Approach to Usage of Renewable Energy Sources in European University Campuses—Case Study

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Manuscript received April 10, 2024; revised May 8, 2024; accepted June 2, 2024; published August 9, 2024

***Abstract*—Nowadays, we can observe various scenarios aiming to promote the decarbonization of the university campuses. Higher education institutions are expected to be pioneers in development and application of sustainable solutions. This paper presents innovative solutions as well as education of society. As many approaches to decarbonization of university campuses are tested and applied it is necessary to study the effects in context to possible application in different climate conditions. In this paper, real solutions applied in Bialystok (Poland), Valladolid and Malaga (Spain), Kaunas (Lithuania) and Athens (Greece) are described as well as future plans for technical solutions to make campuses energy efficient and eco-friendly. As shown, it is hard to find a consistent and one-size-fits-all approach to this issue. Unique needs with the perspective of changes in the heat and cool demand, national rules on development of renewable energy sources, energy price volatility as well as technical possibilities of application of individual solutions on campuses affect the choice of the applied realization.**

***Keywords*—campus, renewable energy, district heating, Heating, Ventilation, and Air Conditioning (HVAC) systems, biomass, Photovoltaic (PV) panels, wind turbines, heat pumps**

I. Introduction

Universities play a key role in promoting decarbonisation and sustainable development. Innovative eco-friendly solutions are applied in different areas as showed in [1]: spatial planning and landscape, renewable and clean energy, energy systems, thermal envelope, green transportation, management and control, human-related performance and smartness. Selection of used technologies depends on social, economic, climatic and political factors. Results of [1] showed that although RE is the most prevalent option for reducing carbon emissions for University Campuses (UCs), only in case of insubstantial campuses renewable technologies were integrated into their energy systems.

It is very important to plan a fast path leading to the sustainable development of campuses, aimed at ensuring that the use of buildings has the least impact on the natural environment while ensuring appropriate comfort of use [2]. This approach is in line with the one proposed by the European Commission as part of the significant changes to the Energy Performance of Buildings Directive (EPBD) published by the European Commission on December 15th, 2021, as part of the "Fit for 55" package, placing great emphasis on the reasonable management of the existing building resources. The new Effort Sharing Regulation (ESR) sets an EU-level greenhouse gas emission reduction target of 40% by 2030, compared to 2005 [3].

There are different approaches to decarbonization of campuses. Montagud-Montalvá *et al.* [4] proposed to use the Stanford Energy System Innovations at Universitat Politècnica de València, of the Mediterranean coast of Spain. Authors paid attention for benefits of waste heat recovery from a data centre located on campus with an almost constant cooling demand throughout the year, amounting to a yearly 1,661,020 kWh, as potential thermal energy savings had been estimated at level of 254,106 kWh/year, while a reduction in CO_2 emissions of at least 64,035 kg/year. On the other hand, as reported in [5] heat pumps are one of the ways to transition the heating of buildings from fossil fuels to renewable energy sources and this solutions can be used low-temperature district heating systems.

II. Examples of Renewable Energy Sources at Analyzed University Campuses

A. Bialystok University of Technology (Poland)

Bialystok University of Technology (BUT) has 3 campuses. Main one includes buildings of Faculty of IT Engineering, Faculty of Mechanical Engineering, Faculty of Electrical Engineering, Faculty of Civil Engineering and Environmental Sciences, Dormitories and Library; while on two small campuses Buildings of Management Engineering Faculty and Architecture Faculty (Fig. 1) are located. All buildings are suppled from a City Power Plant by District Heating System (DHS) where during cogeneration process heat and electricity are generated from coal and biomass. Moreover, in selected buildings on the main campus Renewable Energy Sources (RESs) are installed as presented in Table 1.

B. University of Valladolid (Spain)

University of Valladolid (UVa) rose to the issue of reduction of carbon footprint of the facilities in university buildings by using a new renewable DH heating system. The University of Valladolid has carried out deep energy renovation of the heating system in 19 buildings on two different university campuses, through a biomass (Fig. 2) in order to achieve a near-Zero Energy Campus concept (84.6% of the buildings), and to increase the percentage penetration of renewable energies [6].

Table 1. RESs at BUT

Type of source	Location and system supplied			
	Building	Heat/coal	Hot water	Electricity
Biomass (combined with coal in a local power plant and distributed by city network)	All buildings	+	-	+
Ground heat pumps	Faculty of CEESs	+	-	-
Solar collectors	Dormitory 1	-	+	-
PV panels	Faculty of EE	+	-	+
Green walls, heat recovery, wind turbine, PV panels	Laboratory of Architecture	+	+	+

Fig. 1. Laboratory of Architecture (photo A.Jakimowicz).

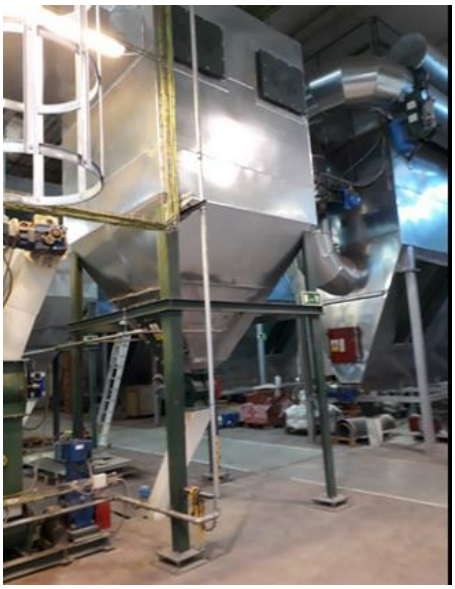

Fig. 2. Biomass heat plant in Valladolid (photo D. Krawczyk).

