Eco Energy Land - Envisioning the Międzyodrze Island in Szczecin: The New Approach to the Urban Design

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Abstract. This paper deals with the possibilities of architectural design in the process of creating a zero-energy city, which encompasses environmental quality of life in highly-urbanized areas. Nowadays, the urban pollution is rising on a global scale. This problem is particularly noticeable in Poland. According to the latest WHO report, 36 of the 50 most polluted cities in the European Union are located in Poland. The paper is focused on a new possibility to resolve the problem of air pollution in developing polish cities by advanced architectural design. One of the examples of cities implementing the zero-energy strategy may be Szczecin. In the process of designing new urban districts in the post-industrial area of the Międzyodrze Islands new opportunities to implement energy self-sufficiency can be given. The first part of the paper presents the need to use renewable energy sources and technologies that clean the atmosphere from nitrogen oxides in the processes of revitalization of degraded urban areas. The second part presents the results of the research program Climate Change Adapted Architecture and Building Structures which has been conducted by Krystyna Januszkiewicz (the Faculty of Civil Engineering and Architecture for a few years at West Pomeranian University of Technology (WPUT) in Szczecin. The presented designs of application of titanium dioxide technology with photovoltaic technology were developed with co-operation of WPUT students. In conclusion, the paper emphasizes the usage of titanium technology and photovoltaic technology as a special independent structures in the urban space. This is indispensable to improve citizens’ health and to clear the atmosphere as well as to stop the emission of new pollution resulting from the dynamic development of polish cities.

1. Introduction

In Poland, more and more electricity consumption is currently noted. Electricity consumption in Poland increased in 2018 by nearly 1.7% and reached the highest level in history - almost 171 TWh. The increase in electricity demand caused the need to import electricity from abroad due to the inability to cover demand by domestic energy production. Currently in Poland, 76% of energy is produced from coal, while only 17% comes from RES. For comparison, the share of coal energy in the EU production mix for 2017 reached a total of 20.6%. Thus, as reported by Sandbag in the report "The European Power Sector in 2017" in 2017 Europe produced for the first time more energy from RES than from coal [1]. The increase in the share of energy obtained from RES is also visible in relation to the energy obtained from the atom. Decreasing costs of energy obtained from renewable sources and high costs of construction of nuclear power plants make us ask about the direction of transformation of the Polish energy sector in the future. One thing is certain, Poland should limit energy production from coal and significantly diversify the structure of energy sources. Currently, the level of CO2 emissions in the
energy production process makes Poland one of the disgraceful leaders in the level of air pollution in cities [2]. Fighting this phenomenon means the need to reduce the energy demand in existing facilities and provide them with renewable sources of heating, cooling and electricity. At the same time, particular emphasis should be placed on providing such sources in newly established facilities, so that they don’t additionally burden the current energetic system. Large revitalization and development projects, currently implemented in Polish cities to a particular degree, should meet the challenges of energy self-sufficiency. This can be helped by the introduction of diversified energy sources based on innovative solutions.

Figure 1. Production and consumption of electricity in Poland, Sandbag/Agora/Eurostat

2. What does the term "Eco Energy Land" mean in urban design?
The phrase "Eco Energy Land" allows us to specify the area with "zero energy" balance, but not only with this. The domain of this type of area is not the balance itself, but the possibility of acquiring and producing energy in this area. In the assumption, eco energy land should be characterized by adequate application of renewable energy sources, in relation to the local properties of a given area. In our vision of “Eco Energy Land”, the essence is to build a coherent system based on complementary energy sources. The analysis of local conditions leads to the conclusion that in many regions there are periodically changing weather conditions that determine RES efficiency. The simultaneous use of different sources results in greater stability of the entire system. In the case of countries such as Poland, simultaneous mitigation of negative factors affecting global warming is also extremely important. The solution in this situation may be the use of connected, air cleaning and energy producing systems. Placing them in the immediate vicinity of residence allows for achieving an energetic self-sufficiency while improving living conditions [3]. The educational value is also very important here. Electricity produced in distant power plants seems to be an abstract and infinite good. Introducing power production into the landscape of our everyday life will certainly increase awareness of responsible energy consumption and production costs. It also means the need to raise the aesthetic value of this type of installation and the possibility of adequately inscribing them into the urban landscape.

