



HAL
open science

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

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

3

4 **Marcela Prada¹, Ioana Francesca Prada², Monica Cristea², Popescu Daniela³,**
5 **Constantin Bungău⁴, Lotfi Aleya*⁵, Constantin C. Bungău^{1,2}**

6

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

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

12 ³Department of Computers and Information Technology, Faculty of Electrical Engineering
13 and Information Technology, University of Oradea, Oradea, Romania;
14 depopescu2012@gmail.com (P.D.E.);

15 ⁴Department of Engineering and Management, Faculty of Management and
16 Technological Engineering, University of Oradea, Oradea 410087, Romania;
17 bungau@uoradea.ro (C.B.)

18 ⁵Chrono-environnement CNRS 6249, Université de Franche-Comté, Besançon, France;

19

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

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

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

23 **Abstract**

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

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

38

39

40

41

42

43

44

45

46 **1. Introduction**

47 Global warming is a real and serious issue for humanity in the fight for the protection and
48 conservation of the environment, and even life itself. In the concerted action to protect the
49 planet from the effects of this heating and climate changes, a relevant role is played by the
50 energy saving. Due to high energy consumption buildings and construction sectors were
51 proved to be among the major factors impacting the environment (Junnila and Horvath,
52 2003). Greenhouse gas emissions of buildings along with their energy consumption
53 (operationl energy consumption) are threatening the environment as well as our economic
54 and social future (Shoubi et al., 2015; Bribián et al., 2009).

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

61 In both developed and many developing countries, significant quantities of fossil fuel
62 energy are consumed in the health sector, even if there are no proper figures for many of the
63 countries (Badulescu et al., 2019; Badulescu et al., 2020). Energy consumption in the health
64 sector and the associated greenhouse gas emissions should be systematically evaluated and
65 measured worldwide. However, some anecdotal evidence exists. In the US, about \$ 6.5
66 billion is spent in the health care sector per year, with hospitals being the second important
67 energy consumers (GGHH, 2012). World health expenditures were US\$ 5.3 trillion in 2007,
68 about 8-10% of global Gross Domestic Product or US\$ 639 per person each year (WHO,
69 2010).

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

75 The present paper is focused on the existing buildings with hospital functions,
76 energy-consuming, currently energy inefficient. At the same time, it is in line with the key
77 objectives and EU policies adopted in 2014 through *“The 2030 climate and energy
78 framework: 1). “At least 40% cuts in greenhouse gas emissions (from 1990 levels); 2). At
79 least 32% share for renewable energy; 3). At least 32.5% improvement in energy efficiency”*.
80 The scheme facilitates the evolution to an economy with reduced carbon emissions and
81 designs an energy model effective for health and environment – e.g. by diminishing air
82 contamination (clim (EC): 2030). The work is based on two case studies (two large buildings
83 from Oradea, Romania, dating from 1968-1989, with the function of hospitals) to which
84 energy efficiency and modernization are performed, ensuring superior comfort of the
85 ambient environment.

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

93

94 **2. Materials and Methods**

95 The constructions on which the study is carried out are two large buildings, comparable
96 in width, size and volume, having similar functions: the building of the Oradea Clinical
97 County Hospital and the building of the Municipal Clinical Hospital “Dr. Gavril Curteanu”,
98 both located in the city of Oradea, the northwestern part of Romania. The two hospital units
99 serve in a city population of $\cong 200,000$ inhabitants and in a county of 564, 000 inhabitants,
100 also considering the existence of the medical tourism (Badulescu et al., 2014). The
101 importance class of buildings is class I, according to (P 100, 2013): having essential
102 functions, for which the integrity preservation during earthquakes is vital for the civil
103 protection, such as: (a) Hospitals and other buildings in the health system, which are
104 equipped with emergency / ambulance services and surgery units. The importance category
105 is B, according to (H.G.R. 766, 1997): constructions of special importance (b). The city of
106 Oradea is located at the intersection of the coordinates $47^{\circ} 03' 05''$ north latitude and $21^{\circ} 56'$
107 $25''$ east longitude, in the Crisurilor Plain (Western Plain). The greatest part of the relief is
108 formed by the Crisului Meadow (average elevation $\sim +125$ m from the Black Sea), subunit of
109 the Crisurilor Plain, and to a lesser extent by the valleys tentacularly formed in the Northern
110 Hills by the Paris, Umbrosu, Sotiteag, Salbatec streams and temporary pluvial ones. The area
111 proposed for investment is located at a distance of 10, respectively 13 km from the Hungarian
112 border.

