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Case Study Regarding the Evaluation of Carbon Dioxide in Modular Tiny Houses

Studiu de caz privind evaluarea dioxidului de carbon în casele mici modulare

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Abstract. *Indoor air quality plays an important role both in the well-being of occupants as well in the efficiency of the performed activities - either they are of an intellectual or physical nature. In this paper, after a general presentation of the main pollutants of indoor air environment, the authors have proposed a study, based on experimental measurements, about the concentration of carbon dioxide in a tiny house, that is part of a larger Start Up Nation project, which proposed several types of prefabricated modular constructionst.*

Key words: Air Quality, Modular Buildings, Pollutants, Carbon Dioxide

1. Introduction

After 1989, there were several currents in our country regarding the construction of residential buildings. In a first stage, as an anti-reaction to the fact that most people lived in modest size apartments, in residential blocks built according to standardized projects, those with financial possibilities opted for single-family buildings, often characterized by excess space. Over time, the disadvantages of living in such big houses have been found, which are mainly aimed at high maintenance costs and energy consumption. Multifamily buildings were then built, also with generous spaces. With the change of generations and the migration of the rural population in the urban area – as source of jobs, the need for new living spaces appeared. Thus, the housing fund has become very different, to satisfy customers with various material possibilities.

A solution that has timidly started to develop in the last years, has been modular houses, which responds to the alert lifestyle, specific to the period we are going through. They are well suited as small dwellings, but can be extended to various destinations, such as holiday homes, social houses that can be fast build in disaster areas. In the unfortunate context of the pandemic caused by Sars Cov 19, in which home office was practiced and families were isolated, frequently appeared the phenomenon to acquire a plot of land near urban areas or in remote areas, on which one can install this type of construction, to which the authorization part is easier.

Due to their small size, they can be transported, without major efforts, by road or rail - if the infrastructure allows [1]. Modular constructions represent an efficient and economical alternative to build, in which the beneficiary of the house can have the certainty of a quality construction, in a relatively short time, made in optimized conditions by specialists in the field, at a mutually agreed price, without further adjustments [1]. At the same time, are characterized by low energy requirement both in the execution and in exploitation phase.

A challenge that these houses pose to specialists in the field of architecture, as well to those in the field of civil engineering and building services, is to ensure a living climate that meets the requirements of normative, to ensure the well-being of occupants. One refers to the indoor environmental quality, which is a more complex concept, respectively to the indoor air quality.

In this paper, the authors' attention focuses on a study on indoor air quality, abbreviated IAQ. After a presentation of the main indoor air pollutants and the main measures for their elimination or reduction, a set of measurements were performed to verify whether, in the case of small volumes of air - as is the case of these modular constructions, an appropriate level of CO_2 is maintained, which does not adversely affect the health of the occupants.

2. Aspects regarding indoor air quality

If outdoor air quality has been in the public attention for several decades, with the primary objective of monitoring greenhouse gases, indoor air quality in residential buildings has been less approached. IAQ has been studied primarily in spaces with special destinations, such as chemical laboratories, pharmaceutical laboratories, hospitals - surgical blocks, workshops in which they work with volatile or semi-volatile substances, etc.

Nowadays, due to the fact that, on average, people spend 60-90% of their time indoors - houses, workplaces, commercial spaces, performance halls, sports halls etc., IAQ also becomes extremely important.

Gases, vapors and odors arise in residential buildings through the release of the human body (carbon dioxide, ammonia, methane, acids, etc.), emanations from furniture, carpets, paintings, paints and other building materials (formaldehyde), by combustion and heating processes (carbon oxide, fuel vapors), by cleaning, by infiltration of external air - polluted with exhaust gases or coming from industrial areas, by preparing meals in the kitchens, from baths, from chemical reactions produced by molds, fungi, or other decaying products [2], [3], [4].

In the indoor air one can find up to 8000 harmful compounds, some from humans, others from building materials and/or from outside. Indoor air pollutants can be grouped, as follows [2], [5]:

- Pollutants from the outside air, which enter either with the occupants, or through natural or mechanical ventilation, without a proper filtration;
- Pollutants that are released into the interior space:
    - Biological pollutants - resulted from the releases of the human body (CO_2), respectively bacteria, viruses, pet hair, pollen, pests; also, here one can categorized mites, mold, generated by wet, unhealthy structure of the constructure or by maintaining a high level of humidity;
    - Volatile organic compounds (VOC) or semi-volatile (SVOC) - emitted from various household products, such as paints, adhesives, sprays, at certain temperatures;
    - Particulate Matter (PM) or fine particles (PM2.5) - Emitted by stoves, heaters, fireplaces where the combustion of fuel takes place;
    - Carbon monoxide (CO) - Emitted from stoves, heaters, tobacco smoke, burning candles;
    - Nitrogen dioxide (NO_2) - Emitted from improperly ventilated stoves, cigarette smoke;
    - Ozone - if the upper layer of ozone in the atmosphere is beneficial because it provides protection against ultraviolet radiation, at ground level it is an odorless pollutant, with negative effects on the airways and some household items (books, furniture, fabrics); it can also raise the level of other contaminants; ozone is formed as a result of chemical reactions between nitrogen oxides and VOCs, in the presence of light;
    - Radon - odorless and colorless radioactive gas formed naturally by the decomposition of uranium that can be found in certain soils; it can penetrate underground buildings, through foundations, basements or cracks;
    - Cigarette smoke, which will be further develop.

A very particular pollution is that due to cigarette smoke which contains a significant number of particles, both solid and gaseous, 1 gram of tobacco producing 0.5 liters of smoke. A single cigarette releases 70 mg of CO [6]. In order not to exceed the limit value of 5 ppm CO, it is necessary to ensure a volume of fresh air of 12.5m^3/h (knowing that 1mg/m^3 CO = 0.9 ppm) [6]. Non-smokers (especially children and sick people) suffer from mucosal and respiratory tract irritations. The most harmful compounds are carbon monoxide and nicotine, which, even in low concentrations, can cause nausea and the debut of intoxication to sensitive individuals. In public places due to the controversial anti-smoking law, in many countries, this type of pollution has been eliminated. But this restriction does not apply to residential buildings and therefore specialists must inform about the negative effects on the occupants.

All these pollutants have negative effects on human health, such as: respiratory problems, the disease known as "building illness syndrome", asthma, mucosal irritations, headaches, nausea, promote lung cancer and in extreme cases can cause death, such as the case of CO intoxication. It also decreases the body's immunity.

In other words, it is essential for a healthy life to monitor these contaminants which, in addition to the suffering of people who are affected by their negative effects, ultimately turn into high costs for the health system.

Measures to eliminate these pollutants are numerous and depend on the type of pollutant.

Thus for those coming from the outside air one can mention [2], [7]:

- ✓ the use of carpets / rugs at the entrance of the houses;
- ✓ careful placement of inlets for the supply of fresh air and filtered air;
- ✓ proper ventilation of the indoors so as to ensure the air exchange rate, without excess, in order to not increase energy consumption;
- ✓ protection against pests;
- ✓ maintaining adequate pressure connections between spaces with various destinations;
- ✓ ensuring the conditions for a proper humidity of the envelope both in the construction phase and in the operation phase of the house.

Regarding the measures that can be taken to eliminate or maintain below the limited values of the indoor pollutants, one can mention [2], [5], [7]:

- ✓ the use of a ventilation or air conditioning system adequate to the space and the demands of the residents;
- ✓ careful selection of the construction materials;
- ✓ elimination as much as possible, respectively limiting the materials that emit VOCs, SVOCs or in case their use is necessary, ensuring a volume of fresh air to counteract their negative effects;
- ✓ keeping a humidity level in the interval imposed by the comfort standards (guidance, relative humidity φ = 35-70%);
- ✓ elimination of smoking inside of dwellings;
- ✓ awareness of healthy cooking and elimination of fried foods in kitchens, respectively the use of hoods to locally extract pollutants, like smoke, chemicals and hazardous particles (PM 10, PM 2.5);
- ✓ maintaining the proper cleaning and hygiene of the spaces, in parallel with the selection of cleaning products;
- ✓ knowledge of reactions regarding air chemistry and reactions that can lead to toxic elements;
- ✓ use of houseplants;
- ✓ attention in the choice of pets;
- ✓ use of air purifiers.

As mentioned above, it has been found that there are a multitude of pollutants, which makes it impossible to monitor quantitatively and qualitatively each of them. In this context, Professor Fanger proposed that all these compounds to be measured by a single parameter: odor, for which purpose he also defined the unit of measurement called OLF. The principle of the method is, in fact, to accept the hypothesis that, by eliminating the odor through ventilation, will simultaneously eliminate all other undetectable pollutants at permissible concentrations values [8].

This method was not unanimously accepted, so it remains as a possibility to follow the indoor air quality the performing of measurements for certain types of pollutants considered essential.

3. Case study

The concentration of CO_2 results mainly from expiration, as well as from combustion, respectively other processes that can take place in the residence.

The CO_2 flow resulting from expiration can be calculated using the equation [9], [10]:

$$G = 4 \cdot 10^{-5} M \cdot S_c \quad (1)$$

where,

G – CO_2 flow from expiration [l/s];

M- specific metabolism [W/m^2];

S_c - the area of the body [m^2], which can be consider approximately 1.8 m^2, respectively can be calculated according to du Bois's formula [11]:

$$S_c = 0.203 \cdot 10^{-4} m^{0.425} h^{0.725} \quad (2)$$

where,

m - the weight of the person [Kg];

h - the height of the person [m].

But, given that CO_2 production is not solely due to expiration, a rigorous method for monitoring it is the effective measurements.

The amount of CO_2 is expressed in either [ppm] or [mg/m^3], and according to the current standards, the concentration allowed is 0.5% from the indoor air [10].

The measurements were performed in a modular construction launched in a Start Up Nation project, through which several types of modular houses were proposed and constructed. The authors have contributed to the conception of these constructions. The tiny house is located in Podeni - Cluj County and has the floor plan represented in Fig. 1, respectively the vertical section presented in Fig. 2.

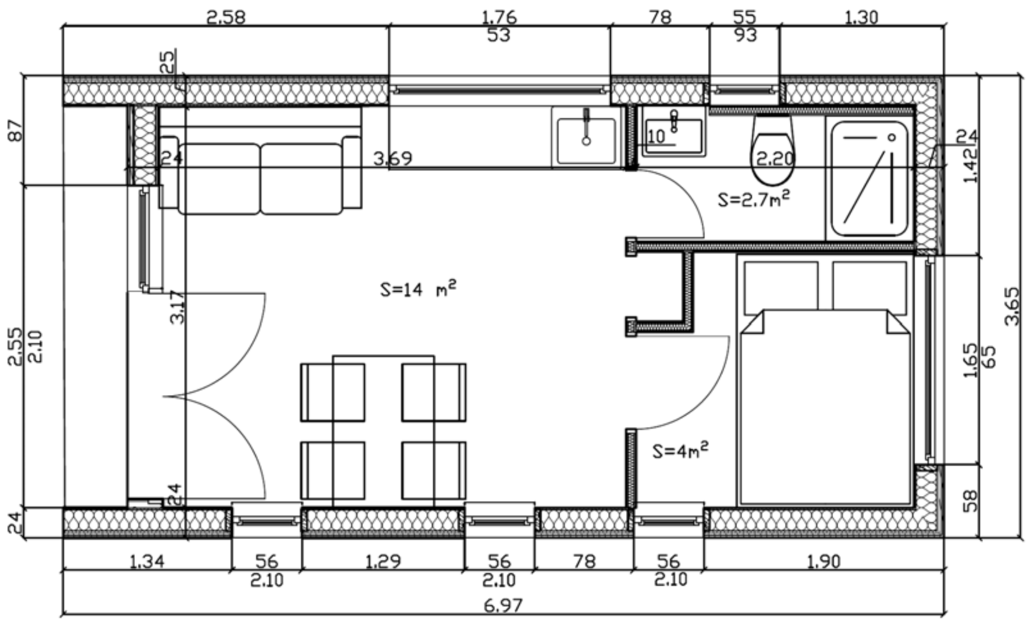

Fig. 1. Floor plan of the modular house

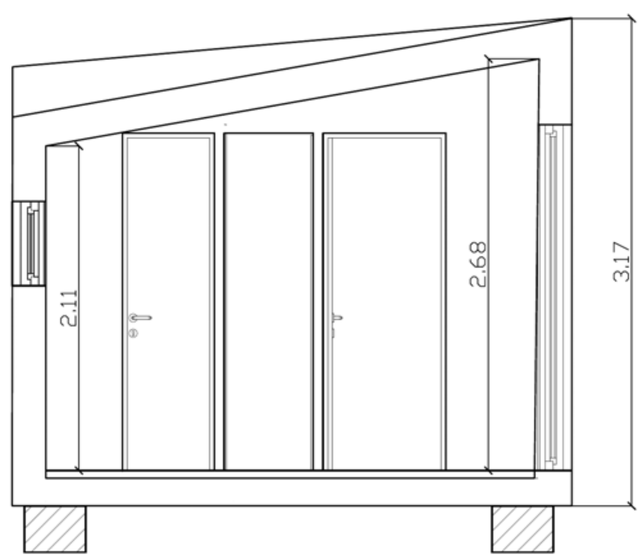

Fig. 2. Section of the modular house

The house is composed of 3 modules with a total living area of 19 m^2, namely: a module that includes the bathroom and bedroom, and two modules are built for an open space for kitchen and living room and was designed as a holiday home serving 2-4 people.

In order to determine if the IAQ conditions are met in terms of CO_2 concentration, it was established that measurements will be made in the bedroom during the night and in the living area during the day. Based on the plan and the section, the air volumes in the two rooms were calculated.

From the vertical section can be observed that it has a trapezoidal shape, and the height regime differs in the bedroom area from leaving area. Thus, the volume inside resulted, and implicitly the volume of air, is V_1 =10 m^3 for the bedroom, respectively V_2 =26 m^3 for living and kitchen area.

The role of the measurements presented in the charts below is to determine whether the air quality requirements are met in a house with a small volume of air or whether additional methods are needed to ensure the necessary oxygen throughout 24 hours.

It was decided to perform measurements in the two spaces, knowing that the type of activity influences a person's breathing. Thus, in the bedroom we have reduced activity or rest type, while in the kitchen- living area we consider a normal activity.

The measurements were made using Netatmo Smart Indoor Air Quality Monitor, device which monitors the level of CO_2, temperature, humidity and noise level at the same time. The CO_2 meter has a range from 0 to 5000 ppm and ± 50 ppm accuracy (from 0 to 1000 ppm) or ± 5% (from 1000 to 5000 ppm). The house was occupied by two adults. During the measurements, the outside temperature had values between 12˚C and 23˚C through the day and between 8˚C and 12˚C through the night.

In a first phase, the concentration of CO_2 was measured in the bedroom, during the night, with all the windows closed. The windows were closed from 20:00 to 07:00 when the house was ventilated by opening the windows. In order to have minimal heat loss during the cold season, the construction was very well insulated and hermetically sealed. For this reason, high values of the CO_2 concentration can be observed in Fig. 3.

The concentration of CO_2 increased from 400 ppm to 2800 ppm, far exceeding the recommended limit at the end of the night. ASHRAE standard, recommends that indoor CO_2 concentrations to be below 700 ppm to ensure human health [2],[12].

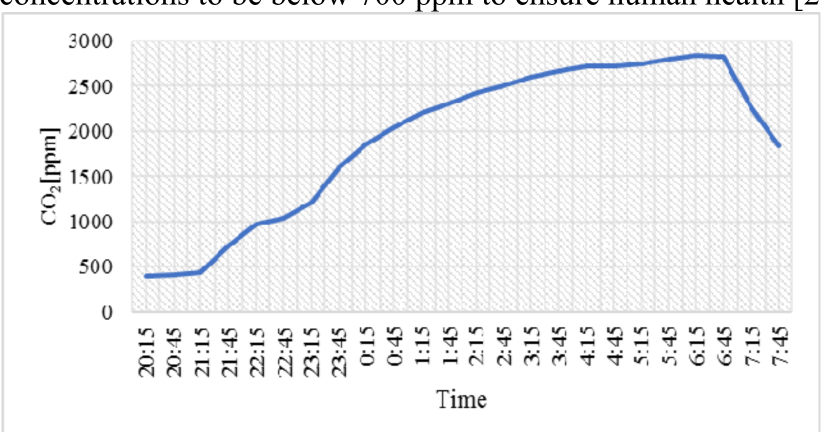

Fig. 3. CO2 concentration during the night – without ventilation

As a measure to reduce CO_2 concentrations during the night, a window was left ajar in the living area with the door to the bedroom open, and the air quality was monitored again. Thus, as can be seen in Figure 4, the CO_2 level remained within the comfort limit imposed by the standards.

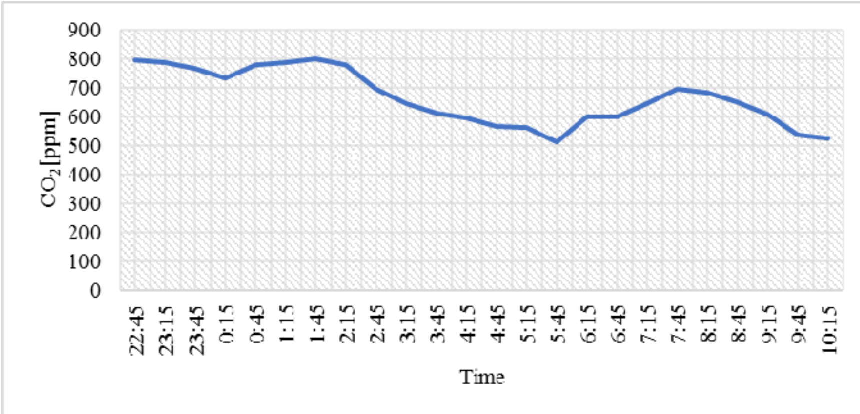

Fig. 4. CO2 concentration during the night – with open window

During the day, even if the measurements were made with the windows closed, the values of CO_2 concentration are within the accepted limits due to the natural ventilation achieved by repeatedly opening the entrance door.

Fig. 5. CO2 concentration during the day

4. Conclusions

The measurements performed in the studied tiny house resulted in a series of conclusions presented below.

During the day, the measurements being performed in the living area, with a larger volume of air, even if the windows were closed, the values of the CO_2 concentration were within the limits recommended by standards, respectively between 315 and 680 ppm. In this case, the fresh air was provided exclusively by opening the entrance door.

During the night, in the bedroom characterized by a smaller volume of air, when the ventilation was not achieved, the CO_2 concentration exceeded the recommended limit, reaching values of 2800 ppm, which means that the air in the room is heavily contaminated, with negative effects on health. In this case, it is necessary to use a ventilation method. It was observed that, if the natural ventilation was achieved by leaving a window ajar, the values of CO_2 concentration were within normal limits.

If natural ventilation is not sufficient or cannot be achieved due to extreme outside temperatures (very low or very high), to decrease the concentration of CO_2, mechanical ventilation shall be used without reservation. For energy savings, it is recommended to use an automated ventilation system with heat recovery.

The final goal is to obtain constructions that meet the quality requirements provided by Law 10/1995, amended by Law 123/2007, which refers to: mechanical resistance and stability, fire safety, safety in operation, ensuring hygiene and health conditions, protection against noise, energy saving in correlation with the appropriate thermal insulation of the envelope, durability and easy maintenance. Also, these constructions must integrate perfectly with the environment, without having negative effects on it.

Complaints about lack of oxygen are generally unfounded, as the amount of oxygen in the air does not fall below 16% of the room volume, which does not affect the feeling of comfort. However, there are also places where the CO_2 concentration is too high, frequently exceeding the maximum allowed, which requires air freshening measures.

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Steady state two-dimensional heat conduction in a square cross section, by using Microsoft Excel® for numerical modeling

Modelarea numerică a câmpului de temperatură 2D într-o secțiune pătrată, în regim termic staționar, utilizând aplicația software Microsoft Excel®

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Abstract. *The paper presents a simple way to study and numerically analyze the 2D temperature field in a square cross section of a beam. A new software tool was built and used for this study, using as the main calculation method the finite difference method (FDM). The steady state heat transfer through a body without internal heat sources was considered and the boundary conditions of the first kind (Dirichlet) were applied regarding the values of temperatures on the delimiting surfaces of the body. The solution of the linear equation system (LES) was obtained using the Solver tool from the Microsoft Excel® software application, finding the numerical image of the temperature distribution in the square cross section. Also, all the numerical results have been translated into a graphical form, for a more intuitive view.*

Keywords: heat, transfer, steady state, temperature, 2D, finite difference, Solver, Excel

Rezumat. *Lucrarea prezintă o modalitate de studiu și analiză numerică a câmpului de temperatură 2D într-o secțiune de formă pătrată a unei grinzi. A fost construit și utilizat pentru studiu un nou instrument software, folosind ca metodă de calcul principală metoda calculului cu diferențe finite (MDF). A fost considerat transferul termic în regim staționar, printr-un corp fără surse interioare de căldură și aplicate condițiile la limită de specia 1 (Dirichlet) privind valorile temperaturilor pe suprafețele delimitatoare ale corpului. Rezolvarea sistemului de ecuații liniare (SEL) format a fost efectuată cu ajutorul instrumentului Solver din aplicația software Microsoft Excel®, obținând determinarea numerică a distribuției temperaturii în câmpul secțiunii pătrate. Rezultatele numerice au fost transpuse și într-o formă grafică pentru o vizualizare mai intuitivă.*

Cuvinte cheie: transfer, căldură, staționar, câmp, distribuție, temperatură, 2D, diferențe, finite, sistem, ecuații, liniare, Solver, Excel

1. Introduction

Paper [1] has indicated the way by which, starting from the fundamental law of heat conduction (Fourier) in the general format (1) described by [2], [3], [4], [5], [6], [7], [8] etc.:

$$\frac{\partial t}{\partial \tau} = a \cdot \left(\nabla^2 t + \frac{\dot{q}_{SIC}}{\lambda}\right) \tag{1}$$

considering a steady state heat transfer $\left(\frac{\partial t}{\partial \tau} = 0\right)$ and taking into account the fact that no internal heat sources (IHS) are present ($\dot{q}_{IHS} = 0$), in the case when the temperature variation along one coordinate axis e.g., Oz may be neglected $\left(\frac{\partial t}{\partial z} = 0\right)$, the Fourier equation is expressed in the simplified form (2) [2], [3], [5], [6] etc.

$$\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} = 0 \tag{2}$$

The second-order partial differential equation (2) may be solved approximately by numerical integration techniques e.g., the finite differences method (FDM) [1], [2], [3], [4], [5], [6] etc., using equation (3) which is based on second-order finite differences

$$\frac{\Delta_x(\Delta t_x)}{\Delta x^2} + \frac{\Delta_y(\Delta t_y)}{\Delta y^2} = 0 \tag{3}$$

where $\Delta_x(\Delta t_x)$ and $\Delta_y(\Delta t_y)$ are expressed in the set of equations (4)

$$\begin{cases} \Delta_x(\Delta t_x) = \left(t_{x+\Delta x,y} - t_{x,y}\right) - \left(t_{x,y} - t_{x-\Delta x,y}\right) \\ \Delta_y(\Delta t_y) = \left(t_{x,y+\Delta y} - t_{x,y}\right) - \left(t_{x,y} - t_{x,y-\Delta y}\right) \end{cases} \tag{4}$$

and the first order finite differences, Δt_x and Δt_y are given, for example, in the set of equations (5)

$$\begin{cases} \Delta t_x = t_{x+\Delta x,y} - t_{x,y} \\ \Delta t_y = t_{x,y+\Delta y} - t_{x,y} \end{cases} \tag{5}$$

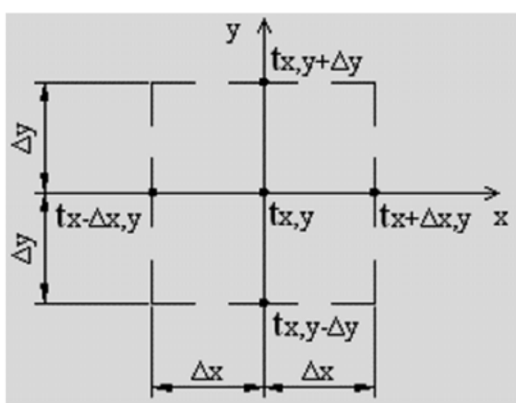

Fig. 1. The temperature $t_{x,y}$ in the node having coordinates (x,y) [1], [2], [3] etc.