2.1. Pro-climate (ecological) revitalisation
According to the Act of 9 October 2015 on revitalization, the definition of revitalization is as follows: "Revitalization is a process of deriving from degraded areas, conducted in a comprehensive manner, through integrated activities for the local community, space and economy, territorially concentrated, conducted by stakeholders of revitalization based on the communal revitalization program” [4]. In the case of Polish cities, a large part of degraded areas are post-industrial areas. The process of getting them out from the crisis is a major challenge for local authorities. At present, it is particularly important to
include the climate issue in addition to the above mentioned economic, social and spatial issues in the revitalization processes. The pro-climate revitalization process should start with the diagnosis of the existing condition - negative factors as well as positive factors favoring reduction of greenhouse gas emissions and pollution in a given area [5]. The introduction of a new function in unused and degraded areas should be neutral or positive for the climate. Ensuring the coherence of the investment process with these requirements means, therefore, creating a strategy, as well as entering relevant provisions in local urban plans and other documents. The revitalization process now gives us the opportunity to transform areas with a negative impact on climate change into an area that mitigates the effects of these changes through appropriate policies and new technologies.

2.2. The "Eco Energy Land" in Hamburg

One of the examples of Pro-climate revitalization and at the same time “Eco Energy Land" strategy can be a project implemented on the island of Wilhelmsburg in Hamburg as part of the International Construction Exhibition IBA Hamburg. In this project three key areas of activity were defined: "Cosmopolis"; "Metrozones" and "Cities and climate change". The last of the actions highlighted above includes projects aimed at making the island of Wilhelmsburg an energy self-sufficient area. In this area, 20 projects were implemented regarding new and existing buildings. These were strictly construction activities, as well as training for the local community or implementation of modern technologies. In terms of ensuring the island's energy self-sufficiency within the framework of the "Metrozones" program, a number of projects introducing and testing new, "intelligent" materials in construction were also implemented. This cycle of activities is part of the "Renewable Wilhelmsburg - Climate Protection Concept" accompanying the exhibition.

According to the assumptions of the project, energy in modern cities should be produced directly by its consumers. To achieve this, it is necessary to strive for new facilities, not only for their self-sufficiency, but also for the production of surplus energy. The exhibition was supposed to show how urban planners and architects can use the ways of saving energy and the potential of renewable energy sources. The assumption of the project is that from 2025 100% of the electricity demand on the island will be met by energy sources located on it. This goal is to be achieved primarily through the implementation of new energy projects [6].

![Figure 2](https://www.iba-hamburg.de/en.html)
Among the new activities, one of the flagship and spectacular projects implemented under the IBA is the adaptation of the anti-aircraft bunker from World War II for the needs of the solar power plant - "Energy Bunker" [7]. As part of this project, a steel structure which solar panels was mounted on the existing bunker structure. For this purpose, the bunker roof and its south façade were used. Nowadays the installation generates about 22,500 hours of MWh of heat and almost 3,000 hours of MWh of electricity, meeting the heating requirements of around 3,000 households and the electricity demand of around 1,000 homes. The essence of the "Energy Bunker" operation is not only energy production, but also its storage. The interior of the former air-raid shelter after making the necessary demolition is used as a large heat reservoir. The stored heat is a safeguard in the case of the inability to obtain solar energy.

