



## **New solutions to reduce greenhouse gas emissions through energy efficiency of buildings of special importance – Hospitals**

Marcela Prada, Ioana Francesca Prada, Monica Cristea, Daniela Elena Popescu, Constantin Bungău, Aleya Lotfi, Constantin C. Bungău

### **► To cite this version:**

Marcela Prada, Ioana Francesca Prada, Monica Cristea, Daniela Elena Popescu, Constantin Bungău, et al.. New solutions to reduce greenhouse gas emissions through energy efficiency of buildings of special importance – Hospitals. Science of the Total Environment, 2020, 718, pp.137446. 10.1016/j.scitotenv.2020.137446 . hal-02490282

**HAL Id: hal-02490282**

**<https://hal.science/hal-02490282v1>**

Submitted on 7 Mar 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

**New solutions to reduce greenhouse gas emissions through energy efficiency of  
buildings of special importance – hospitals**

**Marcela Prada<sup>1</sup>, Ioana Francesca Prada<sup>2</sup>, Monica Cristea<sup>2</sup>, Popescu Daniela<sup>3</sup>,  
Constantin Bungău<sup>4</sup>, Lotfi Aleya<sup>\*5</sup>, Constantin C. Bungău<sup>1,2</sup>**

<sup>1</sup>Department of Civil Engineering and Architecture, Faculty of Civil Engineering,  
Cadastre and Architecture, University of Oradea, Oradea, Romania.  
mfprada29@gmail.com (M.P.); constantin.bungau@csud.uoradea.ro (C.C.B.);

<sup>2</sup>Doctoral School, Technical University of Cluj-Napoca, Cluj-Napoca, Romania.  
pradaifrancesca@gmail.com (I.F.P.); monicacristeaa@gmail.com (M.C.);

<sup>3</sup>Department of Computers and Information Technology, Faculty of Electrical Engineering  
and Information Technology, University of Oradea, Oradea, Romania;  
depopescu2012@gmail.com (P.D.E.);

<sup>4</sup>Department of Engineering and Management, Faculty of Management and  
Technological Engineering, University of Oradea, Oradea 410087, Romania;  
bungau@uoradea.ro (C.B.)

<sup>5</sup>Chrono-environnement CNRS 6249, Université de Franche-Comté, Besançon, France;

\*Corresponding author: lotfi.aleya@univ-fcomte.fr

Phone: + 33 (0) 3 81 66 66 66

Fax: + 33 (0) 3 81 66 57 97

## **Abstract**

Saving energy has an important role in the concerted actions to protect the planet from the effects of global warming, particularly the energy consumed by the existing buildings (with various energy consuming functions, inefficient energy), by implementing environmentally friendly solutions. The present paper emphasizes the need to include elements to stimulate the renovation of the existing buildings and of their energy efficiency in the national strategies, these constructions being important energy consumers. The research started with two case studies (2 hospital buildings) dating from 70-80s, with the aim to be energy efficient and modern constructions in Eastern Europe. In the presented best practice model, significant reductions in greenhouse gas emissions, primary energy consumption along with the use of renewable energy have been achieved by transforming some energy-inefficient buildings into intelligent buildings. Thus, the authors propose a new stake: "70-70-70" for similar buildings.

**Keywords:** primary energy; greenhouse gas emissions (GHG); energy efficiency; renewable energy.

## 1. Introduction

Global warming is a real and serious issue for humanity in the fight for the protection and conservation of the environment, and even life itself. In the concerted action to protect the planet from the effects of this heating and climate changes, a relevant role is played by the energy saving. Due to high energy consumption buildings and construction sectors were proved to be among the major factors impacting the environment (Junnila and Horvath, 2003). Greenhouse gas emissions of buildings along with their energy consumption (operationl energy consumption) are threatening the environment as well as our economic and social future (Shoubi et al., 2015; Bribián et al., 2009).

Therefore, great, unexplored possibilities to optimize the costs related to energy consumption are offered by the building sector. Starting with 2020, in Europe, the standards nearly zero-energy building (NZEB) are required as compulsory. To meet these demands, the most difficult problem of the building sector in decreasing energy consumption is to optimize the restoration rate, as well as the quality and efficiency, given the fact that the present restauration rate is 1.2% each year (EC – CORDIS EU; Prada et al., 2016).

In both developed and many developing countries, significant quantities of fossil fuel energy are consumed in the health sector, even if there are no proper figures for many of the countries (Badulescu et al., 2019; Badulescu et al., 2020). Energy consumption in the health sector and the associated greenhouse gas emissions should be systematically evaluated and measured worldwide. However, some anecdotal evidence exists. In the US, about \$ 6.5 billion is spent in the health care sector per year, with hospitals being the second important energy consumers (GGHH, 2012). World health expenditures were US\$ 5.3 trillion in 2007, about 8-10% of global Gross Domestic Product or US\$ 639 per person each year (WHO, 2010).

Implementation of an energy efficiency and conservation program for existing buildings that reduces energy consumption by at least 10% in one year and continues to produce energy savings of 2% per year, can lead to 10% reduction every 5 years. New buildings should be designed to obtain the energy performance objectives of the building (a consumption of 320 kWh/sqm or less) (GGHH, 2012).

The present paper is focused on the existing buildings with hospital functions, energy-consuming, currently energy inefficient. At the same time, it is in line with the key objectives and EU policies adopted in 2014 through *“The 2030 climate and energy framework: 1). “At least 40% cuts in greenhouse gas emissions (from 1990 levels); 2). At least 32% share for renewable energy; 3). At least 32.5% improvement in energy efficiency”*.

The scheme facilitates the evolution to an economy with reduced carbon emissions and designs an energy model effective for health and environment – e.g. by diminishing air contamination (clim (EC): 2030). The work is based on two case studies (two large buildings from Oradea, Romania, dating from 1968-1989, with the function of hospitals) to which energy efficiency and modernization are performed, ensuring superior comfort of the ambient environment.

Within this context, reducing greenhouse gas emissions through providing new solutions will act against global warming. These new suggested solutions refer to the energy efficiency of hospital buildings (buildings of special importance), with an age of about 50 years, existing in a considerable number in the Eastern part of Europe. Moreover, since these solutions involve a significant amount of renewable energy resources, they are susceptible to become intelligent NZEB through an integrated design along with a judicious approach of constructions.

## **2. Materials and Methods**

The constructions on which the study is carried out are two large buildings, comparable in width, size and volume, having similar functions: the building of the Oradea Clinical County Hospital and the building of the Municipal Clinical Hospital “Dr. Gavril Curteanu”, both located in the city of Oradea, the northwestern part of Romania. The two hospital units serve in a city population of  $\cong 200,000$  inhabitants and in a county of 564, 000 inhabitants, also considering the existence of the medical tourism (Badulescu et al., 2014). The importance class of buildings is class I, according to (P 100, 2013): having essential functions, for which the integrity preservation during earthquakes is vital for the civil protection, such as: (a) Hospitals and other buildings in the health system, which are equipped with emergency / ambulance services and surgery units. The importance category is B, according to (H.G.R. 766, 1997): constructions of special importance (b). The city of Oradea is located at the intersection of the coordinates  $47^{\circ} 03' 05''$  north latitude and  $21^{\circ} 56' 25''$  east longitude, in the Crisurilor Plain (Western Plain). The greatest part of the relief is formed by the Crisului Meadow (average elevation  $\sim +125$  m from the Black Sea), subunit of the Crisurilor Plain, and to a lesser extent by the valleys tentacularly formed in the Northern Hills by the Paris, Umbrosu, Sotiteag, Salbatec streams and temporary pluvial ones. The area proposed for investment is located at a distance of 10, respectively 13 km from the Hungarian border.

The area is characterized by the following climatic particularities: climatic zone of summer temperature values, III  $T_e = +28^{\circ}\text{C}$  (exterior temperature); climatic zone of winter temperature values, II  $T_e = -15^{\circ}\text{C}$  (C107-2005). It is a zone of continental climate with

116 averages of 15.6°C high temperature per year and 5.5°C low temperature per year, the  
117 precipitation per year average being 603.2 mm (Bungau et al., 2019).

