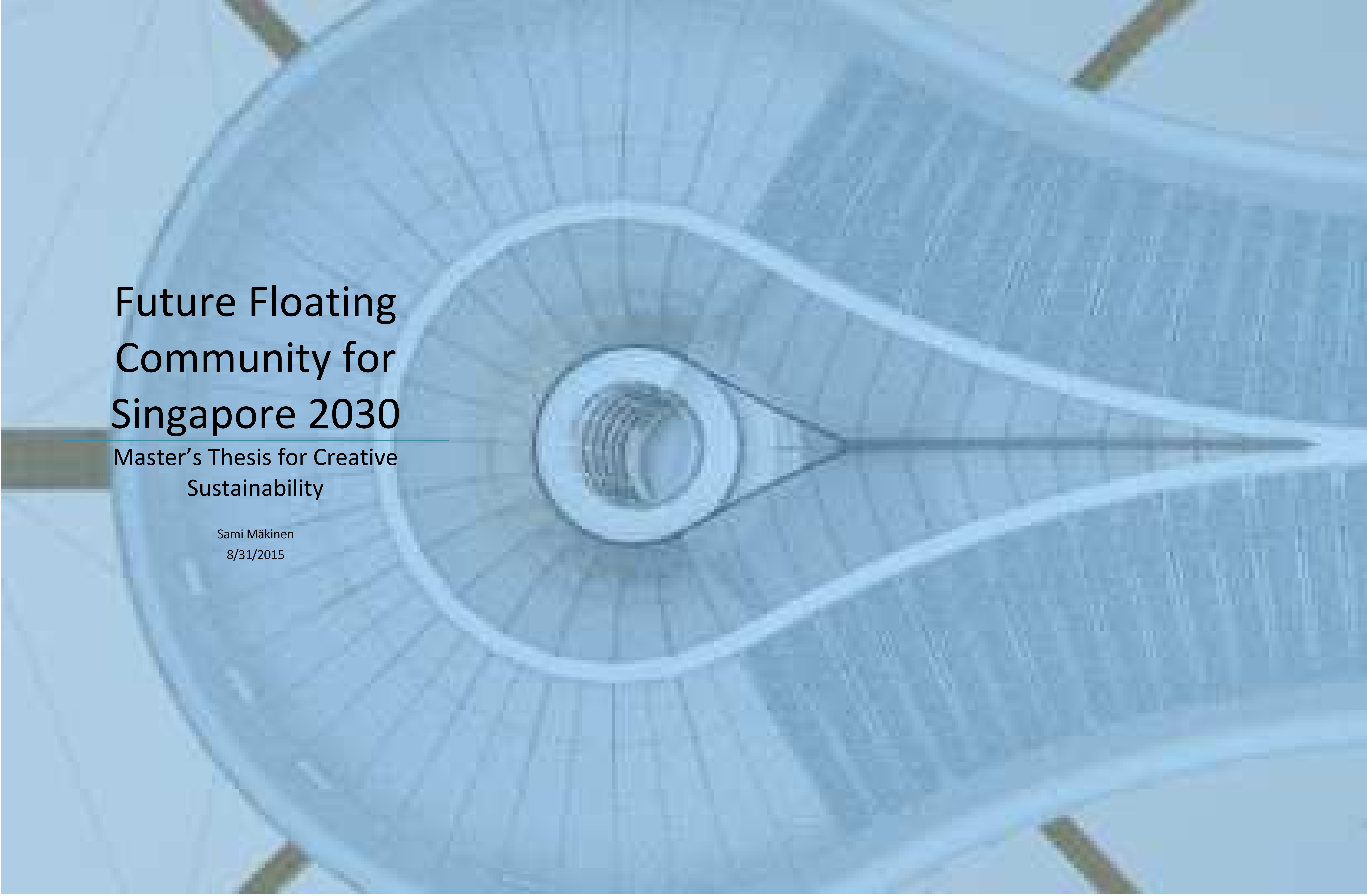


Future Floating Community for Singapore 2030

Master's Thesis for Creative Sustainability

Sami Mäkinen

8/31/2015

Visionary Floating Community Concept: Respecting to the aspects of Cradle to Cradle Building Charter and Future goals for more Sustainable Singapore

Aalto-yliopisto
Taiteiden ja suunnittelun korkeakoulu

Aalto University
School of Arts, Design
and Architecture

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Master of Arts thesis abstract

Author Sami Mäkinen	
Title of thesis Future Floating Community for Singapore 2030	
Department Creative Sustainability	
Degree programme Creative Sustainability Master's Degree Programme	
Year 2015	**Number of pages** 48 **Language** English

Abstract

The subject of the thesis is "Future Floating Community for Singapore 2030". As a starting point the thesis concentrates on creating one visionary floating community concept for Singapore 2030.

Urban development in highly populated coastal cities, high land prices, dense infrastructure and global warming with raising sea level scenarios can put even more pressure towards floating community developments. This kind of situation and pressure can be noticed in Singapore where the sea level has been steadily raising 3mm a year over the past 15years and has already influenced Singapore officials to countermeasures for the future.

Singapore has one of the highest population densities in the world. Singapore officials are respectively trying to keep the limited natural resources and recreational spaces in shape for the future generations. Singapore government has approved sustainable future goals for 2030 and beyond like the "Sustainable Development Blueprint". The future land use plans for Singapore predict massive land reclamations for 2030 and beyond meaning that more land will be reclaimed from the coastal areas of Singapore. These land reclamation projects can be expensive and put great environmental pressure on near shore water areas where the most diverse marine ecosystems are located. By developing sustainable floating communities especially for living and housing purposes the increasing population and shortage of land for Singaporeans could be helped for the future generations 2030 and beyond.

There are various driving forces behind the thesis. First, the Cradle to Cradle Building Charter philosophy gave the environmental design principles for the concept design. Second, the visionary concept development methodology gave guidance how to input future development into the concept. Third, the design background research with examples of floating community cases, review of current developments, system design background and background of Singapore as a possible site for the concept lead the thesis work towards one scenario with features intended to meet the future challenges of Singapore as a partly floating living environment in 2030 and beyond.

Keywords Floating Community, Future Concept, Singapore

Future Floating Community for Singapore 2030

Contents

1 Introduction

The subject of the thesis is "Future Floating Community for Singapore 2030". As a starting point the thesis concentrates on creating one visionary floating community concept for Singapore 2030.

Floating communities have existed already from the beginning of human civilization and one example can be found even from pre-Incan times. The concentration of human development and habitat near the coast and in some cases to floating communities in the history of human civilization has shown the importance of water as a part of living environment. According to NASA's estimates currently around 40% of people on earth live within 100 kilometres of the coast (SEDAC / NASA , 2015, p. 1).

Urban development in highly populated coastal cities, high land prices, dense infrastructure and global warming with raising sea level scenarios can put even more pressure towards floating community developments. This kind of situation and pressure can be noticed in Singapore where the sea level has been steadily raising 3mm a year over the past 15years (National Climate Change Secretariat, 2015) and has already influenced Singapore officials to take countermeasures for the future.

Singapore authorities already prepared for sea level rising by applying flood barriers and the beach embankment height requirements in coastline areas to meet the future challenges (National Climate Change Secretariat , 2013). Singapore has also faced new weather phenomena like more intense rainfall among the first recorded cyclone Typhoon Vamei which caused major flooding in the region (National Climate Change Secretariat, 2015b).

Singapore has one of the highest population densities in the world (Infoplease, 2015). Singapore officials are respectively trying to keep the limited natural resources and recreational spaces in shape for the future generations. Singapore government has approved sustainable future goals for 2030 and beyond like the "Sustainable Development Blueprint". (Singapore Government, 2012). The future land use plans for Singapore predict massive land reclamations for 2030 and beyond (Ministry of National Development, 2013) meaning that more land will be reclaimed from the coastal areas of Singapore. These land reclamation projects can be expensive and put great environmental pressure on near shore water areas where the most diverse marine ecosystems are located (WildSingapore, 2015). By developing sustainable floating communities especially for living and housing purposes the increasing population and shortage of land for Singaporeans could be helped for the future generations 2030 and beyond.

According to research group from National University of Singapore (National University of Singapore - Faculty of Engineering, 2015) floating structures have many benefits over the traditional land reclamation solution and can offer a cost effective option when the water depth is large. The floating community buildings which are floating structures can be designed to be environmentally friendly when they do not silt-up deep harbours or disturb the tidal/ocean currents. The floating community buildings can be easy and fast to construct at shipyards and brought to site for assembling. The modular structure of floating building allows for easy removal and extension in the sea space for the future needs. (National University of Singapore - Faculty of Engineering, 2015).

There are various driving forces behind the thesis. First, the Cradle to Cradle building charter philosophy gave the environmental design principles for the concept design. Second, the visionary concept development methodology gave guidance how to input future development into the concept. Third, the design background research with examples of floating community cases, review of current developments and system design background and background of Singapore as a possible site for the concept lead the thesis work towards one scenario with features intended to meet the future challenges of Singapore as a partly floating living environment in 2030 and beyond.

The concept itself is not to be regarded as an accurate presentation of a future floating building rather a combination of possible future features serving the future development in the Singapore coastal areas where floating community scale developments might be considered instead of expensive and ecosystem testing land reclamation.

In addition the thesis subject is a result of personal interest for floating architecture and sustainable design. I see this thesis as a great learning path towards sustainable design and floating architecture. My background as industrial designer working in sales concept development for Turku shipyard currently known as Meyer Turku Oy and my studies at Aalto University for Creative Sustainability Master of Arts and courses for sustainable architecture directed my interest towards floating architecture. It was clear I wanted to extend my knowledge on the subject. The hint for looking to Singapore was given by architect Aaro Söderlund from Aalto University and I am thankful for him for showing me the direction where to go.

The thesis is structured as follows. The Design Approach for the thesis is introduced in chapter 2. Chapter 3 holds the research and background work information including inspirational cases, driving forces and research findings with environmental research input respecting the Cradle to Cradle Building Charter guiding principles. These factors then form the basis for chapter 4 where the actual visionary future concept design is made and presented.

2 Design Approach

2.1 Overview of the design approach

As a starting point the thesis concentrates on creating one visionary floating community concept for Singapore 2030 as reasoned in the introduction chapter.

The input for the design of the concept comes from combination of design approach defined in this chapter and design background defined in chapter 3. The design for the future concept was done in respect to the "Cradle to Cradle Building Charter" principles and philosophy (Braungart & McDonough, 2009). The future research methodology used for the visionary floating community concept for Singapore 2030 was applied from the book
"Visioiva tuotekonseptointi – Työkalu tutkimus- ja kehitystoiminnan ohjaamiseen" (Kokkonen, Kuuva, Leppimäki, Lähteinen, Meristö, Piira, Sääskilahti, 2005).

As a conceptual and inspirational background for the visionary floating community concept short reviews and findings of seven different kinds of floating community cases and a short review of current developments existing were used.

Local officials and the surrounding environment sets a starting point for the concept development and limitations for building on water. Siting issues for the floating building concept are defined in the design background chapter 3.4.

2.2 Introduction to "Cradle to Cradle Building Charter"

Cradle to Cradle (C2C) environmental design principles including the C2C Building Charter and philosophy was originally created by Michael Braungart and William McDonough (Braungart & McDonough, 2009). C2C Building Charter was specially developed for built environment and it suites well in visionary concept level developments, because it has clear guiding principles covering all the areas of built environment in principal level. In this thesis, the main focus is in C2C Building Charter philosophy and the four guiding principles.

The Guiding principles according to Braungart & Mc Donough (2009) are:

1. "Incorporate materials that are technical and biological nutrients that can become safely reusable.

2. Measurably use renewable energy. Examples of renewable energy include solar thermal, ground based and air-based heat exchange, wind, biomass, hydro and, photo-voltaic.

3. Actively and measurably support biodiversity according to well established biological tools for measuring species diversity.

4. Anticipate evolution and change, incorporating strategies and approaches.

(Braungart & McDonough, 2009)."

Braungart & McDonough (2009) brings out several aspects in the C2C Building Charter which has also worked as guiding principles in the Future floating community concept. Overall the C2C Building Charter guides to think the big picture of systems, products and processes instead of concentrating only one thing at a time. Braungart & McDonough (2009) highlights for example the beneficial thinking and eco-effectiveness and improving the quality of building systems, products and processes. C2C Building Charter encourage to think materials opportunities instead of energy problems and guides to design building systems and processes according to their intended use. (Braungart & McDonough, 2009).

Braungart and McDonough (2009) suggest in many aspects to draw inspiration from nature and its cycles and even. C2C philosophy encourage for innovative solutions in the field of recyclable technical and biological materials. C2C principles encourage to find materials, biological biotechnology mimicking the natures' way of doing things like can be seen in biomimicry (Biomimicry Group, Inc, 2012) and replacing traditional technologies with biotechnology solutions. C2C ideology can be viewed as a preferred way to solve environmental challenges considering the build environment.

C2C philosophy as a design approach supports well the future floating concept design placed to Singapore because Singapore officials are very conscious and green oriented as displayed in the future environmental plans for using their limited environmental resources in densely populated country. (More information about Singapore as a site for the future floating concept in chapter 3.4).

As Braungart and McDonough points out, the traditionally the goal of building designers is to minimize the negative effects on the environment by attempting to reduce the ecological impact (Braungart & McDonough, 2009).

According to Braungart and McDonough (2009) C2C buildings are different. "Buildings which have been built by following the C2C principles are designed from the beginning to create positive impacts and beneficial footprints. A 100 per cent C2C building does not exist yet because of the complexity of buildings, and because the various C2C principles and protocols were only recently developed. (Braungart & McDonough, 2009)." Braungart and McDonough (2009) are convinced that it is still possible to design and construct a building informed by C2C principles, incorporating a wide range of C2C products and materials already found in the marketplace. (Braungart & McDonough, 2009).

2.3 Future research methodology

The methodology for future research aspects of the concept was adaptably used from the book "Visioiva tuotekonseptointi – Työkalu tutkimus- ja kehitystoiminnan ohjaamiseen" (Kokkonen, et al., 2005), in this thesis known as a visionary concept development methodology. The content from chapter 6 (Kokkonen, et al., 2005, pp. 71) was adaptably used for the creation of the "Future Floating Community for Singapore 2030"

There are four steps in visionary concept development methodology which guided the visionary concept development in the future floating community concept (Kokkonen, et al., 2005, pp. 72):

1. Defining the changing factor for the future concept (Subject, timescale, possible operator(open), defining the driving forces for the concept)
2. Building a Scenario (The C2C Building Charter worked as a scenario and frame for the concept)
3. Defining the product needs (Based on research findings and inspirations from reviews)
4. Creating the concept (Defining one concept based on all the input).

(Kokkonen, et al., 2005, pp. 71).

The PESTE analysis (Kokkonen, et al., 2005, p. 71) was not considered in the thesis in the traditional way to outline the alternative future paths but rather as a frame which supports the development of future concept.

These driving forces were found during the design background research part of the thesis where global, local, environmental, social, technical and biotechnological developments input formed the missing peaces for the actual concept future concept for 2030.

The use of different future developments are called scenarios (Kokkonen, et al., 2005, pp. 71) but in this case the thesis concentrates on creating one scenario concept with higher detail on environmental innovations and as a whole working system. The definition of one scenario instead of many is based on the fact that the C2C Building Charter holds elements that can be regarded as one type of scenario approach. The other reason is the extent of the thesis subject as the making of one scenario holds enough work for thesis subject in this case.

The actual future concept design will be divided into design systems in chapter 4 and context level parts shown in the chapter 3 as design background.

2.4 Technical aspects of the visionary future concept

The basic design criteria for the floating building considering the floatation devices and floating building was based on British Columbia Float Home Standard (British Columbia Float Home Standard, 2015). This was used because local guides was not found.

In addition, the technical aspect of the visionary future concept has been discussed and approved in very principal level by professionals having more understanding in certain technical aspects of the concept. Some very preliminary evaluations and calculations for the concept were made with the help of my colleagues from Meyer Turku. These calculations include stability and floatation capability of the concept done by Napa program expert Mr Erik Routi (Routi, 2015). Results will be added to the thesis material. The floatation unit design was approved in preliminary conceptual level by hydrodynamics engineer Mr Raimo Hämäläinen (Hämäläinen, 2013). Idea for mooring system was supported by Prof. C.M.Wang (Wang, 2014) from Singapore University of Conceptual and preliminary structural help assuring some viability considering the building superstructure strength and stiffness in principle under marine conditions was given by experienced naval architect Mr Ari Niemelä (Niemelä, 2014) from Meyer Turku. During the conceptual development process I was very pleased to have the possibility to talk to respected architect Tom Wright (Wright, 2013) visiting Meyer Turku at that time. I presented the concept as a whole and got some comments considering the floating building design. These will be mentioned in the design background chapter 3.

3 Design Background

3.1 Review of water as a living environment of floating communities

Water offers a living environment with rich aquatic ecosystems, livelihood, fairway, trade routes and beautiful shorelines with great scenery for recreational activities and habitat. It is important for us to preserve this lively environment because of they hold such an important role in our ecosystems and effect the climate and weather (National Oceanic and Atmospheric administration NOAA, 2015).

Water is the essential substance for living and exists in every living organism on earth. According to National Oceanic and Atmospheric administration (National Oceanic and Atmospheric administration NOAA, 2015) the oceans covers 71% of the Earth's surface and contain 97% of the planet's water. Due to enormous water surface, the earth offers challenges and opportunities for creating the floating communities now and in the future.

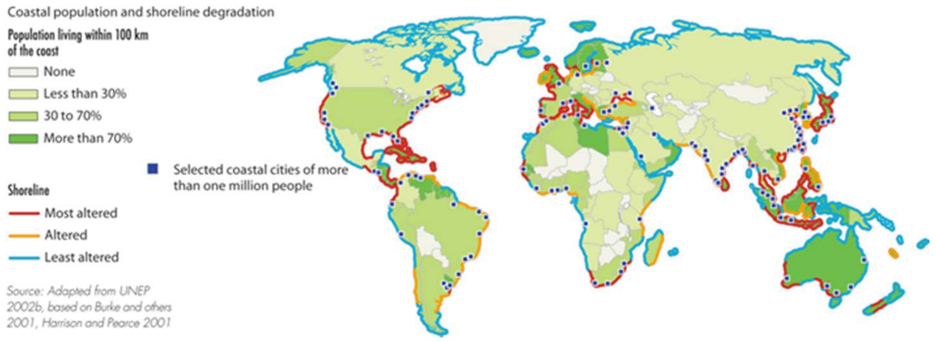


Figure 1. Coastal population and shoreline degradiation.

Human development has always been concentrating near the existing water resources as can be seen in the figure 1. In some cases human communities have formed floating habitat on water in the lakes, rivers, shorelines mostly with short connection to shore. Floating communities and housing have existed from early times of human civilization like in the example of Uros Island pre-Incan community some 3,700 years ago (Ward, 2013). Flooding and tsunami areas have challenging living conditions and communities with floating houses may have benefits in these kinds of situations.

According to my findings during the research, the most active countries with floating communities and developments are in the Netherlands, Japan, England, USA, Canada, Thailand, United Arab Emirates, South Korea, China, Philippines, Cambodia and Vietnam. The floating community developments have evolved from very primitive communities to future visions of city scale urban floating utopias. Based on my findings on the presented cases the people living in wood and reed constructed floating platforms were the first pioneers of floating communities making their living on day to day bases.

3.2 Examples of floating communities

Discovering the long history, variety of floating communities and concepts around the world was inspirational for this thesis. The presented cases are not to be regarded as a presentation of common floating community cases. These cases have been chosen based on their qualities and details in their design having inspirational effect on the future floating community concept for Singapore 2030.

In the end of every presented case the findings and inspirations have been listed and the main findings which influenced the future floating concept design have been pointed out.

All these findings and inspirations mentioned in the cases have affected the outcome in the actual future floating community for Singapore 2030. These influences will be mentioned in the actual design chapter in right places considering the concept and details.

As shown in this chapter with some chosen examples the floating communities have existed for a long time all around the world and have proven success in community level. The dense urbanization in the coastal areas among environmental issues has proven the need for floating buildings and communities.

Living as a community has many benefits compared to isolated floating housing. In a community-scale denser floating building the possibilities for sharing resources apply in many levels and sharing resources can also mean sharing services and expenses for common good. This makes it possible for the community living in a building to make shared investment plans for better technologies and sustainable solutions.

3.2.1 The ancient Uros Islands pre-Incan floating community in Peru Bolivia in the Lake Titicaca

The Uros floating community is a fine example of an ancient and still existing community of people capable of making their way of living in floating islands constructed of reed. This distinctive floating community has formed a tight community in order to survive. "Kot-suñas" - the people of the water, as the Uros population call themselves were forced to take up residence on the manmade floating islands on Lake Titicaca after the Incas expanded onto their land (Promoter, 2014). At that time the floating islands were not so close to the land as they are today (Promoter 2014).

The history of Uros populations of Peru and Bolivia date back to some 3,700 years ago (Ward, 2013). Today their community still exists. It has survived by adapting some of today's living habits and by making a floating communications a tourist attraction. The populations make their living from selling their handicrafts to tourist and from fishing. (Promoter, 2014).

The most impressive quality the Uros population have is the creative and balanced use of natural resources which has also worked as an inspiration in the development of the Future floating Community Concept (Promoter, 2014). The Uros populations have concentrated on using the Totoro reeds which grows in nearshore areas of the lakes. Availability of Totoro reeds and the depth of water below their floating islands has defined the locations of their islands. (Promoter, 2014).

The floating islands are built from layers of knitted Totoro reeds. The Uros people also use the totoro reeds for boats, food, herb tea ingredient, arts and crafts. They also use boats made out of reeds for daily travel, fishing and material gathering. (Promoter, 2014).

The mooring system of the islands is based on anchors which are connected to the bottom of the lake. Each island consists of blocks which belong to several families. The islands are mostly parallel to the shore. (Promoter, 2014).

The Uros community handle the maintenance of these floating islands by adding a new layer of dry reeds on top of the blocks every two or three months until it is about two meters high. They also built compost places to the floating islands. The used biodegradable materials compose through the reed layers and degrade back to the waterbed.(Promoter, 2014).

The Uros community has some common facilities which provides the basic services for the community like early school and community buildings. The community also accepts modern technology like solar panels, television and a radio to stay connected to the outside world. They produce local food partly by domesticated animals. (Promoter, 2014).

The Uros community is a great example of a floating community living mostly in balance with the local near shore ecosystem. Their simplistic and unique lifestyle is an eco-tourism attraction and gives the Uros enough income to preserve their way of life (Promoter, 2014).


Figure 2. Picture showing the extensive use of totor reed in the community.

Figure 3. Local habitant making food.

Findings and inspirations for the concept:

- Uros people have cohesive and simplistic lifestyle concentrated around their floating community and use of Totoro reed for living. The community must work together in order to maintain their way of life and the floating islands. Future floating communities can learn from this kind of setting where everyone must be active in order to maintain their way of life and adapt new to survive. Uros people need to have common goals and effort like will to improve and maintain their community, floating islands, respect for nature, fishing, tourist attraction, arts and crafts.

- The Uros community has some community houses and early school facilities to provide early education. Future floating communities could also facilitate early learning and greater understanding of the surrounding nature and ecosystem.

- The creative use of Totoro as the fully biodegradable main building material and the composting quality of rotten Totoro participating in the composting of biological waste is beneficial for the community. The composting gasification effect of Totoro reed gives the floating islands more floating capacity, but the environmental effect of released biogases like methane and carbon dioxides is not good to the atmosphere. In the future floating communities the formed biogas from local bio waste could be harnessed like in an aerobic digestion process as heat and power source for the community. This is closer to the principles of Cradle to Cradle biological material cycle principles and waste to food principles. (Braungart & McDonough, 2009)

- Uros people use local food production and this can be applied in the future concept to benefit the community. This can lead to benefit the floating community by making them more self-sufficient in food supply, lowering the expenses for food and keeping the food fresh.

- Adjusting to time and modern technology keeps the people connected to the outside world. In future floating community development and in highly developed countries like Singapore the modern technology may be everyday tool for people. We still need to understand the balance of using these technologies, because too much technology may lead in to unwanted amounts of unrecyclable technical materials waste contrary to the C2C material recycling principles.

- Uros people build their floating community platform, housing, boats, arts and crafts from a single material. Using biological fast growing sustainable material from site could be the way to go for future floating developments.

- Reed is used as herb for tea and this way supporting local wellbeing. Medical plants and the wellbeing of local community can be valuable thing in future floating communities. This was considered as inspiration for the future concept.

3.2.2 Ha Long Floating Fishing Communities in Vietnam

In some floating communities the livelihood like fishing is the greatest reason for the community to exist in the area.

Halong Bay in Vietnam holds a community of 1600 people in four fishing villages. These villages are called Cua Van, Ba Hang Cong Tau and Vong Vieng in Hung Thang commune. All the fishing families have small floating houses and earn their living by fishing and marine aquaculture. These floating villages are made on top of plastic canisters connected with wooden frames and light weight houses are built on top of the floating platforms. (World Monument Fund, 2014).

The floating houses are equipped with modern day equipment's like furniture, radio and television. The fish are kept on underwater hutches before they are transferred and sold to the markets in the market places. These surrounding islands have too demanding slopes and forms for build housing. The community are solely dependent on fishing and this is a very fragile way of life. Still there is a possibility for the floating villages to move to another site when needed. These people at the floating fishing village community form a close family relations taking care of each other's. (World Monument Fund, 2014).

Figure 4. Ha Long fishing community.

The biggest problem according to an Thaiways Magazine article (Thaiways Magazine, 2015) in current time is the fact that the problems for the Ha Long fishing communities are mainly environmental because of the bad hygiene, release of waste and byproducts to the waters like industrial runoff, lack of toilets and less conscious tourists. Climate change has recently increased the amount of violent storms in the area killing the fish and harming the equipment. (Thaiways Magazine, 2015). These factors question the very future of this kind of communities and put pressure on solving the environmental solutions of floating communities. Another issue is the fresh water supply which is gathered from rain and sometimes has to be brought from shore. (World Monument Fund, 2014).

The Halong fishing community is an example of floating community having problems with environmental issues affecting their very existence in the area now and in the future.

Findings and inspirations:

- When health issues like bad hygienic and lack of proper fresh water supply is not solved the effect to the health and wellbeing of the community is a great problem.

- When environmental problems like release of waste, industrial byproducts, black and grey water from the toilets and unconscious tourists are not solved the surrounding aquatic ecosystem is in great danger. This should not be the case in future floating communities. Water should be handled in great respect in the future floating community

- Marine aquaculture could have potential for floating community scale developments but the environmental issues of such activity should be solved. This could be a potential local food source in the future concept.

3.2.3 Floating Market Community of Bangkok

Thailand has a long history and lively culture of Floating Markets. According to Thaiways Magazine article the most communities of Thailand were formed at riversides and small river boats were used by people for passing them. (Thaiways Magazine, 2015). "The floating markets become the symbols of the communities in the central plain of Thailand for centuries. This type of market were most popular in the Ayutthaya Period (1350-1767), thanks to the adjoining canals which suited for trading centers. Early in the Rattanakosin Period (1782-1868) this kind of market was still lively. Still soon after the extending road and rail networks people preferred street transportation instead of water and so some floating markets were forced to move onto the ground, some were renovated and some were closed down. Such ways of life of the riverside communities, especially in the Chao Phraya River Basin brought to the rise of a number of floating markets. (Thaiways Magazine, 2015)."

Figure 5. Active floating market in Bangkok.

This example does not present a floating community as habitat but is still as important aspect in the development for floating communities as it holds features that can fuel the very existence of floating community including water traffic, trading for small local businesses like fishing, grocery, flower, herb, arts and crafts and many other locally produced products. The formation of activities related to marine life is also important especially in coastal areas like Singapore. This kind of activity can attract tourists and local people for shopping, using services and trading.

Findings and inspirations:

- The floating market was a very important social, cultural and market driven activity suitable for floating community having activities in the selling and production of their goods like vegetables and fish.

- The aspect of mobility and important connection network to the shore including a sustainable human powered paddling activity used in the small boats is heathy and environmentally friendly way to move in the floating markets and rivers.

- The creation of floating markets, business with recreational and water related activities could be done by creating attractive floating community development intended to offer a platform for such growth. The future floating urban development can form a network of water pathways between the community buildings forming similar effects like in the rivers. The distances between shore and the floating community areas where floating markets might exist is also important to notice. Too long distances may not activate enough market activity. All this was inspiring and taken into consideration when designing the actual future concept. The formation of floating market can be a useful income for the floating community and promote the creation of new businesses around the floating market activity.

3.2.4 Harvest City - A Concept to Recovery

Harvest City floating city concept was developed by Schopfer Associates LLC to respond to the tragic earthquake in the Republic of Haiti in 2010 (Schopfer Assoaciates LLC, 2015). The concept has not yet been developed into a real project, but the features it holds was considered to be influential for the future concept development for Singapore 2030.

The concept as a whole consists of two main philosophies. The first is the design that was based on the principle of archology which in principle embodies an ecologically sustainable and practical urban platform. (Foundation, 2012). This is close to the principles of C2C Building Charter both having Architectural and environmental goals for built environment.

Figure 6. Picture showing the overall layout of the Harvest City with perimeter wave attenuator design.

Figure 7. Picture showing the neighbourhood area with water collection units in the roof areas.

The ideology presented in the Harvest City concept was based on Charter City economic model which was designed for struggling nations. Charter City can be seen as start up thinking at the city scale for future urban developments presented by Paul Romer. (Urbanization Project, 2014). According to Romer Charter Cities share two foundational principles where people must be free to choose if they want to move in and have equality under the law for to ensure everyone has a stake in the economic and cultural life of the new city (Urbanization Project, 2014). In the Harvest City proposal the plan was to build a floating agricultural (two thirds) and light industrial (one third) city with integrated program of economic capabilities (Schopfer Assoaciates LLC, 2015). This integral program for economic model was appealing idea but needed the co-operation from local communities, authorities, developers and businesses to work as common goal.

The main drivers for the Harvest City concept pointed out by Schopfer Associates were the redistribution of population from the destructed area and the establishment of new stable population zones. Restructuring the agricultural and fishing capabilities and finally generating new economic growth in the area. (Schopfer Assoaciates LLC, 2015).

The Harvest City population was designed to be around 30000 residents. Schopfer architects intended to make the design of Harvest City practical and easily constructed with simple refined design. The diameter of the whole city around 2 miles with tethered floating modules. (Schopfer Assoaciates LLC, 2015).

"The layout of the whole city was divided in to four zones of communities consisting four story housing complexes. The outer perimeter of the city had floating crop circles forming one acre of crop and other harvesting land with feeder canals. (Schopfer Assoaciates LLC, 2015)."

In the Harvest City planning the middle harbour areas were designed to hold central buildings like schools, administrative, community activities and general market places for people to use (Schopfer Assoaciates LLC, 2015). "The residential neighbourhood buildings consisted of simple "tilt wall" having 4 stories, white concrete walls and floor system providing also insulation (Schopfer Assoaciates LLC, 2015)." Insulation can be important for lowering the inner space temperature.

The apartments in the neighbourhood were designed mainly as studio apartments size of 45 square meters. 10 % of the apartments were one and two bedroom size apartments. The goal was to offer an home for 1,500 residents in 560 apartment units. (Schopfer Assoaciates LLC, 2015). This was quite proper sizing for a smaller community scale development which was the intension in Singapore.

