Eco-City: Model Concept for Transforming Brownfield into Modern Urban District

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Abstract. Brownfields are undoubtedly a problem in many 21st century cities. Abandoned, degraded, dangerous, overgrown and degrading the image of cities, they also have many potentials and assets. In the context of contemporary urban development trends related to sustainable development and the idea of creating a compact city with a high quality of life, post-industrial areas, especially those located in city centers, are ideal areas for new investments. Polish cities still have a tendency to urban sprawl, which is why the purpose of this article is to draw attention to the transformation of brownfield areas into modern eco and healthy urban districts as a way of creating sustainable urban space. In addition, the article deals with the topic of pro-ecological solutions, including those related to adaptation to climate change. The study uses the case study method. Five significant examples of post-industrial area transformation from Germany, Spain and France were selected. During the analyzes compared masterplans, functional schemes and location of these areas, and then the basic parameters and relationships between them were distinguished in four main categories: general data, environment, land development and attractiveness assessment. The conclusions of the comparative analysis allowed for the definition of detailed guidelines for creating a model concept for land development of the brownfields located in the city structure. The chosen location is placed in Katowice in former areas of Silesia Zinc Plant. The proposed concept presents functional solutions for connecting residential, recreational, commercial office and industrial areas. It is a template solution for the process of spatial, social and economic development. The project proposes pro-ecological solutions and technologies, including: water recycling, use of solar energy, energy storage, intelligent control and monitoring systems, sustainable mobility, building development based on natural ventilation of the city, rain gardens, reducing heat islands, etc. The transformation methods based on modern pro-ecological technologies in the context of adaptation to climate change which were presented in the article may constitute guidelines for the implementation in similar cases of transforming brownfield areas into modern urban districts.

1. Introduction

Due to its industrial heritage, Upper Silesian Metropolis is a highly urbanized and industrialized area. It has a specific and compact urban tissue, which is a characteristic landscape of the Silesian conurbation. In the 19th and 20th centuries, all economic sectors in this region were dominated by: mining, metallurgy and processing. At the end of the 20th century, industrial restructuring began as a result of political and economic transformation. The short and long-term effect of these processes was the massive closure of industrial plants, leaving industrial facilities and areas, unemployment,
degradation of significant areas of cities and the environment, spatial disintegration and lack of spatial order.

Katowice, the main center of the metropolis, is a city in which are many facilities and post-industrial areas. Some of them adapted and received a second life. Others, such as the area of the former "Silesia" zinc smelter described later in this article, remain abandoned and degraded.

In an era of rapid development, Upper Silesian Metropolis is in need of areas for new investments. Offices, commercial and residential buildings under the influence of developer pressure and spatial conditions are being built on smaller and smaller areas or are located outside the city borders, which intensifies the urban sprawl process while in the center there are undeveloped brownfields.

The Eco City concept proposed in the article indicates a model solution of the brownfield transformation in the city center into modern urban district. A multifunctional district intended for residential, recreational, service and industrial purposes. The district's program and its project were based on a large number of analyzes and the study of cases of post-industrial revitalization. They were selected based on parameters and conditions similar to the developed area. An extremely important aspect that was taken into account when creating the concept was to design in accordance with the principles of sustainable development and the use of environmentally friendly technologies. The research part of the project allowed us to select directions of land use based on local planning documents and detailed guidelines of case studies of similar projects. The set of analyzes of the existing state indicated the needs, threats, strengths and weaknesses of the area of the future Eko City district. The acquired informations served as a series of guidelines for the design of a modern, ecological, self-sufficient and multi-functional district.

The inspiration for creating the Eco City concept were the words of the outstanding architect and urban planner Le Corbusier: „The materials of city planning are: sky, space, trees, steel and cement; in that order and that hierarchy.”

