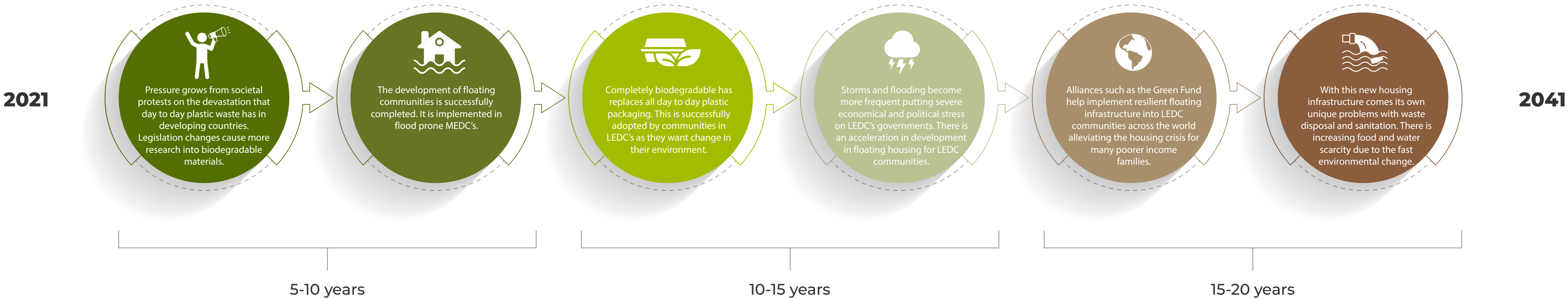
In 2041

The world is in a volatile condition regarding climate change, so there is a necessary design engineering opportunity to intervene in places that will suffer the most. In less economically developed countries climatic unpredictability is causing weather extremes; sea-level rise, salinisation of soil and water, storms, and floods.

By 2041, with the current climate scenario, it is predicted that climate-induced flooding and weather extremes will displace between 300-700 million people (3). This means that a transition to floating communities was a necessity for their survival.

Furthermore, day to day plastic waste is a thing of the past, it has been replaced by organic biomaterials to reduce the devastating plastic pollution in NIC and LEDC communities. This means there is an abundance of organic waste resources that need to be dealt with. People have safe communities on the water to live in however there are still pressing concerns over food security, access to clean water and energy, and proper disposal of organic waste.

Floating Homes in a Rural Village in Thailand



Growing Trend Analysis

Coastal displacement due to sea-level rise and flooding is predicted to increase to affect hundreds of millions of people worldwide over the next century (3). This will create significant economic, humanitarian, and national-security challenges.

Environmental

Significant land loss and flooding of low-lying coastal areas are already occurring in developing countries across the world (5). A major environmental impact from flooding is the destruction of food sources, such as rice, due to high-velocity water flows (6). This has serious implications for food security in the future as rice is the predominant staple food for at least 33 developing countries (7).

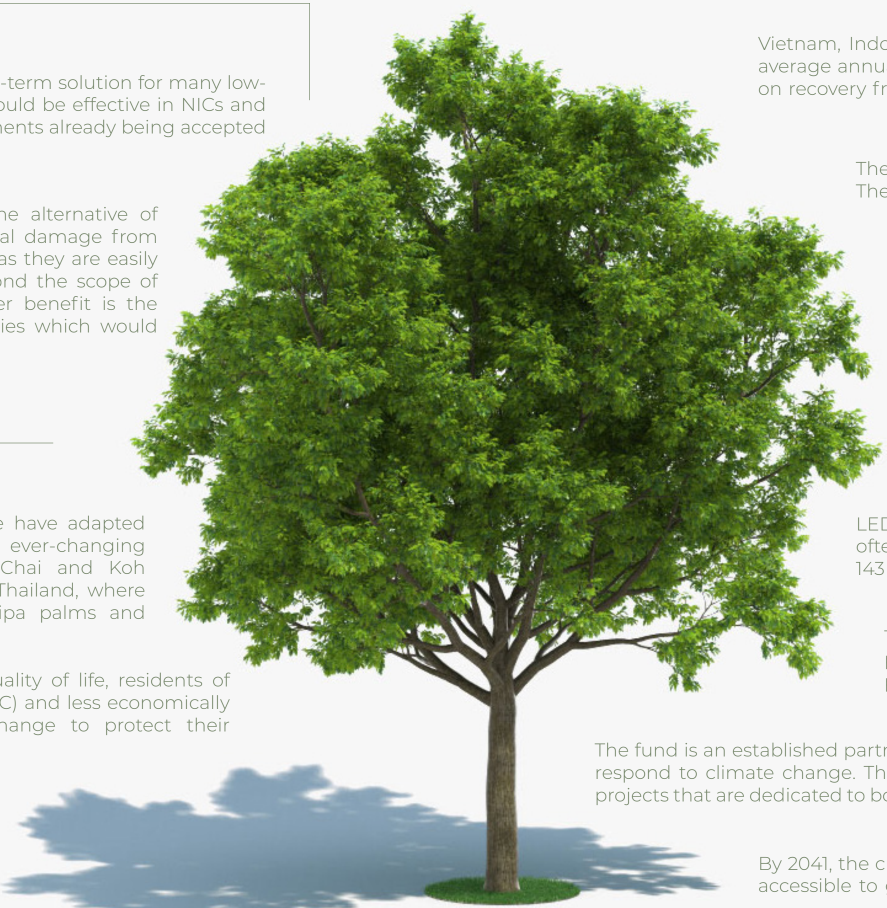
Contaminated floodwater can pollute rivers, water sources and subsequently food chains. This causes a detrimental effect on human health as the rate of infectious diseases and epidemics rapidly after extreme flooding events (8).

Flooding increases the amount of plastic in water systems by 10 times compared to non-flood conditions and in the worst affected areas, "plastic mobilisation increases up to five orders of magnitude" (9). Plastic pollution has been found to significantly affect local economic activities (10). The tangible negative direct day to day impact on people's quality of life from plastic pollution will become more prevalent as flooding increases. This shows that future communities will be more likely to adopt the use of plastic packaging alternatives to reduce the amount of plastic waste ending up in their water supply.

Technological

Floating architecture is seen as an effective long-term solution for many low-lying coastal areas all over the world (11). This would be effective in NICs and LEDCs due to the long history of floating settlements already being accepted and adopted into society.

Floating communities would be safer than the alternative of building on land and risking frequent structural damage from floods. Furthermore, they are more sustainable as they are easily adaptable to needs and the environment beyond the scope of a 20-year climate prediction. Moreover, another benefit is the possibility to safely construct dense communities which would allow for far more efficient energy usage (12).



Social

For centuries, people all over the world people have adapted communities to live on the water in their ever-changing environments. For example, the Baan Koh Chai and Koh Panyee settlements in southern and northern Thailand, where communities live in stilted houses among nipa palms and mangroves (13).

Undeterred by a climate-induced decline in quality of life, residents of floating communities in, newly industrialised (NIC) and less economically developed countries (LEDCs) are open to change to protect their settlements of cultural heritage (14).

Research findings demonstrate that despite people's tradition of perseverance and willingness to adapt, their capacity to do so will be too slow (15), making them the most vulnerable group to climate-induced flooding.

Economic

Vietnam, Indonesia, and Thailand consist of most people on land projected to be below average annual coastal flood levels by 2050 (15). Currently, investments are heavily focused on recovery from flooding related disasters instead of enabling the innovation required to protect and adapt to climatic variability (16).

There will be an exponentially increasing price of access to safe drinking water. The World Commission on Water estimates that by 2025, one half of the world's population will live in conditions of severe water stress (17).

Predicted protective measures for coastlines and land could cost countries trillions of US dollars per year (18). LEDCs cannot afford such measures and physical damage to buildings and infrastructure will be sustained. This means large land areas will be sacrificed, causing a crucial economic drive for reform of investment policies to focus on capacity building and implementation of floating and amphibious infrastructure (19)

Political

LEDC's effectiveness in responding is often short-lived as political instability is often exacerbated by climate-induced disasters (20). This will lead to more than 143 million people being driven from their homes by conflict over food and water insecurity and climate-driven natural disasters in 2050 (21).

The Netherlands' response to flooding can provide imperative flood preparedness for developing countries around the world. Smart innovation paired with initiatives such as the Green Climate Fund so far has helped build resilience for an estimated 350 million people worldwide (22).

The fund is an established partnership between over 190 countries that sought to help developing countries respond to climate change. The fund has raised over $10 billion since 2014 and has directed resources to projects that are dedicated to both mitigation and adaptation like Circulate (23). This shows that countries are working together to combat climate change on a global scale.

By 2041, the cutting-edge technology being developed in MEDCs will be made even more accessible to governments of LEDC's meaning it's feasible to implement this technology into the future scenario.

Project Definition

The defined problem of great significance to address: Existing waste management systems (WMS) in developing countries won't be viable for future floating communities.

In 2019 it was reported that 90% of the waste in developing countries was burnt or left in unregulated dumps (24). For centuries MEDC's have been taking advantage of lenient environmental regulations. Furthermore, the upsurge in flooding events will increase the mobilisation of pre-existing pollutants exponentially meaning landfills will no longer be viable for any type of waste disposal (25). This is a key aspect that shows the urgency for innovation into new WMS for communities living on the water.

