UDC 728.4 DOI: 10.56900/2312-6116_2024_11_23

Article

Integrated Photovoltaic Systems in Ecourbarchitecture

© **Nikola Cekic**

Abstract:

Implementation of integrated photovoltaic systems in building construction represents a strategic step in ecourbarchitectonic, functionally innovated formation of building with an altered esthetics and artistic understanding of spatial compositions. In such a concept, there are renewable energy sources which with modular solar panels bring about a high architectonic quality. They are an integral part of the structure, generating photovoltaic energy. The advent of BIPV technologies opened a very important city-building topic on future harmonic formation of the houses, their positioning and layout orientation in relation to the natural and artifact environment, as well as on the organic, environmental interpolation of physical structures into the existing urban fabric. In general, it is a strategic question of urbanity in terms of further formation of the appearance of houses, streets, squares and plazas in different climates. In the focus is a correct choice of the type of BIPV facades and building material which will improve its performance.

Key words: ecourbarchitecture; fluid forms; blob structures; iconologic character; BIPV technologies; strategic design; space.

Author: **Nikola Cekic**, PhD Academic, Professor, Doctor of Architecture, Faculty of Civil Engineering and Architecture of the University of Nis (Nis, Serbia). E-mail: ncekic@yahoo.com

Introduction

Implementation of integrated photovoltaic systems in building construction represents a strategic step in ecourbarchitectonic, functionally innovated formation of building with an altered esthetics and artistic understanding of spatial compositions. In such a concept, there are renewable energy sources which with modular solar panels bring about a high architectonic quality. They are an integral part of the structure, generating photovoltaic energy. The advent of BIPV technologies opened a very important city-building topic on future harmonic formation of the houses, their positioning and layout orientation in relation to the natural and artifact environment, as well as on the organic, environmental interpolation of physical structures into the existing urban fabric.

Examples of Integrated BIPV Façade Systems in Contemporary Ecourbarchitecture in the World

This paper deals with the accelerated development of “green technologies” in the world, whereby use of BIPV panels in design of ecourbarchitectonic design of exterior surfaces of physical structures in practice is an important strategic issue in the field of healthy building and energy efficiency of buildings. There is a large number of buildings with impressively installed and state-of-the-art economical solar panels as integrals parts of architectonic compositions – solecture, which in addition to rigorous esthetic criteria also meet all the functional technical-electric-energy conditions. For a long time, solar technologies were considered an economic feature only outside of urban areas, which have considerably more sunlight. By turn of the century, a huge environmental and city building progress was made in formation of the building skins, by replacing the classical cladding materials, for instance concrete, brick or metal, with solar panels for generation of renewable electric power with lower investment costs. Ten presented examples of high-quality constructed buildings with BIPV panels in this paper, genuinely confirm such an assertion, and create new opportunity for a radically different ecourbarchitectonic designing of the skin of the buildings that create a new, clean energy (Fig. 1).



Fig. 1. Tesla Tilburg factory solar panels, Holland
a) https://cdn.shopify.com/s/files/1/0173/8204/7844/articles/tesla-tilburg-factory_3a442c00-fb44-4078-9ad3-3258aef0313e_1600x.jpeg?v=1575983483
b) https://www.teslarati.com/wp-content/uploads/2018/01/tesla-tilburg-factory-solar-panels.jpg
c) https://upload.wikimedia.org/wikipedia/commons/c/c2/Tesla_Tilburg_assembly_plant_roof_solar.jpg

The California based Tesla factory, opened its assembly plant in Tilburg, Holland, in 2013 with impressive 18.900 m^2 solar panels on the roof of the building for electric energy production. After a year of operation, the capacity of the assembly plant large hall was expanded threefold, so that the total area of solar panels reached 43.000m^2. It is one of the largest solar installations in Holland, with 88% of building roof covered with solar panels and with a production of up to 3MW of electric energy. No openings are provided for the penetration of daylight into the interior, so that the entire surface area could be used for installation of solar panels. The management of the factory intends to bring the energy management to the level of zero CO2 emission. It is a tendency to have the entire site in the near future covered with solar panels generating clean energy, by covering the areas on the surrounding, sunlit hills with solar panels (Fig. 2).