When a rectangular mesh (or grid) is considered for representing the nodes in which the temperatures will be calculated, as in Figure 1 [1], [3], [6], [7] etc., the generic temperature $t_{x,y}$ in the mesh node having coordinates (x,y) can be expressed by the means of equation (6):

$$t_{x,y} = \frac{\frac{t_{x+\Delta x,y}+t_{x-\Delta x,y}}{\Delta x^2}+\frac{t_{x,y+\Delta y}+t_{x,y-\Delta y}}{\Delta y^2}}{2\cdot\left(\frac{1}{\Delta x^2}+\frac{1}{\Delta y^2}\right)} \tag{6}$$

In usual cases, a square mesh is used for the 2D analysis of the temperature field, by choosing the same spacing step Δx=Δy=Δ for nodal points generation on both coordinate axes Ox and Oy, so the generic temperature $t_{x,y}$ in a mesh node having coordinates (x,y) is calculated as an arithmetic average of the temperature at the four neighboring nodes (7) [1], [2], [3], [4], [5] etc.:

$$t_{x,y} = \frac{t_{x+\Delta,y}+t_{x-\Delta,y}+t_{x,y+\Delta}+t_{x,y-\Delta}}{4} \tag{7}$$

This paper presents a solution for the numerical calculation of the temperature distribution inside a square cross section, applying boundary conditions of the first kind (Dirichlet), by using the Solver instrument from Microsoft Excel®, with the purpose of solving the linear equation system (LES) obtained after running FDM.

The Solver instrument uses a group of cells from the Microsoft Excel® spreadsheet, directly or indirectly correlated with a certain cell called objective (Set Objective), which contains a value specified by the user (Value Of) or, in some other cases, may be maximized or minimized (Max/Min). With the goal to obtain in the objective cell the desired result by minimizing the computed numerical error, the Solver instrument modifies the initial values provided in certain dedicated cells (Variable Cells), takes into account the specified solving restrictions (Subject to the Constraints) that provide the frontiers of the solutions domain and finally calls a problem-solving algorithm, for example Simplex LP.

The proposed solving method is useful especially when initial data can suffer a series of modifications with respect to the situation studied in a certain solving stage, does not require a special effort from the user for the computer implementation and has the advantage of providing quick results, in both numerical and graphical form.

2. Solving the heat transfer problem

The technical application proposed for solving is described in the following statement:

A reinforced concrete (RC) beam with a square cross section of 40×40 cm, has on one of the surfaces the temperature t_{s1}=150ºC, and on the other surfaces the temperatures $t_{s2}=t_{s3}=t_{s4}$=50ºC (Figure 2).
Using the finite differences method (FDM), determine the temperatures in the nodes of a squared discretization grid having an equal spacing step on the both Ox and Oy axes of coordinates, Δx=Δy=10 cm.

Building the automatic calculation spreadsheet for this application requires the completion of certain work stages that will be described as follows.

First, it is necessary to specify and implement the initial data for the discussed problem i.e., the temperature values t_{s1}, t_{s2}, t_{s3} and t_{s4} on the delimiting surfaces of the square cross section (Figure 3).

It is preferable and recommended to specify the values of the temperatures by treating them as separate variables placed in independent cells, instead of using them as constant values placed directly into the formulas that will be inserted.

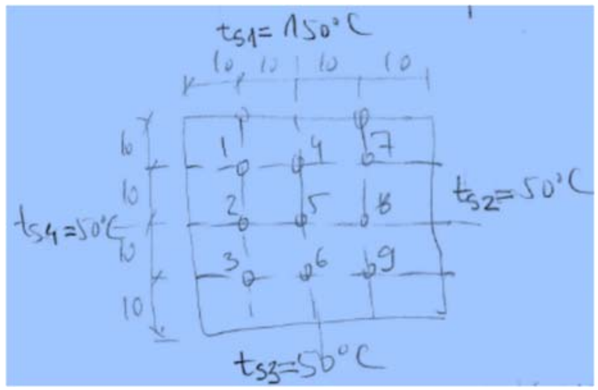

Fig. 2. Squared mesh for nodal temperature calculation (equal step Δx=Δy=10 cm)

When these initial values may suffer some modifications, and especially when it is possible to have different combinations of those values for the study of the 2D field of temperature, the effort of adapting the calculation instrument to the new situation will be largely reduced, by having an easy access to the current values and quickly making the necessary changes.

Marime	ID	U.M.	Valoare
Temp. suprafata 1	ts1	150	C
Temp. suprafata 2	ts2	50	C
Temp. suprafata 3	ts3	50	C
Temp. suprafata 4	ts4	50	C

Fig. 3. Implementing the initial data of the problem (the temperatures t_{s1}, t_{s2}, t_{s3}, t_{s4})

Using relation (7) for expressing the unknown temperatures $t_1 \ldots t_9$ in the nodes of the square discretization mesh from Figure 2, the next equations (8) were obtained

$$\begin{cases} t_1 = \frac{t_{s1}+t_4+t_2+t_{s4}}{4} \\ t_2 = \frac{t_1+t_5+t_3+t_{s4}}{4} \\ t_3 = \frac{t_2+t_6+t_{s3}+t_{s4}}{4} \\ t_4 = \frac{t_{s1}+t_7+t_5+t_1}{4} \\ t_5 = \frac{t_4+t_8+t_6+t_2}{4} \\ t_6 = \frac{t_5+t_9+t_{s3}+t_3}{4} \\ t_7 = \frac{t_{s1}+t_{s2}+t_8+t_4}{4} \\ t_8 = \frac{t_7+t_{s2}+t_9+t_5}{4} \\ t_9 = \frac{t_8+t_{s2}+t_{s3}+t_6}{4} \end{cases} \tag{8}$$

Using an intermediary step (9) in expressing the above equations

$$\begin{cases} 4 \cdot t_1 = t_{s1} + t_4 + t_2 + t_{s4} \\ 4 \cdot t_2 = t_1 + t_5 + t_3 + t_{s4} \\ 4 \cdot t_3 = t_2 + t_6 + t_{s3} + t_{s4} \\ 4 \cdot t_4 = t_{s1} + t_7 + t_5 + t_1 \\ 4 \cdot t_5 = t_4 + t_8 + t_6 + t_2 \\ 4 \cdot t_6 = t_5 + t_9 + t_{s3} + t_3 \\ 4 \cdot t_7 = t_{s1} + t_{s2} + t_8 + t_4 \\ 4 \cdot t_8 = t_7 + t_{s2} + t_9 + t_5 \\ 4 \cdot t_9 = t_8 + t_{s2} + t_{s3} + t_6 \end{cases} \tag{9}$$

gives the LES (10), which has nine equations with nine unknowns and has to be solved numerically.

$$\begin{cases} 4 \cdot t_1 - t_2 - 0 \cdot t_3 - t_4 + 0 \cdot t_5 + 0 \cdot t_6 + 0 \cdot t_7 + 0 \cdot t_8 + 0 \cdot t_9 = t_{s1} + t_{s4} \\ -t_1 + 4 \cdot t_2 - t_3 + 0 \cdot t_4 - t_5 + 0 \cdot t_6 + 0 \cdot t_7 + 0 \cdot t_8 + 0 \cdot t_9 = t_{s4} \\ 0 \cdot t_1 - t_2 + 4 \cdot t_3 + 0 \cdot t_4 + 0 \cdot t_5 - t_6 + 0 \cdot t_7 + 0 \cdot t_8 + 0 \cdot t_9 = t_{s3} + t_{s4} \\ -t_1 + 0 \cdot t_2 + 0 \cdot t_3 + 4 \cdot t_4 - t_5 + 0 \cdot t_6 - t_7 + 0 \cdot t_8 + 0 \cdot t_9 = t_{s1} \\ 0 \cdot t_1 - t_2 + 0 \cdot t_3 - t_4 + 4 \cdot t_5 - t_6 + 0 \cdot t_7 - t_8 + 0 \cdot t_9 = 0 \\ 0 \cdot t_1 + 0 \cdot t_2 - t_3 + 0 \cdot t_4 - t_5 + 4 \cdot t_6 + 0 \cdot t_7 + 0 \cdot t_8 - t_9 = t_{s3} \\ 0 \cdot t_1 + 0 \cdot t_2 + 0 \cdot t_3 - t_4 + 0 \cdot t_5 + 0 \cdot t_6 + 4 \cdot t_7 - t_8 + 0 \cdot t_9 = t_{s1} + t_{s2} \\ 0 \cdot t_1 + 0 \cdot t_2 + 0 \cdot t_3 + 0 \cdot t_4 - t_5 + 0 \cdot t_6 - t_7 + 4 \cdot t_8 - t_9 = t_{s2} \\ 0 \cdot t_1 + 0 \cdot t_2 + 0 \cdot t_3 + 0 \cdot t_4 + 0 \cdot t_5 - t_6 + 0 \cdot t_7 - t_8 + 4 \cdot t_9 = t_{s2} + t_{s3} \end{cases} \tag{10}$$

Taking into account the fact that the Solver instrument from Microsoft Excel® operates with a certain group of cells which are correlated with the objective cell (Set Objective), and after the numerical procedure it can modify the values from these cells indicated by the user, the unknown temperature values $t_1 \ldots t_9$ are initialized as shown in Figure 4, using for example the value 1.0°C.

Implementare in Excel									
	t1	**t2**	**t3**	**t4**	**t5**	**t6**	**t7**	**t8**	**t9**
Valori variabile	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Fig. 4. Initializing the unknown temperatures $t_1 \ldots t_9$ in the nodes of the square mesh

For the linear equation system (10), the usual matrix form (11) was used [1], [2], [3] etc.:

$$CM \times VCV = CCV \tag{11}$$

where:

- CM – The coefficient matrix (12);
- VCV – The variable column vector (13);
- CCV – The constant column vector (14).

$$CM = \begin{bmatrix} 4 & -1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 4 & -1 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & -1 & 4 & 0 & 0 & -1 & 0 & 0 & 0 \\ -1 & 0 & 0 & 4 & -1 & 0 & -1 & 0 & 0 \\ 0 & -1 & 0 & -1 & 4 & -1 & 0 & -1 & 0 \\ 0 & 0 & -1 & 0 & -1 & 4 & 0 & 0 & -1 \\ 0 & 0 & 0 & -1 & 0 & 0 & 4 & -1 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & -1 & 4 & -1 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & -1 & 4 \end{bmatrix} \tag{12}$$

$$VCV = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \\ t_4 \\ t_5 \\ t_6 \\ t_7 \\ t_8 \end{bmatrix} \tag{13}$$

$$CCV = \begin{bmatrix} t_{s1} + t_{s4} \\ t_{s4} \\ t_{s3} + t_{s4} \\ t_{s1} \\ 0 \\ t_{s3} \\ t_{s1} + t_{s2} \\ t_{s2} \\ t_{s2} + t_{s3} \end{bmatrix} \tag{14}$$

The coefficient matrix (CM) is implemented in the spreadsheet as in Figure 5.

Ecuatia1	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0
Ecuatia2	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0
Ecuatia3	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	0.0	0.0
Ecuatia4	-1.0	0.0	0.0	4.0	-1.0	0.0	-1.0	0.0	0.0
Ecuatia5	0.0	-1.0	0.0	-1.0	4.0	-1.0	0.0	-1.0	0.0
Ecuatia6	0.0	0.0	-1.0	0.0	-1.0	4.0	0.0	0.0	-1.0
Ecuatia7	0.0	0.0	0.0	-1.0	0.0	0.0	4.0	-1.0	0.0
Ecuatia8	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	-1.0
Ecuatia9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0

Fig. 5. Implementing the coefficient matrix (CM)

The initial values of the temperatures $t_1 \ldots t_9$ from Figure 4 and the CM (12) associated to the LES were used to calculate a column of initial results (the column called **Rezultat** from Figure 6).

This column has to be compared term by term, by using the operator **Op** equal (=), with the corresponding numerical values from CCV (the column called **Problema** from Figure 6) which are obtained using the temperatures $t_{s1} \ldots t_{s4}$ on the delimiting surfaces of the square cross section.

Rezultat	Op.	Problema
2.0	=	200.0
1.0	=	50.0
2.0	=	100.0
1.0	=	150.0
0.0	=	0.0
1.0	=	50.0
2.0	=	200.0
1.0	=	50.0
2.0	=	100.0

Fig. 6. The initial results (column **Rezultat**) and the numerical values from CCV (column **Problema**)

After numerically solving the LES (10) with nine unknowns, the final values obtained in the column **Rezultat** must be identical with those from the column **Problema** associated to CCV (14).

As already mentioned in §1, because the Solver instrument operates with a cell called objective (Set Objective), in order to point to that cell, it is necessary to use inside the spreadsheet an additional line called **Condiție**, which contains this cell.

For this purpose, any equation from LES (10) may be used, so for example in Figure 7, equation no. 1 was used and emphasized.

Conditie	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	2.0	=	**200.0**

Fig. 7. Using the condition that contains the objective cell (equation no. 1 from LES)

The final form of the computer implementation of the proposed problem in §2 is indicated in Figure 8 and contains all the elements that were previously and individually presented in Figures 4, 5, 6 and 7: initializing the unknown temperatures $t_1 \ldots t_9$, the coefficient matrix (CM), the column of the initial results, the constant column vector (CCV) and the additional line containing the necessary condition for operating the Solver instrument.

Implementare in Excel

	t1	t2	t3	t4	t5	t6	t7	t8	t9	Rezultat	Op.	Problema
Valori variabile	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000			
Ecuatia1	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	2.0	=	200.0
Ecuatia2	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	1.0	=	50.0
Ecuatia3	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	0.0	0.0	2.0	=	100.0
Ecuatia4	-1.0	0.0	0.0	4.0	-1.0	0.0	-1.0	0.0	0.0	1.0	=	150.0
Ecuatia5	0.0	-1.0	0.0	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	=	0.0
Ecuatia6	0.0	0.0	-1.0	0.0	-1.0	4.0	0.0	0.0	-1.0	1.0	=	50.0
Ecuatia7	0.0	0.0	0.0	-1.0	0.0	0.0	4.0	-1.0	0.0	2.0	=	200.0
Ecuatia8	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	-1.0	1.0	=	50.0
Ecuatia9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	2.0	=	100.0
Conditie	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	2.0	=	**200.0**

Fig. 8. The final form of the computer implementation used for solving the problem

The calculation of the temperature values $t_1 \ldots t_9$ in the mesh nodes from Figure 2 is being performed numerically, by solving the LES (10) using the Solver instrument, according to the following steps:

a) From the "Data" ribbon of Microsoft Excel®, it is necessary to call the dialog window "Solver Parameters" (Figure 10) of the Solver instrument.

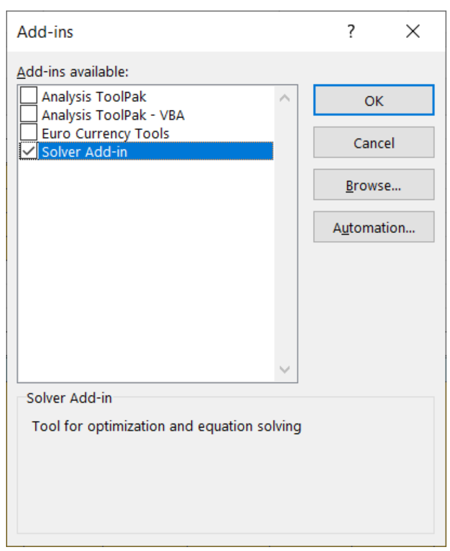

Fig. 9. Installing the Solver instrument as an add-in

Note:
The Solver instrument is an add-in that must be installed before its first use. The installation is made by calling from the menu *File -> Options -> Add-ins ->Excel Add-ins -> Go* ... the "Add-ins" dialog window presented in Figure 9, in which the validation option "Solver Add-in" must be checked and then the OK button must be pressed;

b) Give the reference to the objective cell ($L$43 in Figure 10) contained in the additional line called **Condiție**, check the option "Value Of", then in the text box nearby give the value that must be obtained. Using equation no. 1 of LES (10), the necessary value is the first corresponding value from CCV (14), as shown for example in Figure 8;

c) The cells containing the unknown temperature values $t_1 \ldots t_9$ initialized with the value of 1.0°C in Figure 4 must be indicated directly or by selecting them with the current pointing device (mouse) inside the "By Changing Variable Cells" box. It is recommended that these cells should form a contiguous range in the spreadsheet e.g., $C$33:$K$33 as in Figure 10;

d) Inside the "Subject to the Constraints" list box, it is necessary to give the restrictions (constrains) that are defining the solution of the problem, using the dedicated buttons ("Add", "Change", "Delete") available in the "Solver Parameters" dialog window. These restrictions are defined by the fact that the correct results are obtained when the numerical values from the column **Rezultat** become identical to those from the column **Problema** (Figure 8);

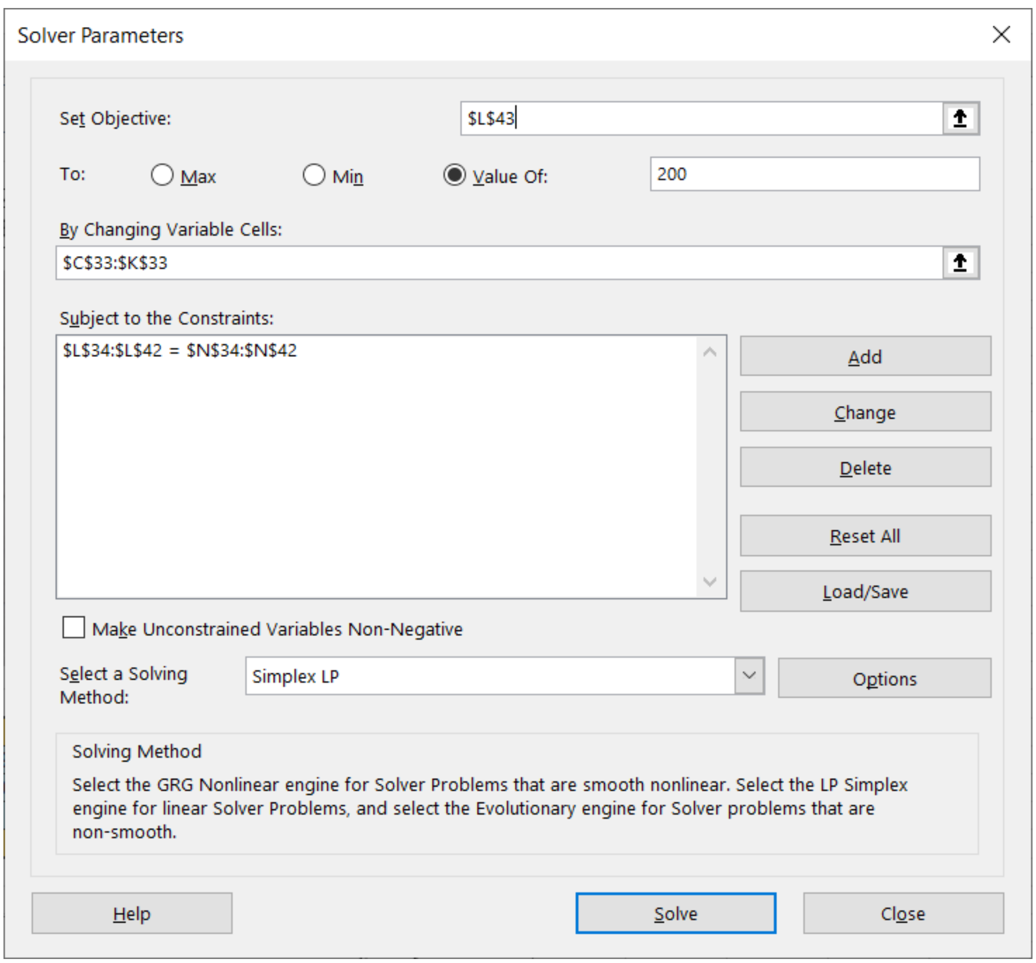

Fig. 10. Specifying solving parameters used by Solver

e) Optionally, other advanced solving preferences may be specified by using the "Options" button;

f) Finally, the "Solve" button must be pressed.

The numerical values of the temperatures $t_1 \ldots t_9$ in the nodes of the chosen square mesh, obtained by solving the LES (10) numerically and modified by Solver in the cells indicated by the user in the "By Changing Variable Cells" box, are presented in Figure 11.

Rezultate

	t1	t2	t3	t4	t5	t6	t7	t8	t8	Rezultat	Op.	Problema
Valori variabile	92.857	68.750	57.143	102.679	75.000	59.821	92.857	68.750	57.143			
Ecuatia1	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	200.0	=	200.0
Ecuatia2	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	50.0	=	50.0
Ecuatia3	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	0.0	0.0	100.0	=	100.0
Ecuatia4	-1.0	0.0	0.0	4.0	-1.0	0.0	-1.0	0.0	0.0	150.0	=	150.0
Ecuatia5	0.0	-1.0	0.0	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	=	0.0
Ecuatia6	0.0	0.0	-1.0	0.0	-1.0	4.0	0.0	0.0	-1.0	50.0	=	50.0
Ecuatia7	0.0	0.0	0.0	-1.0	0.0	0.0	4.0	-1.0	0.0	200.0	=	200.0
Ecuatia8	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	-1.0	50.0	=	50.0
Ecuatia9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	100.0	=	100.0
Conditie	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	200.0	=	**200.0**

Fig. 11. Numerical values of the temperatures $t_1 \ldots t_9$

In order to obtain an overall numerical image of the 2D temperature field for the square cross section, the temperature values $t_1 \ldots t_9$ in the mesh nodes, the temperatures $t_{s1} \ldots t_{s4}$ on the delimiting surfaces of the section and the temperature values in its corners, may be grouped together in an uncluttered region of the spreadsheet, as shown in Figure 12.

100	150	150	150	100
50	92.857	102.679	92.857	50
50	68.750	75.000	68.750	50
50	57.143	59.821	57.143	50
50	50	50	50	50

Fig. 12. The 2D temperature field in the square cross section (numerical representation)

If there is no additional information or technical specifications available regarding the nodes situated at the intersection of two surfaces having constant temperature (the corners of the cross section), the temperature in these nodes may be estimated by using the arithmetic average of the respective surface temperatures (13) [1] etc.:

$$Node\ m-n\colon t_j=\frac{t_{s,m}+t_{s,n}}{2} \tag{15}$$

The numerical image of the 2D temperature field in the square cross section (Figure 12) can be graphically translated, by using one or more methods of graphical representation that Microsoft Excel® gives to the user. For example, in Figure 13 is presented a 2D graphical image of the temperature field, using interpolated contours, and in Figure 14 is showed a 3D image of the temperature values from the field.