118 The buildings have a permanent occupation regime (24 hours a day, 7 days a week,  
119 throughout the whole year), while social activities are carried out - of medical  
120 assistance/medical services, that are of significant importance for the community. The  
121 objectives of the proposed investments are: reduction of the annual consumption of primary  
122 energy to  $\geq 40\%$  compared to the initial consumption; mitigation and adaptation to climate  
123 change by reducing CO<sub>2</sub> equivalent emissions, whose main effect is the global warming of  
124 the atmosphere, below the corresponding values set ( $< 27$  kg/sqm/year) (Order no. 2641,  
125 2017); specific annual consumption of primary energy below the corresponding values ( $< 97$   
126 kwh/sqm/year) (Order no 2641, 2017) implementation of environmentally friendly  
127 solutions; the use of environmentally friendly, sustainable, recyclable materials that do not  
128 support combustion, with thermosystem elements from the fire reaction class A1 and A2 -  
129 s1, d0; the use of passive technologies for the mechanical ventilation system with heat  
130 recovery, which also ensures cooling in the "free cooling" system; introducing alternative  
131 energy production systems from renewable energy sources; accessibility for persons with  
132 disabilities; equal opportunities; promoting the principle of sustainability and durability by  
133 implementing measures to improve the quality of the environment through the use of  
134 technical means to combat pollution and pollutant emissions.

135 The two buildings are included in the Regional Operational Program 2014-2020;  
136 Priority axis 3: Supporting the transition to a regime with low carbon emissions, Investment  
137 priority 3.1. Supporting energy efficiency, intelligent energy management and renewable

energy use in public infrastructures, including in public buildings and in the housing sector, Operation B - Public buildings, call code: ROP/97/3/1 for the 7 regions, title of appeal: POR/2016/3/3.1/B/1/7Regions (Cluster Zepher, 2017a, b).

The framing of both constructions is in the seismic risk class III (minimum performance requirements for taking over the seismic actions, respectively constructions that, under the effect of the design earthquake, may present structural degradations that do not significantly affect the structural safety, but for which non-structural degradations may be important (Cluster Zepher, 2017a,b); the buildings are characterized by a seismic coefficient (acceleration of the land for design)  $a_g=0.15$  g and the corner period  $T_c=0.7$  sec (P100, 2013).

Each of the two hospital units, whose energy performance requires improvement, is made up of two buildings (the H-hospital and the HP polyclinic) that are connected with each other and are considered as a single building in the evaluation of the overall construction performance, being interdependent. The parameters that characterize the two buildings are presented in **Table 1**. The interior spaces of the buildings of both hospital units have specific functions that serve both the hospital and the polyclinic.

### **2.1. Case study 1**

It analyzes the building of the Municipal Clinical Hospital "Dr. Gavril Curteanu " (Cluster Zepher, 2017a) (**Figure 1.a.**), having as holder/beneficiary the Regional Popular Council of Crisana/Oradea Health Section. The building comprises the Hospital body (H1) itself and the Polyclinic body (HP1) (Cluster Zepher, 2017a).

H1 is made up of 3 sections; the horizontal circulation between them is ensured by means of the longitudinal central corridor, this taking over the circulation from the 3



staircases. The useful spaces (salons, medical offices etc.) are arranged on both sides of the central corridor.

Vertical circulation is ensured through the staircase which is located at the right end of the building. Horizontal circulation is ensured through two traffic corridors, disposed on the central area, throughout the construction. Inside, between the longitudinal corridors, the space is provided with bathrooms and changing rooms and the marginal areas are provided with medical facilities. Geothermal water is inefficiently exploited, the used temperature gradient being reduced. The heating system does not allow any adjustment. The exterior joinery is thermally non-performant / inefficient.

## **2.2. Case study 2**

It analyzes the building of Oradea Clinical County Emergency Hospital (Cluster Zepher, 2017b). The building comprises the hospital body (H2) itself and the body of the polyclinic (HP2) (**Figure 1b**) (Proidea, 2019). The existing building of the Oradea Emergency Clinical Hospital was built within the investment scheme "700 beds Hospital and Oradea Polyclinic".

The vertical circulation is ensured by the two existing staircases at the ends of the slab and by the central staircase, located in the connection area between the two bodies, adjacent to the six elevators. For the horizontal circulation an internal central corridor was provided at each level; it ensures the connection between H2 and HP2 through the intermediate body, where a vertical circulation node is provided, as previously shown.

HP2 has a yard of light (10.30x10.35 m); thus, 4 wings of the building are developed, arranged around the yard of light, three of them having a width of 11.30 m and one with a width of 16.70 m. Later, at the ground floor level, in the area of the inner yard of light, there

was a fill extension, with the destination of Emergency Receiving Unit (E.R.U.). Then, at the terrace roof level, a metal platform was arranged, unloaded on the pillars of the structure, with the destination of a platform for helicopters' landing for medical interventions.

### 3. Results

Currently the two buildings are not enveloped, existing significant thermal bridges (**Figure 2a-c and Figure 3a-c**). The characteristic global thermal parameters that describe both initial buildings from the study compared with a reference building (construction with identical geometry and volume, but with the envelope elements corresponding to the minimum thermal resistance required by the current norms (C107/1-7/2005; Mc 001/1, 2006; Mc 001/2, 2006; Mc 001/3, 2006; Mc 001/4, 2009) are included in **Table 2**. The parameters found do not correspond to the current norms, since:  $G > G_{ref}$ ,  $R_{med} < R_{med-ref}$ .

After the energy certification of the initial buildings, the building in the case study 1 is classified in the energy class "C" (**Figure 4a.**), and the building in case study 2 is classified in energy class "D" (**Figure 4b**). The comparative highlighting of the energy consumption of the two constructions is presented in **Table 2**. These consumptions are inadequate (being very high) with the current norms, when talking about newly designed constructions or major renovations.

For the operation of both energy optimised hospital units, the amount of energy required / CO<sub>2</sub> emissions was calculated (**Table 3**), as well as the total annual specific energy consumption (**Table 4**), using the conversion factors of the final energy into primary energy, corresponding to each type of fuel (Mc 001/1, 2006); these values were highlighted in

comparison with the maximum values imposed by the current norms (Order no. 2641, 2017).

**Figure 5** presents these results, compared to the initial situation.

Taking into account the information mentioned in the description of the two case studies, corroborating the energy consumption of the buildings and reporting their annual consumption, the values highlighted in **Table 5** are obtained; **Table 6** reveals eloquent results for the specific annual level of greenhouse gases (tonnes of CO<sub>2</sub> equivalent).

**Table 7** shows the total amount of primary thermal and electrical energy, necessary for the operation of the initial buildings and of the energy optimized ones of the case studies 1 and 2, taking into account the conversion factors of the final energy into primary energy, corresponding to each type of fuel (Mc 001/1, 2006). The data obtained confirm the saving of primary thermal energy and electricity. The renewable energy sources proposed as the solutions of efficiency of the two buildings are presented in **Table 8**.

Analyzing the values of investments for the energy optimization of the buildings in the two case studies, it turns out that their recovery time was 11 years for the case study 1 and 10 years for the case study 2 (**Table 9**). In these calculations, the reference Euro course of 4.5172 Lei / Euro (National Bank of Romania), from 2016-12-30, was considered. The proposed façades for the two buildings taken into study, after the thermal rehabilitation, are presented in **Figure 1c and d**.

#### 4. Discussion

This paper draws attention to the new challenges of the environment and of the existing resources of the planet protection requirements, supporting the inclusion among the priority actions to achieve the EU targets of the energy efficiency of certain buildings in the administrative sector, high energy users and large greenhouse gases generators. The intervention involves both the efficient use of existing building elements and the use of

intelligent solutions to transform these buildings into intelligent buildings that, moreover, efficiently use renewable resources (Popescu et al., 2013; 2018; Prada et al., 2013; 2017;).