The apartments in the planning had minimal features which included a pre-fabricated kitchen and two dividing walls. In The Harvest City design the water harvesting was handled by sloped roofs which led to water fill tanks and potable desalination technology were intended to be used in each apartment unit. (Schopfer Assoaciates LLC, 2015). The use of bamboo was environmental solution as it is fast crowing material with great durability and can be used in many parts of building construction.

In Harvest City design bamboo was used it for large passive shades over the cross vented window. This solution enhanced the air cooling capabilities. In the planning dormitory style bathrooms and showers are used for men and women in each floor. These locations centralize the sewage and grey water collection. (Schopfer Assoaciates LLC, 2015).

In Schopfer architects design the whole city was intended to be protected with perimeter wave attenuators preventing possible hurricanes and typhoon to make remarkable damage. For this size of development a proper connection to the seabed was needed and in this case cable connection was used to keep the floating city stationary and safe. The low draft dead weight and low profile buildings design goes in line with this protecting ability. (Schopfer Assoaciates LLC, 2015). In Schopfer architects design smart recycling was used as the concrete rubble from the earthquake could be used as the breakwater filler was considered to be a sustainable solution (Schopfer Assoaciates LLC, 2015).

This aspect was in line with the C2C Building Charter where recycling and materials opportunities were pointed out (Michael Braungart & William McDonough, 2009). According to my findings, the most used material in the whole floating city concept and floating platforms was based on concrete including the hulls and when comparing to my findings during the design background, majority of floating building projects use marine concrete and different reinforced concrete solution in the flotation design. Schopfer architects pointed out the long lifecycle for the concrete hulls from 60 to 100 years and low tech qualities when thinking about production and final assembly to site (Schopfer Assoaciates LLC, 2015). Finally a secure waste solution is presented by Schopfer architects, where waste processing is handled as decentralized solution having a series of compact treatment plants with small energy consumption (Schopfer Assoaciates LLC, 2015).

Findings and inspirations:

- The ideology called Arcology (Foundation, 2012) and C2C Building Charter goes towards same direction combining architecture and ecology. C2C Building Charter having sustainable and even regenerative aspects in the design has the same coals.

- The Charter City ideology envisioned to build a floating agricultural (two third) and light industrial (one third) city with an integral program of economic capabilities. This ideology could be used in the future concept by designing possible platform for small business and even agricultural or community farming activity to work as combined small business model benefitting the local habitat and visiting people.

- The use of bamboo as a light building material with beneficial sustainability aspect was considered in the future concept as this was used in the Singapore region.

- The simple tilt wall design was proven to be effective as external shading mechanism. This aspect was taken in to consideration in the future concept as low tech but still effective solution.

- Harvest city perimeter wave attenuator hold good design features blocking the harmful wave and even tsunami activity but at the same time allowing the light boat traffic to pass by in to the inner parts of the floating city. This feature with radial shape inspired the wave attenuator in the future concept.

- The extensive use of boats for transporting the goods and people were used. This was considered with sustainable mobility aspects in the concept.

- Extensive use of rainwater harvesting and greywater purification was used to benefit the community. This was also beneficial to be used in Singapore according to local weather with high average rainfall.

3.2.5 Floating Houses of IJburg Amsterdam

The floating houses of Ijburg which have been designed by Marlies Rohmer Architects (Marlies Rohmer Architects, 2011) are one of the very best examples of current developments in contemporary water dwellings forming a community of 75 floating homes. ”The Netherlands has a long history in floating housing but still only recently floating homes have reached a significant role as a solution for Netherlands modern housing (ArchDaily, 2011).” The floating homes form a modular but variant architectural building mass to the Ijburg district in Amsterdam.

Figure 8. Floating Houses of IJburg Amsterdam.

According to the article the floating homes in IJburg are partly rental and owned (ArchDaily, 2011). In Rohmer Architects point of view there are two driving forces effecting the growth and the enthusiasm for living beside the water. “First, the rising sea levels with increased precipitation. Secondly, the increased shortage of new build land. The IJburg district has formed complete floating neighbourhoods including jetties and water canals. (Marlies Rohmer Architects, 2015).”

In the Rohmer architects design the floor plans have three free layout storeys with numerous layout possibilities (Marlies Rohmer Architects, 2011). This offers the aspect of building adapting for different needs over time like in C2C Building Charter (Braungart & McDonough, 2009). According to Rohmer architect plans the in the submerged first floor area are the bedrooms with privacy. In the next floor which is raised from the ground (water) level there is privacy from jetty and passing traffic. There is a patio with peer included for boat. The upstairs offers two verandas allowing space for relaxing spots and socializing. (Marlies Rohmer Architects, 2011).

In the Rohmer architects vision” building on water needed to respect the unique nature of water and surrounding environment” (Marlies Rohmer Architects, 2011). This aspect is important to take into consideration in any floating community development. In their vision they highlighted the possibilities to sense the surrounding world and be close part of everything around the house. For example in their vision it is possible to feed swans from the kitchen window and ice-skate around the house. (Marlies Rohmer Architects, 2011).

Figure 9. Picture showing the different variations in apartment sizes build from modular parts.

Figure 10. Picture showing the recreational activity and facades from the floating buildings of Ijburg.

Figure 11. One floating module house going to the site.

Findings and inspirations:

- The overall exemplary modular building system with considerable variation was inspirational for the future floating concept especially when considering the apartment scale design. The apartment sizes and inner spaces should consist of features allowing flexible use of the existing space like possibly movable wall system allowing adjustable layouts in the apartments. This supports the C2C Building Charter idea of buildings adjusting to the changing needs over time.

- The structure of the floating house units included pre-fabricated parts and this was considered a must for the future concept to reach for better effectivity and pre-fabrication possibilities.

- The houses are transported by water to the location after they are constructed on a shipyard (ArchDaily, 2011). This could still work in even a bigger building having modular construction capabilities like in the future floating community building. This was the principle in the future concept.

- The feeling of living on the water worked as inspiration like in Ijburg community. The aspects of floating living should be enhanced and made rich in the future concept for Singapore by adding recreational possibilities and closeness to nature to the floating building area.

3.2.6 'Mermaid' by JDS architects

Figure 12. Aerial rendering of the Mermaid Concept

According to JDS Architects the floating development named Mermaid is a private floating building project which combine compelling architectural design with sea and air. In the vision of the designing architects the Mermaid consists a large dolphinarium and wellness center. (Designboom, 2015). The target group of the concept is mainly on tourists who want to focus on themselves and life quality (JDS architects, 2009). The 'Mermaid' includes also Holiday-apartments and hotels (Designboom, 2015). The project is now under development as all inclusive resort for the Middle East (Desdema, 2015).

The driving factors for the shape of the Mermaid were the combination of view and internal relations between the main services. The shape of the building was designed so that outside the hills and inside the cave spaces offered view to the water element, harbours and dolphinarium. The concept includes greenery areas inside the building. (JDS architects, 2009).

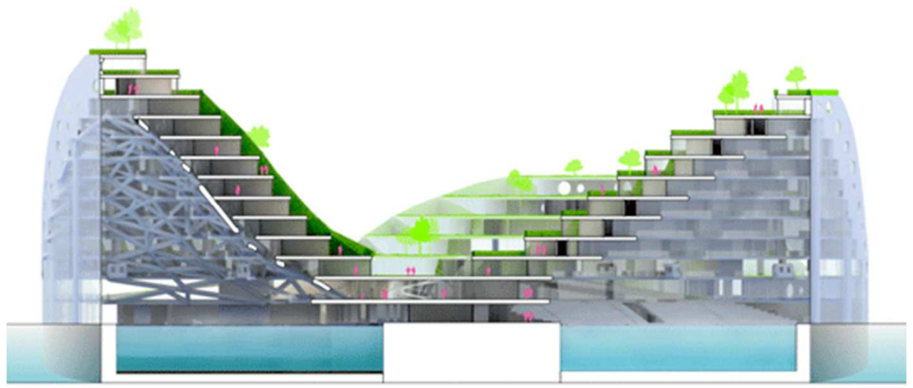


Figure 13. Cross section of the floating Mermaid showing the structure.

Figure 14. Top view of the Mermaid concept showing the top layout of the building and green areas.

Findings and inspirations:

The 'Mermaid' design holds features worth considering in the future floating community design.

- The overall round massing of the floating building in the design of 'Mermaid' holds features like curving arc shaped cave like shading forms which cool down the covered air and seabed. This feature could be beneficial in the design of the future floating concept when natural cooling is the most preferable way to solve the cooling of the building and lower energy consumption. The design can still hold aesthetic value at the same time.

- The extensive use of different green roof spaces was inspirational and could include recreational and community farming activities. These could be beneficial by creating greenery for the future floating building design especially in the top floors of the floating building.

- The aspect of wellness activities and spa was inspirational for the wellbeing of the future floating community habitat having positive effect enhancing and motivating healthy lifestyle.

- The operators on the Mermaid concept were Dolphinarium, Wellness-center, Holiday-apartment and Hotel based businesses. Even if the future floating building for Singapore does not have a client as operator this setting could be close to the possible operator for the future concept and has influence on the concept services.

- The intecration of topsoil and carbon re-use was used in the Mermaid concept.

3.2.7 Review of current developments

The current development of floating communities and architecture has shown great development past years around the world. This can be proven by the amount of big scale projects presented in the media in the recent years. It is evident the future will most likely bring more floating community scale developments.

According to my findings architects, companies and authorities are finding their way to develop floating community scale development especially in densely populated urban coastal areas where floating development has also financial backup compared to land reclamation high land prices. The juridical issues, building standards and sustainability aspects for floating developments are still under development for many countries.

According to my findings institutes like The Seasteading Institute (TSI) and companies like Deltasync and Chimizu Corporation have multi-disciplinary design, research and development resources and are raising new questions by developing concepts for community and city scale to be seen in the public. Deltasync and Chimizy Corporation have studied cities with scalable modular building blocks. For example the 'Green Float' concept by Chimizu Corporation proposes modular floating city for 40000 residents (Chimizu Corporation, 2015). The Deltasync developed the 'Blue revolution' concept. The concept includes creation of new space for food production and urbanization (Deltasync, 2015).

Even concepts for recovery after a devastating earthquake like Haiti in 2010 inspired architects like Schopfer Associates LLC to vision a whole floating city like The Harvest Citywhich was seen in more detail in chapter 3.2.3. (Schopfer Assoaciates LLC, 2015).

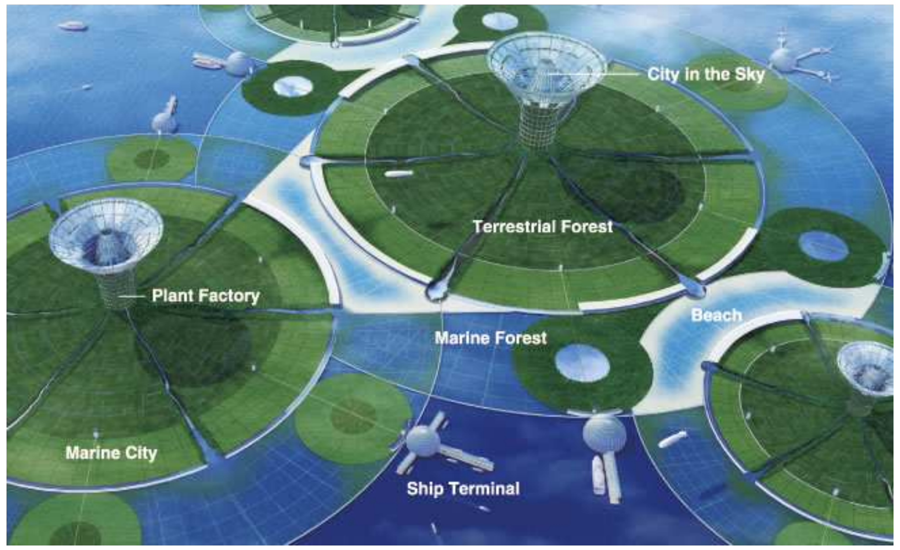


Figure 15. Artistic rendering of the Green Float concept made by Chimizu Corporation

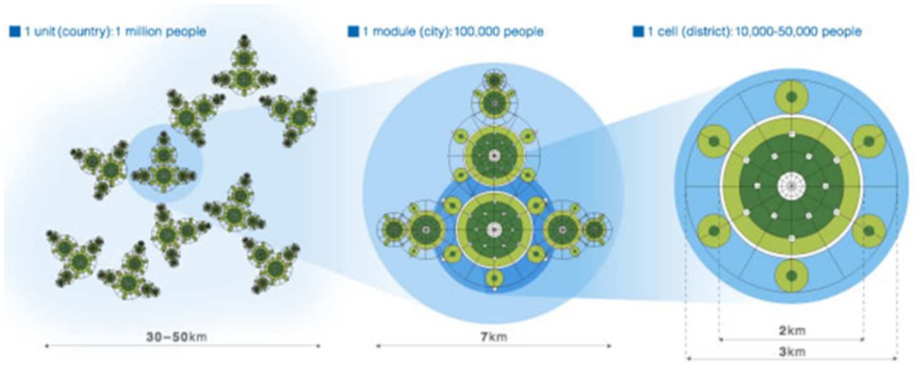


Figure 16. Modular and scalable structures on Green Float

The Green Float concept had a scalable radial modularity which worked as an inspiration for the future floating concept for Singapore using circular platforms and modular expansion possibilities in larger scale.

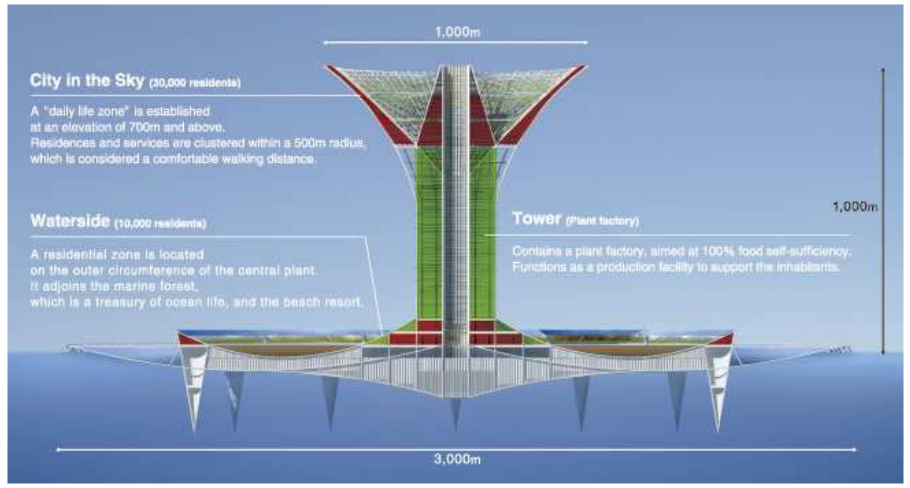


Figure 17. Section describing the different areas on the Green Float

Figure 18. Blue revolution rendering.

3.3 Starting point for the floating community design

3.3.1 Defining the timescale 2030

The timescale for 2030 was based on the fact that a more viable visionary future concept was easier to produce when the timeline for the concept was between 10-20 years giving time for new developments to mature and still not being too far from the current state (Kokkonen et all., 2005, p.71).

The other influencing factor was based on the important future research material like Sustainable Development Blueprint for Singapore (Singapore Government, 2012). It had viable material and goals for 2030 and beyond.

Also the Singapore's future land reclamation plans had great influence to the future floating concepts timescale. It is set by Ministry of National Development (MND) to 2030 and beyond. (Ministry of National Development, 2013).

3.3.2 Possible client for the concept

The possible client for the concept was kept open and the creative part of the future concept open in this aspect. The intention was to create a concept with open possibilities considering the possible actual users, service and operators for the building.

The certain aspect was the concept was intended for community size habitat and small business activities, but the definition whether if it is owned, rental or a hotel housing based is not defined for certain.

More important for the concept was to present an innovative open platform concept for living as future floating community defined for Singapore environment in the future 2030.

Some loose comparison for the apartment sizes was defined compared to local housing operator HDB (Teoalida, 2015). The freedom to adjust the apartment sizes was taken as a starting point to reach wider client base if the concept would get further interest.

3.3.3 Possible siting for the future concept

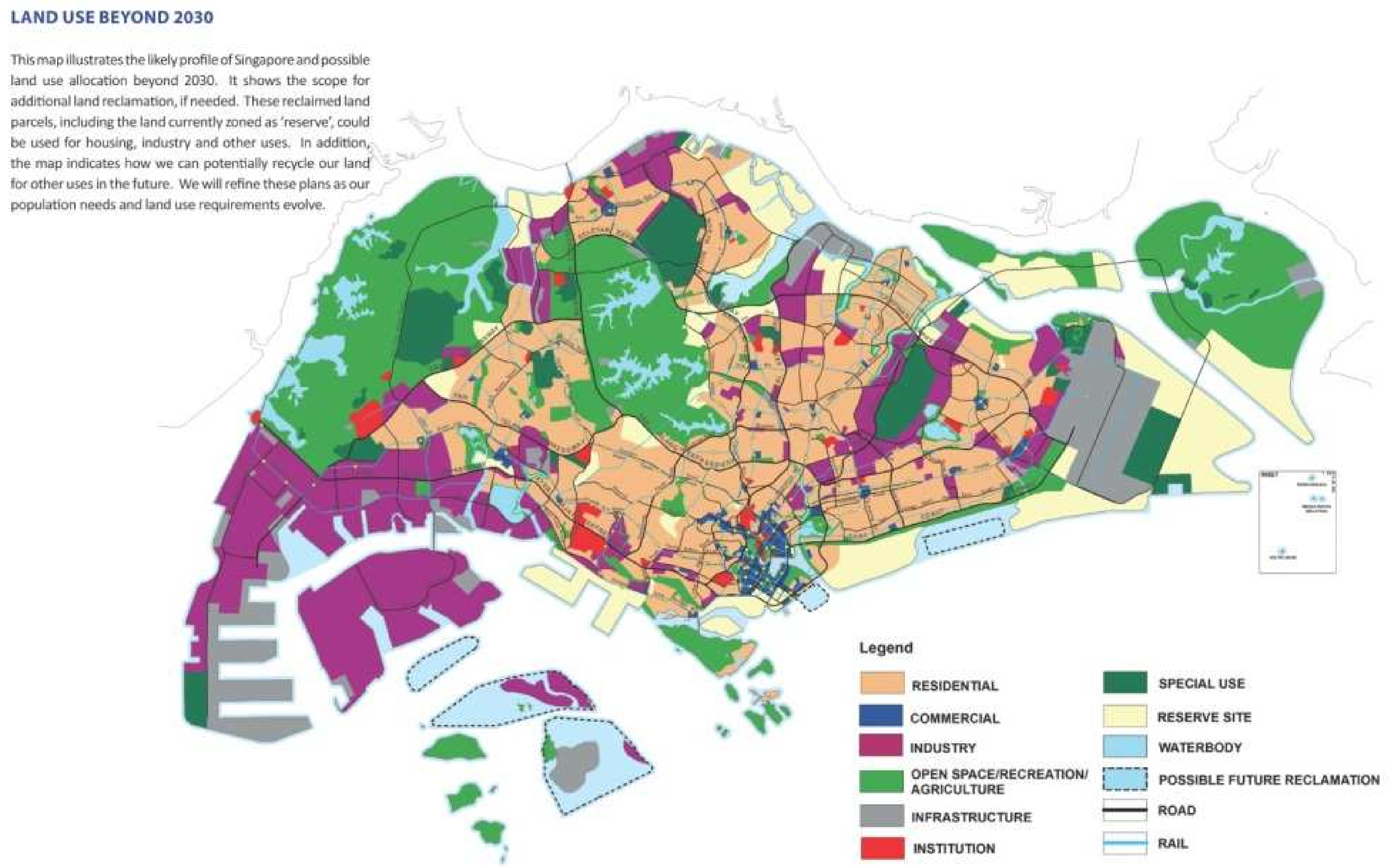


Figure 19. Land use in Singapore beyond 2030.

The possible site for the floating community concept could be the extend reclamation areas which has been shown by the Ministry of National Development in Singapore (Ministry of National Development, 2013). These new land areas can be seen as reserve site areas in the land use plan beyond 2030 seen at the figure 19.

As the concept is intended to be modular, moored to the seabed expandable and with connecting gangways to the shore it is possible to install the concept in many locations. The floating building(s) have also preferable positioning according to wind and sun direction. The sea depth level of the possible site was also important issue as the concept was intended to be positioned in to bit deeper areas across the coastline for environmental reasons.

As shown in the land use plan the number one priority is land reclamation following reserve land development, intensifying new developments and recycling of lower density areas like golf and industrial land areas. Still the number one way of handling the extension is additional land reclamation. This proves the sobriety of the government plans to reclaim land for 2030 and beyond. (Ministry of National Development, 2013).

During my early research I found official comments supporting the idea of future floating development at Singapore. "Experts in Singapore are studying the use of large floating structures, which could support different facilities, and this innovative approach could "create" new land for Singapore (Yiting, 2012, p. 1)."

The same article point out the statements from Maritime and port Authority (MPA) in Singapore that the Singapore waters mainly are used for offshore installations and to support the safe operation of sea going vessels. "As Singapore's sea space is limited, MPA and relevant institutions would regularly review various uses to develop the most ideal plans for future maritime developments. (Yiting, 2012, p. 2)."

3.4 Singapore as a site for future floating community 2030

Architecturally Singapore is known to be very open for pioneering, sustainable and landmark driven architectural solutions in the most recent urban developments. High quality living standards and sustainability goals are a must for the future of Singapore. The current developments in the architectural field of Singapore shows marks of modern architecture suitable for the Singapore's tropical climate.

Singapore has many architecturally remarkable landmarks which has been considered as a background for the future floating concept design. Few of the most significant inspirational buildings in the Singapore coast line are introduced by pictures in this chapter. The design of these buildings worked as a background frame for the concept.

Gardens by the Bay Conservatories with remarkable covered green areas and tropical vegetation. This National Parks Board's (NPARK) vision was to create a 'City in a Garden' capturing the essence Singapore as the premier tropical Garden City with the perfect environment which to live and work in making Singapore a leading global city of the 21th century (Gardens By The Bay, 2015).

Figure 20. Aerial view of Gardens by the Bay Conservatories

Figure 21. View Inside Flover Dome

Figure 22. Aerial artist rendering of the whole consept

Figure 23. View in the Silver Garden showing the remarkable artificial Super Trees

Figure 86. Singapore skyline

The most known and symbolic landmark in Singapore is "The Marina Bay Sands" integrated Resort. The Resort includes the appealing Sands Skypark platform combining the three resort buildings together with stunning views all way around the Singapore skyline. The Skypark has a 360 aerial view all around the Singapore Skyline. (Marina Bay Sands, 2015).

Figure 24. The Main landmark Marina Bay Sands integrated Resort

The shophouses in Singapore have nostalgic and historical value for the locals and play important role in the local architectural heritage. These narrow and small terraced houses have variating colors distinguished them from each other and have different appearance from different periods. (Urban Develpment Authority , 2015).

Figure 25. Typical shophouse styles

The shophouses are used for business and living. They were built between the 1840s and the 1960s and most of the urban fabric from pre-world war 2 times was shophouses in the old city center and in other parts of Singapore. (Urban Develpment Authority , 2015).

The importance of these buildings could be embraced in a symbolic way in the future urban developments as a reminder of these old times when combined in a modern way.

The urban Singapore coastline has already shown some marks by extending towards the sea by presenting two remarkable and very different floating structures right in the middle of the Marina Bay.

The first is the floating Louis Vuitton Maison, Singapore luxury shop. According to Luxury Society article the LV's first Southeast Asian Maison will sit directly on the water as an Island, with floor to ceiling windows overlooking the bay. A contemporary art gallery tunnel is included and connects directly to the Marina Bay Sands Mall. The boutique itself will feature a private lounge with outdoor loggia. (Doran, 2015).

Figure 26. Picture showing the Marina bay including the floating Louis Vuitton Maison, Singapore luxury shop.

The other remarkable floating structure in the area is The Marina Bay Floating Platform, the world's largest floating stage. It serves as a multi-purpose stage for variety of activities in the area.

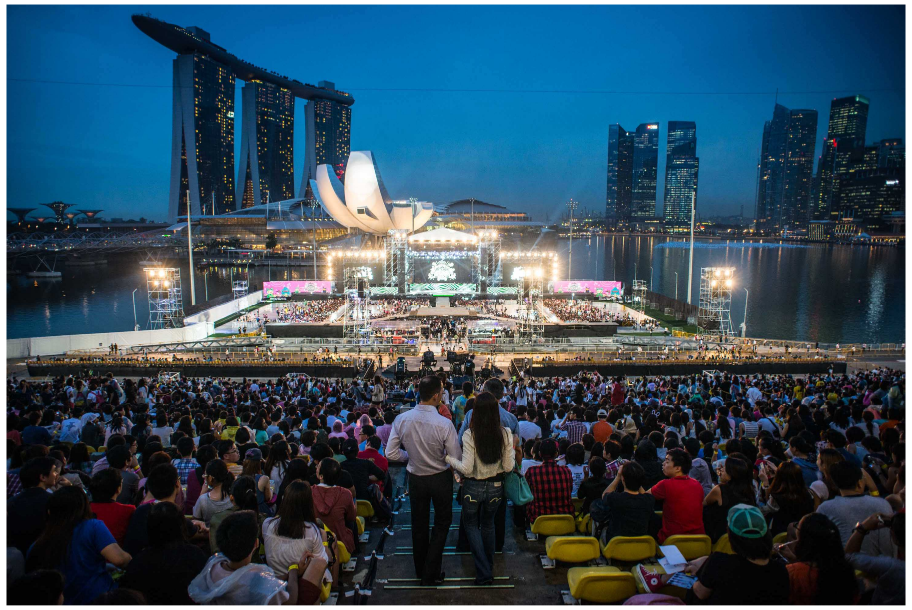


Figure 27. Picture showing The Marina Bay Floating Platform in use for concert.

This kind of innovative floating constructions show the possibilities for using floating structures as extension of the urban space towards the water and might open the gate for the future floating developments in the Singapore coastline.

The raising population

Singapore is an exemplary country with very high population density compared to the land areas size (715.8 sq km) and the population development towards year 2030 can reach at highest estimates to population between 6.5 and 6.9 million. (National Climate Change Secretariat, 2015b). Still the national population rate is expected to slow down and more non–resident including foreign manpower is needed in the future and they will be supported by a smaller base of working-age citizens (National Population and Talent Division, 2013, p. 48).

According to National Population and Talent Division predictions the average age of Singapore citizen will rise from 39 years in 2011 to 47 years by the year 2030 and at the same time, Singaporeans are living longer (National Population and Talent Division, 2014, p. 2). These changes in the population structure should be taken in to consideration when thinking about future floating community development and possible design of the floating building.

Need for new land

Singapore has already reclaimed 17% new land and buried much of Singapore's coasts (WildSingapore, 2015). The estimate for new land reclamation plans is about 5,600ha by the year 2030. This new land will be added to the current 71,00ha land area in Singapore. (Ministry of National Development, 2013, p. 12).

Singapore authorities have limited the floating building floor height to six floor buildings above the waterline was considered. The six floor rule was based mainly on safety and stability estimations. (Yiting, 2012).

Singapore government's goal is to "form an environmentally responsible community where everyone adopts a more environmentally responsible lifestyle and should be part of people and business culture. Singapore Government also wants to encourage Community ownership and participation in building a clean, green and resource-efficient Singapore. (Singapore Government, 2012, pp. 35-36)."

Another important goal which government has set is to "build Singapore into an outstanding knowledge hub in the latest technology and service that will help cities grow in a more environmental friendly way (Singapore Government, 2012, pp. 35-36)."

Singapore wants to offer more clean, blue and green physical environment to its citizens in the future. The city has "a goal to increase the green park space by 900ha to 4,200ha by 2020, and reach a park provision of 0.8ha per 1,000 population by 2030 and increase the length of park connectors (linear parks) from 100km in 2007 to 360kmby 2020. (Singapore Government, 2012, p. 35)."

Singapore wants to also introduce "30ha of skyrise greenery by 2020 and 50ha of skyrise greenery by 2030 and open 820ha of reservoirs and 90km of waterways for recreational activities by 2020 and have 900ha of reservoirs and 100km of waterways open for recreational activities by 2030 (Singapore Government, 2012, p. 35)."

"Open up 820ha of reservoirs and 90km of waterways for recreational activities by 2020 and 900ha of reservoirs and 100km of waterways by 2030 (Singapore Government, 2012, p. 69)." Finally this goal for opening 100km of waterways by 2030 can include activities and connections related to floating community.

3.4.1 The coastline of Singapore and environmental aspect for floating buildings

Singapore has a very active seaborne trade. Singapore's interconnectivity according to sea trading routes makes it the preferred port of call for more than 130,000 vessels totaling some 1.5 billion gross tons. (MPA Singapore, 2015)

Figure 28. Picture showing the great amount of marine traffic in front of Singapore coastline.

This massive sea traffic including the great amount of sea going vessels anchored in the Southern coastline of Singapore and near the port areas set a special demand for the possible floating building near these areas. The collision possibilities with possible floating community if near the anchoring areas of the vessels should be one aspect to handle and taken as one design criteria in the future floating community concept. The possibilities for harmful accidents and spills caused by vessel is also present.

Environmental aspects of building a floating community to Singapore coastline

The environmental aspects on building on coastline of Singapore needed some basic research for better understanding.

Most of the coastal areas where the possible places for the future floating community concept could be are shown in the land reclamation plans for 2030 (Ministry of National Development, 2013).

Those areas are located in water body near the coastline in area called nearshore environment. "Nearshore is very important part of any water body which is located in the band of habitat between dryland and the deep water known as the nearshore environment (Washington State Department of Natural Resources, 2015)."

"Nearshore environment supports a unique community of plants, algae and animals which are the foundation of life for both aquatic and terrestrial wildlife. Unfortunately this critical and sensitive area is the same area where most human activities are. (Washington State Department of Natural Resources, 2015)."

According to WildSingapore the massive changes to the shoreline affects to the coastal areas ecosystems by fragmenting the original habitats. (WildSingapore, 2015). "The high level of coastal activity like shipping, dredging, continued coastal reclamation and construction increases the sedimentation and turbidity of the waters reducing the light penetration into the water. As a result this affects the photosynthesis by seagrasses and other plants including the corals which rely on their symbiotic algae for products of photosynthesis. (WildSingapore, 2015)."

Based on these findings of the current situation in the Singapore coastline the design for floating structures should respect environmental aspect of the nearshore environment and the existing aquatic habitat. The Washington State Department of Natural Resources had a proper scientific topic considering just this issue (Washington State Department of Natural Resources, 2015).

The design issues presented in the list are interpretations to fit the floating community design based on the scientific publication (Washington State Department of Natural Resources, 2015):

- Design the floating structures in deeper water where they cause less shade on aquatic vegetation or design features that allow for sun to pass through them allowing photosynthesis in underwater vegetation
- Design the sanitation system which prevents the release of human waste from entering the water
- Prevent the floating structures and underwater parts from dragging and destroying the seabed
- Design and locate the floating building in a way that the water can more freely flow through to prevent stagnation and buildup waste and sediment
- Locate the floating structures to deeper water away from important aquatic vegetation and important nesting areas
- Strong noise caused in the floating community can traumatize fish, birds and other animals causing them to leave and abandon their nearby nests
- Limit vehicular or foot traffic in shallow water areas or use areas which are less harmful for the aquatic vegetation and habitat.

(Washington State Department of Natural Resources, 2015).

C2C Building Charter emphasizes to increase the species diversity like Flora and Fauna and in this case can also be the underwater vegetation and habitat (Braungart & McDonough, 2009).