In environmentally damaging industries waste is exported, for example, 75% of global waste has its end of life in developing countries within Asia (26). This showed us that floating communities in south-east Asia seemed the most logical place to implement our system first. For the 20-year timeline, it made the most sense to start with a NIC (Newly Industrialised Country) as they have slightly more established access routes and familiarity with new technology. For example, emergent high-tech floating communities in IJburg, in the Netherlands could be adapted first for these climates. From research, floating communities in Thailand, a NIC, were starting to reach out for help, hence this was chosen as the geographical area to first begin implementing our concept.

The future of day-to-day disposable waste in 2021 is predominantly organic, already comprising 60% of all municipal solid waste (MSW) in developing countries (27). From the social and environmental drivers highlighted in the STEEP analysis, communities in 2041 will have effectively adopted biodegradable alternatives to day-to-day plastic waste. This is combined with population growth causing an increase in human waste, a rise in crop production which generates further food waste. All aforementioned factors mean it is feasible to assume that the main type of waste requiring disposal in 2041 will be organic.

Innovation in floating infrastructure up till 2041 was primarily focused on immediate problems, such as designing enough functional housing that could be implemented safely into the environmental conditions in vulnerable regions. This caused the development of waste disposal and collection infrastructure to be left behind causing large issues in communities. For the overall environmental, cultural, and sustainable success of floating structures, a new circular WMS will need to be devised.

Design Objectives

The Design Engineering Opportunities of Focus:

With an ambitious system design and time constraints for the project, the group decided that there were four most important design engineering opportunities that needed to be focussed on:

- Circulate must aim to solve the waste disposal problem on the water as a water-based community expands.
- Circulate must feasibly ensure resources are put back into the community to mitigate problems such as food scarcity and access to clean water and energy.
- The circulating system aims to efficiently collect organic waste to eliminate physical pollutants in the communities' surrounding environments.
- The design process must consider the human behavioural aspects of the community to deliver a seamless adoption of the system.

The key objective is to successfully integrate all these objectives into one system.

Notably, the cost of Circulate was considered at each design stage however it wasn't a central design objective. A balance between functionality and quality was of the utmost importance for the community. This was because research showed that funding within this area is extensive, with predictions for it to keep expanding. Funding is mainly from an organisation mentioned such as the green fund that is partnering together governments to help contribute to sustainable development. Furthermore, the transfer of money that is currently inefficiently spent on reactive and protective measures can put into the proactive development of technology in circular economies for water-based living.

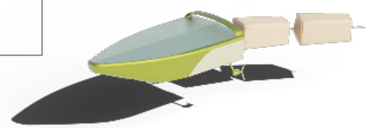
When relevant on each technical page it will be discussed where costs were considered or mitigated.

System Overview

A Waste Management System for Floating Communities

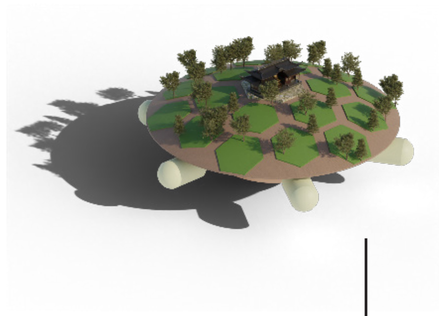
A fully circular waste management system is proposed to help the community be autonomous in terms of food, drinking water and electricity supplies.

Boat Collection



Autonomous boats spread throughout the community collect full bins automatically and transport the waste to the biocore.

Biocore



Organic waste is collected and biodegraded in the Biocore to produce drinking water, electricity, and the mycelium farm tiles for the community farm. It also acts as central community hub for socialising and cultural activities.

Homes

Inhabitatants store their waste in floating bins, waiting to be collected and transferred away. They benefit from food, electricity, and drinking water being provided through the system.

Boat Transport

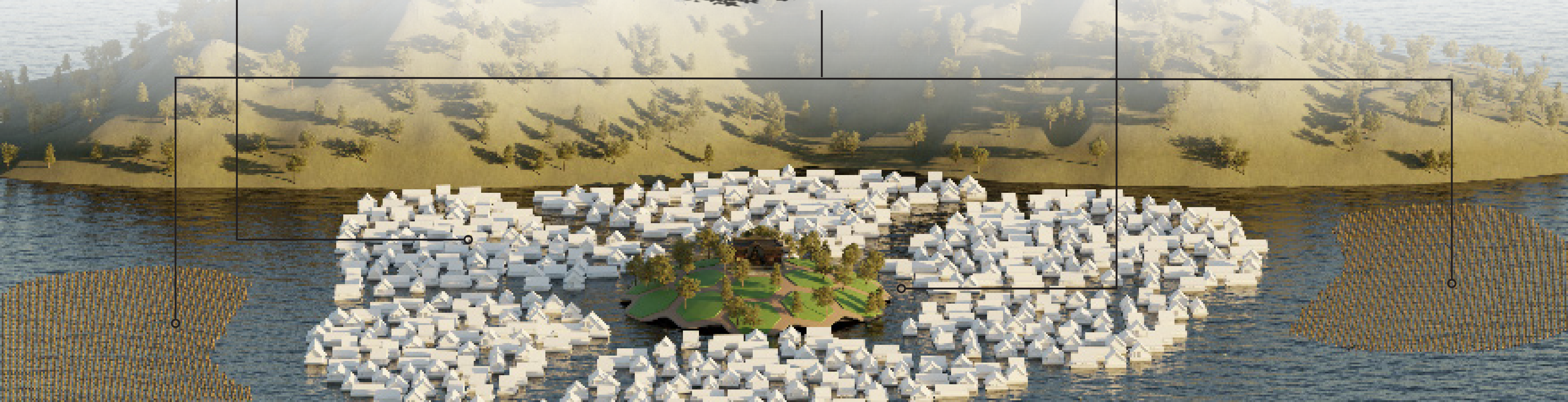
Once the lifespan of a tile is reached it gets transported back to the biocare and reintegrated into the system to be biodegraded.

Mycelium Farms

Community floating farms comprised of hexagonal mycelium tiles, made from waste, ensure food supply for the community and the ongoing circulation of valuable ressources.

Boat Transport

The autonomous boats also take on the responsibility of transporting the mycelium tiles from the biocore the farms outside of the community.



Project Validation

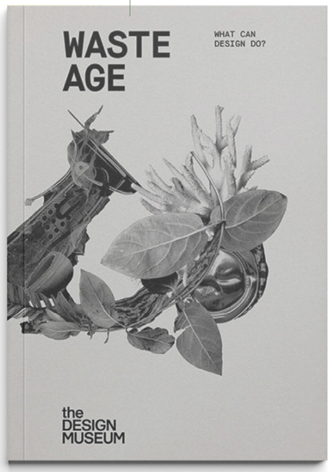
The "Waste Age"

The Circulate group went to observe the cutting-edge work showcased at the 2022 Waste Age Exhibition at the design museum in London. (28)

New generations of designers are rethinking relationships to everyday food waste and packaging. They are finding the lost value in our waste and designing a future of clean materials and a circular economy.

The exhibition showcased visionary designers who are reinventing human relationships with waste. This validated our projections from last year of the movement towards circular design innovation breakthroughs. (29)

'We must face the problem of waste – no longer ignoring what happens to our "rubbish". Instead of thinking that things can have many different lives.' - **Gemma Curtin, Curator**



New Ways of Living

For Circulate, it was necessary to come up with a solution that utilises cross-disciplinary collaboration with biotechnology and engineering.

The Circulate system is based on a future of plant-based materials that replace oil-based materials such as plastics for all day-to-day household waste.

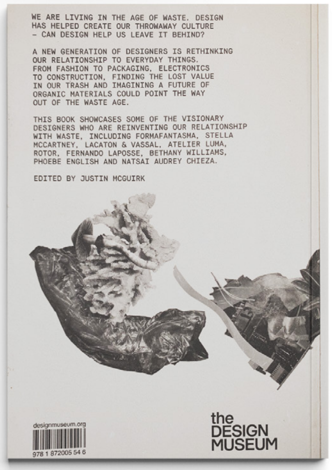
Enablers and work at this exhibit inspired the team to create a method so that nutrient rich future materials combined with food and human waste can be converted into water sources and fertile mycelium bricks for the regeneration of food sources.

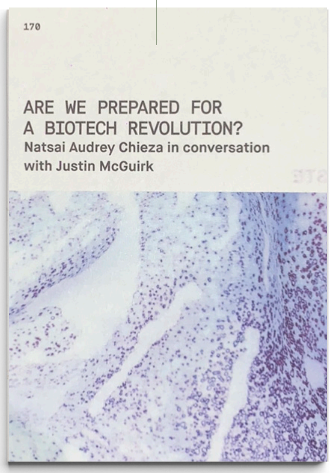
Precious Waste

Our project touches upon the subject of assigning new value to your day to day waste.

A section of the exhibition touched upon the importance of ancient wisdom and utilising millions of years of tradition and evolution in rural communities.

