Sustainable Characteristics of Floating Architecture

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Abstract

According to the climate change and the improvement of income level, floating architecture on water has been emerging as a strong alternative. This study was intended to suggest some reference materials for new floating building projects on water. The concept of sustainability and floating architecture was investigated, and 2 realized projects and 4 planned projects were reviewed in terms of sustainability. Sustainable characteristics of realized and planned floating architecture from the samples can be summarized as recycled and relocatable usage, adoption of renewable energy techniques, installation of self-supporting plant, application of modular system and others like new material & open layout. Sustainable features need to be developed more and more in detail and applied to many types of floating buildings. The introduction of floating architecture will be expanded and contribute enormously to enhance the sustainability of the Earth in the future

Keywords: Floating Architecture, Sustainability, Characteristics, Marine Architecture,

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Introduction

Climate change like global warming atmosphere will bring a rise in sea and river level. Usable land in urban area will be scarce due to continuous expanding development. Reclamation method for land supply is regarded as environmentally negative and very hard to proceed. People like to live and enjoy leisure activities near or on water according to the improvement of income level. Therefore floating architecture on water has been emerging as a feasible and strong alternative.

The aim of this study is to review the concept of sustainability & floating architecture, to investigate the sustainable characteristics through realized and planned floating architectures, and to suggest some reference materials for new building projects around waterside. Research method includes the navigation of related websites and the review of reference documents and literatures. Various types of floating architectures such as apartment, hotel, mosque and others are to be taken into consideration.

Sustainability and floating architecture

Sustainability is the capacity to endure. For humans, sustainability is the potential for long-term maintenance of well being, which has environmental, economic, and social dimensions. According to the Brundtland Commission of the United Nations on March 20, 1987, sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

A universally accepted definition of sustainability is elusive because it is expected to achieve many things. On the one hand it needs to be factual and scientific, a clear statement of a specific “destination”. The simple definition "sustainability is improving the quality of human life while living within the carrying capacity of supporting eco-systems", though vague, conveys the idea of sustainability having quantifiable limits[1].

Sustainable architecture is a general term that describes environmentally conscious design techniques in the field of architecture. Sustainable architecture is framed by the larger discussion of sustainability and the pressing economic and political issues of our world. In the broad context, sustainable architecture seeks to minimize the negative

environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space. Most simply, the idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations. This term can be used to describe an energy and ecologically conscious approach to the design of the built environment[2].
Meanwhile, According to the British Columbia Float Home Standards[3], float home means a structure incorporating a floatation system, intended for use or being used or occupied for residential purposes, containing one dwelling unit only, not primarily intended for, or usable in navigation and does not include a water craft designed or intended for navigation. Therefore floating architecture can be defined a building for living/working space on floatation system without navigation tool.
Therefore sustainability of floating architecture can be interpreted as an energy and ecologically conscious approach to a building for living/working space on floatation system without navigation tool.

Realized floating architecture

Four seasons hotel, Australia

- Location: Great Barrier Reef area in Queensland, Australia
- Year of completion: 1988
- Size & scale: 5 story, 140 double rooms and 34 luxury suites, 322,500sq.ft.

