VERIFIKACIJA OSTVARENIH UŠTEDA U POTROŠNJI FINALNE ENERGIJE ZBOG PRIMENE MERA ZA UNAPREĐENJE ENERGETSKE EFIKASNOSTI U PSIHIJATRIJSKOJ KLINICI „DR LAZA LAZAREVIĆ“

VERIFICATION OF ACHIEVED FINAL ENERGY SAVINGS DUE TO IMPLEMENTATION OF ENERGY EFFICIENCY MEASURES IN PSYCHIATRIC CLINIC “DR LAZA LAZAREVIĆ”*

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U ovom radu je izvršena verifikacija ostvarenih ušteda u potrošnji finalne energije za grejanje, ventilaciju, pripremu sanitarne tople vode, tehnološke potrebe u kuhinji i vešeraju i za osvetljenje zbog unapređenja energetske efikasnosti u klinici „Dr Laza Lazarević“ u Padinskoj Skeli. U radu su prvo dati osnovni podaci o objektima klinike, sistemu grejanja, sistemu mehaničke ventilacije i sistemu osvetljenja pre rekonstrukcije, a zatim su navedene sve mere za unapređenje energetske efikasnosti koje su primenjene tokom rekonstrukcije. Godišnja potrošnja finalne energije za grejanje i osvetljenje prikazana je u poglavlju 3 u kome su takođe prikazani i podaci o zabeleženim prosečnim spoljašnjim temperaturama i obezbeđenom svetlosnom fluksu u objektima klinike pre i posle rekonstrukcije. Osim toga, u poglavlju 3 je izvršeno identifikovanje potrošnje električne energije za novi sistem mehaničke ventilacije koji je tokom rekonstrukcije objekata klinike ugrađen. U poglavlju 4 je opisan metod svođenja ostvarenih potrošnji finalne energije za grejanje pre i posle rekonstrukcije na iste spoljašnje temperature, kao i metod svođenja potrošnje električne energije za osvetljenje pre i posle rekonstrukcije na isti svetlosni fluks. Naime, direktno poređenje ostvarenih potrošnji finalne energije ne bi vodilo korektnim zaključcima zbog različitih uslova pre i posle rekonstrukcije (različite spoljašnje temperature i različit kvalitet osvetljenja). Da bi se dobile uporedive vrednosti i omogućilo donošenje relevantnih zaključaka, bilo je neophodno korigovati ostvarene potrošnje energije za grejanje pre i posle rekonstrukcije, tako da se odnose na istu spoljašnju temperaturu. Ovo svođenje je izvršeno na projektnu vrednost spoljašnje temperature, odnosno na srednju višegodišnju temperaturu u Beogradu tokom zimskog perioda. Isto tako, utrošenu električnu energiju za osvetljenje pre i posle rekonstrukcije bilo je neophodno korigovati na isti nivo osvetljenosti. Pošto nivo osvetljenosti u objektima klinike pre rekonstrukcije nije bio na propisanom nivou, dok novi sistem osvetljenja obezbeđuje nivo osvetljenja koji je propisima zahtevan u zdravstvenim institucijama, to je svođenje izvršeno na nivo svetlosnog fluksa koji je obezbeđen nakon rekonstrukcije. U poglavlju 5 su prikazane svedene vrednosti godišnje utrošene finalne energije za grejanje i za osvetljenje pre i posle rekonstrukcije, kao i ostvarene godišnje energetske uštede, godišnje smanjenje emisije CO₂ i ostvarene godišnje finansijske uštede. Zaključna razmatranja su prikazana u poglavlju 6, a korišćena literatura u poglavlju 7.

Dobijeni rezultati nedvosmisleno pokazuju da je rekonstrukcija objekata klinike “Dr Laza Lazarević”, bar u energetske i ekološke smislu, bila potpuno opravdana. Ukupna ušteda u finalnoj energiji potrebnoj za funkcionisanje klinike iznosi 38.4%, dok smanjene emisije CO₂ iznosi 29.8%. Osim toga, rekonstrukcijom objekata klinike je unapređen kvalitet i komfor života pacijenata i bolničkog osoblja. Očigledni primeri za to su značajno unapređenje nivoa osvetljenja u klinici u odnosu na stanje pre rekonstrukcije, odnosno dovođenje kvaliteta osvetljenja na nivo zahtevan propisima za obrazovne institucije i uvođenje sistema mehaničke ventilacije čime je postignut zahtevani broj izmena vazduha u skladu sa higijensko-zdravstvenim standardima za bolnice.

Rezultati prezentirani u ovom radu potvrđuju da je moguće značajno povećanje energetske efikasnosti kroz rekonstrukciju starih objekata. U pogledu korisne energije za grejanja objekata klinike, koji su stari, loše izolovani i sa lošom stolarijom, ostvarene uštede iznose 51%, dok su uštede u potrošnji finalne energije za istu namenu nešto veće i iznose 54% što je posledica zamene starog i dotrajalog toplovoda i uvođenja boljeg sistema regulacije u kotlarnici. Uštede finalne energije za potrebe pripreme sanitarne tople vode i tehnološke pare za rad kuhinje i vešeraja iznose 22.5%, dok su u potrošnji električne energije za osvetljenje ostvarene uštede od 35.3%. Uz ove energetske uštede, rekonstrukcija klinike je takođe doprinela smanjenju emisije CO₂ za 29.8%. Konačno, ostvarene su i finansijske uštede u troškovima nabavke energenata od 37.9%. Međutim, uprkos postignutim respektabilnim efektima, treba primetiti da se troškovi rekonstrukcije zgrada bolnice ne mogu vratiti u prihvatljivom roku samo kroz ostvarene energetske uštede. Kao generalna preporuka, može se reći da odluku o rekonstrukciji zgrade ne treba donositi zbog mogućih ušteda u potrošnji finalne energije, nego zbog funkcionalnosti zgrade, njene bezbednosti i zdravstvenih uslova. Međutim, kada se takva odluka donese, onda u obim radova na rekonstrukciji obavezno treba uključiti i sve mere za poboljšanje energetske efikasnosti zgrade.

Ključne reči: Finalna energija, grejanje, osvetljenje, uštede

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This paper presents the method of verification and achieved savings of final energy used for heating, ventilation, domestic water heating, technologies of kitchen and laundry room, and lighting due to energy efficiency improvement in Clinic "Dr Laza Lazarević" in Padinska Skela. It includes general data on structures within the Clinic, heating system, system of mechanical ventilation, and lighting system prior to reconstruction and the list of all energy efficiency measures implemented during the reconstruction. Annual final energy consumption has been presented in Chapter 3 along with data on recorded average outside temperatures and the available light flux in buildings of the Clinic before and after reconstruction. Also, Chapter 3 contains data on electricity consumption by the newly installed mechanical ventilation system. Chapter 4 describes method of adjustment of realised final energy consumption values before and after reconstruction of the Clinic according to the same outside temperatures as well as the method of adjustment of electricity consumption for lighting before and after reconstruction to the same light flux. Namely, direct comparison of realised final energy consumption values would not lead to correct conclusions due to different conditions before and after reconstruction (different outside temperatures, and lighting level). In order to achieve comparable values and relevant conclusions, it was necessary to adjust realised values of consumption of energy for heating before and after reconstruction so that they correspond to the same outside temperature i.e. median multiyear temperature in Belgrade during winter. Also, the consumed electricity for lighting before and after reconstruction was necessary to be adjusted to the same level of illumination. Since the level of illumination in buildings of the Clinic had been lower than the level prescribed by the law, while the new lighting system provides the illumination level required in health-care institutions, to je the adjustment of the electricity consumption value was adjusted in accordance with illumination level after reconstruction. Chapter 5 presents the adjusted values of annually consumed final energy for heating and lighting before and after reconstruction, as well as realised savings per annum, reduction of CO₂ emission and financial savings. Conclusions have been explained in Chapter 6, while Chapter 7 contains the list of used literature.

