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ENERGY METAMORPHOSIS OF CITIES AND BUILDINGS

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METAMORFOZA ENERGETYCZNA MIAST I OBIEKTÓW

Abstract
The article deals with energy transformation on an architectural and urban scale. The first part describes the assumptions of the German energy transformation, taking into account both the scale of individual buildings and urban scale solutions based on RES. Selected objects and design concepts from Hamburg and Berlin are presented as model examples. The second part describes the approach to transformation on the example of Warsaw, based on current programmes, strategies and development visions in relation to the architecture and new standards of facilities as well as the use of RES on an urban scale. The German approach was compared to the Polish assumptions, indicating the possibility of implementing some solutions. A discussion and a photographic documentation made 'in situ' of selected Polish and German contemporary RES applications in architecture are presented. Selected examples of modern buildings show the use of energy-saving and RES technologies. The analysis of contemporary architectural designs concerns issues related to energy and the possibility of adapting contemporary architecture to a changing climate. At the end of the paper, challenges in the context of energy transformation are presented. The need to adapt buildings and cities to climate change requires transforming the traditional linear design process into an energy-integrated one operating in terms of the principles of sustainable development. This process will not be possible without the support of digital design and simulation tools as well as mapping to determine the potential of RES in cities in the perspective of 2050. Attention is also drawn to the important role of experimental, educational and popularizing activities that give the opportunity to acquire knowledge about RES.

Streszczenie
Artykuł dotyczy transformacji energetycznej w skalach architektonicznej i urbanistycznej. W pierwszej części opisano założenia niemieckiej transformacji energetycznej uwzględniające zarówno pojedyncze budynki, jak i bazujące na OZE rozwiązania w skali całego miasta. Wybrane obiekty i koncepcje projektowe z Hamburga i Berlina zostały zaprezentowane jako przykłady modelowe. W drugiej części opisano podejście do transformacji na przykładzie Warszawy, opierając się na aktualnych programach, strategiach i wizjach rozwoju w odniesieniu do architektury i nowych standardów obiektów oraz wykorzystania OZE w skali miejskiej. Podejście niemieckie porównano z założeniami polskimi, wskazując na możliwości implementacji niektórych pomysłów. Omówiono wybrane przykłady współczesnych rozwiązań dla architektury Polski i Niemiec i zaprezentowano ich dokumentację fotograficzną wykonaną in situ, na której ukazano zastosowanie energooszczędnych technologii i odnawialnych źródeł energii. Analiza współczesnych projektów architektonicznych dotyczyła zagadnień związanych z energią oraz możliwości adaptacji dzisiejszej architektury do zmieniającego się klimatu. W zakończeniu pracy przedstawiono wyzwania w kontekście transformacji energetycznej. Konieczność adaptacji miast i ich budynków do zmian klimatu wymaga przekształcenia tradycyjnego linearnego procesu projektowania w zintegrowany pod względem energetycznym i operujący w kategoriach zasad rozwoju zrównoważonego. Proces ten nie będzie możliwy bez wspomagania cyfrowymi narzędziami do projektowania i symulacji oraz mapowania w celu określania potencjału OZE w miastach w perspektywie roku 2050. Zwrócono również uwagę na ważną rolę działań eksperymentalnych, edukacyjnych i popularyzatorskich dających możliwość pozyskania wiedzy o OZE.

Keywords: architecture; adaptation; climate change; renewable energy; energy transformation; sustainable development goals – SDG

Słowa kluczowe: architektura; adaptacja; energia odnawialna; cele rozwoju zrównoważonego; transformacja energetyczna; zmiany klimatu

INTRODUCTION

In an effort to reduce the impact of climate change and adapt to it, cities are taking a number of measures. Among the works aimed at reducing emissions of pollutants into the atmosphere and increasing their absorption, the most frequently mentioned are those in the field of changing requirements for construction, thermo-modernization of buildings, replacement of inefficient heat sources, development of low-emission mass transport, introduction of clean transport zones, care for air quality and protection, introduction of solutions for the closed-loop economy model and use of the potential of renewable energy sources. In spatial aspects of cities it is recommended, among other things, to implement pro-environmental solutions in the field of blue-green infrastructure through design measures and subsequent management in a way that is intended to provide a wide range of ecosystem-supporting benefits regarding the development of urban greenery, green walls, rain gardens, greening of roofs or city stops and streetcar tracks. In addition to greenery, rational management of resources, including water and energy, is becoming an important aspect in cities. Reports by the European Environment Agency point to significant issues arising from climate change that cities in Europe will face, which include pollution growing at a dizzying pace, rising noise levels, increasingly frequent extreme temperatures and weather phenomena, and the planet's depleting natural resources. Thus, a strong need for an equitable transformation towards green, sustainable, compact and productive cities that rely on synergistic solutions, including the use of RES, while improving the living environment and the development of urban communities, is drawing. Hence, it is noticeable that efforts are being made at many levels – international, national and local to intensify them precisely in urbanized areas, since it is cities that are credited with more than 70% of greenhouse gas emissions in the atmosphere.

In the article's summary conclusions are made based on study visits,[1] the conducted analysis of selected domestic and foreign objects, major assumptions related to the implementation of the adopted solutions and strategies for RES relations on the architectural scale as well as urban solutions.

1. GERMAN ENERGY TRANSITION AS EXEMPLIFIED BY BERLIN AND HAMBURG

'Germany's energy transition, with its dual goal of moving away from coal- and nuclear-based energy, is of global significance. A global approach matters especially if we take seriously the dual task of protecting the climate and ensuring sustainable energy security' [A. Kwiatkowska-Drożdz et al., 2012].[2]

1.1. Solarwende Berlin

Berlin has been consistently implementing plans to achieve climate neutrality; hence, the adopted strategies to use renewable energy, especially solar energy, are of key significance. Since 2017, the use of solar energy has been monitored as part of the Energy Atlas Berlin. The city has a large potential of vacant sites usable for PV installations, estimated to be an area similar to 3,600 football fields. In 2020, Berlin's Senate passed provisions from the Masterplan Solarcity – Berlin[3] for implementation, which include 9 main areas and 27 complementary activities developed in cooperation with Fraunhofer ISE. Relevant to the topic of the article are the areas of the Solarcity Berlin plan listed below, among others:

- information, consulting and PR activities (Solar Centre Berlin consulting and Solarwende Berlin portal, activities in educational institutions, Solarcity Berlin campaigns);
- breaking down specific barriers (improving connection conditions, activities for historic buildings, increasing energy efficiency);
- improving framework conditions to achieve 25% of solar energy share in Berlin by coordinating the energy needs of new and existing buildings and also through a tenant solution package;
- coordinating and monitoring the implementation of the zoning plan with its release to the public.[4]

A set of these measures is aimed at accelerating the expansion of solar energy on a city-wide scale. Progress from its implementation is subject to monitoring in the form of annual reports and addresses various scopes.