Fig. 2. Black BIPV façade with laminated glass on a public building (children's day-care centre in Marburg, Germany). Project realized by ertex-solar [1]
a) https://images.adsttc.com/media/images/5578/deeb/e58e/ced6/2800/0092/large_jpg/Aussen05a_MG_6710.jpg?1433984736 ; b) https://www.pveurope.eu/News/Solar-Generator/Building-integrated-photovoltaics-European-framework-for-certification-and-approval-procedures-necessary

Integration of photovoltaic technology (Black BIPV) on the building of a clinic in Marburg was implemented on the children's day-care center, with five rooms having capacity of 50 users. By using the modular façade solar panels[2], of total power of 52.3 kWp, the building is constructed in a park environment in 2014. An outstanding appearance of façade planes in the "Vitos Clinic" complex, on the two-storey building was realized. It draws attention with its extraordinary shape and compatible, organic interpolation into the already existing structures, whereby their historical and esthetic value is fully preserved. Roof structures and jagged south-west façade on the top floor are used to accommodate photovoltaic devices. The jagged composition was chosen in order to increase the surface area to accommodate solar modular panels. The characteristic form and favorable disposition of solar panel surfaces have important esthetic-iconic properties and excellent functional conditions for active production of clean "green" energy (Fig. 3).

[1] www.ertex-solar.at/produkte/referenzen. www.opus-architekten.de
[2] Moduli 360 VSG-DESIGN 2/2 | 825 x 1.507 mm



Fig. 3. The Umwelt Arena Spreitenbach[3], Swiss
http://naturschutz.ch/news/umwelt-arena-offnet-ihre-tore/51703
https://www10.aeccafe.com/blogs/arch-showcase/2012/11/08/umwelt-arena-in-spreitenbach-switzerland-by-rene-schmid-architekten/

Designers skillfully unified environment friendly approach and esthetics on the archisculptural composition of the roof structure of Umvelt Arena in Spreitenbach, built in 2011, designed with polygonal solar panels. The remarkable appearance of the roof structure in the form crystals, with an integrated photovoltaic system, enabled transformation of solar energy, so that the building is economically cooled and head depending on the climate conditions. The system is created with a distribution network (TABS) in concrete floors and the system of earthen pipes under the foundation slab of the lower level of the parking. It generates twice as much clean energy than the actual demand of the users. In the summer season, cool water circulates through the network of pipes, and in the winter season, it is hot water. The roof is made of prefabricated wooden multi-layer panels (10 cm of insulation for the value U of 0,14 W/m²K). Photovoltaic panels are supported by the roof structure on insulated, timber, precisely constructed support elements. The active solar surface area is 5.333 m² on the octagonal layout with 33 irregularly insolated surfaces. They are oriented differently, and have an inclination between 6^0 and 62^0. The roof plane extends to the ground level, and it is entirely covered by PV modules (Fig. 4).



Fig. 4. Bursa.Turkey. 2016. The EWE & Bursagaz Head Office building[4] is the headquarters of a local natural gas distributor located in Bursa, one of the biggest cities of Turkey
https://www.archilovers.com/projects/204266/ewe-bursagaz-headquarters.html

New administrative-office building in Bursa was opened in 2016. It has installed devices allowing generation of a portion of electric power from the renewable sources for own consumption. On the roof is installed a 45 (kWp) solar system, while on the façade are installed additional 100 m^2 of BIPV semi-permeable solar cells having the nominal power of 5 kWp. Two wind turbines of with a capacity of 2 kWp are installed on the building, able to generate power at low wind speeds. It is provided for introducing the

[3] UMWELT ARENA AG, Address: Türliackerstrasse 4, 8957 Spreitenbach, Switzerland. Architect: René Schmid Architekten AG. Photovoltaic Installer: BE Netz AG. Photovoltaic consultant: BE Netz AG. Energy Index: 24 kWh / m²a (heating, cooling and electricity). Maximum power: 737 kWp