The results of this study supported and demonstrated the need to include in the national strategies the incentive elements for the renovation of the existing hospital buildings, as mentioned above - large energy consumers. In other words, the study claims that stimulating the energy efficiency works of these buildings leads to a significant reduction - from this perspective - of greenhouse gas emissions and primary energy consumption.

Taking into account the significant value of buildings for residential and administrative purposes, the considerable growth in number and also the global tendency for healthy, durable, ecological, energy efficient environment, the subject of this study is of current interest for specialists (designers, architects, builders, developers) as well as for people who live and work in these buildings (Bungau et al, 2019; Dan et al., 2013). The present research offers the alternative of a healthy indoor environment by rational and clever use of energy together with adequate use of constructions, equipment and installations.

Addressing the subject of protecting the built environment is complex and courageous, the authors considering that "Waste management is a crucial topic for the sustainable development of our society" and "globally, waste generation is expected to grow by approximately 60% by 2050 (Bungau et al, 2018; Popescu et al., 2016; ESWET\_Vision2050). The paper draws attention and gives solutions from a new perspective of intelligent waste management: through modernization and energy efficiency interventions of the large existing buildings - energy inefficient and morally used buildings. The intelligent use of energy resources (constructions and existing building elements) is proposed before they reach the stage of non-recyclable waste. Thus, the efficiency of such energy resources is emphasized differently. From this perspective, the following must be interpreted: due to modern technologies, waste operation becomes a process of integration and supply management of waste, decreasing the use of primary materials, reusing and turning

non-reusable waste into an important resource for the entire society (Bungau et al, 2015; Bungau et al, 2019). To achieve this objective, the first action to be taken is to gradually reduce the polluting dumpsites (ESWET\_Vision2050).

It is suggested in this paper an integrated approach of a model of energy efficiency for the old hospital buildings existing in Romania, with their transformation into intelligent buildings, respectively Near Zero Energy Building (NZEB), in conjunction with the intelligent and efficient management of possible "waste". This proposal can be considered a good practice model and can be implemented in Eastern Europe and beyond, for a clean Europe, with neutral climate, for an unpolluted planet. Thus, a new tool is provided for becoming Climate-Neutral by 2050 – a long term program for a modern, profitable, climate neutral and combative EU economy that: increases the advantages of energy efficiency also incorporating zero emission constructions; increases the use of electricity and alternative energy to completely eliminate the carbon emissions from the energy reserve of Europe; adopts clear, secure and associated mobility; facilitates a circular European economy and a competitive industry to determine the decrease of GHG emissions; creates a proper, intelligent system of interconnections and infrastructures; takes full advantage of the bioeconomy and designs proper carbon sinks; deals with the rest of CO<sub>2</sub> emanation using Carbon Capture and Storage (CCS) (EC, clim(EC): Going Climate-Neutral by 2050).

Considering the shortcomings of the two buildings, in order to improve energy efficiency, the following solutions are proposed:

1. Thermal rehabilitation of the envelope with facade thermosystem arrangement (**Figure 1c and d**) (Cluster Zepher, 2017a, b): the thermosystem, depending on the elements on which it is applied, will have the following composition: opaque vertical surface (outer walls) - ventilated façade with thermal insulation element of basaltic wool 20 cm, reaction to fire

class A1, with metallic structure. It will be anchored against the structure of the building with metallic elements, isolated from the structure and the external plywood to break the thermal bridges. The assembling screws will not come into direct contact with the metal structure. This, in return, will not come into direct contact with the fiber cement facade boards. The vertical ribbings/uprights/columns of reinforced concrete in the joinery area will be provided, for the elimination of the thermal bridges, with 10 cm basaltic wool plates, class of reaction to fire A1. To eliminate the thermal bridges, the covers are plated with 10 cm basaltic wool. The outer plywood will be made of fibrocement tiles. A composite thermal insulation system consisting of 10 cm autoclaved mineral thermal insulation plates and light mineral mortar, up to -1.00 m below the natural terrain will be used to plate the sills.

For the thermal performance carpentry arrangement, the following measures are proposed: replacement of existing joinery with small thermal transmission coefficient with polyvinyl chloride (PVC), aluminum windows with three-layer glass and high-performance ironwork, thermal bridges solved by installing 10 cm basaltic wool insulation boards, class of reaction to fire A1 with access doors having aluminum joinery and insulating windows. Sunshade arrangements are proposed for the windows on the southern and western sides, the shutters from aluminum sheet will be arranged horizontally, with controlled, automated operation.

For the thermal rehabilitation of the roof terrace it is suggested: the restoration of the roof insulations by replacing the existing insulations with thermal insulation of rigid thermal insulation plates of rigid polyurethane foam (PIR) class of reaction to fire A1, with a minimum thickness of 20 cm and waterproofing of membranes with elastomer bitumen; the

slope will be provided with thermo-concrete in thickness of 5-20 cm. It is also suggested the thermal rehabilitation of the terraces and attics (inside the terrace), plated with a composite system of thermal insulation consisting of autoclaved mineral thermal insulation plates and light mineral mortar (20 cm).

A thermosystem arrangement is proposed on the soffit of the ceiling of the technical basement: thermal insulation boards of 15 cm basaltic wool, class of reaction to fire A1.

2. Rehabilitation of the heating and ventilation system, respectively rehabilitation of the heating / cooling system: with heat pumps installed in the central heating system. For case study 1, there are proposed: 2 reversible heat pumps, ground-water type, with useful thermal power  $P_u=140$  kW, which work with 20 geothermal probes each for heating and air conditioning and 4 heat pumps, air type / soil-water, with useful thermal power  $P_u=50$  kW for heating and air conditioning; for case study 2, 3 reversible heat pumps, soil-water type, with useful thermal power  $P_u=170$  kW, which work with 20 geothermal probes each, for heating and air conditioning, and 3 heat pumps, air/soil-water type, with useful thermal power  $P_u=60$  kW that work with 6 geothermal probes each, for heating and air conditioning. The proposed heating/cooling system is the radiant plasterboard system mounted on the ceiling, with pre-assembled 9.9 mm pipes. It is suggested to restore the supply system for consumers through vertical columns and distribution to the floors through ceilings. The configuration and the routes of the pipes were chosen to ensure minimum lengths in the network and self-compensation of the dilations.

3. Introducing a local ventilation system with over 90% heat recovery and 100% fresh air supply so that there is no air transfer between the wards. A heat recovery unit will be

installed for every two rooms. The evacuation of the vitiated air after recovery as well as the absorption of the fresh air will be done through a flexible piping provided with the exterior grid at the exit of the building. The exits of the piping will be made on the side of the construction.

4. Rehabilitation of the sanitary installations system by replacing the existing washbasin batteries with sensor batteries to save hot and cold domestic water; replacing the existing toilets with high water consumption with toilet vessels having recessed tank, with dual flap that have the possibility to choose economical way of washing; replacing the existing urinals with sensor urinals, in order to save water.

5. Rehabilitation of the electricity supply system and lighting, respectively the rehabilitation of the electrical installations by: replacing the existing panels with new and reliable equipment, provided with protections for the safe service of the vital consumers; replacing the existing lighting elements with light-emitting diode (LED) devices; reconstructing the power supply circuits for consumers and protection against electric shocks.

6. Arrangement of renewable energy production system (REPS), which contains the following subassemblies: photovoltaic panel system installed on the terrace type roof Body C1; integrated system of storage for additional photovoltaic produced electricity.

7. System layout: BMS (Building Management System). The management of the buildings will be realized through a system of monitoring, control and energy management installed in a data center (centralized communication center). The BMS system is organized as a network between the server and a designed number of automation controllers. The interconnection of



the different segments is done with network routers. The automation controllers communicate with each other and the server through the internet/ethernet.

8. Elevator replacement. For case study 1, it is proposed to replace 6 elevators, and for case study 2, it is proposed to replace a single elevator, these being morally and physically worn out, with energy-efficient equipments / elevators, from the new generation, which have a consumption with up to 50% lower than the existing one. All the solutions presented are related to the purposes: a "clean planet" and a "neutral climate".