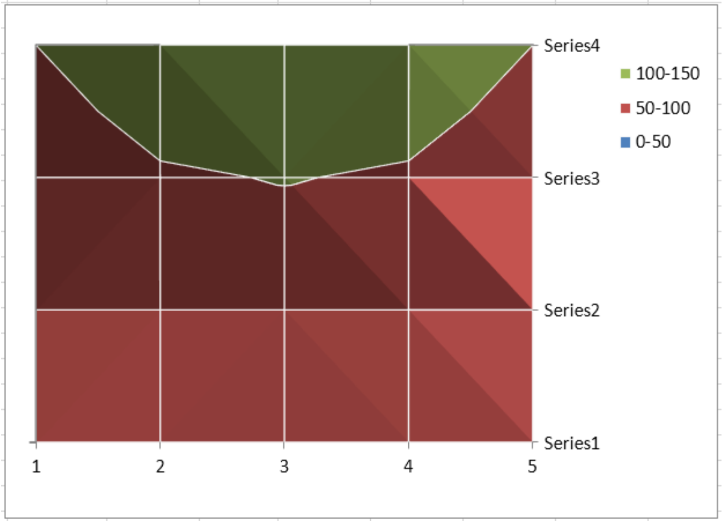

Fig. 13. Graphical representation of the 2D temperature field in the square cross section, using interpolated contours

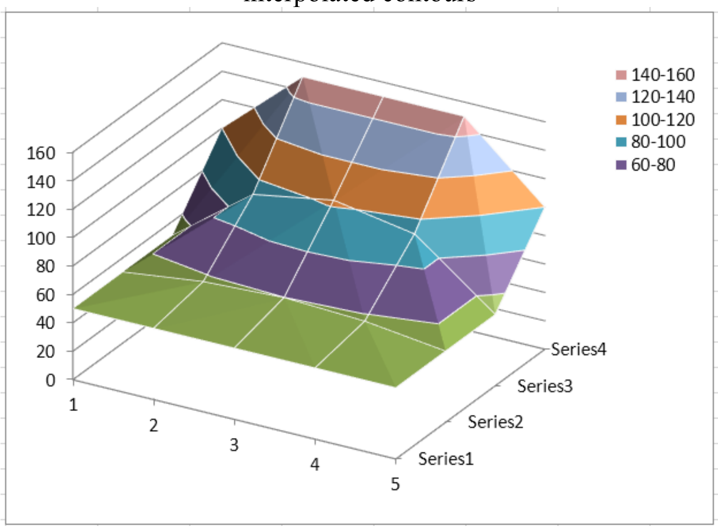

Fig. 14. 3D graphical representation of the temperature values from the square cross section field

3. Studied and solved cases

The presented software instrument solves numerically the application proposed in this paper, but its utility is proven especially in the cases of analysis of the 2D temperature field for the square cross section, when modifications of the initial temperature values $t_{s1}\ldots t_{s4}$ on the delimiting surfaces of the section appear.

With an additional effort for implementing, the instrument can be adapted to solve a more complicated LES, by using a „finer” discretization mesh, having a smaller spacing step for temperature nodal points generation.

In the cases of study and analysis of the 2D temperature field for the square cross section, the temperature values $t_{s1}\ldots t_{s4}$ are modified in the corresponding cells in Figure 3. Later, the Solver instrument will solve the LES (10), using the same parameters as those indicated in Figure 10 and adapting the value from the text box situated on the right of the “Value Of” control to the studied case.

Some of the analyzed situations are presented hereinafter, by indicating in each case: the initial data, the solved LES, the numerical results obtained and the graphical representations describing the temperature field of the square cross section.

Case no. 1

Temperatures on the delimiting surfaces of the square cross section:

$$\begin{cases} t_{s1} = 80°\mathrm{C} \\ t_{s2} = 30°\mathrm{C} \\ t_{s3} = 80°\mathrm{C} \\ t_{s4} = 30°\mathrm{C} \end{cases}$$

Marime	ID	U.M.	Valoare
Temp. suprafata 1	ts1	80	C
Temp. suprafata 2	ts2	30	C
Temp. suprafata 3	ts3	80	C
Temp. suprafata 4	ts4	30	C

Fig. 15. Case no. 1: Initial data

Rezultate	t1	t2	t3	t4	t5	t6	t7	t8	t8	Rezultat	Op.	Problema
Valori variabile	55.000	48.750	55.000	61.250	55.000	61.250	55.000	48.750	55.000			
Ecuatia1	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	110.0	=	110.0
Ecuatia2	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	30.0	=	30.0
Ecuatia3	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	0.0	0.0	110.0	=	110.0
Ecuatia4	-1.0	0.0	0.0	4.0	-1.0	0.0	-1.0	0.0	0.0	80.0	=	80.0
Ecuatia5	0.0	-1.0	0.0	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	=	0.0
Ecuatia6	0.0	0.0	-1.0	0.0	-1.0	4.0	0.0	0.0	-1.0	80.0	=	80.0
Ecuatia7	0.0	0.0	0.0	-1.0	0.0	0.0	4.0	-1.0	0.0	110.0	=	110.0
Ecuatia8	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	-1.0	30.0	=	30.0
Ecuatia9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	110.0	=	110.0
Conditie	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	110.0	=	**110.0**

Fig. 16. Case no. 1: Solved LES

55	80	80	80	55
30	55.000	61.250	55.000	30
30	48.750	55.000	48.750	30
30	55.000	61.250	55.000	30
55	80	80	80	55

Fig. 17. Case no. 1: Numerical representation of the 2D temperature field

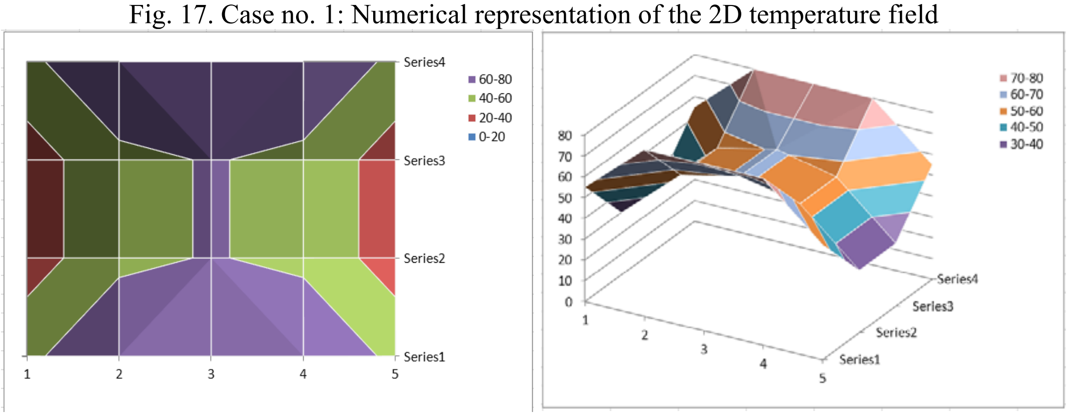

Fig. 18. Case no. 1: 2D and 3D graphical representation of the temperature field

Case no. 2

Temperatures on the delimiting surfaces of the square cross section:

$$\begin{cases} t_{s1} = 45°C \\ t_{s2} = 70°C \\ t_{s3} = 20°C \\ t_{s4} = 50°C \end{cases}$$

Marime	ID	U.M.	Valoare
Temp. suprafata 1	ts1	45	C
Temp. suprafata 2	ts2	70	C
Temp. suprafata 3	ts3	20	C
Temp. suprafata 4	ts4	50	C

Fig. 19. Case no. 2: Initial data

Rezultate

	t1	t2	t3	t4	t5	t6	t7	t8	t8	Rezultat	Op.	Problema
Valori variabile	47.143	45.402	38.214	48.170	46.250	37.455	54.286	53.973	45.357			
Ecuatia1	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	95.0	=	95.0
Ecuatia2	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	50.0	=	50.0
Ecuatia3	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	0.0	0.0	70.0	=	70.0
Ecuatia4	-1.0	0.0	0.0	4.0	-1.0	0.0	-1.0	0.0	0.0	45.0	=	45.0
Ecuatia5	0.0	-1.0	0.0	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	=	0.0
Ecuatia6	0.0	0.0	-1.0	0.0	-1.0	4.0	0.0	0.0	-1.0	20.0	=	20.0
Ecuatia7	0.0	0.0	0.0	-1.0	0.0	0.0	4.0	-1.0	0.0	115.0	=	115.0
Ecuatia8	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	-1.0	70.0	=	70.0
Ecuatia9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	90.0	=	90.0
Conditie	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	95.0	=	**95.0**

Fig. 20. Case no. 2: Solved LES

47.5	45	45	45	57.5
50	47.143	48.170	54.286	70
50	45.402	46.250	53.973	70
50	38.214	37.455	45.357	70
35	20	20	20	45

Fig. 21. Case no. 2: Numerical representation of the 2D temperature field

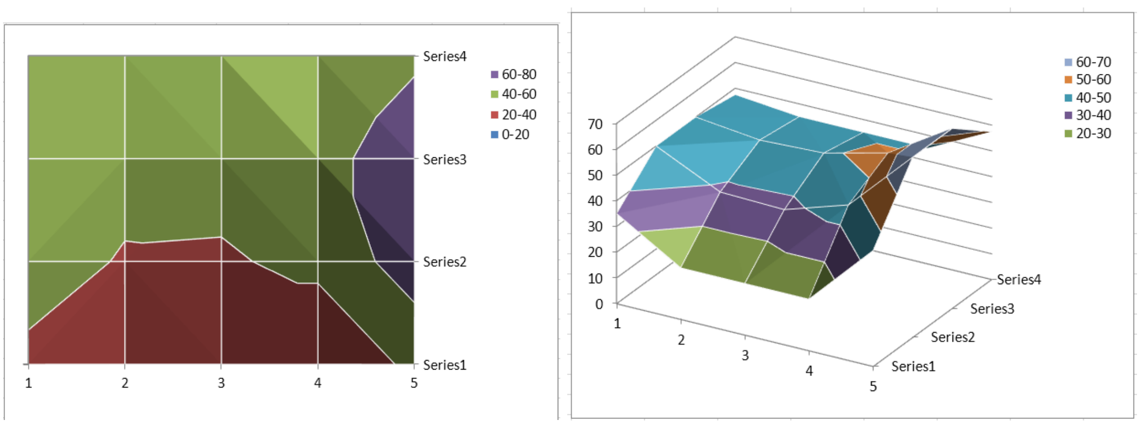

Fig. 22. Case no. 2: 2D and 3D graphical representation of the temperature field

Case no. 3

Temperatures on the delimiting surfaces of the square cross section:

$$\begin{cases} t_{s1} = 50°\mathrm{C} \\ t_{s2} = 25°\mathrm{C} \\ t_{s3} = 0°\mathrm{C} \\ t_{s4} = 10°\mathrm{C} \end{cases}$$

Marime	ID	U.M.	Valoare
Temp. suprafata 1	ts1	50	C
Temp. suprafata 2	ts2	25	C
Temp. suprafata 3	ts3	0	C
Temp. suprafata 4	ts4	10	C

Fig. 23. Case no. 3: Initial data

Rezultate

	t1	t2	t3	t4	t5	t6	t7	t8	t8	Rezultat	Op.	Problema
Valori variabile	27.500	17.098	9.643	32.902	21.250	11.473	32.857	23.527	15.000			
Ecuatia1	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	60.0	=	60.0
Ecuatia2	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	10.0	=	10.0
Ecuatia3	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	0.0	0.0	10.0	=	10.0
Ecuatia4	-1.0	0.0	0.0	4.0	-1.0	0.0	-1.0	0.0	0.0	50.0	=	50.0
Ecuatia5	0.0	-1.0	0.0	-1.0	4.0	-1.0	0.0	-1.0	0.0	0.0	=	0.0
Ecuatia6	0.0	0.0	-1.0	0.0	-1.0	4.0	0.0	0.0	-1.0	0.0	=	0.0
Ecuatia7	0.0	0.0	0.0	-1.0	0.0	0.0	4.0	-1.0	0.0	75.0	=	75.0
Ecuatia8	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	-1.0	25.0	=	25.0
Ecuatia9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	-1.0	4.0	25.0	=	25.0
Conditie	4.0	-1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	60.0	=	**60.0**

Fig. 24. Case no. 3: Solved LES

30	50	50	50	37.5
10	27.500	32.902	32.857	25
10	17.098	21.250	23.527	25
10	9.643	11.473	15.000	25
5	0	0	0	12.5

Fig. 25. Case no. 3: Numerical representation of the 2D temperature field

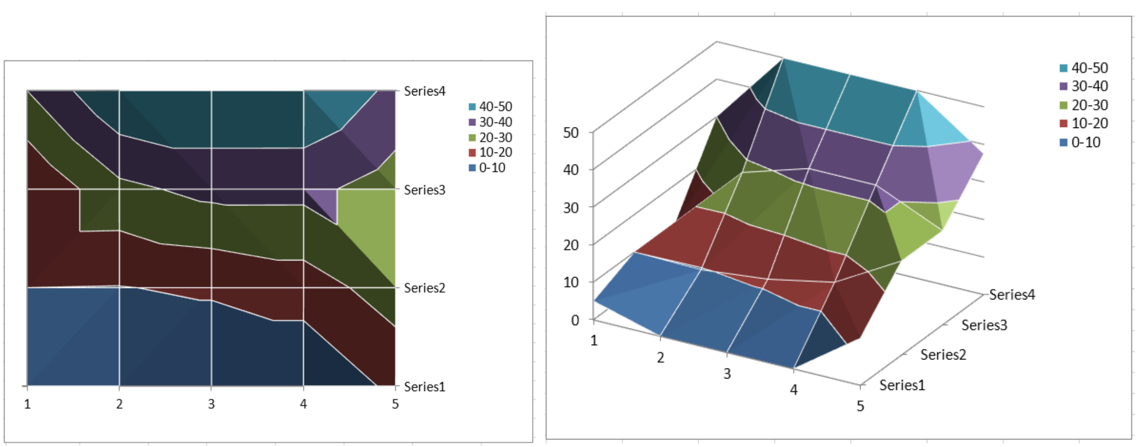

Fig. 26. Case no. 3: 2D and 3D graphical representation of the temperature field

4. Conclusions

The problem of steady state heat transfer in a square cross section may be numerically solved by using the finite differences method (FDM). The differential equation (2) that characterizes the 2D temperature field in the section is replaced by the finite differences equation (3), then a squared discretization mesh with an equal spacing step $\Delta x=\Delta y=\Delta$ for node generation on both Ox and Oy coordinate axes is used, and finally the unknown temperatures in the mesh nodes are expressed using the relation (7).

The resulting linear equation system LES (9) is numerically solved by calling the Solver instrument from Microsoft Excel® software, part of the Microsoft Office® suite. This instrument can modify the initial values indicated by the user in certain cells of the spreadsheet, with the purpose to later obtain the targeted result in the objective cell (Set Objective).

The preparations for solving the studied problem were made in several steps: introduction of initial data as separate variables (Figure 3), initialization of the unknown variables (Figure 4), description of LES (9) in a matrix form (10), successive implementation of the coefficient matrix CM (Figure 5), the constant column vector CCV (Figure 6) and an additional line called Condition (Figure 7). The final form of the computer implementation of the problem-solving process is presented in Figure 8.

The numerical solving of the LES (9) was done by using the Solver instrument, specifying the necessary solving parameters: the reference to the objective cell and the target value, respectively, the group of cells containing the values of the unknown temperatures, the solving restrictions (constraints) and finally the choice for the SimplexLP algorithm as a preferred method for problem-solving (Figure 10).

The obtained numerical results regarding the values of the unknown temperatures in the square section field, the temperatures on its delimiting surfaces and the estimated temperatures in the corners of the section were grouped together in Figure 12 in order to offer an overall numerical image of the 2D temperature field of the section. For a more intuitive visualization, these numerical values may be graphically depicted using the various 2D or 3D types of representations that Microsoft Excel® offers to the user (Figure 13 and Figure 14).

A series of cases were studied and solved, when temperatures on the delimiting surfaces of the square section were modified, generating a certain thermal load, symmetric or asymmetric. Using the separate variable implementation of those temperature values, the modifications were done without any additional complications, and then by calling the Solver instrument, the numerical and graphical results corresponding to each case of study were quickly obtained.

In order to analyze some more detailed 2D temperature fields, the created software instrument can be adapted with an additional implementation effort, by modifying the spacing step for the positioning of the mesh nodes and by increasing the number of unknown temperatures i.e., the number of nodes. However, this strategy will also increase the number of equations in the LES, and consequently, the complexity of the problem that has to be solved. In this case when the number of nodes and temperatures within, respectively, will become very large, it is preferable to better use a dedicated computer software, that will automatically build the discretization mesh and solve the generated LES.

The instrument for the study and automatic calculation of the 2D temperature field in a square cross section that was presented in this paper is useful for both the students of the Building Services Faculty studying the multidimensional heat transfer, and the domain specialists interested in practical solving these types of engineering applications.

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Materiale plastice încorporate în staţie pilot de epurare

Plastic materials incorporated in a pilot wastewater treatment plant

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Rezumat. *Lucrarea analizează utilizarea diferitelor tipuri de materiale plastice în procesul epurării apei uzate dintr-o staţie pilot amplasată în interiorul Staţiei de Epurare a Apelor Uzate din Timişoara. S-a studiat comportamentul acestor materiale la acţiunea apei uzate asupra acestora, respectiv avantajele şi dezavantajele utilizării acestora.*

Cuvinte cheie: canalizare, ape uzate, epurare, polietilenă, răşini epoxidice

Abstract. *Through the present paper it is analysed the use of different types of plastic materials in the process of wastewater treatment in a pilot wastewater treatment plant placed in the Municipal Wastewater Treatment Plant of Timişoara. It was studied the behaviour of these materials through the actions of wastewater upon them, respectively, the advantages and disadvantages of their usage.*

Key words: waste water, wastewater treatment, ployethylene, epoxy resins

1. Introducere

Conform Institutului National de Statistică, în anul 2019, doar 10.514.924 locuitori, reoprezentând 54,2% din populaţia rezidentă a Romaniei, aveau locuinţele conectate la o reţea de canalizare. Repartiţia pe medii scoate la iveală o discrepanţă uriaşă între acestea, 90,9% din populaţia din mediul urban beneficiind de reţele de canalizare, comparativ cu doar 11,3% din populaţia din mediul rural.[1]
În ceea ce priveşte gradul de conectare la staţii de epurare, la nivel naţional, doar 52,9% din populaţia rezidentă a fost conectată în 2019 la reţele de canalizare care beneficiau şi de staţii de epurare. [1]

Se impun, astfel, măsuri pentru creşterea gradului de conectare a populaţiei la reţele de canalizare şi staţii de epurare în scopul reducerii poluării mediului, dar şi pentru creşterea nivelului de trai prin îmbunătăţirea condiţiilor tehnico-sanitare.

În acest scop, s-a conceput o staţie pilot de epurare (SPE), amplasată în incinta Staţiei de Epurare Municipale din Timişoara. Obiectivul urmărit este realizarea unui circuit biologic cu un consum mai redus de energie, care ar putea fi implementat în localităţi mici şi foarte mici, respectiv în zone izolate cu consumuri de apă (hoteluri, pensiuni etc). Astfel, SPE beneficiază de grătarele şi deznisipatorul staţiei de epurare municipal şi efectele acestora. [6]

2. Materiale şi metode

Schema SPE poate fi vazută în figura 1.

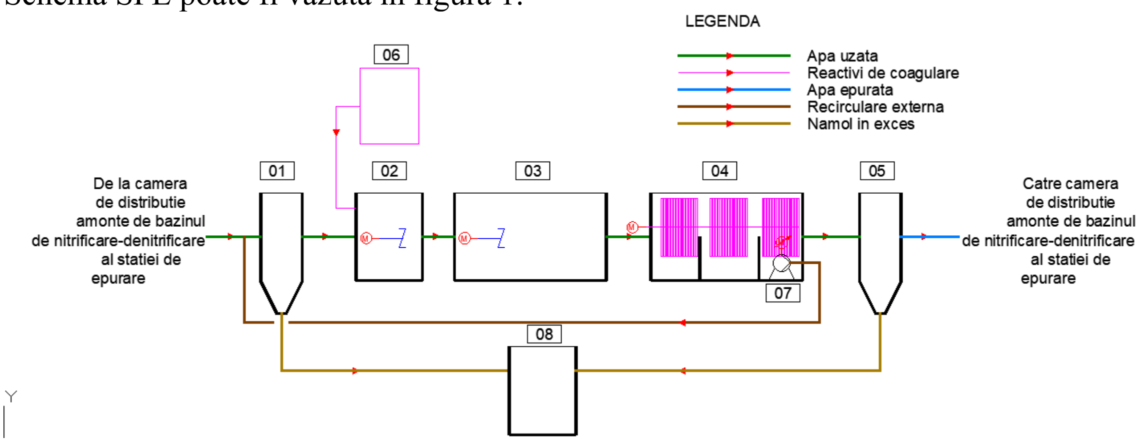

Figura 1 – Schema staţiei pilot

Unde:

1. Decantor primar
2. Bazinul anaerob
3. Bazinul anoxic
4. Bazinul oxic
5. Decantorul secundar
6. Rezervor reactivi coagulare
7. Pompă recirculare externă
8. Rezervor nămol în exces

2.1. Alimentarea SPE

Alimentarea cu influent a SPE se face din camera de distribuţie amonte de bazinele biologice ale Staţiei de Epurare a Apelor Uzate Municipală din Timişoara. În interiorul camerei de distribuţie s-a amplasat o pompă submersibilă cu debit fix de 500 l/h. La aceasta este legată o conductă de polietilenă cu diamentrul exterior de 25 mm prin care este transportată apa uzată spre decantorul primar.

Pe traseul conductei s-a montat un contor de apă cu afişaj electronic, care este folosit pentru a colecta date. Acesta afişează atât debitul instantaneu (in l/h), cât şi volumul total de apă scurs prin acesta de la punerea in funcţiune.

Pentru a putea regla debitul de influent, amonte de contor s-a montat un teu egal din polietilenă cu diametrul exterior de 25 mm, respectiv doi robineţi cu bilă de ¾'', după cum rezultă din figura 2.

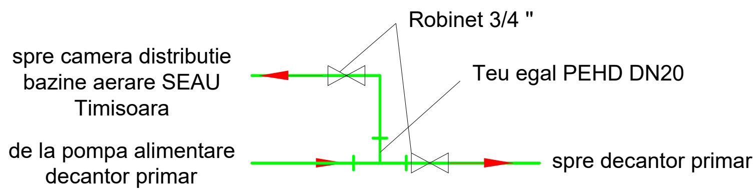

Figura 2 – Alimentarea SPE cu apă uzată

Astfel, prin reglajul realizat cu ajutorul robineţilor şi a citirii debitului instant de pe contor, se va obţine un debit constant de 300 l/h după cum este cerut în dimensionarea SPE. În scenariul ideal, rezervoarele componente ale SPE ar fi trebuit îngropate până la buza superioară a acestora, fiind binecunoscută comportarea materialelor plastice şi a conductelor din polietilenă la compresiune, acoperite fiind de pământ, dar mai ales pentru protejarea acestora împotriva îngheţului. [2]

2.2. Decantorul primar

Pentru o funcţionare eficientă a SPE normativul NP 133 [3] recomandă utilizarea unui decantor primar în schema sistemului de epurare. Acesta reține particulele în suspensie care se pot depune gravitațional în bazinul de stocare a nămolului primar.

Pentru asamblarea obiectului ce urmeaza a fi folosit drept decantor primar s-a folosit fibra de sticlă tip PAFS (GRP). S-a confecţionat un rezervor cu diametrul interior de 1,00 m şi o adâncime interioară de 1,50 m. Pentru construcţia rezervoarelor din PAFS (poliester armat cu fibră de sticlă) se utilizează :

- răşini poliesterice nesaturate, soluţii in stiren, de tip ortoftalic, tereftalic, dianolic (bisfenolice rigide si elastice), izoftalic;
- răşini vinil-esterice
- alte tipuri speciale: răşini poliesterice ignifugate, aditivate cu absorbanţi U.V., aditivate cu agenţi de antistatizare.

