Examples and Concepts of Floating Architecture in the Face of Climate Change - The Example of Szczecin

Tomasz Bradecki, Paulina Konsek

Silesian University of Technology, Poland

paulina.konsek@gmail.com

Abstract. The article presents the issues of the impact of climate change on the architecture of Baltic cities with the example of Szczecin. Although measures are being taken to prevent further warming, the scale of changes requires action in various areas, including urban planning. In the temperate climate of Poland, the projected temperature increase by the end of the 21st century will have been 2-4 degrees Celsius (according to the latest IPCC reports on the effects of global warming). Therefore, the sea level may rise by 60-120cm. The cities of the Baltic Sea region are facing a significant challenge. In the future, they will face a high intensity of extreme weather events and changes in precipitation levels. The rising sea level forces the search for an alternative way of building. One of the cities in Poland where changes will be experienced is Szczecin. Some positive effects of climate change will also appear, such as longer tourist and vegetation seasons in Poland of up to 4-6 months and an increase in the attractiveness of Polish tourist cities. What is more, the country must also be prepared to accommodate the larger population resulting from climate migration. The article presents examples of designs and developments of the floating architecture which can become inspiring in the face of climate change challenges. A discussion on the pros and cons of such solutions was conducted. The authors put forward a thesis that some architectural solutions may prove useful for the upcoming problem, but they require prior improvement and adaptation to the Polish climate and economic conditions.

1. Introduction

The issue of global warming, general climate change and its impact on various areas of life is undoubtedly a topic that has been raised on numerous occasions both in the media and in scientific publications. The most popular publicly available source of data on the above topic is the IPCC Reports summarizing the global changes we are currently observing and forecasting their further progress. The reports are drawn up periodically by the International Panel on Climate Change. The latest available report, drawn up after the UN climate summit, was published in 2019 and deals precisely with changes in the oceans” Ocean and Cryosphere in the Changing Climate” [1]

According to the latest IPCC reports and numerous studies, the most frequently cited causes of climate change are greenhouse gas emissions (including CO2, nitrogen). This is mainly due to the activities of anthropogenic origin, such as by-products of production plants and, above all, the mining and farming industries. [2] We are also struggling with increasing overcrowding and the resulting urbanization of space. This leads to reduced retention - the inability to retain water in the environment. According to Professor Starkel, the changes taking place will result in an increase in extreme weather phenomena such as heavy rains with lightning, floods, storms. In the temperate climate, i.e. also in
Poland, the extreme phenomena that may occur include hurricanes and cyclones. The forecasts for the territory of Poland do not predict a large change in the total amount of precipitation during the year, but their distribution over the seasons is going to change. The most probable forecast is that the amount of precipitation will increase in winter, while in the summer months we are going to struggle with drought. Water scarcity in the summer will most affect the southern regions, including the Mediterranean Basin.

The latest 2019 IPCC report predicts an increase in the average temperature of 2 degrees Celsius by 2030 compared to the pre-industrial era. [3] "The likelihood, intensity and duration of many extreme events can be significantly modified by changes in land conditions, including heat related events such as heat waves (high confidence) and heavy precipitation events (medium confidence). Changes in land conditions can affect temperature and rainfall in regions as far as hundreds of kilometers away (high confidence)." IPCC Summary for Policymakers point A.4.2 [4]

According to the assessment by the IPCC specialists, as also quoted and developed by Dariusz Drzewiecki in the “Przegląd geopolityczny” and Zbigniew W. Kundzewicz and Katarzyna Juda-Rezler in the “Nauka”, the rise in the level of oceans and seas is caused by melting of the ice sheets and (perhaps even more so) thermal expansion of water. [5] The inflow of fresh water from melting ice sheets will also lead to changes in ocean currents, but in the current state of research, it is difficult to predict unambiguously what effects it is going to have [6][3]. At present, the increase in the level of the oceans is 3-3.5mm per year, so it is predicted that the water level will rise by 60-120cm by the end of the 21st century. "The increase in the level of the oceans is a consequence of two physical mechanisms: the expansion of water under the influence of an increase in its temperature and the entry of water from melting glaciers into the oceans"/2/ Dariusz Drzewiecki, Przegląd geopolityczny 2015. According to the current state of research, the stated increase is proportional to the rising temperature. [7]

2. Floating Architecture

The idea of floating architecture has existed for many years as a well-known way of building and living in Asia, used by the Sumer in Mesopotamia. We also know of examples of floating buildings in Thailand and floating villages in Cambodia (Figure 1). [8]

![Figure 1. An example of a floating construction in Cambodia, own research (Adjusted according to reference [8])]()
In the current situation, there are not enough regulations concerning floating architecture. Certainly, attention should be paid to the potential of such buildings to combat climate change, as they provide the possibility to use renewable energy sources (RES). [10] The only regulations on water-based construction that are present are included in a chapter on floating architecture in the “Queensland Development Code 2006”. In that document, the following aspects of floating architecture are reviewed: access, floatation system, mooring piles, materials (generally, fastenings), location, safety equipment, firefighting equipment, minimum water depth [11].

