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Floating Cities: A Solution for Climate Refugees?

İklim Mülteciliği ve Çözüm Önerisi Olarak Yüzen Şehirler

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ABSTRACT

Changing climatic conditions and global warming cause sea levels rising in coastal cities around the world. Climate change in these cities, which are vulnerable to rising sea levels, will create "climate refugees." Therefore, the need to build new regions in the country they live in and suitable for new climatic conditions will arise for these people who had to migrate due to the climate crisis with the rising sea levels. Architects, technology companies, engineers, and governments are trying to develop innovative solutions to this problem. One of these solutions can be considered as "floating cities" rising with the sea, producing their own energy, food, and fresh water, resistant to tsunami and flood, sustainable, self-sufficient, and where nature and technology come together. In this context, in this study, self-sufficient floating city projects will be discussed to provide shelter for climate change refugees. For this purpose, "Oceanix City," Maldives Floating City, and finally Aequorea project were examined. These floating cities, which are described as sustainable and self-sufficient, have been questioned about the advantages and disadvantages they offer in adapting to climate change and creating climate-resilient communities. However, the cities studied were evaluated in the context of inspiration, accessibility, power source, waste management, food production, environmental impact, safety, and social city.

Keywords: Climate change, climate refugees, climate-resilient communities, floating city projects

ÖZ

Değişen iklim koşulları ve küresel ısınma dünyanın dört bir yanında yer alan kıyı kentlerinde deniz seviyelerinin yükselmesine neden olmaktadır. Yükselen deniz seviyelerine karşı savunmasız olan bu kentlerde yaşanan iklim değişikliği iklim mültecilerini oluşturacaktır. Dolayısıyla deniz seviyelerinin yükselmesi ile devam eden iklim krizi nedeniyle göç etmek zorunda kalan bu insanlara yaşadıkları ülke içerisinde ve iklim koşullarına uygun yeni bölgeler inşa etme ihtiyacı ortaya çıkmaktadır. Bu soruna mimarlar, teknoloji şirketleri, mühendisler ve hükümetler bir araya gelerek yenilikçi çözümler üretmeye çalışmaktadır. Bu çözümler deniz üzerine yerleştirilen, deniz ile birlikte yükselen, kendi enerjisini, gıdasını ve tatlı suyunu üreten tsunami ve sele karşı dayanıklı doğanın ve teknolojinin bir arada olduğu sürdürülebilir, kendi kendine yetebilen yüzen şehirler olarak düşünülmektedir. Bu bağlamda bu çalışmada iklim değişikliği mültecilerine barınak sağlamak amacıyla önerilen ve kendi kendine yetebilen yüzen şehir projeleri ele alınacaktır. Bunun için Bjarke Ingels Group (BIG) UN-Habitat ve UN agency ile anlaşma yaptığı "Oceanix City" projesi, Dutch Docklands tarafından tasarlanan Maldives Floating City (MFC), Vincent Callebaut tarafından Rio de Janeiro için tasarlanan Aequorea projesi incelenmiştir. Kendi kendine yeten olarak tarif edilen bu yüzen şehirlerin iklim değişikliğine adapte olma ve iklim değişikliğine dayanıklı topluluklar oluşturma konusunda sundukları avantajlar ve dezavantajlar sorgulanmıştır. Bununla birlikte incelenen şehirler, ilham kaynağı, erişilebilirlik, güç kaynağı, atık yönetimi, gıda üretimi, çevresel etki, güvenlik ve sosyal şehir bağlamlarında değerlendirilmiştir.

Anahtar Kelimeler: İklim değişikliği, iklim mültecileri, iklime dayanıklı topluluklar, yüzen şehir projeleri

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Introduction

The rise in sea levels in the current century brings with it the danger of displacing the people living on the coastlines. It is predicted that by 2050, approximately 800 million people will live in 570 cities

where sea levels may rise by more than half a meter (C40 CITIES, 2018). Global sea level has risen by approximately 20 cm since the 1880s, when scientific records began to be kept (GlobalChange, 2019). The melting of glaciers that add water to oceans around the world and the expansion of water as ocean temperatures increase are factors affecting sea levels. In this case, if the temperature increase continues by 5°C, the global average sea level rise will exceed 1 m by 2100. If this happens, many small island states will experience floods and these islands will become uninhabitable (Bamber & Oppenheimerhttps, 2019).

