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Redefining Urbanism in Perspective of Climate Change: Floating Cities Concept

Krystyna Januszkiewicz [1], Jakub Gołębiewski [1], Bartosz Czarnecki [2,*] and Adam Turecki [2]

[1] Faculty of Architecture, West Pomeranian University of Technology in Szczecin, 70-210 Szczecin, Poland; kjanuszkiewicz@zut.edu.pl (K.J.); jgolebiewski@zut.edu.pl (J.G.)
[2] Faculty of Architecture, Bialystok University of Technology, 15-893 Bialystok, Poland; a.turecki@pb.edu.pl
* Correspondence: b.czarnecki@pb.edu.pl

Abstract: This article analyzes the concept of floating cities in the context of increasing threats resulting from climate change. It explores the potential of a floating city concept to provide sustainable and livable conditions on a large scale in response to the growing climate crisis. Specifically, this article considers whether climate change is prompting a redefinition of urbanism and examines how the floating city concept can be useful from this perspective. The analysis draws on ideas related to megastructures, particularly those based on platforms. A pioneer in this field was Kiyonori Kikutake, who in 1958–1963 presented three concepts of floating cities under the name Marine City. His designs were centered around modularity and mobility. Today, Kikutake's vision is experiencing a resurgence as climate change forces architects and urban planners to rethink traditional cities. Contemporary architects such as Vincent Callebaut and Bjarke Ingels are now gaining attention for their innovative designs of floating cities, which are being closely examined by experts and policymakers. The first part of this article provides a comparative analysis of Marine City with contemporary examples of megastructures, such as the Lilypad and Oceanix projects, illustrating how the concept of floating cities have evolved over the centuries. The question is, which solutions developed by Japanese Metabolists remain relevant and how has modern technology enriched and advanced the concept of living on water? The second part of the article analyzes the potential of floating cities to redefine urbanism in response to the growing threat of climate change. This analysis primarily focuses on the possible interactions between floating cities and the environment. The results show that the challenges posed by climate change are redefining the urban planning paradigms formed in the first half of the 20th century. The floating city concept shows some potential as a viable response to these challenges.

Keywords: floating cities; water urbanism; architecture; climate change; design environment

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1. Introduction

The current rate of climate change is faster now than any other point in the known history. Today, it is widely accepted that rapidly progressing climate change poses a direct threat to life on this planet and is leading to a global catastrophe (NOAA 2007; Tozer 2020). Scientific evidence shows that the primary cause is inappropriate human activity over the past century. Excessive carbon dioxide emissions have led to rising temperatures and continued sea-level rise, putting coastal cities worldwide at risk. Today, concentrated human migration to large coastal cities, combined with flooding and rising sea levels, limits the spatial growth potential of coastal urban areas (UN 2019). Visions for constructing cities on water, developed in the second half of the 20th century, have become obsolete in the 21st century due to the new challenges of global climate change. Now, these concepts need to be redefined. The last century saw the rapid development of cities due to social, economic, political, and technological changes, which contributed to increasing anthropo-pressure on the environment (Januszkiewicz et al. 2021). In the 21st century, floating cities will require new technological solutions and new living strategies. This will likely involve sharing space, food, and energy resources. The new floating cities will offer new opportunities for spatial organization and the processes within these environments.

1.1. Urbanism in Perspective of Climate Change

The magnitude of climate change beyond the next few decades will depend primarily on the global anthropogenic production of greenhouse gasses (GHGs) and on the remaining uncertainties regarding Earth's sensitivity to these emissions. The Kyoto Protocol identifies six major GHGs: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbon, and sulfur hexafluoride, all of which are linked to human activity (World Bank 2010). Several well-known factors contribute to this crisis, including energy generation, sewage treatment, landfilling, fuel for transport, industrialization, urbanization, the burning of fossil fuels, agriculture, water pollution, changes in land cover, and deforestation. Collectively, these activities contribute to the depletion of resources and the degradation of the ozone layer.

Climate change mitigation refers to any action aimed at permanently eliminating or reducing the long-term risks and threats resulting from climate change to human life and property (Adah et al. 2017; Asif and Kamran 2012). The Intergovernmental Panel on Climate Change (IPCC) defines mitigation as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gasses" (IPCC 2007). This includes strategies to reduce greenhouse gas emissions and enhance greenhouse gas sinks. These strategies encompass highly diverse fields and cover a broad range of sectors responsible for greenhouse gas (GHG) emissions (Barker and Jenkins 2007). These mitigation strategies are divided into short-term, medium-term, and long-term strategies.

Climate change adaptation refers to the process of preparing for and proactively adjusting to climate change, addressing both negative impacts as well as potential opportunities (Bicknell et al. 2009; Asif and Kamran 2012). It is defined as the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (Asif and Kamran 2012; Adah et al. 2017).

Scientists have been investigating that climate change will impact four key areas: urban ventilation and cooling, urban drainage and flood risk, water resources, and outdoor spaces, including air quality and biodiversity (Mega 2019). However, addressing these risks requires more than only technical changes, such as transitioning to non-emission energy sources. A paradigm shift is also needed in how cities are designed, with a focus on reducing energy intensity on the scale of entire urban structures, especially in transport (Bicknell et al. 2009; Ikpe Elisha and Ejeh 2017). This includes urban planning concepts aimed at lowering the energy demand for transportation. Examples include the compact city model, the more recent 15-min city concept, and the green city approach, which incorporates elements like greenbelts.

Table 1 summarizes the main challenges for urban planners and designers in perspective of global climate change to restructure existing large cities.

Table 1. The main challenges for urban planners in perspective of global climate change.

Challenge		Planning/Urban Design Answer
An integrated approach to urban development and management that takes into account the mitigation and adaptation to climate change on the environment.	→	Recognition of the links between all the systems and subsystems that make up cities. This approach also needs collaborative effort among agencies of government, private organizations, NGOs and CBOs in order to achieve such urban development that mitigates climate change impacts.

Table 1. *Cont.*

Challenge		Planning/Urban Design Answer
Organization of urban space and development patterns (urban form), enabling management of the effects of climate change and adaptation to them.	→	New land use designation criteria to limit and minimize the use of land vulnerable to climate impacts (e.g., steep and unstable slopes, flood zones, coastal areas exposed to sea-level rise and storm surges, groundwater escape, etc.).
Mass migration and human mobility as a primary mechanism to cope with extreme weather events and migration.	→	Change in scale: medium-size scale, self-sufficient villages, and intervention housing estate.
Transformation of the built environment into a resource-efficient and competitive global or regional urbanism and economy, without greenhouse gas emissions.	→	Economic growth is decoupled from the use of resources. This transformation should cover many areas, including biodiversity, sustainable agriculture, elimination of pollution, climate action, and sustainable industry.
Green development as a new form of development that uses an integrated approach toward economics, society, and ecology.	→	Awareness of the unity of nature and humanity—humankind's respect and coexistence with nature to achieve the mutual benefits of nature and humanity and to maintain a green environment for human beings which leads to sustainable development.
Adapting existing infrastructure to the new climate should be conducted through changes in urban systems that will reduce susceptibility to ongoing climate change.	→	New spatial organization for functional zoning to regulate the location, type, and scale of development in climate hazard areas (flexible local development plans and regulations).
Application of technical innovation patterns, and a new relationship between nature, architecture, and technology.	→	Implementation of performative structures which allow buildings to react to changes in environmental conditions, and it minimizes harmful effects on human health and the environment.

Sources: own elaboration.

Addressing the above challenges will require profound changes, not only in energy sources, technology, and protective measures but also in urban and architectural design, culture, and lifestyle. It will take more than just implementing green technologies; it will require rethinking how we live and reshaping the basic structure of our communities. Cities are dynamic systems that face unique climate impacts; their adaptation must be location-specific and tailored to local circumstances. In managing climate change risks and building long-term resilience, cities have to understand their exposure and sensitivity to a given set of impacts. Moreover, they need to develop responsive policies and investments that address these vulnerabilities. The CIB Agenda 21 on Sustainable Construction, published in 1999, provided a detailed overview of the concepts, issues, and challenges related to attaining sustainable development and construction. This document, along with other local or regional agendas, offers guidance on the implementation of appropriate measures based on local contexts (Sjöström and Bakens 2010). In 2015, the UN defined the 17 Sustainable Development Goals (SDGs), a plan for eradicating poverty and advancing social, economic, and environmental development globally by 2030. It was part of the 2030 Agenda for Sustainable Development (UN 2017). In 2019, the European Union introduced the "Green Deal", Europe's new growth strategy to transform into a modern, green, circular, resource-efficient, and competitive economy. The Green Deal seeks to achieve zero greenhouse gas emissions by 2050, with economic growth decoupled from the use of resources (Brás et al. 2019). Its objectives cover many areas, including biodiversity, sustainable agriculture, the elimination of pollution, climate action, and a sustainable industry

(EU Commission 2009). Environmental and climate change impacts must be avoided or minimized (Capelleveen et al. 2021).

The Climate Change and Coastal Areas

Between 2006 and 2015, global ocean levels rose by an average of 3.6 mm per year, which was 2.5 times the average rate of 1.4 mm per year throughout most of the 20th century. By the end of the 21st century, global levels are expected to rise by at least 30 cm above 2000 levels, even if greenhouse gas emissions follow a relatively low trajectory in the coming decades (Masson-Delmotte et al. 2018). However, sea-level rise at specific locations may vary due to local factors such as flood protection in the upper reaches of rivers, erosion, ground subsidence, and regional ocean currents (Rosenzweig et al. 2011). Rising sea and ocean levels present a new challenge for humanity: How should we design our coastal cities to effectively cope with this problem?

Today, the majority of the world's population (54%) lives in cities and their surrounding areas. A major influence driving this high urbanization rate in recent decades has been the dynamic urbanization in China. Urbanized areas also have the highest concentration of energy consumers and emitters of greenhouse gasses and airborne particulate matter, primarily from housing, industry, and transportation. Hence, transforming urban areas offers the greatest potential to address the anthropogenic drivers of climate change (Azevedo de Almeida and Mostafavi 2016). The United Nations has endorsed further research into floating cities as a response to rising sea levels and the growing number of climate refugees (UN-Habitat 2022b). The challenge of adapting architecture to fluctuating water levels is now a global concern. On 26 April 2022, the UN and the Busan Metropolitan City in the Republic of Korea announced the launch of the world's first prototype of a sustainable floating city. Known as Oceanix City, the project aims to provide breakthrough technology to help coastal cities facing severe land shortages and escalating climate threats (UN-Habitat 2022a). Other floating city projects have also been launched, such as The Maldives Floating City in the Indian Ocean, a joint venture between real estate developer Dutch Docklands and the Maldives government. Additionally, Dutch company Blue21 is developing a series of floating islands on the Baltic Sea. However, none of these projects match the scale or timeline of Oceanix City.

2. Results

This research focuses on floating cities as an effective strategy for acquiring new territories for human settlement. Water urbanism is not a new idea in human history. People have long recognized the numerous benefits of living near and interacting with water (Phaidon Editors 2008; Levy 2017). In fact, the idea of distant lands and floating civilizations has been a part of human imagination since time immemorial, appearing in some of the most well-known myths from the ancient world.

It was not until the second half of the 20th century that new visions of floating cities were created, which aimed to meet the territorial needs of rapidly developing coastal cities and exploring ways to colonize uninhabited areas for the growing population. These visionary urban designs responded to the challenges of industrial civilization, introducing innovative functional and spatial ideas for new forms of urban development. However, industrial civilization also led to anthropogenic changes on the planet, disrupting Earth's natural systems. In the 21st century, global climate change poses new challenges to urban design. The comparative analyses of selected representative examples from these two periods have shown that the earlier visions of floating urbanism have lost their relevance and require rethinking of their ideological foundations, as well as functional, spatial, and social solutions.

2.1. Water Urbanism Ideas Between the Late 1950s and 1970s

In the 20th century, especially in its second half, engineers focused on industrial efficiency, mass production, standardization, and specialization. The Cartesian dualism of res extensa–res cogitans allowed them to view nature as masses of matter to be subordinated to human needs. After World War II, most countries in the East and West enabled engineers to generate enormous amounts of energy by burning natural resources, mass producing everything from houses to vegetables. The technological optimism between the 1950s and the 1970s led architects to explore the possibility of building settlements in inhospitable locations. For example, at the last CIAM congress at Otterloo in 1959, Ralph Erskine presented a scheme for a city in the sub-Antarctic (Mumford 2000). However, the architecture community was fascinated by the idea of living on the water and marine utopias. At that time, master planning respected the approach outlined in the Athens Charter by the Congress Internationaux d'Architecture Moderne (C.I.A.M.) in 1933. This approach recommends functional zoning according to the four components of the city: living, work, recreation, and circulation. Introducing this modernist canon posed a significant challenge for urban planners, especially in the post-war period, when urban structures were undergoing dramatic changes. The rise of motorization resulted not only in enormous mobility within cities but also pushed the boundaries of cities far into their regions. Confronted with a chaotic urban landscape caused by incompatible planning approaches, visionary architects of the post-war generation, especially those in Team 10 (Alison and Peter Smithson) in Europe and Luis I. Kahn in America, called for replacing traditional zoning methodologies. They advocated for new spatial planning strategies where mobility was considered an important feature, essential for restructuring modern cities. Table 2 (below) summarizes the main challenges for urban planners, especially in the post-war period, and the critical issues humanity must address to restructure large cities.

Table 2. Challenges in urbanism after WWII and conditions that should be met.