As part of the implementation of Solarcity-Berlin and the promotion of programmes related to the use of solar energy, reference should be made to the topic of

[1] The Conference of Polish Universities '21st Century Habitat – Sustainable Integration of Culture and Eco-Development / Germany, Denmark, Norway, Sweden,' the Conference of Polish Universities and Research Trip – Germany, Netherlands 'Nature – Technology – Culture – Sustainable Living Environment,' organizers: WBiA ZUT in Szczecin, WBAiIŚ UZ Zielona Góra and individual study tours.

[2] https://www.swp-berlin.org/publications/products/aktuell/2012A37_wep.pdf, https://www.osw.waw.pl/pl/publikacje/raport-osw/2012-12-06/niemiecka-transformacja-energetyczna-trudne-poczatki

[3] See: https://www.berlin.de/sen/energie/erneuerbare-energien/masterplan-solarcity/

[4] See: https://www.berlin.de/sen/energie/erneuerbare-energien/masterplan-solarcity/

Fig. 1. Berlin, Futurium building, design. Richter Musikowski Architekten, 2019; source: photo by the author

promoting specific architectural activities, i.e. the Solar Architecture Prize competition implemented in 2021 by the Senate Department for Economy, Energy and Enterprises (Ger. Senatsverwaltung für Wirtschaft, Energie und Betriebe – SWEB). In its objectives, this competition is a platform to promote RES + architecture solutions – both in new buildings and existing ones that undergo energy revitalization. One of its winners is Futurium (designed by Berlin-based Richter Musikowski Architekten) – a multifunctional building located in the heart of Berlin's government district that demonstrates technologies based on RES, among other things (Fig.1). In accordance with the assumptions, the innovative building meets the standards required for a low-energy building and is powered exclusively by renewable energy. Almost the entire roof surface is covered with photovoltaic panels and solar collectors. They use solar energy to maximize the building's electricity and heat needs. Water collected on the entire roof surface is used to cool the building and water the green areas. The energy concept also provides for the storage of heat and cooling power using an innovative energy storage system with a total volume of nearly 50,000 litres. The used HeatSel technology, which uses a paraffin-based phase change material (PCM), makes it possible to store 1 MWh of heat (214.1 kWp (PV) generates about 222,430 kWh per year. The building was awarded the BNB Gold Certificate of the German Green Building Association DGNB and ranked second in the aforementioned Solarcity Berlin competition – edition 2021. The building is described as innovative, based on RES: 'At Futurium, solar energy generation becomes the theme of urban staging and, as a central design element, provides inspiration for the architecture. Visiting (a part of the roof) integrated into the exhibition tour (the viewer) has a wide view of the solar sea, at the same time as the horizon of the city of Berlin' [Musikowski 2018]. Through the prism of change on Berlin's rooftops – towards an urban energy transition – the facility fits into the demonstration part of the Solarwende, bringing residents and tourists closer to what is important in urban adaptation to climate change and independence from fossil fuel exploitation, being an important point in 'RES-tourism' on a city scale just like the pilot building SolarZentrum Effizienzhaus, which won the first prize in the competition Efficiency House Plus + Electromobility, F87 – Berlin, (design. Werner Sobek + ILEK, University Stuttgart).

Solarcity – Berlin is also currently implementing the 'SolarPlus' programme, which is subject to double funding in the city's 2022-2023 budget – from €2.4 million for 2022 to €23.7 million for 2023. A subsidy for photovoltaic installation on balcony enclosures for owners and tenants is envisaged. Subsidies for rooftop installations also continue. The cited selected measures show how the potential of the city and its residents can be used to gradually and consistently achieve a 25% share of solar energy in Berlin, on the road to climate neutrality.[5]

1.2. Hamburg – energy transition

The City of Hamburg is consistently meeting its climate protection targets. In 2021, by means of regulations the authorities decided to increase the share of renewable energy to 80% by 2030. After the 2022 amendments, it is assumed to achieve CO_2 neutrality earlier

[5] https://www.ibb-business-team.de/solarplus

Fig. 2 a, b. Hamburg – Energiebunker and Energieberg Georgswerder; source: photo by the author by 5 years, i.e. by 2045. It is also planned to increase the promotion of renewable energy technologies and strengthen the city's demonstration function in environmental protection and climate change adaptation to remain a pioneer of transformation in this area. In the construction sector, among other things, a requirement is imposed to use photovoltaic systems on a certain minimum 30% of the roof area starting in 2024. A number of other measures dedicated to both new and retrofitted buildings are also being introduced, the mandatory use of RES in the replacement of the heating system, the introduction of photovoltaic and green roofs, PV installations within outdoor parking lots, the strengthening of infrastructure for a more efficient use of electricity, hydrogen and an increase in the number of publicly available electric vehicle charging points. It is also planned to increase the share of renewable energy used to heat buildings from 15 to 65 percent from 2027.[6]

It is worth mentioning that from 2006 to 2013 Hamburg hosted the IBA Hamburg International Construction Exhibition, which initiated a long-term process of transformation and reconstruction of the inner-peripheral Elbe islands, constituting the 'Leap Across the Elbe' (Ger. Sprung über die Elbe). The exhibition answered the question of the climatic, urban-architectural and social future of cities. The projects carried out in Hamburg during the IBA covered more than 35 km^2 of land and showed how degraded the urban space in a metropolis can be sustainably transformed into one that is safe and interesting for residents and at the same time adaptable to climate change. The implementation of the projects both at the level of individual facilities, as well as for entire urban complexes and areas, employed many new technologies based on RES. Numerous investment activities within the IBA Hamburg linked to climate protection and RES are included in the district's long-term energy self-sufficiency plan –the Wilhelmsburg district with possible implementation of one of three energy transition scenarios. The Energiebunker demonstration project is based on the use of renewable energy (Fig. 2a). The facility of an anti-aircraft bunker from World War II has undergone extensive renovation. Its facades and roof are covered by a 1,750-square-meter PV installation that produces electricity for 1,000 households. The second renewable energy investment is the Energieberg Georgswerder (Fig.2b) – this former 45-hectare landfill site undergoing long-term reclamation has become an Energy Hill. A PV plant of more than 7,000 square meters, 3 wind turbines and heat pumps installed on its grounds produce electricity for about 4,000 households [IBA Hamburg, 2015, Hellweg, 2010].

1.2.1. Energy transition of the Wilhelmsburg district

Hamburg, as part of energy transformation of one of its districts – Wilhelmsburg – according to scenarios from the Energy Atlas, is implementing activities in three thematic areas: city and buildings, energy system, and open spaces. They are summarized in the table below with reference to specific activities.

