Correlations between Climate Change and the Modern European Construction

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Abstract. The aim of the study was to analyze the links between climate change and the way modern cities are structured and responded to climate change. How do these changes affect building materials and technologies, or does climate change affect the type of technology and materials used? The most important results are the effects of analysing selected examples of a modern European building, the use of materials and technology, the adaptation of buildings to the changing climate. Selected examples of contemporary architecture from Germany, Italy and Denmark, Norway and Sweden. There are also examples in photographic documentation. The most important criteria affecting the objects are elements that shape the changing climate, as well as existing legal and technical requirements. The main conclusion was that modern urban space is adapted to the changing climate. Unprecedented climatic phenomena in this area: intense and sudden rain, snow, floods, strong winds, abundant sunshine, high temperature changes, greenhouse effect of the city - “island heat”, atmospheric pollution. Building materials and technologies contribute to the optimal conservation of natural resources, buildings are shaped in such a way as to ensure safety, resilience and environmental protection. However, there is still a need for continuous monitoring of climate change, criteria affecting the design and construction of urban and central facilities. Key words: energy efficiency, renewable energy, climate change, contemporary architecture.

1. Introduction

Contemporary European architecture is characterized by the tendency to use pro-ecological materials and building technologies as well as the implementation of the principles of sustainable development. These directions are the result of introducing sustainability goals, inter alia, throughout the environment.

The concept of “sustainable development” refers also to construction and architecture. This issue was explained in the WCED-Commission on Environment and Development report in 1987. Other important documents dealing with this issue are European regulations and decrees, and also polish ones, for example: Agenda 21 of 1992, Final Documents of the United Nations Conference on Environment and Development, 1993; Amsterdam Treaty of 1997; Constitution of the Republic of Poland art. 5 - 1997 No. 78 pos. 483; Environmental Law - Journal Set 2001 No. 62 pos. 627, 2016 pos. 672, 831, 903; Energy Efficiency Act - Journal Set 2016 pos. 831. These are only selected documents related to this subject.

Sustainable development is mainly to ensure the highest quality of life for present generations while guaranteeing development opportunities for future generations.
The documents focus on saving natural resources, not destroying and protecting the environment and providing a resilient infrastructure for climate change (EU Strategy for Adaptation to Climate Change, a Strategic Adaptation Plan for Climate-Sensitive Areas and Areas by 2020 with a Prospect of Up to One Year 2030, Communication from the Commission to the EP, the Council of the European Economic and Social Committee and the Committee of the Regions - EU strategy on heating and cooling).

Another important aspect is also the improvement of the energy efficiency of buildings, the improvement of the energy system, the increased use of RES. It was assumed that "large savings can be achieved through simple and cheap renovations - insulation of the attic, walls and foundations and the use of two or three chamber glazing’s. Important urban green spaces, green roofs and walls, providing insulation and shading are also important for the decarbonisation of heating and cooling in the EU. ..(Communication from the Commission to the EP, the Council of the European Economic and Social Committee and the Committee of the Regions on the EU Strategy on Heating and Cooling).

Trends in realization of the aforementioned assumptions were divided into application of innovative material and technological solutions and planning activities. The problem analysis was limited to European architectural solutions and discussed only selected elements from the complex problem of adapting architectural space to climate change. An analysis of the subject's literature and photographic documentation "in situ" was conducted. The research problem is the question: what environmental pro-ecological actions in construction have an impact on climate change and the adaptation of architecture to these changes?

2. Selected elements of climate change

The intensification of atmospheric phenomena (the effects of climate change, for example: floods, heavy rain, strong winds, high sunshine) affect the building and the environment (Impact of climate change on the economy, the environment and society, Volume 1, p.131).