During the design background I contacted Professor C.M. Wang from Centre for Offshore Engineering in National University Singapore (NUS). Professor Wang was leading a research group concentrated on Very Large Floating Structures (VLFS). VLFS are defined by their size as if the floating structure is larger than 60meters in any given dimension along the waterline they are called as VLFS (Watanabe. E, 2004, p. 2). The environmental friendliness was also pointed out by the research group led by Professor Wang in the advantages of VLFS over traditional land reclamation (Watanabe. E, 2004).

According to a report by a basic estimate the land reclamation is not a profitable solution when the water depth is more than 20meter in depth (Watanabe. E, 2004, p. 2). The advantages of VLFS described by professor Wang and his research group:

- “They are cost effective when the water depth is large
- Environmental friendly as they do not damage the marine eco-system, or silt-up deep harbors or disrupt the tidal/ocean currents
- They are easy and fast to construct (components may be made at different shipyards and then brought to the site for assembling)
- They can be easily removed (if the sea space is needed in future) or expanded (since they are of a modular form)
- The facilities and structures on VLFSs are protected from seismic shocks since they are inherently base isolated
- Their positions with respect to the water surface are constant and thus facilitate small boats and ship to come alongside when used as piers and berths
- Their location in coastal waters provide scenic body of water all around, making them suitable for developments associated with leisure and water sport activities
- They are not affected by global warming.

(National University of Singapore - Faculty of Engineering, 2015).”

This could be reached if the floating community would have system taking part in the cleansing of the seawater and offer new opportunities for the underwater habitat like for fishes.

3.4.2 Singapore’s weather conditions

According to building authority Singapore has dominating annual wind directions on north and northeast depending on the monsoon season. Singapore has in average low wind speeds and the achieved wind speeds are enough to provide comfort to spaces with the help of optimized design (Building and Construction Authority, 2010, p. 29). This means the use of natural ventilation is preferable and can be used for reaching natural ventilation in the building design.

“The abundant rainfall throughout the year can have average of 178 rainy days and the average annual rainfall is 2338mm (Meteorogical Service Singapore, 2015).” The possibilities for rainwater harvesting are also positive. The average rainfall can be used for preliminary study in the received rainwater to be used as tap water.

“Singapore is situated at 1º20 North of equator and has a climate with uniformly high temperature, high humidity (about 84 RH%). Singapore has annual temperature range from minimum 23 to 27°C and maximum 30 to 34°C. (Building and Construction Authority, 2010, p. 64).”

3.4.3 Singapore’s current energy production mix

As a starting point the findings considering the electric supply and generation mix was taken in to consideration.

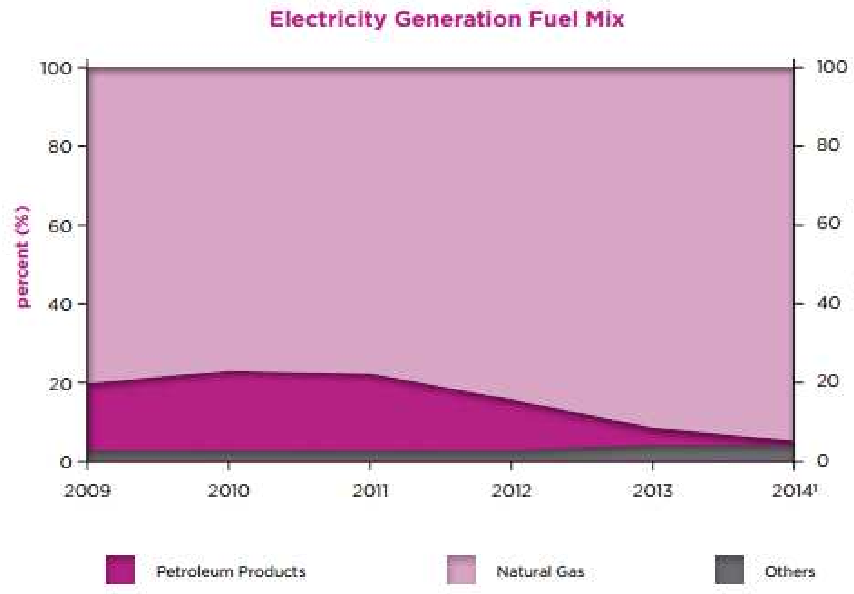


Figure 29. Electricy Generation Fuel Mix showing the use of NG as a main source.

The current dominating source for energy generation in Singapore is natural gas (NG). It generates at highest 95% of the total electric demand in Singapore. The supply for needed LNG is handled via LNG terminal, shipping and before the only option for importing natural gas was via pipeline from Malaysia and Indonesia. (Singapore Energy Statistics , 2015, p. 17).

“Singapore’s electricity generation industry has over the years shifted from using oil fired steam turbine plants to combined cycle gas turbine (CCGT plants). Petroleum products, mainly in the form of diesel and fuel oil, now make up 0.9% of the fuel mix while other energy products (e.g. municipal waste, coal and bio-mass) accounted for the other 3.9%. (Singapore Energy Statistics , 2015, p. 17).”

The surprising fact in the numbers is the amount of municipal waste and bio-mass energy production in the statistics which is low but shows marks for stable raising. The use of biomass for possible energy source was still considered from the very beginning as this supported the C2C Principle for using waste as food and possibly for energy production.

The use of natural NG as the main energy supply makes Singapore vulnerable for possible cuts in the NG supply chain in the case of accidents from now till year 2030 and beyond (National Climate Change Secretariat, 2015b).

3.4.3.1 The use of renewable energy sources in Singapore

The pressure to find sustainable solutions for energy production in Singapore is high and this shows in the number of government funding and incentives for the environment gathered to this site (Greenfuture, 2015).

According to The National Climate Change Secretariat (National Climate Change Secretariat, 2015b) the limitations for viable renewable energy sources at current stage in Singapore have limitations shown in the list:

- "Hydroelectric power cannot be harnessed, as Singapore lacks a major river system.
- Wind speeds are too low and we lack the land footprint for commercial wind turbines.
- The prospects for geothermal energy are low.
- The calm seas, which make a good port, results in tidal ranges that are too low for commercial tidal power generation.
- Singapore small physical size (715.8 sq km), high population density and land scarcity limits the potential for sustainably-grown domestic biomass.

(National Climate Change Secretariat, 2015b)."

Based on these findings the use of solar energy based energy system and possibly biogas based energy solutions are the most desirable approach for the concepts energy production. This idea was supported by the motives for enhancing the amount of topsoil, biomass, resource re-use on site according to C2C Building Charter principles. (Braungart & McDonough, 2009).

3.4.4 Climate Change and the effects to Singapore

The Singaporeans are a remarkable nation showing commitment towards sustainable development in community level activities.
This can be seen in the Blueprint from Singapore Government till 2030 and beyond where many goals head for the more sustainable Singapore in the future 2030 and beyond. (Singapore Government, 2012).

The effects of Global warming and raising sea level has already influenced the future plans for Singapore authorities and actual measures. Singaporean authorities has already planned and executed some countermeasures for the future. For example by increasing the minimum reclamation level of newly reclaimed land.

For example by increasing the minimum reclamation level of newly reclaimed land by 1m in 2011 to cater for long term sea level rise among with heightened shoreline arrangements in many areas as a backup plan (National Climate Change Secretariat, 2015b).

According to Singapore authorities as much as 90% of the national food supply is imported to Singapore (National Climate Change Secretariat Singapore, 2014). In the future the threat of intense storms increase due to climate change and threats the possible food security in Singapore (National Climate Change Secretariat, 2015b). This effect makes Singaporeans particularly vulnerable to fluctuations in global food supply and prices (National Climate Change Secretariat Singapore, 2014). This issue is taken into consideration as a driving force in the Future floating concept and introduced in chapter 4.

3.5 Floating Building System design background

The overall design of the future floating building concept was divided in to parts (systems) where more detailed design drivers, research and findings influence the main aspects of the floating building design. This was also a basic systemic approach to the building. The future floating building as a whole including the sub-systems were intended to design in a way that the interaction between these systems towards the C2C Building Charter goals and values was important.

3.5.1 Floating Building Design, Layout, Superstructure and Orientation

The local authorities have set the limitations for floating building heights in Singapore which also defined the design of the furure floating community concept. According to these limitations there can be six habitable building floors above the waterline based on stability and safety reasons. (Yiting, 2012, p. 3). This limitation affected to the massing, layout and superstructure of the future floating concept introduced later in the chapter 4.

The adaptation for variety of uses over time was considered in the layout design of the building including the modularity. This idea is supported by C2C Building Charter by Braungart and McDonough. (Braungart & McDonough, 2009).

The growing amount of elderly people in chapter sets a design goal to locate elderly living areas to closer access points and to lover levels of the building. Accessibility to the floating building should be easy including the pedestrian routes passages and elevators in the building. This should be shown in basic level in the layout of the building.

For better daylight possibilities the use of small floor plane depth was used trough out the building. This was based on local building authority guidelines (Building and Construction Authority, 2010).

The Ilburg Floating Community designed by Marlies Rohmer to find a flexible modular apartment block solution for the concept allowing some variations in the layout (Marlies Rohmer Architects, 2011) inspired.

3.5.2 Building Envelope

"A building envelope is the separation between the interior and the exterior environments of a building. It serves as the outer shell to protect the indoor environment as well as to facilitate its climate control. Building envelope design is a specialized area of architectural and engineering practice that draws from all areas of building science and indoor climate control. (Building and Construction Authority, 2010, p. 40)."

In the early development of the building envelope when the building mass was already in the final proportion I presented the whole concept to architect Tom Wright visiting Meyer Turku at that time. The discussion with him (Wright, 2013) were positive concerning the whole massing of the concept and in detail we discussed the use of ETFE roof covering in the concept.

"ETFE foil roofs are commonly as a series of pneumatic cushions made up of between two and five layers of a modified copolymer called Ethylene Tetra Flouro Ethylene (ETFE). The ETFE copolymer is extruded into thin films (or foils) which are used to form either a single layer membrane or multi-layer cushions supported in an aluminum perimeter extrusion which, in turn, is supported by the main building frame. ETFE cushions are kept continually pressurised by a small inflation unit which maintains the pressure at approx. 220 Pa and gives the foil a structural stability and the roof some insulation properties. (Wilson, 2013)."

According to Building and Construction Authority there are five performance effecting objectives which affects to the design of the future floating concepts building envelope. These objectives are structural integrity, moisture control, temperature control, control of air pressure boundaries and control of solar radiation including daylight. (Building and Construction Authority, 2010, p. 40). These objectives have been taking into consideration in the future floating concept design and are presented from the concept point of view in the chapter 4.

3.5.3 Flotation System

Based on my findings on the local situation considering the possibilities for vessels to collide to possible floating community in the coastal area of Singapore required some extra measures to enhance the collision safety around the floating community.

As the C2C Building Charter principle point out to anticipate the evolution and change by enhancing the buildings ability to adapt variety of uses in time (Braungart & McDonough, 2009). Also the design of the floatation unit need to adapt in to changes in the surrounding environment. For example possible collision or breaking of floatation units might cause some situations which makes the change inevitable.

Some basic design criteria for the floating building considering the floatation devices and floating building was based on British Columbia Float Home Standard. It gave the needed basic insight for the conceptual design of the floating device. (British Columbia Float Home Standard, 2015).

In this stage the knowledge from Meyer Turku was also needed. The extensive marine traffic is near the possible areas for the floating community building(s). The flotation system should be modular in construction to allow on site assembly, maintenance and dismantling during its lifecycle. This idea was discussed with my colleque Mr Raimo Hämäläinen (Hämäläinen, 2013) specialized in hydrodynamics at Meyer Turku.

3.5.4 Natural Ventilation and Air Quality

C2C Building Charter points out to integrate healthy air production into buildings and area plans so that they produce more healthy air than they use (Braungart & McDonough, 2009).

The use of natural ventilation in the future floating concept was essential for reducing the needed energy for cooling equipment, improving the human comfort in the spaces, improving the air quality and being in control of the thermal comfort (Building and Construction Authority, 2010, p. 58).

"Natural ventilation is a term used to refer to a situation where air movements occur across or within buildings without the aid of any mechanically driven machines such as fan or air conditioning (Building and Construction Authority, 2010)."

The use of stack ventilation for the future concept was possible because of the nature of the building structure. "Stack ventilation uses temperature differences to move air. Hot air rises because it is lower pressure. For this reason, it is sometimes called buoyancy ventilation (Autodesk Sustainabolity Workshop, 2015)."

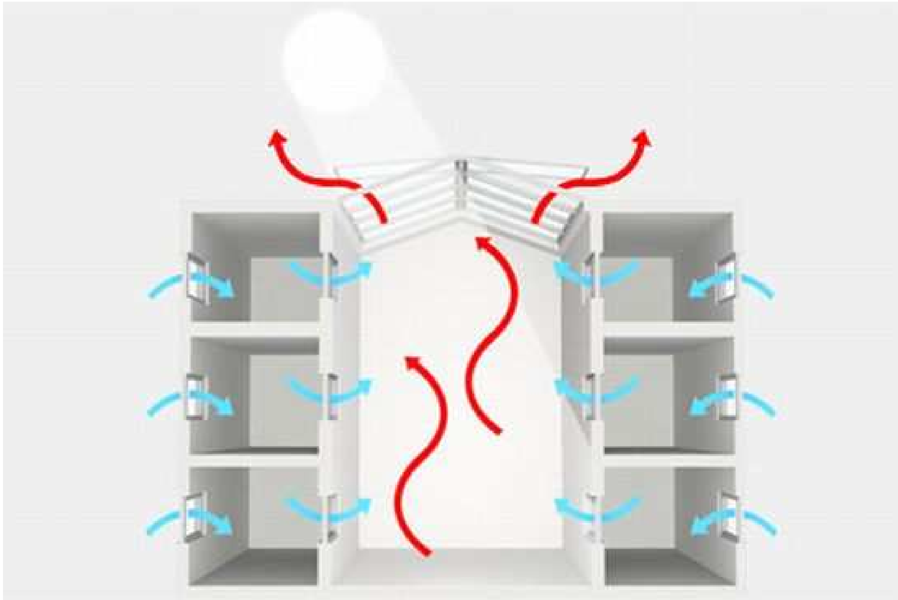


Figure 30. Example of the stack effect principle close to the floating building concept with atrium design.

The use of natural ventilation in the building is not that simple in hot and humid climates like in Singapore. The outside air can carry a large amount of moisture into the building through the envelope by negative pressure inside the building and this can cause mold problems inside the building leading to unhealthy air. (WBDG - Whole Building Design Guide, 2010). This aspect needed a solution which would be reduce the humidity from outside before it reaches the indoor areas of the building. For this issue solution called fog harvesting was found.

"The fog harvesting technology includes a certain kind of nets that trap moisture from the humid air and funnel all the tiny droplets into the water container from where it can be used extra tap water resource when considering the concept (Buczynski, 2015)." This innovation responds to the issues of indoor air quality and extra water resource at the same time. The fog nest system is claimed to be at least five times more effective than any current fog harvesting system. It is possible to collect as much as 10 % of the passing moisture in the air and collect 1 liter of water per day from one square meter of fog nest. (Chandler, 2013).
This could be enough to reach for better moisture comfort levels inside the floating building and at the same time produce drinkable water right into the apartments.

The air quality is major factor when designing a floating building to Singapore environment due to the Sustainable Blueprint goal for 2030. Singapore government's goal is to enhance the air quality. (Singapore Government, 2012, p. 35).

For further development of the future concept's ventilation system a computer simulation based accurate information about annual wind directions shown below would be needed.

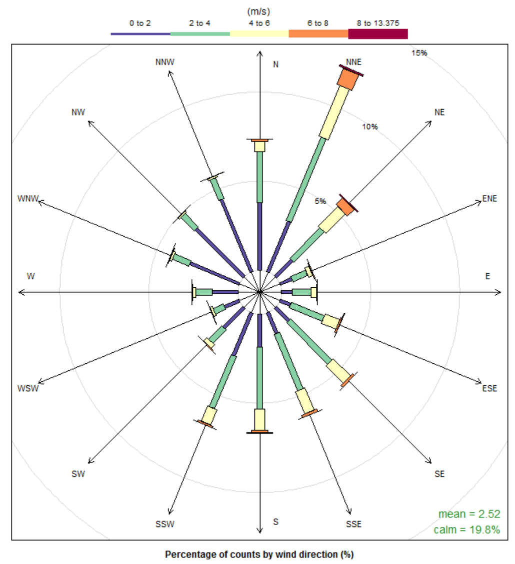


Figure 31. Shows the exact annual wind conditions.

The use of natural ventilation in the future floating concept was essential for reducing the needed energy for cooling equipment, improving the human comfort in the spaces, improving the air quality and being in control of the thermal comfort (Building and Construction Authority, 2010, p. 58).

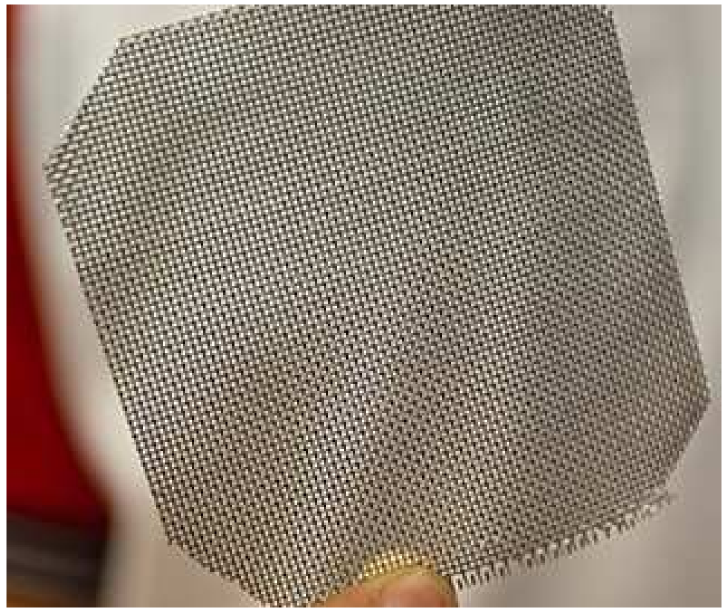


Figure 32. Picture of a test fog harvest mesh

The use of this fog nest system is presented in the building facade design as feature.

3.5.5 Energy

Singapore government is in many ways supporting and increasing the amount of greeneries connected to the built environment.

The C2C building Charter states two guidelines and driving forces which point out the direction for the development towards more renewable energy production and smart use of local resources for energy production. From the C2C point of view the renewable energy should be integrated into buildings and area plans so the buildings produce more energy than they use. Another guideline according to C2C is to think "materials opportunity instead of energy problem". (Braungart & McDonough, 2009).

The idea of using a lot of green spaces which produced biomass came from the combination design inspirations. One environmental way of using the locally produced bio waste for energy sustainable energy production is anaerobic digestion (AD). "AD is the process where plant and animal material (biomass) is converted into useful products by micro-organisms in the absence of air. This biomass can be unwanted 'wastes', such as slurry or leftover food, or crops grown specifically for feeding the digester. (NNFCC and The Anderson Centre, 2015)"

"The feasibility and benefits of the anaerobic co-digestion of sewage sludge and organic fraction of municipal solid waste are dilution of potential toxic compounds, improved balance of nutrients, synergetic effects of micro-organisms, increased load of biodegradable organic matter and better biogas yield (Gashaw, 2014)". To put it simple the biogas production depends on various parameters that affect the yields of the gas from different substrates. The important factors are pH, temperature and more importantly, the Carbon to Nitrogen (C/N) ratio where lower values are usually better for faster composting rates and biogas production (Gashaw, 2014).

There is an example of using an AD digester with the Living Machine in case EVA Centere Lanxmeer in Culemborg (A. Timmeren, 2006). This case has similar functions compared to the floating building concept and important was the actuals process described below from their case.

The founded process was used as to describe the proses in the concept.

- "(1) gathering blackwater on the one hand and green waste on the other, and leading them into the system
- (2) the fermentation process, with biogas, effluent and sludge as its output
- (3) purifying and improving the gas into natural fossil gas equivalent
- (4) purifying the effluent until it has surface water quality
- (5) composting sludge into usable garden compost.

(A. Timmeren, 2006, p. 2)."

Multi-fuel fuel cell technology

According to my findings the most developed fuel cell systems have the quality to use multiple fuel sources like in the case of "Bloom Energy Servers" which "converts natural gas or renewable biogas in to electricity in a direct electrochemical reaction without combustion. According to the Bloom Energy, this highly efficient process is not bound by the same thermodynamic constraints for creating electricity and this enables exceptionally high conversion efficiency. (Bloomenergy, 2015)." The Bloom energy offers more efficiency, multi fuel possibilities and stability to energy production and could be used in the concept.

The exterior of the server fits well with modern environment shown in the figure below.

Figure 33. Bloom energy Server installed into courtyard.

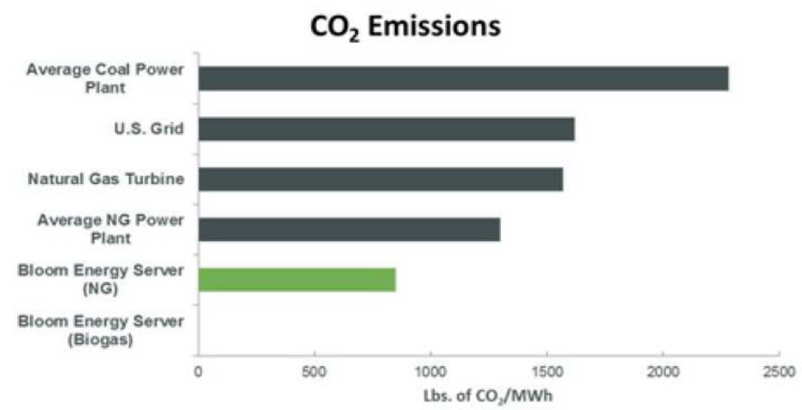


Figure 34. Image by Bloom Energy

The stats show that around 30% lower CO2 emission compared to even average NG Power plants can be reached with this Bloom Energy solution. One issue is the availability of the Bloombox Energy server as it is only produced in USA at the moment but they have plans to go Global and that can happen till 2030. The NG mostly used in Singapore can be a backup system and the driving idea of this type of flexible power source is the possibility to use increasing amount of biogas produced on site when the biodegradable waste amount increases on site. This use of increased biogas leads towards Zero emissions as seen on the CO2 emission stats (figure 34) but extra fuel for the Bloom Box is most probably needed. In this point I have to point that this is a conceptual decription for possible solution. Like in the example case in EVA Centere Lanxmeer in Culemborg had this issue (A. Timmeren, 2006, p. 2). Still the value in using all the possible biowaste onsite is worth the effort. This biogas system supports the waste to food principle in C2C Building Charter (Braungart & McDonough, 2009).

The other supporting fuel for the fuel cell technology is the use of hydrogen and many new developments in the field of solar hydrogen have been done. The use of hydrogen in the energy production as a second fuel source would be possible.

3.5.6 Natural lighting

The sun in Singapore shines almost straight from the top during the day because Singapore is located 1degree north of the equator (Building and Construction Authrity, 2010, p. 35).

The factors for reaching extensive amount of natural lighting for the floating building was considered but not in the expense of extra heat gain. The strong warm sunlight weather in Singapore allows for great amount daylight.

"Minimizing solar heat gains is important, and it is also important to take advantage of and harness natural daylight for spaces. This reduces the need for artificial lighting which requires significant amounts of energy. (Building and Construction Authority, 2010, p. 25)."

The natural lighting and shading capabilities of the building was studied in a very preliminary level in the actual 3d model of the building. This affected the shape and massing of the building shown in chapter 4.3.4.

The East and West side of the building are exposed to greater amount of sunshine during the day. At the same time the North and South sides of the floating building will have better shading capabilities during the day.

A conclusion in this case would be to position the floating building in such a way that the East and West side of the building would have less surfaces and heat gain because of the strong sunshine. These facing windows should have better shading for windows. The Harvest City had a including better reflecting capabilities in the windows.

The other issue considering the whole floating building area including the surrounding structures is the available natural light that passes to the nearshore environment. This was important aspect in the design of the whole area. In the design of the building and whole area it would be better to allow sunlight to pass to the water and trough the floating structure as much as possible. Floating structures causes less shade on aquatic vegetation in deeper water. That allows more sunlight to vegetation and makes photosynthesis possible.

The floating building lighting technology issues are not included in the concept as this would need too much work in concept this size. Still it is important to point out that the lighting technologies till 2030 will have most likely have better energy efficiencies. The extensive use of night time lighting and the effect on underwater habitat and environment is an issue worth studying.

3.5.7 Water collection, purification and recycling

According to Singapore Government the goal to reduce total domestic water consumption from 156 litres per capita per day in 2008 to 147 liters per capita per day by 2020, and 140 liters per capita per day by 2030 was taken into consideration in the concept (Singapore Government, 2012, p. 35).

The greater self-sufficiency and efficiency goal respecting the C2C Building Charter philosophy water recycling for the floating building and the use of biological nutrients in buildings was respected in this design background phase (Braungart & McDonough, 2009).

The use of natural methods for purifying the waste water in the floating community was considered to be most important issue in the concept. The need for recycled water was high because of the considered green areas. The idea was to find effective, low maintenance and scalable natural water purification system to be used and maintained together with the community members. This idea was inspired by the community commitment goal for sustainable development according to Sustainable Blueprint which encourage community ownership and participation. (Singapore Government, 2012, p. 36).

During my research on the subject the innovative system called Living Machine was found. This system presents a biological natural coastal wetlands inspired solution to the water purification and recycling issue. According to Living Machine Systems the system mimics the processes of natural coastal wetlands with specified biological units. (Living Machine, 2012). The reason for the choosing of this system was based on the exceptionally small physical and carbon footprint and great efficiency for cleaning the local black and grey water, flexible scalability. The comparable little maintenance and cost was also great reason for choosing this water cleaning system for the future concept. The actual calculation for water use in the community was not calculated, but the optimized water collection area in the floating building roofs was considered to be important.

The Living Machine has shown successful results already in many projects and is continuously been improved. The technology can be even more effective in 2030.

Living machine system is easily scalable and can be installed as part of the radial wave attenuator as combined unit with the AD system (A. Timmeren, 2006).

The main components of a Living Machine® System are:

-"Primary Tank: here solids settle and begin to degrade
-Equalization Tank: the tank buffers periods of high and low flow.
-Stage 1 Tidal Flow Wetland Cells: these aggregate media-filled planters are alternately drained and filled up to 18 times per day.
-Stage 2 Tidal Flow Wetland Cells: a portion of water moves to Stage 2 and undergoes the same process, where smaller treatment media provides faster treatment.
-Polishing System: water undergoes final polishing and treatment.
-Reuse Tank: treated water enters the reuse tank before moving on to different reuse applications.

(Living Machine, 2012)."

The innovative way to keep the important tap water tank more clean for the community use was the finding of The PAX Water Mixer.

"The mixer pushes water from the bottom of the tank to the top and circulates water throughout the entire tank to prevent conditions favorable to residual loss and DBPs, nitrification. Efficient and effective mixing of large volumes is achieved by the mixer's patented Lily impeller, which is able to establish a powerful flow pattern in any tank, any size. (Pax Water Technologies, 2014)." This was important detail in keeping the big tank water as clean as possible for the habitat to use as tap water supply.

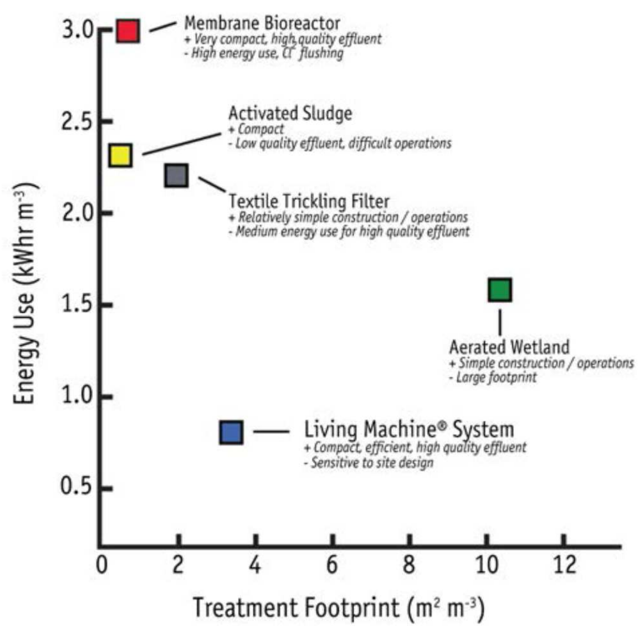
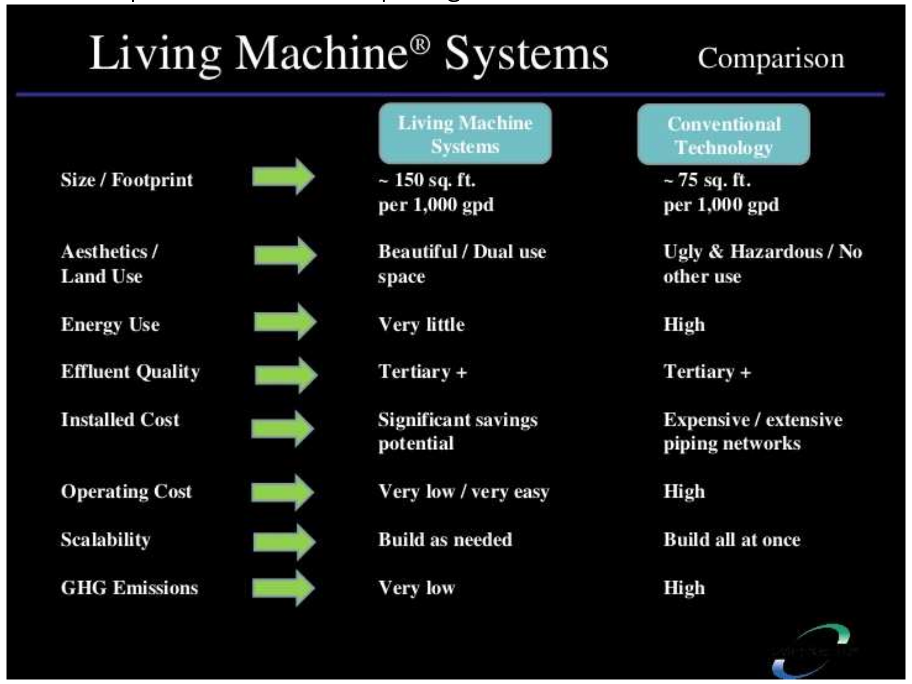


Figure 35. Graph showing the low energy consumption and treatment footprint.

This graphs on figure 35-36. Supports the sustainability aspects of the living machine for this concept. Showing low treatment and energy level compared to other competing solutions in the market.


Living Machine® Systems Comparison

	Living Machine Systems	Conventional Technology
Size / Footprint	~ 150 sq. ft. per 1,000 gpd	~ 75 sq. ft. per 1,000 gpd
Aesthetics / Land Use	Beautiful / Dual use space	Ugly & Hazardous / No other use
Energy Use	Very little	High
Effluent Quality	Tertiary +	Tertiary +
Installed Cost	Significant savings potential	Expensive / extensive piping networks
Operating Cost	Very low / very easy	High
Scalability	Build as needed	Build all at once
GHG Emissions	Very low	High

Figure 36. Comparison to conventional technology.

3.5.8 Floating building greenery and aquatic ecosystem

The floating building greenery and aquatic ecosystem have possibilities to reach for regenerative goals in the future floating community design. The chosen methods in the introduced in this chapter were chosen because of their ability to show regenerative and social and environmental qualities.