In the diagram presented in **Figure 6** it is summarized and underlined that the energy efficiency of buildings of special importance with the function of hospital, similar to those that have been the subject of case studies 1 and 2, is in line with the European directives for 2020 European Commission, Climate Change, 2020 (EC, clim(EC): 2020/ 2030 (EC, clim(EC): 2030) and creates the premises for a clean planet and a neutral climate, promoted by the Long-term Strategy for 2050 (EC, clim(EC): 2030). In the current research, after achieving the energy efficiency, each of the two buildings will have the energy performance corresponding to class A, as shown in Table 4 confirm.

Corroborating all the data obtained in this research, the following results are obtained: 1) renewable energy covers over 62.68% / 75.51% of the energy consumption needed for heating / air conditioning and for the production of domestic hot water; 2) reducing CO<sub>2</sub> equivalent emissions by 77% / 67%, with a direct positive impact on global warming, on pollution and emissions reduction respectively; 3) the proposed solutions bring benefits from the point of view of reducing heat losses, and of improving the comfort of the respective interior environment and of the energy efficiency; from this perspective, the proposed intervention measures lead to a reduction of the annual primary energy consumption of 71.82% / 78.39% compared to the initial consumption, the proposal of the present work being to apply these solutions to all similar buildings made in the 1970s at least in Romania, with a "70-70-70" efficiency, with a 10-year investment recovery period.

The presented solutions are environmentally friendly, as follows:

- it is proposed the use of ecological, environmentally friendly, sustainable, recyclable materials that do not support combustion (mineral wool), ventilated facade system, as well as the use of passive technologies (free cooling) (Vesselenyi et al., 2013);
- the presented solutions consist of the use of passive technologies;
- the principles of durability and sustainability are promoted, the "polluter pays" principle, promoting eco-efficient systems for "clean technologies". The equipments necessary for their implementation will have configurations with as little lead as possible, thus reducing the negative impact on the environment. Using the Internet saves energy and paper, used in the classic way;
- by introducing the Building Management System (BMS), the functions of the building are improved, controlling the energy consumption, including the efficiency of the medical act management.

In response to the European Commission demands for an Europe with a neutral climate until 2050, the paper deepens the problems of the European strategy and gives a solution through which Eastern Europe moves towards a neutral climate, making investments for adequate solutions, enabling people, acting in important fields: financial, research, industry and providing social equity to obtain a proper transition (EC, clim(EC): 2050; EC clim(EC)). The present study points out the importance of restauration for the buildings in use with the purpose to decrease the consequences of climate variations, to reach the 20-20-20 EU energy objectives (Ghemis et al., 2019; European Council: Conclusions 2030) in concordance with the perspective formulated by EU authorities in the Energy Roadmap 2050: Guideline towards a competitive economy with low carbon emissions in 2050 (Sturk; EC, clim(EC): 2020).

## 5. Conclusions

The results of this paper show that applying intelligent energy efficiency solutions of buildings of special importance with the "Hospital" function contributes substantially to the concerted efforts to protect the planet and the environment, while at the same time agreeing and supporting the European strategies 2020-2030 and 2050, which tend towards a clean planet and a neutral climate. The paper proposes the implementation of a program with a stake of "70-70-70" over a period of 15 years, which will stimulate the energy efficiency of all similar buildings of special importance in Eastern Europe. The design, execution and recovery of the investment fall within this range. Reaching the target "70-70-70" aims at: 70% reduction of greenhouse gas emissions of the building, use of renewable energy in proportion of 70% of the total energy consumed, and energy efficiency of the building by 70% (the energy performance corresponding to class A). At present, in the current state, these studied buildings can be considered as "polluting deposits", the authors suggesting their transformation into a valuable resource for the society by using new design and efficiency solutions.

**Author Contributions:** All the authors contributed equally to this paper.

**Funding:** This research received no external funding

**Acknowledgments:** None

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

- 421 Bribián Z.I.; Usón A.A.; Scarpellini S. Life cycle assessment in buildings: state-of-the-art  
422 and simplified LCA methodology as a complement for building certification. *Build*  
423 *Environ* **2009**, 12, 2510-2520.
- 424 Badulescu D.; Badulescu A. Medical tourism: between entrepreneurship opportunities and  
425 bioethics boundaries: narrative review article. *Iran J Public Health* **2014**, 43(4),  
426 406-415.
- 427 Badulescu D.; Badulescu A.; Simut R.; Bac D.; Iancu E.-A; Iancu N. Exploring  
428 environmental Kuznets curve. An investigation on EU economies. *Technological and*  
429 *Economic Development of Economy* **2020**, 26(1),  
430 1-20. <https://doi.org/10.3846/tede.2019.11261>.
- 431 Badulescu D.; Simut R; Badulescu A.; Badulescu A.-V. The relative effects of economic  
432 growth, environmental pollution and non-communicable diseases on health  
433 expenditures in European Union countries. *Int J Environ Res Public Health*  
434 **2019**, 16(24), 5115. <http://dx.doi.org/10.3390/ijerph16245115>
- 435 Bungau C.C.; Prada I.F., Prada M.; Bungau C. Design and operation of constructions: a  
436 healthy living environment - parametric studies and new solutions. *Sustainability*  
437 **2019**, 11, 6824. <https://doi.org/10.3390/su11236824>
- 438 Bungau S.; Suci R.; Bumbu A.; Cioca G.; Tit D.M. Study on hospital waste management in  
439 medical rehabilitation clinical hospital, Baile Felix. *J Environ Prot Ecol* **2015**, 16(3),  
440 980-987.

441 Bungau S.; Tit D.M.; Fodor K.; Cioca G.; Agop M.; Iovan C.; Nistor Cseppento D.C.; Bumbu  
 442 A.; Bustea C. Aspects regarding the pharmaceutical waste management in Romania.  
 443 Sustainability **2018**, 10(8): 2788. <https://doi.org/10.3390/su10082788>  
 444 C107/1-7/2005, Norms regarding the calculation of the global coefficients of thermal  
 445 insulation in the residential buildings. (in Romanian: Normativ privind calculul  
 446 coeficienților globali de izolare termică la clădirile de locuit.) Available online:  
 447 <http://www.stim.ugal.ro/crios/Support/IEACA/Anexe/C107-1-3-2005.pdf>. (accessed at  
 448 30 Aug. 2019).  
 449 C107-2005 - Normative regarding the thermotechnical calculation of the building elements  
 450 of the buildings updated on March 28, 2016.  
 451 [https://lege5.ro/Gratuit/geydknzugezq/ordinul-nr-386-2016-pentru-modificarea-si-co](https://lege5.ro/Gratuit/geydknzugezq/ordinul-nr-386-2016-pentru-modificarea-si-completarea-reglementarii-tehnice-normativ-privind-calculul-termotehnic-al-elementelor-de-construcie-ale-cladirilor-indicativ-c-107-2005-aprobata-prin-ordinu/2016)  
 452 [mpletarea-reglementarii-tehnice-normativ-privind-calculul-termotehnic-al-elementelo](https://lege5.ro/Gratuit/geydknzugezq/ordinul-nr-386-2016-pentru-modificarea-si-completarea-reglementarii-tehnice-normativ-privind-calculul-termotehnic-al-elementelor-de-construcie-ale-cladirilor-indicativ-c-107-2005-aprobata-prin-ordinu/2016)  
 453 [r-de-construcie-ale-cladirilor-indicativ-c-107-2005-aprobata-prin-ordinu/2016](https://lege5.ro/Gratuit/geydknzugezq/ordinul-nr-386-2016-pentru-modificarea-si-completarea-reglementarii-tehnice-normativ-privind-calculul-termotehnic-al-elementelor-de-construcie-ale-cladirilor-indicativ-c-107-2005-aprobata-prin-ordinu/2016)  
 454 (accessed at 12 Nov. 2019).  
 455 Cluster Zepher Asociația. 2017a. Documentația de Avizare a Lucrărilor de Intervenții,  
 456 Proiect: Creșterea Performanței Energetice a Spitalului Clinic Municipal “dr. Gavril  
 457 Curteanu” Oradea. Municipiul Oradea. Mai 2017. (In English: Zepher Cluster  
 458 Association. 2017. Documentation for the Approval of the Intervention Works,  
 459 Project: Increasing the Energy Performance of the Municipal Clinical Hospital “dr.  
 460 Gavril Curteanu”, Oradea. Oradea municipality. May 2017.)  
 461 Cluster Zepher Asociația. 2017 b. Documentația de Avizare a Lucrărilor de Intervenții,  
 462 Proiect: Creșterea Performanței Energetice a Spitalului Clinic Județean de Urgență  
 463 Oradea. Municipiul Oradea. Mai 2017. (In English: Zepher Cluster Association. 2017  
 464 b. Documentation for the Approval of the Intervention Works, Project: Increasing the