It is now time to throw away the 21st century notion that waste is useless and time to view it as a precious resource that has the potential to enrich community living.





Next Steps

Circulate is ready for a biotech revolution.

The next steps in the project were to:

- Define which trends in biotechnology will be adopted into our design.
- Ensuring that tradition is preserved within communities that have a strong connection to their environment.
- Encourage new thinking of viewing waste as a resource.

Technical Enablers

Over the next 20 years the following technologies are anticipated to transition to large scale commercial viability that will enable Circulate; small-scale bioreactors, combining all organic waste streams, farming on the ocean and an autonomous system in even the most rural floating communities.

Genetic Engineering

Biotech Revolution

Water Treatment

Industry 4.0

2022

Gene editing is unlocking the ability to change evolution and tailor an organism's genetics for desirable outcomes. The CRISPR/Cas9 technology has simplified processes and made it an inexpensive process (30). Genetically Modified (GM) crops have been increasingly used in developing regions due to their ability to be biofortified to increase micronutrient quality (31). However due to current public perception and the higher seed price they aren't widely used. (32)

Climate change has pushed communities to move towards circular economy methods. This has created new demand for biodegradable alternatives to replace single-use plastic, driving the explosive growth in biotech. (33) The biomaterials space around packaging is currently primarily made up of start-ups, from companies like Notpla creating seaweed-based plastic to Pluumo using feather waste for packaging insulation. There has yet to be a convergence on the best biomaterials for different tasks and currently, the market is in the Pre-commercial/Pioneering stage.

Newly emerging processing techniques like electrocoagulation, used in the Janicki Omniprocessor, enable the production of potable water from even the most contaminated water sources, such as sewage, for $3 per 1000L (34) which trades off to be 8x more expensive than alternatives. However, due to increasing global water scarcity, investment in preventing water contamination is growing.(35) Moreover, new techniques are constantly streamlining to discover cheaper, more effective ways to process contaminated water (36)

The fourth industrial revolution is impacting the ability to automate highly complex tasks. Machine/Deep learning has enabled difficult problems to finally be solvable. Transportation, logistics and supply chains are becoming increasingly more effective due to the emergence of driverless cars and automated warehouses robots. Technology is evolving beyond automating manual tasks and are now able to automate full systems.(37) Mass gathering of data is becoming possible enabaling tackling of highly complex problems.

2042

GM is predicted to gain widescale adoption in medical, chemical manufacturing and agricultural industries. (38) Hydroponic farms' wide-scale use of GM crops normalises them and public perception will become more accepting of them. (39) As this happens the market size is expected to grow at a compound annual revenue growth rate of 18%. (40)

Biomaterial sceince is constantly innovating to utilise organic waste streams to generate new value-added materials. Hence, the market size is expected to continue growing at 13% a year(41) All day-to-day disposable items are projected to be made from biodegradable alternatives with biomaterial use expanding beyond just packaging. (42)

Due to increased material knowledge, more reliable electrodes and better plant design make electrocoagulation more cost-effective. It becomes the best small-scale decentralised treatment process due to its lower setup cost and its newfound affordability from investment and technology improvements. [(43)

Advanced tech is becoming increasingly affordable and easy to implement. New systems are designed to be "person-less" and fully automated. Starlink and 6G have expanded to global coverage. This enables internet connectivity from anywhere. Smart autonomous systems can operate anywhere in the world without any local computing infrastructure needed. Mass data enables complex relationships to be identified.

Enables

Bioreactor bacteria can be modified to increase methane yield, operate more effectively in lower temperatures, and work even with a variety of different organic waste types. This enables more efficient bioreactors and allows for multiple smaller scale bioreactors to be viable. It also enables simplified collection systems as all organic waste streams can be mixed.

Combining multiple genetics from different fungi species allows new environmentally adaptable mycelium species. This enables water-tolerant mycelium that can desalinate and purify water for crops. It also enables mycelium tiles to be tailored to specific crops by creating better fungal-plant symbiotic matches.

Crop genetics can be modified to add new and improved traits Saltwater resistance can be added to any crop allowing for floating farms on the water. Increased yield enables small-scale farms to produce enough food for communities.

Development enables all day-to-day waste in the floating community to be organic and biodegradable. This creates an abundance of organic waste to be utilised. It then makes investing in waste management infrastructure far more effective as the overall WMS is simpler due to the single waste stream. This large quantity of organic waste also enables bioreactors to fully meet communities' energy requirements.

Electrocoagulation being commercially viable allows for cost-efficient small-scale water treatment plants. These can generate potable level drinking water the most contaminated waste streams. This reduces water scarcity in floating communities, which would have struggled due to its isolation from national water infrastructure. This further enables the mixing of all organic waste sources, allowing sewage, food waste and bioplastics all to be collected together.

New technology enables the system to be run autonomously, even in remote areas of the world. This allows for an autonomous collection system to be designed. The system will be better adopted in these floating communities, as its implementation doesn't impact the day-to-day life of those in the community.

Human-Centred Approach

Current Communities

For centuries, rice farmers and fishermen settled in water-based communities such as Baan Koh Chai in southern Thailand. These communities in Thailand have rich ancestral history alongside their daily livelihood, independence and culture as motivations that contribute to why they want to adapt their infrastructure to protect their ancestral grounds(44).

These people show the complexity of the climate crisis where an understanding of community dynamics is imperative in working towards a more sustainable future.

Current Routine Analysis

After correspondence with Dr Weston Baxter, it was important to understand key moments in residents in rural Thai floating villages daily. This meant Circulate could have thoughtful design considerations which enable the system to be positively impactful with the people.

Research shows that the Buddhism Temple is very central to the community. Buddhist monks live there and lead prayers early every morning. People prepare food for the temple as a way of making merit. The Puyaiban (head of the village) awakes the community with loud public address announcements at 6:00 am and continues to carry out community affairs at the centre of the village each day. A large aspect of life is the genuine support that all members of the village have for each other. The rest of the day for most people involves agricultural work, tending to their homes, harvesting fruit from their own gardens, fishing, and caring for their families(45).

Koh Panyee - Floating Village in Phang Nga Bay Thailand

Key Design Considerations

Community systems often rely on a few key human relationship considerations. These were analysed and then focused on in the next design development phase(45):

- A Centralised Place to Pray, Hold Festivals, and hold Community Meetings
- Agriculture, Livelihood and Maintaining a Traditional Way of Life
- A Respectful Symbiotic Coexistence with the Environment
- Connectivity to Others in the Community

The Barriers for Adoption

Research shows that the main barriers to adoption for new systems and less developed communities are the people not seeing why they are using a new system, and systems having high complex touchpoints with the people.

If tangible positive outcomes can be seen in day-to-day life, then adoption will be much higher(45). Furthermore, interaction with the system should be simple and be a minimal change in their current routine.

People at a local Thai Produce Market

'Unfreeze, Movement, Freeze'

Unfreeze, Change, Refreeze(46), is a method that Circulate used for managing systematic change within a new community. This meant that touchpoints and barriers for adoption were integrated for successful system implementation.

- In the Unfreeze stage of the change management process, there is a motivating event of climatic variability, which creates the need for change and adaptation.
- In the Change stage, the designed changes to the community organizational structure are decided and then started to be implemented.
- In the final Freeze stage, the changes made in the last stage were well-integrated and normalised in the community's day-to-day activities.

System Validation

This page summarises insights from interviews and correspondence with experts and a user. These insights helped form the project and provided validation for the concepts and contextual direction.

Dr. Ioannis Karmpadakis
Coastal and Offshore Engineering.

Dr Karmpadakis emphasised that current drainage systems are under-designed in mitigating flooding scenarios, furthermore, he also said that piping in floating communities would be unfavourable.

He validated the research that current coastal defence methods for flooding are incredibly expensive and, likely, developing countries will simply have to sacrifice large amounts of landmass.

He also gave insights into the current regeneration of mangroves for coastal defence and risk reduction, which could be mimicked using the floating farms to help protect the community from coastal threats.

Professor Michael Templeton
Public Health Engineering focused on water supply and sanitation.

Transplanting the sewage system of developed countries onto floating communities would not be possible. Either localised collection or on-site decomposition of organic waste with vermicomposting bins, taking an example of the vermicomposting toilets that he developed, are favoured.

This transforms organic waste into safe and sterile residues that can be applied for other uses. Furthermore, a contained waste system is a necessity, as it would "be a sanitation hazard to have open wells and toilets that let waste float around when there's a flood".

Dr. Zolton Bair
Mycologist with a background in botany, molecular biology and agriculture.

GE terrestrial crops to be salt-water tolerant is being heavily researched and currently is still an order of magnitude away from being able to handle the salinity level of seawater.

Many marine plants and fungi have already evolved to function in saline environments. Developing existing marine plants and fungi into viable crops might be a more viable route to seawater tolerant crops.

GE plant and fungus to be a symbiotic match would require a full understanding of all host-microbe interactions and how the molecular signalling between the two determines if the relationship is mutualistic or parasitic. If this is identified, the theology is credible.

The Key

System/Context — Floating Farms

Harvey Ward
Floating Community Resident.

Overhead electricity lines often cause problems for boats and if damaged are difficult to fix. Heating uses the most electricity since electric heaters are the sole source of heating.