The use of greenery and recreational space for the floating community needs was strongly directed by the Singapore government's goals. Their goal is to o increase greenery in high-rise buildings to 50 ha by 2030. They are also aiming to have 0.8 ha of green space for every 1000 persons. (Singapore Government, 2012).

The idea was to reach for regenerative design goals in all of the floating community green spaces. During the research several innovative solutions having possibilities were found.

In regenerative design the aim is to go further than sustainable and resilient design. "Regenerative design focus is on restoring ecosystem health and generating new resources for human use. The synergy of natural and human resources to improve environmental conditions over time, and spiral resource production and ecosystem integrity enhancing the system is important. Closed loop systems are typically used to conserve and regenerate resources and ecosystems. (Rottle, 2010, p. 78)." One example is water harvest treatment in wetlands that also provides habitat, and then reuse of that cleansed water in dwelling or industry.

The C2C Building Charter goes for same direction. The products are continually re-purposed to make new materials, and waste is considered valuable material for reuse. (Braungart & McDonough, 2009).

The Aquaponics Cycle grows fish and vegetables together. "The most simple definition is that it is the marriage of aquaculture (raising fish) and hydroponics (the soil-less growing of plants) that grows fish and plants together in one integrated system. The fish waste provides an organic food source for the growing plants and the plants provide a natural filter for the water the fish live in. The third participants are the microbes (nitrifying bacteria) and composting red worms that thrive in the growing media. They do the job of converting the ammonia from the fish waste first into nitrites, then into nitrates and the solids into vermicompost that that are food for the plants. (Theaquaponicsource, 2015)."

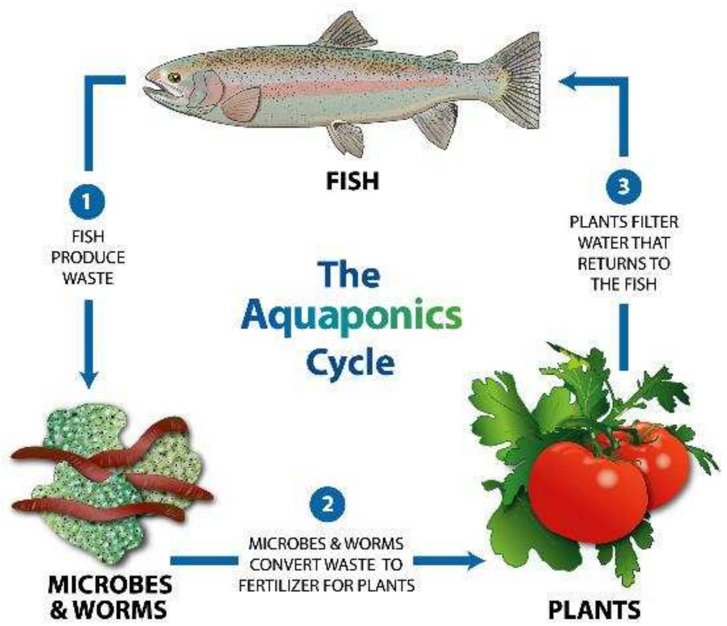


Figure 37. Figure showing aquaponics mix.

The other innovative founding for making floating greenery solution with water purifying quality to the floating building area, was the Biohaven Floating Breakwaters system developed by Martins Ecosystem (Martin Ecosystems, 2015).

The Biohaven Floating Breakwaters (BFB) system basically is a fully recyclable floating plastic mesh like matt allowing many kinds of sea growing vegetation to grow in this mesh. In the BFB The vegetation grow the roots through the mesh below the water surface and allow the roots provide shelter for the fish and aquatic life while also working as filter to remove unwanted nutrients from the waterbody. The other positive factor is the wave absorbing capability of this BFB system and this system can be connected into the floating structure. The other positive aspect of this BFB system is the green vegetation on top the floating mesh, as it works as platform for green vegetation allowing the wildlife to come to these floating platforms of vegetation. (Martin Ecosystems, 2015). System is further explained in the concept. Example case in Singapore was found using same kind of system like the presented BFB system and will be further shown in the design. This case is Sengkang Floating Wetlands project (CPG Consultants, 2015).

The enhanced use of herbal and medicine vegetation currently in Singapore was noted based on local article in Singapore (Siew YY, 2014). This source was used to supports the inspiration from Uros people which used the Totoro reed as herb ingredient for wellbeing purposes. This is shown in the design layout of the 7th roof floor of the floating building concept.

3.5.9 Air purification system based on Hydroponic Plants

Hydroponic plants offers a natural way to keep the air indoors clean and were also taking into consideration while design in the future floating community concept. Active Modular Phytoremediation system's (AMP) main idea is to benefit the microorganisms living on the roots of the plants. Microorganism's absorb Votale Organic Compounds (VOC)s and other pollutants and breaks them down into non-toxic material. After the air is filtered, the air it goes back through the AMP system and circulates around a room. (Labarre, 2015). This innovative solution responds to enhancement of biological systems integrated into the building and to both the coals for higher air quality and greater amount of biomass in the floating building concept. (Michael Braungart & William McDonough, 2009).

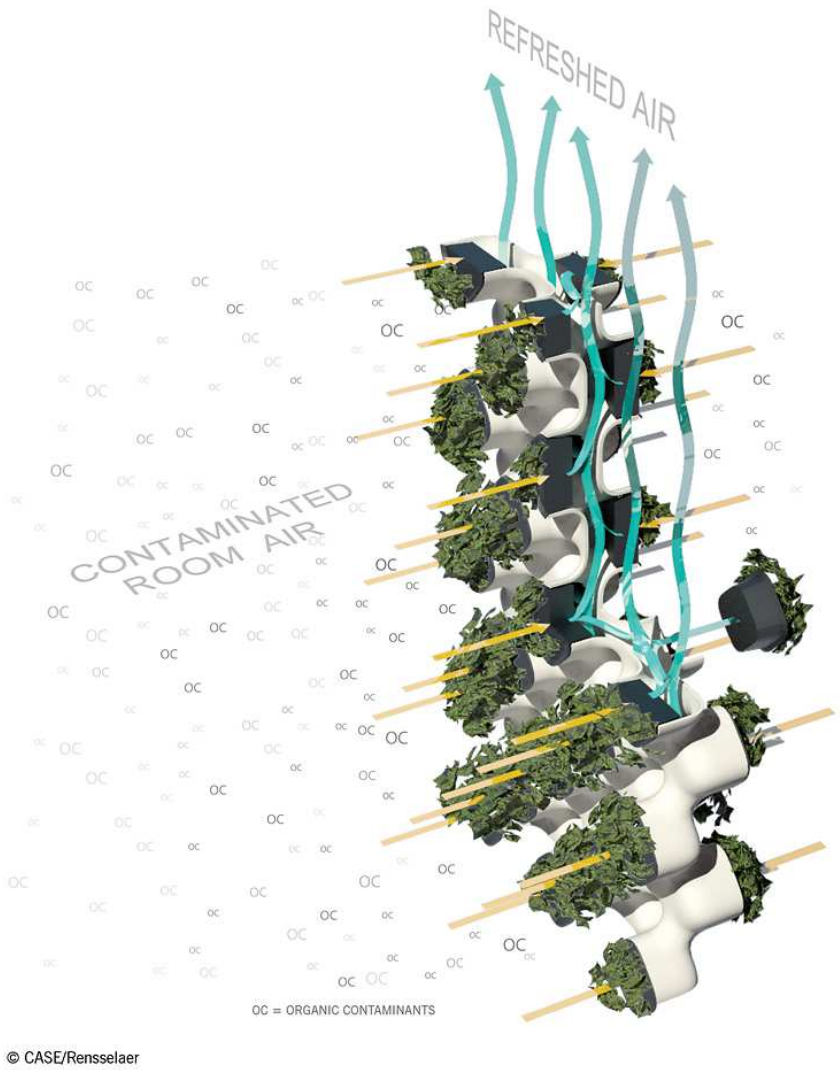


Figure38. Detail rendering of the AMP air purifier.

3.5.10 Moorage

During the final development of the concept where the shape and size of the floating building concept was already defined I contacted Professor C.M. Wang (Ming, 2014) from National University of Singapore (NUS) Faculty of Engineering. Professor Wang has a research group studying very large floating structures (VLFS) and has the most up to date information on the floating structure developments in Singapore. Professor Wang gave consultation for the proper mooring system needed in the concept.

Wang suggested the dolphin system to be most appropriate for the concept. (Wang, 2014). The walkways then usually connects the floating building to the shore and in urban areas usually are well connected to the surrounding traffic network. The walkways have a floatation capability because of the distance from shore to the floating building and have to be moored to the seabed. Common safety requirements considering floating houses and emergency vehicles require a passage to the site and near the building. (British Columbia Float Home Standard, 2015, p. 11).

The "Dolphing –Frameguide" is quite common stationary keeping system used for securing the floating structure to stay in position under wave and other dynamic action like drift (Wang, 2015). Dolphing system is usually used when there is no pier or any shore connected structure to keep the floating structure in position (Wang, 2015).

.

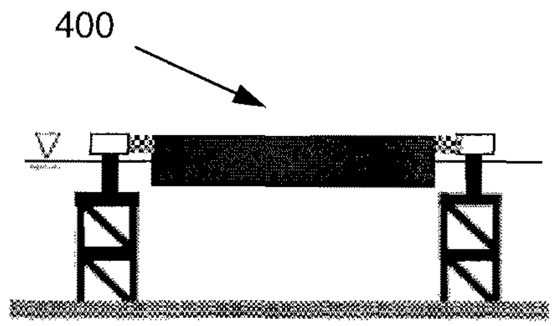


Figure 39. Picture of a dolphin system connected to the seabed

The walkways then usually connects the floating building to the shore and in urban areas usually are well connected to the surrounding traffic network. The walkways have a floatation capability because of the distance from shore to the floating building and have to be moored to the seabed. Common safety requirements considering floating houses and emergency vehicles require a passage to the site and near the building. (British Columbia Float Home Standard, 2015, p. 11).

3.5.11 Wave attenuators and walkway

According to my findings the wave attenuators integrated into the walkway can be the first shield against bigger waves and tidal waves before they hit the actual floating building(s). Wave attenuators are designed to absorb the open sea wave activity and secure the area it protects from harmful or even destructive wave activity.
(WhisprWave, 2015).

This kind of design with radial wave attenuator design was used in Harvest City concept for Haiti preventing the possibly harmful wave activity and tidal waves reaching the inner parts of the floating city and this worked as an inspiration for the concept (Foundation, 2012).

For this concept the detail design for these devices is not included. Only architectural layout and renderings show the scale of these structures and their existence in the concept.

4 Concept Design and Presentation

The main driving force for the whole thesis and the sustainable floating community concept is to offer a new point of view on how to solve the pressure for new housing needs in particular in the coastal and reserve site areas. The future concept is intended to be a flexible floating community scale concept for 2030 and beyond allowing further development to be made if it arouses interest in the eyes of local government, authorities, community developers and possible investors.

Design principles considering the floating building structure and functions was based on my research, basic understanding on naval architecture and the kind support of my colleagues having extensive experience in the field of naval architecture at Meyer Turku. The final overall architectural shape and size of the whole building design was a combination of aesthetical, practical and sustainability driven factors fused in to one coherent shape and scale.

For the future visionary floating community for Singapore 2030 the goal was to reach ingredients for social well-being in the community through the physical environment and supporting the quality of life.

4.1 Short description of the 3d concept creation before final design

Before the actual shape and design of the building was formed some sketches were done with fast hand sketches and 3d model studies to give a loose estimate of the overall shape and size of the floating community building. Fast sketches of different modular shape having different angular shapes were tested and forming groups of different shapes. Quite soon after having discussions with Mr Raimo Hämäläinen (Hämäläinen, 2013) considering the most used shapes and benefit of different shapes considering the sea environment the circle shape were proven to be most usable. These were only preliminary ideas of the whole floating building. Some modular fast studies were made to test modular shapes that could be the shapes for the floatation units and building superstructure sketches. The figure 40 presents an early sketch of the actual idea. This was already done before I discovered the limitation for six floors considering the floating building height.

After the building height limitation the scale and masses started to be in better proportions. After some basic studies on modular forms the idea of sliced round floatation units with combining superstructure with two radius and the benefits of this form started to make sense for the concept. The findings on the example cases like the Mermaid concept influenced the opening inner courtyard and the widening superstructure having shading and natural lighting capabilities including the passage under the building. The two sliced main flotation units were discovered. See figure 41. The idea for the atrium with green spaces on the top 7th roof floor came at that time and I wanted to use the maximum space for the building. This allowed great space for recreational and small farming capabilities. At the same time the ETFE roof idea was created.

During this development architect Tom Wright (Wright, 2013) visited Turku Shipyard and I had the possibility talk about the proportions of the building and size of the EFTE roof. Tom liked the building mass and was convinced about the ideas. We came to agreement of using the roof only in the top side of the building and use glasses in the facades. Mr Tom Wright (Wright, 2013) also suggested to have a rotating building design where the building would turn around the other circular center point of the building. This was interesting idea, but was difficult to do without an underwater passage to the building trough the rotating center. The Harvest City concept gave influence on the radial shape of the floating building with openings and including the integration of greenery and business spaces for these areas. This was the point where the actual shape was ready and the ideation and concentrated to the actual layout and higher detail in the building as a whole including all the technological and biological system findings.

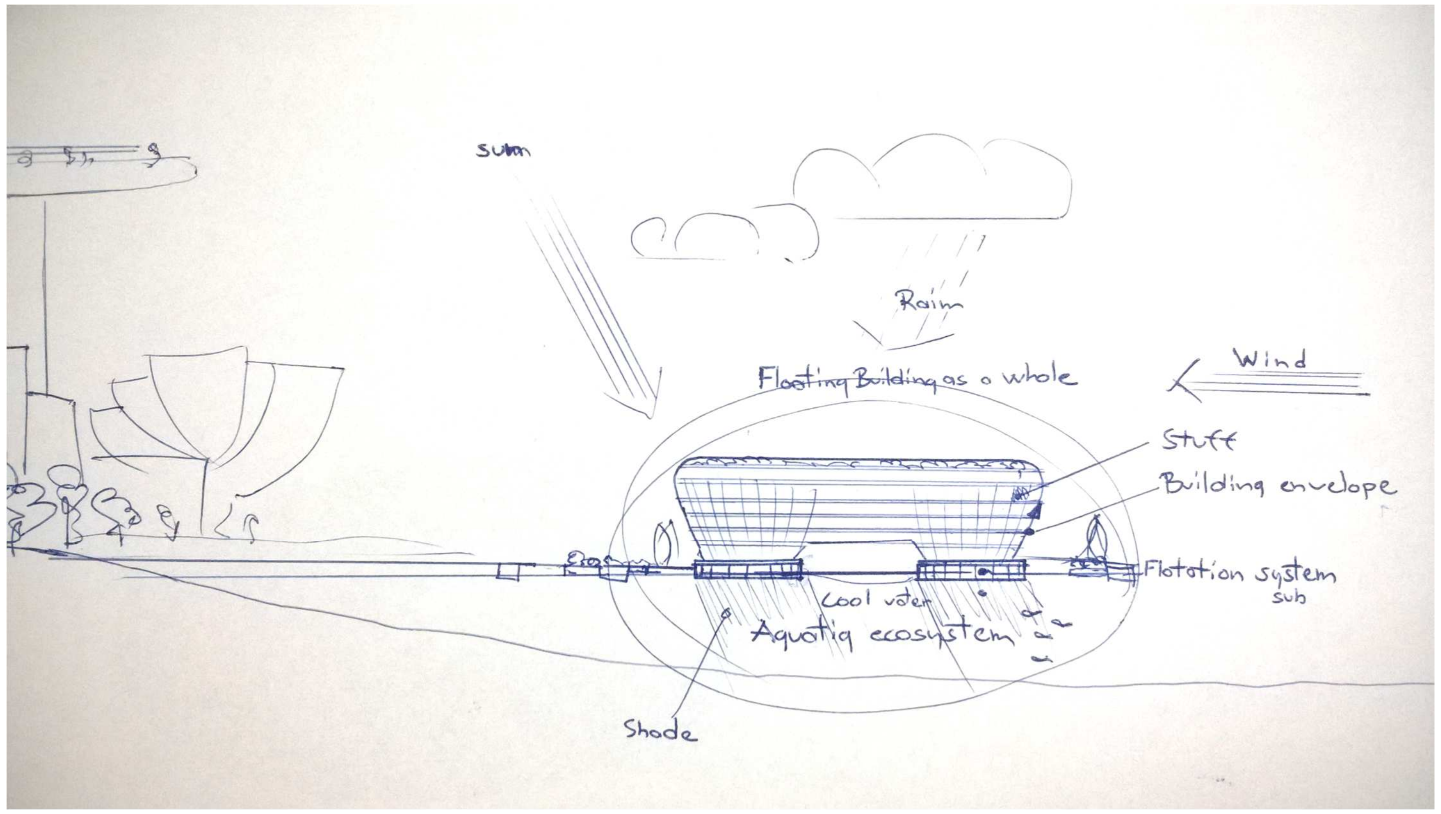
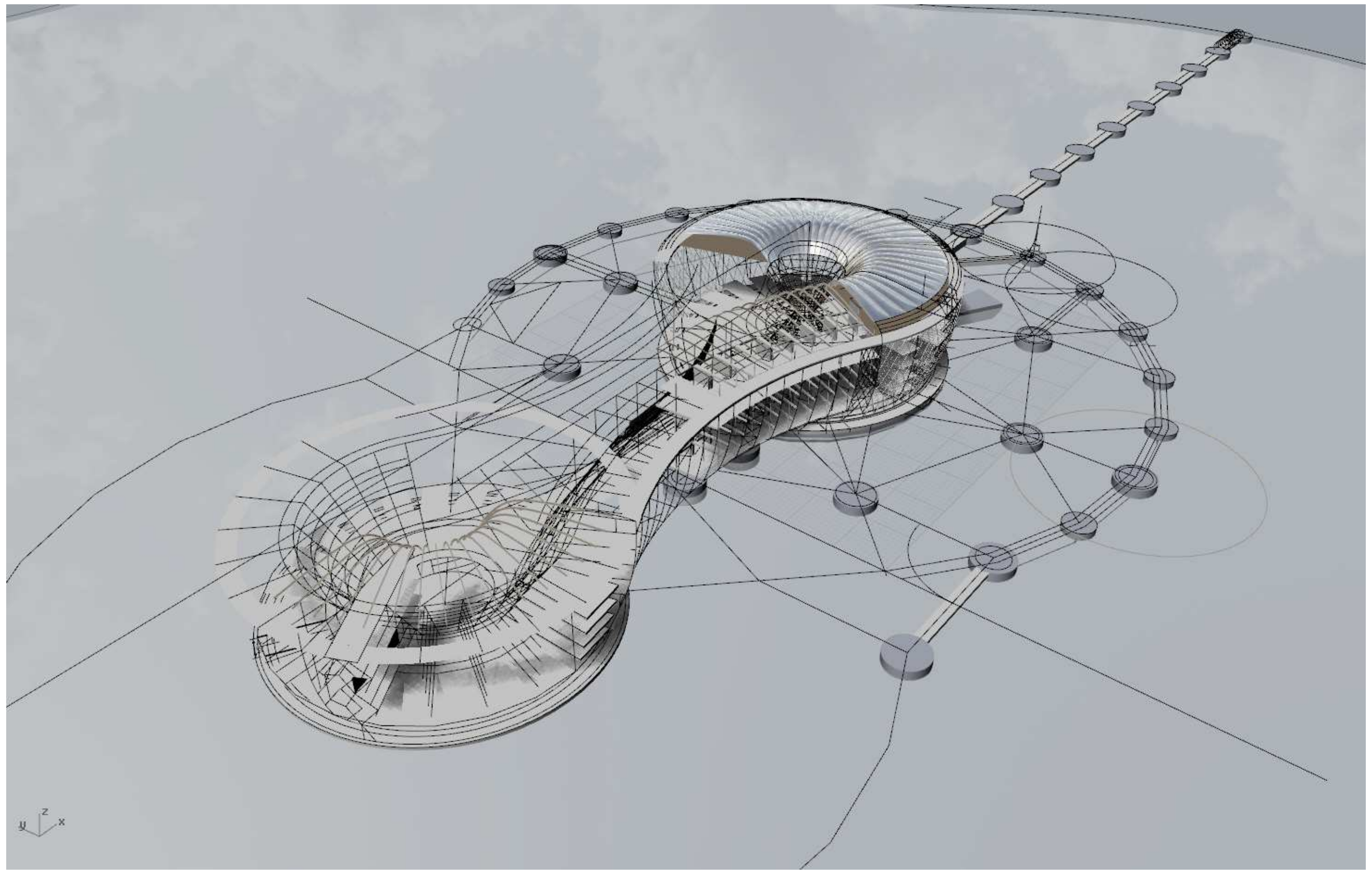


Figure 40. UP RIGHT Early: hand sketch showing the floating building in the surrounding environment.

Figure 41. DOWN RIGHT: Rendering of the early 3d model done on with Rhinoceros 5.0



4.2 Floating Building Design and system design

4.2.1 Layout and spaces of the Future floating concept

The massing and layout of the floating building developed together in to working solution. The layout of the concept supports modular building superstructure with modular buildability.

The limitations to 6 living floors and the extended 7th roof floor with light roofing defined the overall character for the building and formed layout space. The layout was also based on the principle of "all outside" apartment positioning where all the apartments were equally distributed around the building to all directions having a great ocean view from windows and balconies. In the layout only two different main arc shapes are used to form the main characteristics of the whole building. This effect makes simple but architecturally variating tension in to the whole building from inside out.

The idea of radial connectivity was applied to the two circular first floors. This shape allows 360 connection to surrounding elements like walkways and wave attenuator with the spaces. The modular floatation system design was made out of slices with 15 degrees division supported by the upper apartment division. This was considered to be the proper estimate for division based on the created slice sizes and created apartment space layout. In this stage the HDB flat types and their sizes were loosely used as frame (Teoalida, 2015). This can be seen in the divided sliced apartment division in the whole building layout in figure 43. All apartments are shown in the final renderings layout.

The first floor on top of the floatation units is around 1.5-2m above the waterline and the surrounding wave attenuator spaces around 1.2m above the waterline having high enough railing (1.1m) in all areas for safe access to all ages of people. The first floor consists of cycle and light vehicle parking area below the 2nd floor in the open space. Small business (office), service, technical and storage space can be located in the 1st floor.

The large scale elevators 2 in both ends of the building (4 total) allow easy access for all ages all the way to the 7th roof floor. In architectural aspect the 1st floor outer small business spaces and the upper apartments could form a symbolic group of future shophouses in radial form. The building façade could be customized and colored to make variations (see figure 25 and 43). Area is shown with text in the final renderings.

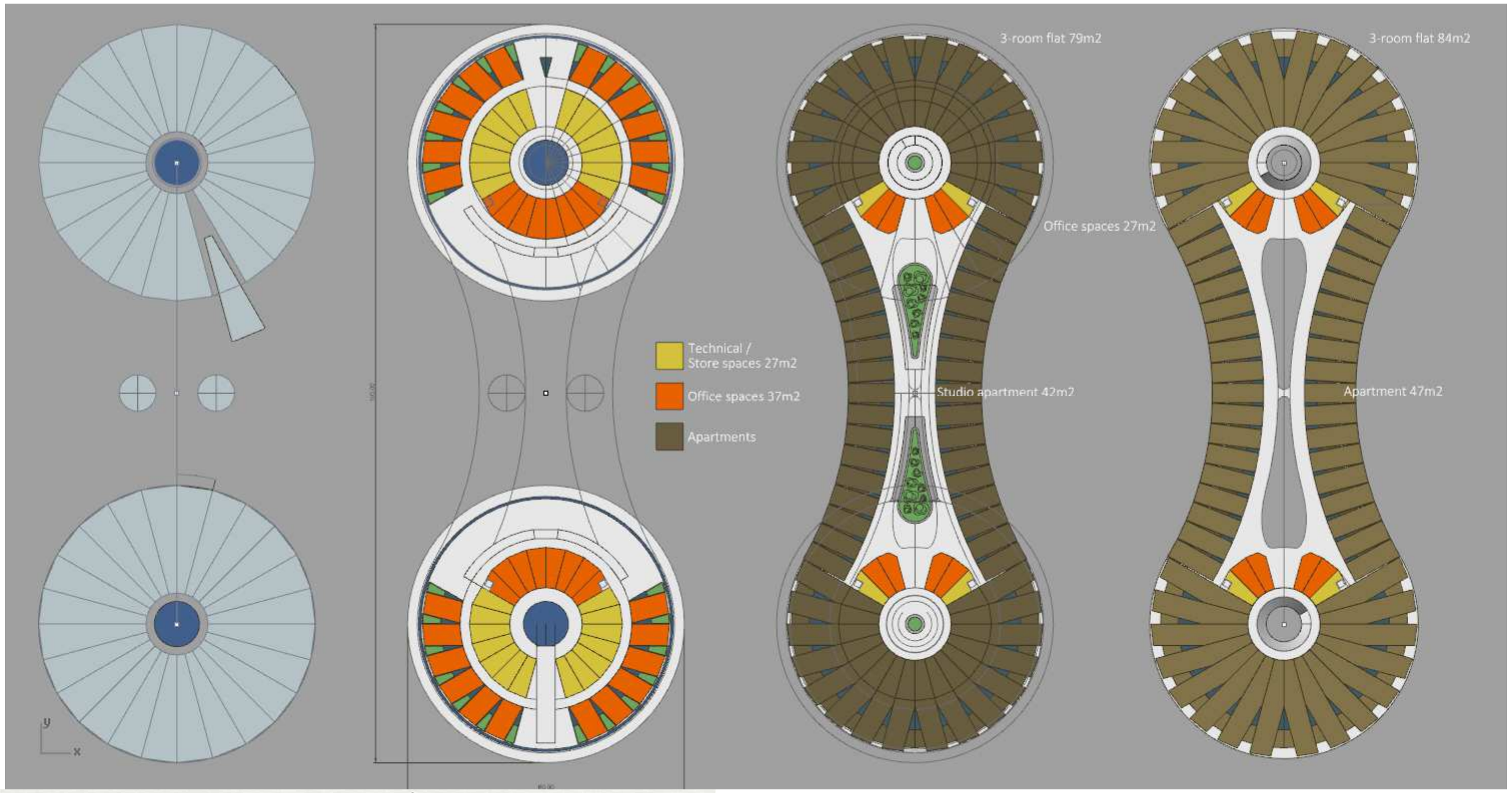
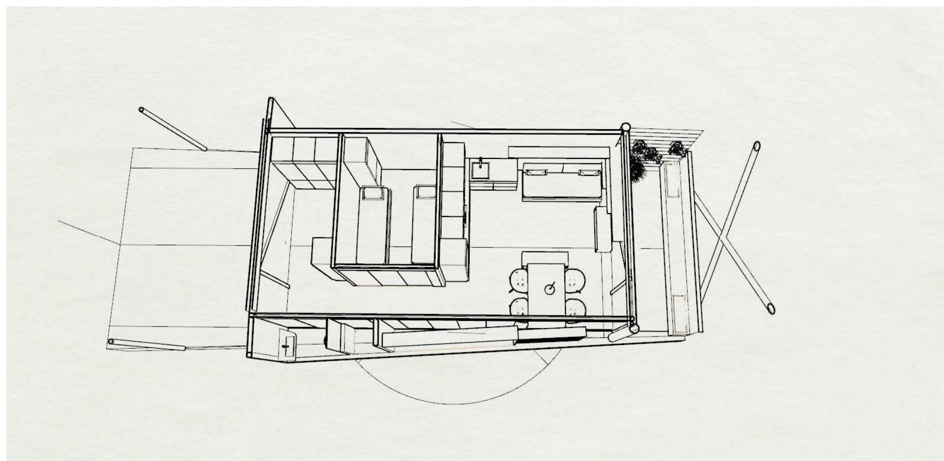


Figure 43. Layout show flotation units and 1-3 floors layout

Figure 42. Buildiing block with 15 degrees division and pedestrian ramp.

The middle modular arc layout consist of smaller studio apartments sizing from single and two person apartments in the 2-3th floor and some bigger 3-4 person sizes in the 4-6th floor.

Figure 44. Rendering showing the smallest 1-2 person apartment.



The lower floor apartments could be preferable living areas for elderly people following the driving force of proportional growth of elderly and retired people till 2030. See figure 44. The upper 4-6th floors could be for younger generation and singles wanting bit more space. The possibility for combining two side by side apartment modules is also possible allowing for bigger apartment sizes if needed for example in the top floors. This is shown in the final renderings layout.

The naturally formed two round apartment arrangements in both ends of the inner courtyard form cylinder shape inner space rising all the way up to the 7th floor. See figure 42. This space could have the AMP air purification system as vertical supporting pillars. This space was used as spiral shaped two way ramps connecting the floors and allowing the light weight pedestrian traffic including people with bicycles to raise all the way up to the 7th green roof floor area. This was important factor motivating the people towards active moving and healthy lifestyle.

The elevators in both ends of the building have enough capacity to handle the amount of habitat and allow the movement for handicapped in all parts of the building was also a must have in the overall layout. The slice structure allows the extension of the apartment sizes towards the top floor forming vertical arch like extending exterior shape this includes some benefits like window and balcony shading. See figure 42 showing the extending arc shape of the facade.

The idea of ocean view for all the apartments was a must have quality enhancing the living quality of the habitats. Natural lighting and natural ventilation capabilities were also enhanced due to this arrangement.

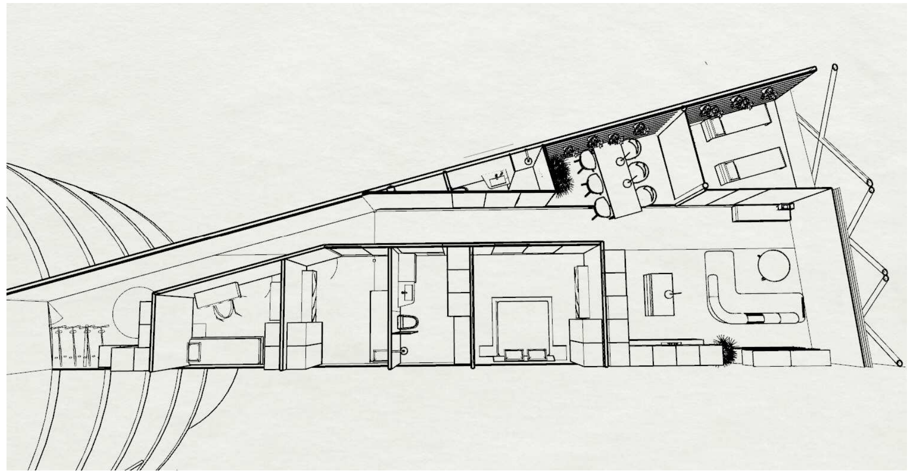


Figure 45. Figure showing the largest apartment for 4 person family.

