# Renewable Energy Application in Floating Architecture

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**ABSTRACT**

*Climate change like global warming brings sea and river level rise. Usable land in urban area becomes less and the price of real estate increases due to continuous development. Reclamation method for land supply has been regarded as environmentally negative. And people want to enjoy the life on water rather than on land or mountain according the improved income level. Therefore floating architecture on water has been emerging as a creative and alternative to the building on the land of waterside region. The aim of this study is to investigate the status of renewable energy applications in sample floating architectures and to suggest some reference ideas for new building projects around the waterside. Most popular renewable energy sources for the floating architecture are solar heat energy, solar photovoltaic energy and hydrothermal energy. Especially hydrothermal use of the water underneath the floating building may have a huge advantage in tropical region and cold region because there is a great temperature difference between the water and the outdoor air in extreme climate regions. Therefore hydrothermal energy can be used for air-conditioning in tropical region and heating in the cold region. Wind energy also can enhance the possibility of self-supporting floating architecture if building intergrated samall wind turbine with little noise is developed. Hybrid system of solar photovoltaic energy with wind power will be highly popular when the design of the hybrid system is intergrated with that of floating architecture. Of course, detailed disadvantages of floating architectures should be investigated and countermeasures to overcome are to be suggested for further study.*

## INTRODUCTION

Climate change like global warming atmosphere brings a rise in sea and river level. Usable land in urban area will be less and the price of real estate is going to rise due to continuous expanding development. Reclamation method for new land supply is regarded as environmentally negative and very difficult to proceed without the public consensus. People like to live and enjoy leisure activities near or on water according to the improved income level. New floating buildings such as house, restaurant, school, exhibition and meeting, yacht club house, hotel, ferry terminal, prison, and café are being built around the world. Therefore floating architecture on water has been emerging as a feasible and strong alternative.

Floating building is easy to get various renewable energy sources because there are not so many physical obstacles in the sea or river. More solar and wind energies can be obtained on the water than on the urban land. Especially hydrothermal use of sea or river water beneath the floating building might be a great advantage because the temperature of water is usually lower than that of outdoor air in summer and the reverse in winter. Therefore hydrothermal energy can be used as cooling in tropical region and heating in the cold region.

Floating Building can be generally regarded as positive in ecosystem because the building has a closed premises services system, sometimes stimulates diversity in water milieus and provides a protected habitats for small fish and other aquatic animals. The underside of floating building foundation can even be rough to encourage the attachment and growth of water plants, algae and shellfish. The water plants have a purifying effect on the water (Koen Olthuis & David Keuning, 2010). A large-scale floating architecture or a number of floating buildings can be criticised as throwing a shadow to the bottom of the water, so some countermeasure for the passage to give the sunlight to the bottom of the water should be considered.

The aim of this study is to review the concept of floating architecture and renewable energy in architecture, to investigate the renewable energy applications in planned and realized floating architectures, and to suggest some reference ideas for new building projects around waterside. Research method includes the navigation of related websites, site-visits, and the review of reference documents and literatures. Sample floating architectures with strong points of renewable energy applications are chosen to analyze.

## FLOATING ARCHITECTURE

As the advantageous points of floating homes have been known to public, the new residents with interesting have rebuilt the new and luxurious floating homes replacing the old and poor ones in San Francisco and Seattle, USA.  In Portland, USA, a large number of modern and large loating homes have been built on the Willamette River and near net zero energy floating home with solar PV system, solar water heating, hydronic heating, rainwater collection and reuse, and reclaimed and certified wood has been built in the North Portland’s Tomahawk Island Floating Home Community. In Steigereiland IJburg, Amsterdam, Netherlands, there are 75 floating homes consisting of detached and row houses. So floating architecture becomes popular and familiar with the ordinary person.


**Figure 1** Floating Homes in Seattle, USA(left) and Portland, USA(right)
(Source: photos by the author, 2012)

Floating architecture can be defined as a building for living or working space that floats on the water with floatation system, is moored in a permanent location, does not include a water craft designed or intended for navigation, and has a premises services (electricity, water/sewage, gas) system served through connection by permanant supply/return system between floating building and a service station on land, or has self-supporting service facilities for itself.

## RENEWABLE ENERGY IN ARCHITECTURE

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water or space heating, motor fuels, and rural (off-grid) energy services (Renewable energy, Wikipedia, 2014).

In architecture, wind power, solar energy and geothermal energy in renewable technologies are generally being applied in the design and practice. Especially various applications of solar energy through solar heat panel and solar photovoltaic (PV) cells, and hydrothermal energy like geothermal energy are usually introduced in floating architectures on water.

Wind power, tidal power and wave power can be considerable if there is proper system to be intergrated with floating architecture and to be harmonized with the natural environment. Wind power is highly expected to be used in floating architecture because wind power resource is abundant on water space and small wind power turbine for the building is under development.