113 The area is characterized by the following climatic particularities: climatic zone of
114 summer temperature values, III $T_e = +28^{\circ}\text{C}$ (exterior temperature); climatic zone of winter
115 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 CO₂ 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

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

141 The framing of both constructions is in the seismic risk class III (minimum performance
142 requirements for taking over the seismic actions, respectively constructions that, under the
143 effect of the design earthquake, may present structural degradations that do not significantly
144 affect the structural safety, but for which non-structural degradations may be important
145 (Cluster Zepher, 2017a,b); the buildings are characterized by a seismic coefficient
146 (acceleration of the land for design) $a_g=0.15$ g and the corner period $T_c=0.7$ sec (P100,
147 2013).

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

154

155 *2.1. Case study 1*

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

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

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

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

171 *2.2. Case study 2*

172 It analyzes the building of Oradea Clinical County Emergency Hospital (Cluster Zepher,
173 2017b). The building comprises the hospital body (H2) itself and the body of the polyclinic
174 (HP2) (**Figure 1b**) (Proidea, 2019). The existing building of the Oradea Emergency Clinical
175 Hospital was built within the investment scheme "700 beds Hospital and Oradea Polyclinic".

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

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

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

187

188 **3. Results**

189 Currently the two buildings are not enveloped, existing significant thermal bridges
190 (**Figure 2a-c and Figure 3a-c**). The characteristic global thermal parameters that describe
191 both initial buildings from the study compared with a reference building (construction with
192 identical geometry and volume, but with the envelope elements corresponding to the
193 minimum thermal resistance required by the current norms (C107/1-7/2005; Mc 001/1,
194 2006; Mc 001/2, 2006; Mc 001/3, 2006; Mc 001/4, 2009) are included in **Table 2**. The
195 parameters found do not correspond to the current norms, since: $G > G_{ref}$, $R_{med} < R_{med-ref}$.

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

202 For the operation of both energy optimised hospital units, the amount of energy required
203 / CO₂ emissions was calculated (**Table 3**), as well as the total annual specific energy
204 consumption (**Table 4**), using the conversion factors of the final energy into primary energy,
205 corresponding to each type of fuel (Mc 001/1, 2006); these values were highlighted in

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

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

208 Taking into account the information mentioned in the description of the two case studies,
209 corroborating the energy consumption of the buildings and reporting their annual
210 consumption, the values highlighted in **Table 5** are obtained; **Table 6** reveals eloquent
211 results for the specific annual level of greenhouse gases (tonnes of CO₂ equivalent).

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

218 Analyzing the values of investments for the energy optimization of the buildings in the
219 two case studies, it turns out that their recovery time was 11 years for the case study 1 and 10
220 years for the case study 2 (**Table 9**). In these calculations, the reference Euro course of
221 4.5172 Lei / Euro (National Bank of Romania), from 2016-12-30, was considered. The
222 proposed façades for the two buildings taken into study, after the thermal rehabilitation, are
223 presented in **Figure 1c and d**.

