Urban Electromobility

Subjects: Transportation

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The growing need for electric energy is forcing the construction industry to greater integrate energy production systems based on renewable energy sources. The energy ought to be used not only to support functions of the building but also to charge electric vehicles, whose number has been increasing for the last few years.

Keywords: energy consumption ; electric vehicle ; real driving conditions ; renewable energy generation ; conversion of a historical building to nZEB

1. Combining Architecture with Alternative Power Sources

The future of the electric vehicle (EV) market is closely connected with the development of the network of charging stations (both in cities, located by main roads, and small, private stations) as they guarantee the real usability of EVs. The technology of charging EVs with energy produced by photovoltaic panels is now perceived as a particularly attractive and forward-thinking solution [1]. Therefore, an interdisciplinary approach to research the possibility of charging EVs from photovoltaic (PV) systems is recommended.

Urban and architectural designing in European culture is an extraordinary challenge. Numerous existing cities are like documents proving their centuries-old traditions. Their past “provides invaluable lessons for the future” [2], which is created by actions researchers take today. Throughout the decades, architects and urbanists have been trying to find optimal solutions regarding urban planning and they agree that the historical nature of cities should be “given strict custodial protection” [3]. At the same time, it is important to keep balance between protection of historical values and of cultural heritage and the implementation of new technologies [2]. Pursuant to the Venice Charter [4], the conservation process should support functioning of historical buildings by allowing changes which are the result of custom and lifestyle evolution. Adding new functions to the historical building or area may not, however, significantly affect the historical urban layout or architectural arrangements.

European cities are in their major parts older than 50 years; over 40% of residential buildings were built before the mid-20th century. They were raised in accordance with the then valid construction rules but, obviously, ignored later detailed energetic regulations stipulated for the construction industry. At the same time, the construction industry is one of the key energy consumers in Europe [5]. The research shows that most historical buildings are ineffective in terms of energy, they generate great energy costs and CO_2 emission. Their proper modernisation that would simultaneously protect and highlight their historical, scientific and artistic values, which constitutes an important element in achieving European environmental goals [6].

At first, initiatives and procedures regarding energy efficiency, implemented in the United States of America, European Union and China, did not take into consideration historical buildings. However, the growing awareness that this part of the construction industry is culturally important and increasing in number, and can no longer be ignored, has resulted in the development of research on that area. Most available literature refers to attempts aimed at the decrease of energy consumption and improvement of thermal comfort inside the historical building, without prejudice to its historical value [6][7][8]. Most analyses have been conducted in 19th and 20th century buildings, as the level of their conservational protection is lower, and their modernisation is easier.

The article [9] presents an analysis of the historical building with a far more complicated structure of historical layers and much older provenance, which means also higher level of conservational protection. The tenement house at Wroniecka 23 in Poznań shows layers from the turn of the 14th and 15th century, superstructures from the end of the 16th century and reconstructions from the 19th and 20th century. Moreover, this building is a unique example of a historical building adapted to parameters of the nearly zero-energy building (nZEB).

The research included analyses of both real energy production in the tenement house and the possibility to use this historical, nearly zero-energy building to charge electric vehicles. This facility was chosen because of its location in the historical area of the Old Town but, what is most important, this is an old house that has become the nearly zero-energy building. Moreover, there is “extensive metering of exploitation processes, focusing on adopted new technologies” and “using innovative solutions improving the standard of the place by applying most effective technologies based on renewable energy” [10].

The building analysed in the presented research is the tenement house located in the Old Town, the historical, urban-architectural complex of Poznań, which is under conservation protection pursuant to the entry into the Register of Monuments (no. A-225/M, decision of 4 June 1979) [11]. This means that, pursuant to art. 36 of the Act of 23 July 2003 on the Protection and Preservation of Historical Monuments [12], any works affecting the outside look of the house, the landscape and the interior of the urban layout shall be conducted upon conservator’s permit. The decision on the permit is made by the Provincial Monument Conservator, and in case of Poznań, by the City Monument Conservator, upon agreement with the President of the City. The tenement house at Wroniecka 23 (Figure 1) is also entered individually to the Register of Monuments (under no. A-133, decision of 25 April 1966) [11]. For designers, it means that any and all works, including those inside the building, shall be conducted under permits described hereinabove and may not negatively impact the historical value of the house; therefore, when they implement new technologies and relevant systems, they shall design their location in a way that does not infringe the historical essence of the place.

2. Electromobility in Urban Conditions

The specifics of vehicle traffic in city centres is mainly focused on vehicles’ dynamic speed changes, which results in increased fuel consumption and exhaust gas emissions, in particular, in case of vehicles with conventional drive [13]. Decreasing the impact of the transport industry on air pollution in urban conditions may be implemented by feeding internal combustion engines with e.g., compressed natural gas, using modern combustion systems or by using electrified driving systems, hydrogen or battery-powered systems [14][15]. A significant local decrease of emissions of harmful and toxic substances is possible through the application of drive systems working without internal combustion engines. Taking into account the aspect of the use of battery-electric means of transport, it is necessary to adapt the urban infrastructure, which involves many problems [16].

The conducted comparative analysis of direct and indirect methods of electrifying drive systems dedicated to private passenger transport proves that the direct use of electrical power in a car is more beneficial in terms of decarbonisation pace and energy consumption in energy transition [17]. The use of smaller means of transport like electric bicycles and scooters can be beneficial in reducing car traffic [18][19].