Hybrid system of solar energy with wind power will be useful and complementary because the sun usually shines when there is no wind in day time and the wind usually rises when there is no sun. So solar - wind hybrid renewable energy system will be popular when the design of the hybrid system can be intergrated with that of floating architecture.

## PLANNED FLOATING ARCHITECTURE

### Floating Mosque, Dubai (2007)

The floating mosque has modern and traditional Islamic designs. The interior is characterized by giant funnel-shaped transparant columns that do not only support the roof, but also allow filtered light to illuminate the inner space (Waterstudio, 2014). The building has 1 storey superstructure and the large pontoon made of concrete and styro-foam, and basically connects the water supply/return lines from the station of inland. But the building is designed self-supporting as possible in terms of energy.

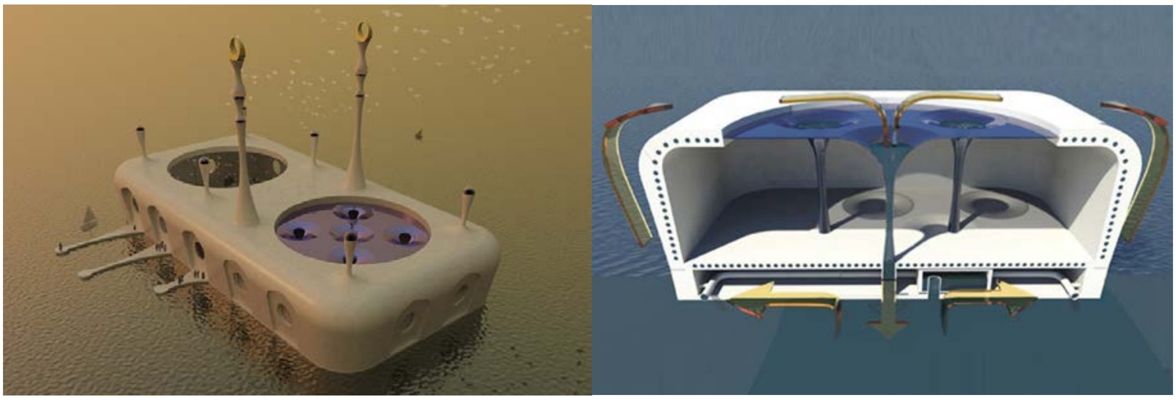

**Figure 2** Model of Floating Mosque (left) and Water Cooling System (right) (Source: http://www.waterstudio.nl/ projects/30, 2014)

The flat-roofed floating mosque is environmentally friendly by using the hydrothermal temperature, pumping sea water from the Arabian Gulf through a vein-like system of wall and floor cools the building structure down by 15 degree Celsius(from 45 degree to 30 degree), reducing the cost of cooling by around 40 percentage. Air conditioning by the electricity from solar photovoltaic cells brings the temperature down even further to 21 degree Celsius. Electricity from solar energy is also required for the pumping machine (James Reinl, 2007).

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 (Koen Olthuis & David Keuning, 2010). Therefore, water cooling system can be more effective than any other measure.

### The Ark (2010)

A massive dome-shaped building concept with living space of around 14,000 square meters, the Ark, is proposed to get maintenance of security and precaution against extreme environmental conditions and climate change together with protection of natural environment from human activities. 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 (Alison Furuto, 2011).

The Ark concept, designed with the UIArchitects Work 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 (Anastasia Vdovenko, 2014).

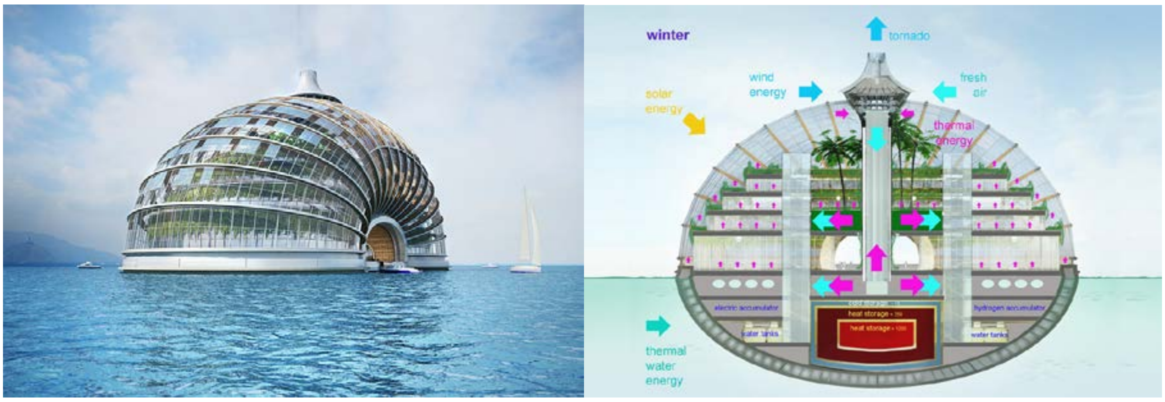


**Figure 3** Perspective (left) and Section Diagram (right) of The Ark
(Source: http://remistudio.ru/en/pages/52.htm. 2014)

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.