The key assumption of the project implemented on the island of Wilhelmsburg was also the diversification of sources of energy acquisition. Modern materials and technologies were used in erected residential and office buildings, enabling solar energy to be obtained in an amount that would satisfy their electricity demand. One of the buildings is equipped with an "intelligent" facade that acquires and stores energy throughout the year, thanks to which the building is able to generate more energy than its residents consume. Even more innovative technology was used for the BIQ object, which is the first in the world to have a façade with a built-in bioreactor. Microalgae are grown in the glass elements, which are then used in energy production. The IBA Hamburg project is, according to the assumptions, a self-sufficient city in the city. The project has become a practical laboratory for innovative solutions in construction, aiming to implement the idea of facilities that meet their own needs for electricity, and even producing it for the needs of other users.

3. Research for implementation of the “Eco Energy Land” within Międzyodrze Islands
The main aim of this research is to demonstrate possibilities of application the „Eco Energy Land” theory as a strategy in revitalisation of polluted urban areas, on the example of Międzyodrze Islands in Szczecin. Szczecin is located in the Lower Odra Valley, 65 km from the Baltic Sea coastline. In the area of the Szczecin lowland, the Odra river divides into two branches. The geographical name of this area, located between the Western Odra and the Eastern Odra (Regalica) is Międzyodrze [8]. The area of Międzyodrze consists of many islands some of which have retained their natural character while others have been transformed by man. In the course of history, the greatest transformations concerned the Łasztownia and Kępa Parnicka islands. Łasztownia was already developed in the Middle Ages, whereas Kępa Parnica started to be developed in the 19th century. At that time new port canals were dug through the islands and as a result, the area was dominated by port and industrial function. The war and the post-war period brought further significant changes in the landscape of Międzyodrze. Pre-war buildings were destroyed in 75% which resulted in the creation of extensive undeveloped land used for storage activities. At the beginning of the twenty-first century, the city has experienced a process of de-industrialization, and a part of the port area ceased to be used. At that time, the process of transforming post-industrial areas into a new residential, service and office district began. However, numerous spatial concepts and planned investments have not been implemented due to the bad economic situation.

3.1. Expected increase in demand for electricity and heat for Międzyodrze Islands
Currently, in the period of prosperity, the new development process of Międzyodrze is becoming more real. Two private land owners have announced the construction of large housing estates on the islands. J.W. Construction Holding S.A. plans to build 810 apartments with a total usable area of 34 thousand square meters on Łasztownia Island. Another development company - Siemaszko announced the construction of 500 apartments on Kępa Parnicka. The presented projects constitute only a fraction of the investment potential of the islands. According to the analysis of the local spatial development plan carried out by the DOMINO architectural studio at the request of the City Planning Office in the area of the plan covering Łasztownia and Wyspa Grodzka, it is possible to build 386 104 m² apartments, and 260 456 m² offices. At Kępa Parnicka, by analogy 687 065 m² apartments and 221 198 m² offices. The assumed development rates mean a significant increase in energy demand in the city, and thus an
increase in CO2 emissions to the atmosphere. In this situation, it seems necessary to introduce in the investment area the possibility of acquiring at least part of the energy from renewable sources.

![Diagram](image)

**Figure 3.** The location of Międzyodrze area in the structure of the city and location of new investment areas. Drawing: J. Golebiewski. Aerial view of Międzyodrze Islands. Source: Municipality of Szczecin

### 3.2. The city's policy regarding the use of renewable energy

As we can read, the provisions of local plans partly allow such solutions: “Supply of heat from existing and planned heating network and from local heat sources, with preference for renewable sources, excluding wind energy. It is allowed to build cogeneration of local sources generating heat and electricity” [9]. The use of renewable energy sources is also part of the city’s strategy named “Szczecin - Floating Garden 2050 Project”. The strategy draws a vision of the city's development as a green, ecological and friendly metropolis. The city has already taken important steps to implement this project. A waste incineration plant built at Międzyodrze – “EcoGenerator” produce approx. 70,000 MWh of ecological electricity. The peak power generated by the incinerator is able now to cover approximately 5% of the city's demand. Another important project implemented by the city is the installation of photovoltaic panels on existing municipal buildings. Photovoltaic installation in twelve buildings covers an average of 53.5% of their electricity demand. As a result of this project a reduction in carbon dioxide emissions was achieved by 429.06 MgCO2 per year. The above example shows how important the share of renewable energy can be in meeting the local demand under the conditions prevailing in Szczecin. Analysis of the current conditions in the area of Międzyodrze indicates the possibility of using various alternative energy sources. The significant potential in this case may be not only natural conditions. It is possible to use the elements of the current development of the area - often with negative impact - for the application of RES technologies.
3.3. Local conditions for the use of renewable energy.