Countries such as Kiribati, an island nation in the Pacific Ocean, are investigating the possibility of artificial islands that can replace natural islands with increasing water levels (Tong, 2015). In addition, the solution to this problem is being studied by many different architects and researchers. In this direction, different ideas and concept projects are produced. The Silicon Valley initiative aims to protect the intellectual structures conceived and patented by Arx Pax by floating them on the water with the logic of a boat (Hawkins, 2016).

From this point of view, the aim of this research is to raise awareness by emphasizing the importance of climate refugees who will have to migrate as a result of climate change and rising sea and ocean levels. In this context, the subject of floating cities, which are designed and planned to be built for climate refugees, who are left with the rise in sea levels as a result of global warming, is discussed in this study. Within the scope of floating cities, Oceanix City, Maldives Floating City, and Aequorea project are examined in the research. In these reviews, decisions taken on issues such as the planning of floating cities, inspiration, accessibility, power supply, waste management, and food production are questioned.

Climate Change and Climate Refugees as Forced Migrations

From the past to the present, natural disasters have left devastating effects on both the environment and the civilizations established by people. The fact that human beings, who consume nature unlimitedly and do not think about the future, see the environment only as a consumption tool for themselves today has caused irreversible climate change. The experienced climate change has triggered environmental problems and their destructive effects to increase and to be experienced on a global scale (Başköy & Kanlı, 2018). In addition, industrialization, urbanization, and rapid population growth have brought many negativities such as fossil fuel use, deforestation, desertification, global warming, and climate change. Evidence of rapid climate change caused by all these events reveals frightening scenarios day by day. However, it is predicted that global temperatures will increase up to 4°C by 2100 (Thuiller, 2007). The increase in environmental problems and natural events has deeply affected societies. As a result of these natural events, people whose safety of life and property were endangered had to migrate to safer areas (Kanlı & Başköy, 2018). The movement of displacement that occurs as a result of natural events such as earthquakes, drought, floods, tsunami, and drought is defined as "climate migration" (Ziya, 2012).

However, the intensification of this global climate change brings with it the concept of “climate change refugee.” A climate refugee is a person who has to leave his place of residence, country, or home due to the severe effects of climate events. Climate refugees cannot shelter in their place of residence and have to go to a safe place due to the climatic dangers they are exposed to such as flood, drought, sea level rise, tsunami, deforestation, and desertification (Berchin et al., 2017).

It is necessary to analyze the reasons and consequences of climate refugees in detail and to produce permanent solutions. Today, approximately 3 billion people, approximately 50% of the world's population live in coastal areas (Creel, 2003). These regions stand out as areas that are predicted to be inundated due to climate change.

Floating Cities as a Recommendation to Adapt to Climate Change

Analyzing the causes of climate change and predicting its consequences are very important. However, not enough attention is paid to the consequences of this situation for people. The foresight in question is an issue that the international community should focus on in the context of interventions and measures for the consequences of climate change for people.

Coastal cities open up space by filling the oceans with sand to create new regions in order to find solutions to rapid population growth. This increasing coastal urbanization threatens ocean and marine life. However, climate change and rising sea levels continue to pose problems. It is predicted that sea levels will affect 90% of the world's largest cities by 2050 (OCEANIX, 2021). As stated earlier, it is estimated that by 2050, approximately 800 million people will live in 570 cities where sea levels could rise by more than half a meter (C40 CITIES, 2018). This problem will also displace people living in coastal cities by destroying infrastructure and houses, along with floods and coastal erosion.

The United Nations has argued that sustainable floating cities can be effective as a solution to the climate change threats faced by urban areas. United Nations Human Settlements Programme brought together experts in the field at the First Sustainable Floating Cities High-Level Round Table Meeting to produce innovative solutions to the threats faced by coastal cities and countries due to rising sea levels (United Nations, 2019). At the First Sustainable Floating Cities High-Level Roundtable, the nonprofit OCEANIX, MIT Center for Ocean Engineering, Bjarke Ingels Group (BIG) presented the project proposal for the world's first resilient and sustainable floating city community called “Oceanix City” (Merdim, 2019).