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 (ARK, 2014).

## REALIZED FLOATING ARCHITECTURE

### IBA Dock, Germany (2009)

In 2010, the international building exhibition IBA had a slogan “City in a Climate Change” with a goal of a $CO_2$-neutral city development. The IBA Dock as the information and event center of Hamburg is constructed upon a floating pontoon. The building is now being used for Urban and Architecture information center in Hamburg and also the 2013 Hamburg International Gardening Exhibition. The IBA Dock not only houses the exhibition IBA, but is also itself an exhibition of innovative building and integrates numerous renewable energy technologies (IBA DOCK, 2014).

The IBA Dock has 3 storeys and 1,640 square meters floor area. The building is situated on an approximately 43m long and 26m wide concrete substructure pontoon and the superstructures of building are made of steel in prefabricated modular construction (IBA Dock/Architech, 2012). The building is setting new standards in the area of climate protection. In addition to 25cm thick insulated outer walls, the IBA Dock uses the sun and water of the Elbe for generating energy.

The building is based on “zero balance concept”, which focuses on solar energy management and systems that provide buildings with sustainable heat and cooling all year round. 16 rooftop solar heat panels with a total surface area of about 34 square meters are positioned facing south at the relatively steep angle of 50 degrees to maximize the heating of water in the colder months.

Solar energy captured from these collectors feeds into an electric heat pump that draws its environmental heat from water taken directly from the Elbe using a heat exchanger built into the base of the concrete pontoon. This provides both the heating and cooling requirements for the water and air conditioning of the building, with excess energy able to be temporarily saved for later use. The building features heating and cooling ceilings that either heat the rooms in colder months or cool the room in warmer months.

**Figure 4** Exterior (left) and Interior (right) of IBA Dock
(Source: left photo by the author, 2011, right photo from http://www.archdaily.com/288198/iba-dock-architech/, 2014)

The 44 kW heat pumps, along with a ventilating machine that provides air exchange for the entire building, are powered by 103 square meters of south-facing solar photovoltaic cells located on the roof terrace and angled at 30 degrees that deliver 14.8 kWp (kilowatt peak). The electricity needed by the heat pump is covered by the photovoltaic device on the IBA Dock. No further cooling or heating energy is needed (Darren Quick, 2012).

**Floating hotel "Salt & Sill", Sweden (2008)**

The first floating hotel in Sweden opened alongside the famous seafood restaurant “Salt & Sill”. The location is small but peaceful island and very limited space was available around the restaurant. Therfore a floating hotel was the only way to realize the owners’ dream to offer a complete service with food, drink, conference and accommodation at the same time (SALT & SILL, 2014). The hotel is very popular even though it is located in rural and coastal area in Sweden. So there are many visitors with different purposes all the year over.

**Figure 5** Exterior (left) and Roof (right) of Floating Hotel "Salt & Sill"
(Source: photos by the author, 2011)

The floating hotel has 2 storeys and 23 rooms with 46 beds. All the rooms have their own entrance and access to an outdoor seating area. The building is mainly made of wood on concrete pontoon. Premises services (electricity, water supply and sewage) are served through connection lines between the floating hotel and the service station of near land.

During the construction of the building, protection of environment has been the most important agenda. A positive impact on outdoor life, little or no effect on the island environment, no noise and pollution of air should be kept. The building used local raw materials such as the pine wood from Swedish forests, and only environmentally friendly paint. They have even used the left over quarrying stone to build a new lobster reef under the concrete pontoon for the consideration of environment. In the hotel, heating energy is actually generated from the warm sea water underneath the floating building in winter (Costas Voyatzis, 2008).

**Autark Home, Netherlands (2012)**

Autark Home is a self-sufficient and passive floating home with European passive house certificate. A prototype of Autark Home is currently anchored in the river Maas, Maastricht, Netherlands and draws a huge number of eco-concious visitors due to its unconventional construction design.

The floating home has 2 storeys and 109.4 square meters floor area, outer wall with 55cm thick massive EPS, isolated windows and doors, triple glass and no cold bridges. In terms of energy, there is an ioloated water tank with capacity of 4,000 liters and 6 solar heat panels on the roof to keep the water at a temperature of 70 to 80 degree Celsius for 4 to 5 days (Autark Home, 2014).