Caracteristicile fizico - mecanice ale răşinii în faza polimerizată trebuie să corespundă valorilor impuse în tabelul de mai jos.

Tabelul 1

Caracteristici fizico-mecanice ale răşinii în faza polimerizată

CARACTERISTICA DETERMINATĂ	Unitate de măsură	Valoare impusă
Densitate la 20 C / 25 C	g/cmc	1,05 / 1,03
Duritate BARCOL , min.	B	31
Stabilitate termică Martens , min.	C	50
Tensiunea de încovoiere la rupere , min.	daN / cmp	800
Rezistenţa la tracţiune la rupere , min.	daN / cmp	400
Alungirea relativă la rupere , min.	%	2
Absorbţia de apă după 28 zile, max.	%	1

Avantajele folosirii materialului de tip fibră de sticlă sunt [4]:

- Este un material mai uşor decât betonul prefabricat
- Manevrare mult mai uşoară a obiectului
- Timp redus pentru perforare, la montarea ţevilor de legătură între obiecte
- Posibilitate de confecţionare la dimensiunile necesare

Dimensiunile decantorului s-au ales după dimensionarea realizată conform [5]. Astfel, este necesară respectarea adâncimii rezultate, încât să se realizeze depunerea sedimentelor în spaţiul alocat, respectiv formarea straturilor de apă specifice decantoarelor. Sedimentele depuse in partea inferioară a decantorului se vor evacua cu ajutorul unei pompe submersibile cu debit fix de 500 l/h. Aceasta nu este fixată în decantor, fiind introdusă în partea inferioară a acestuia periodic, pentru evacuarea sedimentelor. Starea de acumulare a sedimentelor din decantorul primar se poate observa vizual, materialul din care este confecţionat decantorul fiind relativ transparent. Astfel, periodic, când culoarea apei de la partea inferioară a decantorului devine opacă, se introduce pompa. Pompa este legată la tabloul electric al SPE prin intermediul unui cablu cu posibilitate de introducere in priză biploară.

Pentru a asigura linia hidraulică, decantorul primar este amplasat pe un suport realizat din profile metalice tip L din oţel zincat. Acestea sunt sudate electric pentru a asigura o rigiditate suficientă şi stabilitatea ansamblului de rezervor şi conducte de legatură. S-a confecţionat un suport cu patru picioare, peste care s-a poziţionat decantorul primar. Evacuarea apei din decantorul primar spre bazinul anaerob se face prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm. Pentru a realiza menţinerea nivelului apei la cota stabilită prin calcul, s-a montat un cot la 90 grade, care va avea rol de deversor. Partea superioară a cotului este montată la nivelul maxim al apei din decantorul primar.

Pentru montarea conductei de evacuare s-a realizat perforarea peretelui decantorului primar, apoi, pe gaură s-a montat o garnitură de etanşare pentru a evita potenţiale scurgeri. Tot în decantorul primar refulează şi pompa de recirculare externă, amplasată lângă conducta de evacuare a apei din bazinul cu contactoare biologice rotative. Apa provenită de la aceasta este introdusă în bazin prin intermediul unei conducte din polietilenă cu diametru exterior de 25 mm, montată şi încastrată pe buza superioară a decantorului primar, nefiind necesară perforarea peretelui acestuia pentru introducerea conductei în decantor.

Figura 3 – Decantorul primar   Figura 4 – Bazinele anaerob si bazinul anoxic

2.3. Bazinul anaerob

Bazinul anaerob este un rezervor circular din polietilenă cu diametrul de 965 mm şi înălţimea de 800 mm. Aici are loc reducerea biologică a fosforului din apa uzată influentă în SPE. Apa uzata intră în acesta prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm, care face legătura cu decantorul primar. Pentru a introduce conducta în bazin s-a realizat perforarea peretelui acestuia, apoi s-a montat o garnitură pe gaură pentru a evita potentiale scurgeri.

Apa influentă în bazinul anaerob este un amestec de apă uzată provenită de la staţia de epurare municipală şi recircularea provenită din bazinul cu contactoare biologice rotative. În bazinul anaerob are loc amestecul şi omogenizarea acestora, rezultând astfel o reducere biologică a fosforului din apa uzată influentă.[5]

Pentru a realiza omogenizarea apei şi pentru evitarea depunerii de sedimente pe fundul rezervorului, s-a confecţionat un mixer submersibil. Astfel, s-a montat o bară metalică transversală pe buza superioară a bazinului, de care s-a prins o tijă montată vertical. Paletele mixerului au fost obţinute prin dezmembrarea unui ventilator vechi. La alegerea orientării paletelor s-a ţinut cont de faptul că apa trebuie antrenată în sens jos-sus, pentru a evita depunerea particulelor solide din apa uzată pe fundul bazinului. Motorul care antrenează mixerul este provenit de la ştergatoare de parbrize, având puterea de 0,02 kW. Pentru a asigura protecţia motorului faţă de factorii exteriori (ploaie, vânt, temperaturi ridicate/scazute), acesta a fost dotat cu o carcasă metalică.

Pentru a asigura linia hidraulică, bazinul anaerob este amplasat pe un suport realizat din profile metalice tip L din oţel zincat. Acestea sunt sudate electric pentru a asigura o rigiditate suficientă şi stabilitatea ansamblului de rezervor şi conducte de legatură. S-a confecţionat un suport cu patru picioare, peste care s-a poziţionat bazinul ananerob. Evacuarea apei din bazinul anaerob spre bazinul de anoxic se face prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm. Pentru a realiza menţinerea nivelului apei la cota stabilită prin calcul, s-a montat un cot la 90 grade, care va avea rol de deversor. Partea superioară a cotului este montată la nivelul maxim al apei din bazinul anaerob.

În funcţie de rezultate analizelor apei efluente din SPE, se va determina dacă concentraţia de fosfor este suficient de mică pentru a se încadra în normele date de NTPA-001. În caz contrar, se va concluziona că reducerea pe cale biologică a fosforului din apa uzată nu este suficientă, fiind necesare măsuri complementare. Acestea presupun dozarea unui reactiv chimic pentru reducerea fosforului din apa uzată. Pentru prezentul proiect, substanţele cele mai accesibile pentru utilizare sunt: clorura ferică ($FeCl3$), respectiv sulfatul de aluminiu ($Al2(SO4)3$).

2.4. Bazinul anoxic

Bazinul anoxic este un rezervor circular din polietilenă cu diametrul de 965 mm si înălţimea de 800 mm.

Apa uzată intră în bazinul anoxic prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm, care face legătura cu bazinul anaerob. Pentru a introduce conducta în bazin s-a realizat perforarea peretelui acestuia, apoi s-a montat o garnitură pe gaură pentru a evita potenţiale scurgeri.

Pentru a realiza omogenizarea apei şi pentru evitarea depunerii de sedimente pe fundul rezervorului, s-a confecţionat cu mixer submersibil. Astfel, s-a montat o bară metalică transversală pe buza superioară a bazinului, de care s-a prins o tijă montată vertical. Paletele mixerului au fost obţinute prin dezmembrarea unui ventilator vechi. La alegerea orientării paletelor s-a ţinut cont de faptul că apa trebuie antrenată în sens jos-sus, pentru a evita depunerea particulelor solide din apa uzată pe fundul bazinului. Motorul care antrenează mixerul este provenit de la ştergătoare de parbrize, având puterea 0,02 kW. Pentru a asigura protecţia motorului faţă de factorii exteriori (ploaie, vânt, temperaturi ridicate/scăzute), acesta a fost dotat cu o carcasă metalică.

Pentru a asigura linia hidraulică, bazinul anoxic este amplasat pe un suport realizat din profile metalice tip L din oţel zincat. Acestea sunt sudate electric pentru a asigura o rigiditate suficientă şi stabilitatea ansamblului de rezervor şi conducte de legatură. S-a confecţionat un suport cu patru picioare, peste care s-a poziţionat bazinul de denitrificare.

Evacuarea apei din bazinul anoxic spre bazinul oxic se face prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm. Pentru a realiza menţinerea nivelului apei la cota stabilită prin calcul, s-a montat un cot la 90 grade, care va avea rol de deversor. Partea superioară a cotului este montată la nivelul maxim al apei din bazinul anaerob.

2.5. Bazinul oxic

Bazinul oxic cu contactoare biologice rotative este un rezervor in formă de paralelipiped dreptunghic, confecţionat din fibră sticla tip PAFS (GRP), având dimensiunile L x l x h de 2,75x0,7x0,8 m. Caracteristicile materialului din care a fost confecţionat bazinul sunt identice cu cele prezentate la decantoare.

Apa uzată intră în bazinul cu contactoare biologice rotative prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm, care face legătura cu bazinul anoxic. Pentru a introduce conducta în bazin s-a realizat perforarea peretelui acestuia, apoi s-a montat o garnitură pe gaură pentru a evita potenţiale scurgeri.

Bazinul este dotat cu o bară metalică de 1’’ care traversează bazinul longitudinal, prin mijlocul acestuia. Pe aceasta bară sunt încastrate contactoarele biologice rotative. La unul dintre capetele barei, este montat motorul electric care acţionează sistemul bară-contactoare, rotindu-le. Acesta este provenit de la ştergătoare de parbrize.

Motorul electric are următoarele caracteristici:

Putere: 0,02 kW; Turaţie: 3 rotaţii/minut

Contactoarele biologice rotative sunt discuri de polistiren extrudat cu grosimea de 20 mm. Conform breviarului de calcul, sunt necesare 60 de bucăţi pentru a se realiza suprafaţa de contact necesară între apa uzată influentă şi discurile pe care se vor forma bacteriile necesare procesului de epurare a apei uzate.

S-a optat pentru împărţirea discurilor în trei pachete de câte douăzeci de bucăţi, distanţa dintre pachete fiind de 200 mm. De asemenea, distanţa dintre două discuri din cadrul unui pachet este de 15 mm, pentru a se asigura spaţiul necesar formării peliculei de bacterii pe ambele suprafeţe ale fiecărui contactor biologic rotativ.

Pentru a se asigura menţinerea distanţei dintre discuri în cadrul fiecărui pachet, s-au montat distanţiere din metal între discuri. Acestea contribuie şi la rigidizarea poziţiei contactorului, astfel încât, în cazul deteriorării zonei centrale a acestuia, contactorul să se rotească în continuare. Astfel, procesul prin care bacteriile de pe suprafaţa neînnecată a contactorului intră în contact cu apa uzată nu este periclitat.

Pentru a asigura linia hidraulică, bazinul cu contactoare biologice rotative este amplasat pe un suport realizat din profile metalice tip L din oţel zincat. Acestea sunt sudate electric pentru a asigura o rigiditate suficientă şi stabilitatea ansamblului de rezervor şi conducte de legatură.

Evacuarea apei din bazin spre decantorul secundar se face prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm. Pentru a realiza menţinerea nivelului apei la cota stabilită prin calcul, s-a montat un cot la 90 grade, care va avea rol de deversor. Partea superioară a cotului este montată la nivelul maxim al apei din bazin.

Figura 5 – bazinul oxic


Figura 6–Decantorul secundar

2.6. Decantorul secundar

Pentru asamblarea obiectului ce urmează a fi folosit drept decantor secundar s-a folosit fibră de sticlă tip PAFS (GRP). S-a confecţionat un rezervor cu diametrul interior de 1,00 m şi o adâncime interioară de 2,50 m.

Dimensiunile decantorului s-au ales după dimensionarea realizată conform [5].

Sedimentele depuse in partea inferioară a decantorului se vor evacua cu ajutorul unei pompe submersibile cu debit fix de 500 l/h. Aceasta nu este fixată în decantor, fiind introdusă în partea inferioară a acestuia periodic, pentru evacuarea sedimentelor.

Starea de acumulare a sedimentelor din decantorul secundar se poate observa vizual, materialul din care este confecţionat decantorul fiind relativ transparent.

Alimentarea cu apa a decantorului secundar se face prin intermediul unei conducte din polietilenă cu diametru exterior de 25 mm..

Evacuarea apei din decantorul secundar spre camera de distributie a bazinelor de aerare a statiei de epurare municipale se face prin intermediul unei conducte din polietilenă cu diametrul exterior de 25 mm. Pentru a realiza mentinerea nivelului apei la cota stabilita prin calcul, s-a montat un cot la 90 grade, care va avea rol de deversor.

Partea superioară a cotului este montată la nivelul maxim al apei din decantorul secundar. Pentru montarea conductei de evacuare s-a realizat perforarea peretelui decantorului secundar, apoi, pe gaură s-a montat o garnitură de etanşare pentru a evita potenţiale scurgeri.

2.7. Rezervorul pentru stocarea namolului

Rezervorul pentru stocarea namolului este din polietilenă şi are un volum util de 500 litri. Aici se va pompa nămolul provenit din decantorul primar, respectiv decantorul secundar.

Acesta nu are dotări suplimentare, fiind poziţionat la mijlocul distanţei dintre decantorul primar şi decantorul secundar, pentru a facilita extragerea nămolului, fără a fi necesară o lungime mare a furtunului prin care se face refularea din pompă.

3. Rezultate şi discuţii

SPE a avut o funcţionare intermitentă, pentru a se verifica rezistenţa acesteia la interperii pe tot parcursul anului. Rezultatele probelor efectuate pe apa epurata efluentă se pot vedea în tabelul de mai jos:

Tabelul 2

Rezultate probe ale apei epurate din SPE

	21.09.2018		26.10.2018		07.12.2018		14.12.2018	
	Intrare SEAU	Iesire Statie Pilot	Intrare SEAU	Iesire Statie Pilot	Intrare SEAU	Iesire Statie Pilot	Intrare SEAU	Iesire Statie Pilot
pH	7.4	6.5	7.4	7	7.6	6.9	7.5	7.7
CCOCr	302	39.6	332	28.2	354	42.2	326	37.2
N total	27.6	10.2	30.6	9.1	24.1	8.4	34.5	8.4
P total	3.2	3	2.7	1.8	2.9	1	3.1	0.9
MS	120	25	118	18	128	12	102	18
CBO5	129	15	120	12	183	8	171	10

Referitor la comportarea materialelor, sunt câteva observaţii de făcut. Deşi nu este recomandată expunerea conductelor de polietilenă la lumina solară, acestea nu au afişat urme de uzură sau degradare pe parcursul desfasurarii testelor. De asemenea, acestea ocupă un spaţiu redus comparativ cu folosirea, spre exemplu, a rezervoarelor din elemente prefabricate din beton.

Materialele folosite sunt uşoare din punct de vedere a masei specifice, permiţând manevrarea componentelor cu uşurinţă reducând costurile aferente manoperei în cazurile în care se doreşte modificarea schemei de epurare a apei. De asemenea, s-a observat lipsa reacţiilor fizico-chimice dintre apa uzată şi materialele folosite, acestea din urmă având o comportare adecvată aplicaţiei la care au fost utilizate.

De asemenea, este indicată utilizarea rezervoarelor cu secţiuni circulare, deoarece în rezervoarele rectangulare, la colţuri, se acumulează namol, care va fi greu îndepărtat fără a fi oprit procesul de epurare, după cum rezultă din figura 7 de mai jos.

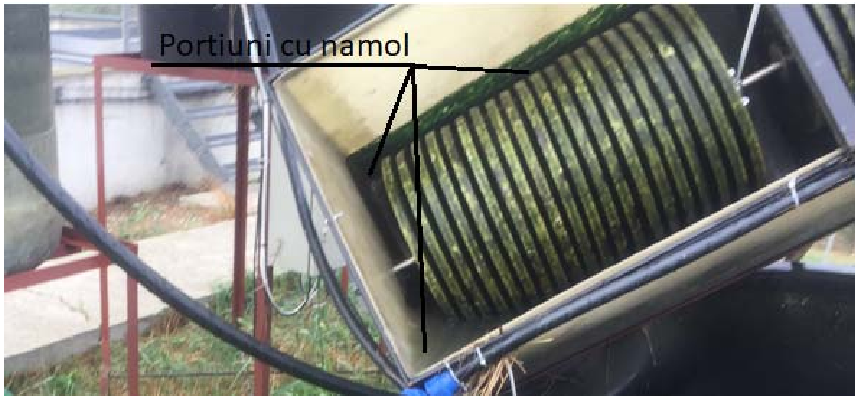

Figura 7 – Porţiuni unde se coagulează namol în unghiuri drepte

4. Concluzii

Putem concluziona că procesul de epurare a fost unul eficient, iar parametrii sunt în limitele acceptabile, SPE atingându-şi, astfel, scopul. SPE permite obţinerea de informaţii utile şi aplicabile, deoarece a fost testate pe apă uzată reală, provenită din influentul Staţiei de Epurare Municipale a Timişoarei. De asemenea, aceasta asigură o flexibilitate ridicată din cauza alcătuirii acesteia. Se pot introduce sau elimina elemente din alcătuire, permiţând, astfel, testarea a diferite scheme sau procedee de epurare a apei uzate.

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Echilibrarea puterilor din sistemul energetic

Balancing the powers of the energy system

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Rezumat. Pentru o funcţionare de calitate, un sistem energetic - (SE) - menţine frecvenţa la o valoare etalon, prin echilibrarea continuă şi în timp real a sumei puterilor furnizate de producători cu suma puterilor utilizate, care variază conform nevoilor utilizatorilor. În acest scop se folosesc şi hidrocentrale de acumulare prin pompaj (HCAP) - care, atunci când frecvenţa este ridicată, cu energie preluată din SE pompează apă din lacuri joase în lacuri situate mai sus, iar când frecvenţa este scăzută redau SE energie, turbinând apă din lacurile de sus în cele joase. Realizarea HCAP este costisitoare, iar utilizarea lor prezintă anual pierderi energetice mari, a căror amploare este ilustrată sugestiv în prezenta lucrare prin raportarea procentuală la întreaga energie electrică utilizată de România într-un an. Aceste neajunsuri (costuri mari şi pierderi energetice mari) impun căutarea unor metode noi, fără HCAP, de echilibrare a puterilor din SE.

Cuvinte cheie: system energetic, hidrocentrale

Abstract. For quality operation, an energy system (SE) maintains the frequency at a standard value, by continuously and in real time balancing the amount of power provided by manufacturers with the amount of power used, which varies according to user needs. For this purpose, pumped storage hydropower plants (HCAP) are also used, which, when the frequency is high, with energy taken from SE pumps water from low lakes to lakes located above, and when the frequency is low they return SE energy, tubing water from the upper lakes in the lower ones. The realization of HCAP is expensive, and their use has high energy losses annually, the magnitude of which is suggestively illustrated in this paper by the percentage ratio to the entire electricity used by Romania in one year. These shortcomings (high costs and high energy losses) require the search for new methods, without HCAP, to balance the powers of the SE.

Key-words: energy system, hydropower plants

⁘ Stadiul tehnic actual

În fiecare ţară funcţionarea de calitate şi în siguranţă a sistemului energetic (SE) se asigură printr-o strategie, uneori publică [1] şi respectă cerinţe tehnice, precum menţinerea frecvenţei la o valoare etalon (denumită şi valoare de referinţă sau de consemn). Pentru etalon s-a adoptat 50 Hz sau, numai în America, 60 Hz. Faţă de etalon se admit abateri mici în plus sau în minus, de până la 200 mHz [2, pag. 29].

Într-un SE, pentru simplificarea expunerii făcând abstracţie – numai în acest aliniat – de pierderile energetice din transformatoarele şi liniile electrice ale SE, când suma puterilor ΣP^f furnizate este egală cu suma puterilor ΣP^f utilizate ($\Sigma P^u = \Sigma P^f$) frecvenţa are valoarea etalon, când SE are excedent de putere ($\Sigma P^f > \Sigma P^u$) frecvenţa creşte peste etalon şi energia este ieftină, iar când SE are deficit de putere ($\Sigma P^f < \Sigma P^u$) frecvenţa scade sub etalon şi energia este scumpă.

Sarcina, adică ΣP^u, variază în timpul (t) al fiecărei zile (24 ore) conform nevoilor utilizatorilor de energie şi se reprezintă prin curba zilnică de sarcină CZS, adică $\Sigma P^u = f(t)$ [2, pag. 35, fig. 3.11]. CZS are zone (şi respectiv ore, puteri şi energii) de vârf, de semivârf şi de bază. Totodat ă, CZS prezintă variaţii lente predictibile (vârfurile de dimineaţă şi de seară şi golul de sarcină - noaptea) care impun compensarea curbei zilnice de sarcină CZS [2, pag. 10, fig. 1.4]. Dar CZS prezintă şi variaţii rapide impredictibile (cu durate de ordinul minutelor) care impun reglajul frecvenţei în timp real, reglaj realizat parţial descentralizat şi parţial centralizat, condus de un calculator [2, pag. 29], [3]. **Problema fundamentală a oricărui sistem energetic este asigurarea continuă şi în timp real a echilibrului perfect între puterea produsă şi puterea consumată,** adică compensarea curbei zilnice de sarcină plus reglajul frecvenţei.

Echilibrarea puterilor este dificilă, căci centralele atomice şi cele termice (mai ales cele pe cărbune) produc eficient numai puteri constante; doar hidrocentralele cu lacuri de acumulare asigură eficient puteri reglabile, dar limitate. Centralele eoliene şi cele solare dau puteri variabile aleator, după cum bate vântul şi străluceşte soarele, făcând şi mai dificilă echilibrarea. Dacă vântul bate atunci când frecvenţa este scăzută, sau în timpul orelor de vârf, energia eoliană transformată în energie electrică poate fi preluată în întregime şi fără dificultate în SE. Însă atunci când frecvenţa este ridicată şi/sau în timpul orelor de bază (noaptea) nu întotdeauna toată energia eoliană transformată în energie electrică ar putea fi preluată eficient în SE, deoarece disponibilitatea acestei energii, nefiind garantată anticipat, în SE se menţin în mod normal în funcţiune şi grupuri termoenergetice şi/sau grupuri nucleare, a căror oprire nu este rentabilă.

În devans faţă de directiva europenă 2009/28/CE (având scopul să crească ponderea energiei regenerabile în producerea energiei electrice necesare, pentru a reduce poluarea, efectul de seră şi încălzirea globală) s-a legiferat în România, încă din 2008, garantarea preluării în SE a energiei regenerabile [3]. Dar astfel au apărut şi efecte secundare păguboase. Concret, mari grupuri termo care ar fi trebuit pornite numai după cel puţin 24 ore de la ultima oprire (pentru a evita uzura accelerată a componentelor) au fost repornite după numai 13 ore, ajungându-se la avarii, precum spargerea cazanelor [3].

De asemenea, pentru a face loc energiei eoliene, s-au oprit cazane ale unor grupuri termo care erau programate să înceapă să producă (deci grupuri care consumaseră deja combustibil, dar încă nu livraseră energie electrică [3].

În aceste condiţii, după realizarea şi racordarea la SE a unor turbine eoliene însumând o anumită putere electrică, SE nu ar mai putea prelua eficient, pe baza soluţiilor tehnice cunoscute, energia livrată aleator de eventuale noi grupuri eoliene, aşa că se sistează (sau amână) amenajarea de noi parcuri eoliene, chiar dacă în zonă mai există încă un mare potenţial eolian neamenajat [3]. Iar la nivel global trebuie subliniat că sursa primară a energiilor regenerabile este radiaţia solară care ajunge pe pământ, iar aceasta depăşeşte de 10.000 ori necesarul mondial de energie [3], [4].