Key issues include, among other things, issues related to the intensification of the effects of climate change. The consequence of this is the need to increase the resistance of buildings to new phenomena, for example: protection of the building and the area from floods (waterproofing, construction, "sealed soil"), energy savings (heat insulation, ventilation, cooling, structure of the building, building materials) Resistance to strong winds, tectonic shocks); Eliminating the effect of the city "heat island" (building construction, buildings facades, heat shield, sun, environmental management), cleaning the atmosphere (for example, building facades, green areas).

Also, the closest environment of an object as an integral part of the environment can have a significant impact on the object itself (for example, stability of the foundation) and on the environment of the environment in terms of climate change (for example, "sealed soil" - theft, tree cutting, reduced soil stabilization).

3. Pro ecological materials and technologies

Among the architectural solutions of the pro ecological are the following innovative technologies and materials:

increasing green spaces, improving microclimate, water management, food crops - green walls, vertical gardens, green roofs, façade gardens; For example: American pavilion at Expo 2015, Milan, Italy; Residential towers with vineyards "Bosco Verticale" in Milan, Italy, Mountain Home in Ørestad City, Copenhagen, Denmark;

- improvement of the microclimate - cleaning of the atmosphere with the technology of synonyms of pollutants, for example: Italian pavilion with concrete facade purifying the atmosphere at World Expo 2015 in Milan, Italy;
- energy savings for lighting, air conditioning, building heating - light control, UV and IR, shading of rooms, for example: SPD Smart Windows in the US Pavilion, World Expo 2015 in Milan, Italy;
• energy production and energy saving - energy produced by algae, for example: BIQ - algae Micro - facade microparticles for energy generation and lighting control, building in Hamburg, IBA, Germany;
• use natural ventilation, natural materials (wood, copper, others), solar heating; For example: exhibition buildings at the IBA Exhibition in Hamburg, Germany and elsewhere;
• shaping the structure of objects using natural phenomena - using natural lighting, natural ventilation, geothermal energy, for example: office buildings; City of Development and Environment; Hamburg; Wilhelmsburg, Germany, seat of the Federal Environment Agency in Dessau, Germany;
• environmental savings - building materials and environmentally friendly, reusable, natural technologies, for example: The headquarters of the Federal Environment Agency in Dessau, Germany.

4. Selected examples of buildings and technology

The work analyzes the criteria of climate change, which affect the objects and space to varying degrees and modes. This results in the need for climate change elements of technological and material innovations:

• the exterior of the building, surrounding:

  • Roofs, roofs - reduction of air temperature (increase of greenery, use of water reservoirs), leveling of atmospheric pollutants (atmospheric cleansing technologies), energy (recovery, savings, renewable energy), pro green materials and technologies (saving materials from the environment);
  • land management - design and "equipment" of the site (water, green areas, natural areas, others), energy sourcing and saving (technologies, RES), pro-ecological materials and technologies;

• instructions of the building:

  • structure of the building - shaping and construction pro-ecological, natural, energy saving, natural biological processes, renewable energy, ecological materials and technologies;
  • structure-mechanical resistance to weather anomalies, pro-ecological materials and technologies;

The above criteria are based mainly on the analysis of the subject literature. The analyzed examples of technology and innovative materials are also often found in facilities where other research elements are presented.

On the other hand, the criterion of selection of objects for analysis was the application of the data of technology and materials in the described building with a narrowing to the modern residential, office and experimental architecture in Europe.

5. External criteria of building, environment - elevations, roofing

The use of green walls, roofs, vertical gardens by increasing the amount of greenery in the city will improve the microclimate, water management and reduce the ambient temperature.

Also the use of greenery on roofs and elevations can serve as additional thermal insulation of the facility, additional space for recreation and relaxation.

For example, green roofs on a multi-family residential building with garages underneath Mountain Dwellings in Ørestad City, Copenhagen, Denmark, the Bjarke Ingels Group BIG Arch 2008 project (Figure 1, 20) and 8 House, Big House Ørestad City, Copenhagen, Denmark, project Bjarke Ingels Group BIG 2008 archives (Figure 2) show the possible solutions of objects introducing green to objects.