2. Method of research

Before creating the Masterplan for the post-industrial district in Wełnowiec, the authors analyzed many examples of revitalizing brownfield areas from Europe. There are relatively few examples of developing multi-hectare industrial wasteland. It is caused by the difficulties associated with the proper preparation of the basic actions, inter alia: soil stabilization, obtaining adequate load capacity and removing unnecessary post-industrial residues. A more popular scheme of activities is the adaptation of individual buildings or their groups, if they are in good technical condition. To formulate guidelines for the preparation of the masterplan, the following research methods and techniques were used according to E. Niezabitowska's classification [1]: method of logical argumentation (analysis and synthesis of planning documents, urban projects, literature sources, etc.); historical and interpretative method (interpretation of historical documents and facts); case study method (searching for relationships between the parameters of various examples). The above methods and research techniques allowed us to formulate design guidelines in the form of tables, graphics and conclusions. Due to the limited amount of space, the article presents only selected aspects, mainly from the analytical and design part, significantly limiting the first - research part.

3. Maslow's human needs pyramid in the context of the benefits of brownfields transformations

Revitalization of degraded and abandoned post-industrial areas cause multifaceted benefits, in particular for society, investors and the city as a settlement unit. The transformation processes in the city's structure are directly related to satisfying the needs of its residents. In order to show, formulate and organize the benefits of this process, authors used the analogy to the pyramid of human needs presented by Abraham Maslow [2]. The list of benefits resulting from the revitalization process for residents can be divided depending on the needs into:

- **physiological** - new commercial and residential investments attract investors and new residents, thanks to which there is favorable social and economic diversification;
security - abandoned, degraded and unprotected post-industrial areas pose a direct threat to people, and also promote the evolution of pathology, unemployment and the phenomenon of “inheriting poverty”. The development of this type of areas significantly increases the level of safety of residents, also giving them new perspectives;

belonging - belonging to a more diversified group of society is undoubtedly a better perspective in the context of living place. Revitalization of degraded areas can be an external stimulus to change lifestyle, set new goals and strive to achieve a higher social status;

appreciation - improving employment conditions and new jobs are important for increasing the quality of life. There is a correlation between the quality of the city area and social prestige;

self-realization - multifunctional areas, availability of services and development of culture are important in the social context for satisfying the individual needs of people.

4. Case study
In order to carry out the case study, 5 examples of post-industrial regeneration from Germany, France and Spain were subjected to detailed analysis. The areas have been selected based on the following criteria: innovation of solutions, variety of functions and availability of information. Three examples were selected from the Ruhr region of Germany, due to the fact that it is a highly industrialized area with a significant industrial heritage.

4.1. Phoenix See
The Phoenix smelter in Dortmund was founded in 1841 and covered an area of approximately 100 hectares. Her activities were mainly related to coal mining and steel production. The plant was closed in 2001. Soon after, new urban spaces were created in this area, which can be divided into 3 parts:

- Phoenix West - a modern center based on new technologies combined with recreation areas and the adaptation of post-industrial facilities,
- Modernized historical part of the complex enriched with new commercial facilities,
- Phoenix See - a modern residential area including office space and recreation areas.

The last of these areas was selected for detailed analysis. Its characteristic feature was the high level of groundwater, which was used as an advantage of the area. In the center of the area, a water reservoir was designed, which is now a place of recreation and water sports for the residents of the district and tourists. On the outskirts of the lake designed single-family and multi-family buildings and office buildings. The described area is an example of an innovative solution for using brownfield land with difficult soil conditions[3].