În SE în care nu se poate asigura echilibrarea puterilor în măsura necesară, trebuie realizate şi utilizate hidrocentrale de acumulare prin pompaj HCAP (denumite şi centrale hidroelectrice de acumulare prin pompaj, simbolizate CHAP sau CHEAP). HCAP, atunci când frecvenţa este ridicată, cu o energie ieftină E_{HCAP}^{pomp} preluată din SE pompează apă din lacuri joase în lacuri situate mai sus, iar când frecvenţa este scăzută, redau SE parte din energia preluată, ca energie scumpă E_{HCAP}^{turb}, produsă turbinând apa din lacurile de sus în cele joase. Restul energiei preluate acoperă parţial numeroasele pierderi energetice de la pompare (adică pierderile prin transformatoarele electrice din HCAP, prin motoarele electrice care antrenează pompele, prin pompe şi pierderile hidraulice prin circuitul hidraulic – priza de apă, galerii, castel de echilibru, vane, conducte şi distribuitor – dintre lacurile de sus şi de jos) şi de la turbinare (adică pierderile hidraulice prin circuitul hidraulic, pierderile prin turbine, prin generatoare şi prin transformatoarele din HCAP). La pompare şi la turbinare orice HCAP utilizează aceleaşi circuite (hidraulic şi electric) şi, de regulă, are maşini reversibile, adică turbinele funcţionează şi ca pompe, iar generatoarele funcţionează şi ca motoare electrice. Eficienţa sau randamentul total al CHAP este de circa 75%-80% [2, pag. 17], deci pierderile totale de energie sunt de aproximativ 20%-25% (în medie 22,5 %) din energia redată SE.

În prezent se preconizează amenajarea de noi CHAP, precum:

- în România CHAP Tarniţa-Lăpuşteşti, cu o putere de 1000 MW şi un cost de 1.150.981.000 € (incluzând staţia de transformare de 400 kV [2, pag. 85]) care să genereze anual o energie E_{HCAP}^{turb}=1649 GWh/an [2, pag. 86, rând 4 jos]; soluţia s-a stabilit şi printr-un grant de la guvernul japonez şi o finanţare de la Banca Internaţională de Reconstrucţie şi Dezvoltare, cu participarea firmelor Ansaldo GIE (Italia), Altshom-Neyrpic (Franţa), Toshiba, Hitachi şi Mitsubishi (Japonia) etc. [2, pag. 37-38];
- în Ungaria CHAP de circa 1200 MW de la graniţa cu Ucraina, pentru care deja s-a finalizat studiul de fezabilitate [2, pag. 14 jos];
- în Olanda o centrală de pompaj de circa 1500 MW [2, pag. 14 jos].

Iar un studiu din 2014 arată că Germania trebuie să crească puterea instalată în HCAP de la 7000 MW la 15000 MW în 2030 (în scenariul cu 60 % energie regenerabilă) şi la 23-25 mii MW în 2050 (pentru 80 % energie regenerabilă) [2, pag. 15].

În Europa sunt 169 HCAP, totalizând o putere de 60,3 GW (adică 60300 MW), anume 151 HCAP operaţionale, totalizând 50,2 GW, 12 HCAP în construcţie, 1 HCAP contractată, 3 HCAP anunţate şi 2 HCAP în reparaţie [2, pag. 16, fig. 2.5 jos].

În lume sunt 341 HCAP, totalizând 177,4 GW, anume 292 HCAP operaţionale, totalizând 142 GW, 31 HCAP în construcţie, 2 HCAP contractate, 11 HCAP anunţate şi 5 HCAP în reparaţie [2, pag. 16, fig. 2.5 sus].

Compania de consultanţă Global Market Insights într-un raport din august 2018 arată că, până în 2024, piaţa globală totală a CHEAP va depăşi 350 miliarde euro investiţii şi 200 GW capacitate instalată [2, pag. 36, rând 1-3 sus] din care în China vor fi peste 46 GW [2, pag. 36, fig. 3.12].

Amploarea acestor valori se poate percepe mai bine prin alăturarea de valorile energiei nucleare din UE. În UE energia nucleară asigură peste 30 procente din energia produsă, cu 1,1 milioane locuri de muncă, o cifră de afaceri anuală de 102 miliarde euro, având 109 reactoare în operare în 15 ţări, plus 4 reactoare în construcţie în Finlanda, Franţa şi Slovacia şi 8 reactoare în etapa de planificare în Bulgaria, Cehia, Finlanda, România şi Ungaria [5].

⁜ **Necesitatea unor soluţii tehnice noi pentru echilibrarea puterilor din SE**

Soluţia cu HCAP este veche de un secol. Atunci nivelul tehnic era modest (de pildă datele nu se puteau transmite şi prelucra rapid) şi nu se conştientiza gravitatea poluării. Astfel, se neglija atât faptul că producerea poluantă a energiei dăunează la fel dacă dă energie ieftină sau scumpă, cât şi caracterul global al efectelor poluării (poluarea din orice loc contribuie la efectul de seră, la încălzirea globală, dăunând astfel pe toată suprafaţa pământului).

Această soluţie prezintă 4 neajunsuri, anume:

1. realizarea HCAP este foarte costisitoare;

2. fiecare HCAP are nevoie, pentru a se racorda la SE, de o staţie de transformare şi de linii de transport al energiei electrice, uneori de sute de km (HCAP Tarniţa-Lăpuşteşti necesită o linie electrică aeriană scumpă de 400 kV de 158 km până la staţia de 400 kV Mintia şi una de 74 km până la staţia Gădălin [2, pag. 71, rând 3-9 sus];

3. la transportul energiilor electrice E_{HCAP}^{pomp} prin transformatoarele şi liniile electrice ale SE au loc pierderi de energie;

4. în cadrul HCAP au loc pierderi de energie de 20%-25% din energiile E_{HCAP}^{turb} pe care aceste HCAP le transmit spre SE din care fac parte.

Aceste 4 neajunsuri apar numai în cazul echilibrării puterilor din SE cu ajutorul HCAP şi, pentru eliminarea lor, se impune căutarea unor noi soluţii tehnice.

În cele de mai jos se detaliază ultimul din neajunsurile menţionate.

Deoarece, pe plan mondial, preţul energiei variază mult şi impredictibil, amploarea pierderilor anuale de energie generate în HCAP la echilibrarea puterilor se apreciază mai sugestiv în continuare, prin raportarea procentuală la întreaga cantitate de energie electrică utilizată de România în întregul an 2017, anume E_{Ro}^{u}=54,6 TWh [2, pag. 6, rând 17 jos]. La calculul pierderilor de energie rezultate anual în HCAP, se consideră că întreaga energie E_{HCAP}^{turb} =1649 GWh produsă ceea ce ar însemna o funcţionare de 1649 ore/an. Acoperitor, se consideră că fiecare HCAP din lume ar funcţiona cu puterea instalată numai 1500 ore/an şi se omit pierderile energetice de la transportul energiei E_{HCAP}^{pomp} prin transformatoarele şi liniile electrice din SE. Asadar,

⁜ cele 151 HCAP operaţionale din Europa, cu o putere totală P_{tot}=50,2 GW, la echilibrarea puterilor din SE generează pierderi anuale de energie:

$E_{pierderi}$ =1500 ore/an x 50,2 GW x 0,225=16.942,5 GWh/an=16,9425 TWh/an, iar procentual, raportat la $E_{Ro}{}^{u}$, rezultă $E_{pierderi}$ =16,9425 x 100/54,6=31,03% $E_{Ro}{}^{u}$.

∴ toate cele 169 HCAP din Europa, având 60,3 GW, generează anual pierderi:

$E_{pierderi}$ =1500 ore/an x 60,3 GW x 0,225=20,35 TWh/an=37,27 % $E_{Ro}{}^{u}$.

∴ cele 292 HCAP operaţionale din lume, având 142 GW, generează anual pierderi:

$E_{pierderi}$ =1500 ore/an x 142 GW x 0, 225=47,925 TWh/an=87,77 % $E_{Ro}{}^{u}$.

∴ toate cele 341 HCAP din lume, având 177,4 GW, generează anual pierderi: $E_{pierderi}$ =1500 ore/an x 177,4 GW x 0,225=59,8725 TWh/an=109,656% $E_{Ro}{}^{u}$. Iar în anul 2024, toate HCAP din lume, având 200 GW, vor genera pierderi:

$E_{pierderi}$ =1500 ore/an x 200 GW x 0,225=67,5 TWh/an=123,626% $E_{Ro}{}^{u}$, din care în China, cu 46 GW, se vor genera pierderi de energie:

$E_{pierderi}$ =1500 ore/an x 46GW x 0,225=15,525 TWh/an=28,43% $E_{Ro}{}^{u}$

Eliminarea acestor pierderi energetice va permite scăderea corespunzătoare, în fiecare an, a cantităţii de energie produsă poluant, protejând astfel mediul.

Mai trebuie subliniat caracterul concurenţial al căutării de soluţii noi şi competitive. Piaţa globală a HCAP însumează sute de miliarde de euro [2, pag. 36, rând 1-3 sus] şi face parte din piaţa şi mai amplă a echilibrării puterilor din toate SE din lume. Conştientizarea dimensiunilor acestor pieţe enorme mobilizează mai multe entităţi (grupuri de specialişti, firme, ţări) ca, independent unele faţă de altele şi chiar în concurenţă, să caute soluţii noi şi avantajoase de echilibrare a puterilor din SE. Dintre aceste entităţi concurente numai cele care vor reuşi primele să găsească, să breveteze internaţional şi să aplice soluţii noi şi avantajoase vor dobândi poziţii privilegiate pe aceste pieţe globale uriaşe.

În fine, necesitatea eliminării cât mai urgente a neajunsurilor menţionate şi conştientizarea atât a acestei necesităţi, cât şi a dimensiunilor pieţei globale de profil şi a concurenţei de pe această piaţă, impun intensificarea şi accelerarea la maximum posibil a eforturilor de găsire, de brevetare internaţională şi de implementare a unor soluţii tehnice noi şi avantajoase de echilibrare a puterilor din SE din toată lumea.

∴ **Concluzii**

Metode noi de echilibrare a puterilor din SE, fără HCAP, ar asigura eliminarea pierderilor energetice anuale, calculate acoperitor în lucrare, precum şi a pierderilor de la transportul energiilor E_{HCAP}^{pomp} prin SE şi ar permite scăderea corespunzătoare a cantităţii de energie produsă poluant, protejând astfel mediul.

În plus, s-ar obţine economii prin eliminarea atât a necesităţii de realizare a unor noi HCAP (cu staţiile de transformare şi cu liniile electrice aferente de transport a energiei electrice) cât şi a mentenanţei HCAP existente.

Firmele şi ţările care vor breveta internaţional şi vor implementa primele noi soluţii tehnice avantajoase vor dobândi poziţii privilegiate pe piaţa internaţională de echilibrare a puterilor din SE, piaţă de sute de miliarde de euro.

Conştientizarea valorii pieţei globale de echilibrare a puterilor din SE impune maximizarea eforturilor de căutare şi de implementare a unor noi soluţii în acest domeniu, iar necesitatea înlăturării urgente a neajunsurilor soluţiei actuale şi conştientizarea concurenţei impun accelerarea acestor eforturi.

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A short overview of IoT based energy metering system Part I Internet of things and the energy sector

O scurtă trecere în revistă a sistemului de contorizare a energiei electrice dotat cu internet

Partea I Internetul obiectelor şi domeniul energiei

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Abstract

This paper focuses on the presentation of a new and modern technology, namely the Internet of Things (IoT). In addition to the definition and history of the IoT in this article we briefly present the architecture and its essential components as well as the advantages and disadvantages of this new technology. Energy experts have shown that the IoT offer a wide number of applications in the energy sector, For this reason in the last part of this paper we present some aspects regarding the application of IoT in the energy sector.

Key words*: internet of things, architecture of IoT, components of IoT, IoT for energy sector*

Rezumat.

Această lucrare se concentrează pe prezentarea unei tehnologii noi și moderne, și anume Internetul obiectelor (IoT). Pe lângă definiția și istoria IoT in acest articol, prezentăm pe scurt arhitectura și componentele sale esențiale, precum și avantajele și dezavantajele acestei noi tehnologii. Experții în energie au arătat că IoT oferă un număr mare de aplicații în sectorul energetic, motiv pentru care, în ultima parte a acestei lucrări prezentăm câteva aspecte privind aplicarea IoT în sectorul energetic.

Cuvinte cheie:*, internetul obiectelor, arhitectura IoT, xomponentele IoT, IoT pentru sectorul energetic*

1 Introduction

Energy is a vital element of all human activities. Between 2001 and 2010, the world energy consumption increased by 29% and it has been estimated to grow by 57% by 2040. Today, coal, crude oil and gas are the primary sources of energy and they form approximately 80% of the world energy supply [1]. As a result of the rapid depletion of these energy resources, mankind is striving hard to uncover new avenues of energy security and management. Energy utility companies can achieve efficient management of electricity networks, ie reduce electricity losses and theft by means of an electricity measurement system based on the Internet of Things **(**IoT**)** For this reason in the first part of this paper we will present some general notions about the IoT and its use in the energy sector

2 What Is the Internet of Things (IoT)?

With the great developments in the field of Internet and technologies, everything has become digital. Internet has become an important part of our lives. A new technology has entered into this picture known as Internet of Things (IoT). Thus type of Internet is a network comprises of many electronic devices and sensors which are connected together to collect and exchange data or information over the web [2-4].

Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure [4]. The IoT allows objects to be sensed or controlled remotely across existing network infrastructure [6], creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention [5-6].

In other words IoT as is defined by ITU[1] and IERC[2] is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols, in which, physical and virtual “things” have identities, physical attributes and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network. [5], [7]

3 History of internet of things (IoT) [8]

The idea of devices exchanging information without human appeared not long ago. Full automation of data transmission was discussed in the late '70s. At that time this approach was considered as "pervasive computing" or “embedded internet”. It took several decades for technologies’ development to start talking about the Internet of Things. In the second half of the nineties, Briton Kevin Ashton worked for Procter and Gamble enterprise and was engaged in the production process optimization. He noticed that optimization directly depends on the speed of transmission and processing of data. It can take days for people who collect the data. The use of Radio Frequency Identification (RFID) has allowed accelerating the process of data transfer directly between devices. He had an idea of things to be collected, processed and transmitted with no human involvement. He decided to call it an "Internet of Things" and became a visionary at that time.

While the phrase came about in 1999, the concept of connected devices dates back to 1832 when the first electromagnetic telegraph was designed, and allowing direct communication between two machines through the transfer of electrical signals. However, the true Internet of Things history began with the invention of the Internet in the late 1960s

[1] ITU is the International Telecommunication Union, a United Nations specialized agency for information and communication technologies – ICTs fonded in 1865
[2] IERC is a European Center for Research Cluster on the Internet of Things

Today there are more than 27 billion devices connected to the Internet of Things, with experts expecting this number to rise to over 100 billion devices by 2030

4 Architecture of IoT

Architecture of IoT (see Fig. 1) [9-10],] depends on various applications of IoT.

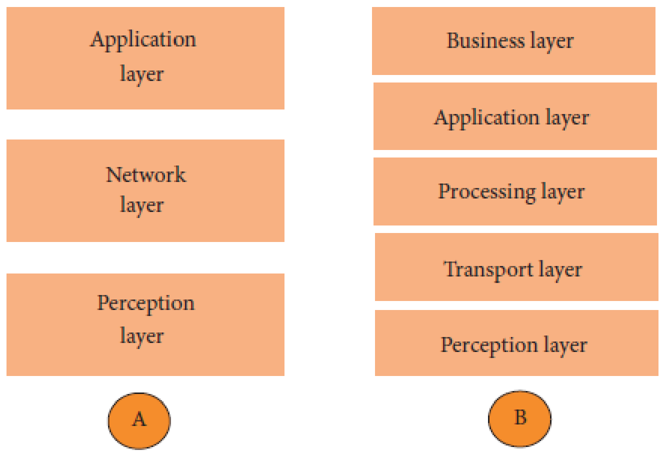

Fig. 1 Architecture of IoT (A: three layers) (B: five layers). [11]

There is no single consensus on architecture for IoT, which is agreed universally. Different architectures such as three- and five-layer architectures have been proposed by different researchers. [11-14],

The most basic architecture is a three layer architecture (see fig. 1 A). It was introduced in the early stages of research in this area and has three layers, namely:
a) The *perception layer* is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment; **b)** the *network layer* is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data, **c)** The *application layer* is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart metering, smart grid, smart meter smart city etc.

This architecture defines the main idea of the IoT, but it is not sufficient for research on IoT because research often focuses on finer aspects of the IoT. That is why, we have many more layered architectures proposed in the literature. One is the five layer architecture, which additionally includes
a) The *transport layer* which transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G[3], LAN[4], Bluetooth[5],

[3] 3G (short for third generation) is the third generation of wireless mobile telecommunications technology
[4] LAN or local area network is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building
[5] Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using ultra high frequency (UHF) radio waves in the ISM bands, from 2.402 GHz to 2.480 GHz,

RFID[6], and NFC[7] and **b)** The *processing layer* also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.

5 Elements of IoT [3]

Essential components [15] (see fig. 2) which are required to build IoT are

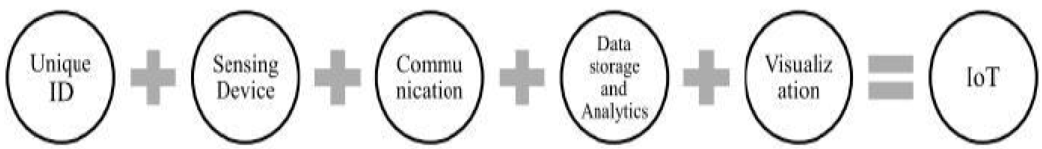

Fig. 2 Essential Key elements of IoT [16]

a) *Unique identification for each smart device* to identify the source of data (e.g., sensors, devices), **b)** *sensing devices* to collect information**, c)** *communication* **[**to send data from smart devices to the database through the communication technologies such as Radio Frequency Identification (RFID), Bluetooth, Near Field Communication (NFC), Wi-Fi,[8] ultra-wide bandwidth(UWB)[9], Z-wave[10], 3G, 4G[11] and Long Term Evolution-Advanced (LTE-A)[12]., **d)** *Data storage and analytics* **[3]** of data supplied by smart devices, **e)** *Visualization*. By using smart phones or laptops of data so that user can interact with centralized database and get the useful information about the actual environment.

6 IoT Characteristics [4]

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reserved internationally for industrial, scientific and medical purposes and building personal area networks i.e a computer network for interconnecting electronic devices centered on an individual person's workspace

[6] Radio-frequency identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID system consists of a tiny radio transponder, a radio receiver and transmitter. When triggered by an electromagnetic interrogation pulse from a nearby RFID reader device, the tag transmits digital data, usually an identifying inventory number, back to the reader. This number can be used to track inventory goods.

[7] Near-Field Communication (NFC) is a set of communication protocols for communication between two electronic devices over a distance of 4 cm or less

[8] Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access.

[9] Ultra-wideband (UWB) refers to a signal that has a −10 dB bandwidth greater than 500 MHz or a fractional bandwidth (bandwidth divided by the band centre frequency) greater than 20%. There has been intense recent interest in the use of such signals for high data-rate, low power, short-range communications

[10] Z-Wave is a wireless communications protocol used primarily for home automation

[11] The term 4G stands for 'fourth generation' and refers to mobile network technology that enables 4G compatible phones to connect to the internet faster than ever before

[12] LTE Advanced is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard LTE (Long Term Evolution) is a standard for 4G wireless broadband technology that offers increased network capacity and speed to mobile device users

The most important features of IoT include: **1)**. *AI* – IoT essentially makes virtually anything “smart”, meaning it enhances every aspect of life with the power of data collection, artificial intelligence algorithms, and networks.**2)**. *Connectivity* – New enabling technologies for networking, and specifically IoT networking, mean networks are no longer exclusively tied to major providers. Networks can exist on a much smaller and cheaper scale while still being practical. IoT creates these small networks between its system devices. **3)**. *Sensors* – IoT loses its distinction without sensors. They act as defining instruments which transform IoT from a standard passive network of devices into an active system capable of real-world integration. **4)**. *Active Engagement* – Much of today's interaction with connected technology happens through passive engagement. IoT introduces a new paradigm for active content, product, or service engagement. **5)**. *Small Devices* – Devices, as predicted, have become smaller, cheaper, and more powerful over time. IoT exploits purpose-built small devices to deliver its precision, scalability, and versatility.

7 IoT– Advantages and disadvantages

The advantages of IoT span across every area of lifestyle and business. Here is a list of some of the advantages that IoT has to offer:

1) *Improved Customer Engagement* – Current analytics suffer from blind-spots and significant flaws in accuracy; and as noted, engagement remains passive. IoT completely transforms this to achieve richer and more effective engagement with audiences.

2) *Technology Optimization* – The same technologies and data which improve the customer experience also improve device use, and aid in more potent improvements to technology. IoT unlocks a world of critical functional and field data. **3)** *Reduced Waste* – IoT makes areas of improvement clear. Current analytics give us superficial insight, but IoT provides real-world information leading to more effective management of resources. **4)** *Enhanced Data Collection* – Modern data collection suffers from its limitations and its design for passive use. IoT breaks it out of those spaces, and places it exactly where humans really want to go to analyze our world. It allows an accurate picture of everything.

Though IoT delivers an impressive set of benefits, it also presents a significant set of challenges. Here is a list of some its major issues:

1) *Security* – IoT creates an ecosystem of constantly connected devices communicating over networks. The system offers little control despite any security measures. This leaves users exposed to various kinds of attackers. **2)** *Privacy* – The sophistication of IoT provides substantial personal data in extreme detail without the user's active participation. **3)** *Complexity* – Some find IoT systems complicated in terms of design, deployment, and maintenance given their use of multiple technologies and a large set of new enabling technologies. **4)** *Flexibility* – Many are concerned about the flexibility of an IoT system to integrate easily with another. They worry about finding themselves with several conflicting or locked systems. **5)** *Compliance* – IoT, like any other technology in the realm of business, must comply with regulations. Its complexity makes the issue of compliance seem incredibly challenging when many consider standard software compliance a battle

8 IoT in the energy sector [18]

Today, the energy sector is highly dependent on fossil fuels. Excessive extraction and combustion of this fuel has a major economic impact due to air pollution and climate change.

The age of equipment in the power sector and poor maintenance problems can lead to high level of energy losses and unreliability. Assets are sometimes more than 40 years old, very expensive, and cannot be replaced easily. IoT can contribute to reducing some of these challenges in the management of power plants. By applying IoT sensors, Internet-connected devices are able to distinguish any failure in the operation or abnormal decrease in energy efficiency, alarming the need for maintenance. This increases reliability and efficiency of the system, in addition to reducing the cost of maintenance [18]

For reducing fossil fuel use and relying on local energy resources, many countries are promoting renewable energy sources (RESs) such as wind and solar energy. This variable renewable energy (VRE) sources pose new challenges to the energy system known as “the intermittency challenge”. In an energy system with a high share of VRE, matching generation of energy with demand is a big challenge due to variability of supply and demand resulting in mismatch in different time scales. IoT systems **1)** offer the flexibility in balancing generation with demand, which in turn can reduce the challenges of deploying VRE, resulting in higher integration shares of clean energy and less greenhouse gases (GHG) emissions. [19].
2) , a more efficient use of energy can be achieved by using machine-learning algorithms that help determine an optimal balance of different supply and demand technologies [22].