Compostable toilets and treated sewage water would initially be difficult, however" at the end of the day, if it works it works". It would take an adjustment period to get over the initial concerns, but then it wouldn't even be thought about.

Professor Uffe Mortensen
Molecular cell biologist focusing on genetic engineering fungi.

Professor Jakob Hoof
Molecular cell biologist focussing on filamentous fungi.

Both validated the ability to engineer salt-water tolerant fungi that are a good symbiotic match for a chosen plant crop.

Both highlighted the difficulty in getting the proper permissions to use GE fungi/plants in an uncontained/ open environment.

Dr. Vincent Merckx
Evolutionary biologist focusing on cross species relationships.

Highlighted the importance of having multiple different organisms in the same ecosystem to created a highly linked network with lots of competition. Using keystone species can increase the density of links between organisms, increasing co-dependance and in turn the overall resilience of the system. Validated the benefits of a successfully symbiotic system.

The design of the network structure (different organisms and their relationships between each other) needs to match the specific goal of the system. A mutualistic system with species working symbiotically together generally follows a nested structure.

Ability to collect large scale data on species via nanopore sequencing. This partly validates the feasibility of multiomics to predict network interactions and predict symbiotic ability.

Multiomics, Network Science and Graph Machine Learning

These sectors are all emerging now, making GE for symbiosis possible(65). This involves mapping relationships from gene level up the hierarchical chain to the overall effect on the ecosystem(66). This enables a prediction of the effect of changing a gene on the ecosystems symbiosis and overall performance

Collection Development

In order to explore potential solutions for the waste collection system, the group created a pairwise matrix that would explore varying levels of system autonomy and inhabitant responsibility.

Pairwise Matrix Summary

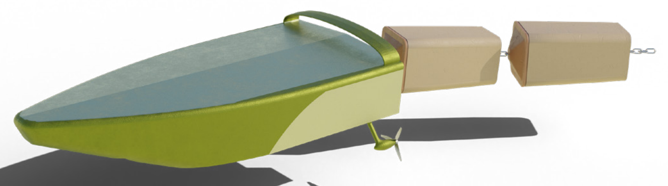
Increasing Inhabitant Responsibility →

Increasing System Autonomy ↓

Concept 1: Waste collectors come to houses and manually empty bins on a regular (e.g., weekly) basis. Draws parallels to the current system, in more developed regions. System ranking: 6th	Concept 2: Inhabitants transport their rubbish to the communal bin, which is collected on a regular basis. The downside is that incentivisation would be needed. System ranking : 7th	Concept 3: People carry their rubbish to the central biocore. A downside is that some form of incentivisation would be needed to achieve this behaviour instead of it piling up. System ranking : 9th
Concept 4: Bins are fitted with sensors, these send a signal to the biocentre when full. Bins are collected when at full capacity, which optimises the collections. System ranking: 2nd	Concept 5: A vehicle (e.g., boat/ drone) will arrive at a house once notified that the bin is full. The user attaches waste to this vehicle, and it is then transported to the bioreactor. System ranking : 5th	Concept 6: Homes are equipped with its own drone or boat. Users remotely activate it, this sends the waste to the bioreactor. The vehicle will automatically return once unloaded. System ranking : 8th
Concept 7: Homes have smart bins, containing sensors to alert the collection system. Each bin will detach and travel autonomously, or an autonomous boat will collect the rubbish. System ranking : 1st	Concept8: Autonomous fleet of boats collect waste at a scheduled times in the week. Responsibility is on the inhabitants to place the rubbish in the correct place, at the right time. System ranking : 3rd	Concept 9: Inhabitants determine when their bins are full. They book slots for collection via the fleet. The fleet optimises collection, reduce congestion and energy consumption. System ranking : 4th

Final Concept: The Sea Snake

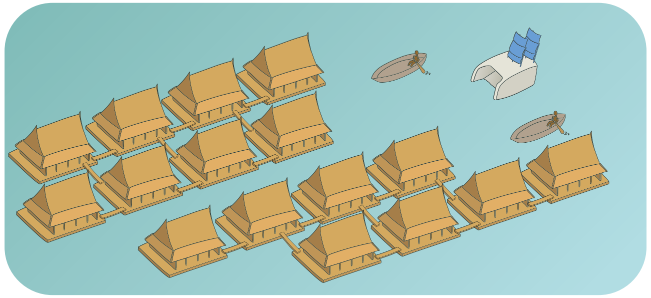
During our exploration, we found that the system with **most autonomy and some to little human responsibility would be easiest to adopt** and prevent against a 'pile up' culture. The final design has developed from concept 7. Methods using drones were considered, Concept 5, as they are expected to make up 30% of deliveries by 2040 (53). However, the final system should be easier to adopt, and with **fewer behavioural change challenges.** We also found the Concepts 2 and 3 would be hardest to adopt since they expect people to have more responsibility for their own waste.

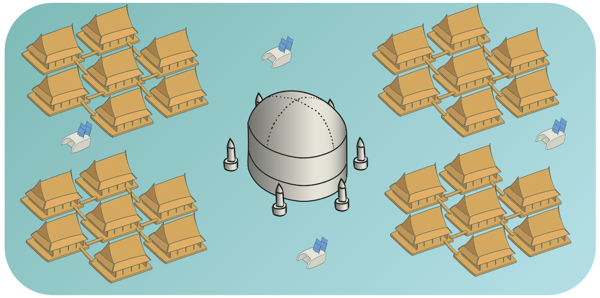


In the final design, users will have a compression bin within their homes where all their waste will be put to make solid dense blocks of waste. Inhabitants are notified that the bin is full prompting the user to carry the blocks to their bin outside their house. The design of the system is not disruptive to their daily routine and will still give people a sense of responsibility (i.e., not letting it pile up). This infrastructure will prevent build-up of waste and consequent pollution. When this bin is full, a signal is sent to the collection fleet via IoT. Once a collection vessel is close, the bin will undock itself and the boat will collect it and add it to the current chain of bins. The bins and boats will make use of tides and wind to optimise for energy consumption. The boats will also be responsible for transporting the mycelium tiles to their designated positions. This design is suitable due to the narrow gaps within a cluster of houses and the limited height created by the pathways between houses. The bins are transported to the biocentre, where the waste is processed. In this system design, people are subtly incentivised to collect their waste and process it since it provides the whole community with energy, food, and water.

Future Development

The aim for this section is to explore how the community will develop to ensure a seamless transition from the current system. Investigated is the structure of the community its expansion over the next 20 years, considering culture and behaviours of the inhabitants. The waste collection system will be designed to fit in with the layout and architecture of the community.





In 5 years time the waste management system in Thai developing floating communities is becoming more established. In many cases, local people clean the water themselves, or waste collectors from the informal sector, not monitored by the government, might come and collect mainly plastic waste to make a living. These waste collectors are incentivised through schemes such as EPR (47), which are policies that give these waste collectors responsibilities to help support public recycling and materials management.Initiatives are starting to grow from companies like The Ocean Cleanup (48) and Bluephin (49) due to increased dumping of waste. This increase has resulted in lower wages for collectors due to material abundance, hence many are looking for alternative income streams, and automated systems are looking more attractive for these collection jobs.

The community will start off as small clusters of houses with pathways to create the sense of community synonymous with Thai culture. As the community develops, it is predicted that the smaller clusters of will grow to around 125 houses. A biocentre will be introduced to the community and the large clusters will all surround it, leaving channels for boat transport. Looking further into the future, if more houses were to be added, they would span outwards, forming a larger circle layout. People would need to travel by boat to get to another cluster.

Waste collection is estimated to have a 93% chance of automation by 2041 (51), so it is safely predicted to expect more autonomous waste collection boats to be implemented while phasing out the need for the informal sector. Thailand was also ranked 8th in the global supply of industrial robots and has seen a shift towards focusing on automation (52). This would further support the idea that Circulate would aim to implement at least a partially autonomous system.

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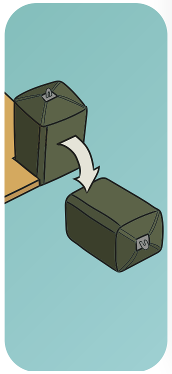
Drawing of the bins undocking concept:



Future Development

Due to time constraints of the project, factors that were not fully designed for and thus would need further work are:

How the bin would dock and undock from the house.

How human waste would be connected to or transported to the bin.

The safety lock mechnaism to prevent leakage of waste into the ocean.

How the bins will connect via chain to the boat.

Final Collection System

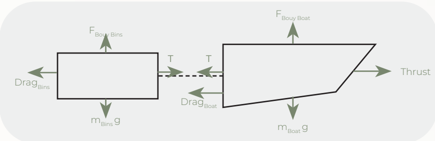
To validate and explore the collection system further, the group specified and calculated aspects of the system such as the boat design, and how the bins will be collected so that it fits the design of the community.