Why is the United Nations Human Settlements Program presenting and researching the floating city project? The answer to this question is that the sea level will rise by more than half a meter in Turkey and Europe in 2100 (OCEANIX, 2021). Istanbul, Amsterdam, Athens, Barcelona, Dublin, Glasgow, Hamburg, Helsinki, Izmir, Copenhagen, Lisbon, London, Marseille, Naples, Odessa, Porto, Rotterdam, St. Many cities such as St. Petersburg and Stockholm will be affected by this situation (CNN Turk, 2017). However, it is estimated that many cities such as Osaka, Alexandria, Rio de Janeiro, Shanghai, and Miami will be flooded (Holder et al., 2017). In this context, the number of climate refugees will increase with these scenarios that are expected to take place. These solutions, which stand as utopian urban projects for now, include the use of advanced technology that promises to meet everything that humanity needs such as shelter, water, food, and energy without harming ocean ecosystems.

For hundreds of years, many people continue to live on the floating islands they have created on the water surface. Examples

Figure 1.
Nueva Venecia, Colombia (Eltiempo, 2018); Uros Islands, Peru (Westend61, 2022); Bajau Laut nomads in Malaysia (PulauMabul, 2022).

of these are Nueva Venecia in Colombia (Eltiempo, 2018), Uros in Lake Titicaca in Peru (Westend61, 2022), and the Bajau Laut nomads in Malaysia (Figure 1) (PulauMabul, 2022).

Today, many more such as nuclear power plants (ForoNuclear, 2016), wind farms (Dvorak, 2017), solar farms (Major, 2016), prison (Chevalier Floatels, 2022), animal farms (Frearson, 2019), hotels (Gbadamosi, 2018) There is a floating structure. In addition, Waterstudio.NL is building many floating offices and houses in order to develop solutions to the problems caused by climate change and urbanization. These structures are built on the water surface by filling the concrete foundations with styrofoam. This construction method has been patented as "pontoon type floating structure" (United States Patent, 2012). The floating villas (Figure 2) designed by Waterstudio.NL and located in Dordrecht in the Netherlands have large foundations set on the water surface (Waterstudio.NL, 2015).

The zero-emission floating houses are designed in collaboration with Waterstudio.NL company, and Arkup 75 has shown the possibility of future implementation of floating cities. These floating homes (Figure 3) include rainwater collection, waste management, and water treatment systems. These livable yachts can withstand floods, strong winds, and hurricanes thanks to their height system (Waterstudio.NL, 2019). These structures are designed to be sustainable, self-sufficient, and environmentally friendly. The roof, which has an area of 2300 square meters, collects rainwater. And the roof surface is covered with 36 kW solar panels that produce enough green energy for off-grid living (Arkup, 2021).

These floating structures in existence today demonstrate the fact that floating cities can be built in the future. These applications, which are at the scale of a single structure, set an example for future floating cities. These structures guide the floating city design in different subjects such as off-grid energy production, water harvesting, and the logic of construction.

Methods

Within the scope of the study, Oceanix City, Maldives Floating City, and Aequorea projects, which are proposed as a solution to climate change, were examined. The projects were analyzed in the context of planning, inspiration, accessibility, power supply,

Figure 2.
Floating Villas Designed by Waterstudio.NL (2015).

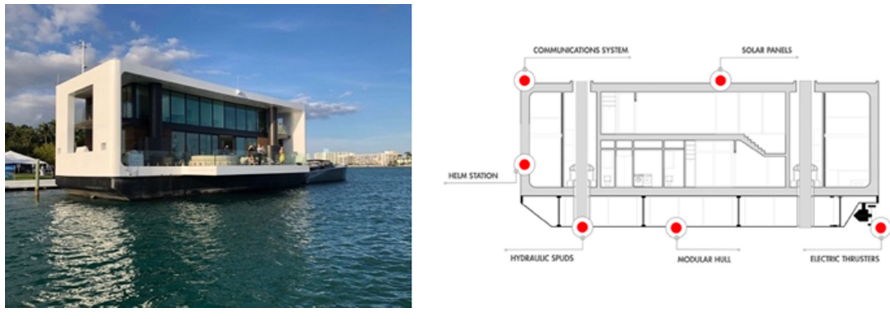

Figure 3.
Arkup 75, Livable Yacht Design (Waterstudio.NL, 2019; Arkup, 2021).