The obtained results show unequivocally that the building reconstruction was completely justified, at least from energy and environmental aspect. Total savings of final energy necessary for operation of the Clinic amount to 38.4%, while reduction of CO₂ emission amounts to 29.8%. Also, reconstruction of the Clinic contributed to improvement of quality and comfort of life for patients and staff of the Clinic. One of the examples is a significant improvement of illumination level after reconstruction i.e. raising of illumination level to the level prescribed by the law and installation of a mechanical ventilation system that provided the required number of air changes per hour in accordance with hygienic and health standards for hospitals.

The results presented in this paper prove that it is possible to significantly improve energy efficiency through reconstruction of old buildings. When it comes to usable energy for heating of buildings of the Clinic that are old, poorly insulated and with doors and windows in poor condition, achieved savings amount to 51%, while savings of final energy for the same purpose are higher and amount to 54%, as a consequence of replacement of the old hot water pipeline and installation of a better operation control system in the boiler room. Savings of final energy consumption for domestic water heating and preparation of steam used in the kitchen and laundry room amount to 22.5%, while savings of electricity consumed by the lighting system amount to 35.3%. Beside these energy savings, the reconstruction of the Clinic also contributed to reduction of CO₂ emission by 29.8% and finally to financial savings that regard costs of energy carriers in the amount of 37.9%. However, in spite of the achieved respectable effects, it should be noted that it is not possible to return the investment into the reconstruction within a reasonable period only through energy savings. It is generally recommended to decide about whether or not to approach to reconstruction of a building based on its functionality, safety and health-related conditions rather than possible reduction of final energy consumption. However, if the decision is made, the works on the reconstruction should include all energy efficiency improvement measures.

Key words: Final energy, heating, lighting, savings

1. Energy-related features of buildings before project implementation

1.1. General information on buildings within the Clinic

Clinic "Dr Laza Lazarević" is a stationary health-care institution which provides specialist consultancy and hospitalization for psychiatric patients of all types.

The building was built in 1963. The land and the buildings are state-owned and the Clinic has a right of use. The Clinic serves 293 patients monthly on average, which makes 3516 patients per year. It spreads over the area of 95918 m². Total gross area of the Clinic's buildings amounts to 11290 m², while the net area amounts to 8978 m². the Clinic consists of the buildings listed in Table 1.

Gross area of 8715 m² is used for patients' accommodation, while a gross area of 2575 m² is dedicated to auxiliary services.

Insulation features of building envelope

Specialised Clinic "Dr Laza Lazarević" was built out of solid brick without thermal insulation, with 44 cm thick external walls. There have never been any reconstructions of the building envelope other than regular maintenance. There were places on the envelope with visible signs of deterioration.

The roof construction is made of wood with galvanized metal roofing on the kitchen and auxiliary building and fibrous cement roofing on buildings occupied by patients. There were leakages on some parts of the roof due to damages on the roofing.

Table 1 the list of buildings – Specialised Clinic “Dr Laza Lazarevic”

Number	Building	Area in m ²	Floors
1.	Ward A	890 m ²	Ground floor + 1 st floor
2.	Ward B	1007 m ²	Ground floor + 1 st floor
3.	Ward C	956 m ²	Ground floor + 1 st floor
4.	Ward D	1007 m ²	Ground floor + 1 st floor
5.	Ward E	956 m ²	Ground floor + 1 st floor
6.	S – Infirmary	1356 m ²	Ground floor + 1 st floor
7.	Daily clinic	634 m ²	Ground floor + 1 st floor
8.	Auxiliary buildings (Boiler room, Kitchen, Laundry room, Tool shed and transformer substation)	2004 m ²	Ground floor
9.	Garage	168 m ²	Ground floor
10.	Gym	229 m ²	Ground floor

The floor base is made of concrete and vinyl asbestos tiles were installed over it in most rooms. Ceramic tiles were installed on kitchen and bathroom floors and in some administration and medical offices floors were covered with laminate flooring.

Wooden windows, double glazed, with one glass surface per layer, were in very poor condition. Since the wooden frames had deviated, the sealing was bad and the cold air was coming into rooms.

1.3. Heating system and types of fuel

Heating of the Clinic during the heating season and production of steam used in the kitchen and the laundry room over the year is done in the Clinic’s own fuel oil boiler room. General information of the boilers was listed in Table 2.

Table 2 General information on heating system

Heating system	
Installed capacity of boilers [kW]	<ul style="list-style-type: none"> • Steam boiler "Minel" TE 105 = 2.3 MW • Steam boiler "TPK Zagreb" BKG15 = 1.15 MW • Hot-water boiler "MIP Čuprija", = 1.1 MW
Efficiency degree [%]	<ul style="list-style-type: none"> • Steam boiler "Minel" TE 105 = 85 % • Steam boiler "TPK Zagreb" BKG15 = 85 % • Hot-water boiler "MIP Čuprija", = 85 %
Year of installation	<ul style="list-style-type: none"> • Steam boiler "Minel" TE 105, manufactured in 1994 • Steam boiler "TPK Zagreb", manufactured in 1976 • Hot-water boiler "MIP Čuprija", manufactured in 2005
Fuel	<ul style="list-style-type: none"> • Heavy fuel oil
Data on methods of regulation	
Automatic operation control of the heat source (Yes/No)	NO
Central regulation of thermal performance (Yes/No)	NO
Local regulation of thermal performance (Yes/No)	NO
Daily outage (hours per day)	8h
Weekly outage (days per week)	-
Season outage (days per season)	-
Overall duration of heating season (hours)	4,392
Number of operating hours during heating season	2,928
Average number of occupants in building (patients and personnel)	810
Average occupation time per person	16 h

The Clinic is heated by a steam boiler "Minel" and the heat exchanger at the outside temperature above 0°C. When the temperature drops below 0°C, a hot-water boiler "MIP Čuprija" is turned on. In coldest winters the hot-water boiler is not potent enough to provide heating for Clinic's buildings. Therefore, consumption of electricity is significantly increased in winter since it is obviously used for additional heating due to inadequate heating system. The Garage has a heating system that differs from other buildings in the Clinic's complex. It is heated by steam at overpressure of 0.5 bars.

Pressure of water inside the hot-water boiler "MIP Čuprija" is 2 bara, and the temperature operation regime is 60/50 °C. Boilers "Minel" TE 105 and "TPK Zagreb" BKG15 are steam boilers. Steam pressure in them is 7 bars for the laundry room and 0.5 bars for the kitchen, while maximum steam temperature is 145°C. All boilers are in very poor condition.