224

225 **4. Discussion**

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

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

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

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

245 Addressing the subject of protecting the built environment is complex and courageous,
246 the authors considering that "Waste management is a crucial topic for the sustainable
247 development of our society" and "globally, waste generation is expected to grow by
248 approximately 60% by 2050 (Bungau et al, 2018; Popescu et al., 2016;
249 ESWET_Vision2050). The paper draws attention and gives solutions from a new perspective
250 of intelligent waste management: through modernization and energy efficiency interventions
251 of the large existing buildings - energy inefficient and morally used buildings. The intelligent
252 use of energy resources (constructions and existing building elements) is proposed before
253 they reach the stage of non-recyclable waste. Thus, the efficiency of such energy resources is
254 emphasized differently. From this perspective, the following must be interpreted: due to
255 modern technologies, waste operation becomes a process of integration and supply
256 management of waste, decreasing the use of primary materials, reusing and turning

257 non-reusable waste into an important resource for the entire society (Bungau et al, 2015;
258 Bungau et al, 2019). To achieve this objective, the first action to be taken is to gradually
259 reduce the polluting dumpsites (ESWET_Vision2050).

260 It is suggested in this paper an integrated approach of a model of energy efficiency for
261 the old hospital buildings existing in Romania, with their transformation into intelligent
262 buildings, respectively Near Zero Energy Building (NZEB), in conjunction with the
263 intelligent and efficient management of possible "waste". This proposal can be considered a
264 good practice model and can be implemented in Eastern Europe and beyond, for a clean
265 Europe, with neutral climate, for an unpolluted planet. Thus, a new tool is provided for
266 becoming Climate-Neutral by 2050 – a long term program for a modern, profitable, climate
267 neutral and combative EU economy that: increases the advantages of energy efficiency also
268 incorporating zero emission constructions; increases the use of electricity and alternative
269 energy to completely eliminate the carbon emissions from the energy reserve of Europe;
270 adopts clear, secure and associated mobility; facilitates a circular European economy and
271 a competitive industry to determine the decrease of GHG emissions; creates a proper,
272 intelligent system of interconnections and infrastructures; takes full advantage of the
273 bioeconomy and designs proper carbon sinks; deals with the rest of CO₂ emanation using
274 Carbon Capture and Storage (CCS) (EC, clim(EC): Going Climate-Neutral by 2050).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

353 In the diagram presented in **Figure 6** it is summarized and underlined that the energy
354 efficiency of buildings of special importance with the function of hospital, similar to those
355 that have been the subject of case studies 1 and 2, is in line with the European directives for
356 2020 European Commission, Climate Change, 2020 (EC, clim(EC): 2020/ 2030 (EC,
357 clim(EC): 2030) and creates the premises for a clean planet and a neutral climate, promoted
358 by the Long-term Strategy for 2050 (EC, clim(EC): 2030). In the current research, after
359 achieving the energy efficiency, each of the two buildings will have the energy performance
360 corresponding to class A, as shown in Table 4 confirm.

361 Corroborating all the data obtained in this research, the following results are obtained: 1)
362 renewable energy covers over 62.68% / 75.51% of the energy consumption needed for
363 heating / air conditioning and for the production of domestic hot water; 2) reducing CO₂
364 equivalent emissions by 77% / 67%, with a direct positive impact on global warming, on
365 pollution and emissions reduction respectively; 3) the proposed solutions bring benefits from
366 the point of view of reducing heat losses, and of improving the comfort of the respective
367 interior environment and of the energy efficiency; from this perspective, the proposed
368 intervention measures lead to a reduction of the annual primary energy consumption of 71.82%
369 / 78.39% compared to the initial consumption, the proposal of the present work being to
370 apply these solutions to all similar buildings made in the 1970s at least in Romania, with a
371 "70-70-70" efficiency, with a 10-year investment recovery period.

372 The presented solutions are environmentally friendly, as follows:

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

385 In response to the European Commission demands for an Europe with a neutral climate
386 until 2050, the paper deepens the problems of the European strategy and gives a solution
387 through which Eastern Europe moves towards a neutral climate, making investments for
388 adequate solutions, enabling people, acting in important fields: financial, research, industry
389 and providing social equity to obtain a proper transition (EC, clim(EC): 2050; EC clim(EC)).
390 The present study points out the importance of restauration for the buildings in use with the
391 purpose to decrease the consequences of climate variations, to reach the 20-20-20 EU energy
392 objectives (Ghemis et al., 2019; European Council: Conclusions 2030) in concordance with
393 the perspective formulated by EU authorities in the Energy Roadmap 2050: Guideline
394 towards a competitive economy with low carbon emissions in 2050 (Sturk; EC, clim(EC):
395 2020).