'Sea Snake' Specifications

The final concept is named Sea Snake, for its biomimicry resemblance. Its specifications are listed below:

- Waste Production = 0.19 m^3 (2dp)
- Bin Dimensions: 0.45 x 0.45 x 0.94 m
- Bin Volume: 0.19 m^3
- The buoyancy of Bins: 35.8% immersed in water
- Boat Dimensions (whole body): approx. 3x0.98x1.9 m
- Boat Dimensions (above water): approx. 3x0.57x 1.49 m
- Number of Bins one boat can carry = 10
- Estimated number of boats = 10 boats
- Reference area for boat = 0.65m2
- Reference area for bins = 0.68m2
- Boat Velocity of 2ms-1
- Total power required per boat = 54202 W

The Force Diagram



- Each motor needs to provide 27Kw = 36hp
- Powered by electricity produced from biogas
- Each bin has its own sensor to communicate its location and other metrics like velocity to the main system via IoT

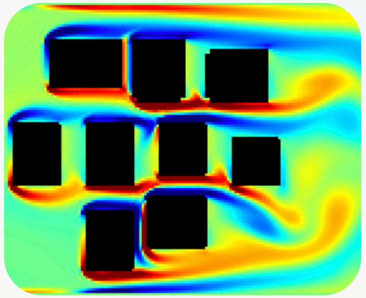
Assumptions:

- Due to the low speeds of the boat, we have not considered air resistance since it would be negligible compared to the drag force.
- The chain of bins has been simplified to a single cuboid.
- Assumed that there is no flow in the water (calm conditions).

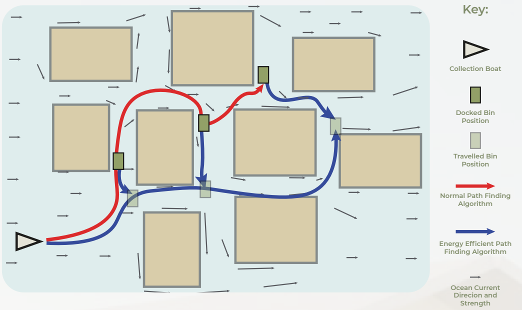
Expert Insights:

- The surface flow of bins and boats will be determined by a combination of wind and tide.
- System can be designed to make use of the predictable, bi-directional nature of tides. He suggested that "you can just move the boat with the tide to collect and then wait till the tide changes to return".
- Since winds can blow in all directions, there were concerns that "if it (the wind) dominates the flow (as well as the drag on the boat) then it will be hard to optimise for since it will change on a frequent basis".
- We can take inspiration from how aeroplanes travel and "go the long way round to go with the flow and the short way around to go against it."

Path Finding Optimisation



Current Simulation Around Houses



Path Finding Algorithm for a House Cluster

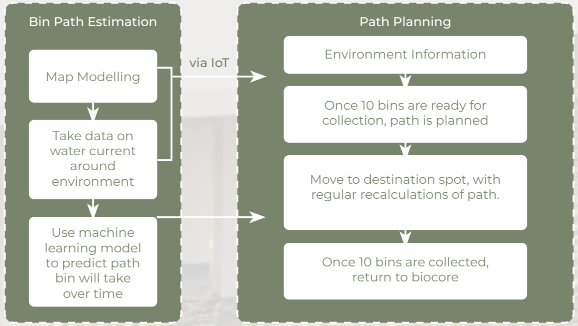
The group carried out a simplified fluid dynamics simulation on a small cluster of houses to study how water would flow around these floating structures. This provided useful insights into designing a pathfinding system that would be more energy efficient for an on-the-water collection system.

Expert Feedback:

You can model this by just specifying a velocity at each point (remembering that mass should be conserved, so if you have a flow into a junction then the total flow in and out should be the same). To a good approximation, you can just choose a speed for the boat and then subtract the flow speed and that will give the actual velocity of the boat relative to the buildings. Then you can just experiment with different routes and see what difference it makes.

Algorithm Logic

The final algorithmic logic design is depicted below:



Algorithm Research

Multi-agent pathfinding algorithms are important to consider so that the multiple collection vehicles do not collide with each other (47). EAMDSP Algorithm for multiple destination pathfinding (48). This will be important for finding the shortest path to take to collect 10 bins in different locations. Constrained A* algorithms have been used for finding more optimal path planning for vehicles in a maritime environment containing dynamic obstacles and ocean currents(49). These paths make use of the current to reduce energy consumption (50).D* lite would be a suitable algorithm since it runs faster than the A* algorithm for similar tasks (51) and is used for changing environments such as moving destinations and obstacles (52).

In the final system, ocean currents will be utilised for both bins and boats to optimise energy consumption. Using a predictive machine learning model, a route is estimated for which the bins would take after undocking. Using a suitable pathfinding algorithm, the best time for undocking, is determined, the point of interception, and finally route of the boat.

The Biocore

At the heart of the floating community, under the cover of the central island, lies the floating Biocore. Through feeding it organic and human waste, and wastewater, it pumps life back to the community in the form of electricity, nutritious floating farm tiles to grow the community's crops, and clean water. High-performance technologies are used in conjunction to maintain high yields and quality standards, ensuring that the whole community's energy and resource needs are met safely.

Bill of material labels: Aluminium, 2DPA-1, Iron, Nichrome, Hempcrete, Polymer

How did we get here?

In the mid-2030 it is projected that in Thailand biofuels (solid, liquid, gas) will continue to be the dominant bioenergy source of the country.

Thailand's primary energy source in 2021 is natural gas (non-renewable), the energy generation facilities are the same for biogas, therefore the conversion to biogas would not be problematic, should they transfer some on-land equipment to the floating communities at first.

The areas which were most important to be focused on:

Water treatment for drinkable water : Circulate aims to make drinkable water circular, to give back to the residents.
Biogas for residential electricity : Circulate is focussed on energy production with biogas to fulfil the community's needs.
Convert solid digestate to farm tiles: This was focussed on as Circulate aims to ensure food security and future resilience.

The Bioreactor

The collected waste is pumped into each of the 6 Bioreactors. A combination of anaerobic processes and ultrafiltration membrane technology is used to separate solid and liquid waste to treat them accordingly(56).

Walls: Hempcrete is a carbon negative biocomposite. It is airtight, very durable, with high crack resistance.

Ultrafiltration Membranes

Fixed at the centre of the Bioreactor and Electrocoagulator, the ultrafiltration module consists of concentric layers of membranes of pore size between 0.001 - 0.05 μm. (57), filtering out solids and even 99.7% of bacteria.

Membranes:

The Tile producer

After grinding, the Bioreactor's solid digestate is pasteurised to remove any plant pathogens (59), inoculated with mycelium spores, and then pressed into fertile farm tiles.

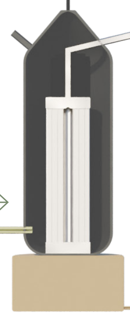
Walls, grinder, presses: 2DPA-1 is 2D polymer sheets that have the same lightness as plastics (1/6 of steel density), but 2x steel's strength. It is also gas-tight making an ideal coating for hempcrete to increase strength of the biocore.

Heating bars:

The Electric Generator

There are 6 electric generators that provide the community 2.55 times the amount of energy that is continuously required. The maximum performance is up to 50%, assuming that more energy can be recovered from heat loss. This was ensured so that parts in the Circulate system could be powered by excess electricity being produced that isn't needed by the community.

Walls:



The Biodome

Biogas produced by the Bioreactor core is transferred to the biodome to be stored. The biogas is then sent out to the electrical generators to be converted into electricity as required. Biogas consumption by combustion produces CO2 but it is carbon that was absorbed by the organic matter during its lifetime, therefore being carbon neutral.

Walls:

The Electrocoagulator

The Electrocoagulator is where the wastewater is filtered for safe drinking. The ceiling and its rods of this section are coated with the sacrificial anode (iron), and the floor and its rods are coated with the sacrificial cathode (aluminium). The purpose of the rods is to increase the electrode's surface area. Direct Current voltage is applied to the electrodes, releasing metal ions from the anode and hydroxide ions produced at the cathode that will coagulate with the remaining microcontaminants (58).

The coagulates are then flocculated and either float or sink to the bottom, depending on their mass and density. After eliminating 99.7% of the pollutants, they are filtered out as the water goes through another ultrafiltration membrane. Finally, the safe water is then stored in the water tank below.