The heat for heating of Clinic wards, kitchen and auxiliary buildings is distributed through an underground heating pipeline in a covered concrete channel that forms a ring around the Clinic's complex. All buildings are connected to this ring. The pipeline consists of a main pipe (Ø219.1 and Ø168.3), and short branches towards the buildings (Ø76.1).

The heating pipeline had no insulation and was in poor condition generally. It was sometimes necessary to add water in the system because of leakage.

The Clinic has its own sanitary water preparation system. Heating of the sanitary hot water is done centrally and also locally in small electric boilers. Central heating of sanitary hot water is done in 3 m³ boilers-tanks installed in the boiler room. The Clinic has two boilers, one of which has been repaired. Domestic sanitary hot water is being prepared using the steam from the steam boiler.

Sanitary hot water pipeline is buried in the heating pipeline trench from the boiler room to individual wards and administration building. Sanitary hot water pipeline was also old and in even worse condition than heating pipeline prior to reconstruction. Due to excessive leakage, energy was being consumed to heat larger amounts of water than the Clinic was using in reality. Sanitary hot water preparation system was not automatically controlled.

1.4. Power consumption

The Clinic is supplied with power through the power distribution network, over a 20-kV overhead line. It is charged by the power distribution company at the tariff for medium-voltage consumption. A 20/0.4 kV transformer station is located within the Clinic's complex.

Electricity is used for lighting, sanitary hot water preparation, air conditioning, mechanical ventilation of the gym, IT equipment, fire-protection equipment, a loudspeaker system and other office appliances.

2. Implemented Energy Efficiency Measures

2.1. EE measures for building envelope

The following EE measures have been applied to envelopes of buildings:

- Exterior wall insulation – 8-cm thick layer of rockwool thermal insulation was installed over façade walls; specific density of the insulation: $\rho=120 \text{ kg/m}^3$; thermal conductivity: $\lambda=0.035 \text{ W/m}^2\text{K}$;
- Roof insulation – 8-cm thick layer of rockwool (specific density: $\rho=120 \text{ kg/m}^3$; thermal conductivity: $\lambda=0.035 \text{ W/m}^2\text{K}$) was installed on ceiling under the concrete slab;
- Thermal insulation of floors – 3-cm thick layer of extruded polystyrene was used as floor insulation;
- Installation of new double-glazed PVC windows.

2.2. EE measures on thermo-technical installations

The following EE measures have been applied to thermo-technical installations:

- Installation of antivandal thermostatic radiator valves,
- Cleaning of radiators,
- De-aeration and hydraulic balancing of the heating system,
- Installation of a new circulation pump with variable flow in the secondary circle (because thermostatic valves enable setting of variable flow of hot water through the installations).

2.3. EE measures regarding electricity consumption

All Incandescent light bulbs were replaced with new, more efficient bulbs and the level of illumination was raised to the level required by the law for this type of institution.

2.4. Other measures implemented during the Clinic building reconstruction

Beside measures that directly impact increase of energy efficiency, other measures were implemented as a part of the reconstruction that enable sustainability of previously implemented direct EE measures. Therefore, electrical installations were replaced (distribution/metering cabinet, conductors, switches and other equipment, earthing and earthing-related installations). Water supply installations were also replaced completely since they were old, rusty and prone to cracking.

Finally, the system of mechanical ventilation was installed with air handling units in all buildings. This is certainly not an EE measure, since installation of this system does not contribute to reduction but to increase of power consumption. However, this system was necessary in order to provide a number of air changes per hour stipulated by the law.

3. Final Energy Consumption

3.1. Temperatures and final energy used for heating before reconstruction

According to data from Hydro-meteorological Office of the Republic of Serbia (References [4] and [5]), average temperatures in Belgrade in heating seasons 2011/12, 2012/13, 2013/14, and 2014/15 16 (i.e. in period from October 16th of one to April 15th of the following year) amounted to: 5.5 °C, 6.95 °C, 8.57 °C, and 7.39 °C, respectively. The average temperature in Belgrade during these four heating seasons amounts to 7.1 °C and is relevant for consumption of final energy in the Clinic.

The fuel was purchased in accordance with the demand and current stocks and consumption. There are records on realised monthly purchases. Data on total annual purchased amount of fuel oil during 4 years (October 2011 - September 2015) are given in Table 3.

Table 3 Purchased amounts of fuel oil during 4 years

Season	October 2011 - September 2012	October 2012 - September 2013	October 2013 - September 2014	October 2014 - September 2015	Total
Purchased amount of fuel oil (t)	363.74	365.66	369.72	353.50	1,452.62

Data in Table 3 indicate that total amount of fuel oil for all Clinic's needs purchased in this 4-year period, before implementation of EE measures amounted to 1,452.62 t. It is also necessary to consider the fact that the reservoir in the Clinic's boiler room contained 35.5 t of fuel oil on 1st October 2011, while on 1st October 2015, at the end of the observed period, there was 39 t of fuel oil left. This means that the Clinic consumed total amount of 1449.12 t of fuel oil during 4 years (1,452.62+35.5-39).

Therefore, the annual average fuel oil consumption in the boiler room at the average outside temperature (7.1 °C) amounted to 362.28t (1449.12/4). This amount of fuel oil was being consumed for heating and ventilation of all buildings of the Clinic during winter and also for preparation of domestic hot water and for needs of kitchen and laundry technology.

Data in Table 4 represent average fuel oil consumption during the summer season (May–September) for domestic water heating and technologies of kitchen and laundry before implementation of EE measures, which amounted to 60 t i.e. 12 t/month (60t/5months).

Table 4 Average fuel oil consumption during the summer season for domestic water, kitchen and laundry

Season	Maj – September 2012	Maj – September 2013	Maj – September 2014	Maj – September 2014	Average consumption
Fuel oil consumption during the summer season (t)	60	60	57	65	60

The above data indicate that total annual consumption of fuel oil for domestic water, kitchen and laundry, amounted to 144t (12 t x 12 months) before energy efficiency measures, i.e. that average annual final energy consumption for domestic water heating and production of steam for kitchen and laundry prior to EE measure implementation amounted to:

$$W_{p,STV} = 144,000 \cdot 41,000 / 3,600 = 1,640,000 \text{ kWh}$$

If total annual fuel oil consumption in the boiler room of the Clinic, which amounted to 362.28 t, is reduced by 144 t consumed for domestic water and steam preparation, the result would be equal to total annual fuel oil consumed for heating and ventilation in the Clinic, which amounted to 218.28 t (362.28-144) i.e. 2,485,967 kWh (218,280 *41,000 / 3,600) at the average outside temperature of 7.1 °C before implementation of energy efficiency measures.

However, the above amount of fuel oil consumed for heating and ventilation before recovery was not sufficient to provide necessary inside temperature in the Clinic's buildings. Considerable amounts of electricity were consumed for additional heating during winter. Based on the average difference between electricity consumption during winter and summer period, it has been concluded that the average electricity consumed for additional heating amounted to 85,922 kWh.

The above-mentioned figures imply that the average annual final energy consumption (fuel oil + electricity) for heating and ventilation before implementation of EE measures at the average outside temperature of 7.1 °C amounted to: 2,571,889 kWh (2,485,967 kWh + 85,922 kWh).