465 Energy Performance of the Oradea County Emergency Clinical Hospital. Oradea  
 466 municipality. May 2017.)

467 Dan, S.; Iures, L.; Badea, C. Impact of structural rehabilitation of existing buildings on  
 468 energy saving in constructions. 13th SGEM – International Multidisciplinary Scientific  
 469 GeoConference of Modern Management of Mine Producing, Geology and  
 470 Environmental Protection, 2013. Albena, Bulgaria, 16-22 June 2013, 451-456.  
 471 <http://toc.proceedings.com/19963webtoc.pdf>.

472 ESWET (European Suppliers of Waste-To-Energy Technology). ESWET\_Vision2050.  
 473 Waste-to-Energy 2050: clean technologies for sustainable waste management.  
 474 Available online: <http://www.eswet.eu/vision-2050.html>. (accessed at 02.01.2020).

475 EC (European Comission). clim(EC): 2020 climate & energy package.  
 476 [https://ec.europa.eu/clima/policies/strategies/2020\\_en](https://ec.europa.eu/clima/policies/strategies/2020_en);

477 EC (European Comission). – CORDIS EU research results: Construction skills: Equipping  
 478 building professionals with new skills to achieve European energy targets.  
 479 [https://cordis.europa.eu/article/id/400910-construction-skills-equipping-building-prof](https://cordis.europa.eu/article/id/400910-construction-skills-equipping-building-professionals-to-achieve-european-energy-targets)  
 480 [essionals-to-achieve-european-energy-targets](https://cordis.europa.eu/article/id/400910-construction-skills-equipping-building-professionals-to-achieve-european-energy-targets). (accessed at 02.01.2020).

481 EC (European Comission). clim(EC): 2030 ate & energy framework.  
 482 [https://ec.europa.eu/clima/policies/strategies/2030\\_en](https://ec.europa.eu/clima/policies/strategies/2030_en). (accessed at 02.01.2020).

483 EC (European Comission). clim(EC): 2050 long-term strategy. Available online:  
 484 [https://ec.europa.eu/clima/policies/strategies/2050\\_en](https://ec.europa.eu/clima/policies/strategies/2050_en). (accessed at 02.01.2020).

485 EC (European Comission). clim(EC): Going Climate-Neutral by 2050 – a Strategic  
 486 Long-Term Vision for a Prosperous, Modern, Competitive and Climate-Neutral EU  
 487 Economy. Luxemburg: Oficiul pentru Publicații al Uniunii Europene, 2019.  
 488 [https://ec.europa.eu/clima/news/commission-calls-climate-neutral-europe-2050\\_en](https://ec.europa.eu/clima/news/commission-calls-climate-neutral-europe-2050_en)  
 489 (accessed at 02.01.2020).

- European Council. Conclusions on 2030 Climate and Energy Policy Framework, Brussels, 24 October 2014. [https://www.consilium.europa.eu/uedocs/cms\\_data/docs/pressdata/en/ec/145356.pdf](https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145356.pdf);
- GGHH (Global Green and Healthy Hospitals) 2012. A Comprehensive Environmental Health Agenda for Hospitals and Health Systems Around the World. <http://greenhospitals.net/wp-content/uploads/2011/10/Global-Green-and-Healthy-Hospitals-Agenda.pdf>
- Ghemis M.T.; Scurt A.A.; Bob C.; Bungău C. An Analysis of Sustainability about Rehabilitation and Reconversion of an Old Building: The 19<sup>th</sup> National Technical-Scientific Conference „Modern Technologies for the 3rd Millenium”, 2019, Romania, 273-278.
- H.G.R. 766. Hotărâre de Guvern pentru aprobarea unor regulamente privind calitatea în construcții. Ministerul Lucrărilor Publice și Amenajării Teritoriului. (In English: Decision of the Government of Romania H.G.R. 766. Government Decision for the approval of some regulations regarding the quality in constructions. Ministry of Public Works and Land Use Planning), România. 1997.
- Junnila S.; Horvath A. Life-cycle environmental effects of an office building. J Infrastruct Syst (2003), pp. 157-166.
- Mc 001/1 – 2006. Methodology for calculating the energy performance of buildings; part I - Building envelopment. (in Romanian: Metodologie de calcul a performanței energetice a clădirilor; partea I – Anvelopa clădirii.) Available online: [https://www.mdrap.ro/userfiles/reglementari/Domeniul\\_XXVII/27\\_11\\_MC\\_001\\_1\\_2\\_3\\_2006.pdf](https://www.mdrap.ro/userfiles/reglementari/Domeniul_XXVII/27_11_MC_001_1_2_3_2006.pdf) (accessed at 17 July 2019).
- Mc 001/2 – 2006. Methodology for calculating the energy performance of buildings; Part II - Energy performance of installations. (in Romanian: Metodologie de calcul a performanței energetice a clădirilor; partea a II-a – Performanța energetică a

- 516 instalațiilor.) Available online:  
 517 [https://www.mdrap.ro/userfiles/reglementari/Domeniul\\_XXVII/27\\_11\\_MC\\_001\\_4\\_5](https://www.mdrap.ro/userfiles/reglementari/Domeniul_XXVII/27_11_MC_001_4_5)  
 518 [\\_2009.pdf](#), (accessed at 20 July 2019).
- 519 Mc 001/3 – 2006. Methodology for calculating the energy performance of buildings; part III  
 520 - the audit and the performance certificate of the building. (in Romanian: Metodologie  
 521 de calcul a performanței energetice a clădirilor; partea a III-a – auditul și certificatul de  
 522 performanță a clădirii.) Available online:  
 523 [https://www.mdrap.ro/userfiles/reglementari/Domeniul\\_XXVII/27\\_11\\_MC\\_001\\_1\\_2](https://www.mdrap.ro/userfiles/reglementari/Domeniul_XXVII/27_11_MC_001_1_2)  
 524 [\\_3\\_2006.pdf](#) (accessed at 20 July 2019).
- 525 Mc 001/4 – 2009 - Methodology for calculating the energy performance of buildings; Part IV  
 526 - summary of calculation of the energy performance of buildings and apartments. (in  
 527 Romanian: Metodologie de calcul a performanței energetice a clădirilor; partea a IV-a  
 528 – breviar de calcul al performantei energetice a cladirilor si  
 529 apartamentelor.) Available online:  
 530 [https://www.mdrap.ro/userfiles/reglementari/Domeniul\\_XXVII/27\\_11\\_MC\\_001\\_4\\_5](https://www.mdrap.ro/userfiles/reglementari/Domeniul_XXVII/27_11_MC_001_4_5)  
 531 [\\_2009.pdf](#). (ccessed at 20 July 2019).
- 532 Ordin nr. 2641 din 4 aprilie 2017 privind modificarea și completarea reglementării tehnice  
 533 "Metodologie de calcul al performanței energetice a clădirilor", aprobată prin Ordinul  
 534 ministrului transporturilor, construcțiilor și turismului nr. 157/2007. (In English: Order  
 535 no. 2641 of April 4, 2017 regarding the modification and completion of the technical  
 536 regulation "Methodology for calculating the energy performance of buildings",  
 537 approved by the Order of the Minister of Transport, Construction and Tourism no.  
 538 157/2007.)
- 539 P 100 - Cod de Proiectare Seismică. Ministerul Dezvoltării Regionale si Administrației  
 540 Publice. România. 2013. (In English: Seismic Design Code. Ministry of Regional  
 541 Development and Public Administration. Romania. 2013.)



