ENERGY INDICATORS FOR PUBLIC BUILDINGS IN AUTONOMOUS PROVINCE OF VOJVODINA WITH FOCUS ON HEALTHCARE, EDUCATIONAL, AND ADMINISTRATIVE BUILDINGS

by

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This paper aims to show the current state of energy consumption and accompanying energy indicators in the public building sector in the Autonomous Province of Vojvodina, Serbia. The public building energy consumption data (healthcare, administration and schools) was collected by surveys supported by on-site measurements, calculations and interviews with people responsible for energy monitoring. Statistical processing of the collected data on the real extent and manner of energy usage in public buildings in Vojvodina was used. This paper presents energy indicators which are on average three times higher than allowed by Serbian Ordinance and what is currently present in neighboring European Countries. It is of the utmost importance to use this data and its implications as a catalyst for the implementation of energy management in the public building sector and an increase in energy efficiency.

Key words: *energy, management, indicator, public, building, administration, healthcare, school*

Introduction

Buildings, as a group, are one of the most significant energy users. According to [1], the total energy consumption of buildings represents, on average, 25% of the total energy balance in the EU27, while in Germany it amounts to 30%. In countries where energy still represents a means of maintaining social peace, and where industrial activity is currently at a low level, the share of energy used in buildings amounts to 40%, perhaps even more, of the balance of final energy consumption.

In developed countries this share is much lower. This is mainly due to a higher level of industrial activity, and therefore a significant share of industry in the total energy balance. However, it is crucial to point out that these are also the countries that make systematic and individual efforts in order to ensure energy is being used in a more rational way.

Public buildings are particularly interesting and important from the aspect of energy efficiency for several reasons. Non-residential buildings have a significant share in the overall energy consumption of buildings, and are a predominant group. Non-residential facilities even make up 46% of the total building area in Austria [2].

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In addition, another important feature in countries in transition is that, almost as a rule, local government or the State own the building properties, while the users are other public social entities. Facility users are also required to maintain the facilities, for which they do not have their own funds. The owner, for example ministries or local governments, covers the expenditures from the State budget. Typical examples are educational, administrational and healthcare facilities.

This is one of the reasons why the specific consumption of energy in these public buildings is higher than is allowed. Consequently, researchers who have studied this issue consider these categories of buildings particularly important for investment in order to improve their energy efficiency [3, 4].The reasons for this are the high potential for energy efficiency improvements, the possibility of a substantial reduction in public expenditure, and their educational role at the broadest social level, as knowledge of energy related issues is the basis for changing the current unsatisfactory state. Among other things, according to [5], lack of knowledge about energy is considered the same as illiteracy. It is indisputable that these buildings, as examples, are particularly suitable for spreading knowledge about the necessity of increasing energy efficiency in buildings as a group.

With their huge impact, energy consuming public buildings with public ownership such as healthcare facilities, schools and offices are exemplary candidates towards the goal of energy efficiency and suitable indoor climate quality (ICQ) representative levels.

Striving to achieve the goals of representativeness, the knowledge of building energy performance is an integral part in the design of energy supply systems [6]. Generally, buildings require energy for hot water, heating, cooling, air-conditioning as well as electricity for appliances and equipment, although the combined demand category of heat and hot water is already widely used, depending on the heat supply methods.

The study, the results of which are partially presented in this paper, included public facilities, education, health care, and administration in the region of Vojvodina of Serbia. The aim of the research is to determine their energy efficiency, to take note of primary system problem spots and causes of unsatisfactory energy efficiency, and contribute to the improvement of the current situation through the production of general systematic measures to eliminate these causes. As a basic parameter of energy efficiency, specific energy consumption per net m^2 of area was used. This is also the most objective parameter for comparison with results from other studies and results from other regions of the country and the world.

Having in mind aforementioned, an overview of energy efficiency in public buildings according to the data from other surveys worldwide (mainly Europe) and Serbia is given, while the methodology used in this research is described as well. Moreover, the research analysis and results are presented followed by discussion and conclusions respectively.

