Energy efficiency in complex buildings

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Abstract. Thermal energy performance of a certain building refers to the process of modelling the energy transfer between the building and its surroundings. The objective of the present work was to analyze the energy performances of complex buildings in terms of energy efficiency. Healthcare buildings are a typical example of complex objects, both from a construction and from a thermo-technical aspect, since they usually need heat and cold generation and distribution systems and facilities. For the purpose of the present analysis, a complex consisting of 16 hospital buildings has been evaluated from the energy efficiency viewpoint. Numerical simulation has been conducted to identify the baseline energy consumption of the considered healthcare buildings. The data have been further processed for analysis and comparison of baseline scenario with the scenario for energy efficient renovated buildings. The results from the analysis show that energy efficient complex healthcare buildings may reach operation energy savings up to 50% compared to baseline situation where the buildings are operating with inefficient heating and electrical systems. The investments simple payback period of the proposed energy efficiency measures is between 5-6 years. Implementation of renewable energy system for sanitary hot water preparation, might address issues related to energy security, i.e. dependency on the energy imports by reducing expenditures on energy, as well as might reduce the consequent environmental impact. The results of the energy efficiency measures implementation in the considered healthcare buildings show significant improvements, resulting with lower energy cost for the buildings, reduction of fossil fuels use and reduction of CO\textsubscript{2} emissions up to 45%.

Key words: complex buildings, hospital, energy efficiency, renewable energy, emission reduction

1. Introduction

Energy efficiency in general means using less energy to produce the same amount / quantity of products or to provide the same services. Due to the limited energy resources, their price and the significant environmental impact of the energy conversion processes the efficient use of energy is a matter of general interest in the world. Better energy efficiency helps achieving cleaner environment, higher living standard, more reliable energy supply and more competitive businesses.

Buildings within different sectors, such as residential, commercial, public etc., are major consumers of energy throughout their lifecycle [1]. Energy savings in buildings have gained a lot of attention in recent years, since the buildings sector is a major energy consumer in many countries. The total energy consumption in European building sector has been estimated at approximately 40% of primary energy usage [2]. A part of it, that is demanded for heating, accounts for over 70% [3]. Since the energy consumption in buildings represents large share of total energy use, as such, this sector possesses huge energy saving potential. This entails renovating the existing building stock, along with intensified efforts in energy efficiency and renewable energy, supported by decarbonized electricity and district heating [1]. A significant part of the energy consumption in the buildings can be attributed to heating, ventilation and air conditioning (HVAC) systems, which plays an important role in maintaining acceptable thermal and indoor air quality conditions. For this reason, improving energy efficiency in buildings is today a primary objective for the building industry, as well as for the society in general.

Due to the limited energy resources, their price and the significant environmental impact of the energy conversion processes, the efficient use of energy is a matter of general interest in the world. Enhanced energy efficiency helps achieving cleaner environment, higher living standard, more reliable energy supply and more competitive businesses [4].

The European Commission has warned about the negative impact on air quality from the use of coal (lignite), as well as hot-water boilers and stoves with poor emission standards for heating, as healthier solutions are available,
easily accessible and more efficient and even cheaper in the long run [5]. Important role in the tendency for energy efficiency enhancement and reduction of the environmental impact plays optimisation of the heating systems in urban areas [6, 7]. Advanced modelling and simulation tools are available for an analysis of building energy performances under various conditions [8].

In the most of the buildings in developing countries energy has been used in non-efficient way, either by fire-wood combustion in low quality stoves for heating or by consuming electrical energy produced in thermal power plants, usually burning fossil fuels (coal and lignite), with all the previously mentioned negative consequences. In addition to the global impact on the environment, the operation of thermal plants on fossil fuels is also associated with significant local pollution. Together with other factors, such as traffic, the rapid rise of urban areas, etc., this is one of the reasons for serious consequences for the health of the population, state of the environment and the economy of the region [9].

The aim of this paper is to demonstrate the power of the energy efficiency improvement in the building sector, with particular emphasize on complex hospital buildings, where, as it has been shown, the implementation of energy efficiency measures can significantly cut the annual cost for heating and cooling, with consequent reduction of the negative environmental impact. Furthermore, implementation of energy efficiency measures will decrease the fossil fuel use for heating the public buildings, as well will help meeting country’s energy efficiency and environmental targets.