Challenge		Planning/Urban Design Answer
Demographic growth	→	Change in scale: megastructres scale, megacities
Increase in mobility, motorization and car traffic	→	New structure for efficient communication and transportation systems and service for high-speed traffic
Natural socio-economic growth and self-sufficiency in nutrition	→	New spatial organization for functional zoning and urban farming
Application of technical innovation pattern, new relationship between architecture and technology	→	Industrialization of building construction, prefabrication, prototyping from management and engineering
Resource depletion, overexploitation of ecosystem services and related environmental destruction, civilization diseases	→	Proto-ecomodernism and research for technologies limiting the negative impact on the environment and human health

Source: own elaboration.

In the 1950s and 1960s, rapid global population growth, economic expansion, and the pressing need for mobility were key factors determining the functional and spatial structure of cities. To support economic activities, industrial capitalism developed infrastructure such as transportation networks, utilities, and communication systems within urban areas. This economic system heavily influenced urban planning decisions, where land use, zoning regulations, and property development were often driven by market forces and profit motives. Circulation patterns played a critical role in determining the functional and spatial layout of cities, as well as the social dynamics within urban areas. The extension of cities onto water, especially in coastal regions, was driven by the capitalist need to acquire additional space for both industrial and residential purposes, thereby increasing profitability.

The visions of floating cities that emerged in the second half of the 20th century show a trend in which solutions to these challenges were inspired by some of the Metabolist movement's principles. During the late 1950s and 1960s, the global boom in cybernetics influenced urban design, leading to the development of megastructure-scale artificial urban systems. These systems were designed to grow and adapt, using mobility, modularity, and plug-in structures to replicate biological systems whose metabolism (based on feedback circuits) enables them to respond to environmental changes. At the core of this technological approach was the idea of building large floating structures in the open ocean to reduce human impact on the land (Huebner 2020).

During the 1960s and 1970s, the global population grew from three billion to over four billion people. Such population growth became an important topic in public debates. During this period, proto-ecomodernist thought emerged, driven by the search for technical solutions to challenges such as resource depletion, the overexploitation of ecosystem services, and the resulting environmental degradation (Huebner 2020).

2.1.1. Megastructures and Metabolic Ideas of Extension Coastal Cities

Between 1955 and 1973, rapid economic growth in Japan, driven by rising exports and economic prosperity, created a growing demand for more space in Japanese metropolises, both for industrial and residential use (Pernice 2009). During the late 1950s, extensive theoretical work on the evolution of cities began. It fueled rapid technical progress and the development of science, which provided the basis for increasingly bold, large-scale urban plans (Kurokawa 1977). One of the dominant design concepts of the late 1950s and throughout most of the 1960s was "megastructure". This concept occupied the difficult middle ground between architecture and town planning. It envisioned the construction of massive, adaptable, multipurpose buildings containing most city functions. It offered architects the opportunity to create super monuments on a scale matching the modern city, while also providing citizens with flexibility to create their own small-scale environments within these enormous frameworks (Banham [1976] 2020). These large-scale structures were inspired by Le Corbusier's concept of the "machine for living" and the superblock. The construction of such facilities would require the efficient mass production and standardization of small-scale spatial units. However, this approach would require a reorganization of the construction industry, which did not always align with the profit-driven goals of industrial capitalism. The megastructure trend reached its peak in 1964 and continued at the 1967 Montreal Expo, driven by a blind faith in the power of technology and industrial supremacy.

At the beginning of the 1970s, the trend disappeared as a result of external factors, such as the economic crisis caused by the 1973 oil shock and the subsequent slowdown in the global economy (Frampton 1999).

The industrial capitalism that fueled economic growth during the 1950s and 1960s was mainly centered in cities. Tokyo in particular faced significant challenges in managing its increasingly complex and disordered urban organism due to the concentration of too many activities and functions. The Japanese Metabolists, including Kenzo Tange, Kiyonori Kikutake, Kisho Kurokawa, and Fumihiko Maki were concerned with the natural growth and development of society as an ongoing process. Their groundbreaking idea was to design cities with flexible connections, allowing parts of the urban organism to grow, transform, and eventually die, while the whole "animal"—the city—continued to live. These utopian schemes gave rise to the notion of the city as a living organism that evolves at various rates (Kurokawa 1977; Frampton 1999), even in aquatic environments. The vision included two basic types of floating cities: the "Floating Structure", a concentric city-scale design (Kiyonori Kikutake), and the "Linear Ocean City", a linear national-scale design (Kenzo Tange).

Initially, floating cities were formed on natural ice in the Antarctic and were recognized as the world's first floating cities (Nemesis 2022). Over time, the concept evolved into a "floating city at sea".

In the 1960s, Buckminster Fuller, a brilliant visionary, scientist, environmentalist, and philosopher, was approached by Matsutaro Shoriki, a wealthy Japanese patron, to design a floating city in Tokyo Bay. The proposed city, called Triton, was to be connected to the mainland via bridges and shaped like a tetrahedron, measuring two miles on each side. It was designed to accommodate 5000 residents. Although Shoriki died in 1966, the United States Department of Urban Development recognized the potential of Fuller's project and began supporting it (Triton Foundation Staf 1971).

2.1.2. Marine City Projects by Kiyonori Kikutake (1928–2011)—Toward Modernist Ecology

Kiyonori Kikutake's *Marine City* designs (1958–1963) are among the earliest and most influential proposals for constructing "megastructures" on the sea, notably Tokyo Bay. They were the first design concepts for cities on water after the dissolution of CIAM. The idea of Marine City evolved through several stages and was represented by separate projects, each offering solutions to the challenges of post-WWII urbanism. Kikutake envisioned a floating metropolis in the ocean that would be self-sustaining, flexible, clean and safe, earthquake-proof, and impervious to flooding—far removed from the urban sprawl on the mainland. Kikutake viewed the city as a "Velella" jellyfish or a living cell, proposing that the city's growth should mirror the biological process of cell division (Figure 1).

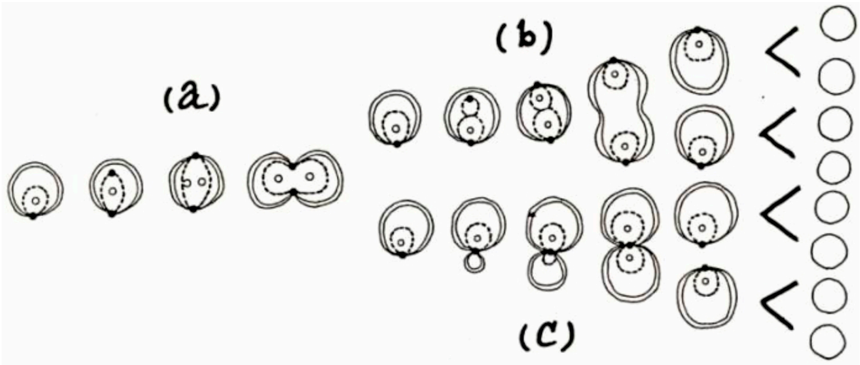
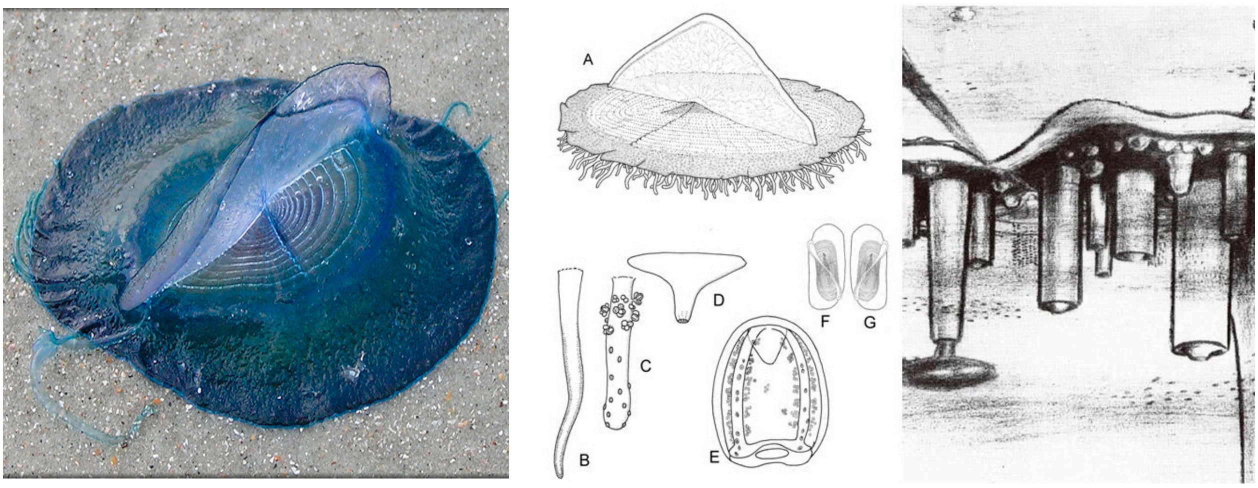


Figure 1. Kiyonori Kikutake; the city growth strategy per an analogy of the process of living cell division: (**a**,**b**)—division starts from inside the cell. A new administration block born on the other side of the inner ring forces the dwelling zone to expand and touches the industrial zone (**a**). At the same time, the control tower is duplicated. Then, the two administration blocks move toward each other, and through the expansion of the two rings, the new city is formed. (**c**)—Division starts outside the cell: the industrial zone first duplicates around the administration block at the connecting point of the two rings (Agnes Nyilas 2016, p. 103).

Kikutake divided his *Marine City* projects into two groups: "Floating Structures", which were concentrically organized on the city scale, and "Linear Ocean Cities". The basic idea of "Linear Ocean Cities" involved creating floating units, separated from the coastal cities, functioning as industrial hubs. These units would be linked into vast urban chains on a national scale. Kikutake drew inspiration for this concept from the "Velella" jellyfish, a species that floats on the surface of the sea, using their small stiff sail to catch the wind and remain afloat. This biological model allowed Kikutake to propose five key concepts for *Marine City* such as the floating foundation, the floating grid, the floating shaft, the floating mat, and the floating unit (Pernice 2009).

In the first stage, Kikutake conceptualized *Marine City* as a cluster of floating industrial units on circular-shaped platforms, serving as artificial land for megastructures. In 1959, he explained a few structural solutions for the construction of 'Floating Platforms'. In view of the ways of balancing weight with buoyancy, these solutions can be categorized into two types based on triangular or hexagonal prisms (Nyilas 2016). Today, there has been growing interest in the hydroelastic performance of floating platforms, which are already used in offshore power plants (Diaz and Soares 2020). These platforms may be used to build modular floating cities such as Oceanix Busan or Maldives Floating City. The initial project, presented in 1958, showed an urban unit that he envisioned as the foundation for the expansion of Tokyo Bay. This proposal featured a gridiron of infrastructural spines, parks, canals, and megastructures on reclaimed land and floating islands. Central to this design was the 'Floating Platform', an urban space connecting a control tower, six floating cylindrical residential towers (resembling vertical buoys), and spherical industrial facilities. The control tower itself was likely designed to float independently on the sea. The *Marine City* project was conceived as a city that invests in the surface of the sea, offering innovative solutions to the challenges of megacity development. It blended architecture and advanced technology to create a new form of "water urbanism". This vision was further refined in the following years, as he believed that floating cities could offer a sustainable alternative to problems faced by mainland cities (Frampton 1999). Kikutake continued to develop this concept, producing several versions of marine cities. Ultimately, he introduced a new vision called *Ocean City*, which was published between 1962 and 1963, and again in 1968.

The *Marine City Unabara* Project (1960) is another vision of a floating industrial city where Kikutake develops his concept of urban growth with an analogy to cell division. The artificial land consists of two irregularly shaped rings: floating platforms and a wave protection zone, approximately 500 m wide (Figure 2). This city is designed as an integrated system of multi-functional urban units. The inner ring accommodates entirely different formal dwelling blocks based on HP shells resembling concrete ships. Below water level, the lower structures contain urban spaces with shared facilities. The outer ring serves as a production zone, while the inner ring is the residential zone. They are separated from each other by the sea, which acts as a natural buffer zone. These two rings are connected by an administration block. The lagoon between the rings is intended for the cultivation of marine products. Located in the middle of the residential zone are two control towers, each extending 500 m above sea level and 1000 m below. These towers act as the city's energy centers, topped with artificial suns.