Status of energy efficiency in public buildings

The beginning of the 21^{st} century has been characterized by intensive systemic work on the creation of regulatory and other relevant conditions that increase energy efficiency in public buildings. In 2002, the Energy Performance of Buildings Directive (2002/91/EC) [7] introduced the mandatory energy certification of buildings in the EU from 2006. Within this context, all Member States (MS) proposed different Energy Performance Certificates (EPC) exhibiting different information expressed in distinct scales.

The situation in the world

Special attention is given to public buildings, including public buildings for educational, health and administrational purposes. As is already known, schools indirectly represent a means of communication with pupils and their families, enabling them to reach many different groups in society [8]. Additionally, their high share in the total state building stock makes them contributors to a considerable part of the overall amount in energy consumption, and consequently of the expenses paid by the national budgets [9]. Schools' energy use figures highly in school running costs, where, after teacher and staff salaries, energy costs are the most significant expense [10].

Likewise, the health sector in the industrialized world and in a growing number of developing nations consumes significant amounts of fossil fuel energy, although there are no adequate figures for most countries. There is a need for systematic measuring and benchmarking of health sector energy consumption and associated greenhouse gas (GHG) emissions around the world [11]. However, some anecdotal evidence does exist. Hospitals are the second most intensive energy-using buildings in the U. S., where the health care sector spends about 6.5 billion $ on energy each year, and that number is increasing exponentially [12]. As the health sector expands in many developing countries, its energy consumption grows as well. In Brazil, for instance, hospitals account for 10.6% of the country's total commercial energy consumption [13]. At the same time, electricity access and hospital electricity consumption in most hospitals in regions such as South Asia and sub-Saharan Africa reflect far lower energy use rates, while hundreds of thousands of hospitals and health clinics across the world suffer from unreliable electricity supply or no electricity access at all [14]. The most efficient hospitals in northern Europe consume roughly 35% of the energy that North American hospitals average (320 kWh/m^2 compared to 820 kWh/m^2), while delivering comparable healthcare services. A study underway by the University of Washington Built Environment Lab suggests that North American hospitals can achieve 60% reductions in energy consumption through adoption of more efficient system strategies [15]. Hospitals in countries ranging from Mexico and Brazil, to India, Australia and Poland have all demonstrated that they can take basic measures to save money, strengthen facility resiliency and increase energy efficiency by 20-30% [16].

In addition, energy is one of the largest controllable overheads in office buildings, which means there are many opportunities to make savings. Reducing energy consumption not only saves money but also improves working conditions, which can increase staff productivity. Furthermore, the environment will benefit from reductions in energy use and carbon emissions, enhancing corporate reputations. The types of businesses based in an office environment are diverse, yet there are several key areas where energy is commonly wasted. The biggest savings can be made in lighting, heating, ventilation, air conditioning and office equipment [17]. It is important to mention that proportions of energy use will vary according to occupancy levels and whether the building has air conditioning or mechanical cooling installed. In offices without cooling, the greatest energy users are heating systems [17].

Bearing in mind the above, specific indicators of overall annual energy consumption in offices, schools and healthcare facilities worldwide, obtained from numerous studies [18-32] are summarized in tab. 1.

Table 1. Specific energy consumption

N°	Country	Average overall energy consumption [kWhm^{-2}]		
		Schools	Schools	Schools
1	Spain	146 [20]	292 [21]	169 [18]
2	Greece	63 [23]	407 [29]	360 [18]
3	Italy			254 [18]
4	Bulgaria	190 [30]	360 [30]	130 [18]
5	France	224 [24]	250 [30]	309 [18]
6	Belgium	100 [26]	390 [31]	193 [18]
7	Ireland	205 [22]	290 [22]	195 [18]
8	UK	120 [25]	405 [50]	221 [18]
10	Austria			251 [18]
11	Czech Republic	240 [30]	430 [30]	294 [18]
12	Germany		410 [31]	194 [18]
13	Slovenia	192 [27]	275 [30]	
14	Slovakia	239 [28]		
15	The Netherlands		555 [21]	213 [18]
16	Norway	162 [19]	311 [19]	230 [19]
17	Finland	170 [28]	350 [30]	165 [18]
18	Sweden		290 [31]	165 [18]
19	Denmark	95 [26]		350 [32]