2. Methodology

Hospital and health-care buildings, in general, represent complex buildings, which need permanent reliable supply of energy for heating, cooling, air-conditioning and other purposes.

2.1. Brief presentation of the considered buildings

In the present case, the hospital buildings, which belong to the Prishtina University Clinical Centre, use electrical energy and thermal energy provided from public utilities, while a small portion of cooling energy is produced locally. For the purpose of the analysis 16 hospital buildings have been evaluated to assess the actual situation of energy efficiency and energy saving potential (Table 1.) [10].

| Hospital buildings | Year of construction | Heated Surface (m²) |
|--------------------|----------------------|---------------------|
| Pulmo- and Dermatology clinic | 1980 | 3,286.6 |
| Infectious disease Clinic | 1980 | 6,496.0 |
| Institutes Building | 1978 | 3,390.0 |
| Orthopedic clinic | 1980 | 3,198.0 |
| Neurology Clinic | 1985 | 2,560.0 |
| Ortho-prosthetic clinic | 1974 | 1,122.0 |
| Psychiatric Clinic | 1985 | 2,591.0 |
| Public Health Institute | 1964 | 4,422.5 |
| Dentistry Faculty | 1975 | 4,563.1 |
| Clinic Center Technical | 1970 | 1,399.2 |
| Gynecological Clinic | 1980 | 20,460.3 |
| Emergency Clinic | 1970 | 6,701.5 |
| ORL Clinic | 1970 | 11,561.3 |
| Medical Faculty | 1969 | 1,720.0 |
| Surgery Clinic | 1957 | 10,702.0 |
| Internal Clinic | 1970 | 5,776.0 |
| **Total** | | **89,949.5** |

As it can be seen, the most of the buildings have been constructed in the period from 1970 to 1980 and some are even older. The energy efficiency performances of these buildings are quite low, stemming from the uninsulated building envelopes, old and inefficient doors and windows, as well as inefficient heating and lighting systems. Since the buildings are operating 24 hours a day, offering medical care for the citizens, such an extent of activities leads to a big energy consumption, with low energy efficiency, low thermal comfort and low indoor air quality. Therefore, they represent a typical example of why energy efficiency improvement measures should be taken into account in order to reduce energy consumption and reduce emissions with local and global environmental impacts, and to improve the thermal comfort and quality of air inside the buildings.
2.2. Description of existing energy supply situation on hospital complex buildings

The hospital building are supplied with electrical energy from public utility company KEK. The electricity sector of Kosovo relies on coal-fired power plants (97%), with efficiency of energy conversion which is around 32%, which are considered as one of the main environmental pollution sources [10,11]. Energy for space heating is supplied by the District Heating Company “Termokos”, which is located in the vicinity of the hospital buildings. By 2014, the central heating system plants operated on heavy fuel oil. In 2014, the project for implementation of a cogeneration system in TPP Kosovo B has been completed, and since then the heating system of Termokos has been supplied with hot water from the power plant through a 10.5 km pipeline. Heating generation plants of DHC Termokos are composed of the main heating plants with an overall installed capacity of 121.62 MWth and auxiliary heating plants, located in the University Clinical Centre, having installed capacity of 14 MWth. Upon the connection of the thermal energy extraction station in unit TPP Kosovo B1, the installed capacity of co-generation of 140 MWth was added to the previous capacity of DHC Termokos heating plants (Table 2) [10].

Table 2. Technical data of the district heating system [10]

| Enterprise               | Installed Capacity | Operational Capacity | Distribution network |
|--------------------------|--------------------|----------------------|----------------------|
| (City-Prishtina)         | [MWth]             | [MWth]               | Network length [km]  |
| HOB-(HFO)                | 2x58=116           | 2x58=116             | 36.5                 |
| HOB-hospital (light oil) | 2x7 = 14           | 2x7 = 14             | 347                  |
| HOB-F.K                  | 2x 0.81=1.62       |                      | 0                    |
| HOB-internal             | 1x4=4              | 1x4=4                | 140                  |
| Cogeneration             | 2x70=140           | 2x70=140             |                      |

Sanitary hot water (SHW) is produced locally, within SHW plant consisting of 2x2500 kW hot water boilers Vitomax 200-HW and one steam boiler Vitomax 200 HS with capacity for steam production of 2500 kg/h. Ten hospital buildings are equipped with SHW compact stations and automatic control devices for monitoring and control of SHW consumption, while 2 buildings are equipped with steam/water compact stations.