- 542 Popescu, D.; Prada, M. Some aspects about smart building management systems - solutions  
 543 for green, secure and smart buildings. Recent Advances in Environmental Science,  
 544 Proceedings of the 9th International Conference on Energy, Environment, Ecosystems  
 545 and Sustainable Development, 2013. Lemesos, Cyprus, 126-132.
- 546 Popescu, D.E.; Bungau, C.; Prada, M.; Domuta, C.; Bungau, S.; Tit, D.M. Waste  
 547 management strategy at a public university in smart city context. *J Environ Prot Ecol*  
 548 2016, 17(3), 1011-1020.
- 549 Popescu, D.E.; Prada, M.F.; Dodescu, A.; Hemanth, J.; Bungau, C. A secure confident cloud  
 550 computing architecture solution for a smart campus. 7th International Conference on  
 551 Computers Communications and Control (ICCCC), 2018, 240-245.
- 552 Prada, M. F.; Brata, S.; Tudor, D. F.; Popescu, D. E. Aspects of Reducing of Gas Emissions  
 553 according to the EU Energy Policy Targets. *J Environ Prot Ecol* **2013**, 14(1),  
 554 209-2013.
- 555 Prada, M.; Popescu, D.E.; Bungau, C.; Pancu, R.; Bungau, C. Parametric Studies on  
 556 European 20-20-20 Energy Policy Targets in University Environment. *J EnvironProt*  
 557 *Ecol* 2017, 18(3), 1146-1157.
- 558 Prada, M.F.; Popescu, D.E.; Bungau, C. Building education, source of energy saving in  
 559 Romania. Proceeding of the 15th National Technical-Scientific Conference on Modern  
 560 Technologies for the 3rd Millennium, 2016. Oradea, Romania, 157-162.
- 561 Proidea, 2019. Available online:  
 562 <https://www.proidea.ro/aplicatii-produse-5/atrea-hote-profesionale-spital-urgenta-oradea-15043.shtml> (accessed at 02.12.2019)
- 563
- 564 Shoubi M.V.; Shoubi M.V.; Bagchi A.; Barough A.S. Reducing the operational energy  
 565 demand in buildings using building information modeling tools and sustainability

- approaches. Ain Shams Engineering Journal, 2015, 6(1), 41-55.  
<https://doi.org/10.1016/j.asej.2014.09.006>.
- Sturk, M. Transport White Paper, Climate Roadmap & Quantitative Modelling Results EU  
Transport GHG: Routes to 2050 II - 1st Stakeholder Conference.  
<http://www.eutransportghg2050.eu/cms/assets/Uploads/Meeting-Documents/2.-Routes-to-2050-II-2050-Roadmap-Conf29Jun11-MS-FINAL.pdf>
- Vesselenyi, T.; Bungau, C.; Husi, G. Research equipment and computation techniques for  
intelligent building applications. 2014 IEEE/SICE International Symposium on  
System Integration, Tokyo, Japan, 228-233.
- WHO (World Health Organization), 2010. Health in the Green Economy: Co-Benefits to  
Health of Climate Change Mitigation. Health Facilities.  
[https://www.who.int/hia/hgebrief\\_health.pdf](https://www.who.int/hia/hgebrief_health.pdf)

## 592    **Figures legend**

593    **Figure 1.** Initial state: a. Municipal Clinical Hospital Dr. Gavril Curteanu - 1980; b. Oradea  
594    Clinical County Emergency Hospital - 2018. Proposed facades: c. Municipal Clinical  
595    Hospital Dr. Gavril Curteanu; b. Oradea Clinical County Emergency Hospital

596    **Figure 2.** Municipal Clinical Hospital „dr. Gavril Curteanu”: a. Thermovision survey  
597    North-Eastern facade; b. Thermovision survey South-Eastern facade; c. Highlighting thermal  
598    bridges.

599    **Figure 3.** Oradea Clinical County Emergency Hospital: a. Thermovision survey Eastern  
600    facade; b and c. Highlighting thermal bridges.

601    **Figure 4.** Energy Performance Certificate - initial buildings: a. Case study 1; b. Case study 2.

602    **Figure 5.** Comparative charts of initial buildings vs. energy efficient buildings - limits  
603    imposed by norms - case studies 1 and 2. a. Annual energy consumption; b. CO<sub>2</sub> equivalent  
604    emissions.

605    **Figure 6.** Energy efficiency of special importance buildings - hospitals, integrated in the  
606    main European objectives agreed for 2020-2030, for climate and energy.