Situation in Serbia

According to a study conducted by the World Bank [33], the estimated savings potential in public buildings is Serbia amounts to roughly 39-44% of current energy consumption. Energy efficiency (EE) in the public buildings sector can be mandated more easily than in the private buildings sector, which directly indicates that the public sector is, therefore, a good place to start EE programs. In addition, the results of this study are based on data collected from 27 hospitals and 11 schools with a heated area of 104,969 m^2 which were renovated. Specific building heat consumption dropped from 266 kWh/m^2 to 162 kWh/m^2. Annual energy consumption could be reduced by more than 39% at investment costs of around 35 €/m^2. Hospitals specific heat consumption could be reduced from an average of 329 kWh/m^2 to 210 kWh/m^2 in general. Excluding two hospitals which had only minor works done, annual energy demand for space heating was reduced by 43.8% through investments with costs ranging from 21.1 to 58.8 €/m^2. Most energy savings would derive from roof insulation and new windows and doors. When it comes to public school buildings, similar results could be achieved, as the average energy demand for space heating could be reduced by 43.4%. Overall energy savings based on programs and audits of 11 school buildings and 27 hospital buildings, are presented in tab. 2.

In the short- to medium-term, prospects are slim for major, sustainable EE programs in countries with low energy prices and high commercial losses. Good EE equipment prices tend to be at world market levels or higher, so payback periods would be too long because consumers typically apply high discount rates to these investments, for example, up to 20%

for households and up to 50% for industry [34]. But public-sector programs for schools, hospitals, and administrative buildings can promote comfort, health, as well as energy savings that will increase over time as energy prices rise. The Serbia Energy Efficiency Project is an excellent example of this [35]. Municipal governments have strong incentives for EE investments due to the scale of their public facilities and street lighting systems, and substantial subsidies for district heating systems and heat consumers; however, funding often needs to come from the central government. EE could also be a cost-effective contribution to the social safety net for the poor [36].

Table 2. Energy savings in public buildings in Serbia [33]

Institutional Buildings	Energy savings (as % of heating energy)	Heating energy (as % of total energy)	Energy savings (as % of total energy)
Schools			
District-heated	43.8	70	30.7
Fuel Oil	56.3		39.4
Coal	10.0		7.0
Hospitals			
District-heated	11.7	70	8.2
Fuel Oil	49.3		34.5
Coal	20.5		14.4

Methodology

Having in mind the importance of the energy efficiency of public buildings, innovative methods for the estimation of building loads, such as statistical analysis [37], spatial regression [38], variable degree days [39], genetic algorithms [40], and climate classification [41] have been proposed while diverse combinations of load types have been investigated, ranging from the prediction of general demands [42] to individual load types of cooling [43], lighting [44], electricity [45], and heating [46].

In this study, the methodology of statistical processing of the collected data on the real extent and manner of energy use in public buildings in Autonomous province of Vojvodina – APV was used. The territory of APV is a complete socio-political, economic, cultural, social, health, educational entity and as such, it is suitable for generalizing results. To record the current situation a specially prepared questionnaire, which collected all the necessary data from users of public facilities, was used. The information collected was supported by measurements and calculations and interviews with people responsible for the use of energy. All three distinct entities and facilities of health, education and administration were included.

Due to the different modes and time of use of certain groups of these facilities they were classified in sub-groups. Educational facilities were split into: elementary schools, secondary schools and mixed schools. Medical facilities categorized into: general hospitals, special hospitals, institutes, health clinics, health centers, medical offices. In addition, an analysis was made on the basis of all information gathered, while estimations were made on the total and specific energy consumption in these facilities. Research and data collection was carried out in the following steps.

Surveys were completed and collected (electronically or in person) and analysis was carried out. A new database was made to systematize the gathered information with the possibility of modification. Lastly, all of the criteria for determining the specific indicators were formed. These indicators served as a primary tool for analysis and comparison of the current state of the observed facilities.

Results and analisis

School facilities

The sample gathered consists of 122 schools (22,6%) of a total number of 540 (100%) in the APV, which was then taken as a representative school sample because of the inability to analyze all of the schools. To properly determine the correct ratio of the results, it is important to know the amount of surveyed school by categories: 99 elementary (81%), 17 secondary (14%) and 6 mixed schools (5%). The following table (tab. 3) shows the energy indicators from the analyzed schools.