1.2.2. Integrated energy network Wilhelmsburg Mitte

Integrated energy network Wilhelmsburg Mitte (Energieverbunds Wilhelmsburg Mitte) is a 'virtual power plant', which consists of an array of interconnected RES distributed generation units. This IBA demonstration project was realised in one of the model building quarters in the centre of the Wilhelmsburg district and now also includes the aforementioned Energy Bunker. Renewable energy-based installations for the buildings were connected to a single system via a central energy and district heating network. By linking network users with different demand and energy consumption at peak times, a synergy effect has been achieved that goes far beyond the energy optimisation capabilities of individual buildings. This solution allows renewable energy to be supplied to the municipal grid economically and reliably. The result is a simultaneous reduction in operating costs and CO_2 emissions.[7]

1.2.3. Hamburg - demonstration facilities

The innovative buildings presented at IBA – Hamburg 2006-2013 are a presentation of model solutions for residential architecture in an era when cities need to adapt to climate change. Intelligent materials and new systems based on RES were demonstrated using several experimental buildings as examples:

- 'BIQ'- algae bioreactor building,
- 'Soft House' equipped with a tracking photovoltaic membrane system,
- 'Smart ist Grün' using solar energy absorbing and storing curtains made of made of phase change materials (PCM);
- 'Woodcube' built in solid wood construction using geothermal energy (Fig. 3 and 4).

[6] See: Hamburgisches Klimaschutzgesetz https://www.hamburg.de/

[7] See: https://www.solar-district-heating.eu/wp-content/uploads/2018/05/SDHplus_BM_Hamburg-Energie-Energieverbunds-Wilhelmsburg-Mitte.pdf , https://www.elbe-wochenblatt.de/2018/04/11/energieverbund-versorgt-wilhelmsburgs-mitte-mit-nahwaerme-auch-das-buergerhaus-ist-jetzt-angeschlossen/

Table 1. Hamburg district energy transformation roadmap – Wilhelmsburg

MAIN AREAS	DETAILED ACTIVITIES
CITY AND BUILDINGS taking action in accordance with the internal logic of the place at the scale of the district, differentiation of functions, consolidation, strengthening, use of natural and artificial light	prudent energy policy that builds local identity, energy revitalization of land and buildings to ensure improved quality of everyday life, supplementing existing development with new facilities of high energy standards, enriching residential areas with other functions, introduction of mixed functions to commercial and service areas, expansion and modernization of existing housing stock, striving for multifunctionality of buildings, temporary use of vacant land, availability of natural light in public spaces, introduction of urban greenery as shading elements, introduction of sustainable urban lighting, optimization of solar gain potential at the city and building scale
POWER SYSTEM new local energy sector, integration of renewable sources into the energy system, harnessing the potential of energy efficiency	development of flagship projects as a boost to economic development, connection of the local energy system with the basic urban infrastructure, promotion of energy trading and its dissemination – prosumerism, integration of RES systems with architecture and urban planning, implementation of RES in neighbourhoods, implementation of new energy systems as key solutions, development of energy development plans, thermo-modernization of existing facilities, promotion and increase of energy efficiency and local energy production in urban space
OPEN SPACES (public spaces, green and waterfront areas) improving the city's climate, improving the quality of space	promotion of greening of roofs and facades, control of ventilation and introduction of wind shields in the city space, countering the problem of heat islands in the city, increasing eco-mobility of residents, promotion of the sharing economy (carsharing) and the 'I live without a car' campaign, strengthening the link between green spaces and waterfront areas, maintaining and nurturing the quality of urban spaces and creating new ones

Source: own preparation based on: Energy Atlas and IBA Hamburg (IBA Hamburg 2015 – www.iba.hamburg.de)

These selected IBA transformations on the scale of Hamburg's districts and facilities represent an important direction of change, important for the city – a pioneer in environmental transformation and climate change adaptation. They are being implemented consistently, in a sustainable, durable and energy-efficient manner, taking into account pro-environmental solutions, including those based on RES.

Hamburg and Berlin, like other German cities, are implementing the new Energiewende – the 'urban expansion of renewable energy' – and especially in the area of harnessing solar potential. Three key factors have been identified that have made the Energiewende necessary in German cities: the noticeable slowdown in the development of the German renewable energy market, the urgency of the growing demand for RES with the simultaneous need to meet the national climate protection target [Yang, 2022] more quickly. On the one hand, the cities' activities are a kind of testing ground for innovation in the field of architecture and its advanced accompanying technologies as well as urban-scale energy transformation. On the other hand, it is an opportunity to promote the city, the country and its achievements, to strengthen its 'green' image as a global leader. Also important from the point of view of innovative materials was the German pavilion at the EXPO in Milan [Czarnecki, 2016; Gumińska, 2016], who presented OPV (organic photovoltaic): organic solutions of photovoltaic technologies, woven into the sculpture-trees – Solar Trees, which may also indicate a shift of RES and architecture-related technological solutions towards small architecture elements. In the

Fig. 3. Hamburg, fragment Wilhelmsburg Central. Smart Material Houses: 'Soft House' and 'BIQ' and in the distance facilities of Walderhaus WOOD 5 ¼; source: photo by the author

Fig.4 a Hamburg - BIQ building and section of algal bioreactor, design. Splitterwerk, **4.b.** WaterHouses, design. Schenk + Waiblinger, **4 c.** SOFT HOUSE building ,design. Kennedy & Violich, Architecture source: photo by the author solutions observed worldwide, one can also see the penetration of RES into art, which is confirmed by exhibitions, RES-art realisations,[8] thematic murals or artistic installations.[9]

2. WARSAW

In order to achieve the goal of Poland's climate neutrality by 2050, multifaceted actions and appropriate measures are required, and to a large extent these measures are necessary in the area of Polish cities. The ability of the urban system to respond flexibly and rapidly to threats of increasing climate change, not only to overcome them, but also to improve the stability of the whole system and to be better prepared for future impacts of climate change, is becoming a necessity. Within the framework of activities at the local level, Polish cities are increasingly supporting various projects, initiatives and new forms of urban dialogue (e.g. civic climate panels), by building relationships and strengthening involvement among the inhabitants; also in the participatory system, documents, strategies or urban adaptation plans are being prepared and implemented in combination with the exchange of knowledge and experience, while taking care to raise the level of knowledge and awareness of the inhabitants particularly within environmental issues, such as climate change and the need to adapt to the consequences of this worsening in a relatively short period of time [Kassenberg et al., 2019].

2.1. Warsaw and action on climate change adaptation

Warsaw has a vision related to action on climate change mitigation and adaptation, which it has been implementing since 2018 in the framework of various programmes, projects and urban strategies, both short-term ones with a 10-15 year perspective and long-term ones with a 30-year perspective. Among others, in 'Green Cities'-2020 under the European Bank for Reconstruction and Development programme and in its climate component supported by the Climate Action Plan (CAP). The GC's support is visible in the financial scope, among others: urban investments in energy, thermo-modernisation, clean urban transport, and waste management. A long-term strategy and scenarios for sustainable urban development have also been prepared within the framework of the GC+CAP together with the development of its short- and long-term goals called the 'Green Vision of Warsaw' (ZWW ver.3.0 of 10/10/2022), which is a roadmap for the capital city with a view to 2050.[10] ZWW is a goal-setting document needed to achieve climate neutrality and resilience by 2050 and meet the 17 goals of the 2030 Agenda for Sustainable Development, while promoting social inclusion.[11] It assumes three action scenarios: business-as-usual, reductionist and extended. The ToR takes into account documents in force at international and EU levels, and there are clear references to the important EU development strategy, the European Green Deal (2019), as well as to the directive on measures to promote the use of renewable energy sources. The Warsaw vision also refers to existing provisions from the national, regional and local level. Mention should be made of the document adopted by the City of Warsaw entitled the Warsaw Climate Panel and its recommendations with regard to, among others, the energy transformation of the city towards RES, in relation to architecture.