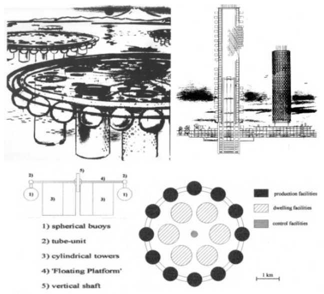
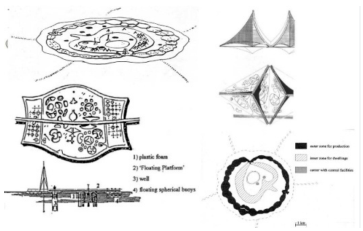
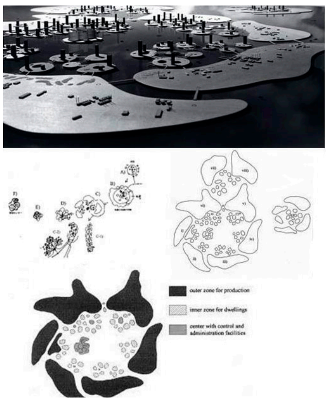


(**a**) (**b**) (**c**)

Figure 2. Living model for *Marine City Project* (1958). (**a**) Joel Wooster, *Velella velella* "By-the-wind Sailor" on the beach at Wilbur-by-the-Sea, north of Ponce Inlet, Volusia Co., Florida, on 21 March 2008; (**b**) Paracoryne huvei Picard, 1957; after preserved material. (A) Dactylozooids and one gonozooid at margin of colony; the scale is more than two times smaller than polyps shown in (B) and (C). (B) Gastrozooid, scale bar of 0.2 mm. (C) Gonozooid with female sporosacs, the same scale as (B). (D) Gonozooid with male sporosacs; sporosac with long process has partially spent its gametes, the same scale as (B), (E) Newly liberated medusa, zooxanthellae stippled dark, scale bar 0.2 mm. (F) Top view of L-form colony (left-sailing, sail running from NW-SE). (G) Top view of R-form colony (right-sailing, sail running from NE-SW) (Schuchert 2010), (**c**) Kiyonori Kikutake, Marine City, 1958; active support system of floating platform, Marine City, 1958 [Photo "(**a**)" from: jaxshells.org (accessed on 1 December 2024); photo "(**b**)" and "(**c**)" from Kindai-Kenchiku, Vol. 14, N. 5, May 1960; in Pernice (2009)].

The *Marine City Project* (1963), also called *Ocean City* or "mother city" (Nyilas 2016), consists of six large islands arranged in a circle. Each circle is intended to house industrial facilities. Surrounding these large islands are smaller islands dedicated to residential facilities, with cylindrical dwelling towers. The control and administrative facilities are located on the central island at the geometric center of the entire composition. Table 3 summarizes the industrial floating city visions (*Marine City*) created by Kiyonori Kikutake in 1958–1963. Their urban characteristics and underlying concepts form the basis for the comparative analysis used in this research.

Table 3. Visions of an industrial floating city created by Kinoru Kikutake in 1958–1963.

Facility Name	Overall Characteristics	Design Ideas
Marina City Project  Design: K. Kikutake (1958) Location: Tokyo Bay Image source: Agnes Nyilas (2016)	Floating industrial city of circular shape diameter: 4 km. Population: 50,000 under the sea. For work: 12 spherical industrial facilities at the periphery, approximately 1,000,000 m^2 of total area. For living: Plug-in apartments on a cylindrical wall of six cylindrical towers. The living units are projected from its inner wall, facing the huge void at the center. For recreation: A control tower at the center, "Marine City" offers "stereo-space for human community on the surface".	Strategy of growth of the city: Clusters of marine cities. Spatial organization: Integrated system of multi-functional urban units and functional zoning. Type of structure: Floating structure with floating horizontal plates. Floating platform as an artificial land for the megastructure. Type of building: Megastructure.
Marine City "Unabara"  Design: K. Kikutake (1960) Location: on the sea Image source: Agnes Nyilas (2016)	Floating industrial city with two irregular-shaped rings as 'Floating Platforms', surrounding wave protection zone, about 500 m wide. For work: Outer ring—production zone. For living: Inner ring—dwelling zone with blocks called "mova-blocks"—two rings connected through the administration block. For recreation: Greenery, parks, canals and "mova-blocks" contain urban spaces with common facilities under water level.	Strategy of growth of the city: Per analogy of the process of cell division. Spatial organization: Integrated system of multi-functional urban units. Energy: Two control towers with a height of 500 m above and 1000 m under the sea each. They also function as energy centers of the city with an artificial sun on the top. Food production: The lagoon between the rings for the cultivation of marine products. Type of building: Megastructure.
Marine City Project  Design: K. Kikutake (1963) Location: on the sea Image source: Agnes Nyilas (2016)	Floating industrial city with six irregular-shaped islands with industrial facilities, and small islands with dwelling facilities gathering around the large islands. For work: Outer zone for production. For living: Inner zone for dwellings, plug-in apartments. For recreation: It is not described in detail. For circulation: Large islands are linked through connecting bridges to form discontinuous production zones, and groups of small islands are linked to form similarly discontinuous dwelling zones inside the production zone.	Strategy of growth of the city: Per analogy to the growth process in plants. Spatial organization: Integrated system of multi-functional urban units and functional zoning. The 'Floating Platforms' are supported by the cylindrical towers with underwater buoys below. The central island with control and administrative facilities is located near the geometric center of the overall composition. Type of structure: Floating structure with floating horizontal plates as artificial land for the industrial facilities and the megastructure dwelling.

Sources: own elaboration.

Analyzing the interrelations between the projects presented above, it is easy to notice that the Marine City project (1958) can be considered the archetype of *Marine City*. Kikutake, like Vincent Callebaut in the 21st century, sought inspiration from living marine organisms to solve the problem of maintaining artificial structures on water using technical means. He envisioned relocating industrial complexes, airports, port facilities, and power plants to floating platforms far from the coast, providing an alternative solution for social and environmental support. Kikutake's proposal was a utopian scenario that drew critical attention to the negative impacts of industrial development on urban coastlines, including the pollution of beaches and their reduced accessibility for recreational purposes.

The modernist idea of relocating pollution to disaster-resilient floating structures in oceanic zones had been a core element of Kikutake's thinking since the late 1950s. However, when he started collaborating with US ocean expert John P. Craven and a group of Metabolists in Hawaii in 1971, his focus shifted from local pollution concerns to tackling environmental problems on a planetary scale. In the early 1970s, a modular and mobile floating industrial complex design developed in Hawaii, featuring an inner ring and modular platform units. Kikutake had contributed two utopian proposals: *Marine City* (1958) and *Marine City Unabara* (1960), and both envisioned relocating industrial plants and transportation infrastructures offshore (Huebner 2020). These projects were among the first major contributions to the Metabolist movement, defining a new radical concept of a floating metropolis in the ocean that is self-sustaining, flexible, clean and safe, earthquake-proof, impervious to flooding, and away from urban sprawl on the mainland.

At the same time, Buckminster Fuller (1895–1983), America's controversial engineer and inventor, introduced the concept of "Spaceship Earth"—the engineer's metaphor for the ultimate ecological paradigm (Fuller [1969] 2008). This metaphor suggests that humanity is responsible for steering this spacecraft and must learn to operate it in accordance with its natural system and limitations. Fuller sought to establish new relationships between nature and technology. Searching for a new type of engineering based on synergy, he wanted to "do more with less" (Fuller and Applewhite [1975] 1979). He believed that a breakthrough from the mechanical cause-and-effect worldview would occur when humanity developed technological capabilities to protect life by adapting economic growth to human needs.

Mineral exploration transformed the sea into a territory that could be scouted, explored, mapped, colonized, and connected to the land-based economies. During the Cold War, the sea was a crucial role in the strategic defense strategies of the United States, NATO, Russia, and the Eastern Block. Significant military funding was channeled to research institutions such as Woods Hole and Scripps, now known as the Woods Hole Oceanographic Institute, to support oceanic research and exploration (Sapolsky 1990).

During the 1960s and 1970s, the global population grew from three billion to over four billion, turning population growth into an important topic of public debate. However, the economic crisis of the early 1970s and the spread of deadly diseases linked to industrial pollution and uncontrolled exploitation of the natural environment undermined the belief in the myth of "fair" and "clean" technology and industry. This period also marked a failure of post-World War II urban planning, as the technological, economic, and social visions behind design approaches began to fall short. At the same time, proto-ecomodernist thought emerged, focusing on technical solutions to address challenges such as resource depletion, the overexploitation of ecosystem services, and environmental degradation (Huebner 2020). The threat of natural resource exhaustion prompted a shift in attitudes, leading to a greater emphasis on recycling, renewable energy, and resource conservation—issues that are now central to addressing the climate change crisis.

2.2. New Urbanism and Floating Cities

In the early 1970s, New Urbanism was a critique of the ideology behind the modern movement, aiming to provide a new theoretical basis for architecture and urban design (Krier 1998; Vanderbeek and Irazabal 2007). This new-urban approach stood in opposition to the doctrines of industrial capitalism, which threatened urban areas treated primarily as the hubs of economic activity, focusing on businesses growth and employment opportunities. New Urbanism sought to move away from the guidelines contained in the Athens Charter CIAM (proclaimed in 1933) and the ideas of Le Coubusier, such as the neighborhood unit (1925) and the superblock, exemplified by projects like *L'unité d'habitation* in Marseille (erected in 1952).

New Urbanism of the second half of the 20th century advocates for a return to the compact, mixed-use development of the traditional urban fabric. This approach emphasizes attractive public spaces, pedestrian-friendly environments, and reduced car dependency, all of which contribute to enhancing the sense of community (Moore and Trudeau 2020). Additionally, there has been growing interest in new energy-saving technologies and environmentally friendly building materials. Thanks to the professional work of Sim Van der Ryn (born in 1935), the application of physical and social ecology principles in architecture and environmental design has gained popularity.

In 1971, a young architect, Jacques Rougerie, in collaboration with a biologist, sociologist, and ecologist, all French, proposed Thallassopolis I, a city designed for 45,000 inhabitants, made up of connected floating villages. The proposal was intended for the western portion of the Banda Sea, aimed at serving the indigenous people of the Indonesian archipelago (Rougerie 1972; Rougerie 1977). The design solutions for living on the seas, like this one, were approached pragmatically, utilizing a wide range of technologies from both hard and soft sciences. Many of the technologies needed to inhabit extreme environments were developed in other fields. As a result, architects and other commentators sincerely believed that the colonization of the sea was imminent. In fact, it was thought that this new "continent" could become habitable within the next decade (MCHalej 1969).

In this atmosphere, architects, engineers, clients, and governments alike saw research and development in marine architecture as a worthwhile endeavor. They began designing and building prototype vehicles, laboratories, habitats, and infrastructure. Proposals for floating and underwater cities by architects were widely published in the architectural media between the late 1960s to the mid-1970s. Several of these speculative projects were eventually realized, including Jacques Rougerie's *Galathea* and 462 prototype cities at sea. Examples include *Aquabulle* in the early to mid-1970s, Cousteau's *Conshelf* experiments, and Kikutake's *Aquapolis* (1975) (Rougerie and Vignes 1978; Rougerie and Rougerie 2018).

This is an age of confusion as far as the man-made environment is concerned. Society lacks a unifying goal, and no comprehensive methodology has yet been developed to address our pressing issues. Values are in a state of flux, and new technologies are emerging at a rapid pace. Meanwhile, pollution has become a growing public concern, especially in the context of the global energy crisis. As a result, environmental planning has now reached a critical crossroads.

In designing *Aquapolis* for the Japanese Government Pavilion at the "International Ocean Exposition 1975" in Okinawa, Kiynori Kikutake conceived the structure as a model of a future marine city. It was equipped with a seawater distillation plant, water purification and circulation systems, and installations for harnessing tidal and solar energy. Thus, he designed *Aquapolis* as a self-contained biotope and a floating structure that was secure, mobile, and durable. Although Kikutake's ideas did not make a spectacular breakthrough at the time, they have been developed in the 21st century into visions of floating cities that are not only resilient to the effects of global climate change but that also perform environmental tasks to contain them.

The trajectory of global architectural discussions was captured during the first UN Habitat Conference ("Habitat I") in Vancouver in 1976. In many ways, the UN has returned to the Vancouver Declaration, calling for the adoption of "bold, meaningful, and effective human settlement policies and spatial planning strategies" and treating "human settlements as an instrument and object of development". A notable shift began in 2008 with Vincent Callebaut's *Lilypad*—a "floating ecopolis for ecological refugees". Where floating cities were once dismissed as too far-fetched, the concept has been reimagined and is re-emerging in public consciousness. This time, it is viewed as a politically viable solution to address the pressing climate emergency.

2.3. Climate Change and New Visions of Floating Cities

Human mobility is a primary coping mechanism in response to extreme weather events, and migration is a potential strategy for adapting to changing climatic patterns. The effects that scientists had predicted are now occurring, particularly changes in the frequency, intensity, and location of weather events like floods, storms, and droughts. These events may have impacts on human mobility, potentially leading to societal strains in many countries and perhaps at a global level (Laczko and Aghazarm 2010; Dal Bo Zanon et al. 2020). Recent research shows that in 2008 alone about 20 million people were displaced due to climate-related disasters. Slow-onset disasters appear to affect a far larger number of people than sudden events. For example: earthquakes, 134 million people; droughts, 1.6 billion people; floods, 2.8 billion people; volcanoes, 4.2 million people; and storms, 718 million people (Laczko and Aghazarm 2010).

In recent years, perhaps one of the most striking developments has been the decision to relocate a major metropolis, such as the Indonesian capital, Jakarta, to a new site. Jakarta, home to more than 10 million people, faces flooding from three causes: rising ocean levels, river flooding, and land subsidence due to the weight of skyscrapers, excessive groundwater extraction, and the resulting lowering of groundwater levels. The proposed plan involves moving the capital to a completely new location in Borneo. However, this is a pristine area, and environmental activists argue that this may not solve the problem but merely shift it elsewhere (Setiadi et al. 2020).

According to the NASA Socioeconomic Data and Applications Center (SEDAC), 40% of the Earth's population resides within 100 km of shorelines. A United Nations report predicts that 90% of the largest cities will be impacted by sea-level rise (UN-Habitat 2019). Given these circumstances, water may represent the last viable option for human settlement (Kirimtat et al. 2024). Recent research on sea-level rise has even suggested floating urbanism as an efficient strategy for managing risks associated with rising water levels (Baumeister et al. 2021; Setiadi et al. 2020).