Table 3. Primary and final (in brackets) energy indicators energy indicators for school facilities

Energy indicators educational facilities	Elementary	Mixed	Secondary
Total annual energy consumption [GWh]	68.45 (46.97)	2.50 (1.74)	23.64 (15.82)
Total annual electricity consumption [GWh]	14.70 (5.47)	0.46 (0.17)	6.99 (2.6)
Total annual heat consumption [GWh]	53.75 (42.59)	2.05 (1.6)	16.65 (13.75)
– Total annual natural gas consumption [GWh]	21.78 (17.42)	0.18 (0.14)	11.74 (9.39)
– Total annual oil consumption [GWh]	14.03 (10.52)	0.45 (0.34)	0.92 (0.69)
– Total annual district heating consumption [GWh]	2.05 (1.64)	0.15 (0.12)	3.10 (2.48)
– Total annual other fuel consumption [GWh]	15.89 (11.92)	1.27 (0.95)	0.89 (0.67)
Average annual heat energy consumption [GWh]	0.54 (0.43)	0.35 (0.27)	0.98 (0.81)
Average annual electrical energy consumption (not including electrical heating) [GWh]	0.15 (0.04)	0.08 (0.02)	0.41 (0.12)
Average annual heat energy consumption per building area [$kWhm^{-2}$]	254 (201)	293 (229)	277 (229)
Average annual electrical energy consumption per building area (not including heat) [$kWhm^{-2}$]	69 (21)	65 (20)	116 (35)

Summarized average values for energy indicators in the analyzed sample (electricity and heat) in elementary schools according to the previous table are 254 (201) kWh/m^2 with annual energy consumption of 68.45 (46.97) GWh. Average values for energy indicators in mixed schools are 293 (229) kWh/m^2 with annual energy consumption of 2.50 (1.74) GWh. Average values for energy indicators in secondary schools are 277 (229) kWh/m^2 with annual energy consumption of 23.64 (15.82) GWh.

Hospital and health care facilities

From the total number of healthcare facilities in the APV (82) to which the survey was sent, 45 responded. However some facilities cover several separate institutions and data was actually collected from 52 institutions (63%). Furthermore, 3 major hospitals were added by collecting data on site. Therefore, the data presented here includes 55 institutions in total. Indicators for healthcare facilities are listed in tab. 4. The share of heated surface area for every type of institution was calculated in the sample as a whole. This share was then used to present real average indicators for the healthcare facilities sample listed in the last column to the right. Average annual electricity consumption is 438 (149) kWh/m^2 while annual heat consumption is 453 (362) kWh/m^2. The total energy used by healthcare facilities on a yearly basis for the gathered sample is 94.5 (55.7) GWh and total average energy consumption is 891 (511) kWh/m^2.

Table 4. Primary and final (in brackets) energy indicators for healthcare facilities

Energy indicator for healthcare facilities	Health center	General Hospital	Special Hospital	Institute	Health Clinic	Health Office	Average (area share)
Healthcare surface area share [%]	23.0	39.5	12.2	11.4	11.3	2.6	-
Total annual energy consumption [GWh]	76.3 (45.9)	161.0 (96.3)	43.2 (28.0)	51.5 (30.7)	2.0 (0.8)	8.6 (5.0)	94.5 (55.7)
Total annual electricity consumption [GWh]	34.1 (12.7)	85.2 (31.7)	15.3 (5.7)	24.5 (9.1)	1.9 (0.7)	4.3 (1.6)	46.5 (17.3)
Total annual heat consumption [GWh]	42.2 (33.2)	75.8 (64.6)	27.9 (22.3)	27.0 (21.6)	0.1 (0.1)	4.3 (45.9)	48.0 (38.4)
– Total annual natural gas consumption [GWh]	20.5 (16.4)	74.9 (59.9)	27.9 (22.3)	27.0 (21.6)	0.1 (45.9)	4.3 (45.9)	39.9 (31.9)
– Total annual coal consumption [GWh]	0.7 (0.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)
– Total annual other fuel consumption [GWh]	21.0 (16.8)	0.9 (0.7)	0.0 (0.0)	0.0 (0.0)	0.0 (45.9)	0.0 (45.9)	8.0 (6.4)
Average annual electricity consumption [kWhm^{-2}]	251 (125)	517 (152)	367 (142)	336 (103)	794 (250)	230 (101)	438 (149)
Average annual heating consumption [kWhm^{-2}]	310 (244)	460 (392)	668 (534)	371 (297)	528 (422)	228 (182)	453 (362)
Average annual total energy consumption [kWhm^{-2}]	561 (368)	977 (544)	1034 (676)	708 (399)	1322 (672)	458 (283)	891 (511)