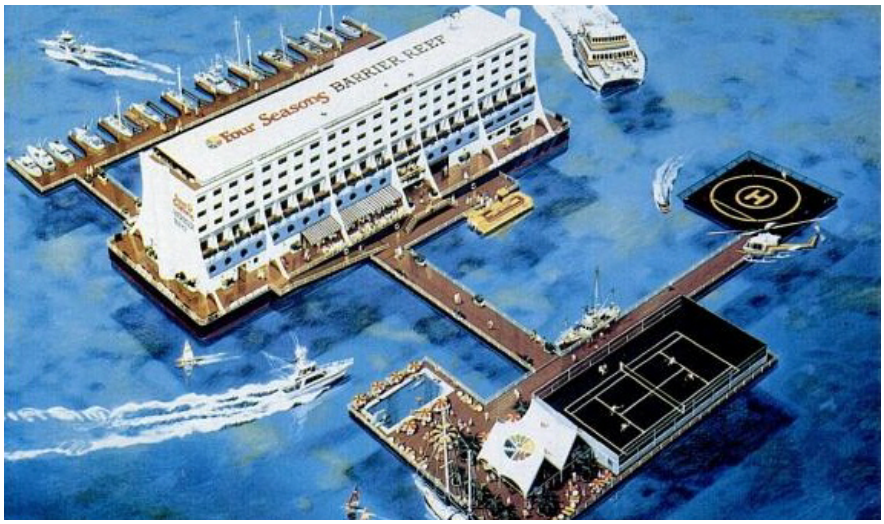

Figure 1. Master plan of Four seasons hotel

The world's first offshore floating hotel, Four seasons hotel had been anchored adjacent to Australia's Great Barrier Reef(GBR) in March, 1988. The idea of a floating hotel came from the geography of the GBR which lies some considerable distance and travelling time from the mainland port. Tour companies estimated that visitation could be significantly increased with shorter or faster trip, or through the provision of onsite fixed offshore accommodation.
This hotel was designed and developed by Swedish naval architect Sten Sjostrand and was constructed by Consafe Engineering in Singapore. After the construction, engineers guided a half-submerged, heavy-lift carrier vessel under the floating hotel structure and then pumped the carrier dry, raising the building out of the water. The ship brought the hotel to the lagoon and reversed the loading process. Work crews connected the hotel building with pontoons that carry tennis court, marina and the rest of the complex.
The hotel was a self-supporting floating building and so had a desalination plant for fresh water, on-board sewage and waste treatment, an underwater observatory and a semi-submersible vehicle for coral-reef cruises, as well as the usual luxury hotel amenities. Anchoring the whole resort is a mooring system originally developed for oil supertankers. The hotel's power plant, according the developers, will operate at almost noiseless levels so as not to disrupt the reef's delicate ecosystem[4].
Several accidents occurred during the early stage of the project. The catamaran designed to carry 400 passengers to the hotel was destroyed by the fire before first service. The hotel was hit by a cyclone and some of the peripheral structures including the floating tennis court were damaged before official opening. And the hotel had been operated for

less than a year until the turn of the century when financial troubles. The hotel had to be put on the international market for sale in September 1988.

After being taken over by Japanese enterprises in April 1989, the floating hotel moved to Ho Chi Mihn City on the Mekong River, Vietnam in August 1989 to mitigate the shortage of quality hotel.

The hotel, Newly named as Saigon Floating Hotel(SFH), was officially opened on December 1989 and was the first international hotel business cooperation between Saigon Tourist and some Cooperation from Japan. The hotel was the first obvious sign that "doi moi" had finally arrived in Vietnam, it was the only place in Ho Chi Minh City where foreigners could meet and socialize[5].

Figure 2. Saigon floating hotel

Its operation ended in August 1996 over 6 glorious years' business for unspecified reasons from the government. SFH was sold for decomposition in Singapore and left Bach Dang quay on April 1st 1997[6].

This hotel in Singapore was bought by Hyundai Group of Korea in November 1998, moved to Kosung port, North Korea and opened as a tourist hotel, named of Hotel Haekumgang, for Mt. Kumgang trip in October 2000. Since then, a lot of tourists from South Korea stayed in this hotel, and also the hotel was used as an official meeting place of separated family members from South and North part of Korea. The interior of the hotel was remodeled in early 2006.

Figure 3. Hotel Haekumgang

As relationship between South and North Korea got worse, the hotel was bound as frozen property by North Korea and has stopped in operation since April 2010. Several ideas including moving library for 5 islands of West Sea after remodeling have been proposed.

Sustainable features of the hotel can be summarized as the long term usage by relocation of various regions, a self-supporting facility with desalination plant, sewage & waste treatment system, and a power plant with at almost noiseless level.

Floating hotel "Salt & Sill", Sweden

- Location: Island of Klädesholmen, near Gothenburg, Sweden
- Year of completion: 2008
- Size & scale: 2 story, 23 rooms(46 beds)

In October 2008, Sweden's first floating hotel, designed by Mats & Arne Arkitektkontor AB, Sweden, opened alongside the famous restaurant "Salt & Sill". The hotel consists of six

two-story buildings on floating pontoon. The hotel has 23 rooms with 46 beds, and all the rooms have their own entrance and access to an outdoor seating area. People can feel a cozy & personal atmosphere and a style characterized by modern Scandinavian simplicity.

Figure 4. Floating hotel "Salt & Sill"

The owner has always been interested in the environment. During the construction of the floating hotel, protecting the environment was obviously top priority. The facility should have a positive impact on outdoor activities, and should have little effect on the living environment, safety or communications. It should not cause any significant pollution of noise, air and water.