The initial findings of the study indicate locations where floating cities could help reduce the risk of flooding and manage population growth. This is particularly evident in the case of fast-growing cities in Southeast Asia. Of the twenty-five cities identified, 64% are located in Asia, of which five are in China. Notably, the list includes only three cities from the United States, and none from Europe. This observation illustrates the global development trends consisting of dynamic population growth and increasing resource consumption. While the 25 cities identified are highly exposed to the risk of flooding and a significant increase in population, none have yet implemented their floating architecture projects. Geographically, the Netherlands stands out as the most advanced country in implementing floating architecture projects. Data suggest that factors favoring the concept of floating cities include territorial shortages (e.g., The Netherlands, Japan), the overpopulation of cities (e.g., China), as well as climate and energy threats that affect the global population. In response to these risks and threats, countries like the Netherlands and China are moving beyond theoretical discussions about floating cities and are beginning to implement experimental solutions (Peters 2016). Additionally, work on "blue urbanization" is receiving financial support from the European Union. As part of the Horizon 2020 Sea and Space project, a concept of modular platforms has been developed, which can be used to build floating structures for various purposes (Flikeema and Waalso 2019).

Hurricane Katrina in 2005 had a significant impact on the design of risk mitigation systems and shaped national approaches to risk and resilience. Being one of the largest hurricanes to hit the United States, it caused an estimated 1833 deaths and left millions of people homeless along the Gulf Coast and in New Orleans. Hurricane Katrina inflicted approximately USD 161 billion in damages (Robertson et al. 2007). In the aftermath of this disaster, urban planners and architects began searching for solutions that could address these new challenges (see Table 2). They envisioned new self-sufficient floating structures capable of adapting to unpredictable weather phenomena and helping mitigate the effects of climate change.

Appendix A shows the selected examples of floating urbanism envisioned over the past two decades. These proposed self-sufficient forms of water urbanism aim to address the main challenges for urban planners in the context of global climate change (see Table 3). These innovative concepts incorporate the latest technologies and are designed to integrate and manage various renewable energy sources, food production systems, and greenhouse gas reduction measures within one facility. The selected visions of floating cities presented in Appendix A are revolutionizing how we adapt to climate change and live together through environmental resilience and intensive energy transformation. These include both land-based settlement expansions, such as the Hong Kong Business District (2007), and examples of self-sufficient amphibious floating cities like Lilypad (2008) and Floating City (designed in 2014). Another broad category consists of anchored floating cities built on modular assemblies of floats. These cities are self-sufficient and maintain secure connections with the mainland, such as Dogen City (2021–2024), which aims to create a maritime economic zone and establish a new economic ecosystem utilizing the oceans' resources sustainably. These projects are not mere fantasies; they are blueprints for tomorrow, prototypes which are already being tested (e.g., Floating City by Slavomir Siska at AT Design Studio, Oceanix Busan by BIG-Bjarke Ingels Group, Floating City French Polynesia by Seasteading Institute, San Francisco, and Maldives Floating City by Waterstudio and Dutch Docklands). Now, the idea and visions of floating cities, once relegated to the sphere of science fiction, are becoming a tangible response to the challenges posed to urban design by climate change (Table 3), especially for coastal agglomerations. These challenges are redefining the approaches to urbanism developed in the second half of the 20th century. They integrate environmentally friendly technologies to minimize the environmental impact of floating cities. Based on the technologies used, three groups of projects can be distinguished.

The first group consists of projects that are intended for construction, as mentioned above. The technologies and structural solutions used in these projects are well established and have already been utilized in other facilities. For example, the Chinese construction company CCCC-FHDI commissioned AT Design Studio (with offices in England and China) to design a floating island utilizing the same technologies that CCCC-FHDI utilized to build a 51-mile island bridge between the cities of Hong Kong, Macau, and Zhuhai. The basic structural element of the floating island would be an underwater tunnel joined by a 150-m-long precast concrete box (Frearson 2014).

The second group consists of projects where the designers aim to combine traditional structural solutions and materials with modern technological advancements. An excellent example is the Oceanix Busan project by BIG-Bjarke Ingels Group, whose prototype consisting of three segments has already been implemented. Transsolar played a key role in the integrated design team, constructing three interconnected platforms for lodging, research, and living. Transsolar has also developed a climate-responsive energy concept targeting annual net-zero energy use, no fossil fuel consumption, and self-sufficiency for up to seven days. "Hydronic tubing integrated with the hull allows the platform itself to act as a giant closed-loop heat exchanger with the ocean for high-efficiency heating and cooling. Loads are minimized by maximizing the use of outdoor and mid-door spaces, such as the research winter garden, calibrating the facades of each platform to its specific needs, and applying a range of state-of-the-art architectural technologies" (Transsolar 2024, p. 1). These technologies draw spatial and material solutions directly from the tradition in this region, such as bamboo structures. Oceanix Busan aims to expand the city's unique character and culture to the surrounding water (Stanković et al. 2021). Similarly, the Maldives Floating City project builds on the local boating community's culture, using canals as the main infrastructure. Floating houses and other structures are designed in local style and made of local materials. The master plan, inspired by coral patterns both above and underneath the water surface, fosters favorable conditions for coral growth. The designers have developed a concept for a new generation of urban housing estates resistant to sea-level rise. This development offers security and development space in the Maldives. By combining green technology, commercial viability, and a new healthy lifestyle, the Maldives Floating City provides a sustainable solution for the challenges of rising sea levels (Stanković et al. 2021).

The third group includes projects inspired by living harmoniously with nature and using natural technologies to mitigate or adapt to climate change, aiming for a positive environmental impact and climate resilience. These projects present visions of floating cities for a new civilization that, according to the designers, will emerge when humanity faces the irreversible effects of climate change and rising sea levels. As coastal agglomerations and islands become submerged, a significant portion of the projected 250 million climate refugees will seek solutions through NGOs focused on water-based urbanization. Vincent Callebaut Architectures creates evocative visions of a new civilization called "The People of the Seas". Taking inspiration from living nature, such as the structure of the Victoria amazonica leaf (Callebaut 2008) and the shape of the crystal jelly Aequorea victoria (Callebaut 2015), they propose new methods of underwater urbanization that are self-sufficient in energy, recycle all waste (including plastics), and combat ocean acidification. Aequorea (designed in 2015) is one such project, envisioning the development of new technologies based on natural form-forming processes, such as natural calcification, similar to how seashells form by fixing the calcium carbonate contained in water to create an external skeleton (Callebaut 2015). Independence and self-sufficiency in raw materials are ensured by "algoplast", a new composite material that mixes algae with oceanic waste. For interior lighting, the project proposes the use of bioluminescence in double glazing, achieved by utilizing symbiotic organisms that contain luciferin, which emits light through oxidation (Callebaut 2015). The challenge of producing clean energy for transport without emitting CO_2 remains critical, and the technology is expected to provide a timely response. Hydrogen, which can be used to produce electricity and biofuel without emitting CO_2 or other pollutants, is currently a particularly promising clean energy option. It attracts the attention of major international scientific teams. In the late 1990s, it was discovered that sulfur microalgae switched from producing oxygen (classical photosynthesis) to producing hydrogen. This discovery inspired the concept of new production technology based on the photosynthesis of dihydrogen (i.e., gaseous hydrogen) from living micro-organisms such as seaweeds from the Chlamydomonas reinhardtii family, which contains hydrogenase enzyme (Callebaut 2010). Another notable project is the Green Float Island City (designed in 2010), a city designed to function like a living plant that continuously absorbs carbon dioxide (CO_2). As in other floating city visions, the Green Float Island City uses photosynthetic plants to recycle CO_2 directly from the atmosphere, which can then be combined to form more complex hydrocarbon fuels like butane (Quick 2010).

The considered visions of floating cities, although varying in functional and spatial solutions, as well as in the form of the proposed structures, each addresses basic issues important for mitigating or adapting to the effects of global climate change, such as the following:

- Net-zero energy achieved through the use of green power, enabling it to self-generate an amount of energy equal to its consumption;
- Waste management, including recycling methods such as microalgae processing, waste-to-energy conversion, and anaerobic digestion; ensuring that all waste is converted into either electricity, energy, recycled materials, or feedstock;
- Freshwater autonomy by continuously collecting rainwater and recycling it efficiently;
- Food autonomy by communal and individual farming;
- Circulation managed through shared mobility systems where integrated transportation modes reduce transportation demand. Living and public spaces designed within a 150-m radius of traffic connections;
- Carbon dioxide reduction achieved through the recycling of CO_2 into oxygen via photosynthesis.

Envisioned cities are designed as ideal places to live or run a business, offering a friendly, safe, and secure community with vast open spaces, along with extensive entertainment and recreational facilities. While these floating cities might seem like a science-fiction fantasy, these innovative projects could soon materialize in our world. The case studies (Table 4) and recent research on sea-level rise (SLR) have suggested floating urbanism as an efficient strategy for managing SLR risks (Setiadi et al. 2020; Baumeister et al. 2021). Currently, the majority of people live in coastal areas where infrastructure investment is substantial. These cities will continue to grow, as will the costs of coastal defense measures. In some cases, relocation may become the only viable solution (Dal Bo Zanon et al. 2020).

Table 4. Floating cities: environmental benefits and climate resilience.

Climate Resilience for Environmental Benefits	**Innovative Solutions**	**Example**
Reduce the long-term risks and resulting threats. The impacts of climate change exhibiting effects: flood risk, urban ventilation and cooling.	Adaptive Structures: Platforms with buildings that can rise with the tides, offering a dynamic solution to sea-level rise. Cooling Effects: The strategic placement of floating structures can help mitigate urban heat island effects, contributing to a cooler planet.	Arcology Habitat NOAH 2005–2009 Lilypad, 2008–2017 Hydrogenase, 2010 Aequorea, 2015 Dogen City, 2021–2024
Ecosystem restoration and enhancement. Integrating aquatic ecosystems into the urban fabric increases biodiversity and restores damaged marine environments.	Artificial Reefs: Structures designed to support marine life, creating new habitats and boosting local biodiversity. Clean Water Initiatives: Innovative waste management and water purification systems ensure a positive impact on water quality.	Perfumed Jungle, Hong Kong 2007 Maldives Floating City, 2020–2021 Lilypad, 2008–2017 Green Float Island City 2010–2025 Aequorea, 2015
Carbon dioxide reduction and oxygen production. CO_2 is the primary greenhouse gas contributing to recent climate change; absorbs and radiates heat.	Adaptive Green Structures: Recycling the atmosphere through greenery that cleanses, recycles, and rejects CO_2 into oxygen in the process of photosynthesis; the use of algae for oxygen (classical photosynthesis) production. Efficient photocatalyst processes; chemical reactions are induced by sunlight in the presence of a catalyst, e.g., TiO_2.	Perfumed Jungle, Hong Kong 2007 Lilypad, 2008–2017 Hydrogenase, 2010 Green Float Island City 2010–2025 Aequorea, 2015
Disaster risk reduction; Floating cities designed to weather storms could redefine disaster-resistant infrastructure.	Floods and Tsunamis: Naturally adaptive structures such as the following: - Buoyant foundations that float offer unparalleled protection against flooding, acting as a built-in life raft for its inhabitants. - Breakwater barriers as community-wide defenses against waves and storm surges, reducing the risk of water-related disasters. Sustainable Materials: From recycled plastics to bamboo, materials that withstand and respect the environment.	Arcology Habitat NOAH 2005–2009 Floating City, French Polynesia, 2017 Dogen City, 2021–2024 Aequorea, 2015 Oceanix Busan, 2008–2025 Maldives Floating City, 2020–2021

Sources: own elaboration.

2.3.1. Environmental Impacts and Climate Resilience

In the era of global climate change, floating cities are envisioned and designed to be safe and resilient against the threats posed by rising sea levels and increasingly frequent extreme weather events. These adaptive structures, such as platforms and buildings that float with the tides, provide a viable solution to the problem of sea-level rise. Floating city projects that have emerged in recent decades provide innovative solutions for coastal areas while harnessing the advantages of marine resources. They also demonstrate the potential to implement new strategies for protecting the marine environment. Furthermore, these projects offer a pathway to a sustainable future, where the built environment coexists harmoniously with nature rather than opposing it. By integrating ecosystem protection strategies into urban planning and design, floating cities could become models for sustainable coexistence with marine environments. Table 4 (below) summarizes the main environmental benefits and climate resilience that floating cities could achieve.

Table 4 shows only the main positive aspects of the impact that floating cities have on the environment, emphasizing their resilience to climate change as demonstrated by the projects analyzed in Table 4. However, the descriptions provided by the designers cannot serve as a sufficient basis for assessing this impact. A comprehensive assessment will also be required to understand the potential effects floating cities may have on marine ecosystems. For example, some studies suggest that artificial floating urban structures could attract populations of fish and other marine organisms, providing them with safe shelter. In doing so, these structures may contribute to the growth of fish stocks, as envisioned in the Floating City (2014) project by AT Design Studio (Frearson 2014).

Another potential positive impact of floating cities could be the protection of coral reefs through the creation of artificial reef-like structures. Submerged infrastructure components can mimic natural coral reefs, providing new habitats for various marine species such as crustaceans, algae, and fish, thereby supporting biodiversity. Developer Dutch Docklands and the architects of Waterstudio have conceptualized blue habitats that stimulate coral growth in their vision for the Maldives Floating City (2021). They propose using artificial coral banks attached to the underside of the city platforms to stimulate natural coral growth. This approach could lead to the creation of new coral reefs within the lagoon, which would act as natural wave breakers, reducing wave impact and providing additional comfort and safety when combined with the connected network of floating platforms (Maldives Floating City 2021). Currently, the largest artificial reef in the world is under construction in Dubai. This floating city, dedicated to marine research and regeneration, will also incorporate eco-tourism.