The recommendations of the Warsaw Climate Panel were viewed from the beginning of the Green Vision for Warsaw project as important input from the public and external stakeholders. As part of the project, following an assessment of the existing state of the city, a series of meetings were held with external stakeholders focused on setting a course of action and important goals in the development of the city, including NGOs, urban movements and entrepreneurs. During these meetings, convergences between the Green Vision for Warsaw and the Climate Panel were discussed. Actions developed as part of the Green Vision for Warsaw will constitute a tool for achieving climate neutrality in Warsaw by 2050,[12] which in essence corresponds to the assumptions of the recommendations of the Warsaw Climate Panel. The links between the activities developed in the WCC and the recommendations are presented further in this paper.

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[8] The term RES-ART was used for the first time by Prof. Tomasz Matusewicz at the Domestic Scientific Conference entitled 'The RESART of the Future.' 'Habitat of the 21 Century – sustainable integration of cultures and eco-development' – Germany – Denmark- Norway – Sweden - 2016 organized by the academic centres of Szczecin and Zielona Góra – West Pomeranian University of Technology and University of Zielona Góra.

[9] https://futurearchitectureplatform.org/projects/bbbf7972-f830-40a2-9b41-7386648335db/ https://artistsandclimatechange.com/2022/03/24/culture-shifts-slowly/

[10] See: Zielona Wizja Warszawy, Zielone Miasta, https://eko.um.warszawa.pl/

[11] https://virtualengage.arup.com/zielona-wizja-warszawy/

[12] ZWW / 2022 https://eko.um.warszawa.pl/

2.2. Warsaw Climate Panel (WPK)

The focus of the WPK's activities was on the possibilities of increasing Warsaw's energy efficiency and the share of RES in the city's energy balance, expressed in such questions as: how to save energy in the city, how to use and produce it more efficiently, RES for Warsaw, which way to consciously shape the city in order to simultaneously support the overarching goal of reducing greenhouse gas emissions by a minimum of 40% by 2030 and climate neutrality by 2050. As well as addressing energy-related issues, thermal comfort and ventilation in buildings, new standards for the construction of the buildings of 'tomorrow' and effective ways to revitalize and modernize the existing stock, and ways for cooperatives and housing communities to work towards more efficient energy management in buildings or ways to finance energy investments, individual prosumers, collective and energy cooperatives.[13] Also related to the activities within the WPK are the documents, strategies and recommendations contained therein, which were also an important contribution to the 'Green Vision for Warsaw. Green City and Climate Action Plan'.[14]

2.3. WPK recommendations

The Warsaw Climate Panel is the audible voice of the city's residents in the discussion on adaptation to climate change – it is a democratic form of integrating residents into the process of shaping urban strategies and development plans. One of the outcomes of the forum's deliberations are the formulated recommendations [Górski et al., 2021],[15] covering the previously mentioned thematic areas, and two selected ones: Renewable Energy Sources and Urban Energy Communities, which will be developed in the article and illustrated (it should be mentioned that some of them are already gradually implemented by the City of Warsaw or envisaged in the long term to be implemented as part of the ZWW), among others:

- development of a '100% RES Roadmap for Warsaw', including calculations of supply and demand potential of renewable energy sources (RES) in the capital city with development perspective paths until 2030 and 2050 and with a time axis, costs, savings, (including maps of potential e.g.: solar insolation, wind conditions, potential for dry and wet biomass, potential for bio-waste, storage systems – energy storage and balancing systems in the city);
- installing PV panels on roofs by 2030 in all city-owned buildings, including P+R car parks and city tram and bus depots, where there are no technical, architectural or conservation objections to the installation of such equipment;
- implementation of pilot projects for different types of buildings with functions which will be an inspiration and at the same time a ready model – a demonstration facility – for the implementation of RES solutions;
- promoting and initiating agreements with owners of large-scale facilities, such as shopping malls and centres, and with private entrepreneurs on the covering of roofs and car parks with PV panels and the use of areas suitable for PV installations;
- retrofitting renovated municipal markets with heat pumps and PV panels on pavilion roofs;
- carrying out a RES audits for all municipal buildings in order to select the most favourable technology, installation capacity, together with an estimate of the investment outlay to prepare a timetable based on the results of the audits in order to achieve the goal: efficient implementation of municipal investments in the most promising renewable energy sources in the field of RES for the most promising results: financial-ecological-energetic;
- adoption of a municipal long-term plan to increase the efficiency of rooftop use, taking into account: the mapping of available rooftop space (under municipal and private ownership), the development of a set of available ways to develop the rooftop space and rules for the widest possible access of residents to the spaces created by the project; public consultation on preferred forms of rooftop space development, taking into account the specificities and needs of local communities (e.g. more attention to the issue of green roofs or the creation of meeting spaces in areas with little space of this type);
- securing the means to enable the widest possible scale of the project;
- consideration – at a later stage – of possible forms of support (organisational/financial) for in-

[13] Warszawski Pakiet Klimatyczny, WPK (2020) https://eko.um.warszawa.pl/
[14] https://konsultacje.um.warszawa.pl/sites/konsultacje.um.warszawa.pl/files/10_10_zielonawizjawarszawy_min_size.pdf
[15] See: Warszawski Panel Klimatyczny – Raport zrealizowany w ramach projektu 'Warszawski Panel Klimatyczny" by Civis Polonus Foundation, Fundacja Pole Dialogu i Fundacja Stocznia, financed by the public task entitled 'Warszawski Panel Klimatyczny' commissioned by the capital city of Warsaw, pursuant to the Ordinance no. 756/2020 by the Mayor of Warsaw of June 15, 2020, https://eko.um.warszawa.pl/

dividuals, communities and cooperatives wishing to join the project;
- further financial support for the installation of PV panels through promotional activities, continuation of the subsidy system, arrangements with the system operator concerning a grid development map enabling a dynamic connection of PV installations, with the concept that, where feasible and reasonable, PV panels should be installed on the scale of buildings and urban areas by 2030 (2035 at the latest);
- recommendations concerning energy communities, individual and collective prosumers and RES, among others: conducting analyses of local RES generation opportunities by potential collective prosumers and energy cooperatives[16] (electro-prosumerism is also linked to this point) [Górski et al. 2021].