The design of the hotel was also done with the environment sustainability in mind as heating energy for the hotel is actually generated through geothermal wheels from underneath the hotel, at the bottom of the sea. The owner used local raw materials such as the wood from Swedish pine forests, environmentally friendly paints and have even used the left over quarrying stone to build a new lobster reef under the pontoon of the hotel. The sea life was increased by creating a perfect habitat for shells and mussels. All toiletries are organic and refillable[7].

Sustainable features of the hotel can be summarized as protection of the environment, the use of local raw materials, the geothermal use of sea water, and the habitat creation for marine life by using the left over stone.

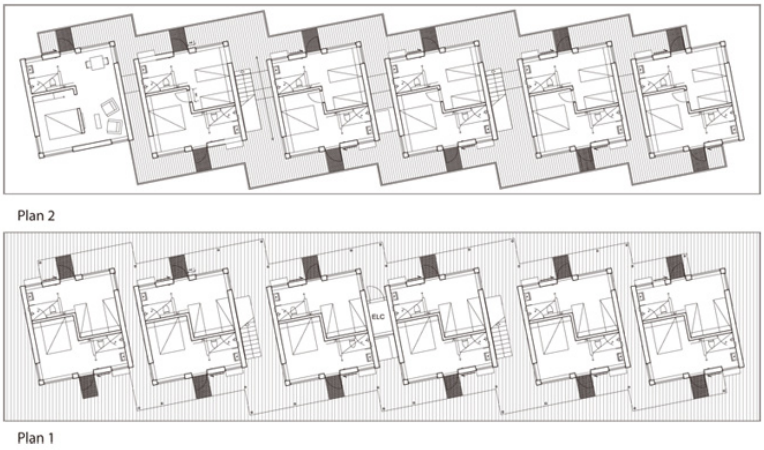

Figure 5. Floor plan of hotel "Salt & Sill"

Planned floating architecture

Floating mosque, Dubai

- Location: Palm Jebel Ali, Dubai, UAE
- Year of design: 2007
- Size & scale: 1 story

The flat-roofed floating mosques, designed by Koen Olthuis of Waterstudio, the Netherlands, have minarets, traditional Islamic arches, and two rows of 12m high transparent plastic columns that do not only support the roof but also give daylight through the prayer hall. They would be kept afloat by giant pontoons of a mixture of concrete and foam and self-supporting as possible in terms of energy.

In the pray hall, the glass roof is supported by five columns representing the pillars of Islam. Roof and columns are made transparent by using composite acrylic material. This material is usually for large sea aquariums. Sea water is led from outside via the filter through the floor and walls to the roof, and it leaves the building again over the glass roof

via the columns. A transport regulator ensures that the columns are always sufficiently full, to give them a visually attractive appearance[8].

And the floating mosques are also environmentally friendly, pumping water from the Arabian Gulf through a vein-like system cools the building down by 15 degree Celsius(from 45℃ to 30℃), reducing air conditioning cost by as much as 40 percentage[9]. Air conditioning from solar related energy brings the temperature down even further to 21℃. Solar energy is also required for the pumping installation.

Figure 6. Perspective of floating mosque

The roof and walls absorb little heat because of porous external cladding, consisting of a sponge-like ceramic material with extremely low density. The thick external walls have a high accumulative capacity due to their high density and large size. Therefore, water cooling system can be more effective.

The core philosophy of engineering company, the Dutch Docklands, is the idea that this revolutionary architecture could be a potential solution for current environmental issues such as rising sea levels and energy sustainability.

Sustainability on water is even more important than on land because emission has to be zero and power plants must be self-supporting and sustainable using solar, wind or wave energy.

Figure 7. Interior of floating mosque

Sustainable features of the mosques can be summarized as daylight influx through transparent roof and columns, the water cooling system by circulating the sea water through the floor, wall & roof, high accumulative thick wall with extremely low density cladding, and the use of solar energy.

The Citadel

- Location: Westland region of South Netherlands
- Year of design: 2009
- Size & scale: 60 apartments

The Citadel, "water-breaking" new project, designed by Koen Olthuis of Waterstudio, the Netherlands, will use 25% less energy than a conventional building on land thanks to the use of water cooling techniques.