Considering the fact that the daily clinic has not been reconstructed, the amount of final energy consumed for heating and ventilation of the daily clinic have been deducted from total amount of final energy consumed for heating and ventilation of entire Clinic so that the comparison of consumption before and after reconstruction is relevant (by adjusting the conditions).

Since there is no metering of energy consumption at individual buildings, the final energy audit report for specialised psychiatric Clinic "Dr Laza Lazarevic" from November 2013 was used as the most relevant indicator of energy consumption in daily clinic before recovery. According to this document, total final energy consumption for heating and

ventilation of daily clinic amounted to 196,468 kWh. Final energy consumption for heating and ventilation of daily clinic had been calculated taking into account the efficiency degree of the heating system of 70.38% (the efficiency degree of boilers: 85%, the efficiency degree of the pipeline: 92%, the efficiency degree of the control system: 90%). Also, it is important to notice that it has been assumed that there are 2 air changes per hour in the daily clinic, as well as in all other buildings. This assumption is in line with the Rulebook on energy efficiency in buildings, according to which 1.2 air changes per hour due to air infiltration should be assumed for buildings with windows in very poor condition such were those in the Clinic. Since there were no mechanical ventilation system, it is assumed that additional 0.8 air changes per hour were achieved by ventilation through open windows. Accordingly, it is assumed that 2 air changes per hour (1.2+0.8) were achieved before reconstruction, in the daily clinic building and all other buildings of the Clinic.

Total annual final energy consumption for heating and ventilation of the Clinic before its reconstruction (except the daily clinic building, which has not been reconstructed yet), at the average outside temperature of 7.1°C amounted to:

$$W_{P,H-T} = 2,571,889 \text{ kWh} - 196,468 \text{ kWh} = 2,375,421 \text{ kWh}$$

3.2. Total light flux and electricity consumption for lighting before reconstruction

Data on annual electricity consumption at different tariffs in period 2011-2015 in Clinic "Dr Laza Lazarević" were given in Table 5. This period is considered to be representative for determining the average annual electricity consumption in the Clinic since the consumption regime was as usual and without drastic changes in this period. Including of 2016 and 2017 in the analyses would not serve the purpose because the works on reconstruction were intensive in that period, which means that the regime of electricity consumption was drastically changed.

Table 3 Electricity consumption in the Clinic

Year	October 2011 – September 2012	October 2012 - September 2013	October 2013 - September 2014	October 2014 – September 2015	Average consumption
High tariff (kWh)	474,396	425,152	407,235	413,832	430,154
Low tariff (kWh)	217,584	195,385	192,556	193,363	199,722
Total (kWh)	691,980	620,537	599,791	607,195	629,876

These data on consumption of electricity regard all consumers in the Clinic, including electric boilers for domestic hot water, circulation pumps for central heating system, HVAC units, IT equipment, and lighting system. Since there is no data on electricity consumption for lighting only, it has been estimated with the analyses shown in further text, while a logical test on the obtained results was done using the above listed figures regarding consumption at higher and lower tariff.

Table 6 includes all types of light bulbs used in the Clinic before reconstruction, their number, wattage, the assumed operation time, consumed electricity over the year, and total light flux provided by such lighting system. Table 6 shows that the installed wattage of the light bulbs in the Clinic (not including the building of the daily clinic) before reconstruction amounted to 58.876 kW

Table 4 Installed wattage, electricity consumption for lighting, and the light flux in the buildings before reconstruction

Lamp type	Number of lamps	Wattage (W)	Operation time (h/yr.)	Total wattage (kW)	Electricity consumption (kWh/yr.)	Total light flux (lm)
Incandescent bulbs E 27	304	100	2,869.26	30.4	87,225	501,600
Neon lamp 2 x 36 W	139	72	2,869.26	10.008	28,716	792,634
Neon lamp 3 x 36 W	47	108	2,869.26	5.076	14,564	402,019
Neon lamp 4 x 36 W	43	144	2,869.26	6.192	17,766	490,406
Neon lamp 2 x 18 W	10	36	2,869.26	0.36	1,033	23,004
Neon lamp 4 x 18 W	95	72	2,869.26	6.84	19,626	437,076
TOTAL:			2,869.26	58.876	168,930	2,646,739

It is important to notice that the distribution of lamps listed in Table 6 in individual rooms and buildings of the Clinic before reconstruction have not been recorded, so it was not possible to calculate the equivalent operation time of the installed light capacity before reconstruction. Therefore, it has been assumed that the equivalent operation time of the installed light capacity would not change after reconstruction. Chapter 3.4 (Installed capacity, total light flux and consumption of electricity for lighting after reconstruction) includes a detailed analysis of using of lighting system and

calculation of that parameter. It has been concluded that total equivalent time of using of the installed wattage annually amounts to approximately 2,870 hours, which is the figure used in this chapter also for calculation of the amount of electricity consumed by the lighting system before reconstruction.

According to the above, total electricity consumed for lighting over an average year in Clinic "Dr Laza Lazarević" before reconstruction amounts to 168,930 kWh.

Finally, in accordance with technical specifications of typical incandescent and fluorescent lamps given in reference [2], the light flux i.e. the amount of light emitted by lamps in the Clinic before reconstruction amounted to 2,646,739 lm.

3.3. Average outside temperature and final energy consumption for purpose of heating after reconstruction

According to data by the Republic Hydrometeorological Service of Serbia, the average temperature in Belgrade during heating season 2017/18 i.e. from 16th October 2017 to 15th April 2018 amounted to 7.31°C (reference [5]).

Even after implementation of EE measures, fuel oil is still used for heating of buildings, domestic water heating and production of steam for technologies of kitchen and laundry room. Some old radiators that deteriorated beyond use were replaced during reconstruction and others were cleaned. Radiators were relocated within buildings in accordance with stipulated demands and thermostatic valves were installed. The heating pipeline was also replaced, smart circulation pumps were installed, and the pipeline for domestic hot water was replaced. Therefore, the central heating system was improved significantly. The efficiency degree of the system after reconstruction has been estimated at 75.07% (efficiency degree of boilers: 85%, efficiency degree of the pipeline: 96%, efficiency degree of the manual control system: 92%), which is completely in line with the Rulebook on energy efficiency of buildings.

However, during recovery of the Clinic, neither the boilers in the boiler room, nor the daily clinic building have been recovered.

According to data provided by the Clinic, total amount of fuel oil purchased from 1st May 2017 to 1st May 2018 amounted to 239.24 t. It is necessary to consider the fact that at the beginning of this period there was 34 t of fuel oil stored in the boiler room, while at the end of it there was 4.5 t left. According to this, it can be concluded that total consumption of fuel oil in the Clinic after reconstruction amounted to 268.74 t (239.24+34-4.5).

Analysis of fuel oil consumption in the Clinic after reconstruction show that consumption in the summer (May – September 2017) for heating of domestic water and technological processes of kitchen and laundry room amounted to 46.48 t (there was 34 t of fuel oil on 1st May 2017 and 13 t of fuel oil left inside the boiler on 1st October 2017; 25.48 t of fuel oil was purchased during the summer) i.e. 9.3 t per month (46.48/5). This means that total annual fuel oil consumption for domestic water heating and production of steam for kitchen and laundry processes after energy efficiency measure implementation amounts to 111.55 t (9.3 t x 12 months).