[4] Project Name: EWE & Bursagaz Headquarters. Architectural Design Office: TAGO Architects. Designer: Gokhan Aktan Altug. Design Team: Muge Eker Eryayar, Mevlut Duymaz, Mete Kiyan, Seda Genc Yildirim, Emre Ertugrul, Emre Kurbak, Eser Gungor. Client: Enervis Enerji Servis Sanayi A.Ş. Project Location: Bursa / Turkey. Project Type: Office Building. Total Project Area: 9.500 sqm. Project Year: 2012-2013. Construction Year: 2013-2016. The building has an area of 820 m² and approximately 9500 m² of building area. It consists of 7 floors and 3 basements.

sunlight using the optic cables into the rooms without natural sunlight. The building in Bursa is equipped with contemporary, efficient, energy saving building technology which meets the highest standards. In the central part, there is a combined thermal electric plant, whose waste heat is simultaneously used for cooling and heating of the building. This will reduce CO2 emissions for 30% and it will be a model for future city-building endeavors. Turkish regulations require that the industrial sector consumes 15% less, and buildings 27% less energy until 2023. The headquarters of EVE and Bursagaz companies is an example for the environmentally extremely acceptable approach with systems of renewable energy sources integrated into - the architectonic design (Fig. 5).

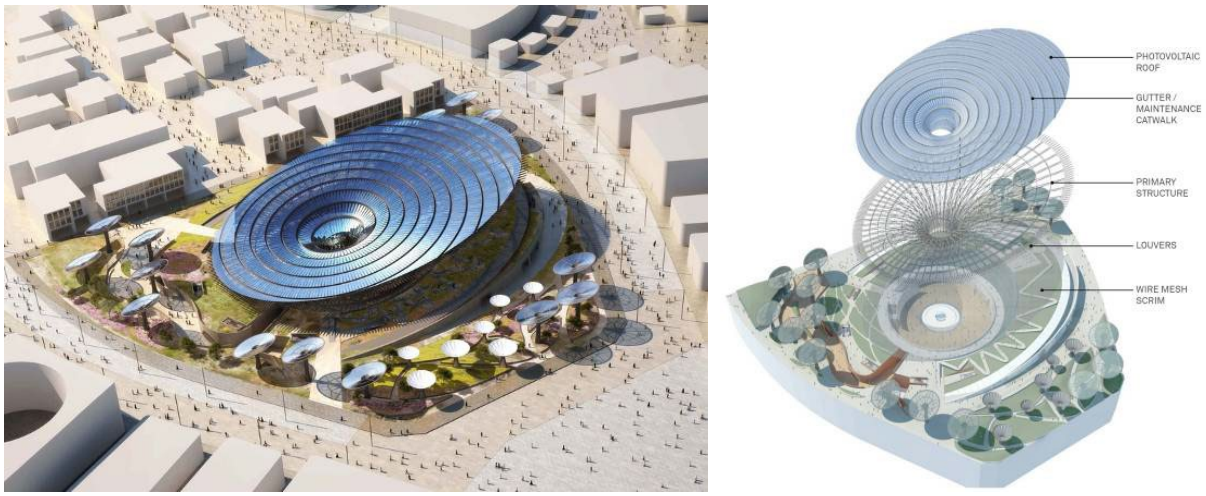

Fig. 5. Grimshaw Architects designed Sustainability Pavilion for Dubai Expo 2020, United Arab Emirates https://www.constructionweekonline.com/article-50793-acciona-unit-wins-expo-2020-dubai-sustainability-pavilion-contract; https://www.floornature.com/media/photos/1/13650/05_grimshaw-arch_dubai-expo-2020_sustainability-pavilion_full.jpg

Grimshaw Architects[5] for Dubai Expo 2020, prepared a design of a new Sustainability Pavilion which will be centerpiece in the global event. The primary motto was to "illuminate the ingenuity and possibility of architecture as society looks to intelligent strategies for sustainable future living,". Inspiring, striking and innovative urbarchitectonic form favors the environmental approach to sustainable technologies and design. The Sustainability Pavilion with 8.000m^2 of exhibition space, auditorium, courtyard and the tank will be a working demonstration of the solar energy efficiency, generation of water and material optimization. The idea stemmed from the complex natural processes, such as the photosynthesis, in order to create a dynamic structure capable of harvesting the solar energy and water from the moisture in the air. The architecture of this physical structure will be self-sustainable even in extreme climate. The saucer-funnel shaped roof of the pavilion, in addition to the shade, will also generate 4GWh of electric power a year through the (PV) panels, tending to the zero energy status. Apart from that, it will generate up to 22.000 liters of water daily from the atmospheric moisture and recycle the waste water, with a plan to achieve a net zero status. It is planned that the Pavilition will continue to operate after EXPO 2020 as a research, education complex "Exploratorium" with flexible elements which will provide reduction of energy resources consumption (Fig. 6).