**Figure 6** Exterior (left) and Interior (right) of Autark Home
(Source: http://www.autarkhome.de/, 2014)

River water is converted to gray water and high-quality drinking water through a filter. And drinking water is made again by purification system through reverse osmosis in combination with the sand and UV filter. Gray water can be used as flushing & washing water and for the floor heating & cooling. Before the waste water returns to the river, the water is cleaned for 90% by a built-in filtration system. Like other passive houses, each room has its own ventilation. The incoming fresh air is heated or cooled by outgoing exhausted air through a heat recovery ventilation system.

The electricity is supplied by 24 solar photovoltaic cells with a total output of 6,360 Wp(watt peak). The electrical energy is stored in 24 batteries, each with a capacity of 1000 Ah, supplying enough electricity for 4 days for a normal family. The system can deliver 5300 kWh a year. On the display of the monitoring system in the living room, solar production can be viewed. In adverse weather conditions, a bio-diesel generator supplies the home with additional power (REM, 2012).

Even though there are no service utilities to be connected around the floating building, this kind of floating building with self-sufficient system can be built and operated without any problem. So floating architecture with self-sufficient system such as water treatment and electiricity power system can be built freely any distance away from the quayside.

## RENEWABLE ENERGY APPLICATIONS IN SAMPLE FLOATING ARCHITECTURES

Renewable energy applications in sample floating architectures are as follows (see Table 1);

**Table 1. Renewable Energy Application in Samples**

| Name of building | Renewable energy source | Remark |
|---|---|---|
| Floating Mosque | hydrothermal energy, solar PV cell | structure cooling system by water |
| The Ark | solar PV cell, solar heat panel , wind power | bioclimatic building, ETFE |
| IBA Dock | hydrothermal energy, solar heat panel, solar PV cell | prefabricated modular construction, heat exchanger |
| Floating hotel "Salt & Sill" | hydrothermal energy | environment protection |
| Autark Home | solar heat panel, solar PV cell | self-sufficient & passive system, bio-diesel generator, heat recovery ventilation system |

Most popular renewable energy sources for the floating architectures are use of sloar energy (heat panel and PV cell) and hydrothermal energy. Especially use of hydrothermal energy may have a huge advantage in tropical region and polar region because there is a great temperature difference in the water and the outdoor air of the extreme climate regions.

Use of hydrothermal energy in renewable energy is applied to the projects such as Floating Mosque, IBA Dock, and floating hotel “Salt & Sill”. And solar PV cells are mostly used in the projects like Floating Mosque, The Ark, IBA Dock, and Autark Home. Solar heat panels are used for The Ark, IBA Dock and Autark Home.

Until now, it is very hard to find out wind power application in floating archietcture. Usually there is more wind resource on water space of sea or river than on urban land because there is daily land and sea breeze circulation and no windbreak on water. If small wind turbine with little noise is developed, it will be applied more often for the floating architecture on water than for the building on urban land.

Usually hybrid system of solar energy with wind power will be useful and complementary because the sun shines when there is no wind in day time and the wind usually rises when there is no sun. So solar - wind hybrid renewable energy system will be more popular when the design of the hybrid system is intergrated and harmonized with that of floating architecture.

## CONCLUSION

Due to the climate change, people’s preference to live and enjoy activities on water, and frequent natural disasters like flooding & earthquake, floating architecture can be a strong and attractive alternative to the existing building on land. This paper aimed to investigate the renewable energy applications in floating architecture and to suggest some reference ideas for new building projects around waterside. Sample floating architectures with strong points of renewable energy application are chosen to analyze.

Comparing with the usual buildings on land, floating buildings on water have great advantages in terms of using renewable energy. Possibilities of solar energy and wind power are much higher in floating architecture because there are no obstacles around water space. And hydrothermal use of the water beneath the floating architecture is easier and more economic than geothermal use in the building on land.

Most popular renewable energy sources for the floating architecture are use of solar energy and hydrothermal energy. Especially use of hydrothermal energy may have a huge advantage in tropical region and polar region because there is a great temperature difference in the water and the outdoor air of the extreme climate regions.

It is very hard to find out the wind power applications in realized floating archietctures until nowadays. Usually there is more wind resources on water than on urban land because there is no windbreak on water space. And also there is daily land and sea breeze circulation around watersides. If small wind turbine with little noise is developed and integrated with the floating building design, wind power can have the priority to be applied due to product efficiency.

Hybrid renewable energy system of solar energy with wind power will be more popular when the design of the hybrid system is intergrated and harmonized with that of floating architecture. And also tidal power and wave power can be considerable to apply if proper system for the floating building is developed.

By the way, disadvantages of floating architectures such as shadows to the bottom, water pollution from concrete pontoon, and other negative effects to the ecosystem should be investigated in detail and countermeasures to overcome are to be suggested for further study.

## ACKNOWLEDGMENTS

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