Smart grids are modern grids deploying the most secure and dependable Information and communications (ICT) technology to control and optimize energy generation, by connecting many smart meters, a smart grid develops a multi-directional flow of information, which can be used for optimal management of the system and efficient energy distribution [20]. The application of smart grid can be highlighted in different sub sectors of the energy system individually, e.g., energy generation, buildings, or transportation, or they can be considered altogether. In a smart grid batteries can be charged wirelessly using an inductive charging technology and in addition, in a smart grid, the energy demand pattern of end users can be analyzed by collecting data through an IoT platform,

IoT can play a crucial role in reducing energy losses and lowering CO_2 emissions.
An energy management system based on IoT can monitor real-time energy consumption and increase the level of awareness about the energy performance at any level of the supply chain [17], [21]. By monitoring and controlling equipment and processes, early stages of IoT started to contribute to the power sector by alleviating the risk of loss of production or blackout. [22]. Moreover, IoT can be applied in isolated and micro grids for some islands or organizations, especially when energy is required every single moment with no exception, e.g., in databases.

9 Conclusions

Putting all the above together you can come to the conclusion that IoT is the network of things, with clear element identification, embedded with software intelligence, sensors, and ubiquitous connectivity to the Internet. This „network of networks” enables things or objects to exchange information with the producer and supplier of electricity and/or other connected devices such as smart electricity meters (see part II and III of this paper). In the energy sector smart meters become an essential part of the IoT. One of the main advantages of installing smart meters is the connection with a reduction in carbon emissions.

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A short overview of IoT based energy metering system

Part II IoT smart energy meters

O scurtă trecere în revistă a sistemului de contorizare a energiei electrice dotat cu internet

Partea II Contoare inteligente de energie electrică dotate cu internet

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Abstract
Saving energy is high on the agenda for consumers and businesses, but with most of the electrical devices today, it's difficult to know how much energy we are actually using at any given point in time [1]. Electrical energy meter is a meter which helps the consumers to know their day to day power consumption to better control their usage and producers to manage production, One of the main method of communication between utilities and customers is Internet of Things (IoT), which is a mobile technology, available all over the world. IoT technology is also ideally suitable for data transfer over an always on-line connection between a central location and mobile devices. Therefore in this paper we will present a short review about smart energy meters based on Internet of Things (IoT) applications.
Key words *, electricity, smart energy meter, Internet of Things (IoT), arduino*

Rezumat.
O problemă foarte importantâ atât pentru producătorii de energie electrică cât şi pentru consumatori o constituie economisirea de energie electrică. Având însă în vedere gama foarte variată de dispzitive şi aparate electrice existente astăzi pe piaţă este foarte dificil să se cunoască câtă energie electrică se consumă de fapt la un moment dat [1], Contorul de energie electrică este un contor care îi ajută pe consumatori să-și cunoască mai bine consumul zilnic de energie electrică pentru a controla mai bine utilizarea energiei elctrice, iar producătorii de energie electrică cu ajutorul contoarelor de energie electrică pot realize o gestonare mai eficientă a producției de energie Una dintre cele mai moderne şi importante metode de comunicare între furnizorii de energie electrică şi clienții lor este Internetul tuturor lucrurilor sau internetul obiectelor (IoT de la expresia din limba engleză Interner of Things), care este o tehnologie mobilă, disponibilă în întreaga lume. Tehnologia IoT este, de asemenea, ideală pentru transferul de date printr-o conexiune întotdeauna on-line între o locație centrală și dispozitive mobile. Prin urmare, în această lucrare vom prezenta o scurtă trecere în tevistă a contoarelor inteligente de energie electrică care sunt prevăzute cu internetul obiectelor,
Cuvinte cheie *electricitate, cpntoare inteligente de enerhie electricăm Internetul obiectelor , arduino*

1 Introduction

Electricity is an important invention without which life on Earth is impossible. So obviously there is a need for measuring the consumed electricity. It is accomplished by the energy meters.

In earlier times utility's distribution and communication was only unidirectional. They generate and distribute electricity to customers. Using the traditional energy meters consumption was recorded and the monthly estimated bill was calculated by man power going door to door to each customers house which is time wasting coasty and inaccurate. Unlike this situation in the case of intelligent electricity distribution networks the communication between utilities and customers is bidirectional. By the implementation of smart meters consumers electricity consumption is recorded in real time and with bill estimation data is sent to the utility with out any need of human interface [2]

With the great developments in the field of Internet and technologies, everything has become digital. Internet has become an important part of our lives. A new technology has entered into this picture known as Internet of Things (IoT). Internet of Things is a network comprises of many electronic devices and sensors which are connected together to exchange some information over the web. The devices based on IoT seem talking and sharing data with each other

Smart meter is one of the applications of IoT It records the consumption and sends the readings to the utility office on regular basis for monitoring and billing [3]

The smart meter should have the following functionalities [3 - 4]:

1. Quantitative measurement namely meter should have the capability to measure the quantity of the medium using various methods and topologies.
2. Control and calibration i.e. meter should be able to compensate the small variations in the system.
3. Communication: meaning meter send and receive data effectively and has the ability to receive upgrades from firmware.
4. Power management i.e. in the case when power source is not properly available meter should be able to perform its task.
5. Display so that customer should be able to see the meter readings so that he/she can control electricity consumption as well as it will be helpful in billing or payment.
6. Synchronization: between the meter and the utility provider's system.

2 IoT Based Smart Energy Meters

IoT based smart power meter (see fig. 1) [3]. [5 -6].contains several parts, namely

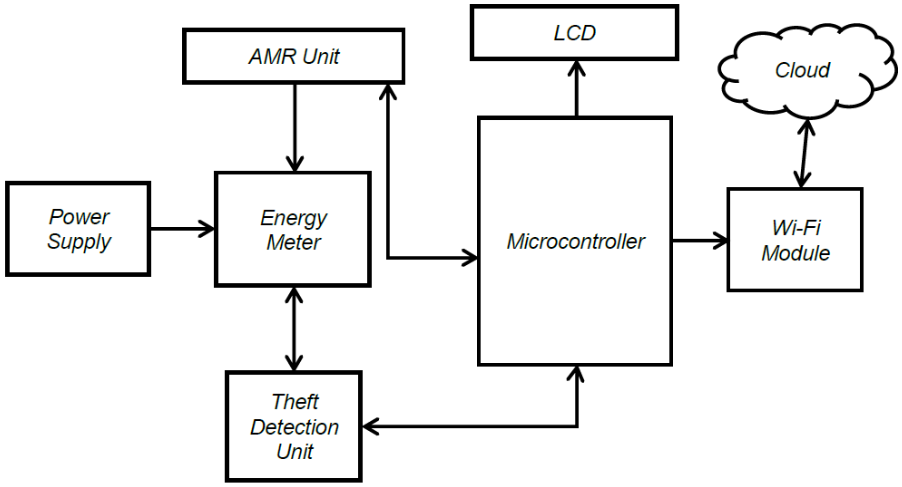

Fig. 1 Block diagram of IoT based energy meter [7]

1 *Main power supply*: The utility company's supply220V- 240V Ac (alternating current) which cannot be used directly.so we have to change it to DC (direct current) using a voltage transformer
2 *Energy Meter:* Energy meter used to measure the energy consumed by the customer is a digital meter because they are having high accuracy, with limited control and theft detection capability at nodes
3 *Electricity measurement circuit*: can be
a) *Hall element current sensor(IN4148 module)* In the measurement circuit, current is sensed based on the principle of Hall effect. [8-9]. According his principle, when a current carrying conductor is placed into a magnetic field, a voltage is generated across its edges perpendicular to the directions of both the current and the magnetic field. Let us not get too deep into the concept but, simply put we use a hall sensor to measure the magnetic field around a current carrying conductor. This measurement will be in terms of millivolts which we called as the hall-voltage. This measured hall-voltage is proportional to the current that was flowing through the conductor [10]. This sensor is chosen due to its low cost and easily interface with microcontroller. The current sensed from Hall effect sensor will be passed to the voltage sensor so as to be changed to direct current using the transformer in the voltage sensor
b) *CT current sensor* which is a type of instrumental transformer specially designed to transform alternating current in its secondary winding, and the amount of current produced is directly proportional to the current in the primary winding.
4 *Theft detection module* contain two CT current sensor, CT sensor 1 works as a main meter and CT sensor 2 works as a sub meter, both are connected to the Arduino using interfacing circuit. The interfacing circuit consists of burden resistor and voltage divider circuit for signal conditioning. During normal operation, the reading of CT sensor 1 should be equal to the reading of CT sensor 2. If the readings of both sensors are equal the message no theft will be displayed on LCD else it will displayed the theft is occur. If theft occurs the relay will operate and this can use for disconnecting the load [7]
5 *Transformers* is a static device which is used to power up or power down the electrical voltage without changing frequency. The transformation of electrical voltage is done with the help of mutual induction process. The frequency remains constant during the process [11]

6 *Microcontroller:* Measurement circuit is interfaced with the Arduino microcontroller - an open source microcontroller board based on the Microchip ATmega328P microcontroller.This microcontroller, which receives the measured data from sensor, using optocoupler (P817) to convert the pulses to electrical signals acting as clock pulses for the microcontrolle and send calculated data to Raspberry Pi. The Arduino software runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows. Arduino power measurement is an advanced method of determining power and this method is more advantageous than other software's such as MATLAB. Cross-platform. being also less in cost as compared to other controller. [10]. Arduino is energy efficient i.e. it consume less power, it is fastest and has two universal asynchronous receiver-transmitter (UARTS). The microcontroller is attached to our traditional energy meters that will scan the meter reading periodically [12]

7 *Relay* is an electrical device which is used to make or break contact. There are different types of relay such as Single Pole single Throw(SPST),Single Pole Double Throw(SPDT) and Double Pole Double Throw(DPDT).There are three contacts in the relay which are Normally Open(NO), Normally closed(NC) and No connection. It can be used for high power applications as well as low power applications. Relay controls the Arduino when the power in switched on and it is used to cutoff the power when overload detection and theft detection [11]

8 *Communication unit design*, can be:

a) *Wi-Fi module* [2] In order to create wireless communication between the device and customers WIFI module (ESP8266) or in other words Wireless Fidelity module is used since its low cost standalone wireless transceiver that can be used for end-point IoT developments. Wi-Fi module acts as heart for IoT. Through Wi-Fi the consumer can set changes in threshold value, he can ON and OFF the energy meter. Time to time the readings of units and cost are displayed on webpage. Consumer can accesses the Arduino board and meter with help of Wi-Fi ESP8266WIFImodule uses TCP/UDP communication protocol in order to communicate the microcontrollers data with client or server. The power calculated by the Arduino including time stamp will be transmitted to cloud server using this Wi-Fi module

b) *GSM/GPRS Module (SIM800C)* [12-13]**:** can accept any GSM network act as SIM card and just like a mobile phone with its own unique phone number. This module will enable the remote access through the internet, SMS and call facility Advantage of using this modem will be that you can use its RS232 port to communicate and develop embedded applications.

GSM is the Global System for Mobile Communication is a digital network that is widely used by the people in the world. The GSM uses the TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access) variations. The mobile devices will be connected using hardware and identifies through the Subscriber Identity Module (SIM). Through these connections the mobile phones can accessed.

9 *IoT Module* Internet of Things (IoT) is the main method of communication between the energy meter and the web server. IoT, being mobile technology, is available all over the world. In IoT everything is configured with internet protocol addresses [14] and it can monitor controlled and access remotely in accordance with web technology.

The main advantage of this technology is that devices are connected smartly with the help of sensors and transducers and these are again connected to (Local area Network) LAN, (Wide Area Network) WAN, via Ethernet or Wi-Fi connectivity [15]

In the IoT part is used an open data platform called Smart Living Make and ThingSpeak which Send Realtime data to the cloud for storage, analyze and visualize the data. Users can also control the meter using mobile application

Thing Speak is an open source platform for Internet of Things (IoT) application and Access Point Index (API) which stores and retrieves data from things by the HTTP and MQTT protocol [16]

10 *LCD Display* Liquid Crystal Display or 16X2 LCD module which comes with 4-bit data and 3-bit control pins is connected with microcontroller to show the consumed units and cost. At the end of each month the data containing the consumed units and cost is shared using internet shield web interfaced data are received and stored in a database at the premises of service. The LCD Contrast can be varied with the potentiometer provided on board [10], [17].

3 Conclusions and future enhancement

Benefits of IoT smart energy meter over traditional electromechanical meters are the following [3], [19]:

1. Smart meters are less error prone. Accurate readings are obtained by the customers and utility providers.
2. Readings can be sent remotely over the web to the utility providers. Employees need not to be physically present at the site.
3. Tampering of these meters can be easily detected by the authorities.
4. Smart meters when programmed with home appliances can be used to control the electricity consumption
5. Intelligent energy meter is easy to install and beneficial for both energy provider and consumer plus its cost effective and energy efficient. [2]
6. One of the main advantages of the smart meter installation is the link to a reduction in carbon emissions [19].

Limitations of smart energy meter are the following [20]:

1. Security to protect the privacy of the personal data collected should be good.
2. There can be an additional fee for the installation of the new meter.
3. The Internet is not available in remote areas.
4. The IOT is a diverse and complex network.

After loading and recording the load consumption of the residents, the data can be accessed and exported by the utility in various formats for further analysis such as:

- residential based load/demand forecasting
- customer behavior analysis (load profiling)
- bad data (electric theft) detection
- demand response program

The development of IoT based smart energy meter demonstrates the concept and implementation of new power metering system (see Part III of this paper) which is a flexible system, has low operating costs and less man power is required. This system is well suited for smart cities [10]

This IoT based energy meter use to access meter reading and bill amount by the use of web server and help consumer to avoid unwanted use of electricity as well as to detect any kind of theft of electricity [18]

Following are the future scope in order to save electric power and to detect theft [18]:-

- there can be a system where Automatic Switching of electric equipments by the use of IoT is applied.
- to make a system where user can receive SMS, if one crosses threshold of electricity usage.
- to make a IoT system where user can monitor energy consumption and pay electricity bill online
- user receives SMS when theft detected at consumer end.
- application of IoT based theft detection buzzer with Energy Meter

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A short overview of IoT based energy metering system

Part III IoT based electricity theft detection and bill generating system

O scurtă trecere în revistă a sistemului de contorizare a energiei electrice dotat cu internet

Partea III Sistem de detectare a furtului de energie electrică și generare a facturilor

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Abstract
In this connected world, the development and widespread use of smart devices has led to a new beginning for machine-to-machine communication anytime and anywhere. As artificial intelligence spreads, this connectivity has created a completely different vision of the Internet of Things (IoT). The IoT has led to the emergence of a virtual network between man and the physical world of various things, thus drastically changing the way various businesses operate. In this context, the paper below describes a system of reading electricity meters based on the IoT and integrated circuits containing microcontrollers known commercially as Arduino. In this paper we also present a remote electricity billing system. This billing process is faster and more efficient, enabling customers to pay their bills earlier.

Key words: *electricity theft, Internet of Things (IoT)*, *billing system*

Rezumat.
În această lume conectată, dezvoltarea şi utilizarea pe scară tot mai largă a dispozitivelor inteligente a condus la un nou început pentru comunicarea de tip mașină - maşină în orice moment și în orice loc. Pe măsură ce inteligența artificială se răspândește tot mai mult, această conectivitate a creat o viziune cu totul aparte cu privire la internetului obiectelor (sau lucrurilor). Internetul lucrurilor a condus la apariţia unei reţele virtuale între om și lumea fizică formată din diverse lucruri, schimbând astfel drastic modul în care funcționează diverse afaceri. În acest context în lucrarea de mai jos se descrie un sistem de citire a contoarelor de energie electrică bazat pe internetul obiectelor şi circuite integrate care conţin microcontrolere cunoscute comercial sub numele de Arduino. În cadrul acestei lucrări prezentăm de asemenea şi un sistem de facturare a consumului de energie electrică la distanţă. Acest proces de facturare este mai rapid şi eficient dând astfel posibilitatea clienţilor, să poată plăti facturile mai devreme.

Cuvinte cheie:*, furtul de energie electrică, internetul obiectelor (IoT), sistem de facturare*

1 Introduction

Energy emergency is one of major problems that the world faces today. The best remedy for this is not the increases in energy production, but the effective use of available energy. By properly monitoring energy consumption and avoiding energy wastage, energy emergency can be reduced to a certain extent. But energy monitoring cannot be done efficient mainly because consumers are not aware of their energy consumption.

They will get an idea about their consumption only when the electricity bills are issued. Usually bill is issued only once in a month or two months. So the consumers will be in dark during this period of time about their energy usage. In this era of complete digitalization, no one will take the pain to go and check their electricity meter reading and compare it with the previous reading so as to get an idea about their consumption. This whole procedure has to be repeated several times in a month to efficiently control the energy usage. If consumers can check their energy consumption using their mobile phone or laptop instead of checking energy meter, it will be a great leap in the area of energy management. Since most of the people are today 24*7 online, it will be really a boon if they can monitor their energy consumption online from anywhere on the globe. In this paper, we are describing a method of electricity energy meter reading using IoT concept [1].

To check electricity consumption by using mobile phone or laptop instead of checking energy meter, can be used an energy meter that involve the IoT concept, (see Part II of this paper). So, there is a way for a consumer to track their electricity consumption from time to time so that they can better control their consumption and manage their budget. This system is useful for both consumers and supply.

This method makes it impossible for a certain consumer of electricity to intervene if he is disconnected from the power supply system as a result of non-payment of electricity bills or theft. In other words a system for measuring electricity consumption based on the Internet of Things (IoT) plays a vital role to inform supplier about any theft that is happing in the network [1].

2 The system for detecting electricity theft

Electricity power theft which is a non-technical electricity power loss is one of the major issues of each developing country. These non-technical losses of electricity are difficult to estimate. In the current electricity metering system, manipulation for the purpose of stealing electricity can be easily done.

Detection of electricity theft has traditionally been approached through physical checks of obvious handling seals by field staff and the use of meters. Although these techniques reduce unmeasured and unbilled electricity consumption, they are insufficient. Indeed, tamper-proof seals can be easily broken, and while meters can detect that some customers are fraudulent, they cannot accurately identify culprits.

There are many methods which have been proposed for theft detection. Many of these methods include load profile analysis of customers to detect abnormal energy consumption patterns. But these methods cannot be used to detect energy thefts when there is a complete bypass of electricity meters. In such cases, electricity losses are calculated by using energy balance between the energy supplied from the distribution transformer and the energy consumed at the consumer's end. An effective way for estimating non-technical losses in the electricity distribution network is correctly estimating the technical losses in the network and then subtracting it from the total loss in the network [2-3].

One of the newest and most modern methods of detecting non-technical losses in the transport of electricity is a method that works on the basis of the Internet of Things [3], [4-8].

A general system architecture for energy monitoring using IoT (see fig 1) can be made up of:

a) bottom layer which contains smart meters and sensors, which may be connected through wired or wireless networks. Smart energy meters available on the market can attain several parameters (e.g. power consumption, max/min of peak voltage and power factor), hence they provide a high level of flexibility in monitoring and analyzing energy consumption.

b) an intermediate level, from where the collected data is sent to a gateway and then transferred to a local computer or the Internet via standard communication protocols such ZigBee.

Eventually, data are fed into Enterprise Energy Management (EEM) software for analysis, into other enterprise systems such as: Building Management Systems (BMS), Advanced Production and Scheduling systems (APS), Manufacturing Execution Systems (MES), Manufacturing Resource Planning (MRPII), or simply into the Enterprise Resource Planning (ERP). The data from smart metering systems can also be integrated with a supervisory control and data acquisition system (SCADA)

In the design of smart energy meter, (see part II of this paper) the microcontroller is interfaced with AMR module, theft detection module and Wi-Fi module. The microcontroller is a core component of the smart energy meter system which is placed at the consumer end for the purpose of measuring the meter reading, theft detection and storing the data. This data is transferred between consumer end and energy supplier end using IoT module (ESP3866 Wi-Fi). The AMR module continuously monitors the meter and collects the reading and sends to the microcontroller. In the current scenario, there is a need to uniquely identify the smart meter device remotely in a reliable manner. To achieve the characteristic of device remotely we have provided IP address for each connection. In this paper we have concentrated on the theft detection, optimum utilization of power and convey the energy consumption information to the user end.

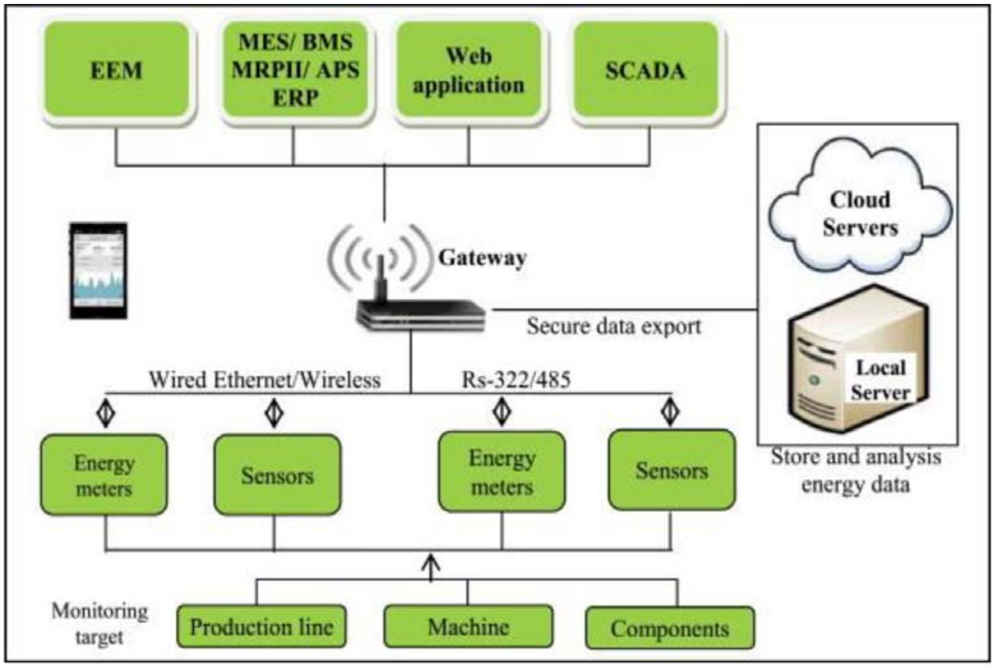

Fig 1. General System Architecture for Energy Monitoring Using IoT [9]

At the consumer end, the power supply module provides the entire power needed by the system to function. Also this power supply charges the Backup Domain Controller[1] (DC Backup) so that when there is no power from the utility company, the DC Backup can energize the system. Microcontroller is used to collect and store the meter reading information from the electricity meter and also performs the control process and sends the required information to energy provider such as number of units consumed using Wi-Fi module. The purpose of LCD module is to get visual information about the number of units consumed, alert messages and connection status. This is a backup power supply unit (DC backup) for the system. The purpose of the DC backup is to makes the system active even there is no energy supply from the utility company. A small 8.4V, 5600mAh rechargeable battery is used here

3 Bill generating system

As time goes on, technology is becoming more and more a part of our daily lives. Although there is unprecedented progress in science and technology today, this progress is not always fully utilized. One such area where improvements can still be made is the area of electricity billing and payment.

Since for electricity board (EB) an automated billing system [10]

1. the need to pay the bills at the EB office

2. allows the user to: **a)** get updated details of the power used in his house, **b)** check if the invoice received is correct or not

[1] A backup domain controller (BDC) is a role a Windows NT computer takes on to help manage access to network resources

3. the wireless method sending data is feasible even when more buildings are being built into the network,
in this part of the paper we will present a system for billing electricity consumption based on the Internet of Things (IoT) [11-16].