[5] Grimshaw Architects (formerly Nicholas Grimshaw & Partners) is an architectural firm based in London. Founded in 1980 by Sir Nicholas Grimshaw, the firm was one of the pioneers of high-tech architecture.



Fig. 6. PAF Head Office, Aland Islands 208 kW, Mariehamn, Finland
https://images.adsttc.com/media/images/582a/c404/e58e/ce0a/f200/01b2/slideshow/9132_087.jpg?1479197654
https://napssolar.com/sites/default/files/2017-06/DJI_0052_2.JPG

The international PAF gaming company of Aland, Finland, constructed an administrative-office energy efficient building[6] which supports the culture and working methods in the company, with a tendency of long term conservation of energy capacity. The façade of the new building, on its south side, is clad in solar cells and solar panels on the roof, so that the installed devices generate the total electric energy demanded for the company operation. The solar energy is harvested by the building via a characteristic conical surface inclined in an arc with 742 installed solar panel having the surface are of 1400m^2, on a 70 cm thick wall. The design of the environmental structure of the building with strong laminated timber supports for sound damping, as well as the "square" spatial organization concept are characteristic, and they indicate a very important aspect of observing the natural environment. The designers insisted that he building is prevalently built of renewable local material, natural, pure, easy to work with and good for use in the interior (Fig. 7).



Fig. 7. HIKARI: A positive energy Building with an architecturally integrated PV façade
and a PV rooftop system (190 KWP) - Lyon, France, 2015
a)https://archello.com/story/42088/attachments/photos-videos/3
b)https://i.pinimg.com/originals/b1/24/a9/b124a92477fe0e67bc15eed045c96728.jpg
c)https://i.pinimg.com/originals/14/d5/d7/14d5d74551925e9b02c937fe60c47543.jpg

Japanese architect Kengo Kuma got the first prize on an international competition for the conceptual design "Hikari"[7], with integrated solar façade panels on three separate residential-office buildings, of the total surface area of 12.300m^2, in the center of the Lyon-Confluence district in Lyon, on a plot having an area of 3.400m^2. Each building has a special efficient energy program: **Higashi** ("East" in Japanese) has 5.500m² of office space; **Minami** ("South" in Japanese) contains 38 apartments on floors having the surface area of 3.400m²; **Nishi** ("West" in Japanese) is a combination of functional areas of the building with 2.600m² and four residential structures with 700m². The business area on the ground level of 1.000m^2 are

[6] Owner: PAF. Completion date: July 2016. Location: Maarianhamina, Aland. Overall module power: 208 kWp. Estimated annual electricity generation:145.000 kWh. Total solar module area: 2159 m^2. Module quantity: 750. Module type: Naps Saana 270 (roof) ja Naps special manufactured trapezoid solar module. Module power: 270 Wp. Cell type: 6" Polycrystalline silicon cell. Type of installation: Made-to-order facade fixing. Type of inverter: SMA STP-series. Number of inverters: 8

[7] Na japanskom jeziku znači: svetlost.

common. The “Hikari” project includes three different sources of renewable energy: photovoltaic panels on the roof and facades of the housing building, geothermal energy and cogeneration power plant. All three energy sources in the system are connected with energy communication. The positive energy building is designed to be equipped with two types of PV systems: a PV façade on the Minami building (21 kWp) and a roof PV system on three buildings (168 kWp). The **c**entral building has a glazed façade. This provided a successful intertwining, visual connection of the interior and exterior space. Two lateral buildings have a combined façade of glass and gray stone material which indicates a careful environmental-designing approach in designing (Fig. 8).