The negative impacts of floating cities on the marine environment are also anticipated. The construction and deployment of floating cities, along with associated drilling activities, such as platforms, pipelines, and seismic surveys can disrupt and destroy marine habitats (Deng and Guo 2024). Such disruptions not only affect species that rely on these habitants but can also destabilize entire ecosystems, reducing their resilience to environmental changes and threatening biodiversity. This is especially concerning for sensitive species like mangroves, coral reefs, and seagrass meadows, which provide important nursery grounds and food sources for other marine life (Scanes 2018).

The future operation of floating cities involves the risk of pollution, including the discharge of sewage and other pollutants into surrounding waters. Such contamination could degrade water quality and negatively affect marine ecosystems. For this reason, the designers of future floating cities (see Table 4) envision implementing state-of-the-art waste management systems to control and treat wastewater and pollutants. By adhering strictly to environmental regulations, these cities will minimize negative impacts on water quality.

Innovative waste management systems not only minimize the environmental impact but also provide valuable materials and energy back to the community (Farooq et al. 2022). The aim is for floating cities to achieve a near-zero waste lifestyle by using reusing and repurposing materials. Additionally, the environmental impact of floating cities can be further reduced by employing eco-friendly building materials and technologies.

2.3.2. Contemporary Achievements in the Implementation of the Idea of Floating Cities

Floating houses and floating estates are not new concepts today. For example, Amsterdam's Floating Neighborhood "Waterbuurt" is a state-of-the-art residential development that consists of 46 individual floating homes on 30 bars moored on Lake Eimer (McNulty-Kowal 2020). In the Netherlands, as in other countries, other ways of using floating structures are also being developed. One of them is floating agricultural production, designed to meet the needs of residents and reduce the need to transport food products from outside the city. For this purpose, abandoned port basins or water reservoirs surrounding the central urban areas are often repurposed. A notable example is the floating dairy farm project in Rotterdam (erected in 2019), a groundbreaking initiative already in operation

(Thesien 2018), such as the Multilevel Floating Farm in Singapore (Asgarov et al. 2020), (Davis et al. 2021). The size of these facilities is incomparable to the visions of floating cities for populations exceeding 10,000 inhabitants. One can indeed ask whether, in this era of digital technologies and rapidly evolving biomimetic innovations, the civilization of Earth's inhabitants is now capable of building floating cities.

Humanity has yet to gain experience in building floating cities in the open sea and deep waters. For years, various elements of floating architecture have been tested, but these structures are typically located along shorelines, often in the immediate vicinity of urban areas. The main technological challenge for floating cities lies in the dynamically changing weather conditions of the sea (Suzuki et al. 2006).

Two leading types of structures, known as very large floating structures (VLFS) with hydroelastic performance are currently leading the way in enabling the construction of cities on water. These platforms are already used in offshore mega-solar power plants, wind farms, and wave energy plants (Diaz and Soares 2020; Bispo et al. 2022). Shortly, these platforms could potentially be used to construct floating cities. Articulated floating modules, which can be connected to form large floating structures, offer a promising approach for the development of modular floating cities, similar to current projects like the Oceanix Busan (2008–2025), French Polynesia Floating City (2017), and Maldives Floating City (2020–2021) (Drummen and Olbert 2021).

In 2008, Dominik and Alex Michaels developed the concept of an Energy Island, designed to integrate various renewable energy sources (Schirber 2008). At the heart of the island would be the ocean thermal energy conversion (OTEC) power plant, surrounded by a 600-m-wide platform equipped with wind turbines and solar collectors. Additionally, wave energy converters and sea current turbines installed under the platform would provide additional energy. The OTEC system operates based on ocean heat conversion. It uses the temperature differences between ocean depths and ocean surface to evaporate and condense a working fluid, such as seawater, which in turn drives the turbine. The projected energy output would be 250 megawatts (MW), sufficient to power a small city. OTEC offers a significant advantage over other marine energy technologies because it can produce energy continuously, 24 h a day, year-round. Renewable energy generation at sea is more effective than land and offshore wind farms already supplying energy to national grids. However, wind energy is just one of many options. At this stage, energy islands could also provide power to existing coastal cities. The estimated cost of exporting electricity from these islands to the mainland ranges from USD 0.9 to 0.13 per kilowatt hour (kWh), compared to USD 0.8 for energy from offshore wind farms and USD 0.4 from coal power plants (Schirber 2008).

The examples presented show that humanity is constantly taking steps to enable the concept of self-sufficient floating cities. Ensuring self-sufficiency in food and energy will be key to the success of the idea of water urbanism (Dal Bo Zanon et al. 2017). Therefore, each experiment carried out in this field is important. Also, breaking down the barriers in colonizing water bodies for housing purposes, which is currently taking place in the Netherlands, brings us closer to the creation of floating cities.

3. Materials and Methods

This research seeks to explore how climate change is redefining the concept of living on water, with a particular focus on floating cities. In this context, the floating city refers to the theory and practice of building structures that allow people to live permanently on water-covered areas of the Earth. The objectives of this research are to review the existing research on floating cities through case studies and to collate and analyze the design, architectural, technical, and planning aspects of floating city visions and projects around the world. This research employed methods of historical review and critical analysis. These approaches helped trace the evolution of the floating city concept and identify the elements applied in the partial implementation of this idea. This research aims to review published visions (especially drawings, sketches, and visualizations) on floating cities through case studies and to collate and analyze the design, architectural, and planning aspects of floating city visions and ideas worldwide. These objects are treated as works of art that capture, in esthetic terms, the state of consciousness of the era in which they were created. We also recognize that this is appropriate in relation to the profile of the journal, which focuses on the conceptual dimension inherent in activity in the field of art. The technical aspects will be considered only when they are an integral element based on a given vision or creative idea. However, the innovative solutions and examples presented here are still science fiction. Therefore, it lacks integration of empirical, quantifiable, or comparative metrics to objectively assess the efficacy of the key ecological contributions of the floating cities presented here.

Underwater cities designed by architects were widely published in architectural magazines between the late 1950s and the 1970s. Seminal examples from this period include Kikutake's "Marine Cities" (1958–1963) and Kurokawa's plan for "Kasumigaura Floating City" (1961) developed by Metabolists in the early 1960s, Kenzo Tange's Tokyo Bay Project (1960), Warren Chalk's Underwater City (1964), Paul Maymont's Projects for Tokyo Bay and Monaco (1959–1964), Ron Herron's Walking City (1964) and Capsule Pier (1964), Peter Cook's Sea Farming project (1968), Edouard Albert's project for the coast of Monaco (1967), Jacques Rougerie's Universite de la Mer (1972), Ferme Flottante (1973), and Les Villages sous-marin (1973), Claus Jurgen's drawings and proposal for a submarine center (1971) and Olympic Games on the sea. From this period of speculative architectural activity, several projects were eventually realized, including Jacques Rougerie's "Galathea and 462 prototype cities at sea", Sandra Kaji-O'Grady and Peter Raisbeck's "Conshelf III and tender ship", Jacques Cousteau's (1963) Aquabulle and Conshelf experiments in the early to mid-1970s, and Kikutake's Aquapolis (1975); Kaji-O'Grady and Raisbeck (2005); Rougerie and Rougerie (2018).

Several key studies from this period were used in this research. Reyner Banham's "Megastructure Urban Futures of the Recent Past"(Banham [1976] 2020) presents the origins and ongoing legacy of the visionary urban megastructure movement. Banham explores its rapid rise, decline, and continued relevance.

"Metabolism in Architecture" (1977) by Kisho Kurokawa collects important architectural works and theoretical writings from the period between 1960 and 1975 (Kurokawa 1977). Additionally, the papers by Rafaele Pernice and Agnes Nyilas provide a comprehensive overview of the historical evolution of the concepts of "marina city" and "artificial urban floating land" within Japanese urban planning and architecture from the 1960s to the 1990s (Pernice 2009; Nyilas 2016; Nyilas 2018).

A useful source of information is also the paper titled "Tackling Climate Change, Air Pollution, and Ecosystem Destruction: How US Japanese Ocean Industrialization and the Metabolist Movement's Global Legacy Shaped Environmental Thought (circa 1950s–Present)" by Stefan Huebner (2020). This article examines the intellectual origins of eco-modernism and similar green growth strategies. The contributions of Kiyonori Kikutake and US ocean expert John P. Craven are at the center of this article. Huebner argues that their two prototypes of floating industrial complexes, tested in Hawaii and Okinawa in the early 1970s, were designed to decouple ocean industrialization from the destruction of ecosystems (Huebner 2020).

Agnes Nyilas' research "On the Formal Characteristics of Kiyonori Kikutake's 'Marine City' Projects Published at the Turn of the '50s and 60s'" (Nyilas 2016) was especially noteworthy. Her article also provided information about technical solutions and structural mechanisms proposed for floating platforms in Kikutake's projects (Nyilas 2018).

These studies allowed us to formulate the basis and considerations of the comparative analysis and to learn how the visions of floating cities sought to provide answers to the challenges posed by urbanism in the second half of the 20th century (Table 1). This primarily concerned new functional and spatial solutions for the city. New strategies and methods for shaping floating cities in response to the challenges were identified and discussed. After that, the group of visions or concept designs, such as Kikutake's 'Marine City' designs

(1950s to 1960s), were considered representative of the period. They are acknowledged as the earliest and most influential 'megastructure' designs of various scales, proposed during the major transition from CIAM to TeamX. A comparative analysis of these projects revealed characteristics that responded to the challenges faced by Modern Movement urbanism, especially in the post-war period. Moreover, they included new urban planning strategies where demographic growth, functional zoning, and mobility were recognized as an important feature and the key to the restructuring of modern cities.

At the beginning of the 21st century, the numerous hurricanes, earthquakes, and tsunamis that hit the coasts of North America and South Asia revived designers' imaginations. Architects and urban planners have faced new challenges. In the last two decades, interest in various floating structures, including floating cities, has generated an extensive body of research addressing specific questions about how cities and urban environments will interact with the challenges posed by global climate change, natural disasters, and hazardous events (Rosenzweig et al. 2011). A variety of proposals and visions aimed at resisting the effects of climate change have been widely published in architectural media between the late 2000s and 2023 (Suzuki et al. 2006; Baumeister et al. 2021; Stanković et al. 2021; Drummen and Olbert 2021).

They constitute the second group of visions considered and analyzed in this research. This group focuses on floating cities, which attempt to respond to the challenges posed by growing weather threats and rising water levels in the seas and oceans due to climate warming. These challenges are summarized in Table 2. Notable examples include the following: Schopfer's NOAH "Noah's Ark" 2005–2006 for New Orleans after Hurricane Katrina; Hong Kong 2007; Lillypad 2008 by Vincent Callebaut Architectures; Shimzu's Corporation, Green Float 2010; IwamotoScott Architecture "HydroNet"—concept for Tallinn's coastline, 2011; Jacques Rougerie, City of Meriens, 2014, AT Design, Floating City, 2014; Vincent Callebaut's Aequorea for Rio De Janeiro (2015)—oceanscraper printed in 3D from the seventh continent's garbage; Vincent Callebaut's Lilypad (2008–2017)—floating ecopolis for climate refugees; Koen Olthuis's (Waterstudio) Maldives Floating City (current); Koen Olthuis's Rose City, Jeddah (2017); TOPCON/Blue21, Floating SMART City project in the North Sea, 2017; Dominik and Alex Michaels, Energy Island, 2017; Bjarke Ingels, Oceanix for Busan (2021); N-Ark's floating city for Dogen; Estudio Focaccia Prieto's Polimetropolis—the vision of the urbanization of the Great Pacific Garbage Patch; URB's floating city for Dubai (2028); Luca Curci and Tim Fu's Floating City (worldwide); Neom development vision for Oxagon's floating city on the Red Sea coast (Saudi Arabia 2030). Selected examples from this group were analyzed and discussed to identify new strategies and methods for shaping floating cities in response to the challenges posed by global climate change.

An important source of information on ongoing climate change has been the annual reports from the Intergovernmental Panel on Climate Change (IPCC). These reports provide comprehensive assessments of the immediate and future impacts of climate change, along with options for Climate Scenario Development (IPCC 2007). The IPCC Special Report (2021) also highlights the characteristic features of hydrometeorological and oceanographic phenomena (Douville et al. 2021). The IPCC further notes that limiting adaptation measures to address rising sea levels without taking into account actual economic, social, political, and industrial adjustments could result in higher costs and greater damages (IPCC 2023).

The applied comparative analysis of two different periods, during which the vision of floating cities was created, revealed both differences and interdependencies in the approaches to understanding and shaping floating urbanism. These differences primarily stem from changing external conditions and technological advancements, which present new challenges for the built environment, particularly cities. The findings of this analysis are presented in tables and summarized in diagrams.