The following part of the article will discuss the results and status of the implementation of the recommendations in relation to the facilities but also the supported activities and standards.[17]

2.3.1 Warsaw Green Building Standard vs RES

The recommendations of the 2020 Warsaw Climate Panel (WPK) also concerned the development of a green and energy building standard for Warsaw. The latter will be cited in the article due to references to RES, which include:
- the creation of an urban energy standard for the existing and newly constructed buildings with regard to RES and building energy management using smart tools. For the existing buildings, the standard would be mandatory for complex renovations and upgrades, provided there are no technical, architectural or conservation counterindications;
- creating a building energy standard with the adoption of, among other things, recuperation and heat recovery as a green standard for newly constructed buildings;
- the development of an energy standard for Warsaw, i.e. an efficiency requirement based on an indicator defining annual energy consumption per m^2 for individual buildings, e.g. residential or buildings with other functions, built by the city alone or under a public-private partnership formula which has not received support [Górski et al. 2021].

2.4. Implementation of the selected recommendations of the WPK and RES

Within the framework of the adopted assumptions, strategies and programmes, opportunities are currently opened for Warsaw residents to apply for subsidies for the use of local RES, including: heat pumps, solar collectors, photovoltaic panels and wind turbines. As part of the Programme for the Development of Municipal Photovoltaics (PRMF), 46 new investments were made in 2020, with a further 125 investments receiving funding for implementation scheduled for 2023-2024. The programme's objectives are to reduce greenhouse gas emissions by 87,000 tonnes by 2030 alone. Savings on the use of fossil fuels by more than 70 million by 2030 are also assumed. The first facilities to be equipped with photovoltaic panels will be municipal crèches, schools, clinics, community centres, social welfare centres, P&R car parks, bus depots and other units. It is expected that more than 200 municipal facilities will be equipped with solar installations by 2024 alone. The capital also has documents: in the form of a roadmap for 100% RES for Warsaw: a calculation of supply and demand potential for renewable energy sources (RES) in Warsaw, and a set of guidelines compiled into a study of specific measures for architecture, i.e. the Warsaw Green Building Standard. The WSZB is the result of meetings and discussions with specialists and experts consulted during the Warsaw Climate Panel and is defined as a set of guidelines and recommendations for new and modernized municipal buildings (e.g. the standard for educational facilities), leading to the achievement of the climate objectives set by the Capital City of Warsaw in the sector [Górski et al. 2021].

2.4.1. Warsaw Green Building Standard

The Warsaw Green Building Standard (WSZB) addresses six areas of sustainable construction, i.e. the greenery and building environment, construction materials and the construction process, energy, water, waste and user comfort and safety. The fourth area – energy – is addressed below. All standardized guidelines in this area relate to four groups of buildings, i.e. requirements for new buildings, existing buildings (undergoing renovation), residential buildings and public buildings.

The document also defines two levels for these standards: mandatory – requirement (W) and optional

[16] https://konsultacje.um.warszawa.pl, https://eko.um.warszawa.pl/

[17] See: Warszawski Panel Klimatyczny – Raport zrealizowany w ramach projektu 'Warszawski Panel Klimatyczny' by Civis Polonus Foundation, Fundacja Pole Dialogu i Fundacja Stocznia, financed by the public task entitled 'Warszawski Panel Klimatyczny' commissioned by the capital city of Warsaw, pursuant to the Ordinance no. 756/2020 by the Mayor of Warsaw of June 15, 2020, https://eko.um.warszawa.pl/

Fig. 5a. Warsaw, office building Spark C, Skanska – Warszawa 2018 and ultra-thin perovskite-based photovoltaic cells on the façade. The size of the cell under test is 1.3 x 0.9 m,

Fig. 5b. Q22 office block, Warszawa 2016 – PV roof; source: photo by the author

Fig. 6a. Warszawa, Służewski Dom Kultury, Mokotów– wind turbine and educational trail on adapting the city to climate change; source: photo by the author

– recommendation (Z), which, according to the author, goes beyond the proposed standards and is not mandatory, and is a confirmation of the greater ambition of the project. Area 4 – energy – according to the WSZB concerns:

a) the use of renewable energy sources and energy storage facilities in the project:
   – a minimum of 50% of final energy from RES or cogeneration/ trigeneration generated on site (W);
   – installation of photovoltaic panels and their integration into a green roof (in the case of flat roofs) (W);
   – installation of solar collectors, heat pumps, energy storage, micro wind installations (Z).

It has also been pointed out that in the future it will be possible to produce energy in photovoltaic installations from partially transparent perovskites, which opens the way for innovative solutions, i.e. the fusion of perovskites with glass in the windows of buildings. Such solutions are currently being tested in the Spark C office building by Skanska (Fig. 5);

b) energy storage – integration of local energy sources with energy storage is recommended (Z);

c) air-conditioning and heating:

Fig. 6b. Education path in the area of KEZO PAN in Jabłonna n/ Warsaw; source: photo by the author

– design of ventilation system with air filtration, heat recovery and humidity control;
– use of high-efficiency energy recovery – in the mechanical ventilation system and energy recovery from used domestic hot water (DHW);
– use of air-conditioning equipment with the highest possible efficiency, use of RES.[18]

The WSBZ document is described as an important initiative to bring facilities in Warsaw up to the climate targets. At the same time, the development of a uniform standard for sustainable construction is one

[18] https://konsultacje.um.warszawa.pl/sites/konsultacje.um.warszawa.pl/files/raport_warszawski_standard_zielonego_budynku_publikacja.pdf

of the guidelines of the Warsaw Climate Panel, conducted at the end of 2020. The city authorities have pledged to implement the WPK's majority-approved recommendations, which aim to increase energy efficiency and the share of renewable energy sources in the city's energy balance.[19]

As part of the recommendation provisions implemented or planned in the WPK, there is also a provision for architectural competition procedures. A special category has been introduced for the competition for the Architectural Award of the President of the City of Warsaw. Prizes for pro-ecological solutions have been awarded since 2020. In the 6th edition of the competition, the Ecopark in Ursus was awarded – a model park next to the former Ursus tractor factory with an area of 5ha (designed by Abies – Architektura Krajobrazu). It includes many pro-ecological elements, implementing the idea of a circular economy, creating an attractive public space combined with ecological educational paths. A lighting system powered by PV panels is also proposed, in their spatial forms alluding to the structures of the trees.