According to the above analyses and calculations, annual final energy consumption for heating of domestic water and production of steam for technological processes of kitchen and laundry room after energy efficiency measure implementation amounts to:

$$W_{N,STV} = 111,552t \cdot 41,000 / 3,600 = 1,270,453 \text{ kWh}$$

Consumption of fuel oil in the entire Clinic during the observed one-year period after implementation of energy efficiency measures amounts to 268.74 t, of which 111.55 t was consumed for heating of domestic water and technological processes of kitchen and laundry room, and 157.19 t (268.74 – 111.55) i.e. 1,790,197 kWh was consumed for heating and ventilation of buildings.

The amount of fuel oil consumed for heating and ventilation after implementation of EE measures was sufficient to provide necessary temperature in buildings of the Clinic, which implies that electricity is not consumed for additional heating of the Clinic anymore.

Considering the fact that the building of the daily clinic has not been reconstructed, final energy consumption for heating and ventilation of the daily clinic have not been considered during comparative analysis of total final energy consumption of the Clinic before and after reconstruction.

According to the final energy audit report from November 2013, annual usable energy demand for heating and ventilation of the daily clinic amounted to: 138,274 kWh. after reconstruction, the efficiency degree of the heating system was improved (after reconstruction it amounts to: 75.07%). This means that annual final energy consumption for heating and ventilation of the daily clinic after reconstruction amounts to: 184,189 kWh.

Annual final energy consumption for heating and ventilation of all reconstructed buildings after implementation of energy efficiency measures and at average outside temperature of 7.31°C amounted to: 1,606,008 kWh (1,790,197 kWh - 184,189 kWh). This figure includes air infiltration due to imperfections of sealing between windows and walls, as well as mechanical ventilation with HVAC units that were installed into buildings during reconstruction. In order to make a relevant comparison between final energy consumption for heating and ventilation before and after reconstruction, it is necessary to adjust the conditions i.e. to use the same inside and outside temperature and the same number of air changes per hour. It is, therefore, necessary to define the number of air changes in the Clinic after reconstruction.

According to the Rulebook on energy efficiency in buildings, 0.5 air changes per hour due to air infiltration should be assumed for buildings with windows in good condition such are those in the Clinic after reconstruction. It has been assumed that habits of the personnel in the Clinic have not changed and that additional 0.8 air changes per hour are achieved by ventilation through open windows. Number of air changes per hour provided by mechanical ventilation

system has been calculated on basis of its electricity consumption, installed capacities of its fans for air extraction/injection and circulation pumps in HVAC units.

According to data provided by the Clinic, average electricity consumption during four 7-month heating seasons (2011/12, 2012/13, 2013/14, and 2014/15) amounted to 449,785 kWh. As mentioned in Chapter 3.1 of this paper, 85,922 kWh of electricity was consumed on average per heating season for additional heating in this period. Therefore, basic electricity consumption for seven months during heating seasons before reconstruction amounted to 363,863 kWh (449,785-85,922).

According to data provided by the Clinic, electricity consumption during heating season 2017/18 amounted to 425,005 kWh. After reconstruction, the personnel of the clinic did not have to use electric heaters for additional heating, so this figure may be considered as basic consumption of electricity after reconstruction. However, because of the improved lighting system, electricity consumption during the 7-month heating season decrease by 20,551 kWh, which will be explained more comprehensively in the following chapter.

The difference between basic consumption of electricity before and after reconstruction increased by the amount equal to the consumption reduction due to lighting system replacement represents electricity consumption of newly installed mechanical ventilation system, which amounts to 81,694 kWh (425,005-363,863+20,551) during seven months of heating season.

Equivalent operation time for mechanical ventilation system is calculated based on the defined electricity consumption, installed capacity of fans for extraction and injection of air, installed capacities of circulation pumps and the coincidence factor of the system operation. Total wattage of fans for air injection that are installed in HVAC units amounts to 27.85 kW, while total wattage of fans that extract air is 15.17 kW. Installed wattage of circulation pumps is 6.735 kW. Since there is no information regarding the coincidence factor of installed devices in the documentation related to HVAC units, the lowest savings were assumed for purpose of the calculation (on the safe side). In other words, it has been assumed that the coincidence factor of devices installed in HVAC units amounts to 1. Accordingly, equivalent operation time of mechanical ventilation system, calculated as a ratio between electricity consumption during HVAC unit operation and installed wattage of the devices (81694/49.755), amounts to 1,642 hours per seven months of the heating season.

According to the Detailed Design, maximum air injection capacity of HVAC units in the Clinic amounts to 87,500 m³/h, which means that the amount of air during the heating season is 143,667,870 m³/7 months (87,500 m³/h*1,642h). Total volume of buildings with mechanical ventilation is 20,079 m³, therefore, total number of air changes amounts to 7,155 during seven months (143,667,870m³/20,079 m³). Since the mechanical ventilation system operates simultaneously with heating system, it operated 3,392 h in total during that period. It can be concluded that number of air changes per hour made by mechanical ventilation system during a 7-month heating season was 2.11 (7,155/3,392).

Total number of air changes per hour during the heating season in the Clinic after reconstruction is 3.41 (0.5+0.8+2.11).

Installation of the mechanical ventilation system significantly upgraded quality of life for personnel and patients of the Clinic. However, improvement of functionality and working conditions also leads to increased consumption of final energy of the fuel oil that is used for heating of the air that is injected and the electricity consumed by mechanical ventilation system. Since there were two air changes per hour in the Clinic before reconstruction and 3.41 after reconstruction, in order to compare energy consumption in the Clinic before and after reconstruction (adjusting to the same conditions) final energy necessary for heating from the outside to the inside temperature of the amount of air that equals to 1.41 air changes per hour should be deducted from actually consumed final energy for heating and ventilation after reconstruction. Based on the thermal capacity of the air, volume of reconstructed buildings, inside and outside temperature difference, and efficiency degree of the heating system after reconstruction, it has been concluded that the adequate quantity of fuel oil was, 46.51 t or 529,648 kWh.

Annual final energy consumption for heating and ventilation (with 2 air changes) of the Clinic after EE measure implementation, at the average outside temperature of 7.31°C, amounts to:

$$W_{N,H-T} = 1,606,008 \text{ kWh} - 529,648 \text{ kWh} = 1,076,361 \text{ kWh}$$

3.4. Installed capacity, total light flux and consumption of electricity for lighting after reconstruction

During reconstruction of the lighting system, all incandescent bulbs were replaced with fluorescent lamps. Total installed wattage of the lighting system decreased from 58.876 kW to 50.56 kW. It should be noted that the system of lighting at the Clinic has not been replaced entirely. Due to lack of finances, a part of the old system was kept with total wattage of 24.508 kW, which makes 48.47% of total lighting system wattage after reconstruction

Electricity consumption for lighting varies over the year, depending of the intensity of natural lighting. Also, it depends on number of rooms and their purpose, number of patients and personnel and their habits. In order to calculate electricity consumption for lighting in the Clinic after reconstruction, we used the methodology described and applied in reference [1] for analyses of lighting in households in Serbia.

According to the applied methodology, primarily all types of rooms in the Clinic were defined, as well as installed wattage of lamps in them, and then electricity consumption was estimated for a typical summer and winter day. Table 7 includes all types of rooms identified in the Clinic, installed wattage of lighting in each of them, the assumed

operation time and estimated electricity consumption during a typical winter and summer day. Term “typical days” entails average days in months when the day is shortest and those when the day is longest i.e. in December and July.