The first attempts are already being made to systematize the issues related to floating architecture. One of the strategies proposed to help in the conscious designing of floating buildings and the proper use of energy issues is the ASEM (Adaptation, Sustainability, Efficiency, Management) strategy described by Shahryar Habibi in “Floating Building Opportunities for Future Sustainable Development and Energy Efficiency Gains”. [12] A clear assessment of the strategy is not possible today, because the technology has not yet been widely used in practice.

3. **Examples of architecture that addresses the issues of global climate change:**
The architecture prepared for the issues of flooding can be divided into three basic types: The first one - **flood resilient architecture** - is a method of building that involves opposing the forces of nature by using sufficiently strong structure and foundations. The second one - **floating architecture** - slightly in opposition to the first group - is not connected to the ground. The combination of these two groups results in a hybrid called **amphibious architecture** - these are buildings, the foundations of which allow them to drift on the water surface [13]

![Figure 2. Diagram of various types of foundation solutions for buildings located on the water - A. flood resilient architecture B. floating architecture C. amphibious architecture before and after water level rise, own research](image-url)
Figure 3. House on Lake Huron, own research (Adjusted according to reference [14])

**House on Lake Huron (BACA Architects)** - responding to climate change. It is designed to adapt to the water level. Due to its permanent connection to the ground, it can be assigned to the group of **flood resilient architecture**. However, the innovative structure makes the building “pushed” upwards with the rising water level. It is a solution that combines the characteristics of both the first and second group of buildings on water (flood resilient and floating, *figure 2, 3*). [14]

Figure 4. “The chichester” floating house, own research (Adjusted according to reference [15])

Figure 5. “Tiny float 2019” floating house, own research (Adjusted according to reference [16])

Chichester House (BACA Architects, Figure 4) is one of the examples of floating houses being built on British waterways. It is a two-story open-plan building with significant glazing. Its narrow shape allows it to be placed even in small channels. Tiny Float (Tiny Floats, Waterstudio.nl, Figure 5) - modular building, adaptable to customer needs [15], [16].

Figure 6. “Dordrecht” floating house, own research (Adjusted according to reference [17])

Figure 7. Floating “Urban Rigger” dorm, own research (Adjusted according to reference [18])
Another example is Floating Villa Dordrecht K.3 (Waterstudio.nl) - this is part of a larger water investment in Dordrecht, consisting of 5 buildings located on a canal in the city center. Another example is Urban Rigger (BIG) - a water-based campus in Copenhagen, created and patented as a 745m² development, including 3000m² of residential space (9+3 students' apartments between 23 and 30m²), 160m² of a shared garden, as well as a barbecue area and a common terrace of the area of 65m². The building is energy-efficient, and its unusual form of architecture is also supposed to create a community of residents (Figure 6, 7). [17], [18]

4. Climate change in the Baltic Sea and the Baltic coast

The changes described above will also be experienced locally in the nearby Baltic Sea. Some of the consequences of climate change can also bring a number of positive developments. Higher water and air temperatures extend the tourist and vegetation seasons. However, the vast majority of consequences are the dangers of climate change. Increased concentrations of carbon dioxide in the atmosphere and water lead to increased acidity of the water and, as a consequence, to the creation of dead zones (with insufficient oxygen for oxygen-breathing plant and animal organisms). This poses a threat to the fishery and a risk of species migration. It also increases the risk of developing sea diseases. [19], [20] On the Polish coast, the cities with the greatest development potential are the port cities. In recent years, we have observed numerous urban-architecture projects of considerable scale and supra-local character (the Szczecin Philharmonic Hall, the Museum of World War II in Gdańsk). One of the largest coastal projects of an urban planning character is the Imperial Shipyard in Gdańsk - the project to revitalize 50 hectares of degraded areas in order to transform them into vibrant, attractive city districts. According to Herning Larsen - the author of the Imperial Shipyards design, the harbor areas can also be used in an ecological way "Before breaking ground at Gdansk, the area will be densely planted with sunflower fields - A natural method of removing pollutants from the soil, remnants from the area's industrial past. Natural filtration will also help cleanse the water along the docks, ensuring the canals can be enjoyed during warm weather. By reviving the natural life before beginning construction, we hope to give the people of Gdansk more reason to make the Imperial Shipyards the new heart of urban life." [21], [22]

The second largest city on the Baltic coast is Szczecin, where large investments in significant areas are also implemented and planned.