2.4.2. RES and urban transport facilities in Warsaw

The Capital City Bus Company (MZA) is deploying an electric and low-emission fleet to operate public transport. By 2020, more than 160 electric buses will be running around the capital. Alongside the increase in the number of buses, MZA is investing in parallel in environmentally-friendly solutions at its own depots. At the Woronicza Depot in Mokotów, energy is obtained from 280 photovoltaic panels with a total capacity of 75 kWp placed on the roofs of the depots, which accounts for approximately 20 per cent of the current energy demand used to meet the current needs.[20] The Annopol depot will be the first in the country to be powered to such a large extent by renewable energy sources. The use of RES will reduce the consumption of fossil fuels (gas); in order to achieve this goal in the planned Warsaw investment, the following will be used: an optimized photovoltaic installation (solar cells mounted on buildings/roofs) with a capacity of approx. 330 kW, ground-based air heat exchangers and gas-absorption air-to-water heat pumps, compressor heat pumps linked to the installation of vertical heat and cold storage, compressor heat pumps as external units of the VRF air-conditioning system. The cited advantages of using RES in Annopol's energy strategy are the reduction of energy consumption from conventional sources, energy independence of the administration's operation on a sunny day, the reduction of CO_2 emissions by nearly 147.33 tonnes/year (50 years = approx. 7,400 tonnes less CO_2).[21]

It is worth mentioning that more than 162 climate-safe electric buses operate in the capital. The city as part of its participation in the 'Green Public Transport' – this priority programme has obtained national funding for the purchase of further electric buses in 2023.[22] It should be added that the highest number of e-vehicles drive in Warsaw, according to data on Polish cities with more than 300,000 inhabitants.[23] As the number of such vehicles increases, so does the number of charging stations, which are a new feature of the urban landscape. Charging of electric vehicles is possible in several ways: from a household socket (AC) to a power amount of ca. 3,7 kW, a wallbox (AC) to a power amount of 22kW, and from a detached dock (AC up to 22kW, DC up to 350kW). Data shows that since 2013 the number of 4 publicly accessible urban charging points in Poland has increased to more than 2,565 in 2022, with the largest number in Warsaw. New investments are being made in the capital, such as the Annopol depot project mentioned above or the one modernized in Mokotów. In the above-mentioned investments, those within the roofs and facades of designed or existing architectural buildings as well as small architectural elements based on PV-based installations come to the fore.

The architectural competition of the Public Transport Authority for the modernization of a car park in Połczyńska Street (2020), whose participants were to propose model solutions based on RES, also seems important. This demonstration project would allow the redevelopment of other Warsaw park-and-ride facilities and the design of new ones using RES. The plans include the implementation of photovoltaic installations, a charging system for electric vehicles, revalorization

[19] Ibidem, and: https://eko.um.warszawa.pl/

[20] https://www.gramwzielone.pl/auto-ekologiczne/26528/warszawskie-mza-inwestuje-w-autobusy-elektryczne-i-pv

[21] https://www.zajezdniaannopol.pl/opis-inwestycji.html 'Budowa trasy tramwajowej do Wilanowa wraz z zakupem taboru oraz infrastrukturą towarzyszącą' under the activity 6.1. Rozwój publicznego transportu zbiorowego w miastach, Oś priorytetowa VI: Rozwój niskoemisyjnego transportu zbiorowego w miastach, Programu Operacyjnego Infrastruktura i Środowisko 2014-202

[22] *The project entitled 'Zakup 12 autobusów niskoemisyjnych dla m.st. Warszawy' is co-financed from national resources of the National Fund for Environmental Protection and Water Management under priority programme no. 6.3 'Zielony Transport Publiczny'.* https://um.warszawa.pl/-/nowe-autobusy-elektryczne-dla-warszawy

[23] See: Raport „Polish EV Outlook 2022", https://pspa.com.pl/2023/informacja/licznik-elektromobilnosci-kolejny-rekordowy-rok-na-polskim-rynku-e-mobility

Fig. 7. Laboratory of Energy-Efficient Architecture at the Faculty of Architecture, Bialystok University of Technology, Białystok 2015 (Idea and concept design:: A. Turecki, construction and development design: A. Rydzewski and team, energy efficiency audit: M. Tur); source: photo by the author

of greenery, development of assumptions for rainwater retention and an educational programme for car park users.[24]

The redevelopment of Warszawa Zachodnia railway station will be another Warsaw project using photovoltaic-based solutions, with a total module area of 12,000 square metres. The Warsaw station will follow the Local Transport Station in Rzeszów, the Bus Station in Sanok and the Transfer Centre in Pszczyna, where installation elements based on photovoltaic modules have been used, including glass-to-glass technology on opaque roofs and photovoltaic modules with illumination and engraving, which fill transparent skylights. It is also worth mentioning foreign projects relating to public transport solutions, such as the environmentally-friendly Sunglider urban railway, a project by a Polish-German team (led by architect P. Kuczia) with an energy-active Xylo-Solar-Roof enclosure, a PV footbridge system – ‘Solar activation of footbridges’ in Beijing, the ‘SolarRoad’ – tested in the Netherlands, Hungarian substrates – PV modular pavements – Platio Solar, a photovoltaic installation integrated into the railway route – TÜV Rheinland, or photovoltaic canopy systems over PV-SUD roads – Fraunhofer ISE. It is in these areas that the greatest number of innovations are observed.

3. DISCUSSION

Low-carbon energy transitions, regeneration and the challenges of electrosumerism In the national energy policy with a view to 2040 – PEP 2040,[25] a reference can be made to the assumed increase in the role of RES, which results from the need for a low-carbon energy transition. It is indicated that the country’s transformation is possible thanks to the diversification of the energy balance and its decarbonization and contribution to the EU-wide target of 32% of RES in gross final energy consumption, as well as decreasing costs of technologies related to energy generation. Poland declares the achievement of at least 23% RES share in gross final energy consumption in 2030 (in the electricity sector – at least 32% net, in heating and cooling – an increase of 1.1 percentage points y/y, in transport – 14%). The PEP 2040 also indicates that, taking into account the assumed technological development of the country, the following will play an important role in achieving the RES target: offshore wind farms, further development of photovoltaics, development of onshore wind farms, an assumed increase in the importance of biomass, biogas, geothermal in district heating and the development of the heat pump segment in individual district heating, while in transport the need to increase the use of advanced biofuels and electricity is indicated.[26] As can be seen in the examples cited, photovoltaics appeared most frequently as a direction for urban-scale RES development and its integration into architecture.