Fig. 8. CIC-ZCP is Hong Kong's first Zero Carbon Building, 2012
a)http://zcp.cic.hk/chi/home b)https://www.jll.co.th/th/trends-and-insights/workplace/how-is-asia-embracing-low-energy-buildings https://www.arup.com/projects/cic-zcb

CIC-ZCP is the first public building[8] in Hong Kong with a zero CO2 emission (Fig. 9)**.** It consists of three floors on the location with a large park vegetation to reduce urban heat in this area. Its goal is to show the awareness of the community about the sustainable life in Hong Kong. The roof of the building is designed with the solar panels from which the energy for the needs of exhibition rooms, exhibition apartment of the eco-house, business space and multifunctional halls is obtained. The installed BIPV devices generate sufficient electric energy from the renewable sources to meet the building demand, and the surplus is exported to the local power grid. A portion of energy is generated from the biofuel made from the waste cooking oil**.** The energy card of the building is: 45% more efficient than the current standard design, 20% of energy saving through passive design, 25% of energy saving through green active systems; estimated energy use116MWh/year; estimated energy use of the landscape area and others 15MWh/year; estimated output from biodiesel tri-generation system 143MWh/year; estimated output from PV panels 87MWh/year; estimated surplus energy export 99MWh/year; estimated net CO2 reduction by onsite renewable energy generation 7,100 tonnes (over 50 years).

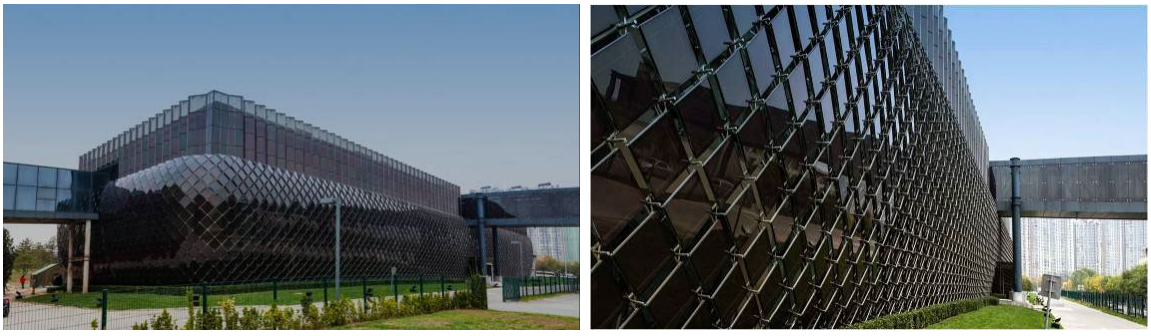

Fig. 9. Hanergy Ranks First in New Energy Sector
https://hanergy.eu/hanergy.eu/wp-content/uploads/2015/05/HanergyHQ.jpg
https://www.hanergy.eu/wp-content/uploads/2014/07/Hanergy-BIPV-8.jpg

Hanergy company[9] completed the first phase of the BIPV project in its headquarters, where clean, safe and suitable energy for its offices is created. Comprehensive BIPV solutions were implemented: combined design, research and development, generation, integration, construction, operation and maintenance. The total installed capacity of the project is 3MW, and it integrates thin-layered solar technology into curtain walls, pavements, flexible roof coverings and canopiesи. The initial production

[8] Architect: Ronald Lu & Partners (Hong Kong) Limited. Location: Put Sheung Iuet 8, bay Kowloon. Location area: 14.700m^2 (including ZCP with around 1400m^2 and a designed public use area). 1st prize for green building 2012.
[9] Address. Block B, Beichen Century Center, Chaoyang District, Beijing, China.

generates of 600kW clean energy, which satisfies 20% of the own electric power consumption. In the second phase of project realization, the capacity of power generation reached 3MW, making the headquarters of the company meet 100% of their demand for electric energy. By completing this project, emission of CO2 is reduced for 2.500 tons, which is equivalent to planting 140.000 trees or gas emissions from 780 cars. In addition to the striking visual impression of façade solar certified green and safe elements having top performance, in various forms, colors and velocities of stable light permeability, created an esthetic impression of the design of green environmental buildings. In the following five years, the applicable surface area for BIPV in Chinese urban areas will reach 1,79 billion square meters, and the estimated electric power generation will be 61,5 billion kWh. Practically, the CO2 emission will be reduced for 52 million tons. It is an equivalent to planting 2,9 billion trees, or to exhaust gasses from 16 million cars.