Walls:

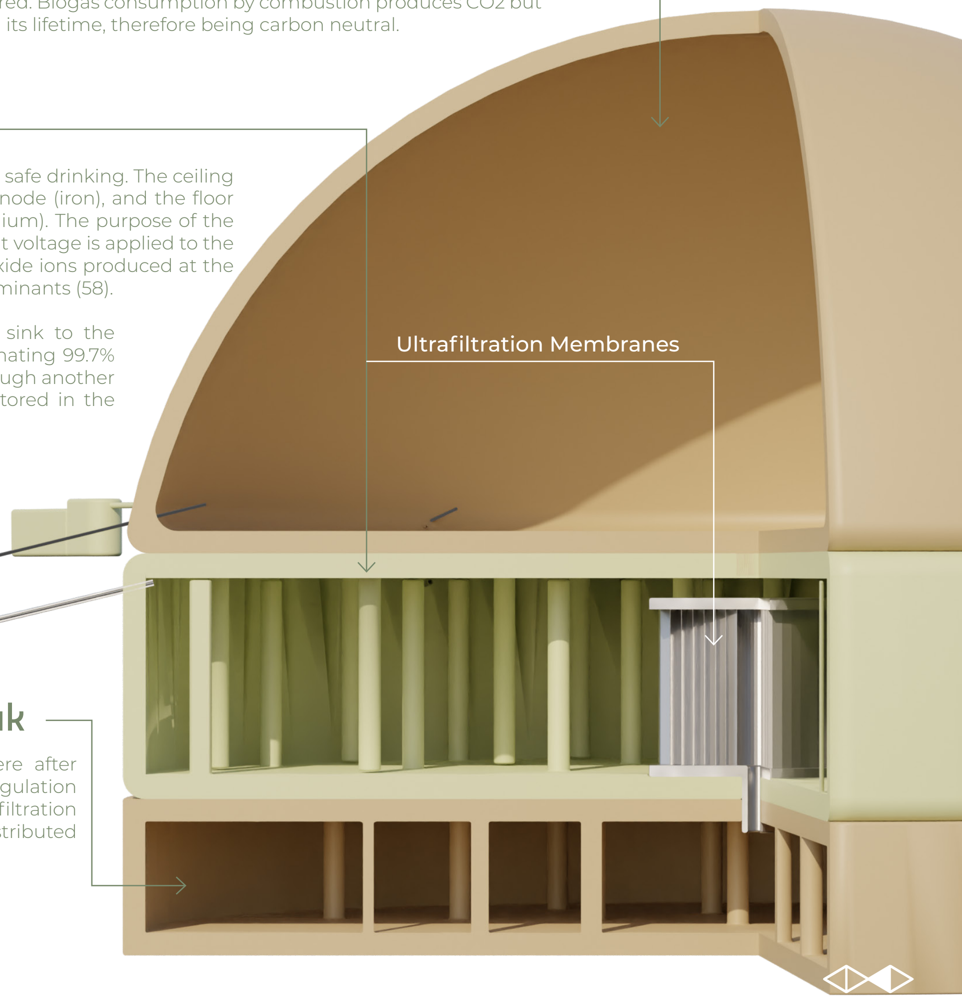
Anode (ceiling):

Cathode (Floor):

The Water tank

Clean water is stored here after going through electrocoagulation and two membrane filtration processes. It is then distributed within the community

Walls and pillars:



Input to Output

Detailed on this page is the theoretical modelling of the Biocore's operations in a floating community of 500 households. Each household contained 6 people which was in accordance with our research of current floating communities in Thailand. Resulting in a population of 3000 inhabitants.

Calculation Assumptions

Performance calculations were dependent on recent demographic and energetic data of Thailand. Due to the 20-year timeline, it was assumed that the floating inhabitants, although still maintaining a traditional lifestyle, will consume more energy by 2040, almost doubling its current consumption. Per capita, it will reach up to 300 kWh, estimating that rural inhabitants will adopt urban energy consumption habits in the new floating communities.

Waste Input

500 6

It was assumed that by 2042, most of the solid waste will be organic since most non-renewable materials will be replaced with biodegradable ones. For bioplastics, current proportions of single-use plastics were taken and the mass per capita was added onto the previous data on solid waste production per capita:

Total solid waste: **4878 kg/day**
- Organic waste: **63.7%**
- Bioplastic waste: **27.9%**
- Human waste: **8.4%**

Total solid waste volume: **1070.5 m³/3 months**

Total liquid waste: **1200 m³/day**

*Calculations for this section are provided on page 20

The Consumption

Total residential electricity consumption:
27393.75 kWh/3 months

Total residential water consumption:
1200 m³/day

Bioreactor Performance

Maximum solid retention time (x safety factor of 3): **3 months**

Maximum liquid retention time (x safety factor of 2): **24 hours**

Methane productivity: **0.624 m³/kg**

Max operational capacity: **450 m³.**

Output

Water Generation

According to an existing attempt to combine electrocoagulation and ultrafiltration membrane, it manages to meet the water quality standard of Indonesia. Total suspended solids (TSS) value of textile is reduced by 99.7% and palm oil by 98.5%.

Tile Generation

Mycelium farm tile output:

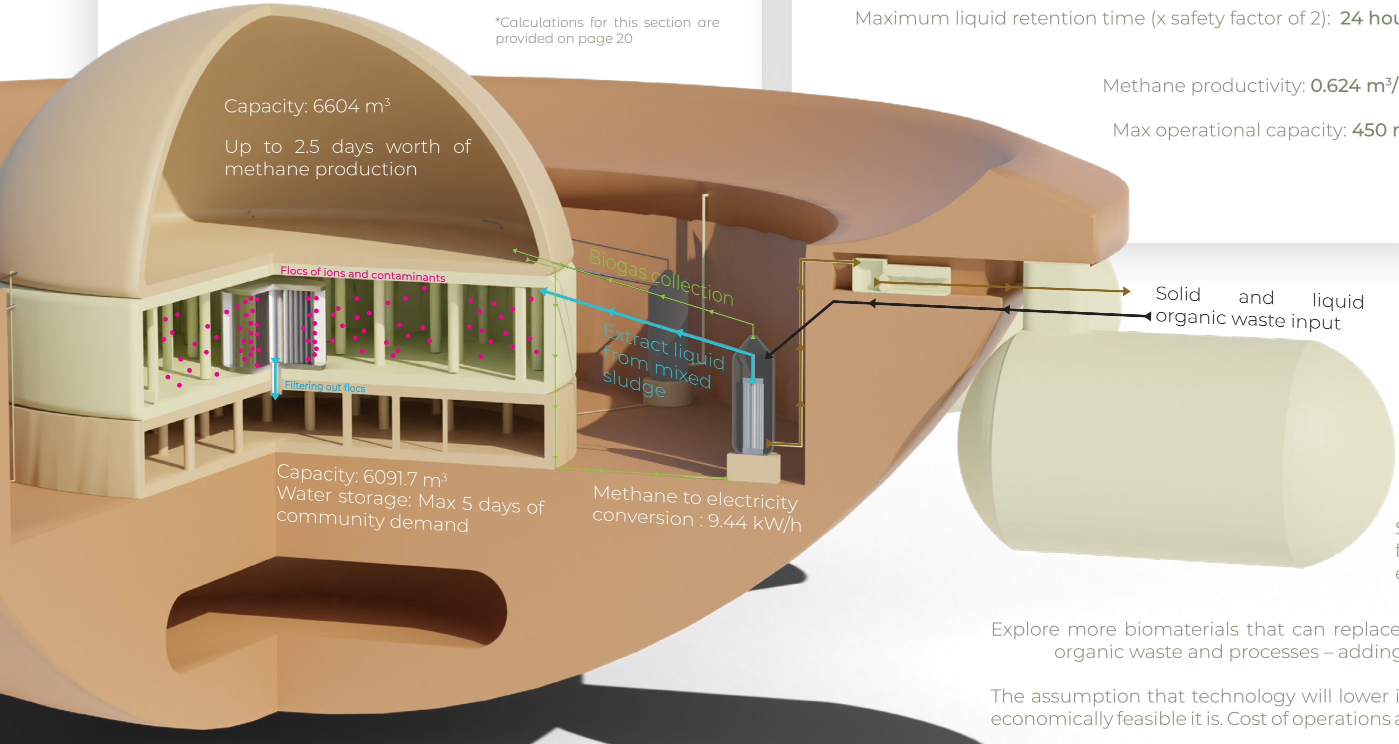
654 tiles/month

Electricity Generation

Electrical conversion efficiency: **40%** (60)

Energy Produced per day: **8813.75 kWh/day**

Peak energy production: **x2 community's demand**



Future Development

The parts that need to be developed in the future for the success of the system: Should explore varying degrees of clean water for different purposes, not all needs to be drinking water.

Extend the capacity of water treatment to provide usable water for agriculture, since it is difficult to grow plants that can only tolerate the high amount of salt.

Seeing that the Biocore's energy production capacity exceeds the demand twofold, future directions in where this excess energy is sent/stored must be explored to expand the circularity of the system (i.e., feeding energy back into the Biocore, to charge the autonomous fleet, stored in backup batteries.

Explore more biomaterials that can replace essential non-renewable materials (i.e., single-use plastics) by sorting desirable organic waste and processes – adding new sorting systems and production centres for specific salvaged organic waste.

The assumption that technology will lower its price in the future, but an exact cost evaluation can be conducted to see how economically feasible it is. Cost of operations and tech was not the main priority, instead, it was performance and future potential.

Mycelium Farms

Outline

Solid digestate waste from the bioreactor is pressed into hexagonal tiles, 1m2 in surface area with varying thicknesses to control buoyancy. The chosen genetically engineered (GE) crop is planted into the tile alongside genetically engineered (GE) fungi that are symbiotically matched for the chosen plant. The addition of fungi also adds structural integrity, due to the created mycelial network, that acts to hold the solid digestate waste together. Tiles are designed for two separate use cases, personal use for home gardens and communal use in the community farm. Each month the bioreactor can output 654 additional tiles for the community to use. The most important aspect to the farm's success was the feasibility of salt-water tolerant crops so this was focussed on for this project.