**a.**



**b.**

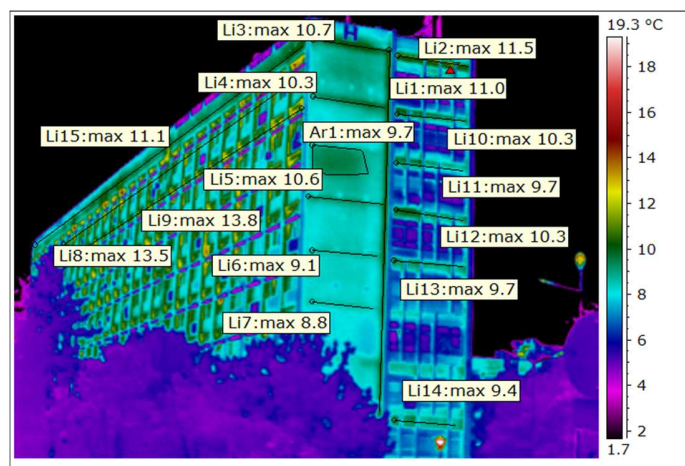


**c.**

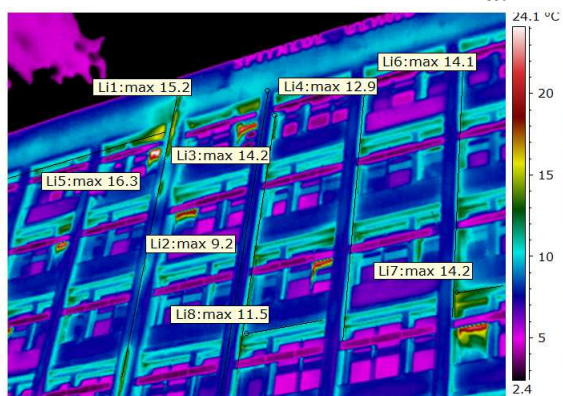


**d.**

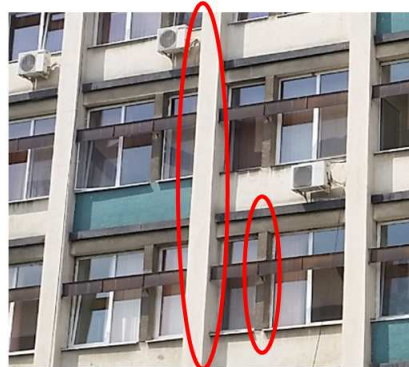
**Figure 1.**



**a.**



**b.**



**c.**

**Figure 2.**

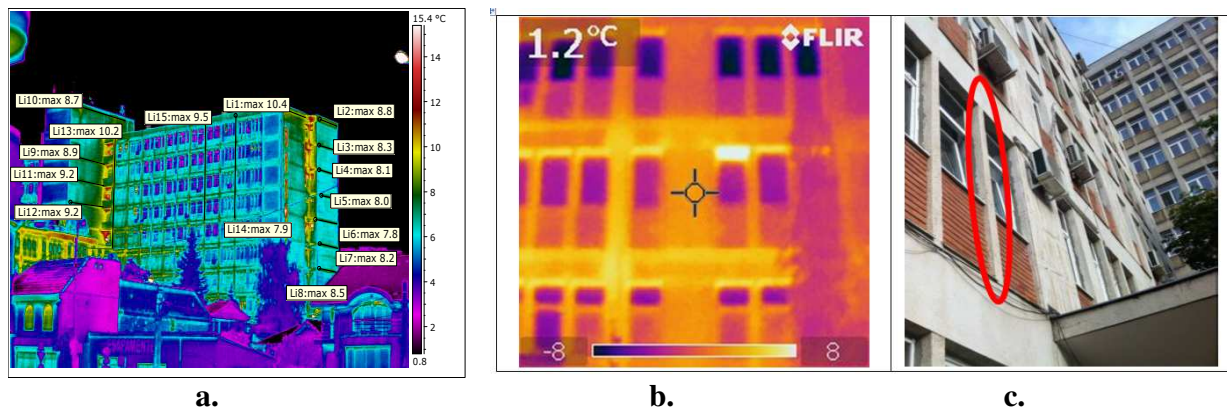
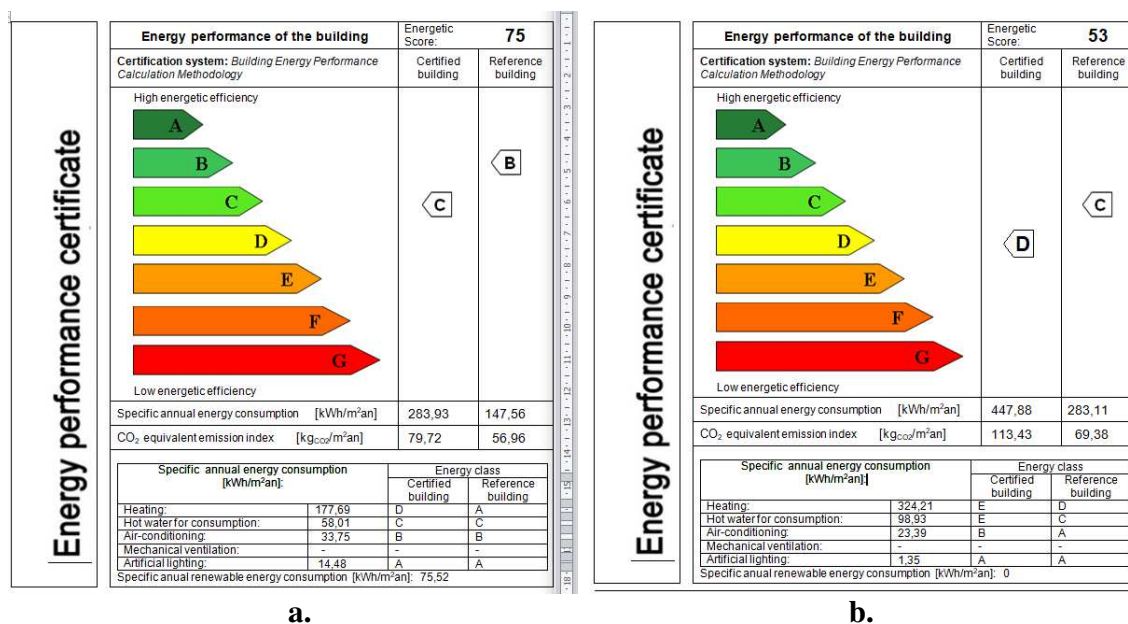


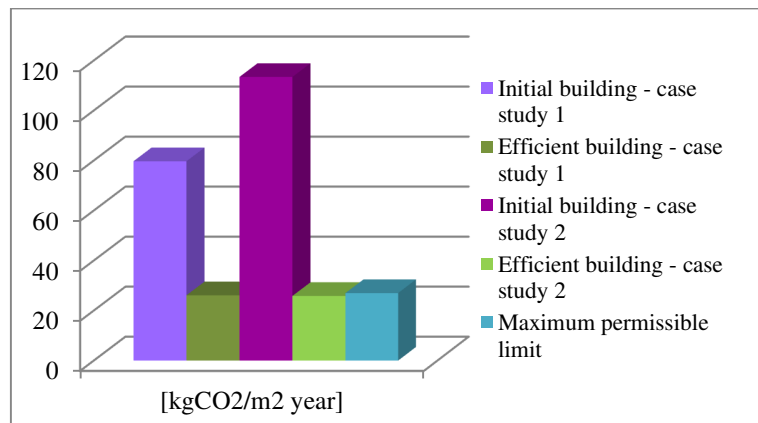
Figure 3.



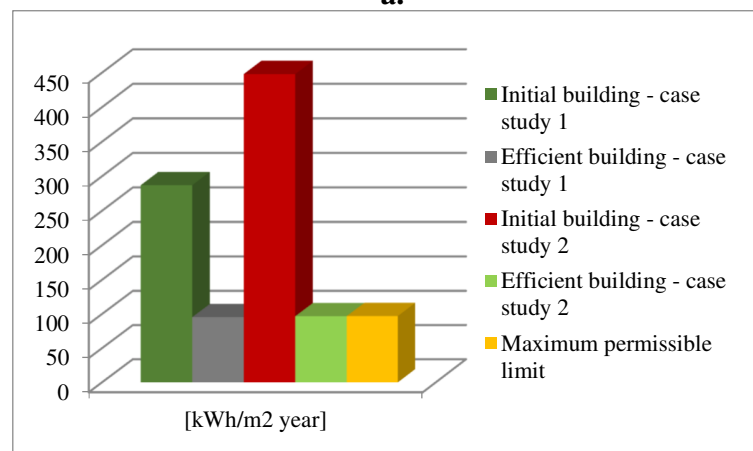
a.

b.

Figure 4.



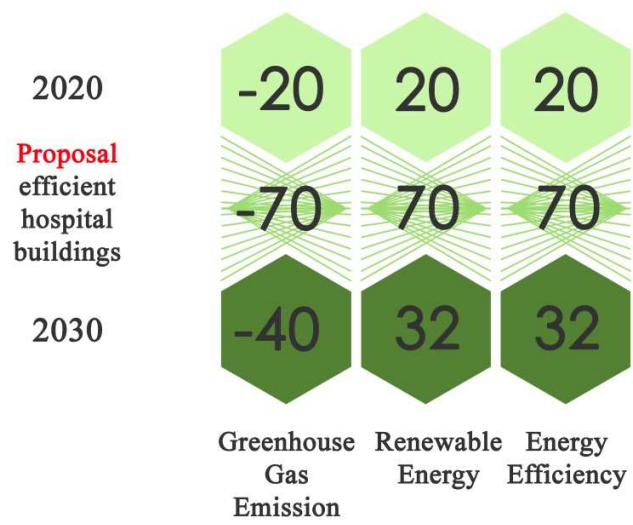
a.



b.

**Figure 5.**





**Figure 6.**

**Table 1.** The parameters that characterize the 2 buildings

The overall parameters of the building		Case study 1		Case study 2	
Period of realization - in use (years)		1965-1969		1978-1979	
Execution project		no. 3220/1964		no. 8481/1977-1978	
Designer		Direction of Systematization and Design of Constructions “Crisana”, Oradea, Romania		County Design Institute Bihor, Romania	
Executor		Local Construction Trust Oradea, Romania			
Function buildings: hospital and polyclinic		H1	HP1	H2	HP2
Height regime (basement + ground floor +floors)		GF+10F	GF+4F	B+GF+8F	B+GF+4F
Shape in plan		Lamellar	Lamellar	Lamellar	Rectangle
Dimensions in plan (m)		12.70x99.00	22.75x48.35	14.59x75.05	32.80x38.20
Maximum construction height (m)		35.20	17.80	31.00	14.55
Ground floor height (m)		4.15		3.60	
Floor height (m)		3.45		3.30	
Useful surface (mp)		16,759.59		14,579.00	
Useful surface heated (mp)		19,032.49		16,357.74	
The surface built to the ground (mp)		2778.00		2643.00	
Developed area (mp)		19,871.00		20,303.00	
Structure of resistance	Foundations	General base concrete slab		General base concrete slab with outboard pillars	
	Vertical	Spatial frames and structural walls of monolithic reinforced concrete		Spatial frames with precast concrete beams, reinforced concrete structural walls	
	Partition walls	Brick masonry, 12.5 cm thick		BCA masonry and brick	
	Floors	Monolithic reinforced concrete		Prefabricated reinforced concrete with over-concrete	
Elements of the insulation	Vertical opaque / closing walls	Masonry of ceramic blocks with vertical holes, thickness of 30 cm, non-thermal performance		BCA masonry, partially veneered with apparent brick plywood	
	Glazing (exterior carpentry)	PVC joinery, non-thermal performance, surfaces exposed to solar radiation, without blinds			
	Roof	Terrace floor - the last floor with retreats		Non-circular terrace floor	Terrace floor: Heliport
Heating	Source of hot water consumption	Geothermal water / primary agent from the city's Electro-Thermal Power Plant		Primary agent from the city's Electro-Thermal Power Plant / pellets / gas fuel	
	Source of heating				
	Heating bodies	Cast iron radiators			
Cold - cooling		Air conditioning devices only in doctors' offices and in "clean rooms" (operator block)			
Ventilation		Natural / artificial only in "clean rooms" (operator block)			
Lighting	Natural	The interior rooms directly provided natural light; exception: rooms where indirect / artificial lighting (lobbies, hallways, corridors, warehouses) are allowed			
	Artificial	Most of the existing devices (neon tubes) are of old construction, having magnetic ballast with high ballast losses (minimum 20%). 900-100 neon tubes defective annually.			
	Lighting fixtures (no.)	1678		1504	
Total net installed power (watt)		102.456		93.128	
Number of elevators		7 (1 new, 6 old)		7 (6 new, 1 old)	
Number of beds		1100		861	
Average number of patients / year		40,000		30,000	