New building of the Ministry of Defense of France[10], in Paris, with 3.125 offices, of gigantic proportions and 146.500 m², is located on a plot of 16,5 hectares (Fig. 10).

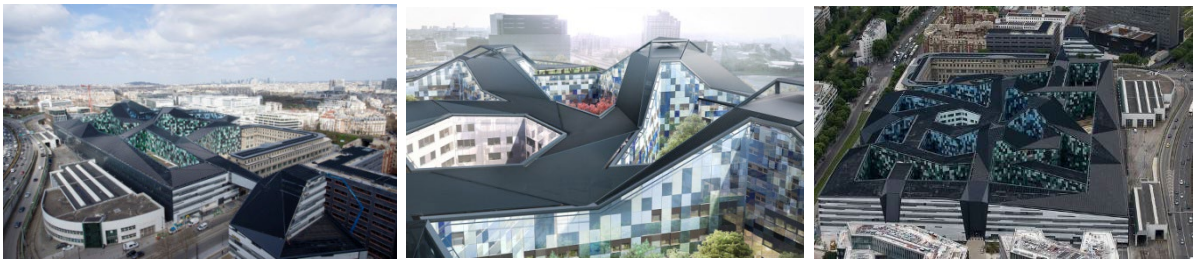

Fig.10. New Ministry of Defense in Paris, 2019.
a) https://cdn-lejdd.lanmedia.fr/var/europe1/storage/images/lejdd/jdd-paris/le-nouveau-ministere-de-la-defense-devoile-ses-secrets-757805/34419179-2-fre-FR/Le-nouveau-ministere-de-la-Defense-devoile-ses-secrets.jpg
b) https://mir-s3-cdn-cf.behance.net/project_modules/max_1200/f89f3528214727.563716fb6bb2f.jpg
c) https://static.lexpress.fr/medias_10660/w_640,c_fill,g_north/hexagone-balard-ou-balardgone-ou-pentagone-francais_5458220.jpg

The dynamical volume of the building leaves an impression of a discreet monumental building with a garden landscape which is 60% of the plot surface area. The idea of the designers was to create a complex energy efficient building with 6.500 m² of photovoltaic roof solar panels – the largest area in Paris, which provide up to 80% of energy demand on the location. Four geothermal water wells, were made, which solved all the cooling needs, via a direct exchange or via two heat pumps, capable for satisfying around 70% of heating needs and provide 100% of hot water. Fresh air is provided by having plants and water in the courtyards and with natural extraction using large vertical ducts owing to the heat gradient and constant air circulation. Therefore, the building has a surplus of energy.

Conclusion

1. Based in the presented illustrative examples of the ecourbarchitectonic buildings with BIPV installations it can be concluded that by the turn of the century there were considerable changes in the manner of conceptual design of building skin and cladding and of the roof surfaces. The visible radical city-building changes have technical and technological, engineering and historical and esthetic and designing character.
2. Façade and roof planes are not only a designing issue concerning the necessary investment for realization, but a very important energy-user factor of whose design depend the advanced performance of comfort in the buildings.
3. In general, it is a strategic question of urbanity in terms of further formation of the appearance of houses, streets, squares and plazas in different climates. In the focus is a correct choice of the type of BIPV facades and building material which will improve its performance.
4. Open, topical questions have a wider character. They relate to the city-building approach in further construction of new physical structures in urban and rural space and to remodeling and maintenance of the existing buildings.
5. Definitively, the world needs new recommendation for the help in making decisions about the suitable best methods for ecourbarcitectonic-energy design of façade and roof planes of high performances.
6. We are in the new, intensive solar ecourbarchitectonic-energy revolution.

[10] Architect: Agence Nicolas Michelin & Associés. Location: Balard, F-75015 Paris.