4. Discussion

Kiyonoru Kikutake's visions of floating cities, while reflecting the Metabolists' biomimetic approach, introduced a new way of thinking about floating cities in the ocean—as sustainable and self-sufficient living organisms. This idea is also present today, though the goals and principles have changed. In the 21st century, the focus is no longer on expanding territories, exploiting raw materials, or colonizing oceans to accommodate the planet's ever-growing population. Instead, the emphasis has shifted to survival. The growth of urban areas, coupled with the increasing threat of climate change, has intensified the need for alternative living solutions. However, capitalist society where the primary goal is profit is often reluctant to embrace changes that benefit the climate, especially when those changes might threaten profitability. In such a system, profit and economic success take precedence over all other considerations, including the environmental and social aspects.

Water urbanism offers self-sustaining communities that could serve as a solution for a world gasping for space and sustainable development. The comparative analyses of the selected examples (Appendix A) reveal new aspects that have gained significance, as well as those that have diminished in importance, in the vision of floating cities. Table 5 shows the evolution of energy management approaches from the industrial age to the post-industrial era.

Table 5. Energy-managing approaches in two ages.

Kikutake's Approach: Industrial Capitalism Era		Climatic Sustainable Development and Ecology: Postindustrial Era
Manifestation of achievements in technology based on burning coal and oil	→	Manifestation of blue technology achievements based on renewable energy sources
Uncontrolled CO_2 emissions	→	Reduction in and control of CO_2 emissions
Extension of coastal cities for more space for both industrial and residential use	→	Efficient strategy for managing sea-level rise
Relocating waste and pollution to disaster-resilient floating structures in oceanic zones	→	All waste converted into electricity, or either energy or recycled materials
Mobility as the key to the structuring of the modern industrial city	→	Climate resilience and withstanding of natural disasters
A city as a flexible organism where its connections and its parts could grow; transform themselves	→	A city adapted to the conditions consistent with the changing characteristics of the climate and ecology.

Sources: own elaboration.

The boundary between the industrial and post-industrial ages in the Western world was marked by the first quarter of the 1970s. The publication of the *Limits to Growth* report by the Club of Rome and the sudden 1973 energy crisis characterized by shortages of fossil fuels made it clear that the industrial model of development was reaching its limits. However, it took another 20 years to change the way we think about humanity's relationship with nature, leading to the recognition that despite all the achievements of civilization, we remain an integral part of the natural world. During this period, new concepts such as sustainable development, eco-development, and integrated planning began to emerge.

Designs based on ecological and sustainable principles have the potential to significantly reduce the environmental impacts of artificial islands on natural habitats (Table 6). According to the widely accepted definition, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Despite the frequent advocacy for sustainable development today, humanity still faces challenges in effectively implementing this doctrine. The global civilization trends that initially sparked the visions of floating cities in the 1960s and 1970s have continued to gain momentum.

Table 6. Main urban data and environmental profits of presented floating cities.

Facility Name	Population	Geometry	Environmental Profits
Arcology Habitat NOAH 2005	40,000	Diamter 500 m, deep 15.24 m	- Production of electricity and biofuel without emitting polluting substances; - Efficiency by the use of passive strategies integrated in the overall sustainability ecosystem of the building;
Perfumed Jungle, Hong Kong 2007	n.d.	2700 m long	- Recycling the atmosphere by arborescent towers (the rejections of CO_2 by photosynthesis); - Biologic purification by lagoons; - Recovery of local fauna and flora by topography which can be infiltrated by the numerous species of the fauna and local flora that will be installed; - Supporting the passive strategies integrated in the overall ecosystem; - Using the metabolism of the ecological towers to produce electrical energy or thermal energy by cogeneration (from combustible rejections) to reinsufflate the urban network; - The newly built spaces are auto sufficient and produce more energies and biodiversity than they consume; - Zero carbon emissions.
Lilypad 2008–2017	50,000	500,000 m^2	- Soft water collecting and purifying the rain waters; - Zero CO_2 emissions by the integration of all the renewable energies (solar, thermal and photovoltaic energies, wind energy, hydraulic, tidal power station, osmotic energies, phytopurification, and biomass) producing thus durably more energy than it consumes; - Absorption of the atmospheric pollution by photocatalytic effect (TiO_2); - Entirely recyclable double skin made of polyester fibers covered by TiO_2; - Recycling the CO_2 and the waste; - Self-sufficient in food supply and recycles waste; - Zero CO_2 emissions.
Green Float Island City 2010–2025	Max. 1,000,000	Diameter 3000 m	- Absorption of carbon dioxide (CO_2); - CO_2 recovery and ocean sequestration; - Solar power generation in space; - Power generation using ocean thermal energy conversion; - Wave power generation; - Cooling system for aerial city; - Self-sufficient in food supply and recycles waste; - Food self-sufficiency by providing a vertical vegetable factory; - Zero emissions and recycling.
Hydrogenase 2010	n.d.	Diameter 180 m	- Use of algae for oxygen (classical photosynthesis) production; - Produce by photosynthesis of dihydrogen (i.e., gaseous hydrogen) from living micro-organisms such as seaweeds from the "Chlamydomonas reinhardtii" family with the enzyme of the hydrogenase type. - Produce electricity and biofuel without emitting CO_2 or other polluting substances; - Recycle up to 80% of carbonic gas and NOx (nitrogen oxides are also very impactful on greenhouse gas emissions).
Floating City 2014	50,000	10,000 m^2	- Improving biodiversity; - Zero CO_2 emissions; - Industry's ability to produce without emit polluting substances; - Producing oxygen by photosynthesis; - Improving the marine biodiversity; - Recycling carbonic gas and Nox.

Table 6. *Cont.*

Facility Name	Population	Geometry	Environmental Profits
Oceanix Busan 2008–2025	10,000	750,000 m^2	- Circular waste management; - Improving biodiversity; - Supporting the passive strategies integrated in the overall sustainability ecosystem of the city; - Coastal habitat regeneration; - Recycling plastic garbage (bottles, cans, bags, and other types of packaging); - Filtration of ocean water and removing the plastic microparticles suspended at depths of 10 to 30 m.
Aequorea 2015	20,000	500 m width	- Energy self-sufficient; - Recycling all waste and ocean acidification; - Zero carbon emissions; - Recycling CO_2 by using greenery; - Recycling 2500 tons of additional CO_2/km^2 by using aragonite (which has a high carbon component) as the construction material for its transparent façades; - Obtaining light by using symbiotic organisms that contain luciferin which emits light through oxidation.
Floating City, French Polynesia 2017	30,000	Diameter ca. 900 m	- Improving the marine biodiversity; - Zero CO_2 emissions; - Run on solar power and continuously gather and recycle its water from the ocean; - Energy self-sufficient.
Maldives Floating City, 2020–2021	15,000	200 ha	- Stimulating coral to grow naturally; - Improving the marine biodiversity; - Preserve and enhance the pristine marine ecosystem using innovative sustainable development technologies and applying ecological best practices.
Dogen City 2021–2024	40,000	Diameter 1580 m	- Improving the marine environment.

Sources: own elaboration based on data from Appendix A.

Over the past two decades, a wide range of proposals and visions for combating the effects of climate change have been published by architects, engineers, and spatial planners in the architectural media. These visions redefine floating urbanism, pushing the boundaries of imagination toward new advanced technologies, often based on biomimetics and renewable energy sources. They have conceptualized ideas involving renewable energy, such as innovative solar panels and wind turbines atop floating structures, as well as sustainable waste management, water desalination, and even aquatic agriculture or "blue farming". The concepts presented vary from completely realistic to hypothetical applications of scientific research or concepts that have yet to be fully implemented, envisioning how such innovations could be used for climate change mitigation or adaptation in floating cities of different scales. From this array of visions and pro-climate approaches, a common theme emerges: the potential to meet the challenges posed to the built environment by global climate change.

This approach could be called Climate Change-Oriented Urban and Architectural Design, defined as the adaptation of urban and architectural conditions to align with changing climate characteristics and ecological needs. In urbanism, this concept redefines patterns for creating an urban fabric that functions as an ecological substrate, supporting the spatial structures of new cities. Vincent Callebaut Architectures implemented continuous perforated cell layers as an ecological substrate in the design of the Floating Central Business District in Hong Kong (2007) (Callebaut 2007). A similar approach is currently being developed at the Rensselaer School of Architecture through the "Geofutures" program (Januszkiewicz and Gołębiewski 2020). In architecture, the term redefines the design process, viewing it not as the creation of a material object but as the multitude of effects, the milieu of conditions, modulation, and microclimates. This emanates from the exchange between the built object and its specific environment, where the exchange between the two creates a dynamic relationship perceived by and interacting with a subject (Januszkiewicz and Gołębiewski 2020).

This type of design seeks to eliminate negative environmental impacts through skillful and sensitive planning. This requires a broader perspective that places a heavy emphasis on interdisciplinary aspects. The primary mission of climate change-oriented design is to cultivate the designer's ability to interpret and implement environmental systems thinking. Therefore, by integrating climate-oriented design principles during the architectural and construction phases, it becomes possible to create more sustainable and climate-friendly built environments.

The variety of strategies available today for mitigating the environmental impact of buildings is indeed very broad, spanning technical, educational, administrative, and political measures. However, the barriers, limitations, and costs associated with their effective implementation still need to be estimated and understood. Nevertheless, in an attempt to provide straightforward guidelines for the integrated and sustainable design of buildings and settlements, there is the inherent risk of providing recommendations that are either too narrowly tailored to specific circumstances or too vague to be actionable. Critical factors such as thermal performances, ventilation, light distribution, and visual comfort must be carefully balanced according to unique environmental contexts, climate scenarios, and technical constraints of each project. In addition, architecture is expected to go beyond merely acting as a filter against the elements; it must also provide the service functions to which users have become accustomed. This raises a practical challenge: How can building design evolve to satisfy contemporary needs while simultaneously reducing energy consumption and environmental impacts? In the case of floating cities, even greater advancements are required, particularly in areas such as unitization and robotic construction, which are more critical than in traditional land-based cities. Although construction plans for floating cities are still largely conceptual, structural engineering will continue to advance through future model projects and prototypes.

In the last decade, the United Nations Framework Convention on Climate Change (UNFCCC) has been supporting, promoting, and directly funding several initiatives aimed at identifying priority actions for responding to urgent needs concerning adaptation to climate change. These initiatives have primarily focused on the least developed countries, which are more vulnerable to climate change and less able to adapt to its consequences. Key initiatives include the Special Climate Change Fund (SCFF), established in 2001 to finance adaptation related projects, the Least Developed Countries Fund (LDCF), created to support the preparation and implementation of National Adaptation Programmes of Action (NAPAs) for vulnerable economies. Additionally, the Adaptation Fund, introduced under the Kyoto Protocol, provides financial support for concrete adaptation projects in developing countries.

Redefining the principles of urbanism in response to climate change, especially through the concept of floating cities, has become an essential step for humanity to survive on planet Earth. Floating cities drifting in the oceans still have an important role to play before the catastrophic visions come true in which most of the land on earth is submerged. Floating cities or floating structures can support existing coastal cities in their sustainable development by offering a new flood-proof living space for residents, fresh air by recycling CO_2, clean energy, as well as food and biofuels. By integrating these features, floating cities have the potential to mitigate the negative factors affecting climate change. Can floating cities save us?

The analyses of representative concepts and examples of floating cities (Table 4) show that these facilities are also designed to perform specific tasks and have certain environmental abilities. Environmental tasks include primarily ensuring safety through resilience to weather threats such as earthquakes and tsunamis, waves and winds (typhoons), sea-level rise, and other natural disasters, as well as recycling CO_2 and waste. The entire structure of the floating city, including municipal buildings and facilities, should contribute to meeting these goals. Environmental abilities refer to the capacity of buildings and structures to adapt to changing environmental conditions through their structural and material behavior.

However, it can also include spatial behaviors such as the adaptability of design, arrangement, and the utilization of internal spaces according to expected environmental conditions. For example, in hot arid climates, occupant spatial patterns—such as relocating activities inside the house according to the seasons and time of day—have provided significant improvements in occupant comfort without the need for any energy-consuming system.

For over a decade, innovative structures, materials, components, and systems have been developed to create more active building envelopes that are responsive, adaptive, and protective in the face of variable and extreme climate conditions (Beasley et al. 2006). In this sense, "buildings envelopes are treated as 'environmental valves' regulating the transmissions of energy, light, air, moisture, and information between interior and exterior" (Januszkiewicz and Paszkowska 2016, p. 516). Modern architecture is expanding to include both built and natural realms, focusing on dynamic systems and environments at various scales, and it will often be connected to other parts of the building, including sensors, actuators, and command wires from the building management system (Wigginton and Harris 2006). A well-known example of this new kind of building envelope is the Media-TIC building (2007–2011) in Barcelona, designed by Cloud 9, which incorporates active technologies. Another example is Al Bahar Towers (2010–2012) in Abu Dhabi, designed by Aedas architects and Arup engineers, whose outer coating regulates solar energy through a responsive building envelope. For floating cities, the need extends beyond just responsive building envelopes; these cities also require a networked structure capable of sensing environmental changes, such as weather threats, and responding dynamically with programmed, designed logic (Beasley et al. 2006). Today, with the use of parametric and multi-criteria optimization digital tools, the built environment can be designed to respond to various environmental requirements.

Nevertheless, the question arises: What environmental data should designers address to creatively leverage dynamic transformations and interactions, and which responsive systems will deliver the expected outcomes? These considerations are giving rise to a new field of multidisciplinary scientific research that integrates art and architecture. The findings from this research are expected to improve the potential positive impact of floating cities on marine ecosystems. The oceans are an invaluable asset to our planet, playing a crucial role in regulating climate impacts. Tiny marine organisms, such as phytoplankton, are essential for understanding the global carbon cycle. Oceans contain 60 times more carbon than the atmosphere and absorb nearly 30% of carbon dioxide (CO_2) emissions produced by human activities (Rohr et al. 2023).