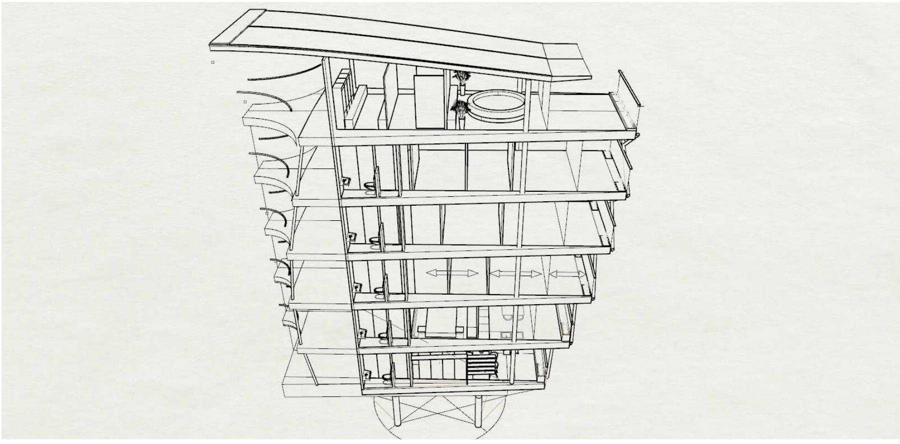


Figure 46. Section from the middle showing the modularity in parts, moving walls and the structure of the middle section.

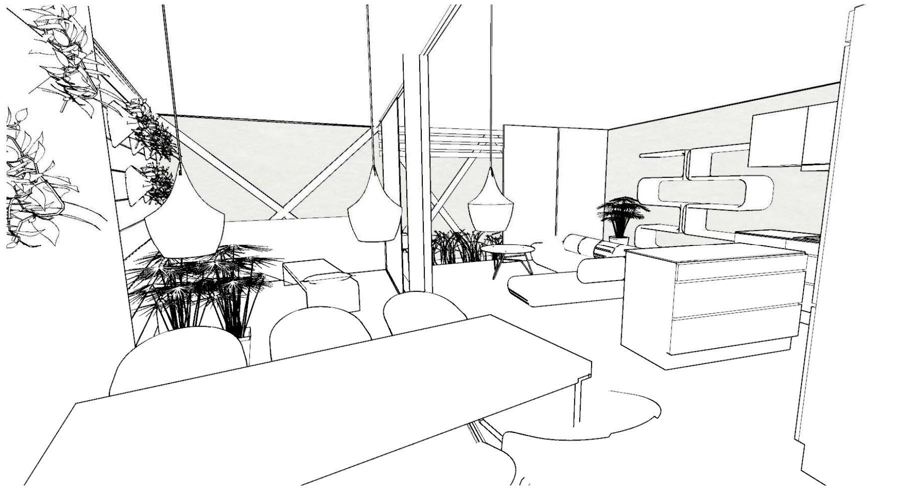


Figure 47. Sketch rendering from inside the largest apartment.

The two circular slicing apartment areas in both ends of the building superstructure form effective layout of expanding apartment towards the 7th roof floor. The central spiral pedestrian ramp with circular floor corridors form an effective entrance to the apartments. The layout of the biggest apartments starts from entrance with storage space follow by variating bedrooms, toilet, shower, master bedroom and finally to the combined kitchen, dining, living room and flexible balcony space. All this space is widening towards outer edge of the apartment giving a sense of openness towards the ocean view. All the apartment have an ocean view. See figure 45 showing the biggest apartment.

The courtyard with shading but light transmitting ETFE cover gives daylight to the courtyard forming an inner space with pedestrian access all the way up to the 7th green roof floor. The widening arc shaped central corridor with connecting bridges in the center and widening spiral ramp towers in the longitudinal ends of the inner courtyard form an appealing over all space including functional means in the forms. The integrated green space and area in the floors make the space even more enjoyable and relaxing for the community. The inner courtyard and sheltered green roof areas would also be used for great refreshing recreational, health and community farming uses for multiple benefits. See the final renderings layout from 7th roof floor.

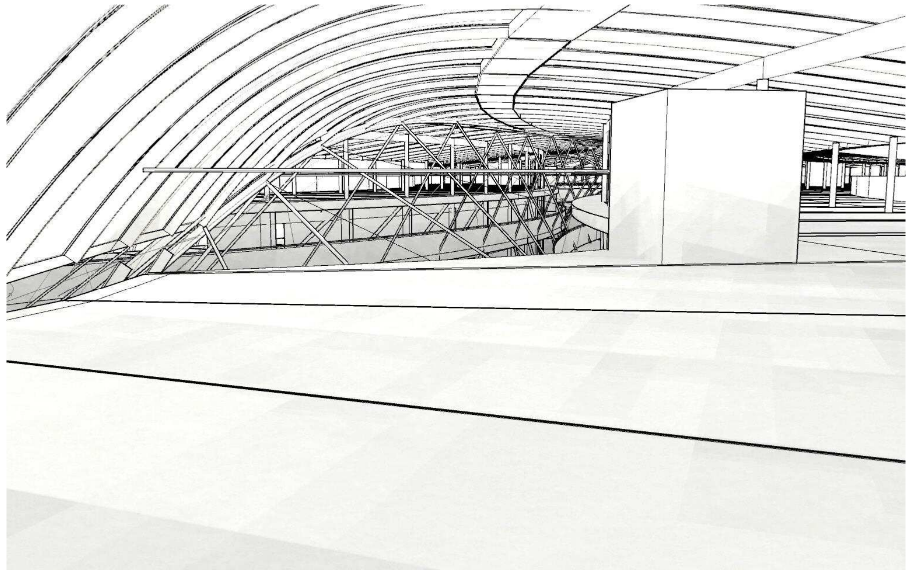


Figure 48. Sketch rendering of the 7nd floor showing the volume.

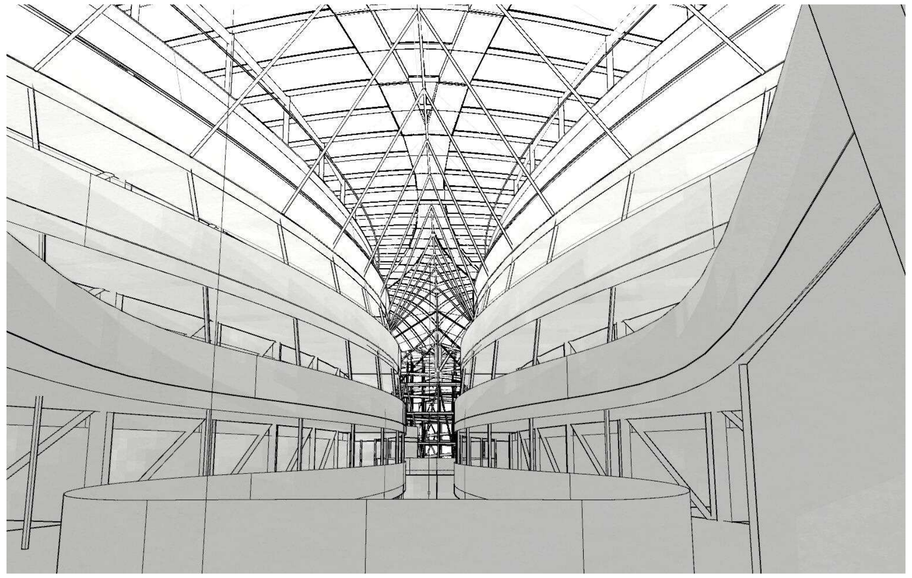


Figure 49. Sketch rendering of the inner courtyard from 3rd floor.

"All outside" principle was used in the ship cabin design for many occasions and proven to give value for the cabins. The two arc shaped in the middle of the building and in the ends of the buildings created the access to the inner courtyard with possible greenspaces and natural lighting coming from the ETFE roof. The light is guite equally distributed to all apartments to enjoy. See figure 49. The longitudinal arc shape with two round endings with vertical ramp passages across all the floors was an important feature that also define the layout of the building. This atrium space is not shown in more detail giving the space further development possibilities. This rendering is intended for preliminary estimations considering the interior volume and main shapes formed around the floors with glass railings.

The first floor consist of storage for pedestrian vehicles like bicycles, technical spaces for building technology like piping, AC, multi-use space, small office and business spaces. The inner courtyard which extends from second floor up to the 7th floor offers a livable common social space with reservations to community use and greenspaces. In the 7th roof floor recreational, sports, wellness and community farming activities work for the benefit of the social sustainability in the building. This space would be calmed down during the night time. These design ideas are presented are presented in the final renderings layout for 7th floor

The arrangement to increase the apartment sizes from 1- & 2- Room Flats in the second floor and to 3, 4 and 5 room & Executive Flats towards the upper floors was loosely based on the Housing and Development Board (HDB) flat sizes most commonly used at Singapore at the time (Teoalida, 2015). The idea in the layout and modular structure supports the adjustment of the apartment sizes by simply adding more length or reducing the length of the prefabricated apartment blocks. The vertical positioning of different sizes of the flats is also adjustable if needed. The apartments design allows for adjustments in the wall positions. This gives resiliency to the building layout to match different needs.

The adjustment of the apartment blocks would naturally change the appearance of the building and structure of the building envelope. The radial structure and sliced modular construction method makes it possible. The reason for the smaller apartments being on the lower floors was based on better accessibility for elderly who mostly would use the lower apartments. The inner courtyard spaces offers shared space elderly people.

4.3.1.1 Activities presented in the seventh roof floor

Community services and sustainable lifestyle input for the layout

Because there are no actual client for the concept and I wanted to keep the concept open for further development in this perspective regarding the services and spaces. These suggested services for the community are very preliminary and light in their context. They have been inspired by the research.

They still have connection to the C2C Building Charter ideology and Singapore Blueprint goals for 2030 or findings.

Community Sports Area

This area in the 7th floor and possibly in the radial walkway area offers sports activities for the community to reserve and enjoy. The basic activities like Running track(360), Gym and multi-use court with possible enhanced interactivity devices offer many single and group activities. In the water level around the radial wave attenuator possible water sports spaces and boating activities can offer enjoyment at water. (This idea reflects to healthier lifestyle and activity.)

Ocean View Bath

This 7th floor space is for relaxation and nurturing features like water massage and mineral bath which can relax your mind after work and where you can socialize with other people. This serves the sports area as well. (This feature was inspired by the mermaid concept and the Marina Bay Sand's having a pool area in the top of the building.)

Herbal and medical garden

The herbal and medical garden works as shared medical plants and herb area to be used for community health and wellbeing purposes a database for community can help people to find the cure they need. (This was inspired by the Uros people using the Totoro as herb and local study where medical plants have now been used more widely (Siew YY, 2014).

Community kitchen and gathering space

This common facility with dining and bar possibilities offers a plase for celebration, food making and health bar activity, where the herbs, sallads and fishes are close by in case you want to make fresh food for the community, family of just by our self. This idea is inspired by the Singaporeans being a lively, sustainable and living community and the issue of food scarcity presented in the chapter 3.4.4.

Hydroponic garden

Garden with fish tanks and relaxing greenery offers a place where you can just enjoy a private time or have a picnic with your friends.

4.2.2 Building Superstructure

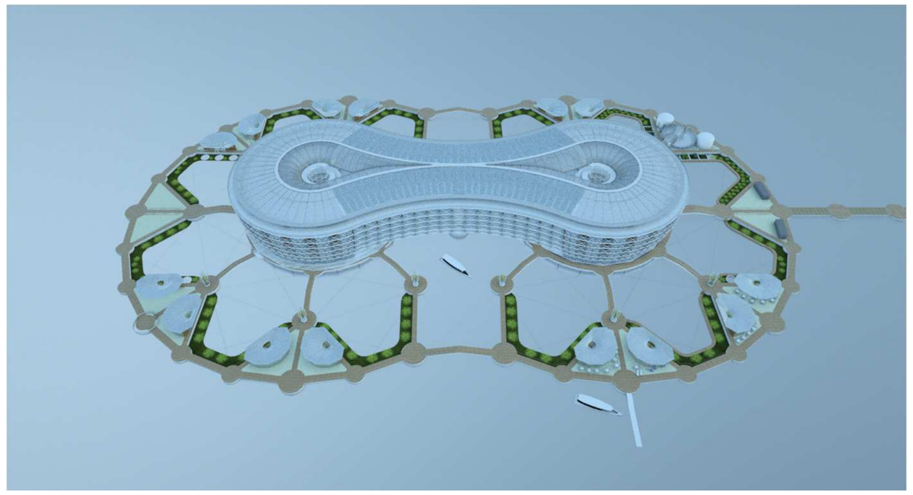


Figure 50. Rendering of the whole building

The actual shape and size of the building is a combination of many beneficial aspects supporting environmental, architectural and modular values. Some inspiration for using round shape came from Haiti's Harvest City and Mermaid concepts.

The aspect of Singapore urban coastline in architectural sense was taken in to consideration when finding the right scale and shape for the floating building. The six floor limitation (more detailed in chapter 3.4) was still a current state and till 2030 the limitations for floating building heights could be changed if the pressure for populating the sea area would extend. The idea of using two big round main floatation units made from slices came in to consideration at very early stages of the shape building development. The possibility to replace all the floatation unit slices when needed required certain distance between the two round flotation systems. This was a great benefit to be used in the concept and in my opinion set the difference from any concept I have discovered before. The building superstructure on top would then combine the two main floatation systems together. The idea of slice shaped apartment units on top of the two round main floatation units was naturally formed at the same time and the inclining arc shape in the building superstructure between the two round floatation units came naturally for esthetic and practical reasons like shading. The inclining shape allowed the mass of the bridging superstructure to stay close to formed longitudinal centerline enhancing the stability of whole floating building in the between area.

The use of roof floor as light weight seventh floor with possible recreational and green roof functions came to my consideration already in the very early stages of the design process. This idea was based on the fact that Singapore authorities has plans to add green areas to the city (Singapore Government, 2012).

The inspirations and insight on current building architecture in Singapore chapter 3.4 was also taken as a background for the building superstructure. The idea was to design a building which would fit the architectural coastline of Singapore.

4.2.2.1 Superstructure strength study

The load and strength elements in the concept were studied in co-operation with naval architect Mr Ari Niemelä (Niemelä, 2013) having extensive experience from ship steel structures. With the help of Mr Ari Niemela the basic structural elements in the floating building concept were discussed and the principles considering the strength issues in the superstructure, see figure 51. The challenging issue was the separated main floatation units which were connected by the building superstructure. The load and bending forces in the middle are moved towards the main flotation units. In the final rendering a supporting floating element can be seen in the middle of the buildings below floor2 as supporting backup plan.

The tree primary main strength elements in the concept were the 2nd floor as a whole forming a bridge like platform with lower supports. Secondly the façade grossing tube elements and thirdly the atrium walls with floors. The secondary elements consists of vertical honeycomb walls, pillars and apartment module supporting beams.
The rest of the building superstructure materials would consist of very light and durable modular building materials. The details of the concept regarding this aspect is not shown in more detail.

Conclusion based on the 3d-model according to Mr Ari Niemelä (Niemelä, 2013) was that the superstructure could work when developed further.

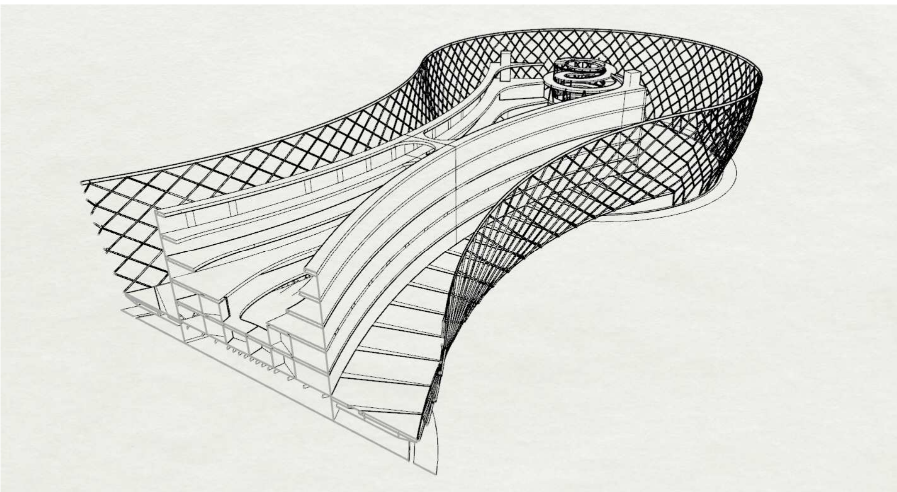


Figure 51. Rendering showing the section and tree main strength element the framing façade element, the main load beating atrium walls and the 2nd floor as a whole.

4.2.3 Building Envelope

The design of the building envelope is divided into two main parts roof and the vertical façade part including all the floors with balcony areas.

In the roof design many aspects including sustainable goals taken into consideration. First and most important aspect was the use of light weight solution on the roof structure that could still be used effectively on rainwater harvesting, possible energy production and can have great adjustable shading qualities.

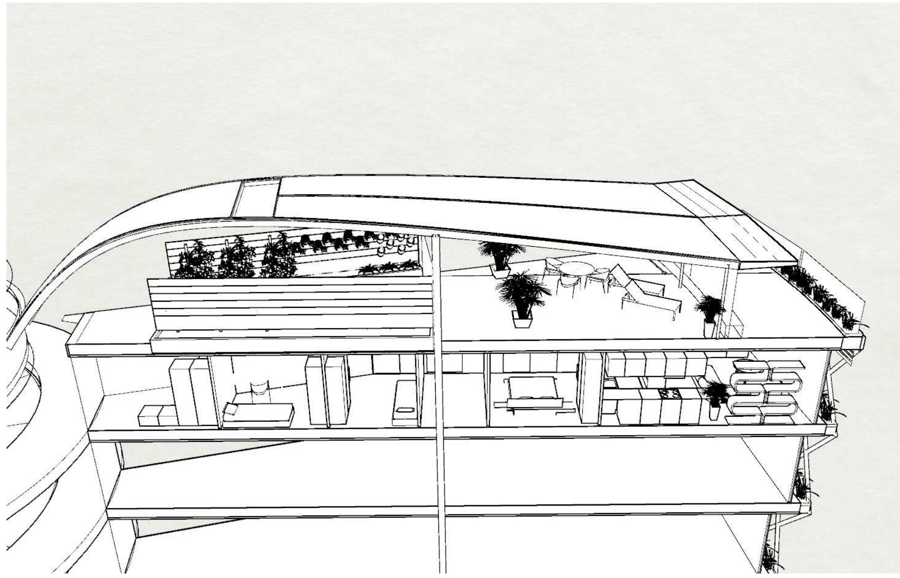


Figure 52 Section from the Light ETFE roof and upper spaces of the building.

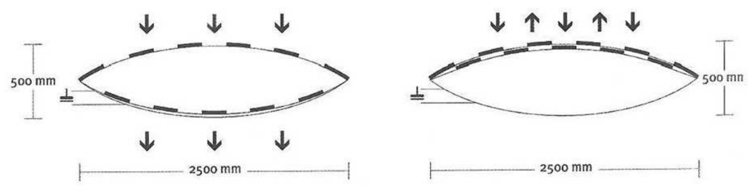


Figure 53. The shading function of the ETFE cushion using the inner layer movement.

See figure 53 of ETFE material with air cushion solution was considered to be the best for the concept. This made it possible to make lightweight roof and at the same time have the possibility to integrate future energy generating solution into this structure. The ETFE cushion can allow and energy production component between the cushions. The ETFE cushion layer has good light transmitting and also blocking capabilities with better U-values than triple glazing depending on the top coating and printed texture. This ETFE cushion can also block the unwanted sun and heat gain when coated with white coating and the cushions having 3 layers can have adjustable light emitting capabilities. ETFE is also very durable long lasting and recyclable material having lifecycle of 25 years (Architecten Landrell, 2012).

According to my findings the frame structure supporting the ETFE roof can be made out of fast grown bamboo inspired by the Harvest City concept where bamboo was used for building façade shading. Bamboo can be used in many details like roof beams having durable and long lasting qualities and and is 20%-40% more stable in climate and temperature changes (Lamboo, 2015). All the bamboo beams have same arc shape and can be more easily produced. The overall design of the ETFE/bamboo roof forms an architecturally appealing convex shape following the overall massing of the whole building with two radius as seen from the top. The roof also has great water collecting capabilities.

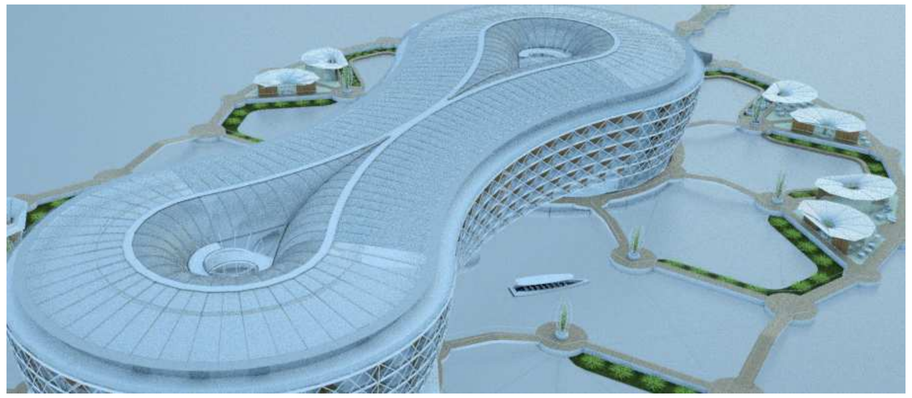


Figure 54. Aerial rendering showing the ETFE roofs in the main building and in the wave attenuating peer on the small business spaces on the right.

As a special architectural detail concerning the building arc facade shown in the section in figure 55. The shophouses had a 1st floor for business space like in the concept and apartments starting from the 2nd floor. The variating colors between the shophouse rows could be expressed in the façade design. This was only a preliminary idea worth developing allowing local influence for the building.

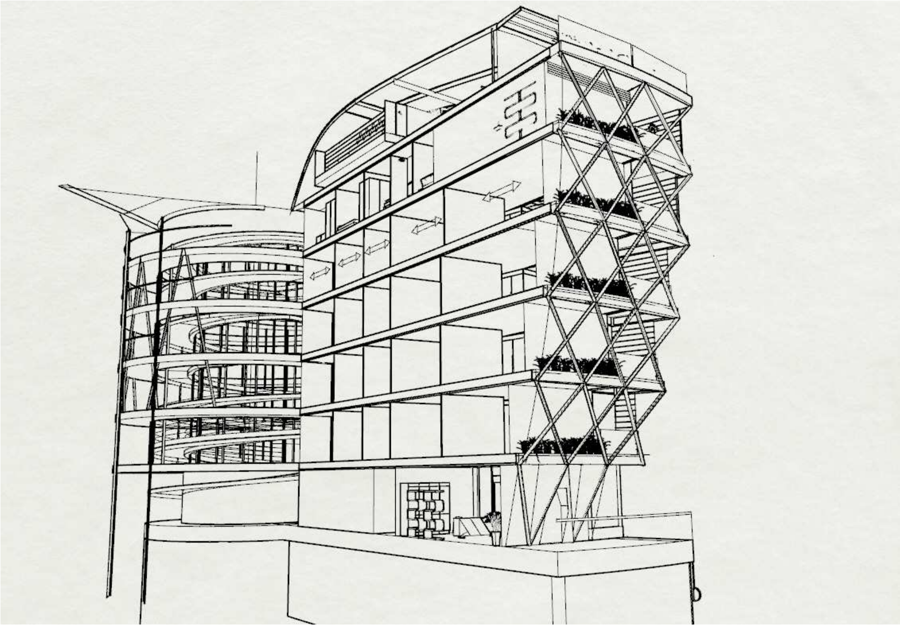


Figure 55. Section from the apartment block showing the modularity, façade and the pedestrian spiral ramp

The building envelope design for the concept can be regarded as a preliminary study to design the principles of the building envelope. Building envelope was done only based on used principles well known practice without calculated simulations. More important was to find potential solution which then can be developed further when needed.

Figure 56. Rendering of the largest apartment front façade including the sliding fog nest frames in front of the windows.

The facade detail located in the larges apartment in figure 56. Shows some more details included in the building envelope for the apartments. The crossing beam in front of the apartment take part in the structural integrity of the building and building envelope supporting well both vertical and horizontal stress for the building. (approwed by Mr Ari Niemelä (Niemelä, 2013).

In front of the living room window and possibly balcony, the fog nest frame (brown frames) with the fabric filtering the incoming humidity take part of the humidity away as water supply. The air goes in from the vents near the window frames. The sliding balcony doors could also have a fog nest frame when needed for better comfort. These fog nests also filter the extra wind and can be shading element's in front of the windows. The overhanging top floor also takes part in the shading and the installed vegetation in the floor level in front of the windows make fresh appearance to inside and shade some of the lower solar radiation towards the windows. An automatic watering system could be used for the apartment's vegetation irrigation in the wall and façade areas. The use of bamboo elements like in the walls, shading elements and furniture's could present a sustainable material approach inspired by the Harvest City concept.

All these mentioned details regarding the building envelope respond to the building structural integrity, moisture control, temperature control, control of air pressure boundaries and control of solar radiation including daylight (The Centre for Sustainable Buildings and Construction, Building and Construction Authority, 2010, p. 40).

4.2.4 Orientation of the Future floating concept

The shape and design of the floating building also defines the best orientation for the building for reaching better natural lighting and use of the natural ventilation effects in the concept.

Based on the information about Singapore's wind conditions it was important to take in to consideration the annual wind directions shown wind direction sides of the building where the most annual wind direction with the greatest amount of wind are coming. This information led to the conclusion of the orientation and enhance their possibilities for natural ventilation in the floating building.

This arrangement allows the best possible amount of wind to ventilate the building in windy days through the apartment to the central atrium and from the first floor all the way up forming the stack effect. The possible extra humidity on site was designed to be reduced by fog nest system in the building facades and air intakes.

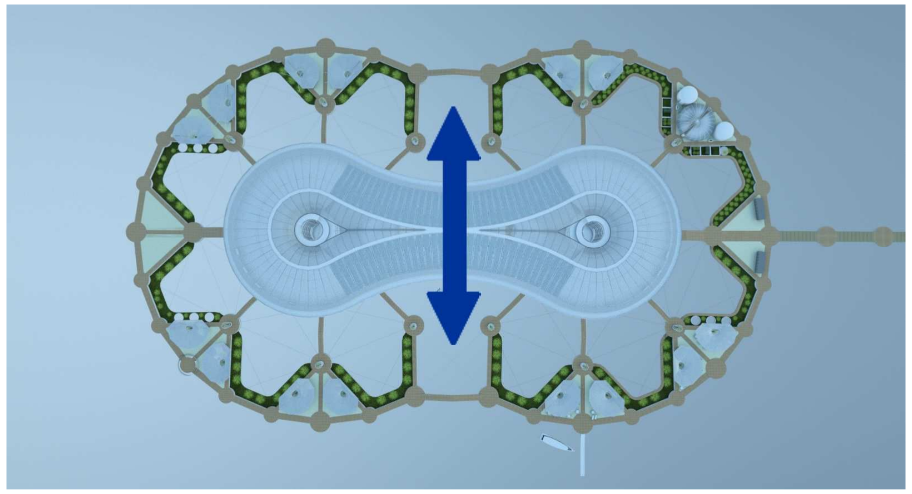


Figure 57. Picture showing the best wind direction for the building.

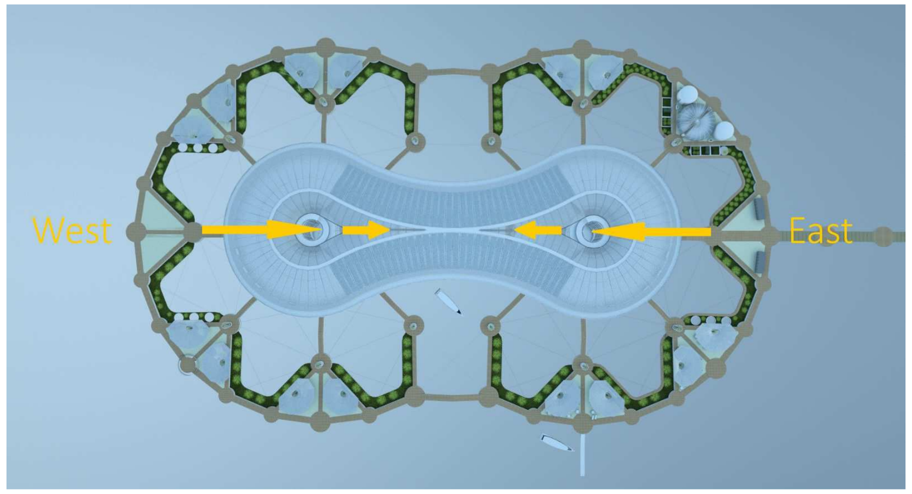


Figure 58. Rendering showing the main sun access along the building shape.

The access of sunlight to the inner courtyard works well with the shape of the building allowing the daylight pass to the inner courtyard. See figure 58. At the same time the widening apartment facades towards the top floor in the north and south side of the building where the most apartments are concentrated have shading because of the inclining facade and arc shape. The east and west side apartment may need some more shading capabilities during morning and evening hours.

4.2.5 Flotation System for the concept

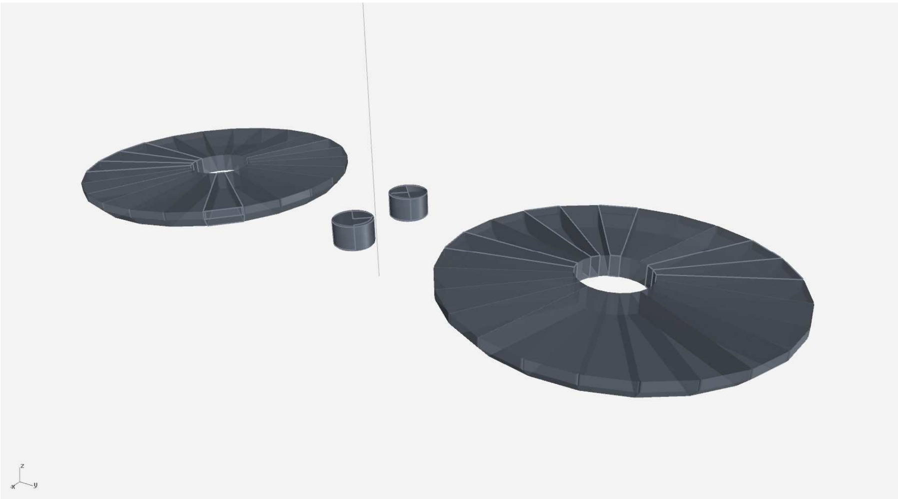


Figure 59. Floatation unit modules.

The whole Southern coastal area of Singapore has quite heavy ship traffic and many of the ships are anchored along the coast near the possible building areas. Possible danger for ship collision and common safety for the floating building and habitat had to be taken in to consideration. The round shape of the floatation units was considered to be the most suitable for the design consulting with Mr Raimo Hämäläinen (Hämäläinen, 2013) having deeper understanding from hull structures. Two 60m diameter round main flotation units made out of slices was considered and the idea of combining them with the superstructure.

The 60m diameter was also considered to be wide enough to absorb most wave activity for more comfortable balance in the building superstructure according to preliminary comment from Mr Raimo Hämäläinen (Hämäläinen, 2013). The idea of the surrounding wave attenuator gave the floating building extra safety measure against collision or bigger wave activity. Each of the slices is independent floating unit including a possible ballast water tank allowing the floating unit to be raised and lowered when needed. This function is needed when the unit needs to be installed, repaired and removed.

The adjustment of buoyancy is needed when the slice town to site for assembly is installed on site. When the buoyancy needs to be adjusted based on household and area weight differences. During the installation of a single slice the slice needs to be lowered, pushed in place and locked under the first floor plinth and to the building. According to my knowledge this innovation is not used in floating houses and buildings before.