An invoice generation system based on the Internet of Things consists in the continuous monitoring of an intelligent electricity meter, i.e, in collecting the consumed units, generating the invoice and sending it automatically to the user. Therefore in the automated EB billing system there are two modules namely EB office module and customer home unit (see fig. 2)

The EB office module consists of a database at the back end for storing values which are got from the home module. After the values are got from the home units the cost is calculated and the values are sent back to the home unit and they are displayed in the LCD display for the user to make note of it.

Customer home unit includes a energy meter that informs the consumer the exact consumption and billing that the load consumes through IoT, ATmega328 microcontroller, which is used in Arduino-Uno platform applied in case of communication through IoT, ESP8266 Wi-Fi module which allows the circuits to be connected to the internet, a liquid-crystal display (LCD), 12V relay, server (web page) and load

An intermittent LED, mounted in the meter, emits pulses that are directly proportional to the electricity consumed. power consumed. The higher the electricity consumed, the faster the intermittent pulses of the LED. To obtain the value of energy consumed in real time above the flashing LED, a sensor is mounted, the output of which is connected to an ATmega328 microcontroller

Fig.2: Block diagram of bill generating system [15], [17]

Whenever the LED blinks, it then gives an interrupt signal to the microcontroller of the ATmega328 family and thus the program of the microcontroller counts the pulses and displays the reading on the LCD duly interfaced to the microcontroller for every minute / daily / weekly or monthly as programmed which is sent to the screen of server. For every 30 seconds, the PIC controller tries to send the value received to the central public server through IoT. We are using Wi-Fi which acts as a heart for IoT. Through Wi-Fi the consumer can set changes in threshold value, it can ON and OFF the energy meter. When the load connected to the meter is ON then the meter will start counting the watt hour cycles being used, interface is provided between energy meter and microcontroller by means of a step down transformer and C program is embedded into the microcontroller which helps it to calculate the number of units used by the consumer by means of input KWH cycles taken by energy meter and the relay will operate for disconnecting the load. The calculated units are displayed on an LCD which is connected to microcontroller. By this user can manage his usage of power and save the electricity and plan his budget.

Daily energy consumption can be monitored and viewed through a graphical representation using a web portal or web page. The daily limit of energy usage can be set. The server collects all information received from the energy meter units installed in every home and stores it in a central database. It is accessible to end-users through web portal/mobile app. End-users can monitor their energy consumption and view their bills. Monitoring server actively monitors for the data from the energy meter and records the information received in the database. The switching of any load can be done. The web page will have a admin login option so that we can keep our system secure. This page can be access by both server and consumer. Bill generation is done automatically by this server at the end of every month without any manual work involved.

4 Conclusions

In the most of the developing countries, the effort of collecting electricity utility meter reading and detecting illegal usage of electricity is a very difficult and time consuming task which requires a lot of human resources. Energy meter reading and monitoring system using Internet of Things (IoT) present an efficient and cost-effective way to transfer the information of energy consumed by the consumer wirelessly as well as it provides facilities to detect the illegal usage of the electricity. Such a system also allows the automatic generation of the bill necessary to pay for electricity consumption. This system which helps in controlling energy consumption and avoiding energy wastage is very important. The system is based on an Arduino and implementation of energy meter using IoT concept.

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Energy and environmental strategies in the context of climate change

Strategii energetice și de mediu în contextul schimbărilor climatice

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Abstract. *In the current context of increasing energy consumption, greenhouse gas (GHG) emissions and the serious consequences for the environment, society and the economy, at global, European and national level, the countries of the world are taking measures to fight the effects of climate change by establishing energy and environmental strategies and policies.*
Starting from the commitment established at European level to neutralize net greenhouse gas emissions by 2050, the paper presents the energy and ecological framework of Romania in 2020, the energy and ecological objectives for 2030 and the measures proposed to achieve the targets on reducing GHG emissions, improving energy efficiency and promoting renewable energy sources.

Keywords: greenhouse gas, GHG, emission, neutralization, strategy, energy, ecology, environment, climate change, Romania

Rezumat. *În contextul creșterii consumului energetic, al emisiilor de gaze cu efect de seră (GES) și al consecințelor tot mai grave asupra mediului, societății și economiei, atât la nivel global, cât și european sau național, statele lumii iau măsuri de combatere a efectelor schimbărilor climatice, prin stabilirea unor strategii și politici energetice și ecologice.*
Pornind de la angajamentul stabilit la nivel european de neutralizare a emisiilor nete de gaze cu efect de seră până în anul 2050, lucrarea prezintă contextul energetic și ecologic al României la nivelul anului 2020, obiectivele energetice și ecologice pentru anul 2030 și măsurile propuse pentru atingerea țintelor privind reducerea emisiilor de GES, îmbunătățirea eficienței energetice și promovarea surselor regenerabile de energie.

Cuvinte cheie: gaze, efect de seră, emisie, neutralizare, strategie, energie, ecologie, mediu ambiant, schimbări climatice, România

1. Introduction

In the current context of the disastrous impact of climate change, proved by extreme weather events: floods, drought, forest fires, rising sea and ocean levels, lowering of the ice caps, rising temperatures etc., fighting the increase in greenhouse gas (GHG) emissions, considered the main cause of climate change, is an increasing priority at global, European and national level.

Globally, the year 2020 was the warmest year ever recorded (on par with the record of 2016), with the global average temperature in 2020 being 0.6^0C higher than in 1981-2010 and around 1.25^0C above the pre-industrial period 1850-1900 (Figure 1). At European level, the average temperature in 2020 was 0.4^0C above that of 2019 and 1.6^0C above the 1981-2010 reference period.

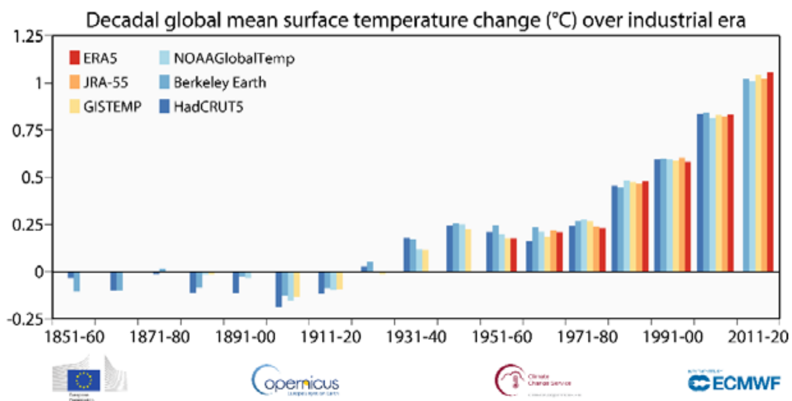

Fig. 1. Global average temperature relative to pre-industrial era [1]

Atmospheric CO_2 emissions continued to growth at a rate of around 2.3 ppm/year in 2020 (lower than in 2019), reaching a peak of 413 ppm in May 2020 (Figure 2).

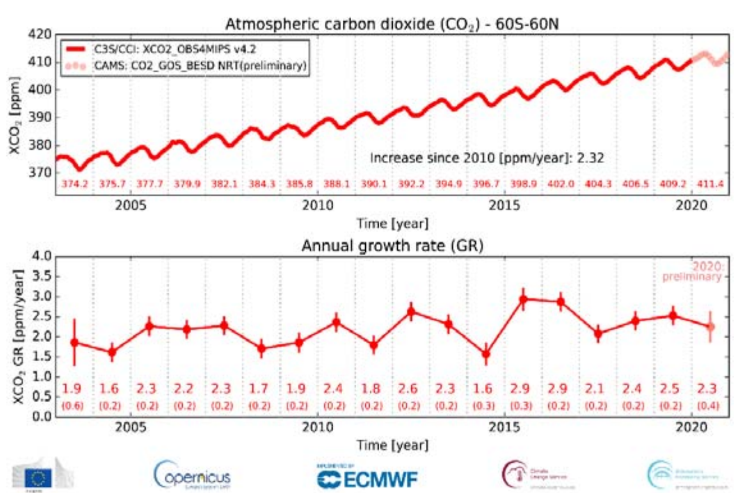

Fig. 2. Global monthly atmospheric CO_2 emissions for the period 2003-2020 and annual growth rate (GR) [1]

The increase in the frequency and intensity of extreme weather events will generate serious consequences for both people and the economy. To reduce the risk of climate change, efforts to reduce greenhouse gas emissions will need to be continued.

2. EU climate change goals

By adopting the Paris Agreement on climate change (2015), the countries of the world are committed to fight the effects of climate change, limiting the increase in the global average temperature by well below 2^0C (as far as possible to 1.5^0C) compared to 1990 levels, and to presenting national plans to reduce emissions, reviewing their commitments every 5 years.

To highlight the importance of limiting global warming, Figure 3 presents several future scenarios (2020-2100) for GHG emissions: no climate action, if current policies continue, and if all countries have achieved their goals and necessary pathways compatible with limiting global warming to 2^0C (or 1.5^0C). According to the IPCC's Special Report on 1.5°C and the works of Michael Raupach published in *Nature Climate Change*, the presented scenarios underline that urgent and rapid reductions in greenhouse gas emissions will be needed [2], [3], [4], [5].

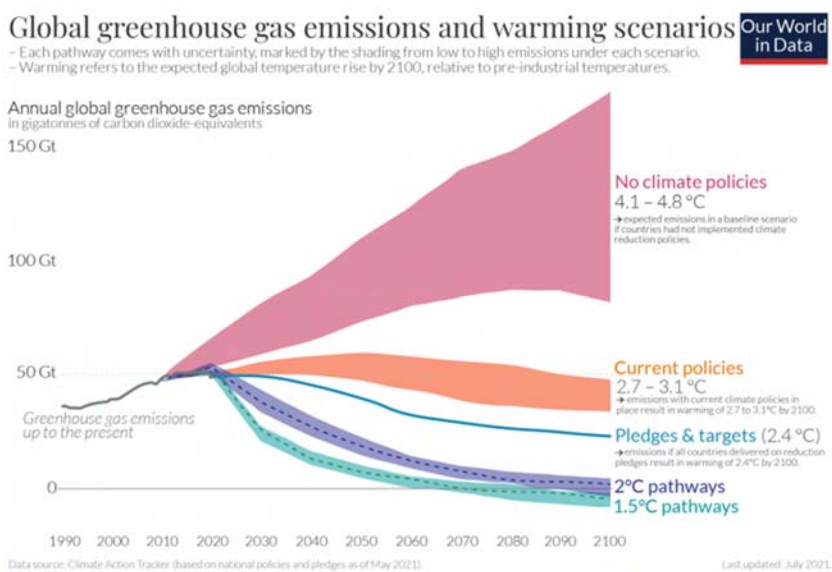

Fig. 3. Climate scenarios and policies on GHG emissions [5]

The current commitment of the European Union (EU) and its Member States is to reduce emissions by at least 55% in 2030 compared to 1990, with the aim of achieving climate neutrality by 2050, pointing for an economy free of greenhouse gas emissions. Romania supports the EU's objective of climate neutrality for 2050 and the implementation of the European Green Deal (EGD).

To overcome the threatening challenges to the environment and society, the European Green Deal aims to transform the EU into a modern, resource-efficient and competitive economy by neutralizing net GHG emissions by 2050 and ensuring economic growth without depleting resources.

3. Romania in the context of climate change. Energy and environmental objectives

Given that 75% of EU greenhouse gas emissions come from energy production and consumption, the focus will be on review the energy sector to ensure climate neutrality [6]. The European Union has thus set the following energy and climate important targets for 2030 [7]:

- The reduction of greenhouse gas emissions by at least 40% by 2030 compared to 1990;
- Renewable energy consumption of 32% in 2030;
- Improving energy efficiency by 32.5% in 2030;
- Interconnection of the electricity market at a level of 15% by 2030.

In order to achieve the proposed targets, EU Member States have submitted National Energy and Climate Plans for the 2021-2030 period, setting out national targets and contributions in terms of energy efficiency, renewable energy and greenhouse gas emission reductions.

Romania's energy and environmental objectives for 2030, included in the National Integrated Plan in the field of Energy and Climate Change 2021-2030 (PNIESC 2021-2030) are highlighted in Table 1.

Table 1

The main objectives of the PNIESC 2021-2030 for the year 2030 [7]

ETS emissions (% vs 2005)	-43.9%
Non-ETS emissions (% vs 2005)	-2%
Overall share of energy from renewable sources in gross final consumption of energy	**30.7%**
Share of RES-E	49.4%
Share of RES-T	14.2%
Share of RES-H&C	33%
Energy Efficiency (% compared to PRIMES 2007 projection at 2030 level)	
Primary energy consumption	-45.1%
Final energy consumption	-40.4%
Primary energy consumption (Mtoe)	32.3
Final energy consumption (Mtoe)	25.7

In Romania, GHG emissions experienced a downward trend in the 1990-2017 period, the largest share of emissions being recorded in the energy sector.

In the context of the current measures, Romania is expected to reach a reduction of about 49% of emissions in 2030, compared to 1990 (Figure 4).

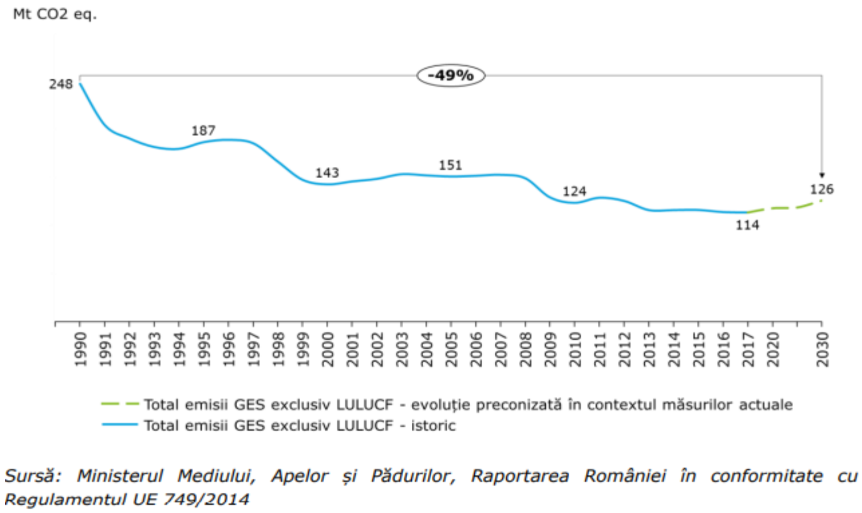

Fig. 4. Expected evolution of GHG emissions in Romania [7]

The expected economic growth for 2030 is shown by the increase in final energy consumption in the transport sector, the industrial sector, the tertiary sector and a decrease in energy consumption in the residential sector as a result of improved energy efficiency.

Figure 5 shows the final energy consumption for 2020 and the projections for 2025 and 2030 in two scenarios: the modelling scenario in the context of existing measures (WEM) and the modelling scenario in the context of planned measures (WAM).

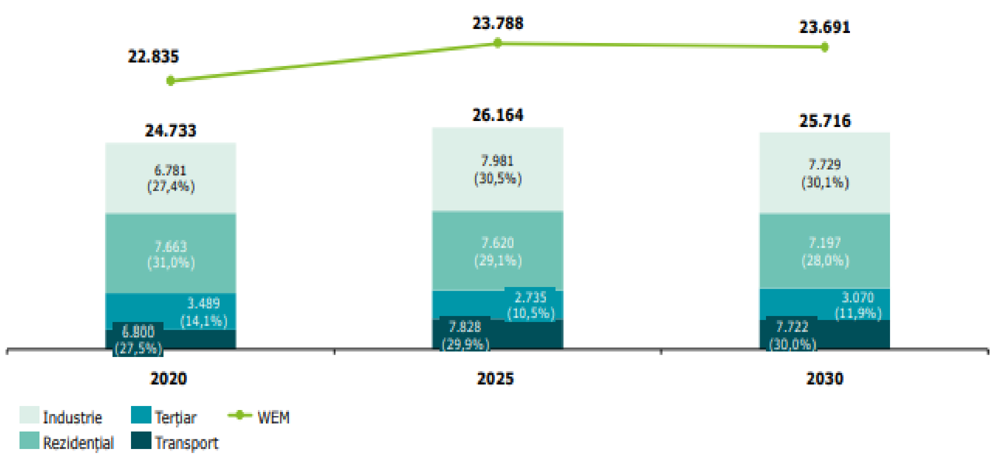

Fig. 5. Final energy consumption in Romania [7]

According to reports over the 1990-2020 period (Figure 6 and Figure 7) it is observed that, both at European and national level, although fossil fuels still dominate in securing energy supply, there is a growing annual increase in the share of renewable energy.

In order to reduce emissions, improve energy efficiency and increase the share of energy from renewable sources, Romania will aim to reduce primary and final energy consumption, focusing on the use of renewable energy sources (RES) in the relevant sectors, namely: heating &cooling (RES-H&C), electricity (RES-E) and transport (RES-T).

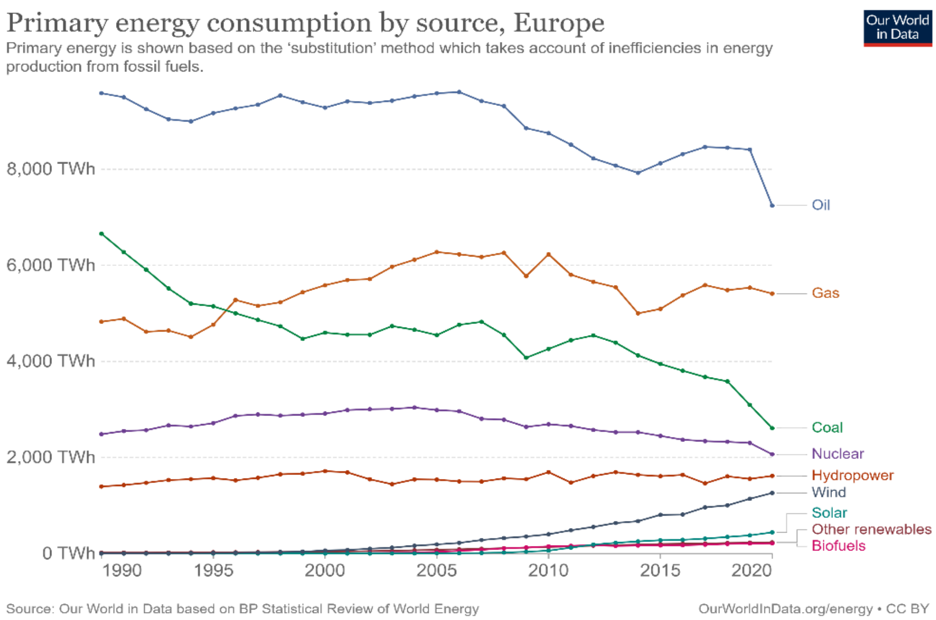

Fig. 6. Primary energy consumption by source in the EU [8]

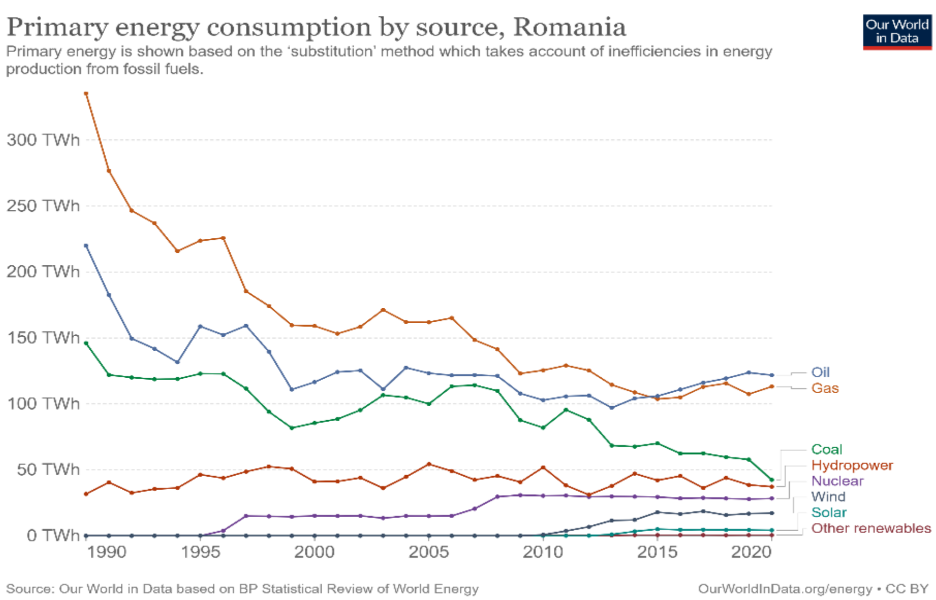

Fig. 7. Primary energy consumption by source in Romania [8]

Tables 2, 3 and 4 show the estimated trajectories of renewable energy, distributed by technology, for the 2021-2030 period.

Table 2

Anticipated evolution of renewable energy in gross final consumption of energy in the heating &cooling sector for the 2021-2030 period [7]

ktoe	2020	2025	2030
Final energy demand	3481.2	3892.1	4026.5
Derived heat	76.2	170	263.7
Heat pumps	-	55	119.6
Total gross final consumption of energy from renewable sources in the Heating&Cooling sector	**3557.4**	**4117**	**4409.8**

Table 3

Anticipated evolution of renewable energy in gross final consumption of electricity for the 2021-2030 period [7]

ktoe	2020	2025	2030
Hydro-energy	1415.9	1457.9	1460.3
Eolian	564.6	828.8	1004.9
Solar	170.4	424.6	632.6
Other renewable sources	77.4	77.4	77.4
Total gross final consumption of energy from renewable sources	**2228.4**	**2788.7**	**3175.2**

Table 4

Anticipated evolution of renewable energy in gross final consumption of energy in the transport sector for the 2021-2030 period [7]

ktoe	2020	2025	2030
Renewable electricity in transport road	2.2	10.5	55.7
Renewable electricity in transport rail	46.9	72.2	97.6
Electricity from renewable sources in other types of transport	1.3	5.3	16.2
First generation biofuels	505.7	490.5	474.3
Second generation biofuels	-	40.5	63.6
Total gross final consumption of energy from renewable sources in the transport sector	**635.4**	**728.4**	**989.9**

The gross final consumption of energy from renewable sources in the heating &cooling sector is estimated to increase by 24% in the 2021-2030 period, based on the availability of biomass sources (firewood, agricultural waste etc.) and the introduction of heat pumps to provide the necessary heating demand (taking into account the estimated reduction in heat pump costs).

It is also planned to install solar panels and integrate other renewable energy sources into the production of thermal energy for district heating systems.

The share of energy from renewable sources in the transport sector will have to reach 14% in the gross final consumption of energy in transport at the level of 2030, through measures such as: accelerating the electrification of transport, the convergence of the costs of light electric vehicles with those of internal combustion cars at the level of 2024 etc.

To achieve the energy and climate objectives, a series of important policies and measures will be needed in the energy sector, including [7]:

- Promoting investments in new electricity production capacities with low carbon emissions, replacing important increased emission source-based capacity with new, efficient and low-emission power plants on gas, nuclear energy and RES, which will lead to a reduction of consumption and GHG emissions. This objective will also be achieved for heating in centralized heating systems of CHSS (Centralized Heat Supply System) type, through the energy transit over the NPS (National Power System) and the use of heat pumps as energy sources, also using the electricity market mechanisms;
- Usage of revenues from the EU ETS (EU Emissions Trading System) and from the Structural Funds under the new Multiannual Financial Framework 2021-2027 for projects in the RES field and energy efficiency at national and international level;
- Encouraging the development of energy storage capacities;
- Development of high-efficiency cogeneration projects;
- Promoting advanced technologies in the energy sector;
- Digitalization of the energy system;
- Liberalization of energy markets.