396

397 **5. Conclusions**

398 The results of this paper show that applying intelligent energy efficiency solutions of
399 buildings of special importance with the "Hospital" function contributes substantially to the
400 concerted efforts to protect the planet and the environment, while at the same time agreeing
401 and supporting the European strategies 2020-2030 and 2050, which tend towards a clean
402 planet and a neutral climate. The paper proposes the implementation of a program with a
403 stake of "70-70-70" over a period of 15 years, which will stimulate the energy efficiency of
404 all similar buildings of special importance in Eastern Europe. The design, execution and
405 recovery of the investment fall within this range. Reaching the target "70-70-70" aims at:
406 70% reduction of greenhouse gas emissions of the building, use of renewable energy in
407 proportion of 70% of the total energy consumed, and energy efficiency of the building by
408 70% (the energy performance corresponding to class A). At present, in the current state, these
409 studied buildings can be considered as "polluting deposits", the authors suggesting their
410 transformation into a valuable resource for the society by using new design and efficiency
411 solutions.

412

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

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

415 **Acknowledgments:** None

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

417

418

419

420 **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-completarea-reglementarii-tehnice-normativ-privind-calculul-termotehnic-al-elementelor-de-construcție-ale-clădirilor-indicativ-c-107-2005-aprobata-prin-ordinu/2016>
452
453 (accessed at 12 Nov. 2019).

454
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;
- 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-professionals-to-achieve-european-energy-targets>. (accessed at 02.01.2020).
- 481 EC (European Comission). clim(EC): 2030 climate & energy framework.
482 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. (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
489 (accessed at 02.01.2020).

- 490 European Council. Conclusions on 2030 Climate and Energy Policy Framework, Brussels,
491 24 October 2014.
492 https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145356.pdf;
- 493 GGHH (Global Green and Healthy Hospitals) 2012. A Comprehensive Environmental
494 Health Agenda for Hospitals and Health Systems Around the World.
495 [http://greenhospitals.net/wp-content/uploads/2011/10/Global-Green-and-Healthy-Hos-](http://greenhospitals.net/wp-content/uploads/2011/10/Global-Green-and-Healthy-Hospitals-Agenda.pdf)
496 [pitals-Agenda.pdf](http://greenhospitals.net/wp-content/uploads/2011/10/Global-Green-and-Healthy-Hospitals-Agenda.pdf)
- 497 Ghemis M.T.; Scurt A.A.; Bob C.; Bungău C. An Analysis of Sustainability about
498 Rehabilitation and Reconversion of an Old Building: The 19th National
499 Technical-Scientific Conference „Modern Technologies for the 3rd Millenium”, 2019,
500 Romania, 273-278.
- 501 H.G.R. 766. Hotărâre de Guvern pentru aprobarea unor regulamente privind calitatea în
502 construcții. Ministerul Lucrărilor Publice și Amenajării Teritoriului. (In English:
503 Decision of the Government of Romania H.G.R. 766. Government Decision for the
504 approval of some regulations regarding the quality in constructions. Ministry of
505 Public Works and Land Use Planning), România. 1997.
- 506 Junnila S.; Horvath A. Life-cycle environmental effects of an office building. *J Infrastruct*
507 *Syst* (2003), pp. 157-166.
- 508 Mc 001/1 – 2006. Methodology for calculating the energy performance of buildings; part I -
509 Building envelopment. (in Romanian: Metodologie de calcul a performanței energetice
510 a clădirilor; partea I – Anvelopa clădirii.) Available online:
511 [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_3_2006.pdf)
512 [_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).
- 513 Mc 001/2 – 2006. Methodology for calculating the energy performance of buildings; Part II -
514 Energy performance of installations. (in Romanian: Metodologie de calcul a
515 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
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
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
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

566 approaches. Ain Shams Engineering Journal, 2015, 6(1), 41-55.