In the second half of the 20th century, the sea was largely viewed as free territory, open to uncontrolled exploitation of natural resources. However, in the 21st century, the oceans have come to be recognized as a common good, representing a potential new living environment for the inhabitants of Earth. This shift raises critical questions about the political status of floating cities. As these cities are envisaged as self-sufficient, environmentally friendly, and climate-resistant floating organisms, sustained by their own food and energy resources, there is a growing argument for granting them significant political autonomy. This perspective is championed by the Seasteading movement headed by the Seasteading Institute; a nonprofit organization based in San Francisco. The movement seeks to create human-made ecosystems of communities designed to grow, adapt, and transform over time.

5. Conclusions

The concept of life on water can be traced back to antiquity, as seen in stories like *Odysseus* and *Noah's Ark* in the Bible. However, as a subject of serious consideration by engineers and scientists, the concept of floating cities has gained wider attention since around the 1970s. In this article, we have presented the most significant concepts of floating cities from different eras. These ideas often reflected the most progressive ideologies of their time and hinted at future technologies and systems in their early stages. Thus, we begin with the futuristic visions of the Metabolists in the 1950s, with a special focus on the work of Japanese architects. We then explore the growing influence of ecological thinking in urban planning and architecture, which flourished after the 1973 energy crisis, spearheaded by figures like Ralph Erskine. In the continued exploration of examples and the evolution of the idea of living on water, we observe a growing awareness of the importance of water in urban planning. There is a noticeable restoration of water's role in the conception and functioning of cities, a role that was taken for granted from ancient times up until the industrial era. In ancient times, cities and settlements were predominantly located near reservoirs or watercourses, which provided defense, drinking water, food, transportation infrastructure, and sanitation. However, as cities expanded in size and the industrial era emerged, cities began to move away from water. Waterways and reservoirs shifted to serve primarily as waste receptacles, increasingly enclosed and built over.

The emergence of the ecological trend in urban design and planning has revitalized the role and multifaceted importance of water in shaping urban environments and the living conditions they offer. This shift has been reinforced by the principle of sustainable development, which has dominated the development paradigm since the early 1990s. The principle is reflected in concepts such as integrated design and sustainable housing estates. However, the full importance and potential threat of water to urban areas, along with the concept of cities built on or coexisting with water, has been highlighted by the growing awareness of climate change and its consequences.

Floating cities will also need intelligent systems to manage limited space and available resources efficiently. Current intelligent systems for "smart cities" have begun to use innovative solutions such as the Internet of Things (IoT), big data, and cloud computing technologies to develop effective connections between various components and city layers. The concept of a "smart" floating city should also consider human needs in selecting and integrating key technologies for environmental monitoring and improving the quality of life. This includes monitoring weather, environmental conditions, public transport, and managing people flows. In this article, we clearly distinguished this shift and highlighted the impact of this phenomenon on how decision-makers and planners perceive and approach the water environment.

Analyzing the interrelations between the visions of floating urbanism presented above (Table 4) and the main challenges for urban designers in the context of global climate change (Table 3), it is evident that the primary tasks facing urban design today are the following:

- Developing new guidelines and patterns for creating an urban fabric that serves as an ecological substrate for the functional and spatial structures of new cities; and
- Elaborating guidelines for transforming the existing built environment into efficient urbanism and an economy without greenhouse gas emissions.

These challenges redefine the approach to urbanism that was developed in the 20th century. In the second half of the 20th century, urban design was largely associated with architects, landscape architects, and planning specialists. However, as cities worldwide face pressures of economic restructuring, mass migration, and climate change, urban design is evolving rapidly. Today urban design should extend beyond its traditional scope to include new areas of knowledge, addressing not only urban ecology but also ocean ecology, water infrastructure, and the construction of floating structures.

The ongoing development of blue technology today offers a new perspective on the ocean, transforming it into a space that can be utilized for scenic living, commerce, recreation, and the regeneration of marine ecosystems.

However, the new civilization that will emerge from the climate revolution will also need to address pressing challenges such as climate resilience, dynamic urban development, overpopulation, the shrinking availability of living space on land, and the depletion of natural resources. In the 21st century, envisioned floating cities offer more than just an innovative way of living—they present a new pathway to a sustainable future, where our urban environments function in harmony with nature rather than in opposition to it.

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Appendix A

The additional table consists of data characterizing selected examples of concepts of floating cities.

Table A1. Selected concepts of floating urbanism envisioned during the past two decades (2005–2024).

Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Arcology Habitat NOAH 2005–2009  Design: Kevin Schopfer Location: New Orleans, Mississippi River Image source: https://www.designboom.com/ (accessed on 14 September 2024).	Floating intervention housing estate (for extreme weather events). **Type:** The anchored floating city. Population: 40,000 inhabitants. **Building Structure:** 300 m tall triangular framed megastructure. **Floating structure:** A water-filled basin, approximately 500 m in diameter and 15.24 m deep in which the NOAH foundation floats thanks to a multi-cavity hull at the base of the structure. **Connection with land:** High-speed rail and bus system. **For living:** 20,000 residential units, three hotels, and a few casinos. Additionally: a school system, healthcare facilities. **Food autonomy:** Hydroponic vertical farms. **Waste management:** Including recycling (e.g., with using microalgae), waste to energy.	**Resistance to:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** - Responding to changeable weather phenomena; - Efficiency by the use of passive strategies integrated in the overall sustainability ecosystem of the building. **Environmental abilities:** - Ability to withstand extreme weather: wind, flooding, and other natural disasters (tsunamis, hurricane and the equivalent); - Supporting the passive strategies integrated in the overall sustainability ecosystem of the built environment; - Produce electricity and biofuel without emitting polluting substances.

Table A1. *Cont.*

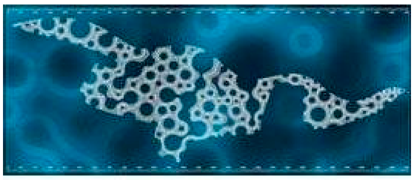
Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Perfumed Jungle, Hong Kong 2007     Design: Vincent Callebaut Architectures Location: South China Sea Image source: https://vincent.callebaut.org/ (accessed on 14 September 2024).	Floating central business district—the ecological amphibious master plan. **Type:** The anchored floating city. **Expanding the territory of the coastal city** using a continuous layer pierced with cells as an ecologic substrate for the elaboration of the urban fabric. **Area of water surface:** 2.7 linear km. **Spatial organization:** Integrated system of multi-functional urban units. **For transport:** A mesh of irregular cells integrates all the relevant modes of transport (airport rail, underground rail, ferries, fast boats, private yachts), various circulation roads. **For living:** Continuous open space between the cells overlap in alter- nate rows and spaces inside the ar- borescence towers which are dedicated to the private sphere of the housing. **For work:** Spaces «outside » the branches towers are dedicated to the bureaucratic service sector and leisure. **For well-being:** Open-air swimming pools, marinas, new quays and pedestrian sections, bicycle paths, piers, swamps, oceanography museums, and subaquatic operas. **For food production:** Cascade of aquatic and vegetable terraces. **Waste management:** Including recycling (e.g., with using microalgae) and waste to energy.	**Resistance to:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** - Recycling the atmosphere by ar- borescent towers, (the rejections of CO_2 by photosynthesis); - Biologic purification by lagoons; - Recovery of local fauna and flora by topography which can be infiltrated by the numerous species of the fauna and local flora that will come to be installed. **Environmental abilities:** - Ability to withstand of natural disasters; - Supporting the passive strategies integrated in the overall ecosystem; - Using the metabolism of the ecological towers to produce electrical energy or thermal energy by cogeneration (from combustible rejections) to reinsufflate in the urban network; - The newly built spaces are auto-sufficient and produce more energies and biodiversity than they consume; - Zero carbon emissions. **For recycling the atmosphere:** a field of techno-organic towers on which the structure grows vertically along the trunk with many ramified arborescent branches; A fishnet envelope profiles the environ-mental façades.

Table A1. *Cont.*

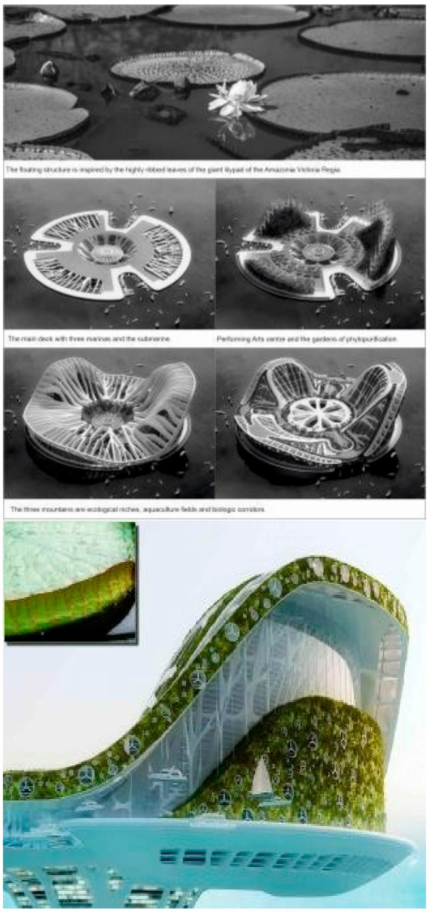
Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Lillypad 2008–2017  Design: Vincent Callebaut Architectures Location: Oceans Image source: https://vincent.callebaut.org/ (accessed on 15 September 2024).	Floating ecopolis for climate refugees auto-sufficient amphibious city. **Type:** Independent of shore seasteads. **Area of water surface:** 500.000 m^2. Population: 50,000 inhabitants. Spatial organization: Non-modular structures, integrated multi-functional system of space and structures. **For circulation:** All the relevant modes of mobility. **For living:** The living area is covered by a stratum of planted housing in suspended gardens. **For work:** Hydroclimatic factors for food production. **For public use:** Commercial, cultural, entertainments, and sport facilities. **For food production:** Biodiverse farming in the central lagoon. The ecopolis is directly inspired of the highly ribbed leaf of the great lilypad of Amazonia Victoria Regia increased 250 times. Double skin is made of polyester fibers covered by a layer of titanium dioxide (TiO_2).	**Environmental tasks:** - Soft water collecting and purifying the rain waters; - Zero CO_2 emission by the integration of all the renewable energies (solar, thermal and photovoltaic energies, wind energy, hydraulic, tidal power station, osmotic energies, phytopurification, and biomass) producing thus durably more energy than it consumes. **Environmental abilities:** - Ability to withstand natural disasters (tsunamis, hurricanes, and the equivalent); - Absorption of the atmospheric pollution by photocatalytic effect (TiO_2) - Entirely recyclable double skin made of polyester fibers covered by of TiO_2; - Recycling the CO_2 and the waste; - Self-sufficient in food supply and recycling of waste; - Zero CO_2 emissions. **Resistance to:** - Earthquakes and tsunamis; - Waves and winds (typhoons, hurricanes); - Sea-level rise.

Table A1. *Cont.*

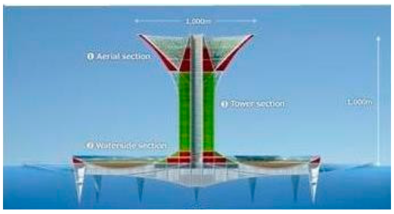
Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Green Float Island City 2010–2025    Design: Shimizu Corporation Location: equatorial region of the Pacific Ocean. Image source: https://newatlas.com/green-float-ocean-cities/16896/ (accessed on 16 September 2024).	Environment-friendly floating city. **Type:** Independent offshore seasteads. **Population:** Up to 1 million people. **Spatial organization:** Integrated system of multi-functional floating units. **Strategy of growth of the city:** By adding more units when the population increases. It aims to create a city that functions like a living plant and continuously absorbs carbon dioxide (CO_2). **Floating city cell:** 3000 m in diameter with a central tower 1000 m in height. **For living:** A daily life zone on the top of the tower (home to 30,000 people) sits above 700 m in elevation, with a constant temperature ranging between 26 and 28 degrees Celsius; the beach front residential areas, with a population of 10,000 people on the outer circumference of the structure. **For work:** Plant factories into the middle stem part of the tower, outer natural farms and artificial lagoon. **Waste management:** Including recycling waste to energy. The megacity requires unitization and robot construction more so than a city on land.	**Resistance to natural phenomena:** Locating the city at a low latitude near the Equator. **Environmental tasks:** - Withstanding of natural disasters; - Maintaining a pleasant and comfortable temperature in the living zone all year round; - Providing drinking water by storing rainwater (the rainy seasons) and controlling its consumption throughout the city; - Formation of diverse ecosystems in rural and coastal areas; - Creation of shallow ocean space (inland sea); - Creation of a mangrove as an ecotone (buffer zone); - Maintenance of tropical rainforest and securing of a brackish water zone. **Environmental abilities:** - Absorption carbon dioxide (CO_2), - CO_2 recovery and ocean sequestration, - Solar power generation in space, - Power generation using ocean thermal energy conversion, - Wave power generation, - Cooling system for aerial city, - Self-sufficient in food supply, and recycle waste, - Food self-sufficiency by providing a vertical vegetable factory, - Zero emissions and recycling.