The Intergovernmental Panel on Climate Change (IPCC) points out in the sixth report – *Climate Change 2022: Mitigation of Climate Change* – on possible

[24] https://architektura.muratorplus.pl/konkursy/eko-pr-polczynska-edukacja-ekologiczna-na-parkingu_11145.html;
[25] See: PEP 2040, https://www.dziennikustaw.gov.pl/MP/2021/264, https://www.cire.pl/artykuly/serwis-informacyjny-cire-24/174947-trzy-glowne-filary-projektu-polityki-energetycznej-polski-do-2040-r
[26] Ibid.

different pathways for the energy transition of cities and opportunities for climate change mitigation. Three main conclusions come to the fore, which are: new innovative technologies, moving away from fossil fuels and a just transition, taking into account the different ways to achieve it. Witajewski-Baltvilks points out that: 'We have pathways that focus on RES, those that attribute a greater role to increasing forest cover and using the earth's resources. We also have those that are based on finding the most efficient ways to use energy. Each of these has different implications'.[27] Among the many projects, strategies and revitalization activities aimed at improving energy efficiency in the above described German cities and Warsaw, it is also worth mentioning those undertaken in Szczecin and Białystok, concerning possible scenarios for the revitalization of modernist housing estates built in Szczecin between 1918 and 1925 and in Białystok between 1950 and 1990, which do not meet current standards but constitute architectural heritage [A. Turecki, M. Tur, B. Czarnecki, K. Januszkiewicz, P. Fiuk 2022], indicating possible and likely options for RES that can be related to similar activities in the country and the 'Wave of Renewal' programme. Among the concepts for the regeneration of waterfront areas, it is worth mentioning Szczecin Garden Island [Paszkowski, Gołębiewski, 2017; Paszkowski, 2013] and Ecoenergy Land taking into account the use of RES [Januszkiewicz, Gołębiewski, 2019].

Also linked to the topic of RES are the increasingly cited concepts of energy cooperatives, energy production and consumption of energy, a just transition or individual and collective prosumerism, which has evolved towards electrosumerism.[28] The latter also involves the implementation of recommendations from the Warsaw Climate Panel and the Green Vision for Warsaw, which refers to a study by a team led by Popczyk containing scenarios for the energy transformation of the capital city referred to as the 'Energy Model for the Capital City of Warsaw 2050, taking into account electrosumer conditions.'[29] The vision of a segment of the post-transformation world is starting to become visible and refers to the 'efficiency ranking of the five areas of energy transformation' of cities defined in the Transformation of Energy in Breakthrough Innovation Mode (TETIP). Some of these refer to architectural and building scopes. The five scopes indicated are: passivation of buildings; electrification of heating; electrification of transport; electricity use, electrotechnology development, industry 4.0, circular economy; re-electrification of renewable energy sources – RES. An additional economic area (indirectly related to electrosumerism, through the carbon footprint and a circular economy) is agriculture and livestock.[30] These issues need to be discussed at greater length, but due to their scope they constitute a separate topic and are only mentioned here to illustrate the multi-faceted approach to urban energy issues.

3.1. Maps of urban RES potential

In order to visualize RES potential on a city scale, maps are an important digital tool. The most widespread are the solar ones – as tools for mapping and assessing the potential for solar energy on existing buildings and/or newly designed ones are based on GIS, they are a decision support tool for different users (politicians, urban planners, architects, investors). They can and do refer to different scales: political – area, urban – town planning, architectural – specific building – roof. They are also helpful in different phases: planning, construction, revitalization of areas or buildings, and prediction of energy needs in a smart city. Taking these three aspects into account, the solar potential map tool will influence the first stage of the solar energy process on the scale of cities, areas and buildings, significantly accelerating it.

In the country, maps of the solar potential of roofs are made public on the websites of Polish cities and the use of them is free of charge, compared to those in Europe for a smaller number of cities. The map of the solar potential of building roofs in Katowice – 'Katowice for a change in 3D' – was created on the basis of aerial and oblique photographs, photoplans, orthophotos, la-

[27] See: https://ppte2050.pl/platforman/bzppte/static/uploads/3.%20Piotr%20Plis%20-%20Transformacja%20energetyczna%20Warszawy%20do%20elektroprosumeryzmu.pdf for the outcomes of work included in the report *Climate Change 2022: Mitigation of Climate Change* IPCC , J. Witajewski- Baltvilks, Head of the Warsaw Ecological Economics Centre of the UZ, member of the Working Group IPCC 2022, www.architektura-murator.pl

[28] The definition of the electro-consumer (Polish, EU, Euro-Atlantic zone) is the modern electricity consumer who individually realizes the global Paris climate agreement and the EU climate neutrality goal 2050 (moving away from fossil fuels) within the framework of the practical conditions produced by the principle of subsidiarity at each level of democratic power (in particular, local government state, EU and institutionalized global governance) – TETIP energy transition (energy transition in a disruptive innovation mode) to electropower as a vehicle for the future here and now, Popczyk J. - https://ppte2050.pl/

[29] https://ppte2050.pl/platforman/bzppte/static/uploads/3.%20Piotr%20Plis%20%20Transformacja%20energetyczna%20Warszawy%20do%20elektroprosumeryzmu.pdf

[30] https://biznesalert.pl/popczyk-elektroprosumeryzm-spoleczenstwo-gospodarka-energetyka/

[31] https://katowice.eu/Strony/Plan-adaptacji-do-zmian-klimatu.aspx

ser scanning and a 3D numerical model of the objects. The map runs in the Oracle Cloud and facilitates decision-making for residents and city authorities regarding the use of roof surfaces of municipal and individual buildings for the installation of solar energy devices. Like Warsaw, Katowice has developed a 'City of Katowice Climate Change Adaptation Plan 2030-project' (2019).[31] Warsaw has interactive maps of solar and geothermal potential; in the detailed guidelines of the ZWW vision and the Adaptation Plan there are specific provisions for their energy-active use and promotion as demonstration solutions for inhabitants and investors – individual and collective prosumers – as well as within the framework of electrosumerism. Below is a summary of the most popular urban solar potential mapping tools, which confirms the growing interest in the topic.

Table 2. Solar maps – overview

Solar potential maps of selected cities			
Country	**City/area**	**Name**	**Website**
USA	Cambridge, Boston, Boulder, New York, San Francisco, Washington,	Mapwell	mapdwell.com/en/cambridge,.mapdwell.com/ en/boston, mapdwell.com
	Boston	Renew Boston Solar	CityofBoston.gov
	Los Angeles	LA Country Solar Map	solarmap.lacounty.gov
	New York	NYC Solar Map	nysolarmap.com/
	Austria	pv-map.apvi	pv-map.apvi.org.au/
Germany	Aachen	Stadt Aachen , Solarkataster	solare-stadt.de/staedteregion-aachen
	Berlin	Solaratlas Berlin	businesslocationcenter.de-
	Dusseldorf	Solarkataster, Dusseldorf	detailskronos.solare-stadt.de/duesseldorf/
	Hamburg Wilhelmsburg	Energy atlas	hamburgenergie.de/ueber-uns/energieerzeugung/solaratlas/
	Munich	Solar Meunche	maps.meunchen.de
	Osnabruck	Sun-Area	-
Sweden	Lund	solkartan	solkartan.se
	Gotenburg	SEES	-
Switzerland	Basel	Solarpotenzial	-
	Geneva	InfoEnergi	https://sunroof.withgoogle.com/ -
Austria	Vienna	Solarpotenzialkataster	www.wien.at
Poland	Warsaw	Mapy potencjału solarnego	um.warszawa.pl
	Wroclaw	Mapy potencjału solarnego	https://www.geoportal.wroclaw.pl/mapy/solarna/
	Katowice	Mapy potencjału solarnego Katowice dl odmiany w 3D"	http://sip.katowice.eu/
Global		Global Solar Atlas	https://globalsolaratlas.info
		Photovoltaic Geographical Information System Interactive maps	www.re.jrc.ec.europa.eu

Source: own preparation based on data of: mapdwell.com, pv-map.apvi.org.au, solkartan.se, iba-hamburg.com

3.2. Educational dimension of architecture and RES

The subject of renewable energy sources is attracting increasing interest. Various forms of experimental, educational and popularization activities offer the opportunity to acquire knowledge about RES, but also present a wide range of possibilities for financing RES investments, which is particularly important for the energy transition.