Improvements proposed has transformed the campus categorically, thus exceeding the objectives set in the Spanish National Integrated Plan for Economy and Climate (PNIEC) for 2030, which requires a minimum renewable energy penetration level of 42%.

C. University of West Attica (Greece)

University of West Attica has implemented green rooftops in the large renovation project of 2017, using Mediterranean herbs and small plants for the arid regions of the Mediterranean regions in order to minimize the water demand. Also, reduction of energy consumption necessary to provide and maintain good indoor air quality is planned by installation of shading devices (electric shading systems, glass made facades with adjustable blinds). At Egaleo Park Campus, 2 kW photovoltaic system and a 1 kW horizontal axis wind turbine are installed. Moreover, the Cogeneration Power Station (CPS) provides 600 kW of maximum electrical power, 650 kW of heat and almost 850 kW of cooling using the absorption technique, that should cover a significant part of the University energy needs. The CPS unit is also integrated with a thermal storage tank of hot water, mainly used for feeding the boilers of the respective buildings in case of extremely cold days [7]. In second campus (the Ancient Olive Grove Campus) several 1–3 kWp PV systems are installed, used for various purposes, including charging electric vehicles.

Fig. 3. Green roof top in Ancient Olive Grove Campus (photo Google Earth).

University of West Attica is on the procurement process of 880kWp of PV divided in in 2 parts planning to cover the electricity needs of the 2 campuses of Egaleo Park and

Ancient Olive Gove, as a part of the long-term strategic plan to reduce its carbon footprint to zero.

D. Kaunas University of Technology (Lithuania)

Responding to the latest trends in the field of sustainable development, KTU installed PV panels on roofs (Fig. 3). Transformation started from a hybrid energy generation system that was developed in the selected buildings located at the campus in 2019. It combined technical equipment generating and storing different types of energy, such as a solar power plant (380 kW), thermal energy storage unit, a 170 kW heat pump, and a waste heat energy collection system [8]. Moreover in 2021, solar photovoltaic power plants were installed on the roofs of four buildings on the KTU student, while in 2022 in the roofs of four more buildings. Investments in alternative energy sources resulted in a significant share or RES. In 2022, the university purchased 30% less electricity, and the amount of purchased thermal energy fell by more than half [9].

E. University of Malaga (Spain)

The University of Malaga, specifically at the School of Industrial Engineering and the Smart Malaga project, are excellent examples of how universities can integrate renewable energy technologies and intelligent systems to enhance energy efficiency and contribute to a more sustainable environment. The School of Industrial Engineering features a renewable energy production through photovoltaic solar power. It consists of a 1 MW photovoltaic installation (Fig. 4), effectively generating electricity from renewable sources, thus reducing dependence on non-renewable energy sources. Furthermore, the implementation of energy management systems that control heating, ventilation, and lighting is crucial to optimize energy usage and reduce waste. This involves tailoring energy consumption to specific needs, thereby enhancing efficiency. Also noteworthy is the integration of innovations for Smart Buildings. Being part of the Smart Malaga project showcases the university's commitment to innovation and the adoption of advanced technologies to decrease energy consumption and improve air quality in university buildings.

Fig. 4. PV panels in Kaunas (photo D. Krawczyk and J. M. Rey-Hernández).

III. Factors Influencing the Choice of Energy Source

As shown, it is hard to find a consistent and one-size-fits-all approach and recommend one optimal solution for all European campuses.

Cited examples are in line with sustainable development of campuses, however we can still see a limited share of renewable energy sources installed. In case of water heating in buildings it seems to be reasonable to pay attention on biomass that can be used in both cases: own sources and plants on the campus (example of Valladolid) and district heating supplied by CPP (like in Bialystok). Lately, District Heating and Cooling (DHC) that is known as an effective solution for delivering heating, hot water and cooling services through a network of insulated pipes, from a central point of generation to the end user, starts to gain ground. Many European projects granted last years aimed to development of new solutions for district heating and cooling networks enable the integration of renewable sources (geothermal, solar thermal and biomass) [10]. Nowadays, the big demand for solutions that for a significant reduction in the dependency on fossil fuels and manage energy security are welcome. On the other hand, taking the opportunity of national programs supporting PV systems and heat pumps, these kinds of sources are supposed to rise in numbers on campuses.

However, despite of development of RESs there is a need to analyze parameters influencing energy consumption and undertake projects that reduce energy load for heating and cooling (renovation of buildings to limit U values of external walls and roofs [11]). It could be a big challenge in case of old campuses with historical buildings that characterized by high heat transfer coefficient of external barriers while taking into account their historical and cultural value are under the supervision of a conservation officer, and must be refurbished with special conditions [12, 13]. Moreover, actions that disseminate knowledge about development of sustainable and green campuses between academic community, including examples of good practices in other countries are required, not to preach to the converted. Amaral *et al.* [14] found a tendency for countries with higher income economies to engage in initiatives that involve greater investment, such as the adoption of renewable energy systems or efficient buildings systems.

Unique needs with the perspective of changes in the heat and cool demand, national rules on development of renewable energy sources, energy price volatility as well as technical possibilities of application of individual solutions on campuses affect the choice of the applied realization.

IV. Future Plans

We see the need for a stronger HEIs commitment to environmental protection and aims to contribute to tackling the energy crisis by real actions on campuses and educational and training activities that can boost awareness and engagement at multiple levels [2]. In campuses long-term plans and actions should be planned, starting from the

identification of strategies and opportunities for institutions to improve environmental sustainability, by development of tested case scenarios to dissemination of the results.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

DAK planned the study; DAK, JRMH, FJRM, JS, BS, SCP prepared and analyzed the data and wrote parts of the paper; DAK prepared the final version of the paper; all authors had approved the final version.

Funding

The research was conducted under W/WB-IIL/2/2023 grant.

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