Table 7 shows that total installed wattage of the lighting system in the Clinic after reconstruction is 50,562 W. In some rooms, consumption of electricity for lighting was estimated in accordance with their purpose and assumed needs for lighting in them. Operation time figures in Table 7 represent equivalent operation time of the lighting system in each room.

The results shown in Table 7 indicate that approximately 507.07 kWh per day is consumed for lighting in the Clinic during short winter days, while during long summer days almost twice as less electricity is consumed (287.87 kWh per day). Operation regimes are practically the same during business days and weekends.

Table 5 Installed wattage and daily consumption of electricity for lighting in typical rooms of the Clinic after reconstruction

Rooms in the Clinic	Installed wattage (W)	Winter		Summer	
		Tz (h)	Wzd (Wh)	Tl (h)	Wld (Wh)
Rooms	9,936	11	109,296	6	59,616
Hallway	5,576	17	94,792	12	66,912
Doctor's rooms, infirmaries	12,152	11	133,672	6	72,912
Sanitary facilities	6,528	7	45,696	5	32,640
Stairway	1,085	11	11,935	6	6,510
Rooms under the stairway	84	0.5	42	0.5	42
Façade of the building	350	1	350	0.5	175
Pharmacy	864	4	3,456	1	864
Kitchen – dining rooms, storage unit operator, nutritionist	1,372	4	5,488	2	2,744
Kitchen – storage unit, pantries	1,224	2	2,448	1	1,224
Kitchen – thermo block, refrigerator, food processing	1,127	8	9,016	4	4,508
Kitchen – sanitary facilities, entries	1,092	4	4,368	2	2,184
Kitchen – hallway, entrance space where the stuff washes their hands	3,168	12	38,016	8	25,344
Laundry room	2,500	3	7,500	0	0
Boiler room	2,032	18	36,576	6	12,192
Garage	1,472	3	4,416	0	0
TOTAL	50,562	10.03*	507,067	5.69*	287,867

Based on these data it is possible to calculate total equivalent operation time of the lighting system on typical summer and winter day. These figures were represented in the last row of Table 7 (marked with *) and they were calculated as a ratio between the daily energy consumed for lighting and total installed wattage of the system and they amount to 10.03 h and 5.69 h per day respectively.

Needs for lighting vary over the year due to differences in natural lighting so the equivalent operation time of the system also varies between the two calculated limit values. Since the daylight periods change over the year, it is assumed that these variations are linear in the first equation and that the equivalent operation time also changes in the same manner. This means that in days before and after winter solstice the equivalent operation time during the day is the longest: 10.03 hours. After that, it linearly decreases to only 5.69 during days close to the summer solstice, when it begins to decrease again to maximum 10.03 hours in December. Generally, the equivalent daily operation time of the lighting system during a month can be determined as:

$$T_{ei} = T_{emin} + k * \Delta M_i \quad (1)$$

$$k = (T_{emax} - T_{emin}) / 6 \quad (2)$$

where:

- T_{emin} represents minimal equivalent operation time of the lighting system in days close to summer solstice i.e. in June;
- k – the constant of proportionality;
- ΔM_i – distance of the month i from June ($\Delta M_i=1,...,6$);
- T_{emax} – maximum equivalent operation time of the lighting system in days close to winter solstice i.e. in December.

Number of days per month and equivalent operation times for lighting were listed in Table 8.

Figures in Table 8 indicate that the equivalent operation time of the lighting system over the year amounts to approximately 2,869.26 hours.

Accordingly, total electricity consumption for lighting in the Clinic during a typical year after reconstruction amounts to 145,039 kWh.

Table 6 Number of days, equivalent operation time and consumption of the lighting system in the Clinic per month after reconstruction

<i>Month</i>	<i>Number of days</i>	<i>Equivalent operation time (h)</i>	<i>Consumption for lighting (kWh)</i>
January	31	9.31	14,586.54
February	28	8.58	12,152.01
March	31	7.86	12,321.48
April	30	7.14	10,828.01
May	31	6.42	10,056.41
June	30	5.69	8,636.01
July	31	6.42	10,056.41
August	31	7.14	11,188.94
September	30	7.86	11,924.01
October	31	8.58	13,454.01
November	30	9.31	14,116.01
December	31	10.03	15,719.08
Total	365	7.86	145,039

However, it should be noted that, although installed wattage of the lamps and electricity consumption decreased, reconstruction also provided the mandatory prescribed level of illumination i.e. a significant increase in light flux that had not been achieved before reconstruction. Table 9 represents total light flux i.e. total illumination provided by all lamps in the Clinic after reconstruction (3,509,626 lm).

Table 7 Total light flux in the Clinic after reconstruction

<i>Lamp type</i>	<i>No. of lamps</i>	<i>Wattage (W)</i>	<i>Illumination level (lm/W)</i>	<i>Total light flux (lm)</i>
Neon lamp 2 x 36 W	101	72	79.2	575,942
Neon lamp 3 x 36 W	30	108	79.2	256,608
Neon lamp 4 x 36 W	8	144	79.2	91,238
Neon lamp 2 x 18 W	39	36	63.9	89,716
Neon lamp 4 x 18 W	95	72	63.9	437,076
PSP 262X49W	44	49	75	161,700
LUNA ROUND 210 2X26W/840	146	52	73.1	554,975
ALTRA ORION 2, 10W	92	10	115	105,800
PSP 262X14W/840	6	14	115	9,660
LSP 322X28W/840	466	28	75	978,600
MLM 352X28W/840	65	28	75	136,500
SLOTLIGHT 1X14W	6	14	115	9,660
REFLEKTOR MACH2 ASYM 70W	5	70	75	26,250
Ordinary lamps E 27	46	100	16.5	75,900
TOTAL				3,509,626

4. Method of adjustment of quantities to the same temperature and lighting quality

4.1. Adjustment of final energy consumed for purposes of heating

Direct comparison of realised consumption of final energy for heating before and after reconstruction would not lead to a relevant conclusion due to differences in outside temperatures in the observed periods. Therefore, it is necessary to adjust these values to the same outside temperature. Methods of adjustment used in this chapter have been described in Reference [3] - using equivalent average outside temperature during winter (5.6 °C) and the inside temperature of 22 °C prescribed by the Rulebook on energy efficiency of buildings (Reference [6]).

The applied method of adjustment of the consumed final energy for heating to the same outside temperatures is based on the physics regularity according to which the consumed energy for heating is proportional to the difference between the inside and the outside temperature of a structure. So, the consumed final energy in the heating season "i" may be represented as follows:

$$FE_{ij} = A_j \cdot \Delta T_{ij} = A_j \cdot (T_{ij} - T_{oi}) \quad (3)$$

where:

- FE_{ij} – final energy consumed in structure "j" during heating season "i",
- A_j – constant of proportionality for structure "j",
- T_{ij} – inside temperature, in structure "j" during heating season "i",
- T_{oi} – average outside temperature during heating season "i".