4.1 Characteristics of Szczecin:

Szczecin is located in the West Pomeranian Voivodeship, 100 km from the Baltic Sea, accessible via the Oder River and the Szczecinski Lagoon. As the largest city of the West Pomeranian Voivodeship, it is a tourist, cultural and academic hub. Its significance does not differ from that of other tourist cities in Poland, such as the Tricity, Poznań or Wrocław. In 2008, as many as 40% of the city's visitors declared their willingness to arrive her for leisure reasons. [23] A new type of sea tourism, i.e. sea cruises, has become more and more popular for the last several years. Szczecin has its University as well as the West Pomeranian University of Technology in Szczecin. The city is also characterized by a thriving maritime economy. Due to its favorable location and transportation connections, it is also a catalyst for development with German cities. It boasts about all the possible types of external communication, such as: railway (the city has a railway hub), road, air, inland and sea transportation.

The city is situated at the Dąbie Lake at the Szczecin maritime region, has 403,274 inhabitants and covers an area of 300 km², of which 24% is underwater. There are depressive areas between the arms of the Oder. It is characterized by a humid climate.

In the immediate vicinity of the old town and the center of Szczecin, there is the river island called "Lasztownia” surrounded by the arms of the West Oder, Duńczyca, Kanał Wrocławski, Kanał Zielony
and Parnica. In the Middle Ages, here ran the oldest transportation route from east to west. Łasztownia
has belonged to Szczecin since 1283 when the city bought the island. The whole history of the island is
connected to the trade port located on the Oder River between the Długi and Kłodny bridges. There
used to be grain granaries, warehouses for salt, herring, and a place for loading goods, where the modern
name of the island comes from (“łaszt” – a former unit of volume for bulk goods). [23], [24]

As regards the forecasts of water rise, floods and lightning, it can be safely assumed that Szczecin
is a city exposed to a high degree to the probability of occurrence of the above-mentioned phenomena.
An indicative diagram based on the flood-map (Figure 8) shows the areas with the highest probability
of flooding (the very unstable water level in the Oder should also be taken into account).

![Figure 8](image)

**Figure 8.** The area of the Szczecin Łasztownia currently and the projected flooding in 50-100 years
own research (Basemap [25])

5. Conclusions

Good recognition and implementation of the floating architecture will have a number of positive effects.
It is an attractive, innovative solution that enables development of the city’s structure in the face of
anticipated overpopulation and population migration. Amphibious architecture also allows adapting to
changing water levels (the house on Lake Huron).

As the substrate for construction, water is an inexhaustible source of energy. The introduction of
appropriate systems would enable the production of energy (ocean thermal energy conversion) - the
technology that allows drawing energy from ocean waters, and more precisely from the temperature
difference between deep and surface waters. [9] Another advantage is the possibility of introducing
cleaning and rainwater storage systems.

Unfortunately, apart from a number of advantages, the method is characterized by numerous
understatements. The historical context of the city stands in opposition to the floating architecture. The
form of present-day cities has been shaped for centuries. A completely different solution could upset
the balance. In Poland, the form of floating architecture is still unrecognized, and at present, there are
no proper legal regulations. Implementation of this form of architecture requires a solution to the
problem of wastewater disposal and the appropriate protection of water against pollution. Many of the
problems we may encounter are highlighted by Shahryar Habibi. These include, among others, high
costs implementation and materials. Currently, this type of construction is produced from titanium and
its alloys which also require prior protection against harmful effects of the water to ensure proper
durability and lifespan. It is also important to set such limits as the minimum amount of water needed
for floating buildings to be feasible, and to solve the issue of foundation in case of drought or severe conditions, such as hurricanes or heavy rainfall, which we can also expect in the future. [12]

The potential of the Baltic cities, as well as the directions and pace of development indicated in the article, indicate the need for further development and expansion. However, the global climate change that we are going to face will require proper adaptation. The technology of building floating architecture needs to be properly recognized and systematized in order to be fully utilized in Polish climatic and economic conditions. The adaptation of that architectural method may be inevitable in the face of upcoming changes.