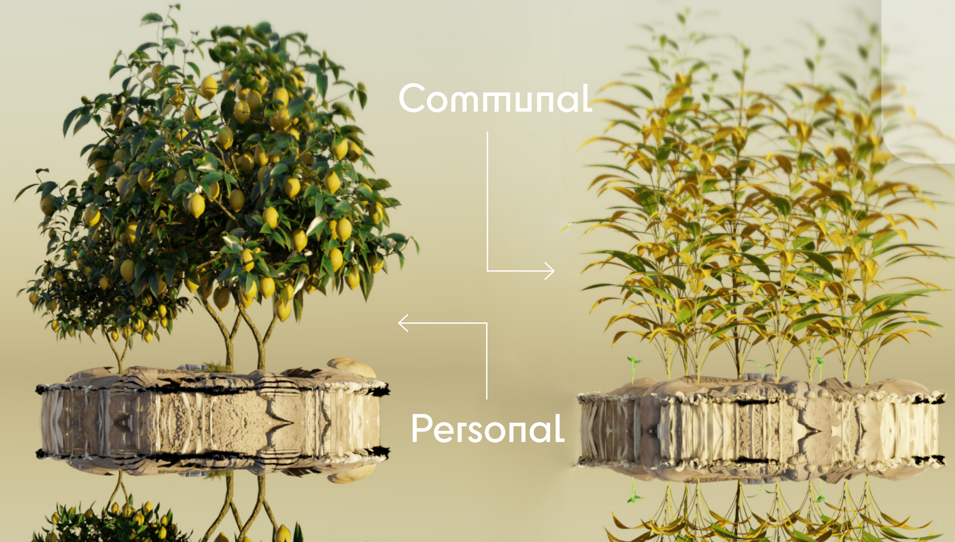
Buoyancy

Buoyancy is controlled by varying the thickness of the tile. Heavier plants, like tress, require thicker tiles whilst lighter weight plants require thinner tiles. Example thickness's:
20cm thick tile able to hold 172kg (small bush) [123]
50cm thick tile able to hold 430kg (small tree) [123]

Controlling the buoyancy also allows tuning of the irrigation level of the tile, based on how submerged it is or not. This ensures tiles remain at Field Capacity, which is the optimal water saturation, guaranteeing the best conditions for crop growth.

Use cases

Individual tiles are distributed by the community leader on a need-by-need basis. This can be done since they have a strong sense of sharing in the community and often rely on the Phu yai ban for any requests. Initial ideation was done using a morphological chart to create ideas of varying levels of centralisation and autonomy of the farms. Analysis of designs based on community behavioural analysis revealed the importance of having both personal and communal farms, as individuals like to have their own space to grow fruit. Some technological assistance is inevitable for crop harvesting however full automation was avoided for this timeline as these communities expressed that they want to continue with their traditional farming methods.



GE Crops

All crops are genetically engineered (GE) for increased yield density and biofortification to increase their productivity and nutritional quality. The specific crops grown will vary based on which method of making viable salt-water tolerant crops is most successful:

1. GE marine plants and fungi to become viable crops
2. GE existing terrestrial crops to be salt-water tolerant

Currently, method 2 has only achieved salt-resistant rice up to 0.3% which is still an order of magnitude from the required 3% hence method 1 looks to be the most feasible (61). Tiles are impregnated with multiple different bacteria and fungi to create a highly linked competitive network to increase

GE Fungi for Symbiosis

Mycorrhizal fungi and bacterial endosymbionts/endophytes (organisms that live inside the plant) are GE to optimise their symbiosis with the chosen plant crop(66). A good symbiotic fungal-plant match supports growth and fitness, increases yield and productivity, and improves the plants' ability to survive under adverse conditions, such as high salinity environments, heat waves and disease (62) (63). A nested structure is used specialists organisms linked to generalists) to encourage mutualistic relationships between organisms (64). This makes the community's food supply climate resilient.

The Output

Calculated output for how much output increases each month, assuming all tiles 0.2m and are rice crops:

$654m^2$ of farm means 1200kg of edible food, equals 100 people properly fed

Future Development

The end-of-life of the tile needs to be explored. When deteriorates/is it depleted of nutrients can it be used as a food source for fish? Can depleted tiles be used for other purposes?

The use of GE in an uncontained environment comes with political and ethical concerns.

Eco-system effect on farms. Would crops generated from marine plants be eaten by aquatic life?

The mechanism that keeps the tiles are anchored together.

Daily Life

5am

Wake up and get ready to walk to the temple in the community center. Morning shower is made possible using fresh water generated by the system.

Improved access to clean water and basic sanitation frees up time spent collecting water and prevents the spread of disease in the community.

5:30am

Food is cooked at home and taken to the temple for the monks and community. Food offcuts and packaging are thrown out into the community bins.

The contained bins prevent contamination of the water improving aquatic health. This in turn improves the communities health as they consume large quantities of seafood from this water source. It also acts to prevent the attraction of pests and vermin by containing the smells of the food residue.

6am

Phu yai ban (village chief) wakes community using speaker system power via the system. They read out announcements and praise is given for those going above and beyond in the community.

7am

Travelling to the communal farm to work the crops.The automated boat fleet drops off multiple mycelium tiles at the farm.

Presence of large farmland acts to reduce wave action and help protect the community from climate change induced flooding events. The increased biofortification and yield of crops due to GE lead to increased nutrition and a healthier community.

12am

Lunch is cooked at home. Fresh choy sum and tomatoes are picked from the families own mycelium garden tiles. The whole family enjoy lunch together. Time is taken to talk and play with the children before they are taken back to the temple for schooling.

Due to the increased availability of food from the farm tiles parents don't have to spend the whole day on the farm. Additional time can be spent with their children helping to teach them. This will lead to improved literacy rates and stronger parent and child relationships.

5pm

Community all gather in the center of the village. Harvested crops from the farm are brought to the central market to share out and make sure everyone has enough food. The Phu yai ban hands out mail and answers any and all community concerns that are brought up.

Due to increased crop productivity not as much time is needed to tend the farms and so everyone is able to spend more time on the community matters. This helps to futher build a stronger community that makes them more resilient.

6:30pm

It begins to turn dark so the house lights begin to turn on, using power from the system. The parents of the household prepare dinner whilst kids watch TV.

Availability of electricity and internet gives access to a more diverse range of education sources increasing communities opportunities and lays the foundations for a more inclusive society.

10pm

Sewage waste is taken from compostible toilet and added to bin. Bin has exceeded 90% capacity and signals to the collector that it is ready to collect. Boat undocks and uses ocean currents to meet collection boat along its current route.

Upholding a Way of Life

Their life is very similar to how it is now as the system is designed to fit around the community. The community maintain their farming essence and can cultural traditions.

Ripple Effect /Quality of life

The community now have reliable access to clean drinking water, electricity and climate resilent crops. This has knock-on effects improving the overall quality of life allowing for increased literacy rates and healthier lifestyles.

Project Achievement

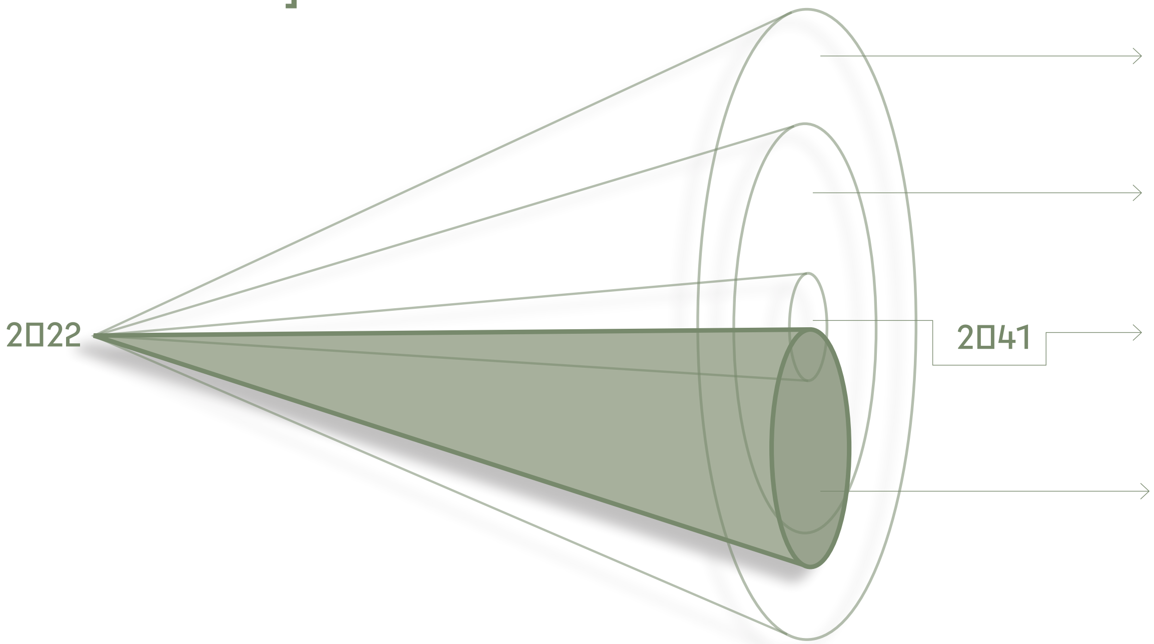
This pages methodically goes through all of Circulates main objectives. Detailed next is how they were achieved in the design. Importantly each of these achievements are critically evaluated for different scenarios to ensure robustness of the system.