Table A1. *Cont.*

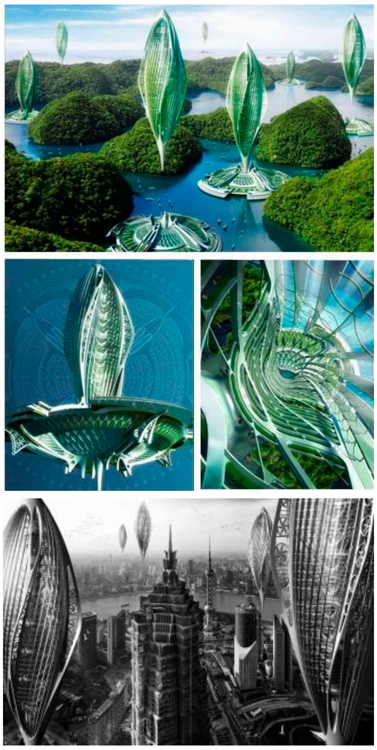
Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Hydrogenase 2010  Design: Vincent Callebaut Architectures Location: Shanghai, South China Sea Image source: https://vincent.callebaut.org/ (accessed on 17 September 2024).	Floating algae farm and bio-hydrogen airship (emergency housings, scientific laboratories, freight) as a new generation of state-of-the-art hybrid airships. **Type:** Independent offshore seasteads. Hydrogenase is a jumbo jet vessel (DGP) that flies at an average of 2000 m high. This cargo measures almost 400 m high for 250,000 m^3. It can carry up to 200 tons of freight at 175 km/h (i.e., twice the speed of a ship and more than one and a half times more than the one of a truck). Seven times slower than an airplane, it has an action potential between 5 and 10,000 km and re-teaches our contemporary travelers the long time of sea cruises and the praise of the slowness. The history of the transports which was, until now, summarized in a study, reveals to always go faster and is finished soon for the benefit of "better travel" in airship. **Important data:** Freight: 200 tons; speed: 175 km/h; action field: 5–10,000 km; height: 480 m; diameter: 180 m; surface area: 350.000 m^2; inhabited floor count: 67; agricultural fields: 8; wind turbines: 20; hydro prollers: 32.	Hydrogenase is a semi-rigid not pressurized airship. **Environmental tasks:** - Produce electricity and biofuel without emit polluting substances; - Humanitarian missions, rescue operations; - Installation of platforms for scientific studies, and of course to air freight; - Complementary activities such as the following: entertainment, eco-tourism, hotels, human transports, air media coverage; and territorial waters surveillance; - Environmental impacts management via innovative strategies. **Environmental abilities:** - Use of algae for oxygen (classical photosynthesis) production; - Produce by photosynthesis of dihydrogen (i.e., gaseous hydrogen) from living micro-organisms such as seaweeds from the "Chlamydomonas reinhardtii" family with the enzyme of the hydrogenase type; - Produce electricity and biofuel without emitting CO_2 or other polluting substances; - Recycle up to 80% of carbonic gas and NOx (nitrogen oxides are also very impactful on greenhouse gas emissions).

Table A1. *Cont.*

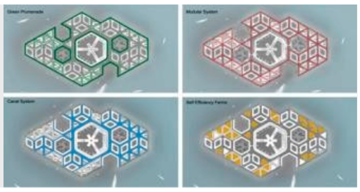
Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Floating City 2014     Design: CCCC-FHDI & AT Design Office Slavomir Siska. Location: On the sea Image source: https://www.dezeen.com/2014/05/13/floating-city-at-design-of-fice/ (accessed on 17 September 2024).	Floating City as an ocean metropolis with underwater roads and submarines. **Type:** Independent offshore seasteads. **Population:** 50,000 aquanauts area of water surface: 10 square km floating island. **Spatial organization:** Integrated system of multi-functional units. Basic unit: a prefabricated block—(150 m × 30 m). **For circulation:** Internal and external traffic system via canals above and below the water. Underwater tunnels with walkways and roads permit horizontal communication. **For living:** A new urban nucleus of world-class residential complexes. All living spaces have traffic connections within its 150-m radius, enjoying proximity to local facilities, services, public transport, and gardens. A club located at the top of each block and a gravity regulation system located at the bottom. **For public use:** Commercial, cultural, and sport facilities. For recreation: two public greenbelts, one on the water surface and one under water, and vertical gardens interconnected with this public greenery system. **For work:** A production base and manufacturing factory in the upper part of the triangle plot. **For power:** Tidal power generation device is located in the lower part of the triangle plot. **For food:** The peripheral area houses, farms, and hatcheries (self-efficiency). **Waste management:** Including recycling waste to energy.	**Resistance to natural phenomena:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** - Noise, waste, and other environmental impacts management through innovative strategies; - Improving biodiversity; - Complementary activities such as the following: entertainment, eco-tourism, hotels, human transports, air media coverage, and territorial waters surveillance; - Supporting the passive strategies integrated in the overall sustainability ecosystem of the city; - A resilient and a typhoon-proof habitat. **Environmental abilities:** - Withstanding of natural disasters (tsunamis, hurricanes, and the equivalent); - Zero CO_2 emission; - Industry's ability to produce without emitting polluting substances; - Producing oxygen by photosynthesis; - Improving the marine biodiversity; - Recycling carbonic gas and NOx.

Table A1. *Cont.*

Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Oceanix Busan 2008–2025     Design: BIG—Bjarke Ingels Group, Prototype: UN-Habitat, Transsolar, Location: on the sea, Busan, Image source: https://big.dk/projects/oceanix-city-6399 https://big.dk/projects/oceanix-busan-4711 (accessed on 17 September 2024).	Design and a prototype for sustainable floating cities. **Type:** The anchored floating city area of water surface: it has yet to determine the size of the habitat (10,000 people can live in an area of 75 hectares). **Population:** 10,000 residents. **Spatial organization:** Modular structures, integrated system of multi-functional series, floating platforms with modular buildings (not rising more than seven levels). The platforms are dedicated separately to shelter, culture, healthcare, and other necessary structures with a special electrified limestone coating that strengthens with age. **Basic unit:** Each small hexagonal composition of modular islands contains 12 hectares and can accommodate 1650 people. **For energy:** Incorporates systems for obtaining renewable energy (such as underwater and wind turbines and solar panels), producing food, and managing wastes. **For food:** Underwater farms prototype for three interconnected platforms: - Lodging (30,000 m^2) with gues trooms, organic dining, communal terraces, and skylight greenhouse amenities; - Research (37,000 m^2), coworking and maritime hub, communal terraces; - Living (34,000 m^2) village of residential buildings and local cultural programming. **Waste management:** Waste recycling.	**Resistance to natural phenomena:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** - Obtaining renewable energy; - Rainwater harvesting; - Circular waste management; - Improving biodiversity. **Environmental abilities:** - Ability to withstand a number of natural disasters including tsunamis and the equivalent of a category 5 hurricane; - Supporting the passive strategies integrated in the overall sustainability ecosystem of the city; - Coastal habitat regeneration. The floating city prototype has six integrated systems that make it function: zero waste and circular systems, closed-loop water systems, food, net-zero energy, innovative mobility, and coastal habitat regeneration for a resilient and a typhoon-proof habitat.

Table A1. *Cont.*

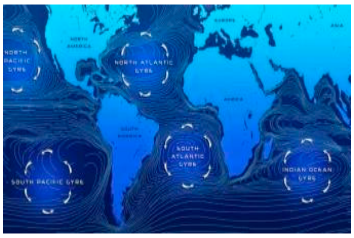
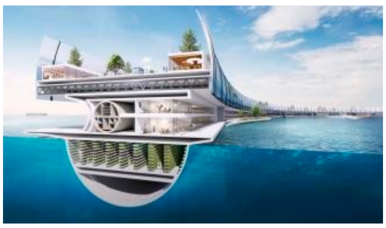
Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Aequorea 2015   Design: Vincent Callebaut Architectures Location: The 5 Ocean Gyres and Rio de Janeiro, Brazil Image source: https://vincent.callebaut.org/ (accessed on 18 September 2024).	A multi-use oceanscraper (under-water village) printed in 3D from algoplast (mixture of algae and garbage from the seventh continent). **Type:** Independent offshore seasteads. **Population:** Each Aequorea village can welcome up to 20,000 aquanauts. **Dimensions:** 500 m in width, 1000 m in depth, 250 floors (one-fourthfor permaculture and agro-ecology). **Spatial organization:** Non-modular structures, integrated multi-functional system of space and structures. **For living:** 10,000 housing units (between 25 and 250 m^2). **For work:** Fab labs, offices, coworking spaces, and workshops. Repurposing of plastic waste into impervious durable materials. **For food production:** Sea farms, organic agriculture, community orchards and food gardens, phyto-purification lagoons, coral gardens, etc. **Waste management:** Waste recycling using microalgae.	**Resistance to natural phenomena:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** - Recycling plastic garbage (bottles, cans, bags, and other types of packaging); - Filtrating ocean water and removing the plastic microparticles suspended at depths of 10 to 30 m. **Environmental abilities:** - Energy self-sufficient; - Recycling all waste and ocean acidification; - Zero carbon emissions; - Recycling CO_2 by using greenery, and recycling 2500 tons of additional CO_2/km^2 by using aragonite (which has a high carbon component) as the construction material for its transparent façades; - Responding to natural disasters and sea-level rise; - Obtaining light by using symbiotic organisms that contain luciferin which emits light through oxidation.
Floating City, French Polynesia 2017   Design: Seasteading Institute (Peter Thiel), San Francisco Location: South Pacific Ocean, French Indonesia Image source: https://www.architecturaldigest.com/ (accessed on 18 September 2024).	The City for "liberate humanity from politicians" and "rewrite the rules that govern society" with its own government and its own cryptocurrency. **Type:** The anchored floating city. **Population:** Up to 30,000 residents. **Spatial organization:** Buildings in multiple clusters; all living and public spaces of urban units with traffic connections within its 150-m radius. **Basic unit:** Multiple-reinforced concrete, four- or five-sided platforms (50 by 50 m in size each), accommodate up to 300 people. The platforms will be able to sustain three-story buildings, along with parks, offices, restaurants, and apartments for people to live in. **Food production:** Aquaculture, which involves breeding plants and fish in water. **For energy:** Large solar panels and wind turbines. **For recreation:** Greenery, parks, and canals. **Waste management:** Waste recycling.	**Resistance to natural phenomena:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** Responding to natural disasters: - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise; - Improving the marine biodiversity; - Zero CO_2 emissions. **Environmental abilities:** - Ability to withstand a number of natural disasters including tsunamis and hurricanes; - Run on solar power and continuously gather and recycle its water from the ocean; - Energy self-sufficient; - The island will be located about a half-mile away from the shore. People will return to land using a ferry.

Table A1. *Cont.*

Facility Name	Overall Characteristics	Environmental Tasks and Abilities
Maldives Floating City, 2020–2021    Design: Waterstudio and Dutch Docklands Location: Lagoon next to the Aarah island Image source: https://maldivesfloatingcity.com (accessed on 19 September 2024).	Sustainable and modular urbanization, ten minutes by boat from the capital Male. **Type:** The anchored floating city. **Population:** Up to 15,000 residents. **Area of water surface:** Lagoon over 200 ha. **Spatial organization:** Lagoon with 5000 floating homes. Mixed-use community: residential, hotels, shops, restaurants; all living and public spaces with connections are within its 150-m radius. **For circulation:** The canals as the main infrastructure for logistics and gateways. Boats, no cars, only bicycles and electric noise-free buggies/scooters. **For energy:** The reduction in energy consumption and production of green/blue energy in a smart grid. **Waste management:** Waste recycling using microalgae. Maldives Floating City is based on the local culture of this seafarers nation.	**Resistance to natural phenomena:** - Earthquakes and tsunamis; - Waves and winds (typhoons); - Sea-level rise. **Environmental tasks:** - Stimulating coral to grow naturally; - Improving the marine biodiversity. **Environmental abilities:** - Eesponding to dynamic demand, weather, and climate change by a dynamic flexible city with a smart grid; - Ensuring comfort and safety through the coral reefs of the lagoon, which will provide a natural wave (reduction) breaker; - Preserve and enhance the pristine marine ecosystem by using innovative sustainable development technologies and applying ecological best practices.
Dogen City 2021–2024   Design: N-Ark design and NEW OCEAN consortium Location: Port in Hamamatsu city the Japan Sea Image source: https://www.n-ark.jp/en/dogen-city (accessed on 19 September 2024).	A smart healthcare floating city for victims of natural disasters and climate refugees. **Type:** Anchored floating city. **Population:** 40,000 residents. **Dimensions:** 1.58 km in diameter and approximately 4 km in circumference. **Spatial organization:** The city is made up of three main parts: - An outer ring that contains the main living areas and facilities for water, sewage, and energy; - Inside the ring there are floating buildings that can move freely around; - Below the water's surface, there is an undersea data center and medical research facilities. **For sports and recreation:** A sports stadium, floating parks. For food production: Fresh vegetables will be grown in the city through a method of agriculture that incorporates seawater. **Waste management:** Including recycling waste to energy.	**Environmental tasks:** - Responding to natural disasters; - Improving the marine environment; - Accommodating climate refugees; - An economic impact (development using new technologies and businesses in addition to traditional shipping, resources, and national defense); - Healthcare and medical tourism with residents on a daily basis. **Environmental abilities:** - Produce 7000 tons of food; - 22,265 GW of power; - Freshwater autonomy (2 million liters of clean water). Dogen City integrates food environment, architecture, data, energy, and ocean resources with a focus on healthcare.

Sources: own elaboration.

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