4.2. Essen 51
The second example from the Ruhr region is Essen 51 located in the city of Essen. The original function of this area was the Friedrich Krupp steel factory, which was closed in 1943. Reconstruction of the area of 52 hectares began in 2009. The post-industrial area is located just 2.5 km from the city center, therefore it is an ideal place for the development of a modern urban district. The functional program includes multi-family housing, office, commercial and recreational facilities. As in the example of the Phoenix See described above, a water reservoir was designed in the center of the complex. The Essen 51 district is based on the use of environmentally friendly technologies and renewable energy sources, including electric car rentals, economical and publicly available public transport, highly developed bicycle paths system, Smart House system, soil drainage system, rainwater management and obtaining energy from geothermal sources. As a result, Essen 51 is able to produce enough energy to power all facilities, in case of its surplus, it supports municipal power[4].
4.3. IBA Emscher Park
The kitchen appliance factory in Gelsenkirchen worked from 1875 to 1943 on an area of about 8.8 hectares. In 1994, as part of the international construction exhibition Emscher Park, the Szyszkwowitz-Kowalski design office presented a district that combines residential, service and recreational functions. The concept of the area is based on building social contacts by creating common spaces of various dimensions and locating them both in the center and on the edge of the study boundary. The area is divided into three parts which are diversified in terms of building height and bonded with recreation areas [5].

4.4. The ZAC Bercy
"The Bercy neighborhood" located in the 12th district of Paris on the area of 51 hectares is the place where the "Bercy" winery once operated. The design and reconstruction of the area took quite a long time (17 years). The main designers were: F.Ghery, R. Piano, J.P Buffi + B Huet and M. Marcy. The main assumption of the project was to divide the area into modules of various sizes, which allows effective and orderly land development. Modularity in the design is also visible in the forms of residential buildings. In this way the district which is primarily a combination of residential, service, industrial and recreational functions was created. In the central part of the complex located an extensive park surrounding historic post-industrial facilities. To the east of the park designed residential buildings in the form of building quarters, whose western facades allow their interiors to be connected to the "Bercy" park. Thanks to such solutions, green areas have become an integral part of all facilities located in the study area. A distinctive feature of the design is the mixing of various functions, which allows the efficient functioning of the district [6].

4.5. Abandoibarra
A shipyard operated in the area of 35 ha in Bilbao until 1984. Due to the industrial crisis that took over Spain in the 80s, the shipyard was closed. The area underwent revitalization in 1998. The architect who designed the extremely attractive urban space was Cesar Pelli. The district's program assumes sustainable development with the location of extensive recreation areas that are in short supply in the neighborhood. Besides extensive green areas, cultural and scientific, residential, office and commercial facilities were constructed. The main boulevard was designed on the site of a pre-existing depot and connects the Guggenheim Museum with the Opera. A boulevard with pocket parks was created along the river. In the middle of its length located a bridge that connects the university with the opposite waterfront. Bridge extension creates a central axis that runs through Euskadi Square and the main entrance to downtown. In addition to visible linear systems, the similar in shape to the lens area has a height difference of almost 10 meters [7].

4.6. Summary
The results of the case study analyze were described and compiled in a table to organize information and compare with the developed area. The first part summarizes basic data on selected examples. The second part is a compilation of analyzes of the nearest environment that affects the development of the urban space. The next one presents detailed data on the revitalization carried out. The last part is a subjective author's assessment, in a very synthetic way showing the results of the analyzes.

As can be seen from Table 1, Abandoibarra ranked the highest in the subjective assessment of the attractiveness of individual projects, scoring 19 out of 20 points. The next, second place was taken by Phoenix See, which is characterized by less attractive surroundings and lower aesthetics, but a more favorable location than Abandoibarra. IBA Emscher Park was definitely the worst rated. The design was less attractive than in other examples in terms of location and surroundings.
Table 1. Summary of analysis results and subjective assessment of attractiveness