Administrative buildings

From the total number (45 in APV) of administrative (municipal) institutions which received the survey, 26 municipalities filled in the survey with sufficient data. Some municipalities sent the data for several buildings in their possession. Therefore the total number of administrative buildings analyzed is 63. The majority of buildings consume natural gas as a heating source or are connected to the district heating system, paying on a yearly basis per m^2 of heated surface. However, municipalities use varied energy sources, such as coal, oil, electricity and geothermal, for heating. Several municipalities use two energy sources for heating while the majority uses electricity for reheating, if needed. From the total number of administrative buildings that were analyzed, 70% of the facilities use payment per their monthly energy consumption while the other group of 30% has a set monthly price per m^2 of heating. There were great discrepancies in energy indicators between the municipalities, nevertheless, average values could be extrapolated. Average annual electricity consumption is 213 (63.3) kWh/m^2 while annual heat consumption is 254 (194) kWh/m^2. Cumulative indicators for energy consumption for the administrative building sample were given in tab. 5. Average total annual energy use for the gathered sample is 34.69 (20.4) GWh.

Table 5. Cumulative primary and final (in brackets) energy indicators for the sample administrative buildings

Energy indicator for administrative buildings	Data from the analyzed sample
Total annual energy consumption [GWh]	34.69 (20.4)
Total annual electricity consumption [GWh]	15.86 (5.9)
Total annual heat consumption	18.83 (14.4)
– Total annual natural gas consumption [GWh]	5.13 (4.1)
– Total annual oil consumption [GWh]	10.53 (7.9)
– Total annual other fuel consumption [GWh]	0.38 (0.3)
– Total annual hot water/steam consumption [GWh]	2.80 (2.1)
Average electricity consumption [kWhm^{-2}]	213 (63.3)
Average heating consumption [kWhm^{-2}]	254 (194)
Average total energy consumption [kWhm^{-2}]	467 (257)

Discussion

Comparison between Serbia's Ordinance [47], energy indicators from other countries and indicators collected in the APV must be made in order to evaluate and understand the APV's current energy status.

Table 3 shows that energy indicators from the analyzed schools at more than 250 (200) kWh/m^2 are far higher than those anticipated by the Ordinance on energy efficiency of buildings issued by the State. According to the Ordinance, already existing educational facilities should not exceed 75 kWh/m^2 of heat consumption (tab. 6). Having this in mind, immediate interventions are needed on the building envelopes as well as on existing energy systems. If the buildings were adapted to fall in line with the Serbia's ordinance, 65% of final heating energy could be saved, amounting to roughly 36.2 GWh.

Table 6. Allowed annual final energy consumption – existing buildings [47]

Building type	Maximal energy consumption for heating [kWhm^{-2}]
Administrative and office buildings	65
Education buildings	75
Healthcare and social buildings	120

The educational facilities analyzed have an average total final energy consumption of 229 kWh/m^2 and heating consumes 206 kWh/m^2 annually. In Germany, the final specific energy consumption in schools is 129 kWh/m^2, while 88.3 kWh/m^2 is spent for heating purposes. In Slovenia the average energy consumption in schools is 192 kWh/m^2. Greece has an energy consumption of 77 kWh/m^2 for a typical school building, while energy efficient schools consume 42 kWh/m^2. Electricity consumption is 21 kWh/m^2. In Turin, Italy, the average heating energy indicator for school buildings is 100 kWh/m^2. In Flanders, energy consumption in schools averages 197 kWh/m^2, and 119 kWh/m^2 in Northern Ireland. Great Britain shows good case studies with consumption of 157 kWh/m^2 and 110 kWh/m^2 [18-32]. These energy indicators show that the APV has, on average, double the energy needs of the majority of European countries.