The project will be built on water in a polder, a recessed area below sea level where flood water gathers from heavy rains. The Citadel will purposely allow the polder to flood with

water and all the buildings will be perfectly suited to float on top of the rising and falling water.

Figure 8. Perspective of the Citadel

The Citadel will be the first floating apartment complex, although there are plenty of floating homes out there. Built on top of a floating foundation of heavy concrete pontoon, the Citadel will provide 60 luxury apartments, a car park, a floating road to access the complex as well as boat docks. With so many units built into such a small area, the housing complex will achieve a density of 30 units per acre of water, leaving more open water surrounding the structure. Each unit will have own garden terrace as well as a view of the lake.

A high focus will be placed on energy efficiency inside the Citadel. Greenhouses are placed around the complex, and the water beneath the pontoon will be used as a cooling source after it is pumped through submerged pipes. As the unit is surrounded by water, corrosion and maintenance are important issues to consider. As a result, aluminum will be used for the building facade, due to its long lifespan and ease of maintenance. The individual apartments are built from prefabricated modules. The Citadel will be situated on a shallow body of water, and in the future numerous buildings, complexes and residences will float on the water alongside it[10].

Sustainable features of the apartment complex can be summarized as the use of water cooling techniques, the choice of aluminum facade to avoid the corrosion and maintenance problem, and the adoption of prefabricated modules.

Figure 9. Perspective of the Ark

The Ark[11]

- Location: -
- Year of design: 2010
- Size & scale: Living space 14,000 ㎡

A massive hotel concept, the Ark, designed by Russian architect Remistudio can endure extreme floods. The arch-shaped building has a structure that enables it to float safely and stay autonomously on the surface of the water. The Ark was also designed to be a bioclimatic building with independent life-supporting systems, including elements ensuring a closed-functioning cycle.

The building has an optimal relationship between its volume and its outer surface, significantly saving materials and providing energy efficiency. Its shape is convenient for installing solar photovoltaic cells at an optimal angle toward the sun and wind turbine on the roof.

The cupola, in the upper part, collects warm air which is gathered in seasonal heat accumulator to provide an uninterrupted energy supply for the whole building complex independently from outer climate conditions in winter. The heat energy from the surrounding environment - the outer air, water or ground - is also used.
A plenty of daylight penetrates through the transparent roof area to illuminate the inner rooms as well. The tiered balconies can serve as social & recreational areas and the Ark has an open layout that can easily be changed to different functions over time.

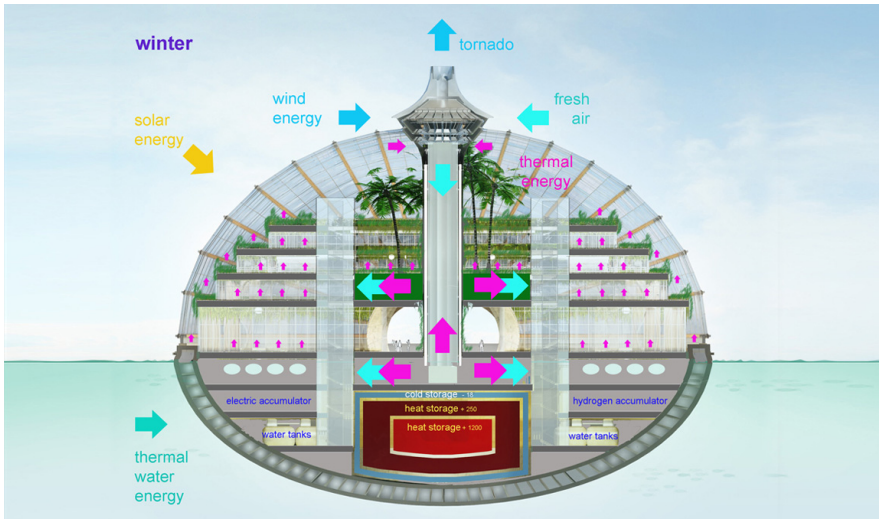

Figure 10. Section concept of the Ark

The structural solidity is provided by compression of timber arches and tension of steel cables. The framework is covered by a special foil made of ethyltetrafluoroethylene(ETFE). It is a strong, highly transparent foil that is self-cleaning, recyclable, and more durable, cost-efficient and lighter than glass. The foil itself is affixed to the framework by special metal profiles, which serve as solar energy collectors for heating water and as gutters for collecting rainwater from the roof.
The Ark concept, designed with the Union of International Architects' program "Architecture for Disaster Relief," could be realized in various climates and especially in seismically dangerous regions because its basement is a shell structure without any ledges or angles. A load-bearing system of arches and cables allows weight redistribution along the entire corpus in case of an earthquake. And also Its prefabricated frame can allow for fast construction.