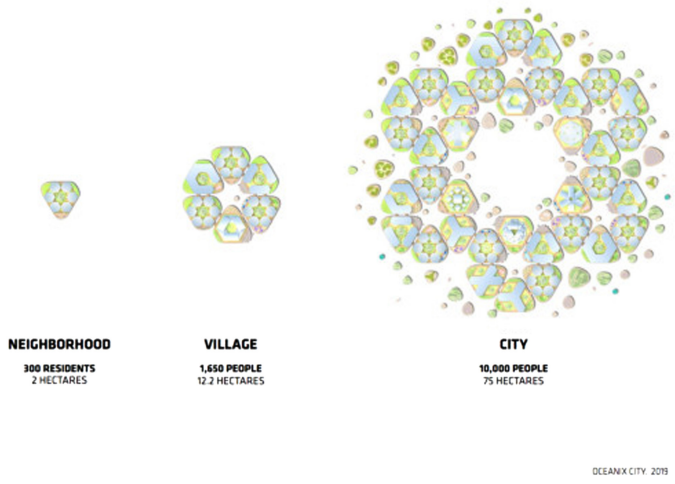

Figure 4.
Oceanix City (Oceanixcity, 2021).

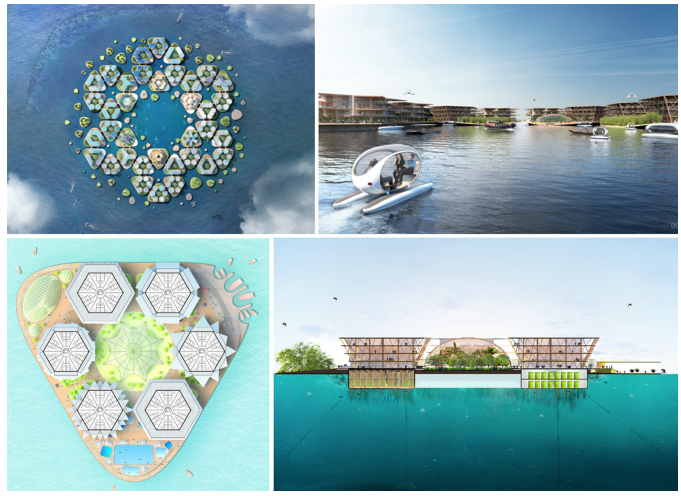

Figure 5.
Low-Rise Neighborhood Settlements (Oceanixcity, 2021).

waste management, food production, environmental impact, safety, and social city criteria, and the data obtained were evaluated.

Analysis and Findings

Oceanix City

UN-HABITAT is a collaborative project with many participants such as BIG, ARUP, MIT Ocean Engineering Center, and Korea Maritime and Ocean University. A sustainable and floating city design has been considered where 10,000 people can live in an area of 75 hectares. Sustainable Development Goals have been taken into account in many subjects such as water, food, energy, and waste in modular plans. This city is designed to grow and adapt organically over time by growing and developing from neighborhood to village, from village to city (Figure 4) (Oceanixcity, 2021).

In this city design, many issues that are needed in a sustainable city such as net-zero energy, fresh water autonomy, plant-based food, zero waste systems, shared mobility, and habitat renewal have been considered. Modular neighborhoods, where approximately 300 people can live, consist of self-sufficient 2 hectares of area. All the structures here are designed to resist the wind and create a low center of gravity under seven floors. In this project, the city is anchored to the ocean floor at certain points (Figure 5).

In addition to all this information, the findings obtained in the context of city design planning, inspiration, accessibility, power supply, waste management, food production, environmental impact, security, and social city characteristics are given in Table 1.

Maldives Floating City

Maldives Floating City (Figure 6), which includes companies such as Waterstudio and Dutch Docklands, is defined as another innovative solution that can prevent coastal people from becoming climate refugees. This experimental study, which can be increased in number on a global scale, was welcomed by government authorities. The inspiration for this project, which is planned to be implemented a few minutes away from the capital Male, is brain coral. However, the project with hexagonal labyrinth planning covers an area of 200 hectares (Maldives Floating City, 2021).

Table 1.
Oceanixcity's General Decisions

Planning	Modularity, hexagonal planning
Source of inspiration	-
Accessibility	Bicycles, delivery boats, delivery cars, hydrofoil water taxis
Power source	Green/blue renewable energy sources
Waste management	Controlled waste disposal
Food production	Agricultural areas, fish farms in the city structure
Environmental impact	Use of recycled materials, layout with consideration for underwater life
Safety	Taking precautions against natural events by connecting the city to the ocean floor from certain points
Social city	Consisting of small towns and expandable design

This project (Figure 7), which is planned to start in 2022, includes residences, schools, hospitals, shops, recreational facilities, and public spaces for local people to use. The project, which consists of low-rise residential buildings, also includes commercial facilities to meet the needs. However, the hexagonal structures of the city are anchored to the island. In addition, these links are considered a link that can be adapted to rising sea levels. It is emphasized that the project, in which the use of green technology is considered, is applicable for future floating cities (Thukral, 2021).