|   | Name | 1 Phoenix See | 2 Essen | 3 IBA Emscher Park | 4 The ZAC Bercy | 5 Abandoibarra |
|---|------|--------------|--------|-------------------|----------------|---------------|
| 1. | Country | Germany | Germany | Germany | France | Spain |
| 2. | Town | Dortmund | Essen | Gelsenkirchen | Paryż | Bilbao |
| 3. | District | Hördel | Nordviertel / Bochold | Feldmark | XII dzielnica (Bercy) | Indautxu |
| 4. | Primary function | Ironworks Phoenix | Cast steel factory Friedricha Krupp’a | Cooking equipment factory | Vineyard Bercy | Shipyard |
| 5. | Current function | Residential, Service: - office - recreation | Residential, Service: - office - recreation | Residential, Service: - office - recreation - cultural - commercial | Residential, Service: - office - recreation - cultural - commercial - education |
| 6. | Foundation year | 1841 yr. | 1811 yr | 1875 yr | X | 1900 yr |
| 7. | Closing year | 2001 yr | 1943 yr | 1943 yr | X | 1984 yr |
| 8. | Year of adaptation | 2001 yr | 2009 yr | 1994 yr | 1988 - 2005 | 1998 yr |
| 9. | Acreage | 100 ha | 52 ha | 8.8 ha | 51 ha | 35 ha |
| 10. | Architects | Norbert Kelzenberg | Die Thelen-Gruppe | Szyszkwitz-Kowalski | J.P Buffi + B Huet, M.Macary, F. Gehry, R Piano | Cesar Pelli |
| 11. | Plot shape | average | good | average | good | average |
| 12. | Building area | 64.5 ha | 25 ha | 4.7 ha | 22 ha | 15 ha |
| 13. | Greenery | 38 ha | 12 ha | 1.2 ha | 13 ha | 35 ha |
| 14. | Main leisure function | Lake Phoenix See: 24 ha | Lake Niederfeld | Lens-shaped park | Park de Bercy | Main boulevard |
| 15. | Parking places | No data | No data | 3300 | No data | No data |
| 16. | Expandability | Expansion possibility | No expansion possible. | No expansion possible. | No expansion possible. | No expansion possible. |
| 17. | Functions located in the area | Residential Service | Fully revitalized Residential Service | Fully revitalized Residential Service | Fully revitalized Residential Service |
| 18. | Modularity | no | yes | yes | yes | no |
| 19. | Location attractiveness | 5 | 5 | 3 | 4 | 4 |
| 20. | Surroundings attractiveness | 4 | 3 | 3 | 5 | 5 |
| 21. | Security | 5 | 4 | 4 | 4 | 5 |
| 22. | Aesthetics | 4 | 5 | 4 | 4 | 5 |
| 23. | Totality | 18 | 17 | 14 | 17 | 19 |
5. Eco City of Wełnowiec
The author's concept of the project was made on the basis of many analyzes, the conclusions and guidelines resulting. In addition to the case studies mentioned above, existing planning documents were analyzed, inventories of the existing area of the study and its surroundings were made, and a SWOT analysis was performed. Due to the many undeveloped areas around the border of the study, it is possible to develop the new created district in the future.

5.1. Area of study and its surroundings
The area selected for the 'Eco-city' project is located in Wełnowiec - one of the northern districts of the city Katowice, the capital of the Silesian Voivodeship. The area is located only 3 km from the center, which is why it is an attractive space for potential investors and residents. Initially, the scope of the study was 52 hectares, but after analyzing and recognizing the existing conditions, it was decided to enlarge the boundaries of the study area to 92 hectares. The most important argument to make this decision was the possibility of creating a comprehensive district design that fully uses external and internal conditions, existing infrastructure and takes into account the guidelines of the local plan. The area with a shape similar to a triangle is surrounded by existing and planned road infrastructure. Green areas are the dominant areas in the immediate vicinity of the development boundaries and are an attractive place for outdoor recreation for residents. The highest intensity of residential areas is in the north and south-west. Areas with industrial functions are not grouped together. Warehouse functions are situated close to them. Service buildings are mostly located in residential areas. The territory includes facilities that are under the protection of the voivodship conservator, some of them have been adapted for office purposes due to their good technical condition. The adaptation project was carried out in accordance with respect for cultural heritage.