The connectivity of the sliced floating units under the round plinth in the first floor was mechanically challenging but was principally thought to have elastic connection mechanism allowing some wave movement to effect on the slices. The whole floatation system is renewable peace by peace on site in for installation, maintenance and dismantle. The slices can be made out of long lasting marine steel or fiber reinforced marine concrete slice units depending on the local shipyard resources.

The overall buoyancy and stability of the whole floating building was calculated with Napa program by approved naval engineer Mr. Erik Routi. This is only a preliminary calculation is added to chapter 6 as reference material to prove the floatation possibilities and stability of the building.

For the weight the calculation the floatation units and plinth in the first floor was calculated as a marine steel structure. The 6 Floor building superstructure calculated as a steel honey comb structure closest to the estimated buildings superstructure. The deadweight (whole weight with furniture) tonnage was taken from cruise ship cabin area close enough in comparison with housing apartment.

The 7th roof floor was calculated including glass roof structure with steel framing. The actual roof in the concept was designed to be a 2-3 layer ETFE roofing with lighter frame structure than calculated. Still the possible green spaces and furniture with accessories in the roof floor would add more weight to the 7th floor. The whole flotation system was calculated as a steel structure. The weight was calculated by cubic meters for the whole floor area in every floor.

The stability in case of damage to the floatation units in longitudinal direction allowed for 1/4th either side of the volume area (90degrees) part from either main flotation units to be destroyed and still the floating building as a whole would stay stable enough to be repaired.
The surrounding radial wave attenuator, peer, walkway and spaces were not calculated for the concept.

The calculation have been added as an attachment in the end of the thesis.

4.2.6 Ventilation - Natural Ventilation

In this early conceptual stage estimating the natural ventilation possibilities of the building was difficult. Still the structure of the building holds elements which can be estimated enhance this quality. First factor in the midsection is lower part of the building holding the bridge like load structure which wan be cooler on surfaces due to the amount of shading in the area. The upper floor areas gather more sun radiation and heat gain, even though the ETFE roof can help with adjustable shading features. The result is most likely a heat difference between the lower and upper air inside the building forming the stack effect presented in design background. The other issue is the high air humidity rate closing to 90% especially in the morning hours. The found fog nest technology could be simple and low tech solution to lower the humidity for better comfort inside the building.

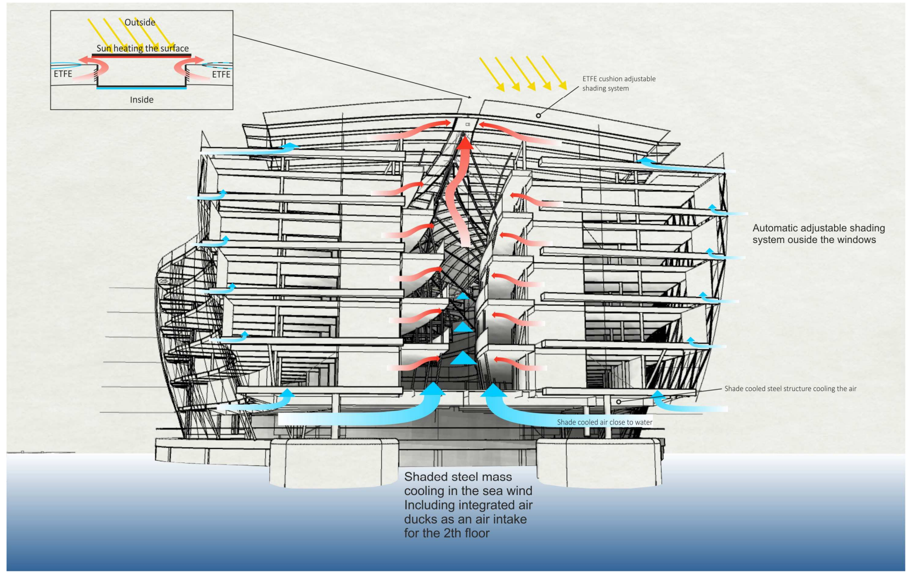


Figure 60. Section showing the natural ventilation and air breeze passages.

The use of adjustable air flow passages trough out the building can let the sea breezes reach the inner courtyard take part in to the needed ventilation during windy days. The stack effect also takes the air flow through the apartment and trough the "Fog Nest" filters towards the inner courtyards and from there all the way up through the highest point in the curved ETFE roof with defined air duct allowing the warmed air to escape but not allowing the rain to pore in. This was the main principle in natural ventilation for the concept.

For enhancing the inner air quality in the use of natural airflow and air purification with the found AMP system the air quality could be enhanced 80% by reducing the need for mechanical ventilation HVAC equipment in the building. The HVAC is not shown in the concept. The AMP system could be integrated into the atrium 2nd floor in pillar like formations where the stack effect sucks the cooled outside air from below trough the ducts and AMP system purifies the incoming air. This could greatly enhance the indoor air quality. The extra humidity of outside air could also be handled in this part of the process.

As the AMP system is natural vegetation based system the need maintenance could be handled by community effort or professional.

4.2.7 Floating Building Materials

This chapter concentrates on presenting the floating building main structural materials with innovative aspects which has been chosen according to my findings during the design background research.

- ETFE Roof Cushion with adjustable shading capabilities
  The different textures and graphics possible in the ETFE coating can create interesting and adjustable sharing to the 7th floor

- Bamboo roof structures, facades, and supporting structures
  The bamboo as a fast growing and near source material is durable and naturally mold resistant material suitable to be used in the upper parts of the building and façade details. Bamboo can be used in roof structures supporting the ETFE roof as frame structure giving more natural and organic appearance.

- Steel honeycomb can be the main load bearing material in the building superstructure, but most likely also basic steel structures are needed with marine resistant coating. Honeycomb has less heat conducting qualities especially when having lighter coating colors.

According to my findings during the research the materials used in modern floating buildings have mostly same requirements in the upper building superstructure area as in land based buildings (British Columbia Float Home Standard, 2015, p. 9).

The salty sea water and the humid hot weather in the Singapore area still raises the bar for possible floating building materials. The corrosion and possible rust resistance against salty and humid marine weather conditions require durable and corrosion resisting material solutions. According to my research findings the use of marine approved materials in the areas where closer contact with seawater is needed. For example the floatation system and areas above the waterline like the first floor of the building where salty and humid water can be spread at times.

The mooring system and the connection to the seabed is regarded as the most mechanically and environmentally demanding area for marine steel and possible marine concrete structures where the lifespan of 50-100 years would be needed. This was approve by my
The other thing is the easy maintenance of different structural elements in the building as the cradle to cradle building charter embodies the idea of use of materials with biological and technical cycles.

The main idea when considering the weight and strength of the materials was to use stronger and more strength demanding materials in the lower parts of the floating building as a whole and have lighter the needed amount of material and weight towards the upper parts of the floating building considering the floating building is to use harder and more durable structures and materials in the lower parts of the floating building and use lighter and still strong durable materials in the top parts of the building superstructure allowing the overall weight point to stay low.

4.2.8 Energy solution for the concept

The cradle to cradle ideology motivated me to find a conceptual solution with ongoing development prospects that could be possible solutions by 2030 and close to zero pollution.

In this thesis it is not possible to present calculated exact energy solution because this is not my area of expertise. The energy production part of the concept is not an accurate scientific and calculated presentation. This is a possible future development with features I considered having potential in the future development for 2030.

Aim was to find a solution with technology capable of using today's local resources and advance towards zero pollution and renewability towards 2030. The most difficult part in the concept at this stage is the scale, size character and capacity of the Waste to Energy system. This was estimated by comparing projects close to the same size if available and some found figures.

Based on the findings represented in the chapter 3.5.7 the most potential source for renewable energy generation in Singapore is concentrated around solar power and solar related future technologies. The energy solution for the concept is a hybrid solution where both local waste converted with AD digester system to biogas and water concerted with sunlight in to hydrogen is used to produce the needed energy for the floating building and community. The fuels including created biogas and hydrogen is used as a fuel for next generation fuel cell solution called Bloom Box Energy server. As an estimate, two of these servers can produce the needed energy for whole floating building and community. As a security measure the fuel cell can also use the locally greatly used natural gas as fuel.

The innovative use of solar hydrogen energy production as a main power source was based on several research findings showing promising results and development possibilities for 2030 and the technology for splitting water and even bio-waste in to hydrogen has taken many interesting direction lately.

Because the developments in water to hydrogen production with the help of sunlight has showed so many promising development lately. I desided not to take any particular solution and show it on the future concept. The main idea is that hydrogen would be produced onsite from water with the help of sunlight to support the missing fuel supply with hydrogen to be stored to tank and then used in the Bloom Energy server.

Just to show what kind of this solution could be, here is an example.
The system is called Artificial leaf system which is a new type of coating called "photoanode uses sunlight to oxidize water molecules to generate oxygen gas, protons, and electrons, while the photocathode recombines the protons and electrons to form hydrogen gas (Than, 2015).

Rendering showing the "Waste to Energy System" integrated in to the floating building: The use of biomass like biodegradable municipal waste, black and gray water as possible energy source was taken into consideration as possible power supply for the floating community concept. The C2C Building Charter supports this way of thinking like the materials 0opportunity aspects (Braungart & McDonough, 2009). This was also because of the slow but raising trend in use of municipal waste and bio-mass in the electricity energy mix chart and the raising interest for using greenery and green spaces in buildings and surrounding that could be possible sources for extra biomass. This showed potential growth to be expected by 2030.

In the search for proper biomass to energy technologies the use of anaerobic co-digestion (AD) came up during the search for right solution. AD was a proven to work well with mixed input like possible sewage, greenery and household biodegradable waste possible in the concept. The actual size of the possible AD reactor compared to the side and demand of the floating building was done by comparison for projects near the same size.

The estimated amount of habitat and households in the floating building formed around 340 apartments for 2-5 people apartment sizes with building technology consumption including the possible business spaces integrated to the radial wave attenuator, taxi boat service with loading stations needing their part of the energy consumption.

The next step was to find most promising biogas to energy production method. The locally used gas turbine used of latest developments in the field of fuel cell technology showed most promising results in energy production.

One power generation innovation came to be the most promising when thinking about flexible fuel use addressing possible changes in future demands and supply in Singapore 2030. This was the innovative fuel cell technology behind the Bloom Energy.

The efficiency for household appliances in the future 2030 can even reduce the amount for needed energy. This means the floating building concept needs around two Bloom Box Energy Servers at the current production rate which could be enhanced till 2030. Use of energy efficient household appliances 2 Bloom Energy Servers with 200kW energy output (160 households) would be enough for the energy needs in one floating building in the highest use. During the maintenance of either server there would still be half of the energy available. The increased efficiency in the energy production till 2030 can change the situation for better. As a backup plan the server can use local natural gas supply but is less environmentally friendly.

So the big plan would be to keep the NG as a backup for the energy production by using latest fuel cell technology in the floating community visionary concept and produce the main energy supply as a hybrid of biogas and hydrogen produced on site and stored on tank for overnight energy need. The target would be close to zero pollution in time.

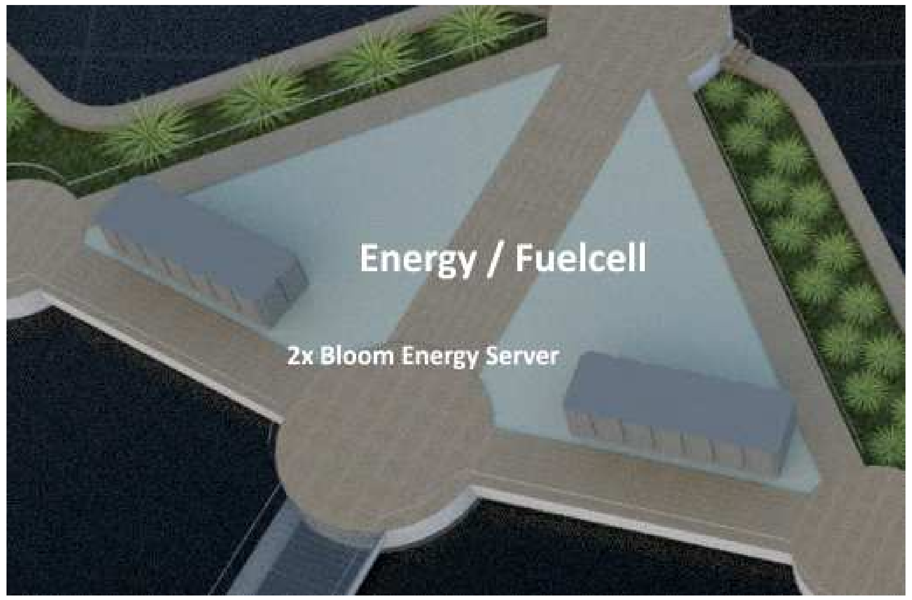


Figure 61. Rendering showing the Bloom Energy servers situated near the main walkway for maintenance reasons.

4.3 The floating building greenery and aquatic ecosystem

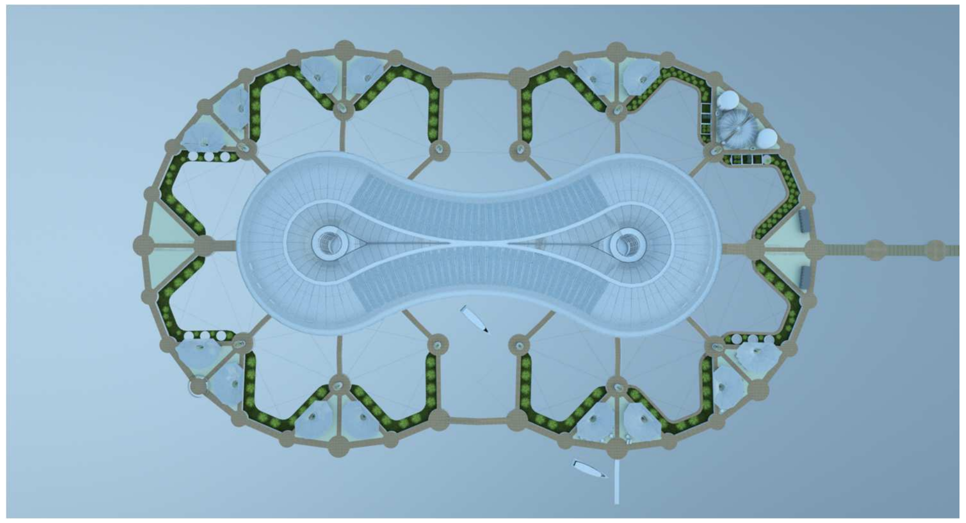


Figure 62. Aerial rendering of the wave attenuators including the floating greenery.

In this future visionary concept the floating building greenery and aquatic ecosystem are the biological systems in connection to the surrounding environment and floating building.

The respect for surrounding environment like in the case of Uros floating community with the use of Totoro reeds and the use of biological materials to build their floating community was great example of how to live with local biological system.

The Halong fishing communities showed signs of unhealthy living with polluting and over fishing the aquatic environment and that way endangering their own living environment.

These cases showed both the nature friendly and violating way to use the local biological systems. The interaction and full potential of these systems to reach environmental and societal coals was considered to be most important part in the concept.

The basic findings on current situation on Singapore including the aquatic environment and nearshore area opened some more understanding on the local situation.

Increasing the vegetation and species diversity on site considering the floating building was important goal for the concept. The idea behind the regenerative design holds this ideology as described by Nancy Rottle (Nancy Rottle, 2010, pp. 78-79) and this supports the C2C Building Charter philosophy (Braungart & McDonough, 2009).

Singapore's plans to 'make city more clean, blue and green physical environment' as introduced in chapter 3.4. Also the recycling of water and biological nutrients in buildings, landscaping and spatial plans and the possibility to increase the diversity of species played a great role in the concept and respects the cradle to cradle building charter.

The intentions for reaching a working concept by integrating multi use green spaces for the floating community use are one key element in the findings presented in this concept. Secondly according to my findings the solutions for the concept and for Singapore Blueprint for 2030 and beyond the use of green technologies and spaces have started to bloom in most recent years in Singapore and have started to form almost as a standard for the new buildings in the Singapore area. According to my findings on articles considering the greening of Singapore and their ultimate goal to evolve into city within a garden, like described in this article from Green Roof Technology (Yurek, 2013) the development of these "green" solution is justified.

The goal for the concept when thinking about use of water was to create a vision of a possible system that would address the raising need for higher recycling rates of community water use, would use as much rainwater after cleaning as tap water as possible and would be able to purify the water from household, greenery and municipal waste to be reused as irrigation and flushing water for the floating community. As a backup system connection to the Singapore tap water network and seawater to drinking water cleaning system would be beneficial for the floating community.

4.3.1 Water collection and reuse

As Singapore has a very humid and rainy hot weather the use of rainwater collection is for the floating community use was an easy decision. This was also recommended by the local building authorities (Building and Construction Authority, 2010).

In the concept the idea was that rainwater was collected from the roofs to provide the main source for tap water supply because of the amount of rainfall on yearly basis. This can be supported by the fog nest innovation. The design the extensive use of lightweight ETFE roof covering most of the building as the main rainwater collection surface was applied. The possible business and recreational spaces in the radial wave attenuator peer design included also ETFE roofs with design allowing the water collection for same purposes.

The use of big enough water tank to store enough tab water for the community needs was not counted but the cylinder design allows for scalability in the concept stage and can be adjusted to right volume if counted later. The idea of using water tank that would move in vertical direction depending on how full it is was also considered. This solution would separate it from effecting the buoyancy of the floatation units. The other idea in the positioning of the water tanks to the center in both ends of the building and mostly under the water was the cooling effect of sea water and shade which would enhance the water quality.

The main principle of the water collection and use is described in the figure 56. The spiral vertical floor ramp shape with in the inner border towards the center includes rain spout used for rainwater collection from the center parts of the ETFE roof going all the way down to the first floor where the water is to be further cleaned and stored in a big tap water tank for habitat use. The outer radius of the ETFE roof also collected the rainwater to the same water tanks. The water quality was enhanced with the Pax Water impeller allowing the tank water to stay in good quality for longer period.

The wide lightweight ETFE roof on the building worked as water main tap water collector. As a backup plan a water pipe to the local water network should be connected in case of maintenance.

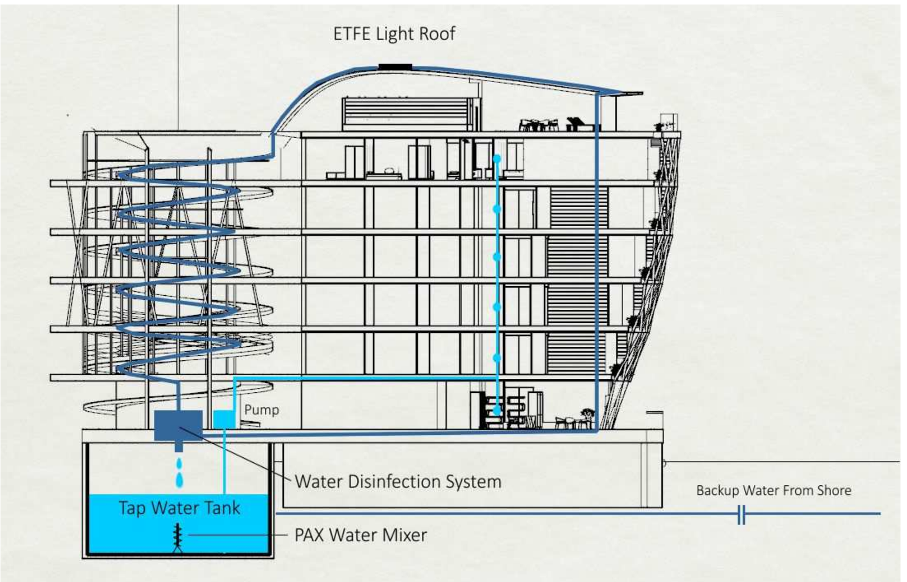


Figure 63. Rendering showing the rainwater collection including the PAX water impeller technology sustaining better water quality in the main water tank.

Figure 64. Rendering showing the ETFE roof covering the floating building used for main rainwater collection.

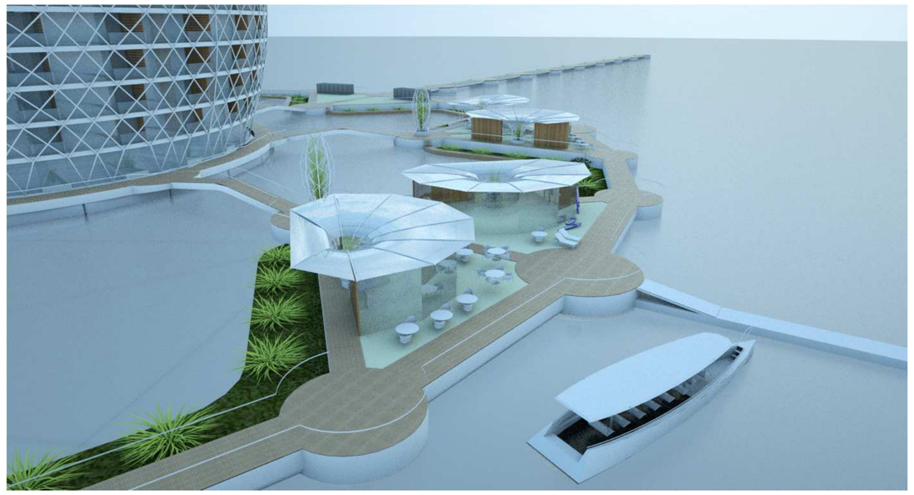
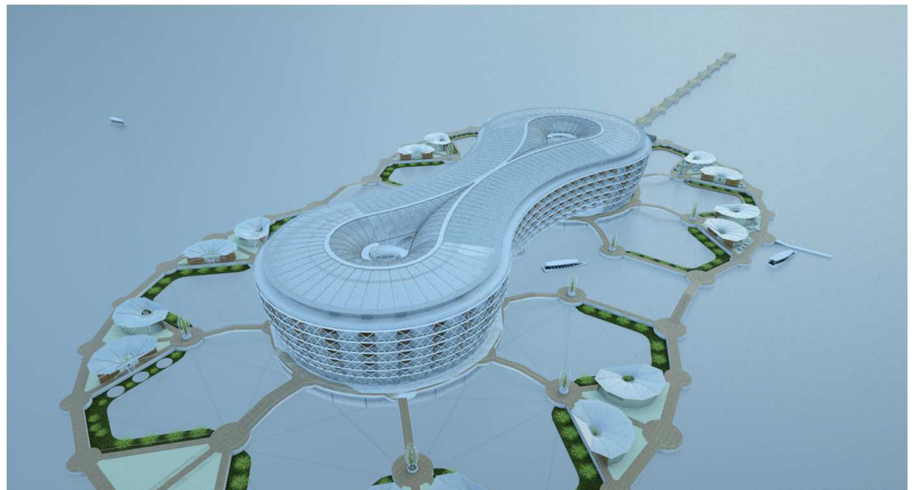


Figure 65. Rendering showing the business space and recreational space ETFE roof covers used for rainwater collection.



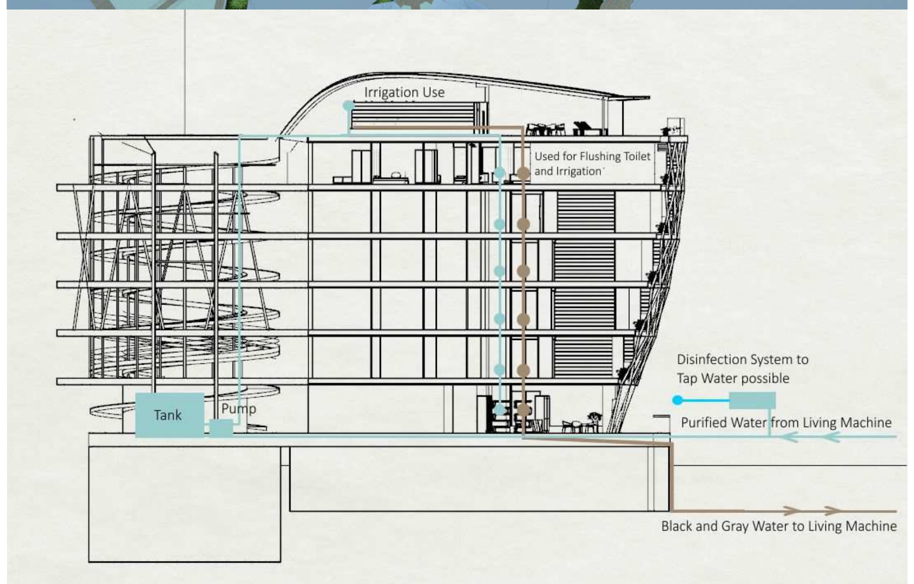


Figure 66. Rendering showing the reuse of the purified water from the Living Machine for irrigation purposes and washing the toilets. After disinfection system the water can be as tap water if needed.

4.3.2 Local food production

The idea of local food production in the greenery areas of the floating community was inspired by the several positive factors. Firstly it was inspired by the Haitis Harvest City Concept including the 'Charter City Concept' where a pre designed business model and facility possibilities for local food production was defined. This could be the case for the floating community for Singapore when designed in a right scale.

The possible use of green roof area, green walls and finding of floating greenery technology like floating wetlands supported this ideology as a possible growth platform for food production. The other effective idea for food production based on findings on Hydroponics and fish farming.

Based on the driving force of food supply and need to extend the greenery in living areas at Singapore the idea for floating community scale farming came up. The idea of using the possible roof space for farming was already quite common phenomena in city farming activities over the world and in Singapore.

These finding suited well for the ideology of C2C Building Charter and regenerative design intentions. The fact that, this kind of activity would be beneficial for the community by giving extra food supply on site reducing the need to buy it from stores and even form small business or income by selling farmed products.

4.3.3 Integrated floating wetlands

The idea of floating wetland came when I was thinking added functions for the wave attenuator walkway design and the idea of floating vegetation for the concept. The Biohaven Floating Breakwaters (BFB) beneficial aspects like the seawater cleansing capability, recreational values and increase in the overall green areas (C2C Building Charter Goals).

I was glad to find a local experiment in Singapore using same kind of Floating artificial islands including wetland vegetation. This actual local experiment in Singapore using the same kind of system called the Sengkang Floating Wetlands project (CPG Consultants, 2015). This installment is located in the Punggol Reservoir in Singapore.

The BFB work as integrated part of the wave attenuator taking part in the wave absorbing work. In field test these Floating treatment wetlands (BFBs) have survived high storm conditions like 90miles an hour (Martin Ecosystems, 2015b).

The BFB work as floating recyclable plastic based mat which offers a growing platform for seawater and coast grown vegetation. The use of this BFB system is shown in the final renderings of the concept around the wave attenuator and walkway area.

Figure 67. Sengkang floating wet lands in Singapore.

Figure 68. Image showing hydroponic farming that could be used for example on the green roof floor area.

4.3.4 Aquaponic farming

The symbiosis of the fish and vegetation make the aquaponics farming activity almost a closed loop system where the fish vegetation feed each other. The maintenance of this system is needs some community effort but the benefits for local fish and for example salad production are worth the effort. The activity can be installed in the concept to the 7^{th} floor as habitat shared activity and to the radial wave attenuator small business space reservation for example fish restaurant support unit. These pools also offer great recreational value for the habitat. The aquaponics systems in the concept are shown in the 7^{th} floor final rendering in chapter 4.4

Figure 69. Picture showing the Aquaponics fish farming.

4.3.5 Waste and recycling

The waste created in the floating community when considering the biodegradable and liquid waste (blackwater) will be handled according to the found solution combining Biogas and Living machine systems (A. Timmeren, 2006, p. 2).

This section show the very basic flow of the biological and technical material out from the floating building. See figure 70.

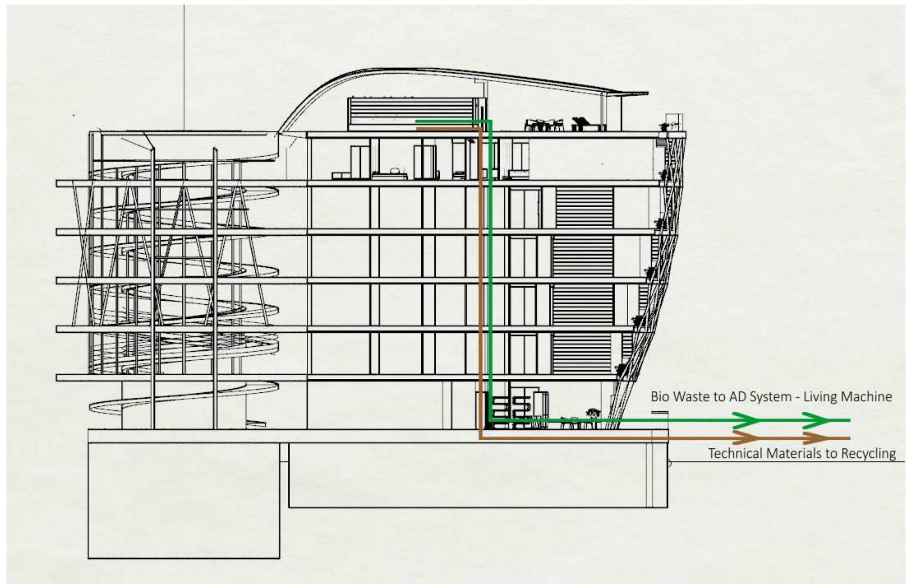


Figure 70. Basic sematic of the waste flow.

The process of the biowaste to AD system and living machine system can be described according the process used in the reference:

Stage 1. The blackwater and green waste is collected from the building and green areas into the system (mixing the substances will produce better production results).

Stage 2. The fermentation process and anaerobic digestion process is started resulting biogas, effluent and sludge output.

Stage 3. Purifying system improves the gas into biogas and is stored to gas tank to be used by Bloom Energy Server.

Stage 4. The remaining effluent is led to Living machine system and purified by natural wetland technology in to an irrigation water supply for the community and green areas.

Stage 5. The composting sludge is usable in the green areas as a fertilizer.

(A. Timmeren, 2006).

The maintenance of the system could be handled by the community members with the support of specialized professional. The maintenance of the system can be a community effort towards more sustainable lifestyle and include educational elements helping people to understand the natural cycles included in the system.

The design of the Living Machine and Biogas system is hypothetical in design considering the biogas and fermentation unit. The actual size of the Living Machine wetlands system was calculated to fit the floating green areas beside the Living Machine and Biogas system. (The numbers for calculation was found in comparison graph in figure 36.)

Figure 71. Rendering of the living machine and biogas system.

See final rendering in chapter 4.4

4.3.6 Moorage system of the floating building

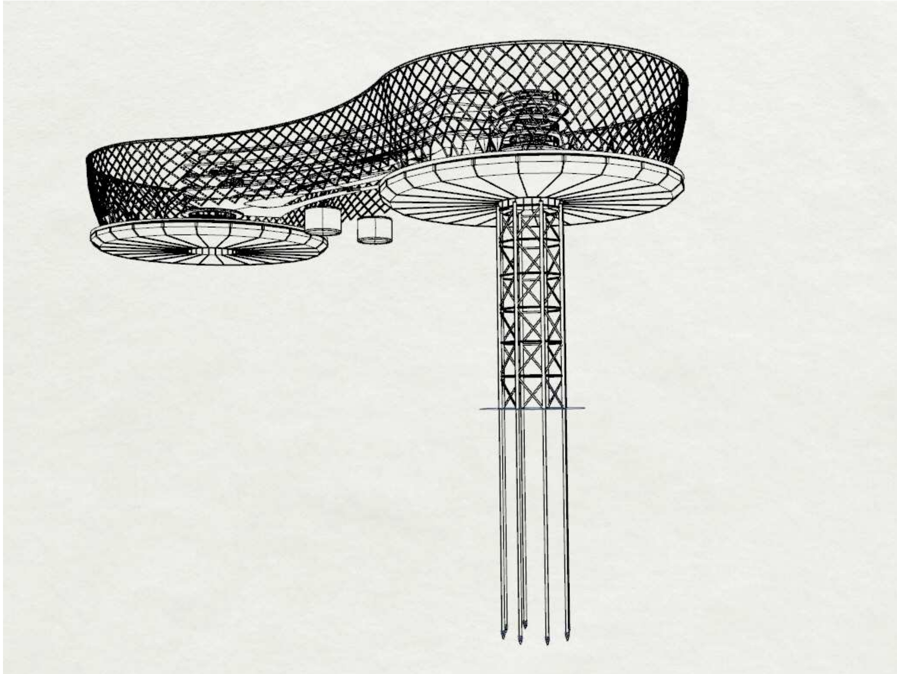


Figure 72. Moorage system inspired by the dolphin seabed system.