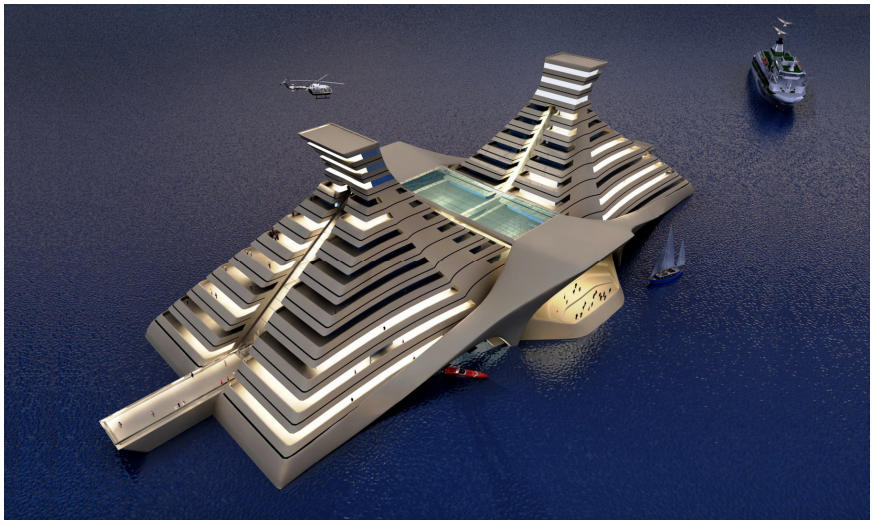

Figure 11. Perspective of Maya Hotel

Sustainable features of the Ark can be summarized as a bioclimatic building with independent life-support system, use of solar photovoltaic cells and wind turbine, enough daylight penetration through transparent roof, open layout to adapt different functions over time, new material "ETFE" for covering, and prefabricated frame for fast construction.

Maya Hotel

- Location: Cancun, Mexico
- Year of design: 2007
- Size & scale: 350 rooms

The Maya Hotel, a vast floating pyramidal resort, is designed by Oceanic Creations, Sweden. The secret factor for the project is a unique plastic composite material which

offers built-in insulation that makes the constructions suitable for all climate, from the freezing cold to extreme heat. This remarkable material is reportedly up to 6 times lighter and 10 times stronger than steel (depending on the reinforcement material used). It is also claimed that it reduce maintenance costs by 30 to 40 percent. The material was formerly used only by the Swedish Military but after the cold war it was allowed for this kind of private company to use.

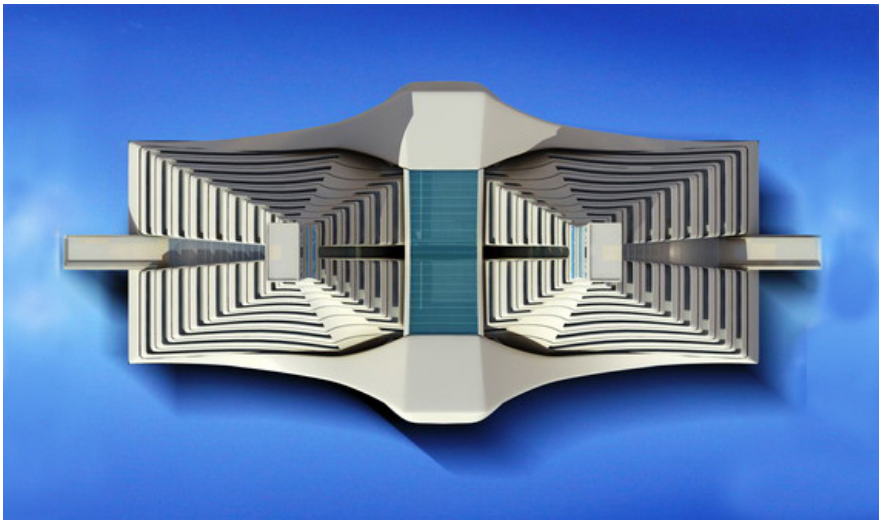

Figure 12. Site plan concept of Maya Hotel

According to the head of international marketing for Oceanic Creations, this material will prove very cost-effective for places like Dubai and Abu Dhabi who work a lot with landscaping and usually use sand and mud to build, and for many cities that don't have a real solution to what do with their water. More than $6.5 million has already been invested in the venture, the Maya Hotel is expected to cost $209 million to complete[12].