In order to properly implement the floating architecture, it is not only necessary to recognize it but also to create legal regulations.

The area of Szczecińska Lasztownia, as the area exposed to the highest risk of flooding, is a suitable place for implementation of the first floating architecture settlements. This gives the opportunity to populate places with high potential and good location, as well as to create a housing reserve in the case of flooding of existing buildings.

Acknowledgements
Sketches have been made by authors on the basis of photographs. Sketches reveal proportions and intentions.

References
[1] H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N.M. Weyer, “IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate”, p. 4-6, 2019.
[2] D. z Drzewiecki "Coastal areas safety in the southern part of the Baltic Sea basin based on the latest IPCC report (AR5) “, p. 17-20, 2015,
[3] L. Starkel, and Z. W. Kundzewicz “Consequences of climate change for urban planning”, p. 89-95, 2008.
[4] P.R. Shukla, J. Skea, Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley, “IPCC, 2019: Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems”, p. 14, 2019.
[5] Z. W. Kundzewicz, and K. Juda- Rezler “Threats related to climate change”, p. 70-74, 2010.
[6] Ziemiaanarodzrozu, ocean currents predictions [Online] 2020 [Accessed 15.04.2020] Available at: https://ziemiaanarodzrozu.pl/encyklopedia/91/zmiany-pradow-oceanicznych.
[7] R. S. Nerem, B. D. Beckley, J. T. Fasullo, B. D. Hamlington, D. Masters, and G. T. Mitchum "Climate-change-driven accelerated sea-level rise detected in the altimeter era", p. 5171-5174, 2013.
[8] TravelFreak, Cambodian buildings [Online] 2020 [Accessed 15.04.2020] Available at: https://travelfreak.com/chongknease-floating-village-poverty-in-siem-reap-cambodia/#lightbox/8/.
[9] H. Stopp, P. Strangfeld, and A. Malakhova "Floating Architecture and Structures- an Answer to the Global Changes", p. 290, 2016.
[10] C. Moon, PhD "Renewable Energy Application in Floating Architecture”, p. 3-5, 2014.
[11] Queensland Development Code Floating Buildings Publication Date, p. 4-10, 16 November 2007.
[12] S. Habibi “Floating Building Opportunities for future Sustainable Development and Energy
Efficient Gains”, p.5, 2015.

[13] ICAADE, amphibious architecture information [Online] 2019 [Accessed 15.04.2020] Available at: http://icaade.org/amphibious-architecture.

[14] Baca, Amphibious house, the chichester [Online] 2015 [Accessed 15.04.2020] Available at: https://www.baca.uk.com/amphibious-house.html.

[15] Baca, the chichester [Online] 2015 [Accessed 15.04.2020] Available at: https://www.baca.uk.com/floating-home-the-chichester.html

[16] WaterStudio, Tiny float, Dordrecht [Online] 2019 [Accessed 15.04.2020] Available at: https://www.waterstudio.nl/projects/tiny-float-sneek-2/.

[17] WaterStudio, Dordrecht [Online] 2019 [Accessed 15.04.2020] Available at: https://www.waterstudio.nl/projects/dordrecht-alice-de-boer/.

[18] Urban rigger [Online] 2020 [Accessed 15.04.2020] Available at: https://www.urbanrigger.com/

[19] Z. Zwoliński “Global climate changes and their implications for the sculpture of Poland”, p. 7-9, 2011.

[20] Noizz, ecology reports [Online] 2019 [Accessed 15.04.2020] Available at: https://noizz.pl/ekologia/raport-ipcc-o-oceanach-lodowcach-i-kriosferze-2019/3qehvzx.

[21] Stocznia Cesarska, imperial shipyard project information [Online] 2020 [Accessed 15.04.2020] Available at: https://stoczniacesarska.pl/pl/dziedzictwo/.

[22] Henning Larsen, imperial shipyard project information [Online] 2020 [Accessed 15.04.2020] Available at: https://henninglarsen.com/en/projects/1600-1699/1689-gdansk-imperial-shipyard/.

[23] D. Zarzecki “Szczecin for You - development strategy of Szczecin”, p. 113-121, 2011.

[24] Łasztownia island information [Online] 2020 [Accessed 15.04.2020] Available at: http://lasztownia.szczecin.eu/.

[25] GlobalFloodMap, Interactive BaseMap [Online] 2020 [Accessed 15.04.2020] Available at: http://globalfloodmap.org/.