The dolphin mooring system suggested by Professor C.M. Wang (Wang, 2014) and the findings related to the nearshore environment draw in to conclusion that the floating building(s) should not be too close to the shore if more environmentally friendly installation would be made. This arrangement naturally affects the distance of the walkway from shore to the floating building(s). The design and installation of the dolphin mooring system and walkways is a subject for whole new study and has environmental issues unknown to my current understanding. To be noted this rendering is just a sketch to viewed for further study. In this idea the dolphin system is drilled to the seabed and the structure raises up from the seabed to the middle of the floatation units around the water tank. Other idea is to use a group of smaller dolphin systems connected to the radial wave attenuator walkway system.

4.3.7 Surrounding wave attenuating walkway system and spaces

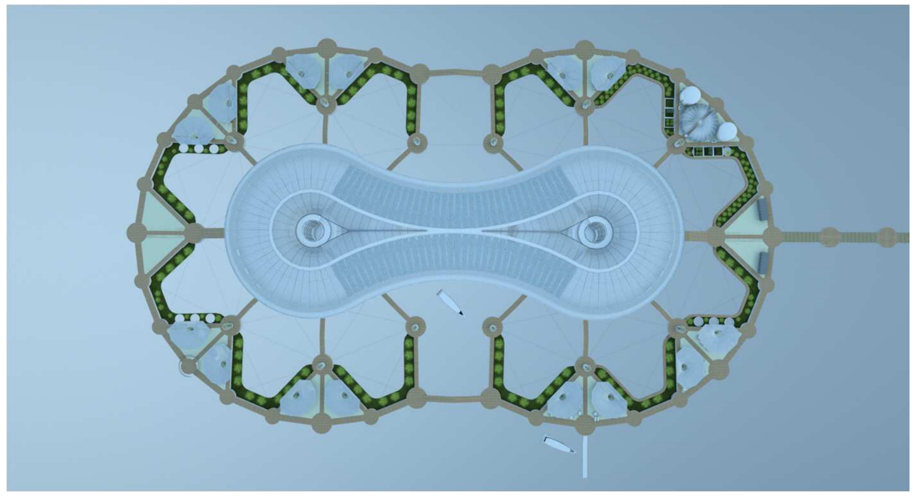


Figure 73. Top view of the floating building.

In the concept for Singapore the idea of using wave attenuators came naturally when thinking about the floating building security (collision), comfort and stability concerns. This idea was integrated into the architectural point of view for creating an enjoyable multi-use recreational space around the floating building.

The main idea was to form a floating courtyard like space for the habitats to enjoy and live in where they could socialize and have small business activities. The other effecting factors were based on ideas for integrated small pedestrian traffic routes, business space, floating greenery, fish tanks with hydroponics and last but not the least the idea of integrating the living machine floating wetlands purification system with energy generation system integrated in to the wave attenuator. All these integrated parts formed a floating recreational space around the floating building with multiple benefits.

The design of the wave attenuator shapes and size was first based on the radius that would allow for maintenance of the sliced flotation units under the first floor of the building and plinth. The bridges connected to the between the wave attenuator and the floating building was of loosely based on the idea of allowing the sliced floatation units among other parts on the surrounding and modular wave attenuator peace's to be changed in all positions for assembly, maintenance and dismantle.

The average wind conditions in the coastal areas of Singapore allow intense ship traffic and anchoring in southern coastline of Singapore in the areas where the possible new land reclamation areas are located. The use of wave attenuators to secure at least the open sea side or all around the floating building(s) gives an extra barrier against possible marine traffic collision like ships and wave activity. This arrangement will also be more secure solutions against possible future enhanced weather phenomena like in the case of the first recorded cyclone Typhoon Vamei which caused major flooding in the region.

The wave attenuator still do not disturb the underwater currents when they are not so deep under the waterline and this is good for the nearshore ecosystem health when the currents can pass the nutrients freely for the underwater vegetation all the way to the coast (Washington State Department of Natural Resources, 2015). The actual effect of the wave attenuators would need simulations to be approved. According to my findings the issue of the yearly average wind conditions in Singapore are in favor for floating building and this was also verified in the article. Still the idea of safety reflecting on possible more extreme weather conditions in the future 2030 and the ship activity keeping the danger for collision a possibility formed the idea of the using the wave attenuator as a buffer preventing harmful collision with ships. These factors verified it was needed in the concept.

The new ideas came when I discovered the floating island and wetland technology already used for some time around the world for natural water purification purposes with promising results. Floating wetland had a great wave absorbing qualities and they had even been tested to work in salty seawater for some time. These qualities naturally led to the conclusion of using the wave attenuator with new design feature to the concept. The driving forces like C2C and Blueprint 2030 greenery backed up the idea.

Basically the new idea was to use the radial wave attenuators also as floating greenery areas with wave absorbing qualities and integrate some floating rental spaces to be used in various activities around the floating building for example Water sports rental, fish restaurant, boat club, water park, waste & power unit and so on. The wave attenuators inner space would be used for small boat peer area and floating greenery spaces for recreational use with integrated floating black/grey water cleansing areas where living machine technologies would be used.

Radial gangways with low bridge like parts allowing light and low boat traffic to pass under would connected to the both circular first floor in both ends of the building. This arrangement would form two circular wave attenuator radius with crossing points. The crossing points would work as gate like areas where the light water traffic could pass and go to the surrounding water courtyard space or pass right through and under the floating building allowing the floating building area work as a mobility and passage point for water light water traffic in the area.

4.3.8 Mobility

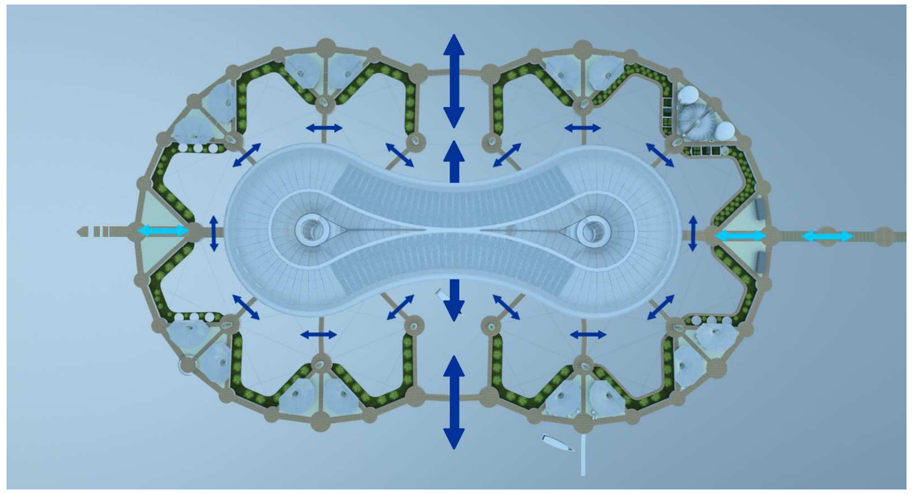


Figure 74. Picture showing the traffic routes in the floating community area.

4.3.8.1 Traffic routes and security

The main traffic route for the floating building concept area would be based on the floating walkway which allows pedestrian and small vehicles to come to the floating building see figure 71. The light blue arrows point out the main root. The floating walkways are a must for security and comfort reasons (British Columbia Float Home Standard, 2015, p. 12) The requirement for the emergency situations was considered by allowing a wide enough walkway for emergency and firefighter vehicle to arrive to the floating building site and make a turn for way back to shore. This access was needed for all the floating buildings when designed in multiple formations.

The firefighting capabilities for the floating building could also be enhanced by seawater pump and firefighting units integrated into the walkways and wave attenuator in most needed areas. Two lane wide walkways can be considered to the floating building but this would be an option if there would be a real need for more car traffic.

Otherwise the walkways including the ones in the wave attenuator areas would allow pedestrian light traffic in the areas and inside the floating building. The stability for the walkways against wave activity could be enhanced by integrating the floating wetland greenery in both or one side of the walkways when needed having water cleansing and wave absorbing capabilities. These areas would also work as a recreational green spots with vegetation along the walkways. Inside the wave attenuator and across under the floating building a light boat traffic with 2m height limit would be allowed because of the bridges. Sailboats and higher motor boats can only park outside around the wave attenuator because of the height limit of the bridges and the building superstructure. This could be a matter for further development.

4.3.8.2 Taxi boat system

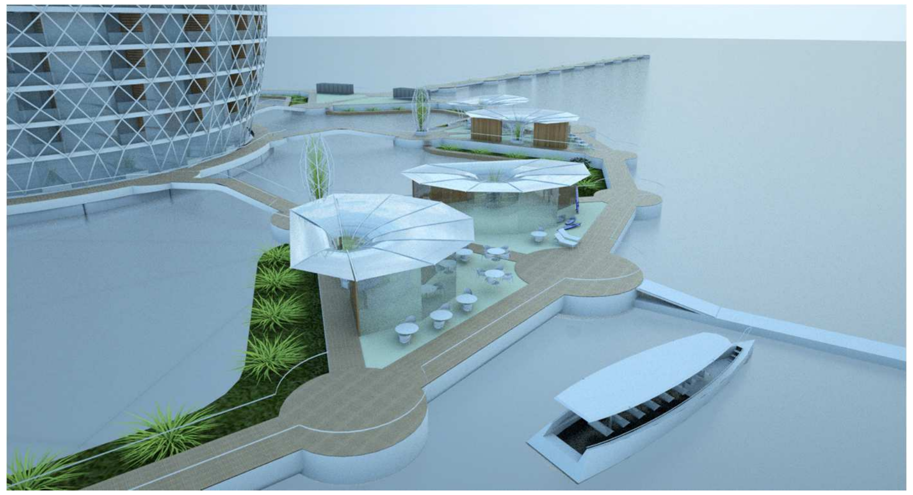


Figure 75 Figure shoving a 3D skech of a possible electric taxiboat in the area.

The idea of an intelligent local taxi boat service (Figure 75) for the floating building(s) as a community service came in the very early stage of the concept development. This was inspired by the floating market in Thailand (chapter 3.2.3) and by Harvest City (chapter 3.2.4) concept chapter and this would be very beneficial for habitat and people wanting to visit the floating community area by boat and this would help the possible small local businesses in and around the floating building(s). Taxi boat stop dock areas could be situated along the urban coastline of near the floating community in points where public transport framework has important connection points helping to further enhance the mobility capabilities in the floating community area. The taxi boats would be electric powered by local powered energy supply in the floating building(s) or in the taxi peers on the shore and loaded in the loading dock while stationary. Electric taxi boat and light boat traffic would also be more preferable in the proximity of the floating buildings because they cause less noise are this way suitable for the nearshore environment preventing extra noise and pollution.

Finally here are some examples of light water traffic vehicles that could be used in the community.

Figure 76. Example of waterbike that could be used in the floating community

Figure 77. Example of solar powered taxi boat.

The maintenance issues for the concept are left open, but in principle the water routes and gangways are possible the maintenance routes for the building and maintaining the systems in the floating community.

The idea of whole design in the floating community area is the forming of mobility network on light water traffic around the floating community with trading, recreational and even tourist attraction. The vision of lively floating community driven floating market and mobility network along the urban coastline of Singapore could form a new kind of culture among Singaporeans.

4.4 Final presentation rendering

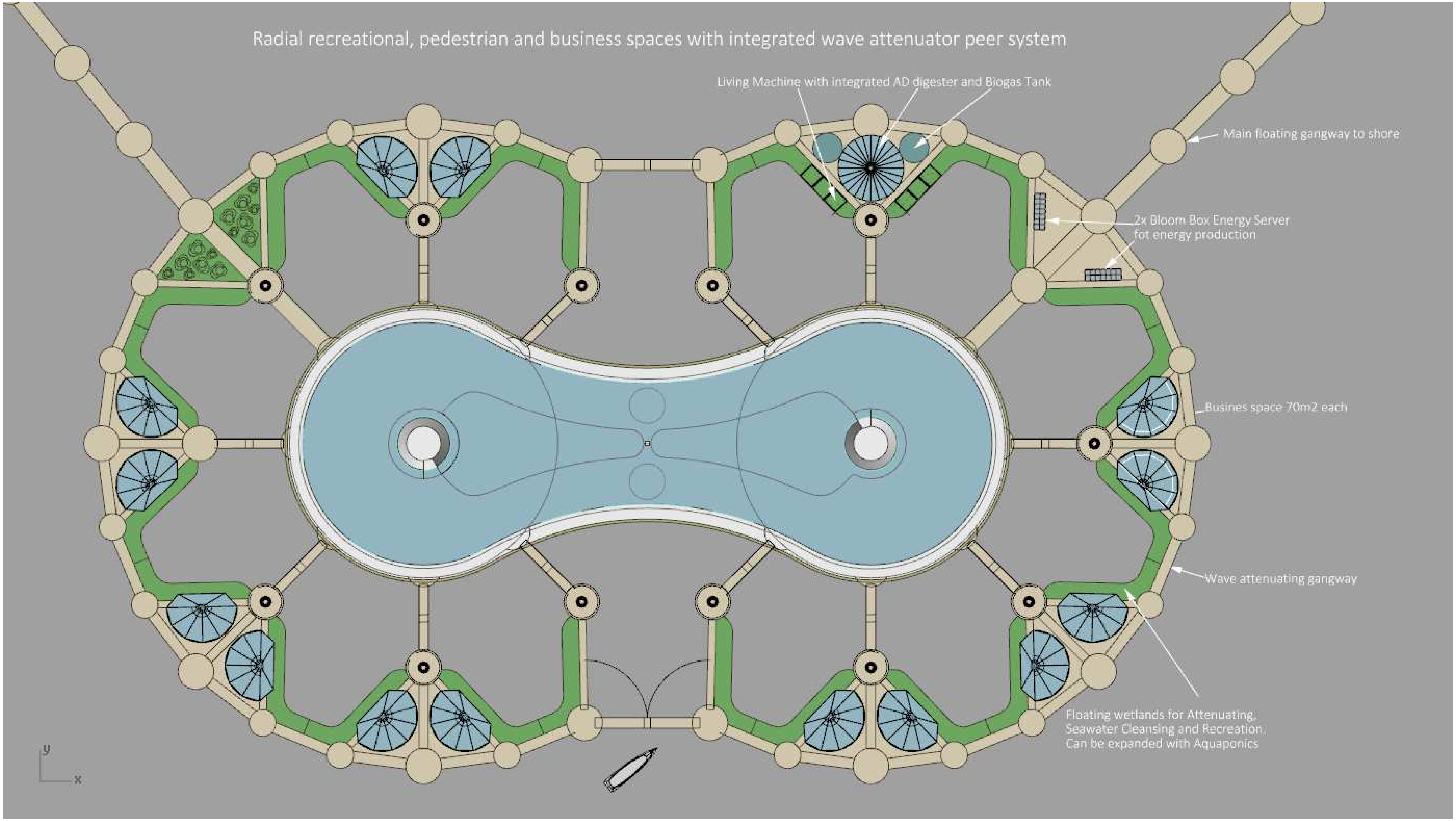


Figure 79 Showing the modular mooring system slices and 1st Floor with Office spaces, technical space reservation and 2-3 floors with elderly apartments and studio apartmens.

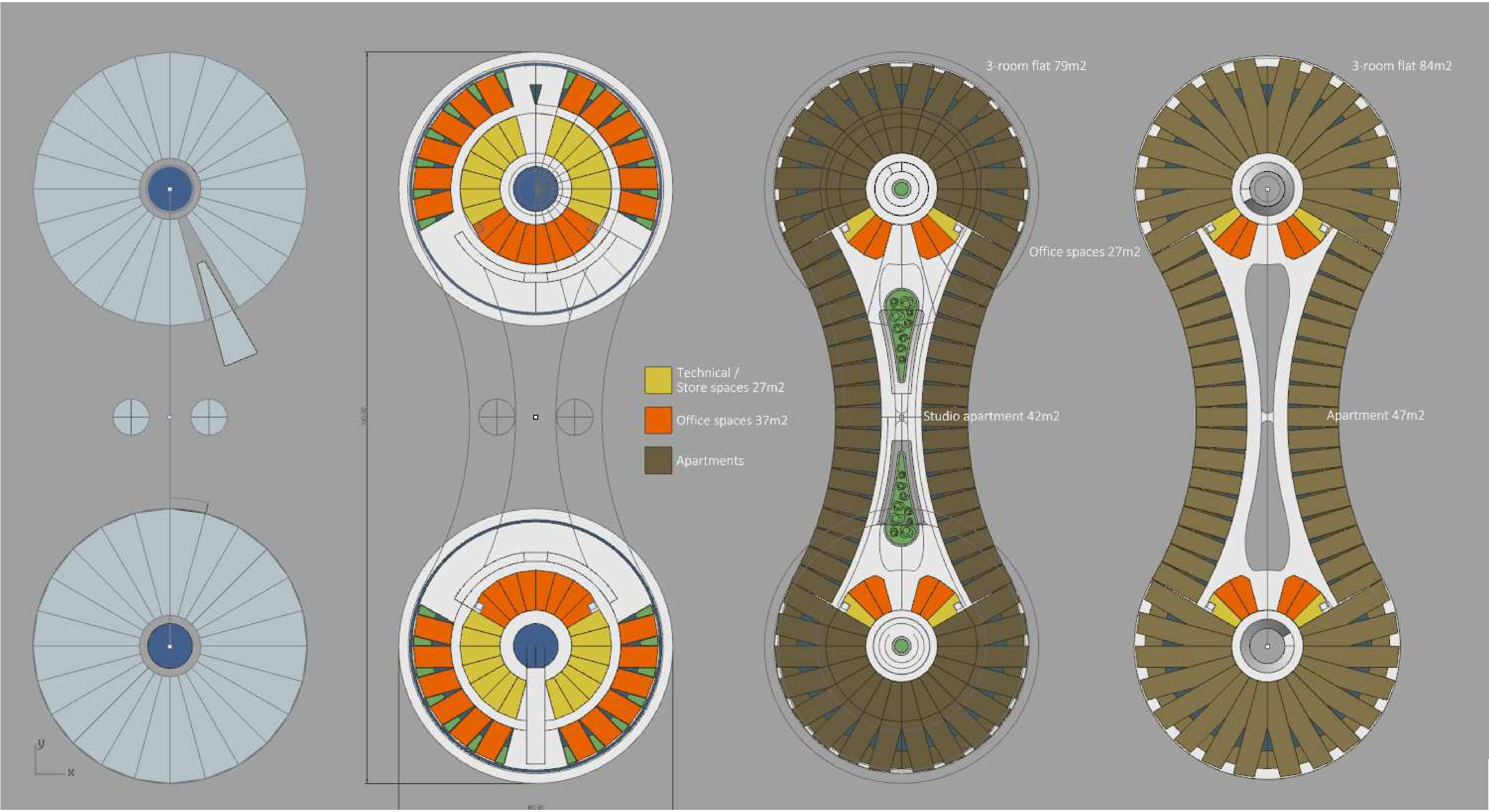


Figure 80. Rendering showing the aparments in floors 2-7

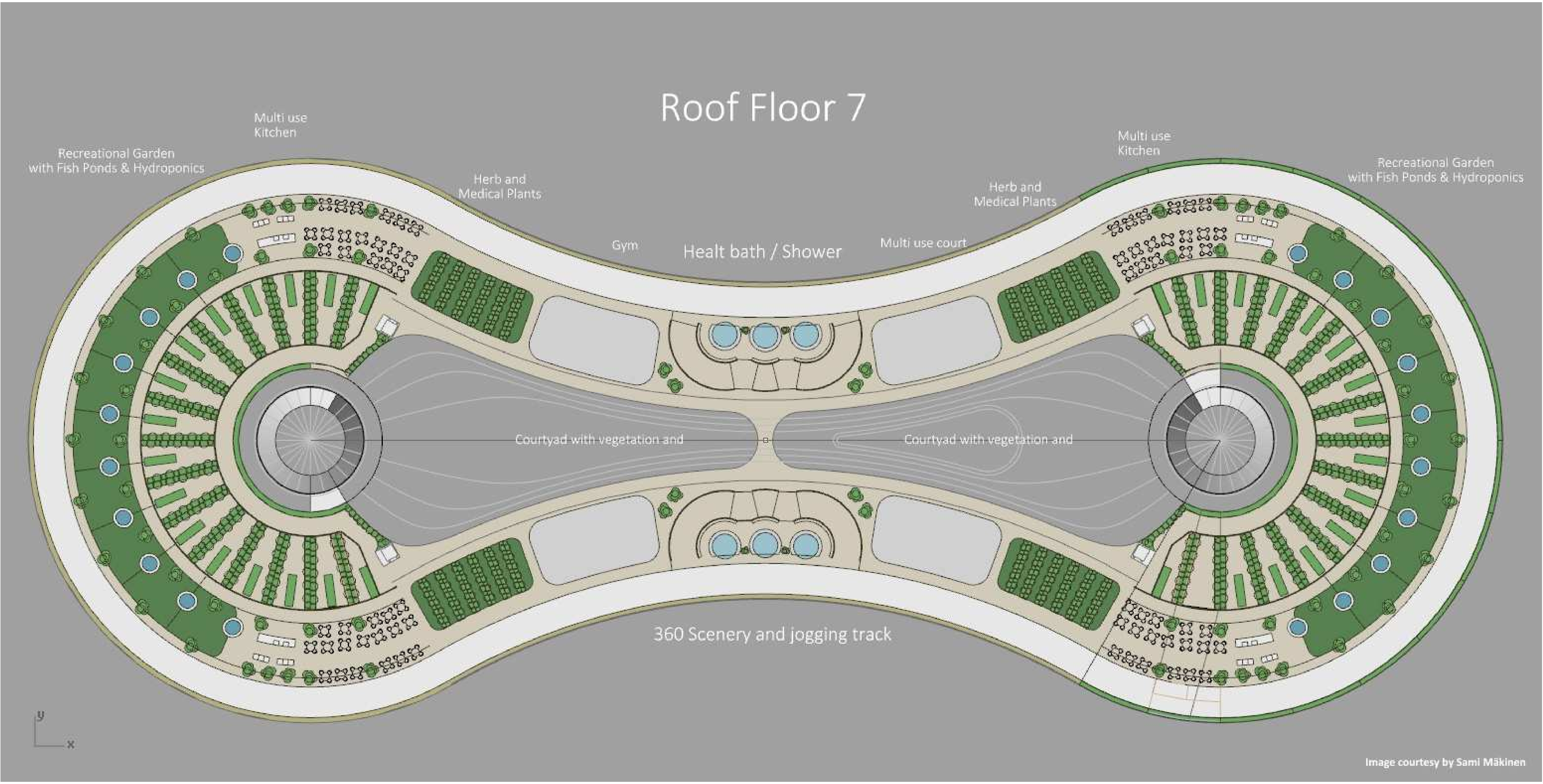


Figure 81. Layout of the 7th floor including the services

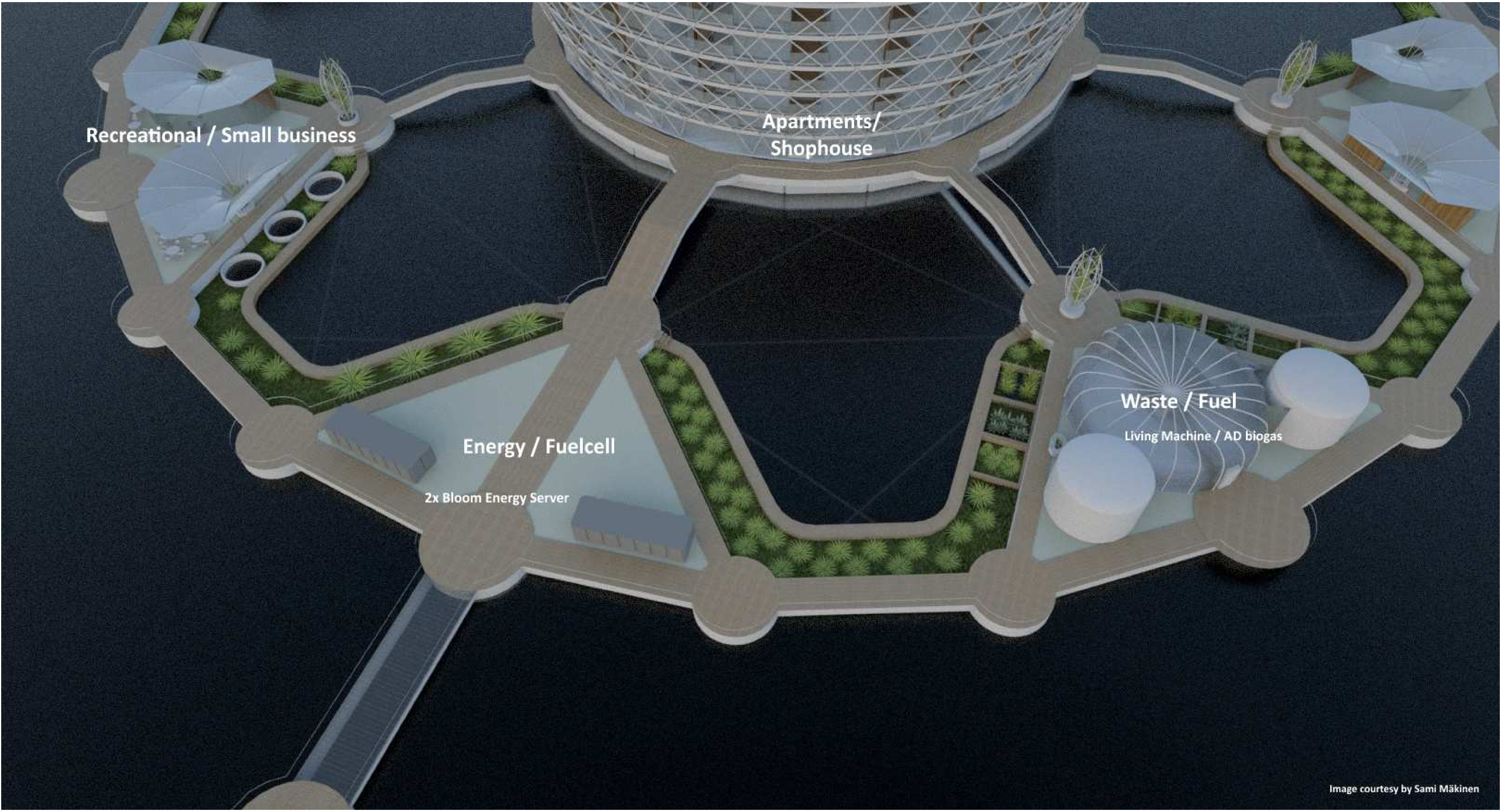


Figure 82. Rendering showing the Spaces around the wave attenuator walkways with floating wetlands

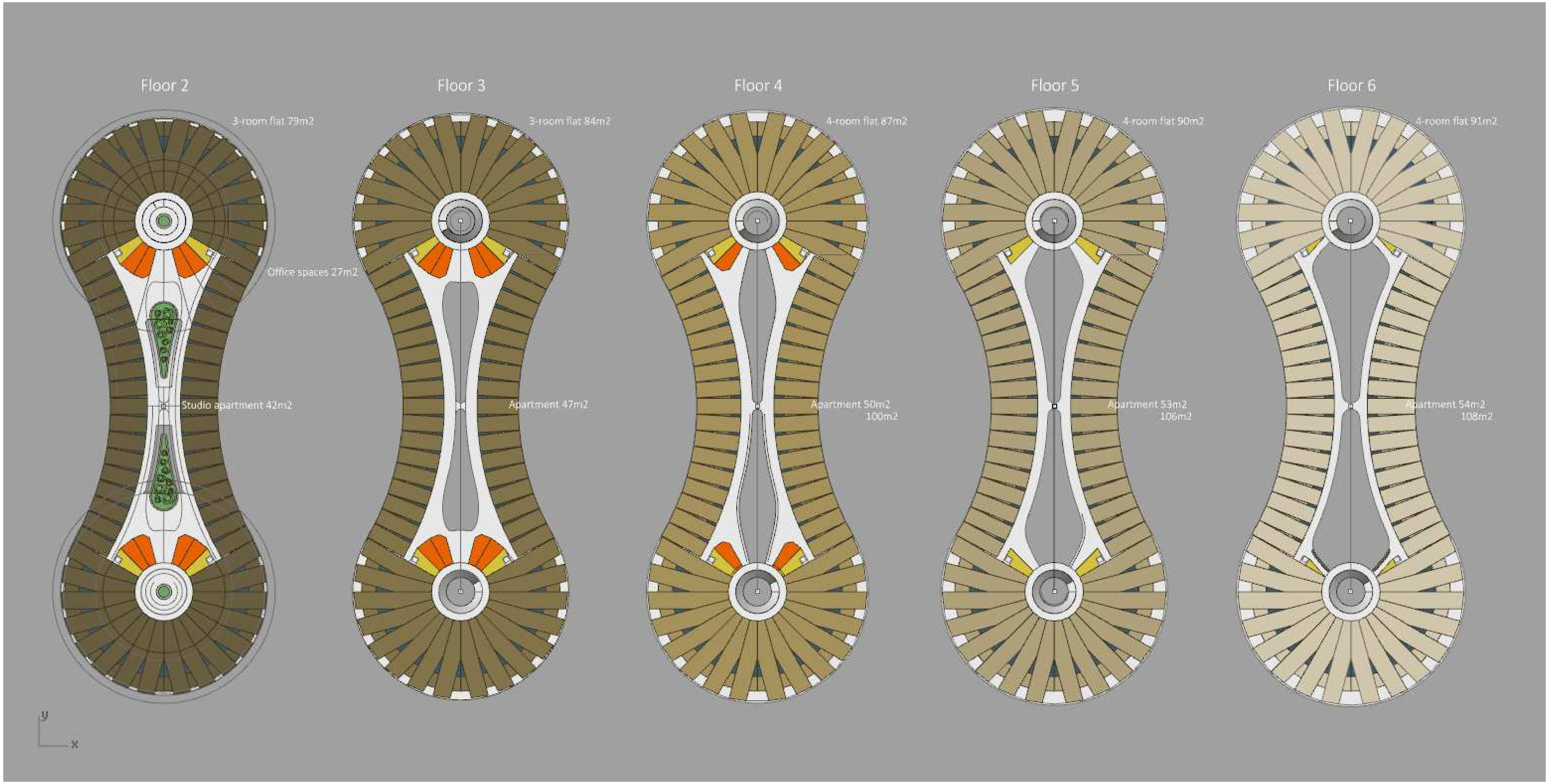


Figure 83. Layout of the apartment floors.