Air conditioning is carried out locally, in the hospital buildings, using air conditioning units and chillers to provide cold water. The capacity of the air conditioning systems varies from building to building.

2.3. Methodology for evaluating energy efficiency in complex buildings

Analysis of energy consumption of hospital buildings - In order to assess the energy consumption of the buildings the energy audit has been carried out in more than 12 buildings, while for the rest of the buildings the energy data’s has been collected from the hospital staff. As a basis for the energy audits, the EC directives EPBD (energy performance of the buildings Directive) 2002/91/EC and 2010/31/EU have been used [12]. During the energy audits, a baseline energy performance level of the surveyed buildings has been identified and energy efficiency measures have been proposed to reduce energy consumption and emissions. Additionally, the identified measures improve thermal comfort, indoor air quality, and reduce maintenance and operations problems in the building.

The energy audit pointed out to the main energy consumers and provided a detailed analysis of the way of energy usage, the savings that could be made and the costs of achieving these savings. The energy audit report provides an estimate of the savings, costs and financial performance indicators. The key elements that are studied during this process are: building façade, roof / ceiling, windows, heating system, electrical installations and sanitary hot water system.

Calculation methods for energy efficiency measures - Energy losses through building envelope are calculated according to EN ISO 13790 - Calculation of energy use for space heating and cooling, with minor simplifications related to the heat gains [11,12]. In general, the thermal calculations have been conducted in accordance to the recommendations and directions given in [13-17]. The heating load is calculated according to:

\[ Q_{\text{heat load}} = Q_{\text{tr}} + Q_{\text{ve}} - \eta_{\text{hp}} (Q_{\text{int}} + Q_{\text{sol}}) \] [kWh]

Transmission losses are obtained by multiplying the U-value of each element - external walls, windows and exterior doors and the considered element area. Ventilation losses take into consideration two types of losses, infiltration losses and window opening losses. Solar gains are calculated using data on solar irradiation in the region. The solar gain factor was simplified in order to obtain results in an easier way. Internal gains are included in the calculation according to the general recommendations, by taking a specific value of heat released by human and equipment during the heating season, assuming an average number of people present in the premises. The calculated overall heating load was then multiplied by a standard heating correction factor in order to account for
intermittent heating regime.

The ventilation system losses (where applicable) are calculated by determining the ventilation design flow(s) and heat recovery rate.

The losses at the heat source and the distribution system are considered through observation of the boiler plants type, age, actual technical condition and operation practices, distribution system condition and regulation system efficiency (where applicable). In each case, the boiler seasonal efficiency has been calculated on a basis of its average load, fuel type used and according to the outside temperature.

Sanitary hot water (SHW) preparation is also taken into account by applying benchmark consumption data according to the number of occupants and type of building. The average consumption and the peak consumption of SHW have been calculated in order to obtain relevant values for later implementation of a solar thermal system or SHW system refurbishment (where applicable). It should be noted that systems which do not have the necessary infrastructure, i.e. buildings which do not have a pre-installed central SHW preparation, were not considered for a solar thermal installation.

The calculation of electricity consumption for lighting and electrical equipment is based on listing all lights and devices that use electricity, determining the power of each device and then multiplying by estimated working time.

**Calculation method for the source heat load (boiler size)** - The heating load for the existing situation and the situation after refurbishment was calculated according to EN 12831, by taking into account transmission losses, ventilation (where exists) and infiltration losses.

\[
\theta_{HL} = \theta_{tr} + \theta_{vent} + \theta_{inf}
\]

The transmission part of the equation includes the characteristics of all envelope parts multiplied by the difference between internal design temperature (for most of the rooms in the buildings \( t_i = 20^\circ\text{C} \)) and external design temperature (for the city of Prishtina \( t_e = -18^\circ\text{C} \)). Infiltration losses are calculated by using the number of air exchanges in the building, the building volume and the difference between internal design temperature and external design temperature. Ventilation losses take into account the recovery rate of the mechanical ventilation system along with the air flow of the ventilation system.

Constant heat balance equation with constant (i.e. time independent) view:

\[
L_T(t_i - t_e) + L_v(t_i - t_e) = \theta_s + \theta_l + \theta_h
\]

Where the temperature difference \((t_i - t_e)\) depends on the manner of the building use and climate and, as such, it is difficult to change. Therefore, since the transmission heat loss depends on \(U\)-values, areas and the location of thermal bridges, this was one of the main focuses of the efficiency analysis. Reduction of transmission heat losses is possible with necessary measures for minimizing the building envelope conductance.