**Table 2.** Global thermal parameters and energy consumption

Parameter	Symbol	Unit	Case study 1	Case study 2
Global thermal parameters				
Overall coefficient of thermal insulation of the existing building	$G$	$m^2K/W$	0.512	0.545
The average corrected thermal resistance of the existing building	$R_{med}$	$m^3K$	0.586	0.479
The global coefficient of thermal insulation of the reference building	$G_{ref}$	$m^2K/W$	0.220	0.178
The average corrected thermal resistance of the reference building	$R_{med-ref}$	$W/m^3K$	1.580	1.550
Energy consumption / year				
Energy consumption	$Q_{total}^{an}$	kWh	5461,655.86	7326,424.47
Specific energy consumption	$q_{total}^{an}$	kWh	283.93	447.887
Emissions index equivalent CO <sub>2</sub>	$e_{CO_2}^{an}$	kgCO <sub>2</sub> /m <sup>2</sup>	79.72	113.43

**Table 3.** Energy consumption / CO<sub>2</sub> emissions / year

Functions	Consumption (fossil fuels)	Consumption (renewable sources)	CO <sub>2</sub> emissions	Specific energy consumption
	kWh/year		kgCO <sub>2</sub> /m <sup>2</sup> year	kWh/m <sup>2</sup> year
Case study 1				
Heating	112,330	540,625	9.065	34.30
Domestic hot water	112,776	437,325	7.67	28.90
Lightening	61,419	-	0.96	3.23
Air conditioning	335,118	43,033	5.84	19.87
Ventilation	116,876	55,117	2.57	9.03
Case study 2				
Heating	220,186	595,012	13.37	49.84
Domestic hot water	13,625	450,019	7.31	28.30
Lightening	33,308	-	0.61	2.04
Air conditioning	92,309	54,922	2.55	9.00
Ventilation	28,420	95,043	2.01	7.54

**Table 4.** Total specific energy consumption / total CO<sub>2</sub> emissions for energy efficient buildings / year vs. the maximum value allowed by the rules (Cluster Zepher, 2017a, b)

Parameter	Unit/year	Case study 1	Case study 2
Total specific energy consumption	kWh/m <sup>2</sup>	95.34	96.76
Total emissions of CO <sub>2</sub>	kg CO <sub>2</sub> /m <sup>2</sup>	26.13	25.86

**Table 5.** Equivalent annual energy consumption (primary energy, non-renewable sources, renewable sources)

Parameter	Unit/year	Case study 1		Case study 2	
		Initial building	Energy efficient building	Initial building	Energy efficient building
Primary energy consumption	kWh	7326,424	1582,843	6439,040	1814,619
Final energy consumption in the building (from non-renewable sources)	tep*	639.06	136.12	490.45	156
Total specific primary energy consumption (from non-renewable sources), of which: - for heating / cooling	kWh/m <sup>2</sup>	447.88	21.67	283.93	38.80
		347.6	19.10	211.44	23.51
Total primary energy consumption from renewable sources, of which: - for heating / cooling	kWh	0	1194,996	1148,190	1076,100
		0	595,012	838,358	5400,625

\*tep= tons of oil equivalent (toe)

**Table 6.** Specific annual level of greenhouse gases

Initial building	Energy efficient building	Savings
[tonnes equivalent CO <sub>2</sub> / year]		%
Case study 1		
1,855	423	77.20
Case study 2		
1,517	497	67.24

**Table 7.** Total energy consumption (in kWh/year) for the initial buildings vs. the energy efficient ones and the primary energy economy

Primary energy	Initial building	Energy efficient building	Savings %
Case study 1			
Thermal energy	4034,179	225,106	94.4
Electricity	2404,861	513,413	78.6
Total	6439,040	738,519	88.5
Case study 2			
Thermal energy	6367,992	233,810	96.3
Electricity	254,127	124,037	51.2
Total	6622,119	357,847	94.6

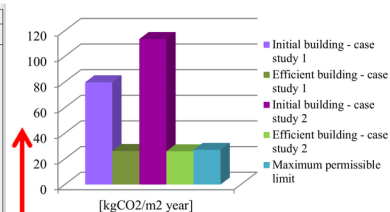
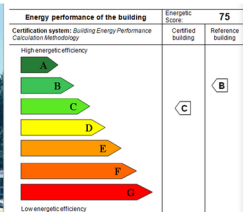


**Table 8.** Energy efficiency solutions for the 2 buildings: renewable sources

Utilities of buildings		Solutions - renewable sources	
		Case study 1	Case study 2
Heating / cooling system	Source of hot water consumption	Geothermal water / 2 reversible heat pumps, ground-water type, with useful thermal power $P_u=140$ kW, which work with 20 geothermal probes each for heating and air conditioning, and 4 heat pumps, air type / soil-water, with useful thermal power $P_u=50$ kW for heating and air conditioning	3 reversible heat pumps, soil-water type, with useful thermal power $P_u=170$ kW, which work with 20 geothermal probes each for heating and air conditioning, and 3 heat pumps, air/soil-water type, with useful thermal power $P_u=60$ kW that work with 6 geothermal probes each for heating and air conditioning
	Source of heating		
Ventilation		Natural / local ventilation system with over 90% heat recovery and 100% fresh air supply	
Lighting	Natural	The interior rooms directly provide natural light	
	Artificial	Renewable energy production system (REPS)	
Renewable energy production system (REPS) which contains: <ul style="list-style-type: none"><li>• photovoltaic panel system;</li><li>• integrated system of storage for additional photovoltaic produced electricity.</li></ul>			

**Table 9.** Investment value / Cost of energy saving unit / investment recovery time

Building	Inventory value of the construction [thousands of euros]	The value of the investment [thousands of euros]	Cost of energy saving unit [euros]	Total energy savings / year of operation [thousands of euros]
Case study 1	8,509	7,657	0.1268	8,045 / 11 <sup>th</sup> year
Case study 2	16,149	7,954	0.1222	7,955 / 10 <sup>th</sup> year



1. Thermal rehabilitation of the insulation – ecomaterials
2. Rehabilitation of the heating system – renewable energy
3. Rehabilitation of the ventilation system with heat recovery (>90%) and fresh air supply (100%)
4. Arrangement of cooling system – renewable energy
5. Rehabilitation of the energy supply and lighting system – LED input
6. Disposition of renewable energy production system (SPER)
7. BMS (Building Management System)
8. Replacing lifts with energy efficient equipment

Initial building	Energy efficient building	Savings %
[tonnes equivalent CO <sub>2</sub> / year]		
Case study 1		
1855	423	77.20
Case study 2		
1517	497	67.24