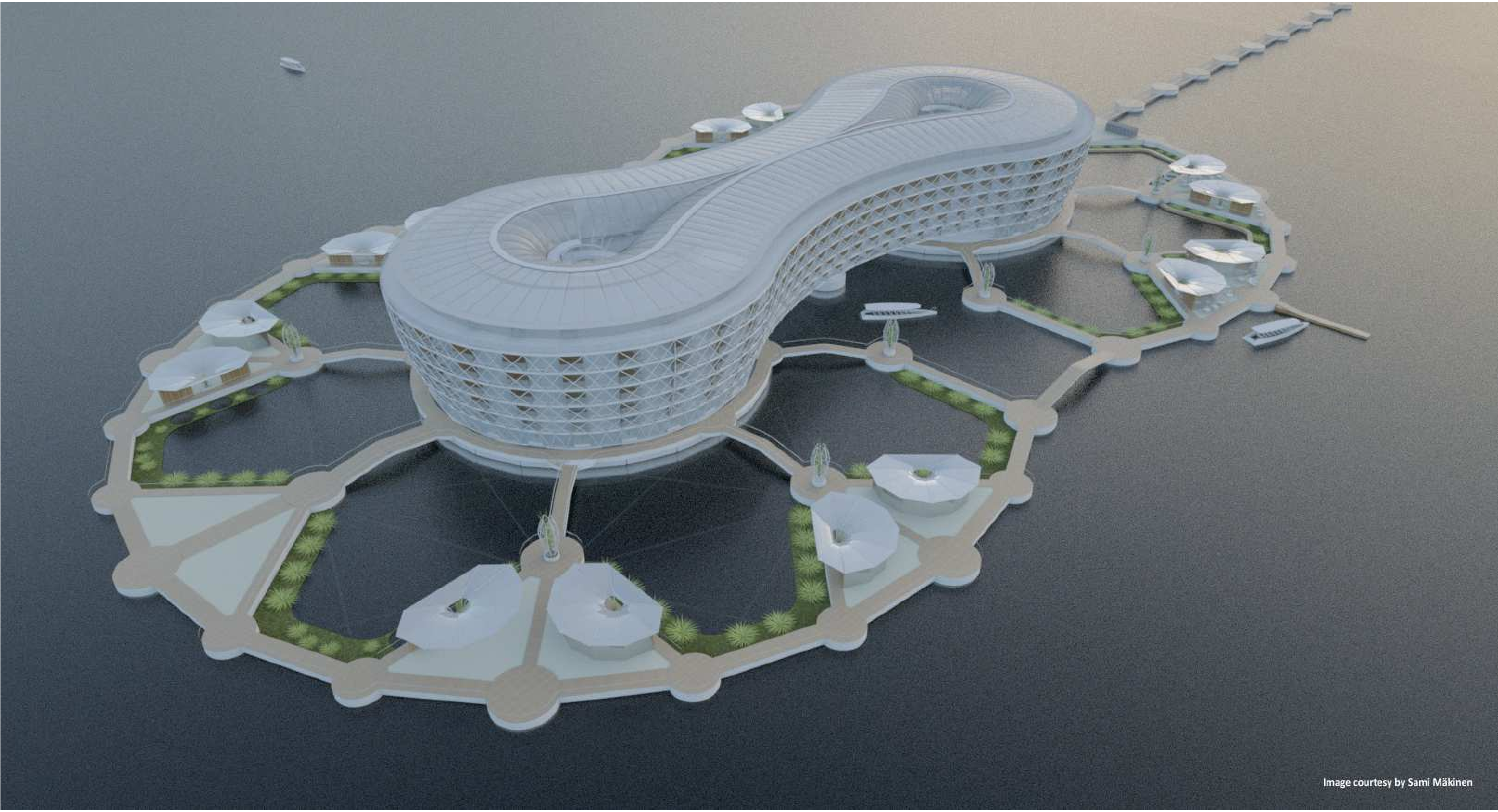


Figure 84. Exterior rendering showing the whole concept.

4.4.1 Example siting for the concept

Showing a test placement of the floating community concept in to the Singapore coastline near the Bayshore Park.

Figure 85. Example site with the floating building layout near the coastline. Backrgound Image courtecy by Google maps

5. Conclusions

The whole process of finding the issues effecting the design of the future floating community for Singapore 2030 was a very challenging task to take. At first there was so many open issues and questions before I was able to form any reasonable conceptual vision, but as the process continued the pieces for the great puzzle started to come together.

As a visionary future concept the amount of uncertain variables is always present and many issues for concept were still left open and unsolved. The other challenging issue was multidisciplinary material needed for the concept and the amount of material not as familiar to a person with my background as industrial designer concentrated mainly on ship exterior design.

The most important findings during the research on the thesis according my perception was the findings related C2C Building Charter main philosophy, to nature and how nature can help us to solve issues concerning the build environment.

The basic findings on issues considering aquatic ecosystem, floating wetlands and building on water were interesting and in my opinion offered some new perspectives on the design of the future concept not so much seen before.

The innovations behind bio waste to energy, future fuel cell technologies and the rising innovative developments in local hydrogen production with the help of solar energy could form a very interesting future in near future.

Personally I would like to see the more advanced level of the future concepts environmental issues with actual calculated and more defined details, which could tell the actual capabilities of the future concept since this concept is done solely on current and future findings with theoretical basic background information.

As a structural and modular form I see combination of many beneficial issues including the innovative exchangeable floatation units and variable sizing in apartments with extensive modular pieces seen in some details like the sliced apartment and structure details to for resilience with ocean views, and the surrounding radial wave attenuator floating courtyard with many integrated qualities having environmental, recreational, small business and even regenerative qualities to be the most promising creations of the concept which could be a good frame for actual development.

This actual development could be the in form of local user research integrated in to the concepts for further development towards a real interest in Singapore. This could be done in co-operation with the local interest, authorities and National University of Singapore.

I see the great value of the future concept to be in the combination features forming whole, rather any particular defined detail. If we search enough for solutions respecting the nature, we might have a brighter future after all.

6. References

Building and Safety Standards Branch, 2011. *British Columbia Float Home Standards.* [Online]
Available at:
http://www.housing.gov.bc.ca/pub/htmldocs/floathome.htm
[Accessed 14 11 2012].

WhisprWave, 2015. *WhisprWave - Wave Attenuators.* [Online]
Available at: http://www.whisprwave.com/products/wave-attenuators/
[Accessed 28 8 2015].

A. Timmeren, M. T., 2006. *Integration of Living Machine and Biogas plant Case EVA Centre Lanxmeer, Culemborg.* Geneva, Climate Design & Environment, Faculty of Architecture, Delft University of Technology, Delft, The Netherlands.

ArchDaily, 2011. *ArchDaily.* [Online]
Available at: http://www.archdaily.com/120238/floating-houses-in-ijburg-architectenbureau-marlies-rohmer/
[Accessed 30 3 2015].

Architecten Landrell, 2012. *ETFE Foil: A Guide to Design.* [Online]
Available at: http://www.architen.com/technical/articles/etfe-foil-a-guide-to-design
[Accessed 14 11 2012].

Autodesk Sustainabolity Workshop, 2015. *Autodesk Sustainability Community - Natural ventilation.* [Online]
Available at:
http://sustainabilityworkshop.autodesk.com/buildings/stack-ventilation-and-bernoullis-principle
[Accessed 27 8 2015].

Biomimicry Group, Inc, 2012. *Biomimicry.* [Online]
Available at: http://biomimicry.net/about/biomimicry/lifes-principles/
[Accessed 14 11 2012].

Bloomenergy, 2015. *Bloomenergy/clean-energy.* [Online]
Available at: http://www.bloomenergy.com/clean-energy/
[Accessed 10 6 2015].

Braungart & McDonough, 2009. *c2carchitecture.* [Online]
Available at: http://c2carchitecture.org/wp-content/uploads/C2C_charter_EN.pdf
[Accessed 1 6 2015].

British Columbia Float Home Standard, 2015. *British Columbia Float Home Standard.* [Online]
Available at: http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/guides/2003_float_home_standard.pdf
[Accessed 3 8 2015].

Buczynski, B., 2015. *Inhabitat - MIT develops advanced fog harvesting material that pulls 5x more water from thin air.* [Online]
Available at: http://inhabitat.com/mit-develops-advanced-fog-harvesting-material-that-pulls-5x-more-water-from-thin-air/
[Accessed 23 8 2015].

Building and Construction Authority, 2007. *Universal Design Guide.* 1st ed. Singapore: Building and Construction Authority.
Building and Construction Authority, 2010. *Building Planning and Massing.* [Online]
Available at:
http://www.bca.gov.sg/GreenMark/others/bldgplanningmassing.pdf
[Accessed 27 2 2014].

Chandler, D., 2013. *MIT News - How to get fresh water out of thin air.* [Online]
Available at: http://news.mit.edu/2013/how-to-get-fresh-water-out-of-thin-air-0830
[Accessed 23 8 2015].

Chimizu Corporation, 2015. *TRY2025 The Environmental Island - GREEN FLOAT-.* [Online]
Available at:
http://www.shimz.co.jp/english/theme/dream/greenfloat.html
[Accessed 26 3 2015].

CPG Consultants, 2015. *CPG Consultants - ABC Waters Programme (Sengkang Floating Wetland).* [Online]
Available at:
http://www.cpgcorp.com.sg/CPGC/Project/Project_Details?ProjectID=1296&TypologyID=1
[Accessed 31 5 2015].

Deltasync, 2015. *Deltasync.* [Online]
Available at:
http://www.deltasync.nl/deltasync/fileadmin/template/main/projectimg/BlueRevolution.pdf
[Accessed 26 3 2015].

Deltasync, 2015. *Deltasync - water based urban development.* [Online]
Available at:
http://www.deltasync.nl/deltasync/index.php?id=homepage&L=0
[Accessed 26 3 2015].

Designboom, 2015. *designboom.* [Online]
Available at: www.designboom.com/architecture/jds-architets-mermaid/
[Accessed 20 02 2015].

Dolphin, H., 2014. *halongdolphin.com/halong-travel-guide/11-ha-long-fishing-villages.* [Online]
Available at: http://www.halongdolphin.com/halong-travel-guide/11-ha-long-fishing-villages.htm
[Accessed 3 27 2014].

Doran, S., 2015. *Luxury society.* [Online]
Available at: http://luxurysociety.com/articles/2011/08/the-latest-boutiques-yves-saint-laurent-gucci-lamborghini
[Accessed 31 7 2015].

E. Watanabe, C. T. T., 2004. *Very Large Floating Structures: Application, Analysis and Design,* Singapore: Centre for Offshore Research and Engineering, National University of Singapore.
Foundation, C., 2012. *Arcosanti.* [Online]
Available at: https://arcosanti.org/theory/arcology/main.html
[Accessed 10 4 2015].

Gardens By The Bay, 2015. *Gardens By The Bay - History of Gardens by The Bay.* [Online]
Available at: https://www.gardensbythebay.com.sg/en/the-gardens/about-the-gardens.html#!/history
[Accessed 2 8 2015].

Gashaw, A., 2014. *Science Publishing Group.* [Online]
Available at:
http://www.sciencepublishinggroup.com/journal/archive.aspx?journalid=227&issueid=-1
[Accessed 10 6 2015].

Greenfuture, 2015. *Greenfuture - Guide to Singapore Government Funding and Incentives for the Environment.* [Online]
Available at: http://www.greenfuture.sg/2015/02/16/2015-guide-to-singapore-government-funding-and-incentives-for-the-environment/
[Accessed 10 6 2015].

Grip Arendal / UNEP, 2006. *Grid Arendal a Centre Colloborating with UNEP.* [Online]
Available at: http://www.grida.no/graphicslib/detail/coastal-population-and-altered-land-cover-in-coastal-zones-100-km-of-coastline_7706#
[Accessed 27 2 2014].

Housing an Development Board (HDB), 2015. *Housing an Development Board.* [Online]
Available at: http://www.hdb.gov.sg/
[Accessed 22 7 2015].

Hämäläinen, R., 2013. *Flotation system design* [Interview] 2013.
Infoplease, 2015. *Infoplease / Population Density.* [Online]
Available at: http://www.infoplease.com/world/countries/highest-population-density.html
[Accessed 24 6 2015].

JDS architects, 2009. *JDS Atchitects.* [Online]
Available at: http://jdsa.eu/
[Accessed 10 6 2014].

Kokkonen, V. et al., 2005. *Visioiva tuotekonseptointi - Työkalut tutkimus- ja kehitystoiminnan ohjaamiseen.* 4/2005 ed. Helsinki: Teknologiateollisuus ry.

Kokkonen, V. ym., 2005. *Visioiva tuotekonseptointi, Työkalu tutkimus- ja kehitystoiminnan ohjaamiseen.* 1nd toim. s.l.:Teknologiateollisuus ry.

Labarre, S., 2015. *Ecofriend.* [Online]
Available at: http://www.ecofriend.com/case-develops-air-purification-system-based-hydroponic-plants.html
[Accessed 31 08 2015].

Lamboo, 2015. *Lamboo - Exterior component solutions.* [Online]
Available at: http://www.lamboo.us/#!exterior-solutions/c1yqw
[Accessed 7 8 2015].

Lianhe Zaobao, A. Y., 2012. *National University of Singapore, Engineering Science Program, News.* [Online]
Available at:
http://www.esp.nus.edu.sg/news_and_events/News/2012%20news/

My%20home%20in%20the%20sea.pdf
[Accessed 10 4 2015].

Living Machine, 2012. *Living Machine.* [Online]
Available at: http://www.livingmachines.com/About-Living-Machine/Tidal-Flow-Wetland-Living-Machine-System.aspx
[Accessed 11 6 2015].

Living Machine, 2012. *Living Machine.* [Online]
Available at: http://www.livingmachines.com/About-Living-Machine/Tidal-Flow-Wetland-Living-Machine-System/Living-Machine-Components.aspx
[Accessed 31 7 2015].

Malcolm, M., 2005. *Building structures: from concepts to design.* 2nd ed. New York: Spon Press.
Marina Bay Sands, 2015. *Marina Bay Sands.* [Online]
Available at: http://www.marinabaysands.com/
[Accessed 2 8 2015].

Marlies Rohmer Architects, 2011. *Floating Houses IJburg.* [Online]
Available at: http://www.rohmer.nl/en/project/waterwoningen-ijburg/
[Accessed 26 3 2015].

Marlies Rohmer Architects, 2015. *Floating Houses IJburg.* [Online]
Available at: http://www.rohmer.nl/en/project/waterwoningen-ijburg/
[Accessed 26 3 2015].

Martin Ecosystems, 2015b. *Martin Ecosystems - applications - costal.* [Online]
Available at: http://www.martinecosystems.com/applications/coastal
[Accessed 6 6 2015].

Martin Ecosystems, 2015. *Martin Ecosystems - Coastal Restoration.* [Online]
Available at: http://www.martinecosystems.com/coastal-restoration-protection/
[Accessed 7 4 2015].

Meteorogical Service Singapore, 2015. *Meteorogical Service Singapore - Climate of Singapore.* [Online]
Available at: http://www.weather.gov.sg/climate-climate-of-singapore/
[Accessed 21 8 2015].

Metereological Service Singapore, 2015. *Metereological Service Singapore - Climate of Singapore.* [Online]
Available at: http://www.weather.gov.sg/climate-climate-of-singapore/
[Accessed 24 8 2015].

Michael Braungart & William McDonough, 2009. *c2carchitecture.* [Online]
Available at: http://c2carchitecture.org/wp-content/uploads/C2C_charter_EN.pdf
[Accessed 1 6 2015].

Michael Braungart, W. M., 2009. Cradle to Cradle. In: *Cradle to Cradle: Remaking the Way We Make Things.* s.l.:s.n., p. 208.
Ministry of National Development, 2013. *mnd.gov.sg/landuseplan/.* [Online]
Available at: http://www.mnd.gov.sg/landuseplan/
[Accessed 31 3 2014].

Ministry of the Environment and Water Resources - MND, 2015. *Ministry of the Environment and Water Resources - Sustainable Singapore Blueprint 2015.* [Online]
Available at: http://www.mewr.gov.sg/ssb/files/ssb2015.pdf
[Accessed 9 6 2015].

MPA Singapore, 2015. *MPA Singapore - Port & Shipping.* [Online]
Available at:
http://www.mpa.gov.sg/sites/port_and_shipping/port/port.page
[Accessed 23 7 2015].

Nancy Rottle, K. Y., 2010. *Basics Landscape Architecture 02 - Ecological Design.* 1 ed. Lausanne: AVA Publishing SA.
National Climate Change Secretariat , 2013. *NCCS / Climatechallenge.* [Online]
Available at:
https://www.nccs.gov.sg/climatechallenge/issue07/what-are-doing-about-climate-change.html
[Accessed 24 6 2015].

National Climate Change Secretariat Singapore, 2014. *Partnership for Market Readiness - Documents.* [Online]
Available at:
http://www.thepmr.org/system/files/documents/Singapore%20_Briefing%20on%20Climate%20Change%20%20_PMR_3%20March%202014%20_Submission.pdf
[Accessed 31 5 2015].

National Climate Change Secretariat, 2015b. *National Climate Change Secretariat.* [Online]
Available at:
https://www.nccs.gov.sg/sites/nccs/files/Climate%20Change%20and%20Singapore_1.pdf
[Accessed 5 6 2015].

National Climate Change Secretariat, 2015b. *National Climate Change Secretariat (NCCS) - Singapore's Approach to Alternative Energy.* [Online]
Available at: https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/singapores-approach-alternative-energy
[Accessed 25 6 2015].

National Climate Change Secretariat, 2015. *National Climate Change Secretariat - Files.* [Online]
Available at:
https://www.nccs.gov.sg/sites/nccs/files/Climate%20Change%20and%20Singapore_1.pdf
[Accessed 13 4 2015].

National Climate Change Secretariat, 2015. *NCCS - Climate Change and Singapore.* [Online]
Available at: https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-climate-change-singapore
[Accessed 2 6 2015].

National Population and Talent Division, 2013. *A Susutainable Population for a Dynamic Singapore - Population Whitepaper,* Singapore: National Population and Talent Division.

National Population and Talent Division, 2014. *National Population and Talent Division.* [Online]
Available at:
http://www.nptd.gov.sg/portals/0/news/Occasional%20Paper%20-%20Citizen%20Population%20Scenarios.pdf
[Accessed 7 6 2015].

National University of Singapore - Faculty of Engineering, 2015. *National University of Singapore - Faculty of Engineering - Engineering Science Programme.* [Online]
Available at:
http://www.esp.nus.edu.sg/people/Prof%20Wang%20Chien%20Ming%20Web/Very%20Large%20Floating%20Structures%20%28VLFS%29.html
[Accessed 31 5 2015].

Niemelä, A., 2013. *Floating building superstructure and strenght* [Interview] 2013.

Niemelä, A., 2014. *Structural strenght and integrity in principle for the concept* [Interview] (5 2014).

NNFCC and The Anderson Centre, 2015. *NNFCC the Bioeconomy Consultants.* [Online]
Available at: http://www.nnfcc.co.uk/publications/nnfcc-renewable-fuels-and-energy-factsheet-anaerobic-digestion
[Accessed 2 8 2015].

NOAA, 2015. *National Oceanic and Atmospheric administration.* [Online]
Available at: http://www.noaa.gov/ocean.html
[Accessed 9 4 2015].

Park, K. et al., 2013. *Optimal Design of Permeable Fiber Network Structures for Fog Harvestin.* [Online]
Available at: http://pubs.acs.org/doi/full/10.1021/la402409f
[Accessed 23 8 2015].

Pax Water Technologies, 2014. *paxwater/tank-mixer.* [Online]
Available at: http://www.paxwater.com/news-events/bid/73201/Water-Quality-A-Case-of-Mix-and-Match
[Accessed 1 4 2014].

Prafulla.net, 2015. *Prafulla.* [Online]
Available at: http://prafulla.net/graphics/travel-and-tourism/uros-uro-people-the-floating-man-made-islands-on-lake-titicaca-in-peru/
[Accessed 25 3 2015].

Promoter, P. p., 2014. */graphics/travel-and-tourism/uros-uro-people-the-floating-man-made-islands-on-lake-titicaca-in-peru/.* [Online]
Available at: http://prafulla.net/graphics/travel-and-tourism/uros-uro-people-the-floating-man-made-islands-on-lake-titicaca-in-peru/
[Accessed 26 3 2014].

Routi, E., 2015. *Napa program specialist* [Interview] (6 2015).

Schopfer Assoaciates LLC, 2015. *Planning Harvest.* [Online]
Available at: http://www.schopferassociates.com/planning/harvest/
[Accessed 26 3 2015].

SEDAC / NASA , 2015. *Socioeconomic Data and Applications Center (SEDAC) / Papers.* [Online]
Available at:
http://sedac.ciesin.columbia.edu/es/papers/Coastal_Zone_Pop_Method.pdf
[Accessed 24 6 2015].

Siew YY, Z. S. S. W. N. S. T. C. K. H., 2014. *PubiMeD - Ethnobotanical survey of usage of fresh medicinal plants in Singapore.* [Online]
Available at: http://www.ncbi.nlm.nih.gov/pubmed/25058874
[Accessed 18 7 2015].

Singapore Energy Statistics , 2015. *Energy Market Authority/ Publications.* [Online]
Available at:
https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/EMA_SES%202014.pdf
[Accessed 9 6 2015].

Singapore Government, 2012. *Sustainable Development Blueprint.* [Online]
Available at:
https://app.mnd.gov.sg/PDF/sustainbleblueprint_forweb.pdf
[Accessed 14 11 2012].

SOM, 2012. *fastcodesign.* [Online]
Available at: http://www.fastcodesign.com/1669116/som-s-giant-vertical-flower-pot-is-an-air-purifier-on-steroids
[Accessed 06 06 2015].

Teoalida, 2015. *Housign in Singapore - HDB flat types and their sizes.* [Online]
Available at: http://www.teoalida.com/singapore/hdbflattypes/
[Accessed 26 8 2015].

Thaiways Magazine, 2015. *Thaiways Magazine.* [Online]
Available at:
www.thaiwaysmagazine.com/thai_article/2505_floating_markets/floating_markets.html
[Accessed 10 4 2015].

Than, K., 2015. *Caltech - News.* [Online]
Available at: http://www.caltech.edu/news/one-step-closer-artificial-photosynthesis-and-solar-fuels-45875
[Accessed 31 08 2015].

The Guardian, 2012. *theguardian/environment.* [Online]
Available at:
http://www.theguardian.com/environment/2012/nov/14/ha-long-bay-fishing-pollution
[Accessed 27 3 2014].

Theaquaponicsource, 2015. *Theaquaponicsource.* [Online]
Available at: http://theaquaponicsource.com/what-is-aquaponics/
[Accessed 2 8 2015].

Urban Develpment Authority , 2015. *Urban Develpment Authority - Conservation.* [Online]
Available at: https://www.ura.gov.sg/uol/conservation/vision-and-principles/The-Shophouse.aspx
[Accessed 2 8 2015].

Urbanization Project, 2014. *Urbanization Project - Charter Cities.* [Online]
Available at: http://urbanizationproject.org/blog/charter-cities
[Accessed 18 8 2015].

Wang, C. ,. W. B., 2015. Great Ideas Float to the Top. In: *Large Floating Structures - Technological Advantages.* Singapore: Springler Science+Business Media Singapore, p. 13.

Wang, C., 2014. *Professor* [Interview] (25 3 2014).

Ward, L., 2013. *National Geographic / Explorers Journal.* [Online]
Available at: http://voices.nationalgeographic.com/2013/09/12/dna-research-reveals-uros-people-of-peru-and-bolivia-to-have-distinctive-genetic-ancestries/
[Accessed 21 6 2015].

Washington State Department of Natural Resources, 2015. *Washington State Department of Natural Resources - Preventing impact to important aquatic habitat.* [Online]
Available at:
http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_preventing_impacts_to.aspx
[Accessed 17 4 2015].

WBDG - Whole Building Design Guide, 2010. *HVAC System Design for Humid Climates.* [Online]
Available at:
https://www.wbdg.org/resources/hvac_humidclimates.php
[Accessed 23 08 2015].

WildSingapore, 2015. *wildfact sheets.* [Online]
Available at:

http://www.wildsingapore.com/wildfacts/concepts/loss.htm
[Accessed 27 2 2014].

Wilson, A., 2013. *Architecten Landrell.* [Online]
Available at: http://www.architen.com/articles/etfe-foil-a-guide-to-design/
[Accessed 2 8 2015].

World Monument Fund, 2014. *wmf.org/journal/overview-ha-long-bay´s-fishing-villages.* [Online]
Available at: http://www.wmf.org/journal/overview-ha-long-bay%E2%80%99s-fishing-villages
[Accessed 27 3 2014].

Wright, T., 2013. *Architetural massing of the flaoting building and etfe roof* [Interview] (8 2013).

Wright, T., 2013. *Discussing the Flaoting building concept and ETFE roof* [Interview] (7 2013).

Yiting, A., 2012. *National University of Singapore/News&Events.* [Online]
Available at:
http://www.esp.nus.edu.sg/news_and_events/News/2012%20news/My%20home%20in%20the%20sea.pdf
[Accessed 25 4 2014].

Yurek, S., 2013. *Green Roof Technology - Green Roofs in Singapore.* [Online]
Available at: http://www.greenrooftechnology.com/green-roof-blog/green-roofs-in-singapore
[Accessed 26 8 2015].

Figures used in the thesis:

Attachment 1: Stability and Bouyancy calculation provided by Mr. Erik Routi

MEYER TURKU
SHIPYARD 1737

Kelluva talo

Tilamalli

Geometria on määritetty NAPA ohjelmalla paino ja vakavuuslaskelmia varten.
Malli on 3D tilamalli missä pinnat rajoittavat eri tilakokonaisuuksia.

Paino

Painolaskenta on jaettu seuraaviin osiin.
- teräspaino
- sisustuspaino
- LVI paino
- varustelu paino
- sähkö ym.

Vakavuus

Kelluvan talon vakavuus on erittäin hyvä, GM (alkuvaihtokeskuskorkeus) = 24 - 100 m mikä on erittäin suuri, suurella matkustaja laivalla GM on noin 4 – 5 m.

Syväystä on mahdollista säätää tarvittaessa painolastilla.

MEYER LD DATE 15-03-18
Turku E
FIG/SAMI Page 1

LOADING CONDITION L1

LOADS

Location	Description	Filling %	Weight (t)	L.C.G. L/2(m)	T.C.G. (m)	V.C.G. (m)
Deadweight			0.0	0.00	0.00	0.00
Lightweight			11664.7	0.00	0.00	11.93
Displacement	(1.025 t/m3)		11664.7	0.00	0.00	11.93

FLOATING POSITION

Mean draught	(below keel)	2.16 m	KM above the moulded base	112.46 m
Draught at AP	(below keel)	2.16 m	KG above the moulded base	11.93 m
Draught at FP	(below keel)	2.16 m	GM0 (solid)	100.53 m
Trim		0.00 m	Free surface correction	0.00 m
			GM (fluid)	100.53 m

PAINOYHTEENVETO LAIVA -99999

Pituus	160.00 m	Nopeus		0.00 KN
Leveys	60.00 m	Pkteho		0 kW
Syväys maks.	3.50 m	Akteho	kW	
Syväys sop.	m	Prop. teho	kW	
Laitakorkeus	m	Matkustajat		0
		Miehistö		
RHO	1.025 t/m3	Sisustusala		35812 m2
Uppouma sop.	t	Brutto		38899
Deadweight	t	Varustelunro		5629
Luokka				
		Luovutus		
Viimeinen päivitys		Vesillelasku		
Sopimuspäivä		Kölinlasku		

ID	DES	REFQNT	WKCH kg	W t	XCG m	YCG m	ZCG m
L0	LAIVAN OMAPAINO			11664.7	0.00	0.00	11.93
L1		SISM2	0.0	0.0	0.00	0.00	0.00
L3	Runko, kansirak.ja maali	VTON	52.4	6750.5	0.00	0.00	10.74
L4	Sisustus	SISM2	130.0	4655.5	0.00	0.00	12.92
L5		SISM2	0.0	0.0	0.00	0.00	0.00
L6		PBT	0.0	0.0	0.00	0.00	0.00
L7		PTOT	0.0	0.0	0.00	0.00	0.00
L8	Laivan ohjailu, hallinta ja yl.	VTON	2.0	258.7	0.00	0.00	25.08
L9		VTON	0.0	0.0	0.00	0.00	0.00

Alumiinia (ei tutkamastoa) 0.0 t
Kiinteä painolasti 0.0 t

RESERVI

Sallittu omapaino t
Omapainoreservi t %

Kevytpainon kuutiopaino 90.62 kg/m3

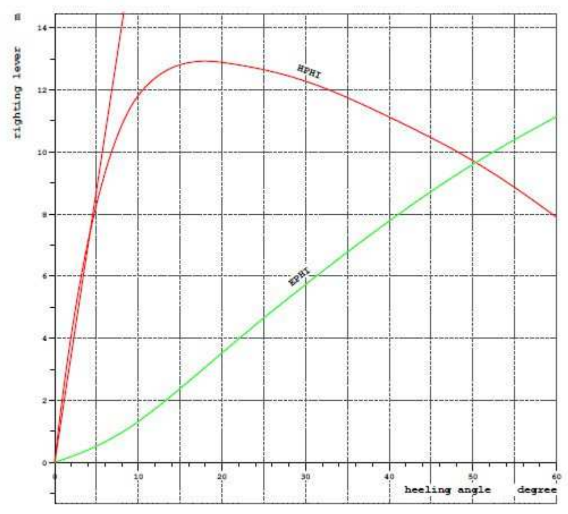
DES	Tilavuus m3	ZCG m	Teräksen kuutiopaino kg/m3	ZCG m	Suhde %
Hull	21160	2.00			
Deckhouse	107563	13.31	44.95	14.21	106.7
Total	128723	11.45			

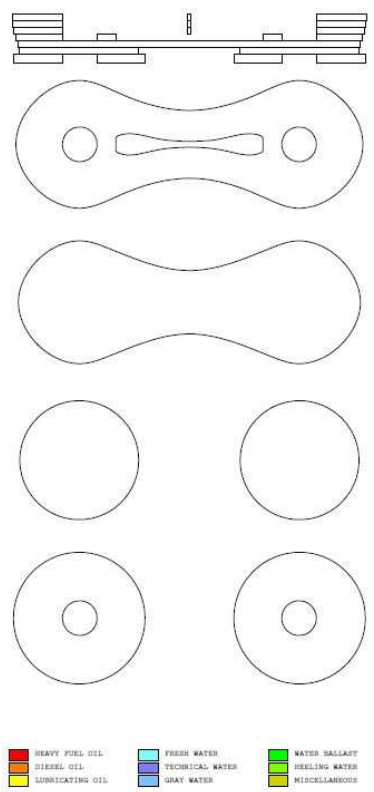
GMreq m

Stability criteria according to SOLAS 90

STABILITY CURVE

Heel	(deg)	10.0	20.0	30.0	40.0	50.0	60.0
MS	(m)	-5.634	-21.498	-37.989	-53.499	-67.297	-79.172
GM0sin(phi)(m)		17.458	34.385	50.267	64.622	77.014	87.065
dGZ	(m)	0.000	0.000	0.000	0.000	0.000	0.000
GZ	(m)	11.823	12.887	12.278	11.123	9.716	7.894
e(phi)	(mrad)	1.315	3.525	5.728	7.776	9.599	11.141





				x		frame
Shear force (min)	-1846.1	t	position:	-24.4	m	-24
Shear force (max)	1844.1	t		24.4	m	24
Sagging moment	-71084.4	tm		0.0	m	0
Hogging moment	0.3	tm		-80.2	m	-80