In general, the reduction of the building envelope conductance is based on the expression given below:

\[
L_T = \sum_i U_i A_i + \sum_j \partial_j l_j + \sum_k X_k
\]

Energy efficiency measures for reduction of \(U\) values and reduction of areas \(A_i\) by minimising the area of the building envelope, i.e. increasing the compactness of the building were evaluated, while reduction of correction factors \(\partial_j l_j + \sum_k X_k\) in view of thermal bridges depends on design of building details.

Apart of the building envelope insulation (outside walls, roof) and the replacement of old windows and doors, the main recommendations for the energy efficiency improvement are related to the heating system: installing new TR
valves, replacing damaged or non-operating radiators, installation of new VFR circulation pumps, insulation of the equipment in the substations etc. [18-20].

Calculation method for renewable energy applications - Calculation procedures have been set up in order to evaluate the possibility of implementation of renewable energy resources. The focus of these calculations is evaluation of the feasibility and viability of solar thermal systems. The basis for calculation of a solar thermal system is sanitary hot water consumption. The calculation takes into account the monthly solar irradiation, monthly distribution of SHW consumption and the proposed solar fraction for the summer period (Table 3).

| Month | Office building | Clinic - hospital | Public building | School - Faculty | Student accommodation |
|-------|----------------|------------------|----------------|------------------|----------------------|
| 1     | 9.42%          | 8.33%            | 9.16%          | 12.16%           | 10.97%               |
| 2     | 9.42%          | 8.33%            | 9.06%          | 12.16%           | 10.97%               |
| 3     | 9.42%          | 8.33%            | 8.69%          | 12.16%           | 10.97%               |
| 4     | 9.42%          | 8.33%            | 8.41%          | 12.16%           | 10.97%               |
| 5     | 7.08%          | 8.33%            | 7.29%          | 5.81%            | 10.97%               |
| 6     | 6.77%          | 8.33%            | 7.47%          | 3.23%            | 6.13%                |
| 7     | 6.37%          | 8.33%            | 7.38%          | 0.00%            | 0.00%                |
| 8     | 6.77%          | 8.33%            | 7.57%          | 0.00%            | 0.00%                |
| 9     | 7.08%          | 8.33%            | 8.32%          | 5.81%            | 6.13%                |
| 10    | 9.42%          | 8.33%            | 8.69%          | 12.16%           | 10.97%               |
| 11    | 9.42%          | 8.33%            | 8.88%          | 12.16%           | 10.97%               |
| 12    | 9.42%          | 8.33%            | 9.09%          | 12.16%           | 10.97%               |

Energy price basis and cash flow parameters for analysis - The Office of energy regulator has issued the prices for the incoming years that have been summarized in Table 4.

| Energy Source | Electrical | Diesel | Wood | Lignite | District heating | Raw wood | Wood pellets |
|---------------|------------|--------|------|---------|------------------|----------|--------------|
| Price [EUR/kWh] | 0.11 | 0.091 | 0.017 | 0.02 | 0.06 | 0.04 | 0.0377 |

A fuel escalation rate of 3% per annum for all fuel and electricity was agreed upon for this project (Table 5). A detailed cash flow analysis is performed for each efficiency project. The financial parameters that have been used in the calculation are given in Table 5.

Table 5. Parameters for cash flow analysis

| Parameters for cash flow | value |
|--------------------------|-------|
| Rate of inflation        | 3% constant |
| Start of project         | 2017 |
| Discount rate            | 10% |

3. Results and discussion

The collected data from the energy audit of the buildings have been processed using the RETScreen Clean Energy Project Analysis Software [21], as a powerful decision support tool for evaluation of energy conversion, savings, costs, emission reduction, financial viability and risk for various types of energy efficient and renewable energy technologies.