567 <https://doi.org/10.1016/j.asej.2014.09.006>.

568 Sturk, M. Transport White Paper, Climate Roadmap & Quantitative Modelling Results EU

569 Transport GHG: Routes to 2050 II - 1st Stakeholder Conference.

570 [http://www.eutransportghg2050.eu/cms/assets/Uploads/Meeting-Documents/2.-Route](http://www.eutransportghg2050.eu/cms/assets/Uploads/Meeting-Documents/2.-Routes-to-2050-II-2050-Roadmap-Conf29Jun11-MS-FINAL.pdf)

571 [s-to-2050-II-2050-Roadmap-Conf29Jun11-MS-FINAL.pdf](http://www.eutransportghg2050.eu/cms/assets/Uploads/Meeting-Documents/2.-Routes-to-2050-II-2050-Roadmap-Conf29Jun11-MS-FINAL.pdf)

572 Vesselenyi, T.; Bungau, C.; Husi, G. Research equipment and computation techniques for

573 intelligent building applications. 2014 IEEE/SICE International Symposium on

574 System Integration, Tokyo, Japan, 228-233.

575 WHO (World Health Organization), 2010. Health in the Green Economy: Co-Benefits to

576 Health of Climate Change Mitigation. Health Facilities.

577 https://www.who.int/hia/hgebrief_health.pdf

578

579

580

581

582

583

584

585

586

587

588

589

590

591

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. CO₂ 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.

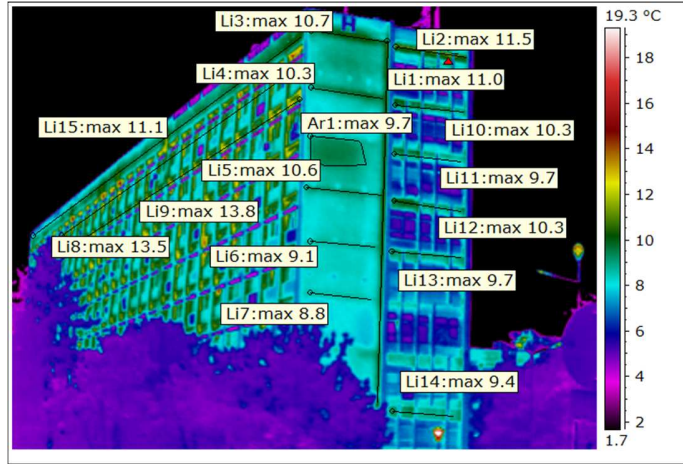


c.

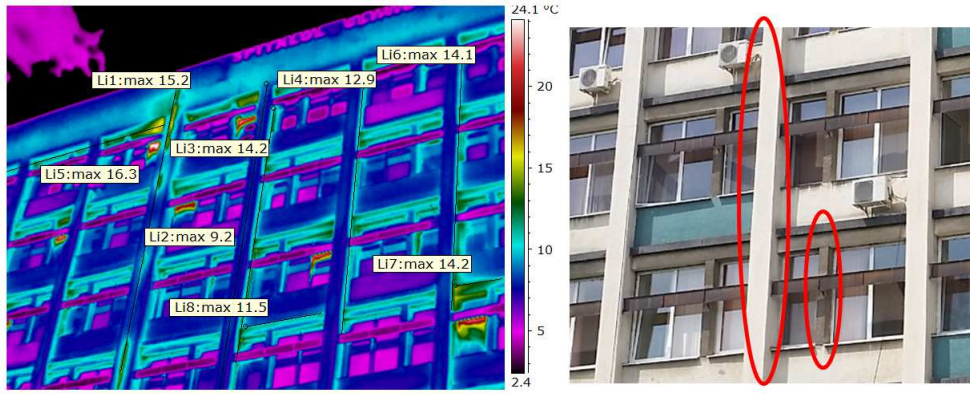


d.

Figure 1.