The hotel is supposed to be 220m long, 70m wide, and 70m+ high. Due to its large size, it would have no problem of withstanding storms. The floating hotel will have an underwater marina and be completely self-supporting in terms of electricity and water by having power plant generating 30MW and a desalination plant with a capacity of 150,000 ton of water per day. It will accommodate 350 bedrooms as well as restaurants, conference halls, a nightclub and other amenities.

The project is destined to be finished by 2010-2011 and is shaped as a double Maya pyramid floating building on pontoons. The hotel in itself will be 4 meters above sea level. Temporarily named The Maya, this floating hotel is being built in Bulgaria and will be towed to Cancun, Mexico.

Sustainable features of the hotel can be summarized as the use of unique plastic composite material with characteristics of lighter, stronger, and economical to maintain, and self-supporting in terms of electricity & water.

Sustainable Features from Sample Floating Architectures

Sustainable features of the sample floating architectures can be summarized as followings(see Table 1);

- Recycled usage and relocatable: Four Seasons Hotel showed good example of long term usage by relocation of 3 areas. Floating building can be moved to different locations and used by different people for a long time.
- Renewable energy: Most floating building adopts various renewable energy systems such as geothermal use of sea water, solar energy, and wind power. Renewable energy on water is easier to get than land because there are no obstacles.
- Self-supporting plant: Large floating buildings have self-contained system in terms of electricity, water and sewage treatment because connecting and maintaining the service lines far from the land is not easy.
- Modular system: Some planned floating buildings suggest prefabricated module. Construction waste can be discharged to the minimum and the building might be very easy and economical to maintain.

- Others: New materials such as ETFE covering instead of glass and plastic composite material instead of steel & concrete, and open layout to adapt different functions over time are introduced.

Table 1. Sustainable features of the sample buildings

Name of Building	Sustainable Features
Four Seasons Hotel	- long term usage by relocation of various areas - self-supporting facility with desalination plant, sewage & waste treatment system - power plant with at almost noiseless levels.
Floating Hotel "Salt & Sill"	- protection of the environment - use of local raw materials - geothermal use of sea water - habitat creation of marine life by left over stone.
Floating Mosque	- daylight influx through transparent roof and columns - water cooling system by circulating the sea water through the floor, wall & roof - energy efficient wall material - use of solar energy.
The Citadel	- water cooling techniques - aluminum facade to avoid the corrosion and maintenance - pre-fabricated modules.
The Ark	- bioclimatic building with independent life-support system - solar cell & wind turbine - enough daylight penetration through transparent roof - open layout to adapt different functions over time - new material "ETFE" for covering - pre-fabricated frame for fast construction.
Maya Hotel	- plastic composite material with characteristics of lighter, stronger, and economical to maintain - self-supporting in terms of electricity & water.

Conclusion

According to climate change and improvement of income level, floating architecture on water has been emerging as a strong alternative. The aim of this study is to suggest some reference materials for new building projects around waterside. The concept of sustainability and floating architecture was investigated, and 2 realized projects and 4 planned projects were reviewed in terms of sustainability.
Sustainability of floating architecture can be defined as an energy and ecologically conscious approach to a building for living/working space on floatation system without navigation tool.
Sustainable characteristics of floating architecture from the samples can be summarized as followings: recycled and relocatable usage, adoption of renewable energy techniques, installation of self-supporting plant, application of modular system and others like new material & open layout.
Sustainable characteristics need to be developed more and more in detail and applied to many types of floating buildings. With the development of pontoon, mooring and related

floating technologies, the introduction of floating architecture will be expanded and contribute enormously to enhance the sustainability of the earth in the future.

Notes

1) Sustainability, Wikipedia(http://en.wikipedia.org/wiki/Sustainability)
2) Sustainable architecture, Wikipedia(http://en.wikipedia.org/wiki/Sustainable_architecture)
3) British Columbia Float Home Standards, Housing and Construction Standards: (http://housing.gov.bc.ca/building/floatho1.htm)
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