Using the collected and calculated data, a baseline scenario for complex hospital buildings is developed, on the basis of which it is possible to identify and determine the manner of energy use for heating, cooling, sanitary hot water, for operation of electrical devices and lighting. Further on, different scenarios have been evaluated to seek for feasible energy usage improvements, including the investment cost evaluation. Since the buildings sector is significant energy consumer, as such, it possesses large energy saving potential. In that frame, complex health-care buildings are some of the biggest energy consumers in the building sector. In the present case, the processed data indicate significant saving in energy consumption, as well as CO₂ reduction potential (Table 6).
### Table 6. Energy efficiency analysis results

| Name of the Building               | Total energy consumption | Specific energy consumption | Investment costs | Net savings | Period PBP | CO2 reduc. | Spec. invest. |
|------------------------------------|--------------------------|----------------------------|-----------------|-------------|------------|------------|---------------|
|                                    | Before [kWh/a]          | After [kWh/a]              | Savings [kWh/a]| Before [kWh/m².a] | After [kWh/m².a] | Savings [kWh/m².a] | [€] | [€/year] | [y] | [t/year] | [€/m²] |
| Pulmo & Dermatology clinic         | 716,451.20              | 340,721.70                 | 375,729.50      | 217.99       | 103.67     | 114.32     | 151,478.00    | 22,975.20 | 6.6 | 133.38   | 46.09  |
| Infectious disease Clinic          | 660,579.77              | 327,763.99                 | 332,815.79      | 101.69       | 50.46      | 51.23      | 168,528.80    | 25,975.50 | 6.5 | 118.15   | 25.94  |
| Institutes Building                | 1,253,960.60            | 535,870.00                 | 718,090.60      | 284.53       | 112.64     | 171.83     | 407,436.00    | 66,538.20 | 6.1 | 254.92   | 120.19 |
| Orthopedic clinic                  | 909,929.97              | 360,224.69                 | 549,705.29      | 296.12       | 72.72      | 223.41     | 120,975.00    | 35,489.50 | 7.1 | 195.15   | 78.45  |
| Neurology Clinic                   | 1,188,966.47            | 511,703.26                 | 677,263.21      | 464.44       | 199.88     | 264.56     | 246,875.00    | 38,252.60 | 6   | 88.98    | 96.44  |
| Orthoprothetic clinic              | 332,250.90              | 81,589.00                  | 250,661.90      | 257.15       | 57.11      | 200.44     | 331,191.80    | 43,536.20 | 7.6 | 349.22   | 150.5  |
| Psychiatric Clinic                 | 1,304,371.20            | 252,564.40                 | 884,691.50      | 308.49       | 137.92     | 170.56     | 331,191.80    | 43,536.20 | 7.6 | 314.07   | 74.89  |
| Public Health Institute            | 1,137,255.90            | 252,564.40                 | 884,691.50      | 308.49       | 137.92     | 170.56     | 331,191.80    | 43,536.20 | 7.6 | 314.07   | 74.89  |
| Dentistry Faculty                  | 1,068,677.50            | 455,832.00                 | 612,845.50      | 234.2        | 99.9       | 134.3      | 204,460.00    | 40,891.00 | 5   | 217.56   | 44.81  |
| Clinic Center Technical Service    | 1,100,642.60            | 190,949.60                 | 909,693.00      | 786.62       | 123.76     | 379.67     | 389,936.70    | 51,152.70 | 7.6 | 349.22   | 150.5  |
| Gynecological Clinic               | 6,311,736.97            | 2,821,949.64               | 3,489,787.3     | 308.49       | 137.92     | 170.56     | 967,826.00    | 223,654.00 | 4.3 | 1,238.8  | 47.3   |
| Emergency Clinic                   | 1,848,975.37            | 835,800.04                 | 1,013,175.3     | 275.9        | 124.72     | 151.19     | 332,485.00    | 55,187.00 | 6   | 359.68   | 49.61  |
| ORL Clinic                         | 2,661,729.33            | 1,580,606.17               | 1,081,123.1     | 230.23       | 136.72     | 93.51      | 386,501.00    | 73,557.00 | 5.3 | 383.8    | 33.43  |
| Medical Faculty                    | 727,014.30              | 443,575.22                 | 283,439.08      | 422.68       | 257.89     | 164.79     | 192,857.60    | 34,526.20 | 5.6 | 100.62   | 112.13 |
| Surgery Clinic                     | 2,598,324.00            | 1,919,004.00               | 679,320.00      | 242.79       | 179.31     | 63.48      | 384,592.00    | 78,580.00 | 4.9 | 241.16   | 35.94  |
| Internal Clinic                    | 2,254,510.00            | 1,482,190.00               | 772,320.00      | 543.26       | 467.57     | 75.7       | 403,330.00    | 139,750.00 | 2.8 | 274.17   | 69.83  |
| **Totals**                         | **26,075,376**          | **12,460,996**             | **13,614,379**  | **346**       | **151**    | **195**    | **5,183,953** | **988,122** | **5.85** | **4,833** | **79.26** |
The total energy consumption before the implementation of energy efficiency measures is 26,075,376 kWh/a (Table 6), while after the implementation it drops to 12,460,996 kWh/a, so that the total savings for all 16 buildings is 13,614,379 kWh/a which is 52% saving (Fig. 1). The average annual specific CO₂ emissions reduction follows similar pattern as energy consumption, which means the reduction is 47% compared to the initial state (Fig. 2).