5.2. Design concept
The main assumptions of the concept are: ecology, multifunctionality and self-sufficiency of the designed "Eco-city" area. The division into individual quarter’s results from the urban composition - existing buildings, technical infrastructure and functions. The extension of the characteristic building lines allows the development of real urban tissue. Two areas of multi-family housing function were designated, one area of industrial function, the area of the science and technology park and the main avenue connecting recreation areas with office and service facilities. Quarter buildings refer to the features of existing residential buildings.

The designed quarters of buildings are surrounded by streets, however, the main directions of communication are avenues, which are a natural barrier between areas of various purposes. Communication serving industrial areas and the area of the science and technology park is located in the northern part of the area. This infrastructure solution allows the segregation of commercial and passenger vehicle traffic. To minimize traffic jams, roundabouts were designed to increase intersection capacity. Collective above-ground car parks occur between residential quarters, while parking spaces are located along and at an angle of 90 degrees to the road axis. 50 underground car parks were located under residential and commercial buildings, including park places for people with disabilities, standard and places for motocycles. The communication system includes pedestrian paths, bicycle paths, city squares occur inside residential quarters, in recreation areas and in front of public facilities. The water reservoir is surrounded by the main promenade consisting of a pedestrian and bicycle path. Newly designed green areas have been combined with existing ones through the use of green alleys that create natural ecological corridors. The main green axis is located in the center of the development area, surrounding the water reservoir and is a smooth extension of the existing forest in the northern part of the development. The designed system also includes greenery in the building quarters and two water reservoirs, which are recreation areas. The location of new buildings and the programming of functions results from the development of the character of existing buildings. In the central part around the green axis, it was decided to locate buildings with mixed, administrative and office functions. In
the northern part of the area there are facilities that supplement the industrial function, while in the west there are residential, service and commercial functions.

Figure 1. Functional scheme

5.3. Pro-ecological solutions
The use of pro-ecological solutions is not only beneficial, but actually necessary today. The Paris Climate Agreement signed in December 2015 obliges countries as well as society to minimize the impact of human activities on climate change. The use of environmentally friendly technologies has many benefits. It leads to a reduction of energy consumption from non-renewable energy sources, and also affects the protection of the natural environment. So these are activities such as: minimizing or reducing emissions by using the latest technologies [8].
Today's technology development and unlimited access to information to recognize and use of many interesting, ecological and cost-effective solutions during process of urban design. Existing pro-ecological solutions can be divided into two groups [9]: - architectural solutions that are related to the location of objects on the plot, relative to each other and parts of the world, such as creating natural air corridors regulating air temperature and improving its quality, creating a microclimate inside the urban interiors to minimize the occurrence of heat island phenomenon, functional connections, choice of materials, etc. The second group consists of technological solutions such as, intelligent management systems, energy-saving systems, the use of renewable energy sources and the reuse of resources. Below are selected solutions and technologies that were used in the design of the Eco City. Connecting green areas with the creation of corridors for ventilation of downtown spaces has a significant impact on the comfort of land use by residents and their satisfaction of the needs associated with close contact with nature. Green roofs and walls that are designed to filter the air and maintain adequate humidity and temperature in the city have a positive effect on the proper functioning and use of space by people. A significant percentage of biologically active areas in the form of parks, water tanks and rain gardens create a sense of life in a friendly, sustainable urban space and have a positive impact on the social relations of the area.

The use of gray wastewater, rainwater storage is one example of the re-use of existing resources. They can be used for: flushing the toilet bowl, prewash, garden irrigation, cleaning and even cooling buildings. In the city's Eco project, Rainwater storage tanks are located mainly at residential as well as office buildings located in the surroundings of green areas. In residential and office buildings authors planned installation of supplying stored water to flats [10]. In accordance with the principles of promoting ecological and economical life for electric car users, there is a possibility of using a free self-service car wash located next to a large commercial center that will use stored resources of rainwater.