In Mountain Dwellings an innovative layout of a multi-family building has been applied, divided horizontally into individual apartments with individual small terraces and gardens for each apartment. For the sunshine of flats and gardens, and parking spaces for residents under the building, the whole structure of the building rises towards less sunshine.
The next examples of the use of greenery in multi-family buildings are "residential towers" with vertical gardens "Bosco Verticale", arch. Stefano Boeri; 2014 in Milan (Figure 3). The structure of the building has been designed to allow the introduction of large amounts of greenery including trees and the use of irrigation systems.

The 8 House multi-family house is also an interesting example of architectural design with the greenery on the roof and south façade, where individual green terraces are designed. The building was shaped in such a way as to ensure maximum sunshine of individual dwellings (plan "8" with opening and change of height).

Increasing the number of active and active greenery in the city can contribute to the location of vertical farms and gardens on building elevations. An example of such a garden - a vertical farm may be the site of the American Pavilion at the World Exposition EXPO in Milan in 2015 (Figure 4). The pavilion shows the possibilities of vertical cultivation of vegetables and fruits. The vertical crop system enables the irrigation, maintenance and harvesting of cultivated plants from the inside of the building by means of rotating inwardly vertical containers of cultivated plants.

The use of increased amounts of greenery can contribute, among other things, to the reduction of city temperatures, the purification of the atmosphere, the enlargement of recreational areas and the increased thermal protection of buildings.

Innovative technologies and building materials for building facades can be used to clean the atmosphere. An example of such a purifying facade is the concrete facade of the Italian Pavilion at the Expo 2015 World Expo in Milan, Italy (Figure 2 a), b)), a facade made of structured concrete slabs with atmospheric cleansing technology. The "i.active BIODYNAMIC" concrete slabs used with active TX active from Italcementi in contact with sunlight purify the air pollution by converting them into inert salts. The whole object in its structure, technology and symbolism refers to the tree. The applied technology gives the opportunity to achieve "0" energy demand (structure of an object, energy-saving materials, technologies of obtaining energy from renewable sources).

Light control technologies, UV and IR blocking technologies can also be used to control the sunlight and to manage the amount of light supplied, also for shading and screening of rooms, such as SPD Smart Windows. The technology was used at the American Pavilion at the Expo 2015 World Expo in Milan, Italy (Figure 3a), b)). This technology reduces energy expenditure on cooling large glazed areas and protects against excessive sunlight and reduces visibility with very simple electronic control of the light transmission in the panels.

Energy saving is also protection against excessive sun exposure (also in Figure 2a)-d)).
An example of the control of light and shade in a building using glass panels with microalgae is the multi-family building BIQ – Mikroalgae in Hamburg at the IBA Exhibition in Germany (Figure 3 c)). It is an experimental building to produce energy from renewable sources.

The facade of this building is made up of panels filled with microalgae for energy generation, carbon dioxide from the atmosphere, and biomass production from which biogas is produced. Currently, the system achieves an efficiency that accounts for 50% of the total energy requirement of the facility. Technology is in the experimental phase.

Another pro-ecological trend is the use of large glazing units in the elevations of large buildings with less glazing and sun-reflective materials. This contributes to reducing the temperature (in addition to the internal temperature of the building) of the building's surroundings, and thus to improving the microclimate parameters in the given space (Figure 2 c, d)).

Figure 2 a) The use of construction material on the façade that purifies the atmosphere from impurities, as well as the reduction of the surface reflecting the sun; Italian Pavilion, World Expo EXPO, Milan, 2015., photo by Anna Gumińska, 2015.

b) The use of construction material on the façade to clean the atmosphere from impurities, the detail of the façade of concrete panels active BIODYNAMIC seen from inside the pavilion, Italian Pavilion, EXPO World Exhibition, Milan, 2015

c) Reduce the surface reflecting the sun in Oslo Barcode objects, Fjord City, project. Dark Arkitekter, A-Lab and MVRDV, Oslo, Norway, photo by Anna Gumińska, 2016.

d) Reduce the surface reflecting the sun in Oslo Barcode, a new district of the city of Fjord City, the project. Dark Arkitekter, A-Lab and MVRDV, Oslo, Norway, facade of one of the objects.