The constant of proportionality before reconstruction of the Clinic can be determined by inserting values of average annual consumed final energy for heating of the corresponding buildings in period 2011/12 - 2014/15 and values of the average outside temperatures into formula (3). As explained in Chapter 3.1, these values amounted to 2,375,421 kWh and 7.1 °C, respectively. Therefore, the common coefficient of proportionality for the Clinic before reconstruction amounts to: $ABEFORE = 159,424 \text{ kWh/}^\circ\text{C}$.

The common coefficient of proportionality for all buildings of the Clinic before reconstruction can be determined using equation (3) and values defined in Chapter 3.3. of this paper – consumed final energy (1,076,361 kWh) and the average outside temperature in heating season 2017/2018 (7.31 °C). Therefore, the common coefficient of proportionality for the Clinic after reconstruction amounts to: $AAFTER = 73,272 \text{ kWh/}^\circ\text{C}$.

The constant of proportionality in formula (3) has a clear physical meaning. Namely, it represents the additional amount of final energy that needs to be consumed for maintaining of the required temperature of the building during a heating season in case that the outside temperature is by 1 °C lower than the projected value prescribed in the Rulebook on energy efficiency of buildings (Reference [6]).

4.2. Adjustment of electricity consumed for purposes of lighting

Direct comparison of realised consumption of electricity for lighting before and after reconstruction would not lead to a relevant conclusion due to significant differences in the total light flux achieved in the Clinic before and after reconstruction. In other words, illumination had not been at the prescribed level for health-care institutions before reconstruction and after reconstruction that level was achieved. Therefore, it is necessary to adjust electricity consumption in the Clinic before reconstruction in accordance with the illumination level achieved after reconstruction. Practically, this adjustment helps us determine the amount of electricity that would be necessary for the old lighting system to maintain the same illumination level as the new one.

The applied method of adjustment assumes that the consumed electricity for illumination by one lighting system is directly proportional to the achieved light flux:

$$EE_j = B_j \cdot F_j \quad (4)$$

where:

- EE_j – electricity consumed for lighting in structure "j",
- B_j – constant of proportionality for structure "j",
- F_j – total light flux achieved in structure "j" with the observed lighting system.

Constants of proportionality of both buildings before and after reconstruction is possible to determine by inserting values of average annual consumed electricity for lighting of buildings and values of the achieved light flux into formula (4). As explained in Chapter 3.2, before reconstruction these values amounted to 168,930 kWh and 2,646,739 lm. Therefore, the constant of proportionality before reconstruction amounted to $BBEFORE = 0.064 \text{ kWh/lm}$. Although for purposes of adjustment of electricity consumption it is not necessary to determine the values of proportionality constants, it is interesting to calculate it, which is easily done using the total electricity consumption and total light flux after reconstruction defined in Chapter 3.4 of this paper (145,039 kWh and 3,509,626 lm, respectively). Accordingly, the constant of proportionality after reconstruction of the lighting system amounts to: $BAFTER = 0.041 \text{ kWh/lm}$.

5. Energy, environmental and financial effects of reconstruction of the Clinic

5.1. Achieved annual savings in final energy consumption

Adjusted values of final energy consumed for heating of the large and the Clinic before and after reconstruction have been calculated by inserting the value of proportionality coefficients determined in Chapter 4.1 and the prescribed projected temperatures into formula (3):

$$W_{\text{fgBEFORE}} = 159,424 * (22 - 5.6) = 2,614,557 \text{ kWh}$$

$$W_{\text{fgAFTER}} = 73,272 * (22 - 5.6) = 1,201,655 \text{ kWh}$$

Accordingly, annual savings of final energy necessary for heating and ventilation of the Clinic achieved after reconstruction amounts to 1,412,902 kWh i.e. 54.0% less than the adjusted consumption for the same purpose before reconstruction. These final energy savings represent total savings achieved because of improvement of building envelopes but also because of general improvement of the heating system, especially by introduction of thermostatic valves, replacement of the heating pipeline and installation of a smart pump in the boiler room.

It is interesting to notice that savings of usable energy for heating amounts to 51%. Difference between savings of final and usable energy of 3% (54%-51%) represents contribution of heating system improvement to reduction of final energy consumption for purposes of heating and ventilation in the Clinic.

Final energy consumption for domestic water heating and for technological processes in the kitchen and the laundry room before reconstruction has been calculated in Chapter 3.1 and it amounts to 1,640,000 kWh per annum, while final energy consumption for same purposes after reconstruction has been calculated in Chapter 3.3 (1,270,453 kWh per annum). Total annual savings in final energy required for heating of domestic water and production of steam for kitchen and laundry after reconstruction amounts to 369,547 kWh i.e. 22.5% less than final energy consumption for same purposes before reconstruction. Namely, domestic hot water and water for heating are prepared in the same central heating system and the same boilers. However, they are transported independently. Such high savings have been achieved due to a catastrophic condition of the domestic hot water pipeline before reconstruction. The pipes were broken and hot water was flowing out of them under pressure into the surrounding ground. In other words, savings achieved due to the system for domestic hot water preparation and steam production have not been achieved only because of reduction of heat losses caused by a poor insulation of the domestic hot water pipeline, but also because of losses of actual water by leakage in some sections of the pipeline. Therefore, contribution of the system for preparation and distribution of sanitary hot water to overall final energy savings for this purpose is much higher than contribution of the system for preparation and distribution of hot water used for heating.

Adjusted value of annual amount of electricity consumed for lighting before reconstruction is calculated by inserting of an adequate constant of proportionality and the required light flux into equation (4):

$$EE_{\text{sop}} = 0.064 * 3,509,626 = 224,005 \text{ kWh}$$

In other words, the above value represents the annual amount of electricity that would be consumed in order to achieve the prescribed level of illumination with the old lighting system. Of course, this value is hypothetical and it would be applicable only if some additional lamps with the same characteristics as in the old lighting system would be installed in the Clinic for purpose of achieving the prescribed illumination level.

Adjusted value of annual amount of electricity consumed for lighting the Clinic after reconstruction is equal to the value calculated in Chapter 3.4 (145,039 kWh). In this case no adjustment is necessary since the new lighting system provides the necessary light flux.

Therefore, total adjusted annual amount of electricity consumed for lighting of the Clinic after reconstruction amounts to 78,966 kWh i.e. 35.3% less than the adjusted electricity consumption for the same purpose before reconstruction.

Consumption of electricity for purposes other than lighting and additional heating may be determined using the recorded value of total annual average electricity consumption before reconstruction (Table 3) and total annual electricity consumption for lighting before reconstruction, that has been calculated in Chapter 3.2. This value amounts to 363,684 kWh (629,876 - 85,922 - 180,270 = 363,684). It is reasonable to assume that this value will remain unchanged after reconstruction since the implemented EE measures did not have a direct impact to consumption of other appliances (boilers, computers, refrigerators etc.). It is important to underline that the increase in electricity and heat consumption due to mechanical ventilation system operation will not be taken into account since this energy is being consumed for purposes of improvement of life and work conditions in the Clinic i.e. for providing of mandatory number of air changes per hour prescribed by the law. The purpose of this method is to primarily adjust consumption of final energy before and after reconstruction to the same operating and weather conditions and only after that to calculate the achieved savings. By introducing this assumption, it is possible to determine values of total adjusted annual final energy necessary for functioning of the Clinic as a sum of final energy required for heating, ventilation, domestic water heating, technological processes of the kitchen and the laundry room, lighting system, and other uses before and after reconstruction. According to results of previous calculations:

$$W_{\text{BEFORE}} = 2,614,557 + 1,640,000 + 224,005 + 363,684 = 4,842,246 \text{ kWh}$$

$$W_{\text{AFTER}} = 1,201,655 + 1,270,453 + 145,039 + 363,684 = 2,980,831 \text{ kWh}$$

Total annual savings of final energy necessary for operation of the Clinic after reconstruction amounts to 1,861,415 kWh i.e. 38.4% less than the adjusted consumption before reconstruction.