Wind and solar energy in the West Pomeranian Voivodeship is well-established and has good development prospects. [10] Solar radiation necessary for photovoltaic panels depends on sunshine duration, which depends on cloud cover, latitude and altitude. In the case of Szczecin, the average annual total radiation is between 3700-3800 MJ/m². Taking into account the variability of this phenomenon, it gives a result between 4.2-4.4 hours of sun exposure per day. When comparing the relative sunshine during the year, the highest values are obtained in summer (42-44%), then in spring (38-41%) and autumn (26-28%), and the lowest in winter (15-18%). As the presented data show, there is a big difference in the possibilities of using solar energy in summer and winter. At the same time, in the winter, the demand for electricity and heat is greatest. Assuming the maintenance of energy from renewable sources at the same level, it is necessary to diversify the sources themselves. In this respect, it is possible to use both wind power and river flows.

The West Pomeranian Voivodeship, through the vicinity of the Baltic Sea, has good wind conditions, especially in the Baltic coast belt. The highest wind speeds are recorded in the period from November to March, while the smallest in the summer months. Thus, in the winter period, wind can be an alternative source of energy in relation to solar energy. The prevailing wind directions during the year are the western (W) and south-western (SW) directions. The winds are most rarely from the east. In wind energy, the speed and direction of wind in the higher parts of the troposphere is particularly important (about 30 m above ground level). The average annual wind speed at this level is largest on the Coast and around the Szczecin Lagoon, where it is about 4.5 m / s. In the case of Szczecin, we can record speeds from 4-4.5 m / s, which gives a maximum of 750 kWh / m² of useful wind energy per year. In the scale of Poland, the West Pomerania Voivodship play the role of a leader in this energy sector so far. In all poviatos surrounding Szczecin, we will notice the occurrence of wind farms [11].

The last source of energy that can be used in the case of Międzyodrze is flowing water. It is true that the fall of the Odra River in its lower bank is small, and the construction of any water levels due to shipping is impossible, however, water can also be used for the production of clean energy. The solution that can be used in this case are floating tidal power plants. Water flowing in the riverbed is also dispersed energy which can be used for energy purposes. This method was used in the past in the case of floating water mills in which the driving wheel of the mill was mounted. Currently, river current energy is used in various ways: by mounting a propeller turbine or roller on floats (mobile power plants), or by placing the device in the mainstream on the bottom of the river (static power plants) [12]. Efficient application of this solution in the case of Międzyodrze seems justified due to the particularly strong current of water occurring in the winter. During this period, the north wind pushes a large mass of water from the Baltic Sea upstream. This does not, of course, preclude the use of this type of installation also during other periods during the year.

4. Result and discussions

4.1. The strategy for Lasztownia Island

The presented examples prove that Międzyodrze is a convenient place for acquiring energy from three primary sources of renewable energy - sun, wind and water. Their variable intensity, however, determines the need to use them in a hybrid way. In the strategy for the area of Międzyodrze as the “Eco Energy Land”, we therefore propose a number of solutions based on these three energy sources. The selection of solutions and their arrangement are supported by the analysis of the condition of the existing development of islands and planned investments.
Figure 4. The location of ecological installations and facilities implementing the “Eco Energy Land” strategy in the area of Międzyodrze.