Energetical cooperation of a small household solar power station with a battery electric vehicle is an attractive trend in the development of electromobility [20][21]. In the recent years there has been a dynamic increase of power produced by photovoltaic panels: it reached the value of 633.7 GW in 2019 [22]; the number of LDV increased by 43% in 2020 compared to a previous year [23]. The development of the abovementioned branches of the transport industry and power supply is particularly essential in the face of planned restrictions regarding access of vehicles to city centres [24].

The variety of aspects and characteristics of the vehicle dynamics in urban conditions is subject to numerous analyses [25][26], which indicate the significant impact of types of streets, drivers and driving conditions. Taking into consideration the use of a battery-powered EV, Desreveaux et.al [27] indicated the lowest value of energy consumption in urban conditions per 100 km, compared to the use of the vehicle in extra-urban and motorway conditions. The comparison of an internal combustion engine (ICE) vehicle and an electric vehicle proved a reverse tendency in energy consumption per 100 km [28]. In urban conditions, the EV driving in accordance with RDE requirements consumed about 63% less energy than the ICE vehicle. The increased energy consumption in the case of EV is caused i.e., by the changing outside temperature. In research conducted by HAO et al. [29], the lowest energy consumption was registered at the temperature of 19 °C. This proved the negative impact of low temperatures on internal conductivity in the battery.

While examining energy consumption of the vehicle, it is important to select an adequate test for the drive system. The comparison of NEDC, WLTP and RDC test results obtained in simulated conditions [30] indicates significant discrepancies. The highest value of energy consumption was shown in RDC results.

Adding the photovoltaic infrastructure as a source of power significantly improves the power balance of urban areas which constitute 2% of the area on Earth but consume 2/3 of the produced energy [31]. In Berlin, the city authorities consider implementing an obligation to install photovoltaic panels in new buildings and include solar systems while renovating roofs. The aim is to achieve the result of 4.4 GW of installed power [32]. Optimal estimation of the potential regarding PV panels on roofs proves the possibility to obtain up to 87% power surplus that can be returned to the grid [33]. In urban conditions, where there is considerable housing density, the estimation of available roof area can be made on the basis of satellite or UAV images [34]. In Ibadan (Nigeria), estimation based on satellite images and other techniques gave proved that the total roof area is 49.54 km^2, out of which only 7.54 km^2 is suitable for PV panels [35].

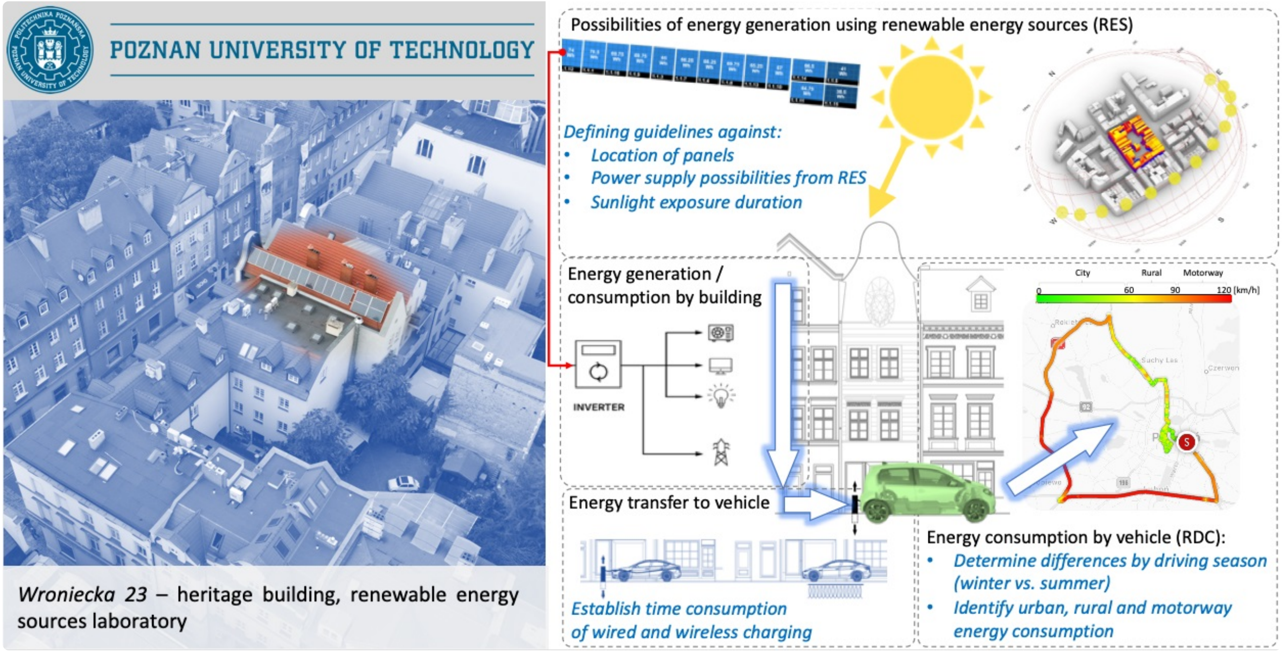

Figure 1. Wroniecka 23 in Poznań.

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