Objectives	How They Were Achieved	Evaluation for Progression
Aims to solve the waste disposal problem on water as a water based community expands.	Iterative prototyping methods were used alongside expert interviews to inform the best way to deal with a waste management system on water. We also animated how the community would move and expand to see how the system could naturally grow with the community and environmental changes.	With the ability to process 100% of the communities waste and the behavioural analysis to make it user friendly, it solves all the everyday waste successfully. This is under the assumption that all day-to-day waste will be organic, this may not be the case and the system inputs and outputs will need to be adjusted.
Ensuring resources are put back into the community to mitigate problems such as food scarcity and access to clean water and energy.	The design of using the system to get rewards for your community enabled behaviours to be formed to discourage though away culture for day to day waste. The system also enabled new crop growth, immediate access to clean water and electricity.	The Circulate focus has gone into lots of detail on what was deemed the most innovative and fundamental focus for the system in the scope of this project. Moving forward with development certain technical aspects need to be explored and defined.
This system aims to smoothly collect organic waste to eliminate physical pollutants in the communities surrounding environments.	The system collection was carefully planned through stages in the 20 year time line so that it could be designed to gently be introduce in the concept for these communities which haven't ever had much of a waste system infrastructure.	This part of the concept relies on the predicted growth of the community and rate of autonomous acceptance within the people. There should be alternate scenarios of growth or projected acceptance of these technologies to account for unexpected paths of integration.
Considering the human and behavioural change aspects for a seamless adoption of the system.	Effective behavioural analysis techniques were used to find the best design for smooth integration and development of the system. An overall reward system was created to incentivise adoption, while ensuring that community traditions could continue as they had for many generations.	Human behaviour towards maintaining culture, energy consumption, and attitude towards climate change may not develop as predicted. This means that more research would need to be done by visiting these rural communities in person to have a better prediction of these main behavioural aspects.
The key objective is to successfully integrate all these features into one system.	Circulate started with informed assumptions about community size and corresponding consumption metrics and waste production. The amount of waste input allowed the calculation of the solid distaste output which then provided the amount of farm times produced and amount of food the community could grow. There is clear integration between all stages of the system.	Each stage is completely reliant on the one before it, and it starts with assumptions based on the community. If those assumptions differed form what is predicted, further calculations will need to be made to ensure the outputs meet the consumption needs.

To 2041 and Beyond

On this page is a depiction of the comparison of possible, plausible, probable and preferable future scenario's in 2041. Furthermore future objectives and projected milestones are further discussed.

Scenario Projection



Possible → Everyone who is displaced due to climate induced flooding lives in water based communities. Amphibious technology in these communities has developed and they have stable floating homes and infrastructure.

Plausible → All day to day waste in rural Asia is organic. Some facilities are in place to collect it but don't extract any value from this waste resource. Some facilities try to compost it but they aren't accessible for rural floating communities.

Probable → Circular design considerations are implements in all systems from the start of their creation. This means that future technology has developed the most efficient ways of extracting value out of organic waste.

Preferable → Circular is widely integrated into Thai floating communities. It is the future of centralised living on water for developing communities. It improves quality of life and reduces the threat of energy, food ,and water insecurity in the most vulnerable regions.

Future Objectives...

Circulate has defined future objectives and predicted their corresponding milestones in time.

2050

LEDC's that surround Thailand begin have developed, they face the same problems and have seen how effective the implementation has been in Thailand.

Technology in the first implementation is developing. This has solved the future development objectives such as find a way to distribute electricity without the inefficiency of wires. Electricity and data can be transferred through the water. GM crops are accepted throughout rural communities as they provide unparalleled food security.

2060

The majority of floating communities in Asia have adopted the circular system. The Thai system's are streamlined and efficiently adapted to growing population needs.

The biocomposites used in the biocore become even more durable, cost effective and environmentally friendly to produce than traditional alternatives such as concrete and steel. Literacy rate's for the next generation is high in South East Asia hence advanced automated robotics is even more accepted in rural communities.

2070

Other developing regions globally have seen the development in Asia. This also marks the next development stage to ensure global climate adoption.

Circulate aims to be able to implement its system into any culture and climate by 2070. This would require a rigorous evaluation of the next geographical regions and communities to implement in. Research would start with the differences in climatic conditions and behavioural culture that may effect the ease of adoption.

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123. Link to calculation spreadsheet here.

Appendix

Full calculations for autonomous boat specifications:
Waste Production:

11.72 m3 waste in community per day
11.72/500 = 0.002344 m3 waste per household
For weekly collection give space for 7 days + 1 day for excess
0.002344 x 8 = 0.18752 m3
= 0.19 m3 (2dp)

Bin Dimensions:
0.45 x 0.45 x 0.94 m
Volume : 0.19 m3

Buoyancy of Bins:

Average Waste Density:
300(4428/(4428+450)) + 1060(450/(4428+450)) = 370 kgm-3
0.19 x 370 = 70kg

m = pV
V = 70/1025

V = 0.068 m3

0.068/0.19 = 35.8% immersed in water

Boat Dimensions (whole body):
approx. 3 x 0.98 x 1.9 m

Boat Dimensions (above water):
approx. 3 x 0.57 x 1.49 m

Number of Bins one boat can carry = 10

Estimated number of boats:
If each bot does 5 trips throughout the week,
5 x 10 = 50 bins collected per boat per week
500/50 = 10 boats needed

Reference area for boat = 0.65m2
Reference area for bins = 1.893 x 0.358 immersed
Velocity of 2m-1
Cd = 9.94

Cd = 2Fd/pu^2A
Fd boat = 13245
Fd bins = 13856
Fd total = 27101

P=Fv
= 27101 x 2
= 54202 W

Each motor needs to provide 27Kw power = 36hp
Estimated voltage = 350V (based on current outboard motor)

Based onPure outboard:
350V
Matched Pure Watercraft 8.8kW battery pack(s) • Actively thermally managed • Can be combined for greater capacity/range
shaft length 50.8 cm
Battery recharge time 50-100%: 1 battery pack: 1.5 hours (220V), 4.5 hrs (110V), 2 battery packs: 1.5 hours (220V), 9 hrs (110V)

Project Management

Meeting Minutes and Action

Continuing from last term, Notion was used as the online platform of choice to take notes for meeting minutes and actions. It has proven to be an efficient tool for the team to have written records. Building upon last term's habits on having rotating roles for chair and secretary, post-meeting reorganisation and refinement of meeting notes were enforced.
Actions were set as usual to remind each team member of their work. This term, main milestones of the project were set in advance to lay out a proper long-term plan, so that everyone knows what to expect after completing each task. The meeting notes and actions can be viewed here.

Task and Resource Allocation

When setting up actions, each team member's skill expertise, as well as availability, are considered. At the start of this term, each team member expressed their interest in which part of the project they wanted to be involved more in – Eve focussed on the behavioural design of the system for future inhabitants along with further contextual setting , Leonhard dedicated himself to Blender modelling and renders as well as the video production, David worked on the theoretical implementation of the Biocore, Tomas researched on off-shore farming using recycled floating tiles and mycelium-crop symbiosis, and Aran developed the autonomous bin collection fleet system and its motion planning algorithm logic.
Resources of the concept's development mainly stems from online research articles, as well as organised meetings with experts in concerned fields for validation. Each team member is entrusted to individually find good papers and develop valuable insights to drive the final design. 3D modelling software such as Blender, Solidworks, and Fusion 360 were used to build digital prototypes of the system. One technical issue encountered was the heavy load of high-quality 3D rendering on one's computer, limiting rendering time to the computer's hardware specifications. To overcome this, connecting to more

Communication and Collaboration

Like last term, team meetings with Elena are done weekly in person whenever possible. These meetings consist of catching up on each other's progress, as well as reflect on any on-going challenges that require the attention.
Microsoft Teams and third-party private messaging platforms remain as our off-hour's communication platforms. One issue encountered when using these platforms is the dilution of important information as the conversation lengthens. To mitigate this, it was established that important information (i.e., change of plans, new findings that potentially challenge the core concept, ...) should be communicated through live meetings to be recorded by the secretary, only leaving small updates to be announced through text messages.

Risk Management

Looking back at last term's risk mitigation table, one of the biggest risks was to underestimate the scope of the project. Throughout this term, it was made sure that the concept's scope was well-defined, and it was acknowledged that some elements of the project (i.e., distribution of recycled resources, underlying bin mechanisms, etc.) had to be kept at a surface level for the sake of time and project scope constraints. This enabled us to fully focus on the most important aspects of the system, with enough scope to keep the final concept solid. Another issue arisen from last term was the underestimation of the workload. This was mitigated by setting in advance milestones to complete and get regular feedback, considering extra time for potential setbacks. This was proven effective to a certain extent, but the schedule was ultimately pushed back due to most of the team being ill for a week due to unforeseen circumstances.