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.

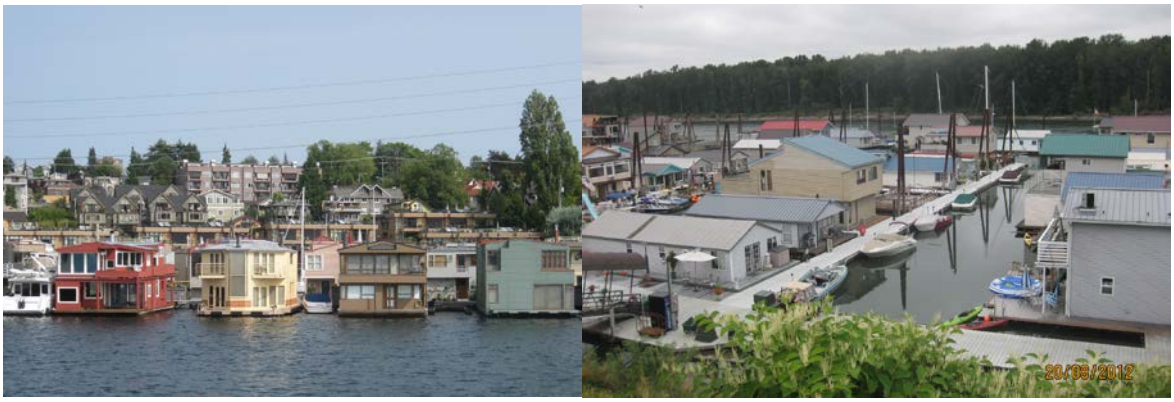

Figure 1 Floating Homes in Seattle, USA(left) and Portland, USA(right)
(Source: photos by the author, 2012)

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

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

This research was supported by a grant (10 RTIP B01) from Regional Technology Innovation Program funded by Ministry of Land, infrastructure and Transport of Korean government.

REFERENCES

Alison Furuto. The Ark / Remistudio. Archdaily. 2011.1.14. (http://www.archdaily.com/103324/the-ark-remistudio/, 2014)

Anastasia Vdovenko. Remistudio's Massive Floating Ark Battles Rising Tides. (http://inhabitat.com/remistudios-massive-ark-building-can-save-residents-from-flood/. 2014)

ARK. Remistudio. (http://remistudio.ru/en/pages/52.htm, 2014)

Autark Home. (http://www.autarkhome.de/, 2014)

Costas Voyatzis. The first floating hotel in Sweden. Yatzer. 2008.12.31. (http://www.yatzer.com/The-first-floating-hotel-in-Sweden, 2014)

Darren Quick. IBA_Dock: The green, floating building, 2012. (http://www.gizmag.com/iba-dock-floating-building/21941/, 2014)

REM. Floating passive house close to mass production. Renewable Energy Magazine, 2012. (http://www.renewableenergymagazine.com/article/floating-passive-house-close-to-mass-production-20120917, 2014)

Housing and Construction Standards. British Columbia Float Home Standards. Ministry of Energy, Mines and Natural Gas. (http://www.housing.gov.bc.ca/pub/htmldocs/floathome.htm#_1_5, 2014)

IBA Dock/Architech. Archdaily. 2012.11.3. (http://www.archdaily.com/288198/iba-dock-architech/, 2014)

IBA DOCK. (http://www.iba-hamburg.de/en/projects/iba-dock/projekt/iba-dock.html, 2014)

James Reinl. "Floating Mosques for Palm" & "Creating a Modern Place to Worship", Emirates Today(2007.11.1) 1 &18.

Koen Olthuis & David Keuning. Float! Building on Water to Combat Urban Congestion and Climate Change, Frame Publishers, 2010, pp.210-220.

Office of Housing and Construction Standards, Ministry of Energy, Mines and Natural Gas, British Columbia, Canada. (http://www.housing.gov.bc.ca/pub/htmldocs/floathome.htm, 2014)

Renewable energy. Wikipedia. (http://en.wikipedia.org/wiki/Renewable_energy, 2014)

SALT & SILL. (http://www.saltosill.se/home__1033, 2014)

Waterstudio. (www.waterstudio.nl, 2014)