The following annual energy savings were achieved by implementation of EE measures in the Clinic:

1. Final energy for heating and ventilation: 1,412,902 kWh (54.0%);
2. Final energy for heating of domestic water and preparation of the steam for laundry and kitchen: 369,547 kWh (22.5%);
3. Final energy for lighting: 78,966 kWh (35.3%);
4. Total final energy for functioning of the Clinic: 1,861,415 kWh (38.4%).

5.2. Achieved annual reduction of CO₂ emission

In order to calculate achieved annual reduction of CO₂ emission due to implementation of energy efficiency measures, it is necessary to consider all types of energy carriers used and CO₂ factors for all of them. Table 10 contains CO₂ emission factors for all types of energy carriers used in the Clinic, final energy consumption before and after reconstruction and corresponding CO₂ emission.

Table 8 Annual reduction of CO₂ emission due to implementation of energy efficiency measures in the Clinic

Energy carrier	CO ₂ emission factor (kg/kWh)	Before reconstruction		After reconstruction		CO ₂ emission reduction (kg)
		Consumption (kWh)	Emission (kg)	Consumption (kWh)	Emission (kg)	
Fuel oil	0.279	4,254,557	1,187,021	2,472,109	689,718	497,303
Electricity	1.502	587,689	882,708	508,723	764,102	118,606
TOTAL	-	4,842,246	2,069,730	2,980,832	1,453,820	615,909

Total annual reduction of CO₂ emission due to implementation of energy efficiency measures in the Clinic amounts to 615,909 kg i.e. 29.8% less than the emission before reconstruction.

It should be noticed that value of the emission factor for electricity applied above is used in EU countries. This factor implies that the achieved savings in electricity consumption will be evenly transferred to all power plants that contribute to generation. In Serbia, this means that it is assumed that generation of thermal power plants would decrease by cca. 2/3 of this value due to savings in electricity consumption, while the remaining 1/3 will be reduced in hydro power plants. From the aspect of calculation, this assumption is on the safe side and therefore it is applied in practice. However, at least in case of Serbia, this assumption is not realistic since it is certain that consumption reduction will lead to reduction of generation in thermal power plants only, while generation of hydro power plants will remain unchanged. Therefore, the above-calculated CO₂ emission reduction is considered to be a conservative (minimal) value, while in practice it will certainly be higher.

5.3. Achieved annual financial savings through expenses for procurement of energy carriers

Achieved annual financial savings may be assessed based on market prices of energy carriers in Serbia. Current prices of energy carriers procured by the Clinic are: 4.94 c/kWh for fuel oil and 5.9 c/kWh for electricity. Therefore, total annual financial savings that the Clinic has achieved by implementation of EE measures amount to:

$$F = (1,782,449 * 4.94 + 78,966 * 5.9) / 100 = 92,712 \text{ €}$$

The above value represents 37.9% of total annual expenses for procurement of energy carriers before reconstruction, that would, assuming adjusted amounts of different energy carriers, amount to 245,013 EUR. This reduction is certainly a significant one. However, in comparison to total investment costs for reconstruction of the Clinic (2.164.231 EUR), achieved financial savings are proportionally small. Simple payback period of the investment from energy savings only is very long: cca. 23.3 years.

6. Energy, environmental and financial effects of reconstruction of the Clinic

Based on the energy audit of the Clinic "Dr Laza Lazarević" in Padinska Skela, after a detailed analysis of conditions before reconstruction including characteristics of all elements of building envelopes, heating system, lighting system, electrical, sewage and water supply installations, a proposal was given of measures for sustainable improvement of energy efficiency of buildings. The proposed and implemented measures have been described in Chapters 2.1, 2.2. and 2.3. of this paper. However, the results of the energy audit implied that, beside the listed measures, it was also necessary to replace old electrical and water supply installations during the reconstruction. Implementation of measures described in Chapter 2.4. was suggested in order to ensure sustainability of implemented direct energy efficiency measures (to evade cracking of water supply pipeline and damage to the newly reconstructed walls and eliminate danger of fire as a consequence of poor electrical installations). Additional motivation for implementation of these measures came from the fact that the buildings are used by patients and the personnel of the Clinic who are in danger by using the old electrical installations daily.

Implementation of the above measures increased energy efficiency in buildings of the Clinic improved energy efficiency, reduced CO₂ emission, reduced annual expenses for energy carriers and improved safety. The analysis of the final energy consumption before and after implementation of EE measures in buildings of the Clinic gave the following results:

- Final energy consumption in buildings of the Clinic before implementation of EE measures amounted to 4,842,247 kWh/year. After implementation of EE measures, final energy consumption was reduced to 2,980,832 kWh/year i.e. by 38.4%;
- Annual CO₂ emission due to consumption of different energy carriers in the Clinic before reconstruction amounted to 2,070 t. After implementation of EE measures, it amounts to 1,454 t. It was reduced by 29.8%;
- Costs of necessary energy carriers before reconstruction amounted to cca. 245,013 thousand EUR, while after reconstruction these costs were reduced to 152,232 thousand EUR i.e. by 37.9%.

The results of the analysis presented in this paper are considered as clear evidence that the implemented reconstruction of Clinic “Dr Laza Lazarević” was completely justified in terms of savings in final energy consumption and CO₂ emission reduction. The achieved financial savings are also considerable. However, the simple payback time from the achieved energy savings only is very long: over 23 years. All of the above lead us to conclusion that energy and corresponding financial savings should not be the only or the most important reason for building reconstruction.

It is interesting to compare the above results with results presented in Reference [7] that relate to previously achieved savings through reconstruction of Elementary School “Olga Petrov”. The EE rehabilitation of the school was done during 2016 as a part of the same project as EE rehabilitation of the hospital and was also entirely financed by the Government of the Swiss Confederation. Final energy savings, CO₂ emission reduction and financial benefits achieved in the school amount to 31%, 41.5% and 17.7%, respectively. A higher percentage of final energy savings in the hospital than in the school (38.4% comparing to 31%), despite much bigger influence of the base energy consumption, is a result of replacement of windows in all buildings of the hospital (that had not been done in the school!) and generally of a lower level of EE in the hospital prior to EE rehabilitation. The situation is opposite in regard with CO₂ emission reduction (29.8% in the hospital comparing to 41.5% in the school) due to giving up of the use of coal in the school, which is the energy carrier that was not used in the hospital even before EE rehabilitation. However, the same reason makes an opposite difference in financial savings (37.9% in the hospital comparing to 17.7% in the school), since coal is, by far, the cheapest energy carrier in Serbia. In general, final energy savings, CO₂ emission reduction and financial benefits achieved in the school and hospital through EE rehabilitation of buildings are significant and quite consistent to each other.

7. References

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