![Fig. 1. Potential energy savings](image1)

**Fig. 1.** Potential energy savings

![Fig. 2. CO₂ reduction potential](image2)

**Fig. 2.** CO₂ reduction potential

The analysis shows that the specific investments cost differs from building to building, starting from 25.94 €/m² up to 174.81 €/m², as shown in Fig. 3, which is an indication that in some buildings the feasibility of energy efficiency implementation measures is limited.

![Fig. 3. Specific energy efficiency measures investment cost €/m²](image3)

**Fig. 3.** Specific energy efficiency measures investment cost €/m²

The results of the conducted analysis show that besides the measures for energy efficiency, there is a huge potential for energy saving and emission reduction by using solar thermal systems for sanitary hot water.

From the calculations of the investment cost for energy efficiency measures in hospital complex buildings, a clear conclusion can be drawn that they are feasible, since energy savings are over 52% annually and the simple payback period is shorter than 6 years. Apart of this, the building stock will be renewed and the comfort for the occupants will be significantly improved.
Fig. 4. CO₂ reduction potential with investment on energy efficiency

The financial indicators of the project should help decision makers to decide on investment on implementation of energy efficiency measures. The corresponding financial indicators of the project are presented in Table 7 and Fig. 5, taking into account the lifetime of the project of 20 years, constant inflation rate at 3%, discount rate (minimum acceptable rate of return) of 10%.

Table 7. Calculated financial indicators

| Element                  | EE Measures |
|--------------------------|-------------|
| Investment cost          | 5,183,953.80 € |
| Annual Savings           | 988,122.50 € |

| Year | Investment | Benefit | Price | B-C | Discount | Benefits after discount rate | PBP |
|------|------------|---------|-------|-----|----------|-----------------------------|-----|
| 0    | 5,183,953.80 € | 0.00 € | 0     | -5,183,953.80 € | 1         | -5,183,953.80 € | -5,183,953.80 € |
| 1    | 988,122.50 €    | 0.03    | 1,017,766.18 € | 0.91 | 898,293.18 € | -4,285,660.62 € |
| 2    | 1,017,766.18 € | 0.03    | 1,048,299.16 € | 0.83 | 841,129.07 € | -3,444,531.55 € |
| 3    | 1,048,299.16 € | 0.03    | 1,079,748.14 € | 0.75 | 787,602.90 € | -2,656,928.87 € |
| 4    | 1,079,748.14 € | 0.03    | 1,112,140.58 € | 0.68 | 737,482.50 € | -1,919,446.37 € |
| 5    | 1,112,140.58 € | 0.03    | 1,145,504.80 € | 0.62 | 690,551.80 € | -1,228,894.57 € |
| 6    | 1,145,504.80 € | 0.03    | 1,179,869.94 € | 0.56 | 646,607.59 € | -582,286.97 € |
| 7    | 1,179,869.94 € | 0.03    | 1,215,266.04 € | 0.51 | 605,459.84 € | 23,172.86 € |
| 8    | 1,215,266.04 € | 0.03    | 1,251,724.02 € | 0.47 | 566,930.58 € | 590,103.44 € |
| 9    | 1,251,724.02 € | 0.03    | 1,289,275.74 € | 0.42 | 530,853.18 € | 1,120,956.62 € |
| 10   | 1,289,275.74 € | 0.03    | 1,327,954.01 € | 0.39 | 497,071.61 € | 1,618,028.23 € |
| 11   | 1,327,954.01 € | 0.03    | 1,367,792.63 € | 0.35 | 465,439.78 € | 2,083,468.09 € |
| 12   | 1,367,792.63 € | 0.03    | 1,408,826.41 € | 0.32 | 435,820.89 € | 2,519,288.89 € |
| 13   | 1,408,826.41 € | 0.03    | 1,451,091.20 € | 0.29 | 408,086.83 € | 2,927,375.72 € |
| 14   | 1,451,091.20 € | 0.03    | 1,494,623.94 € | 0.26 | 382,117.67 € | 3,309,493.39 € |
| 15   | 1,494,623.94 € | 0.03    | 1,539,462.66 € | 0.24 | 357,801.09 € | 3,667,294.47 € |
| 16   | 1,539,462.66 € | 0.03    | 1,585,646.54 € | 0.22 | 335,031.93 € | 4,002,326.40 € |
| 17   | 1,585,646.54 € | 0.03    | 1,633,215.93 € | 0.2 | 313,711.71 € | 4,316,038.12 € |
| 18   | 1,633,215.93 € | 0.03    | 1,682,212.41 € | 0.18 | 293,748.24 € | 4,609,786.36 € |
| 19   | 1,682,212.41 € | 0.03    | 1,732,678.78 € | 0.16 | 275,055.17 € | 4,884,841.53 € |
| 20   | 1,732,678.78 € | 0.03    | 1,784,659.15 € | 0.15 | 257,551.66 € | 5,142,393.19 € |