Figure 6.
Inspired by Brain Coral and Master City Plan (Maldives Floating City, 2021).

Figure 7.
Examples From the City Structure (Maldives Floating City, 2021).

Table 2. *Maldives Floating City General Decisions*	
Planning	It consists of rows of honeycomb-like hexagonal labyrinths
Source of inspiration	Brain coral
Accessibility	Access to different points by canals, ships, bicycles, electric scooters.
Power source	Use of green and sustainable technology, floating solar panels
Waste management	-
Food production	Fresh water production, floating agriculture, product supply within the city
Environmental impact	Underwater life contemplated, creating artificial coral islands
Safety	Island barriers around the lagoon
Social city	Consisting of small structures and expandable design

In addition to all this information, the findings obtained in the context of "Maldives Floating City" design planning, inspiration, accessibility, power supply, waste management, food production, environmental impact, safety, and social city features are given in Table 2.

Aequorea Floating City

Located in Rio de Janeiro, the project consists of approximately 10,000 residences. In addition to residential areas, the project also includes formations such as offices, workshops, laboratories, co-working spaces, organic farming gardens, coral gardens, marine farms, and plant treatment lagoons (Figure 8) (Vincent Callebaut Architectures, 2015).

Figure 8.
Design Concept Inspired by Jellyfish (Vincent Callebaut Architectures, 2015).

Figure 9.
Aequorea Project (Jenkins, 2016).

Table 3. *Aequorea Floating City General Decisions*	
Planning	Non-modular structures
Source of inspiration	Jellyfish/biomimetic city
Accessibility	Access to different points by yachts and ships
Power source	Green and blue renewable energy sources, light generation with bioluminescence
Waste management	Waste recycling using microalgae
Food production	Organic farming gardens, marine farms
Environmental Impact	Production by recycling garbage, waste management
Safety	Form designed with natural events in mind
Social city	No duplication, no articulation

The Aequorea project (Figure 9) is conceived as self-contained, spiral oceancrapers that reach the ocean surface from mangrove-lined marinas to the seafloor. Each structure included in the project will be constructed using recycled plastics called the "Great Pacific Garbage Patch" or "The Seventh Continent". However, with a depth of 1000 m, it will take root in the ocean. The aim of the project is to purify and convert seawater to drinking water, to recycle organic wastes with the use of microalgae, and to produce light with bioluminescence. The geometry of the towers has been designed by considering all kinds of natural events that will occur in the ocean (Jenkins, 2016).

In addition to all this information, the findings obtained in the context of "Aequorea" design planning, inspiration, accessibility, power supply, waste management, food production, environmental impact, security, and social city features are given in Table 3.

Conclusion and Recommendations

These floating cities, described as self-sufficient, have several advantages and disadvantages in adapting to climate change and creating climate-resilient communities. First of all, all of these cities aim to stay on the water surface without filling the ocean or the sea, that is, without land reclamation. However, another advantage of these cities is that they are designed to be flexible in the face of natural events such as floods, tsunamis, winds, and

tides. All these advantages do not seem possible with today's technologies. However, with the development of technologies in this direction, this will become possible.

Maldives Floating City, Oceanix City, and Aequorea projects have been produced as concepts that reference nature. Projects imitate ecosystems and living things in nature. It has been tried to find solutions for many factors such as producing from renewable materials, using renewable energy, waste management, and considering environmental conditions. These cities have been thought of as a self-contained ecosystem cycle such as renewable energy sources such as algae, solar panels, turning salt water into drinking water, and decomposing garbage using microorganisms.

The possibility of floating cities to pollute the ocean nature can be said as a disadvantage. The use of traditional materials is seen in the Maldives floating city project. In this case, it has the disadvantage that construction wastes occur after the end of its useful life.

Floating cities as technofuturists propose a solution to rising sea levels that are self-sufficient and can stand as platforms on the water. The examined city designs aimed to create a self-sufficient ecosystem that includes water, food, and waste management. Today's cities are not yet considered competent in this regard. Therefore, today's cities present future cities with problems that need to be solved. In this context, floating cities need to find solutions by taking these problems into account.

These cities, which can be considered as futuristic, have the potential to be produced in the future. But the important thing is that the negative developments created by today's technologies and cities are not repeated in these new cities. For this purpose, it should be noted that the cities that will be built on water are nature-friendly, use renewable energy and recyclable materials, and transform wastes.

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