There is a growing interest in experimental facilities using RES technologies and educational pathways on energy and climate change adaptation in cities (e.g. Warsaw, Służewski Cultural Centre, KEZO PAN in Jabłonna near Warsaw, NFOŚiGW headquarters in Łódź), (Fig. 6).

At this point, attention should be drawn to the demonstration facility of the Faculty of Architecture at Bialystok University of Technology – Laboratory of Energy-Saving Architecture and Renewable Energies (concept design: A. Turecki, construction and detailed design by A. Rydzewski and team, energy audit, M. Tur), (Fig. 7), dedicated to architecture students, or two research facilities of the University of Zielona Góra's CBZiE located in the Science and Technology Park in Nowy Kisielin – Zielona Góra. Renewable energy and the activities undertaken in the aforementioned experimental pavilion FA BUT – Laboratory of Energy-Efficient Architecture and Renewable Energy – in the space where students of architecture at the University of Zielona Góra can learn about innovative energy-active technologies in a practical manner and later implement selected ones in their own design studies, so that they ultimately meet selected sustainable development goals, e.g. 7 – 'Clean and Accessible Energy'.

The concept for the Research and Education Campus of the Faculty of Environmental Engineering of Wrocław University of Science and Technology and the 3E Energy – Ecology-Education 3E Campus (design. P. Kuczia in collaboration with a team of researchers at WIŚ PWr, 2011) could be the perfect combination of a facility that would serve as zero-energy headquarters of a Polish university and, at the same time, be a training ground for demonstrating how RES-based systems work.

In 2022, there has also been an increase in the amount of investment made by universities and colleges using the solar potential of their roofs, i.e. Pomeranian Medical University in Szczecin (3 dormitories), the Nicolaus Copernicus University – Institute of Psychology, the University of Gdańsk – the University's Neophilology.[32] In addition to roofs in existing buildings, solutions are being applied to improve the energy efficiency of existing systems, but also efforts are being made towards energy-efficient facades, skylights and balconies; also car parks are being converted into carports (Wrocław University of Environmental and Life Sciences – Geo-Info-Hydro Centre, the Medical University of Warsaw – Swimming Pool, KEZO PAN in Jabłonna n./Warsaw) or hybrid solutions. There are also changes in the roofs of sacred buildings (Church – Sanctuary of the MBNP in Jaworzno, Church in Tychy, Chełmno, Stężyca) in the concepts for their expansion (design of the external chapel of the 'Arka Wiary' at the Church of the Ascension of the Lord in Ursynów[33] in Warsaw, design. M. Budzyński – glass chapel with a visible outline of the BIPV grid within the roof area [Budzyński, 2021, p. 149-151], the concept for the Revitalization of the Gubin Parish Church, design. M. Małachowicz, 2013),[34] facades (a photovoltaic cross on the facade of the church of Our Lady of Czestochowa in Pleszew, 2019), as well as landscaping (a church in Nowy Sącz with a ring-shaped PV system on the ground). The scale of applied solutions has also changed from individual to energy cooperatives (e.g. a multi-family building in Wrocław with 3,000 PV panels, using the potential of balconies also in a multi-family building in Sopot). The roofs and facades of hospitals and sports facilities are also going into the direction of transformation towards RES (e.g. hospitals in Bielsko-Biała, Częstochowa, Warsaw, Gorlice, Dąbrowa Górnicza, swimming pool in Jasło). One could also cite a foreign project for the design of PV roofs at the Ministry of Defence Headquarters in Paris with an area of 4 000 m^2 (project ANMA, Agence Nicolas Michelin & Associés), which is not just a surface for PV substructures, but a form following the energy, aesthetically merging into a coherent whole [J. Juchimiuk 2019].

The increase in the number of institutions, associations, clusters dealing with RES, including architectural ones, among others, can also be cited as part of the activities: Circle of Sustainable Architecture at Warsaw Division of the Association of Polish Architects (SARP) and its activities in the field of #Architekcidlaklimatu or joint activities in the series 'Architecture of the climate crisis' undertaken in cooperation with the Warsaw Zodiak Architecture Pavilion, the Polish Green

[32] https://swiatoze.pl/polskie-uniwersytety-stawiaja-na-energie-sloneczna-i-oszczedzaja-100-tys-zl-rocznie/
[33] https://issuu.com/marek_budzynski/docs/m_budzy_ski_przekszta_canie_przestrzeni_dla_trwani?utm_medium=referral&utm_source=mbarch.pl
[34] http://doi.prz.edu.pl/pl/pdf/biis/326

Building Council PLGBC. There is also a growing number of publications on energy efficiency or energy-active architecture [Z. Bać 2020]. One could also mention a platform related to electrosumerism – the Universal Platform for Energy Transformation PPTE 2050 with 5 prosumerism platforms, taking into account the three waves – the prosumer, the innovator pretender and the collective pretender, or the idea of the author of the article: an e-learning platform – Atlas of Polish Architecture with RES – ozearch.pl (currently under construction),[35] which aims to bring national realisations closer to the public with the possibility of adding own objects and sharing knowledge as an application extension of further dissertations on the relationship between architecture and energy.[36]

CONCLUSIONS

The image of cities and RES use presented in this article offers a range of strategies, directions in which the energy transition is heading. Some cities are implementing changes in an unhurried manner, undergoing only metamorphoses, while others are well established as pioneers of the transformation on a European scale but have slowed down a bit or are changing the scenario to a more conservative one, where others have visions of a post-energy-transformation era and pose further questions.

The solutions presented in this article exploit the urban potential of combining low- and high-tech RES-based technologies. This observed tendency allows to assume that in the near future, realisations of such a pro-environmental character will constitute the vast majority in the Polish landscape of cities and towns, a good example of which is the metamorphism of the architecture of the capital city, which falls under the provisions of the Warsaw Green Building Standard, implementing European trends of change. Similar standardized solutions could also be reflected in the architecture of other national buildings and transformations on a city scale. However, in order for this to be possible, a concerted effort must be made to build a sustainable system based on the use of RES potential, which will support key pro-environmental initiatives and the energy transformation of cities in a multifaceted way (also involving buildings), individual and collective prosumerism and urban energy cooperatives, as well as an increase in the environmental awareness of residents and designers in the era of the need to adapt cities to climate change and achieve climate neutrality.

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