References

1. Ajla Aksamija, *Sustainable Facades: Design Methods for High-Performance Building Envelopes,* ISBN-10: 1118458605, ISBN-13: 978-1118458600. Publisher: Wiley; 1 edition (April 22, 2013).
2. Andreas Athienitis and William O'Brien, *Modeling, Design, and Optimization of Net-Zero Energy Buildings (Solar Heating and Cooling), Modeling, Design, and Optimization of Net-Zero Energy Buildings (Solar Heating and Cooling),* ISBN-10: 3433030839, ISBN-13: 978-3433030837. ASIN: B00SWVD04C. Publisher: Ernst & Sohn; 1 edition (January 26, 2015).
3. Andy Walker, *Solar Energy: Technologies and Project Delivery for Buildings,* 1st Edition, ISBN-13: 978-1118139240, ISBN-10: 9781118139240. ASIN: 1118139240. Publisher: RSMeans; 1 edition (September 23, 2013).
4. Basant Agrawal, Gopal Nath Tiwari, *Building Integrated Photovoltaic Thermal Systems: For Sustainable Developments (RSC Energy Series),* ISBN-10: 9781849730907, ISBN-13: 978-1849730907. Publisher: Royal Society of Chemistry; 1 edition (December 17, 2010).
5. Bernhard Weller and Jens Schneider, *Engineered Transparency 2016: Glass in Architecture and Structural Engineering,* ISBN-10: 3433031878, ISBN-13: 978-3433031872. Publisher: Ernst & Sohn; 1 edition (March 6, 2017).
6. Jean-Christophe Hadorn, *Solar and Heat Pump Systems for Residential Buildings (Solar Heating and Cooling)*, ISBN-13: 978-3433030400, ISBN-10: 3433030405. Publisher: Ernst & Sohn; 1 edition (September 8, 2015)
7. Laura Maturi, Jennifer Adami, *Building Integrated Photovoltaic (BIPV) in Trentino Alto Adige (Green Energy and Technology)* 1st ed. 2018 Edition, ISBN-13: 978-3319741154, ISBN-10: 3319741152. ASIN: B079NCSPRL. Publisher: Springer; 1st ed. 2018 edition (February 6, 2018).
8. Maria Mandalaki, Theocharis Tsoutsos, *Solar Shading Systems: Design, Performance, and Integrated Photovoltaics (SpringerBriefs in Energy),* ISBN-10: 3319741152, ISBN-13: 978-3319741154. Publisher: Springer; 1st ed. 2018 edition (February 6, 2018).
9. Shahin Vassigh, *Best Practices in Sustainable Building Design: Includes an interactive DVD*, ISBN-10: 1604270683, ISBN-13: 978-1604270686. Publisher: J. Ross Publishing; Har/DVD edition (October 1, 2012).
10. Tomislav Pavlovic, *The Sun and Photovoltaic Technologies (Green Energy and Technology),* ISBN-10: 3030224023, ISBN-13: 978-3030224028. Publisher: Springer; 1st ed. 2020 edition (October 27, 2019).

Article Summary ***Design. Art. Industry, 2024*, Issue 11**

DOI: 10.56900/2312-6116_2024_11_23

Integrated Photovoltaic Systems in Ecourbarchitecture [Интегрированные фотоэлектрические системы в экоурбархитектуре]

Аннотация:

Внедрение интегрированных фотоэлектрических систем в строительство зданий представляет собой стратегический шаг в экоурбархитектуре, функционально инновационном формировании здания с измененной эстетикой и художественным пониманием пространственных композиций. В такой концепции есть возобновляемые источники энергии, которые с модульными солнечными панелями обеспечивают высокое архитектурное качество. Они являются неотъемлемой частью структуры, генерируя фотоэлектрическую энергию. Появление технологий BIPV открыло очень важную тему градостроительства о будущем гармоничном формировании домов, их позиционировании и ориентации планировки по отношению к естественной и артефактной среде, а также об органической, экологической интерполяции физических структур в существующую городскую ткань. В целом, это стратегический вопрос урбанизации с точки зрения дальнейшего формирования внешнего вида домов, улиц, площадей и плазов в различных климатических условиях. В центре внимания правильный выбор типа фасадов BIPV и строительного материала, который улучшит его характеристики.

Ключевые слова: экоурбоархитектура; фотоэлектрические системы; технологии BIPV; текучие формы; стратегический дизайн; интеграция.

For Citation

Cekic Nikola. Integrated Photovoltaic Systems in Ecorubarchitecture *Design. Art. Industry*: International Journal of Scientific Research Editor in chief N M Shabalina. Chelyabinsk: Tekhne Publishing House, 2024, Issue 11, pp 23–31. https://doi.org/ 10.56900/2312-6116_2024_11_23