4.2. Photovoltaic cell application in the Międzyodrze area

According to the analysis carried out in the area of Międzyodrze, there are great opportunities to use space for the location of photovoltaic cells. The most efficient location for this type of installation are roofs of buildings, therefore it is proposed to use the existing port warehouse buildings for this purpose. The introduction of installations and facilities producing energy is envisaged in areas excluded from development or unused. As an enlargement of the area of industrial solar farms, it is proposed to use unused port basins and river barges anchored in them. Barge deck has significant potential for the location of photovoltaic cells that will power buildings erected on land. In this way, extensive artificial port basins will gain a new function and the reason for their economic maintenance.

Figure 5. Rain Water (Flower) Power Station located on Grodzka Island. Collage: J. Golebiewski, project design and visualisation: M. Kiernowicz, K. Sasim, J. Szklarski.
It is also proposed to introduce new installations, which in their attractive form will diversify the landscape of the islands. One of them is “Flower Power Station”. Flowers were designed as elements generating solar energy. We can see here several ecological systems in one architectural object. Petals and leaves of flowers are covered with anatase-shaped TiO$_2$ layer of nanofibers, which allows to purify the air around it, as well as lamellar photovoltaic cells. This type of technology is available in different colors and levels of transparency. An additional advantage of the flower is the opening and closing mechanism, which allows for the collection of rainwater. The flowers were placed in areas excluded from the building - in the green surroundings of Grodzka Island and the Green Island, where they fit into the natural landscape, and also between the flyover of the “Castle Route” where they eliminate pollution emitted to the atmosphere by the intense traffic of vehicles.

4.3. The use of wind power by introducing wind turbines
The existing local plans exclude the introduction of wind turbines as installations extracting energy in the area of Międzyodrze. Despite this, it is suggested to consider such options. Contemporary architectural practice provides a large number of examples for the integration of wind turbines with architectural and engineering objects. Turbines can also be placed on the roofs of existing high objects. In the case of Lasztownia, a convenient solution seems to be the possibility of using existing concrete anti-aircraft shelters for this purpose. On Lasztownia Island we also propose the introduction of a wind farm integrated with the construction of the devil’s mill, which could be a landmark of the entire “Eco Energy Land”.

Figure 6. Rain Water Power Station located between the flyover of the “Castle Route”. Collage: J. Golebiewski, project design and visualisation: M. Kiernowicz, K. Sasim, J. Szklarski.

Figure 7. Wind turbines located on the roof of the anti-aircraft bunker from the times of World War II. Collage: J. Golebiewski.
4.4. The use of kinetic energy of water
The last of the presented solutions is a hybrid hydroelectric plant. The power plant anticipates the use of water wheel based on two floats and connected by a chain with a generator. In addition, the floating hydropower plant will be equipped with a shield, the coating will consist of photovoltaic cells combined with the TiO2 layer of nanofibers. This solution will allow the use of an alternative energy source in the absence of a sufficiently high water flow. Designed floating power plants will form larger teams that will allow efficient production and transmission of energy. Their location will depend on the conducted research regarding the optimal flow of water in the river's current.

![Solar barge with hydroelectric power plant on the Odra River. Collage: J. Golebiewski, project design and visualisation: K. Kołodziejczak and A. Muszalska.](image)

5. Conclusions
In the face of climate change, new urban districts must be planned responsibly to mitigate the negative impact of built environment on the natural environment. The process of transformation of post-industrial areas into new functions is a unique opportunity to implement pro-ecological solutions that will serve this purpose. In our “Eco Energy Land” strategy for Międzyodrze Islands we propose environmentally friendly, modern ecological habitat. "Eco Energy Land" benefits from its aquatic location and other atmospheric conditions for creating an energy self-sufficient district. It is possible with the optimal use of space, existing structures and applications of new technologies in a modern architectural form. The presented application possibilities of various installations producing energy from renewable sources, however, require an appropriate strategy for their implementation. In this context, it is necessary to develop appropriate provisions in local development plans that will make the new district a truly ecological area. In the aspect of implementing the Floating Garden vision, Eco Energy Land could become an example of a model pro-ecological revitalization that embodies the vision of Szczecin as an innovative and citizen-friendly city.

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