Figure 3 a) SPD Smart Windows technology used in the American Pavilion at the World Expo 2015 in Milan, Italy; panels partially open to light,

b) SPD Smart Windows technology used in the American Pavilion at the World Expo 2015 in Milan, Italy; panels partially closed to light,

c) BIQ - Microalga - micro algae for energy generation, light and shadow control in building in Hamburg, IBA, Germany; Photo of the building without panels with micro albums.

The above mentioned criteria relate to the exterior of the building, such as façades, roofs. Applied technologies and materials affect: air pollution reduction (environmentally sound concrete technology, increased greening), energy saving, energy production and production (micro algae panels), reduction of air temperature, building (increase of green areas, reduction of sunlight).
6. External criteria of building, environment - area management

Equally important in the application of the principles of sustainable development apart from the proper, pro-ecological and energy-efficient shaping of the building itself is the development of the area around it.

These elements can be classified as terrain and use of natural materials such as gravel, avoidance of so-called "sealed soil", green, water, others, as well as renewable energy, environmental, natural materials and innovative technologies.

An example of such development is the inner courtyards of the 8 House, Big House house in Ørestad City, Copenhagen, Denmark, Bjarke Ingels Group BIG arch. Project (Figure 1 b)). There is a public green area, the area is varied, and the passage is covered with gravel (soil permeability).

Examples of the impact on the microclimate of the city by reducing the temperature are water houses in Amsterdam, Holland (Figure 4 a)) and in Hamburg, Germany (Figure 4 b)).

The housing estate of floating houses on the water in Amsterdam, Netherlands (Figure 4 a)) is located in the bay and houses are "moored" to the piers connected to the mainland. This location also allows for water communication. The architecture of the houses is diverse, with different materials, but limited by the same parameters of the maximum cubic capacity. Constant water temperature ensures energy savings and good microclimate.

The Hamburg complex consists of three buildings with 3 independent 2-storey apartments and a 10-storey tower with 22 apartments. All buildings are located in a water reservoir, which is a rainwater warehouse. Water also plays a role in reducing the ambient temperature and thus improving the microclimate.

![Figure 4 a) Technologies Water Houses Steigereiland Zuidbuurt IJburg, Steigereiland, Amsterdam, Netherlands, 2003 - 2010, photo by Anna Gumińska, 2015.](image1)

![Figure 4 b) Water houses IBA_Hamburg, WaterTower 9 / TriPlex Houses 3 (Schenk + Waiblinger Architekten, Hamburg) Hamburg, Germany, 2011-2013; Photo by Anna Gumińska, 2015.](image2)

These selected parts of the objects are examples of the influence of the external elements of the building and the development of the environment on the environment.

7. Internal criteria of the building - structure of the building

Shaping the structure of objects is important in eco-friendly shaping of space. These facilities use natural lighting, ventilation, geothermal energy, for example office buildings in Germany, Hamburg and Dessau.

An example of an object with a variety of ecological solutions is the Hamburg Municipal Office for Development and the Environment of the Archbishop of Berlin, Sauerbruch Hutton Architekten, from 2013 (Figure 11). The reduction of energy consumption in the building was achieved by the combination of active and passive means, namely the thermal insulation, the facade used limited transparency needed and protection from intense sunlight, natural lighting was used (fragmentation). Solar energy and geothermal energy.