5183953.8 0.00 € 0 5142393.2
Fig. 5. Financial appraisal NPV and payback period

The savings against investment ratio (SIR) is 1.99, the internal rate of return (IRR) is 10.3% and the net present value (NPV) is 86,549.45 €.

The financial indicators show that the investment on EE measures is feasible since the NPV value is positive even after 20 years of the project lifetime. The IRR is above 10%, savings against investment ratio SIR > 1, which shows that the project makes more money than it costs and it shows project’s relative feasibility. The dynamic payback period taking into account inflation rate of 3% and depreciation of 10%, is 7.09 years (Table 8).

| Financial Indicators | Value       |
|----------------------|-------------|
| SIR                  | 1.99        |
| IRR                  | 10.30%      |
| NPV                  | 86,549.45 € |
| Project lifetime     | 20 years    |
| Dynamic Payback Period | 7.09 years |

Buildings energy rating is an indication of the energy performance of the building. It rates the building in categories from A to G, showing how efficient are the buildings in the energy use. The results of the average specific energy consumption presented in Fig. 6, based on Directive 2013/31/EU, show that complex hospital buildings in the Clinical Centre in Prishtina are categorized deeply in category G before the implementation of EE measures, while with implemented EE measures they have reached category F, quite near to E.
4. Conclusions

The healthcare buildings are an example of complex buildings, both from constructing and thermotechnical viewpoints, since they need systems for the production and distribution of heat and cold energy, as well as for covering other energy needs. Improvement of the energy efficiency in the buildings sector, especially in complex hospital buildings, will reduce the demand for electricity from power plants, which have positive impact in reducing local pollution, as well as CO₂ emission. For the purpose of this analysis, from the point of view of energy efficiency, a complex of 16 hospital buildings was evaluated, based on the results of detailed energy audit. Numerical simulation has been conducted to identify the baseline energy consumption of the buildings and the data have been further processed for analysis and comparison of baseline scenario with the scenario for energy efficient renovated buildings.

The main recommendations for the energy efficiency improvements are: insulation of the building envelope (outside walls and roof), replacement of old windows and doors, technical improvements of the heating system and renovation of the lighting system. Implementation of EE measures will ensure reduction of energy use and energy cost for the buildings, increase the thermal comfort for the building users, reduction of greenhouse gases, improve the work performance for the medical staff and will enable renewed building stock. Furthermore, introducing solar energy systems for sanitary hot water have additional benefits by replacing fossil fuel for this purpose.

Having in consideration energy calculations before and after the implementation of the energy efficiency measures and RES and achieved results, it can be concluded that in hospital buildings it is necessary to invest in such measures in order to increase the thermal comfort of the buildings and to reduce the operation cost. Energy savings after the implementation of EE measures can exceed 50%. The CO₂ emissions can be reduced by almost 50%, while reduction of fossil fuels use for heating in the considered public buildings in this case is 11.74 toe. Financial indicators show that the investment in EE measures is feasible, since the NPV value is positive even after 20 years of project lifetime. The IRR is above 10%, the savings against investment ratio SIR >1, and the dynamic payback period taking into account inflation ratio 3% and depreciation 10%, is 7.1 years.

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