Energy from solar radiation can be exchanged for electricity or heat. The location of photovoltaic panels is foreseen mainly on buildings with large roof areas, such as the buildings of the science and technology park, industrial, public and some of the residential buildings. Energy can be used in these facilities and in charging stations for electric vehicles. In addition, photovoltaic panels should be used on lamps illuminating the development area and benches that allow you to charge your phone or other electric mobile device. The use of intelligent energy management systems in apartments aims to reduce unnecessary energy consumption. An interesting solution proposed in the Eco-City is Road Solar Collector - it is a system used in sidewalks and roads, which are most often heated in summer. Through the system of pipes placed in the surface, the water is heated and stored, it can be used to heat and cool buildings and the roads themselves. Considering the numerous systems of gaining energy, one should foresee the way of its use and storage. It is worth designing energy storage facilities. Intelligent energy management systems can be used on a small scale mainly in apartments to reduce unnecessary energy consumption and on a larger scale as intelligent waste management system which can monitors in real time through applications.

Solutions such as public transport enabling you to move around the district without using a car, a bike path system and city bike rental stations are designed to reduce exhaust gas production. Promoting public means of transport and benefits in the form of a free self-service car wash using rainwater for people with electric cars are aimed at encouraging residents to an ecological lifestyle and indicating various options to replace harmful processes.

6. Results and discussion
The effect of developing the concept of revitalisation post-industrial areas is a masterplan for the Eco-City. The proposed functional and spatial solutions are designed to ensure the comfort of use of facilities and recreation areas to potential residents, as well as an economic and healthy lifestyle.
The diagram presents the percentage share of individual functions in the developed area. The largest area is biologically active areas, which include green and water. Next authors described existing objects and designed buildings. Technical infrastructure ranks third in the classification and consists of roads, pavements and parking lots.
7. Conclusion
The main purpose of the study was to develop a model concept for the development of the brownfield area located in Katowice, taking into account pro-ecological technologies and the principle of sustainable development. In the era of the spreading urban sprawl, the regeneration of brownfield sites in city centers is an important issue. Taking into account the principles of sustainable development and the use of environmentally friendly technologies during process of design brings multi-faceted advantages in the context of climate changes, economic and social sectors. The study indicates the possibilities of combining selected processes and technologies for the optimal use of natural resources and minimizing the costs associated with everyday life. Strongly urbanized areas, which undoubtedly are the cities of Upper Silesian Metropolis, are areas that are able to effectively reduce the demand for electricity and the costs associated with it through the use of appropriate solutions. The use of pro-ecological technologies is often associated with large financial costs caused by the high price of given solutions. Therefore, people should try to minimize the costs of production of given technologies for their dissemination. Such action has mutual benefits for both producers and users.

References
[1] Niezabitowska, E.: “Research methods and techniques in architecture”, Silesian University of Technology Publishing House, Gliwice 2014, pp. 164-168.
[2] A. Maslow, “Motivation and personality”, PWN, Warszawa 2009, pp. 62–76.
[3] 'PHOENIX Eine neue Stadtlandschaft in Dortmund' - information outline.
[4] https://www.thelen-gruppe.com/essen51/ - [access 24/01/2019]
[5] Architecture murator 12.1999, IBA Emscher Park 1989-1999, pp. 87-90
[6] ZAC Bercy – Urban Design Report (2013) , https://www.academia.edu/6640483/ZAC_Bercy_-_Urban_Design_Report_2013_- [access 22/01/2019]
[7] http://www.balmori.com/portfolio/abandoibarra-masterplan- [access 28/01/2019]
[8] Paris Climate Agreement, Le Bouget, 2015, https://www.consilium.europa.eu/pl/policies/climate-change/timeline/, - [access 21/01/2019]
[9] Marchwiński J, Zielonko-Jung K, “Contemporary proekological architecture” , PWN, Warszawa 2009.
[10] Grzelak A., Fialkiewicz-Kozielski B.: “Prospects and potential risks of gray water reuse.” Engineering and Environmental Protection nr 2/2017, pp. 27-41