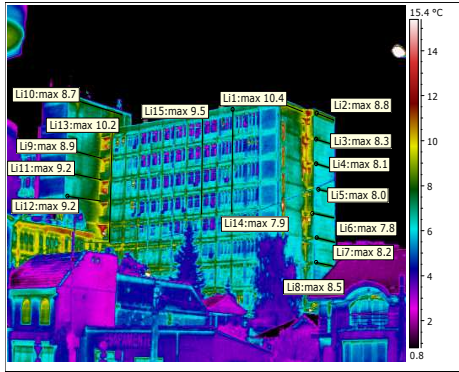
a.



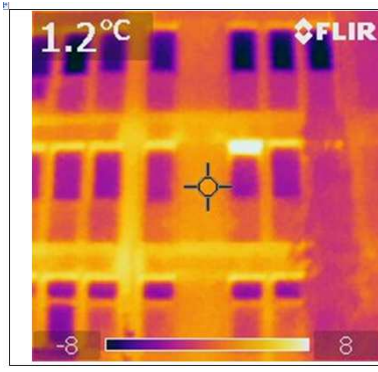
b.

c.

Figure 2.



a.



b.



c.

Figure 3.

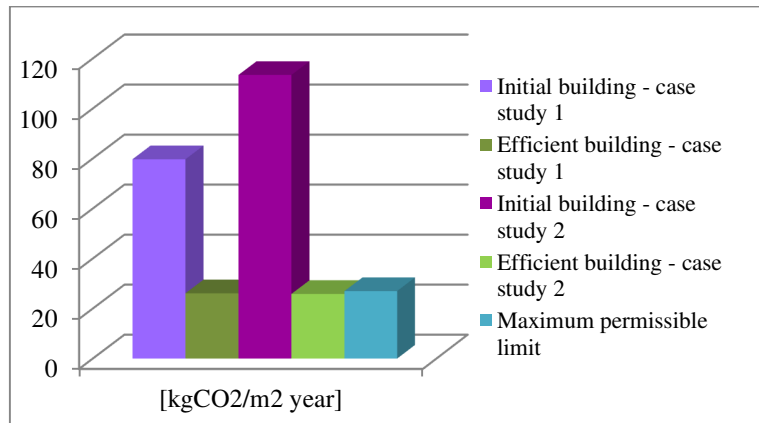
Energy performance certificate	Energy performance of the building		Energetic Score: 75	
	Certification system: Building Energy Performance Calculation Methodology		Certified building	Reference building
	High energetic efficiency			
	Low energetic efficiency			
	Specific annual energy consumption [kWh/m²an]		283,93	147,56
	CO ₂ equivalent emission index [kg _{CO2} /m²an]		79,72	56,96
	Specific annual energy consumption [kWh/m²an]		Energy class	
			Certified building	Reference building
	Heating:	177,69	D	A
Hot water for consumption:	58,01	C	C	
Air-conditioning:	33,75	B	B	
Mechanical ventilation:	-	-	-	
Artificial lighting:	14,48	A	A	
Specific annual renewable energy consumption [kWh/m²an]: 75,52				

a.

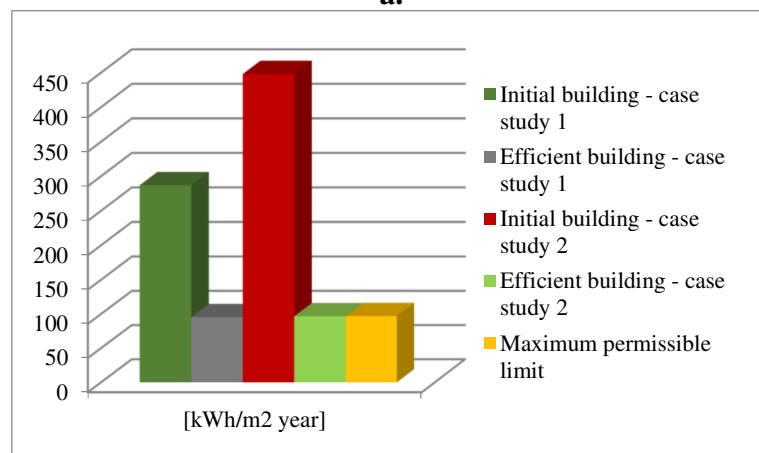
Energy performance certificate	Energy performance of the building		Energetic Score: 53	
	Certification system: Building Energy Performance Calculation Methodology		Certified building	Reference building
	High energetic efficiency			
	Low energetic efficiency			
	Specific annual energy consumption [kWh/m²an]		447,88	283,11
	CO ₂ equivalent emission index [kg _{CO2} /m²an]		113,43	69,38
	Specific annual energy consumption [kWh/m²an]		Energy class	
			Certified building	Reference building
	Heating:	324,21	E	D
Hot water for consumption:	98,93	E	C	
Air-conditioning:	23,39	B	A	
Mechanical ventilation:	-	-	-	
Artificial lighting:	1,35	A	A	
Specific annual renewable energy consumption [kWh/m²an]: 0				