An example of the next energy efficient building is the headquarters of the Federal Agency for the Environment in Dessau, Germany, the project of Sauerbuch & Hutton - Matthias Sauerbruch, Germany and Louisa Hutton, England 2005 (Figure 5 a)).
A similar building block was used as in the previous example for good interior lighting and good natural ventilation. The windows of the building have a double window system that reflects the excess light, disperses it and allows the user to control the room temperature, and the additional glass protects against glare. The exterior facades are 40% glazed and 60% covered with a double glass panel structure made of larch wood and safe glass in 33 different shades. The four-storey building uses energy-saving technologies: partition walls are made of Clay bricks (to increase the thermal mass), the atrium acts as a climate buffer and regulates the temperature, groundwater serves as a seasonal magazine, night cooling by means of motorized ventilation panels, Geothermal air intake, heat exchanger and other ecological materials such as tinned copper, cellulose insulation, larch.

Figure 5 a). Building with reinforced thermal insulation, energy saving design; Office Building Ministry of Development and Environmental Protection, Hamburg-Wilhelmsburg, Germany, 2013 (Arch. Sauerbruch Hutton Architekten, Berlin); Picture A. Gumińska, 2015.

b) Plan - Energy-efficient building - Office building of the Federal Environment Agency, Dessau, Germany, 2013 (arch. Sauerbruch Hutton Architekten in Berlin);

The use of natural and harmless materials, saving the environment is an important element of sustainable development. Another example of the eco-friendly facility is the Energy-plus-house settlement in the Vauban district of Freiburg built in the years 2000-2005 by Rolf Disch, Figure 6 a) b). Energy Plus is a building that produces more energy than it uses alone and has a positive energy balance and is free from CO2 emissions.

The Energy - plus - house consists of smaller series of buildings with a division of interior space into different categories with a variety of uses, with a large amount of greenery and recyclable materials. This is an example of the possibility of introducing energy production technology for housing.

Figure 6  a) Building of the Energy-plus-house Energy Building, built in 2003-2008, designed by Rolf Disch, Vauban, Freiburg im Breisgau, Germany; Anna Gumińska, 2015.

b) Energy-plus-house, built in 2003-2008, designed by Rolf Disch, Vauban, Freiburg im Breisgau, Germany, interior of the foundation, object; Anna Gumińska, 2015.
8. Internal criteria of the building - construction of the building
An important element of the building is its structure and structure, which is resistant to wind loads. An interesting example is the Turning Torso building in Malmo, Sweden, project Santiago Calatrava, 1999-2005, Figure 7 a), b). It is a 190 m, 54 storey, office-residential property, from the base to the top is twisted by 90 degrees (structure twisted cubes). The load bearing structure is also visible on the elevation. These irregular, pentagonal cubes rotate around a vertical core that is supported by an outer steel structure. Construction inspired by human torso, rotating, twisted torso according to sculpture Calatrava. Such a construction of the tallest building in Sweden is resistant to weather anomalies including heavy wind loads.

Figure 7  a) Structure of the Turning Torso building in Malmo, Sweden project Santiago Calatrava, 1999-2005, photo by Anna Gumińska, 2016.  
b) Turning Torso in Malmo, Sweden project Santiago Calatrava, 1999-2005, detail of construction, photo by Anna Gumińska, 2016.

9. Conclusions
These examples are just a few of the areas where sustainable development principles are applied. The way of shaping modern architecture shows the adaptation to legal regulations and social awareness of climate change. Selected examples show great possibilities for adapting various types of objects to ecological requirements. The use of natural, native materials in construction is a response to environmental pro-environmental development.

Undoubtedly, these activities have an impact on improving the quality of the environment and are less invasive in the environment. These activities must be long-term, multi-range and of great scope to affect the quality of life of present and future residents.

Examples include technologies and building materials designed to save energy, clean up the atmosphere, improve living conditions. They show the variety of measures used to protect the environment and adapt the infrastructure to a changing climate.

However, are the above mentioned actions sufficient to improve the environment and quality of life of the population? Will they provide a natural environment for future generations?
Certainly such and similar actions leading to the "immunization" of climate change architecture will improve the living conditions of its users.

The applied innovative materials and construction technologies show great potential for use in architecture and urban planning to save the environment.

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