The current state of APV healthcare building energy use is the same as with educational buildings. Energy use is not at all in accordance with Serbia's Ordinance, which states that existing healthcare facilities final annual heat energy consumption should not exceed 120 kWh/m^2 (tab. 6). Currently, average annual electricity consumption is 149 kWh/m^2 while annual heat consumption is 362 kWh/m^2 (tab. 4). It is important to mention the fact that some of the facilities were built during the beginning and the middle of the last century and that envelope and energy system revitalization is necessary but complex. Most of the energy systems are outdated in terms of function and EE, contributing massively to the current high levels of energy consumption.

By comparison Healthcare facilities in Poland consume between 88 and 147 kWh/m^2 for heating, in Greece 107 kWh/m^2 electricity is spent and 129 kWh/m^2 for heating energy and in Scotland 71 kWh/m^2 for electricity and 239 kWh/m^2 for heating energy. The analysis again points to the fact that energy is wasted and that Europe can offer good practice solutions for energy efficiency measures [18-32].

Table 7. Degree days for the mentioned countries

Country	Degree days
Germany	3063
Slovenia	2774
Italy	1829
Great Britain	2990
Belgium	2696
Greece	1449
Serbia	2520
Vojvodina (APV)	2680

Administrative buildings in Greece consume on average 71 kWh/m^2 of electrical and 70 kWh/m^2 of heating energy annually. In Great Britain, 139 kWh/m^2 of electrical and 140 kWh/m^2 of heating energy are used and Sweden has an equal heating and electricity consumption of 160 kWh/m^2. Slovakia's administration consumes on average 40 kWh/m^2 of electrical and 70 kWh/m^2 of heating energy annually, while Portugal spends 95 kWh/m^2 on electricity and 30 kWh/m^2 on heating. Germany consumes 35 kWh/m^2 for electricity and 180 kWh/m^2 for heating annually, while France uses 119 kWh/m^2 for electricity and 165 kWh/m^2 for heating. Also, Denmark spends 60 kWh/m^2 on electricity and 270 kWh/m^2 on heating and Austria consumes 55 kWh/m^2 for electricity and 90 kWh/m^2 for heating [18-32]. The energy analysis in the APV administration calculated specific annual consumption of electricity to be 61 kWh/m^2 and 253.5 kWh/m^2 for heating energy. It must be added that the second group (Annual set price for m^2) was excluded from the discussion. Therefore, the presented results are slightly higher than the current state.

To make an accurate comparison of indicator, degree days for the geographical locations were also taken into account. Table 7 shows the examples for some of the above mentioned countries.

Conslusions

The ultimate objective was to introduce accurate and reliable data about the current state of the public building sector as an important foundation for Serbia's long-term energy consumption reduction planning and devising of measures to improve EE.

Within this study, a wide range of factors was considered when analyzing the energy consumption indicators for specific public facilities, based on the aforementioned sample in the APV. The causes of the high energy consumption are the age of the buildings, poor energy infrastructure, bad envelope insulation, nonexistent energy management and inadequate use of the facility and its energy systems. Many survey results had to be rejected due to inaccurately filled surveys, bad recording systems and a lack of data, irregular readouts and payments for the energy consumed or subventions made by the government, contributing to the confusion surrounding energy consumption. Users of the public building sector are not the same as the building owners. The building operating costs as well as energy consumption falls on the owner. This aspect further deters the user from rational energy use during building operation. The implementation of energy management system would remove even this negative irrational attitude towards energy.

Further, it is clearly shown that the gathered and analyzed energy indicators on the territory of the APV for buildings in the public sector are drastically higher than in other European countries and what is allowed by Ordinance. It is a necessity and a priority to reduce this energy waste and respect the law. Compared to the Ordinance, the current state of educational and administrative facilities needs to improve threefold, while healthcare needs to reduce its use to half. Investments in energy efficiency will be beneficial for the government as it will greatly reduce operating costs, create job opportunities and improve the working and living conditions for the building occupants. Decisive steps need to be taken in order to achieve this goal and Serbia should learn from and cooperate with countries that have gone through this transition period.

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