b.

Figure 4.



a.



b.

Figure 5.

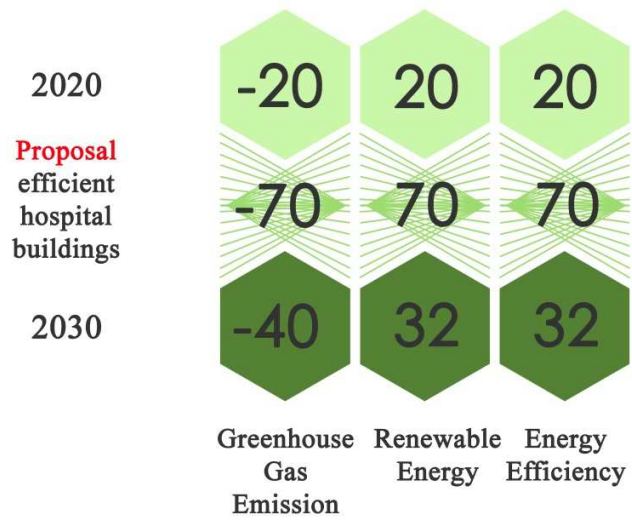


Figure 6.

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 ² K/W	0.512	0.545
The average corrected thermal resistance of the existing building	R _{med}	m ³ K	0.586	0.479
The global coefficient of thermal insulation of the reference building	G _{ref}	m ² K/W	0.220	0.178
The average corrected thermal resistance of the reference building	R _{med-ref}	W/m ³ K	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 ₂	e _{CO2} ^{an}	kgCO ₂ /m ²	79.72	113.43

Table 3. Energy consumption / CO₂ emissions / year

Functions	Consumption (fossil fuels)	Consumption (renewable sources)	CO ₂ emissions	Specific energy consumption
	kWh/year		kgCO ₂ /m ² year	kWh/m ² 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 CO₂ 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 ²	95.34	96.76
Total emissions of CO ₂	kg CO ₂ /m ²	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 ²	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 ₂ / 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

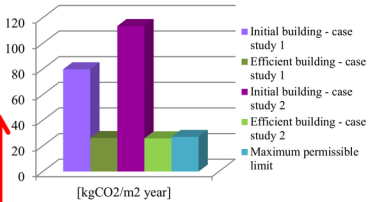
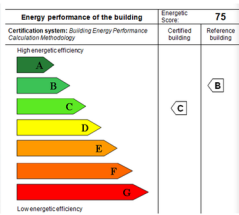
Primary energy	Initial building	Energy efficient building	Savings %
Case study 1			
Thermal energy	4034,179	225,106	94.4
Electricity	2404,861	513,413	78.6
Total	6439,040	738,519	88.5
Case study 2			
Thermal energy	6367,992	233,810	96.3
Electricity	254,127	124,037	51.2
Total	6622,119	357,847	94.6

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"> • photovoltaic panel system; • integrated system of storage for additional photovoltaic produced electricity. 			

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 th year
Case study 2	16,149	7,954	0.1222	7,955 / 10 th 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 ₂ / year]		
Case study 1		
1855	423	77.20
Case study 2		
1517	497	67.24