With regard to the building sector (residential and tertiary), in order to be transformed into an energy-efficient and low-GHG-emitting sector, it is proposed to implement the Long-Term Renovation Strategy (LTRS). This involves, in addition to the renovation of buildings in order to increase energy efficiency, the adoption of RES technologies, such as the installation of solar thermal panels, photovoltaic panels and heat pumps, which will support the fulfilment of the RES-E and RES-H&C targets for 2030 [7]. Reducing the energy consumption in buildings will also help reduce the GHG emissions.

4. Conclusions

In the current context of the disastrous impact of climate change on the environment, man and the economy, highlighted by increasingly extreme weather events in recent years, the high priority of the world's countries is to limit the increase in the global average temperature (as much as possible to 1.5^{0}C compared to the level of 1990) by urgently and rapidly reducing the GHG emissions.

In order to achieve climate neutrality at European level by 2050, Romania sets the following energy and environmental targets for 2030:

- Reduction of ETS emissions by 43.9% compared to 2005 levels;
- Increasing the share of energy from RES in the gross final energy consumption to 30.7%;
- Improving energy efficiency by 40.4% (reduction in final energy consumption compared to 2007 levels).

The focus will be mainly on the sector with the most GHG emissions, namely the energy sector.

In order to meet the national energy and climate objectives, it will be pursued:

- Promoting investment in new low-carbon electricity generation capacities;
- Development of high-efficiency cogeneration projects;
- Adoption of advanced technologies;
- Development of energy storage capacities;
- In the buildings sector the renovation strategy, the increase of energy efficiency and the adoption of RES technologies: heat pumps, solar thermal panels and photovoltaic panels will be implemented.

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Aspects regarding heating and cooling in energy efficient buildings using heat pumps

Aspecte privind încălzirea și răcirea în clădiri eficiente energetic folosind pompe de căldură

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Abstract. *In the current context in which heating and cooling accounts for half of the EU's energy consumption and is responsible for 27% of greenhouse gas (GHG) emissions, reducing the energy demand for heating and cooling and increasing the share of renewable energy represents key elements to fulfill the EU's climate and energy goals.*
The paper presents the potential of the heating and cooling sector to improve energy efficiency and increase the share of energy from renewable sources, focusing on promoting energy efficient buildings and heat pumps. Using Casanova software, the authors have proposed for analysis a passive-green building designed according to passive standard and using environmentally friendly materials, simulating heating and cooling demand in different climate zone in the context of achieving passive house heating and cooling requirements. By comparing different heating systems, for Bucharest city, the simulations highlighted the potential of heat pumps in reducing the final and primary energy consumption.

Keywords: heating, cooling, greenhouse gas, emissions, energy efficiency, heat pump, ecological, passive standard

Rezumat. *În contextul actual în care încălzirea și răcirea reprezintă jumătate din consumul de energie în UE și sunt responsabile pentru 27% din emisiile de gaze cu efect de seră (GES), reducerea cererii de energie pentru încălzire și răcire și creșterea ponderii energiei din surse regenerabile reprezintă elemente-cheie pentru îndeplinirea obiectivelor UE în materie de climă și energie. Lucrarea prezintă potențialul sectorului de încălzire și răcire de a îmbunătăți eficiența energetică și de a crește ponderea energiei din surse regenerabile, concentrându-se pe promovarea clădirilor eficiente energetic și a pompelor de căldură. Folosind software-ul Casanova, autorii au propus pentru analiză o clădire pasivă-verde proiectată în conformitate cu standardul pasiv și folosind materiale* *ecologice, simulând cererea de încălzire și răcire în diferite zone climatice, în contextul limitării necesarului de încălzire și răcire în casele pasive. În comparație cu diferitele sisteme de încălzire, pentru orașul București, simulările evidențiază potențialul pompelor de căldură în reducerea consumului de energie finală și primară.*

Cuvinte cheie: încălzire, răcire, emisii, gaze cu efect de seră, eficiență energetică, pompă de căldură, ecologic, standard pasiv

1. Introduction

At global level, combating climate change is the main challenge for the world's countries, which have committed themselves to a severe limitation of greenhouse gas (GHG) emissions, which are considered the main cause of climate change.

As the energy sector (energy use in industry, energy use in buildings and transport) is responsible for almost three-quarters of world-wide GHG emissions (Figure 1), global actions will be needed to transform the energy sector from fossil-based to zero-carbon until 2050 [1], [2]. Regarding this aspect, the strategies and policies on global scale will focus first on the decarbonization of the energy sector as a key part of the 2050 climate neutrality target. But to reach that target, efficient solutions will be needed across all sectors.

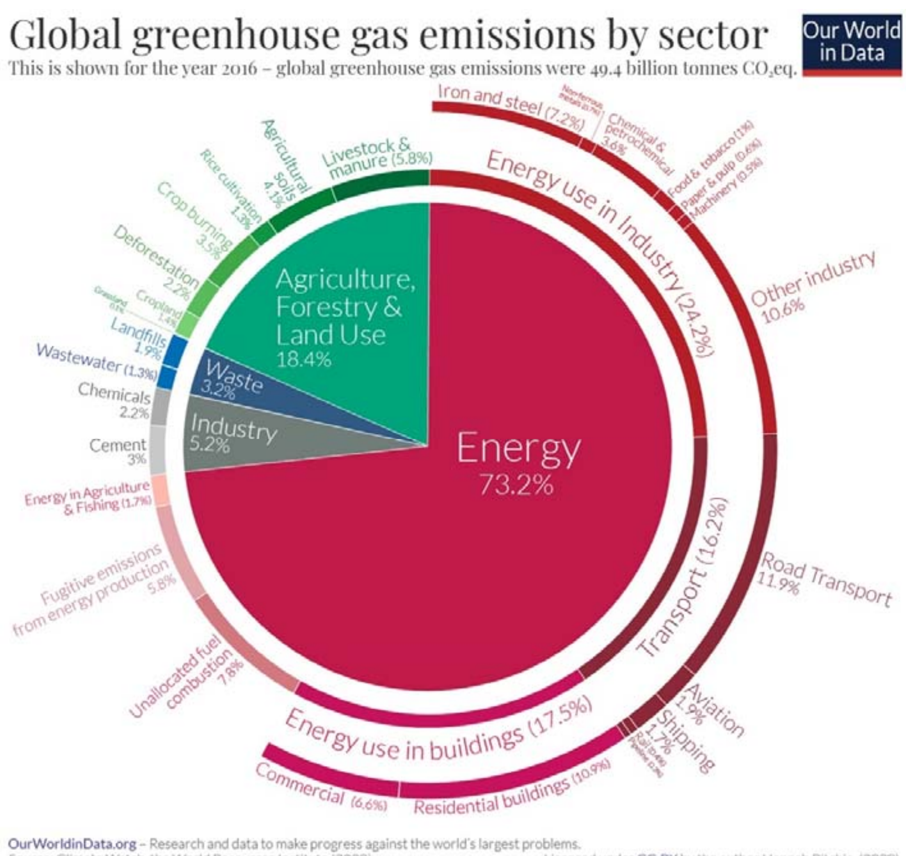

Fig. 1. Global greenhouse gas emissions by sector [1]

To secure the transition to a low-carbon energy sector, while modernizing the economy of European Union and creating opportunities for innovation, investment, jobs and growth for all European citizens [3], [4], energy from renewable energy sources (RES), together with increased energy efficiency, can potentially reach 90% of the required carbon reductions before 2050 [2].

The paper presents the potential of the heating and cooling sector to improve energy efficiency and increase the share of energy from renewable sources, focusing on the potential of energy efficient buildings and heat pumps in reducing GHG emissions and harnessing renewable sources of energy. The authors have proposed for analysis a passive-green building designed according to passive standard, which would use environmentally friendly materials.

2. Heating and cooling

Heating and cooling for residential and commercial buildings (water heating, cooking, ambient heating and cooling, refrigeration) and for industrial purposes (ambient heating and cooling, process heating) accounts for around 50% of global final energy consumption (46% is used in buildings) and more than 40% of global energy-related CO_2 emissions [3], [5], [6].

Given the increasing demand for energy, and the fact that most of this energy comes from fossil fuels (Figure 2), to meet the goal of achieving climate neutrality by 2050, a key role will be played by the decarbonization of the heating and cooling (H&C) sector.

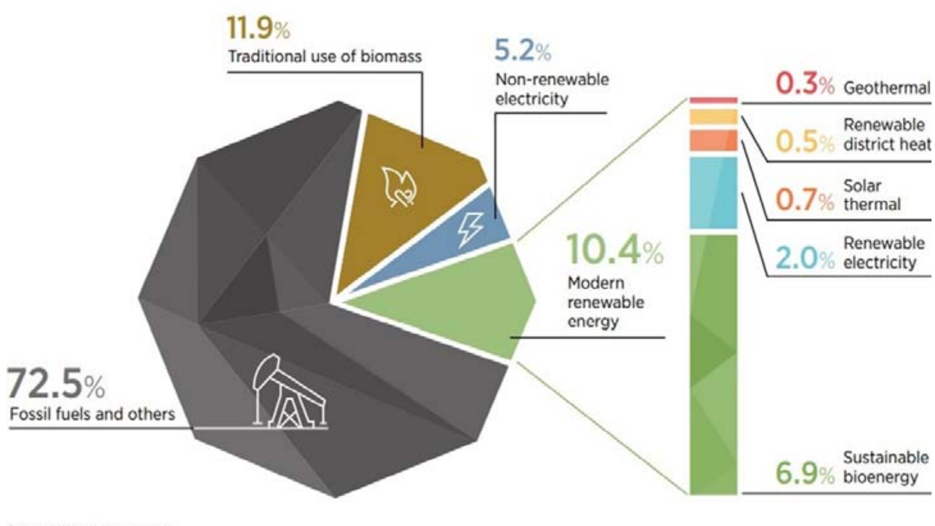

Fig. 2. Share of energy sources in total final energy consumption for H&C, 2019 [6]

This will require strategies to:

- Reduce the use of fossil energy for heating and cooling;
- Increase the share of energy from RES in total final energy consumption for heating and cooling;
- Improve energy efficiency by reducing energy consumption for heating and cooling the buildings.

In the European Union (EU), heating and cooling accounts for half of the EU's energy consumption and mainly relies on fossil fuels [7], [8]. Also, heating and cooling sector is responsible for 27% of GHG emissions [9].

Reducing the energy demand for heating and cooling and increasing the share of renewable energy represents key elements to fulfill the EU's climate and energy targets.

In Romania, the heating and cooling sector accounted for the highest share in the final energy consumption in 2020. According to estimates for 2030, the energy used for H&C will cover half of the total energy consumption (Figure 3).

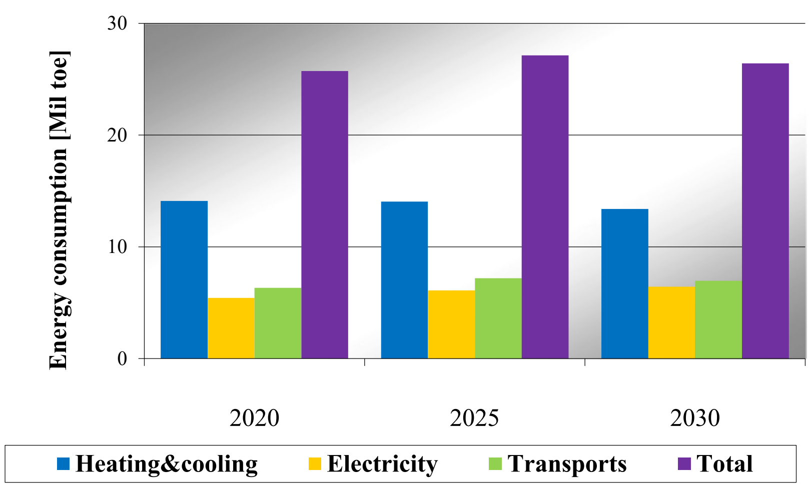

Fig. 3. Estimated trajectory of the final energy consumption by sector [10]

It is obvious that, both at EU and national level, the heating and cooling sector has significant potential to improve energy efficiency and increase the share of energy from renewable sources.

EU member states have committed to improve energy efficiency by at least 32.5% in 2030, to increase the share of energy from renewable energy sources by at least 32% and to reduce GHG emissions by at least 55% compared to 1990 [11].

The share of renewable energy sources in the EU's energy mix has increased from 10.2% in 2005 to 19.7% in 2019, while renewable energy sources accounted for 22.1% of the total energy used for heating and cooling in 2019 (Figure 4).

In Romania, renewable sources of energy contributed 24.3% in gross final energy consumption in 2019. More than a quarter (25.7%) of the energy used for heating and cooling came from renewable energy sources, in 2019 (Figure 5).

In RES used for heating and cooling are also included derived heat and heat energy extracted by heat pumps from air, ground or water, which has contributed more than one quarter of the energy from renewable sources used for heating and cooling [12].

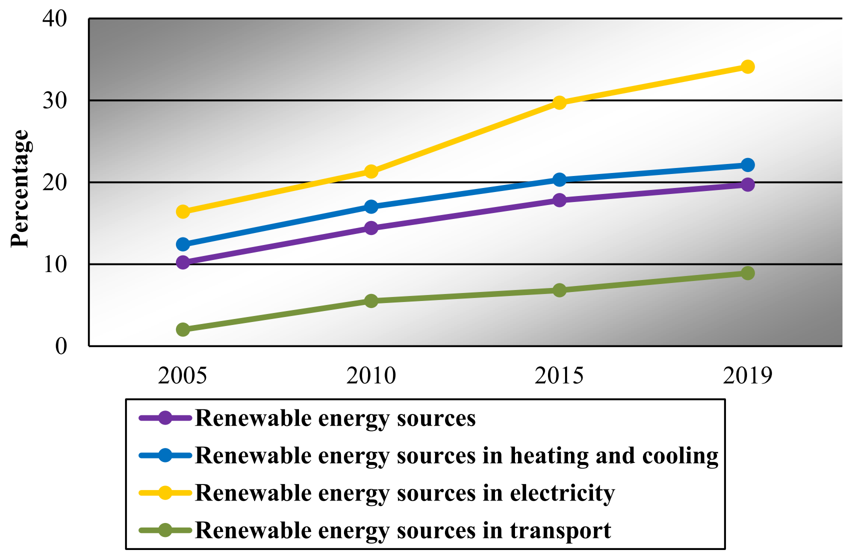

Fig. 4. Share of energy from renewable energy sources, at EU level [13]

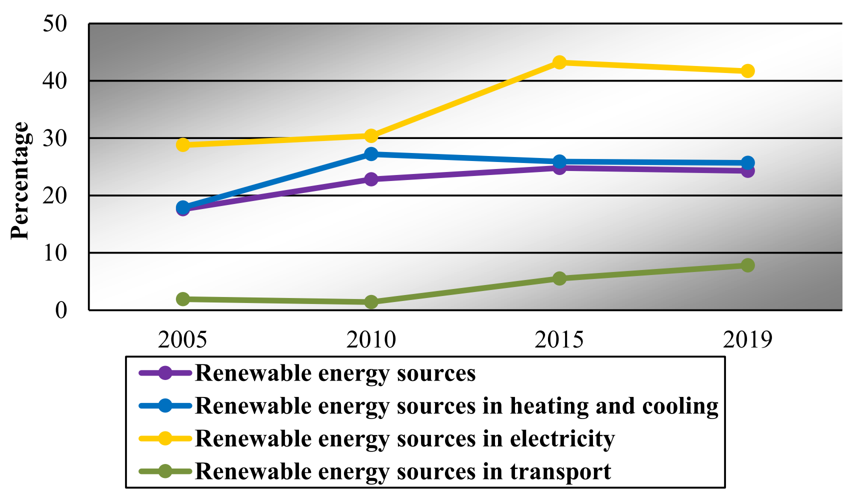

Fig. 5. Share of energy from renewable energy sources, in Romania [13]

Considering that at EU level buildings cover 40% of energy consumption and 36% of greenhouse gas emissions (emissions largely from construction, usage, renovation and demolition of buildings) [14], the heating and cooling sector has significant potential to improve energy efficiency and increase the share of energy from renewable sources.

Heat pumps use about 75% of energy from renewable sources and the remaining 25% from other sources (electricity). If electricity is generated from renewable sources (photovoltaic, wind, hydro) then the heat pumps are fully renewable and CO_2-neutral [15]. According to the International Energy Agency, heat pumps could save 50% of the building sector's CO_2 emissions, being one of the most promising solutions for decarbonizing the heating and cooling sector [15], [16].

3. Case study and simulation results

Energy and environmental strategies to reduce energy consumption and pollutant emissions of GHG have raised concerns for the development of energy efficient and environmentally friendly buildings. These buildings must be designed and built to ensure optimum comfort, energy efficiency and the lowest possible environmental impact.

Passive buildings represent a top standard in the current context of energy efficient buildings, with the aim of ensuring the highest indoor comfort conditions at low cost. The standard of passive building focuses mainly on the comfort of the occupants of the building, indoor air quality requirements and the reduction of energy consumption: energy demand for heating and cooling of spaces $\leq$15 kWh/m$^2\cdot$year, primary energy demand $\leq$120 kWh/m$^2\cdot$year [17].

An ecological or "green" building can be more than a passive house, a building constructed and used in a responsible way with respect to the environment, throughout their entire life cycle [18].

While limiting energy consumption, these "green" buildings also aim to reduce the negative ecological impact using environmentally friendly materials and renewable sources of energy.

The authors propose for analysis a family house with a useable area of 175 m^2 built on wooden structure and thermal insulation from wood. The choice of materials was made based on energy and environmental performance: thermal conductivity as low as possible and as little environmental impact as possible (kg CO_2 eq).

Based on the two principles on which the construction of passive houses is focused, namely the optimization of its components and the reduction of losses, we start from the following passive designing strategies:

- A compact form of the building with a Surface/Volume ratio S/V=0.75;
- Most of the windows oriented towards south;
- External shading systems;
- A high degree of thermal insulation and tightness;
- Heat recovery.

In order to limit the global heat transfer coefficients (U-values) at envelope level according to the passive standard (U$\leq$0.15 W/m$^2\cdot$K for external walls/roof/floor slab and U$\leq$0.8 W/ m$^2\cdot$K for windows), the following solutions were chosen:

- Exterior walls from wood, flexible wood fiber insulation (360 mm), clay board, rear ventilated cladding, the global heat transfer coefficient U=0.11 $W/m^2 \cdot K$;
- Floor slab from wood, rigid wood fiber insulation (300 mm), clay screed, the global heat transfer coefficient U=0.12 $W/m^2 \cdot K$;
- Upper floor ceiling from wood, rigid wood fiber insulation (320 mm), clay plaster, the global heat transfer coefficient U=0.12 $W/m^2 \cdot K$;
- Triple glazing windows with low emissivity (Low-e) and highly insulated wood window frames, the global heat transfer coefficient U=0.7 W/ $W/m^2 \cdot K$.

Due to good insulation and sealing, to ensure conditions of thermal comfort and indoor air quality, it will be necessary to provide a domestic mechanical ventilation system with heat recovery from the exhaust air.

The simulations were made with the Casanova software [19] for different climate zones: Bucharest (Romania), London (United Kingdom), Lisbon (Portugal), Barcelona (Spain), Helsinki (Finland) and two cases: Case no. 1 - without mechanical ventilation system, Case no. 2 - with mechanical ventilation system and heat recovery (88% efficiency).

The results obtained for all analyzed cities are summarized in the following table (Table 1).

Table 1

Heating and cooling demand for all analyzed cities

City	Minimum temperature of the year [^{0}C]	Maximum temperature of the year [^{0}C]	Mean temperature of the year [^{0}C]	Case no. 1		Case no. 2	
				Heating [kWh/ $m^2 \cdot$year]	Cooling [kWh/ $m^2 \cdot$year]	Heating [kWh/ $m^2 \cdot$year]	Cooling [kWh/ $m^2 \cdot$year]
Helsinki	–20.7	26.5	4.8	105.1	-	23.7	2.2
Bucharest	–16.3	35.9	10.9	61.3	5.3	11.5	11.8
London	–6.7	28.8	10.7	52.3	0.4	6.9	2.3
Lisbon	–0.8	38.2	16.5	14.2	12.6	0.3	17.3
Barcelona	0.2	37.7	15.7	20.9	12.3	0.8	15.9

As a result of the simulations, we notice that:

- For the city with the lowest minimum temperature of the year i.e., Helsinki (–20.7 ^{0}C) the energy demand for heating exceeds 100 $kWh/m^2 \cdot$year (case no. 1) and 15 $kWh/m^2 \cdot$year (case no. 2), but the cooling demand meets passive standard for both cases;

- For cities with a minimum temperature of the year of –16.3^{0}C (Bucharest), –6.7^{0}C (London) and 0.2^{0}C (Barcelona) the energy demand for heating (case no. 1) matches the energy efficient buildings.
  In accordance to the Romanian certifying system, these buildings are in type A class of energetic efficiency;
- For Lisbon (–0.8^{0}C minimum temperature of the year) the energy demand for heating fulfills the passive requirement;
- For all analyzed cities, the cooling demand in case no. 1 is below 15 kWh/m^2·year;
- Providing a domestic mechanical ventilation system with heat recovery (case no. 2) the energy demand for heating decreased below 15 kWh/m^2·year (except for Helsinki) and the cooling demand increased to maximum 15 kWh/m^2·year for the coldest cities (Helsinki, Bucharest, London) and over 15 kWh/m^2·year for the hottest cities (Lisbon and Barcelona).

In order to meet the requirements of the passive standard, for limiting heating and cooling demand to 15 kWh/m^2·year, while preserving the shape and dimensions of the building, it will be necessary to adapt the orientation of the building and windows, shading systems and the degree of thermal insulation (global heat transfer coefficient or U-value) according to the climate zone.

It is known that heat pumps can play an important role in decarbonizing the heating and cooling of building sector by reducing the dependency of fossil fuels, promoting renewable sources of energy and reducing finally and primary energy demand. To highlight the potential of heat pumps we analyze, for Bucharest (case no. 1 and case no. 2), the influence of different heating systems on primary and final energy demand (Figure 6 and Figure 7).

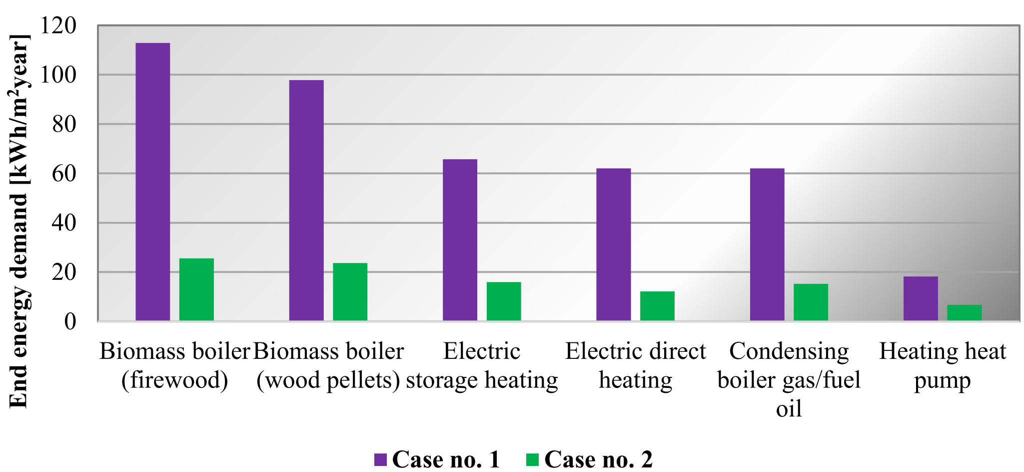

Fig. 6. Final energy demand for different heating systems

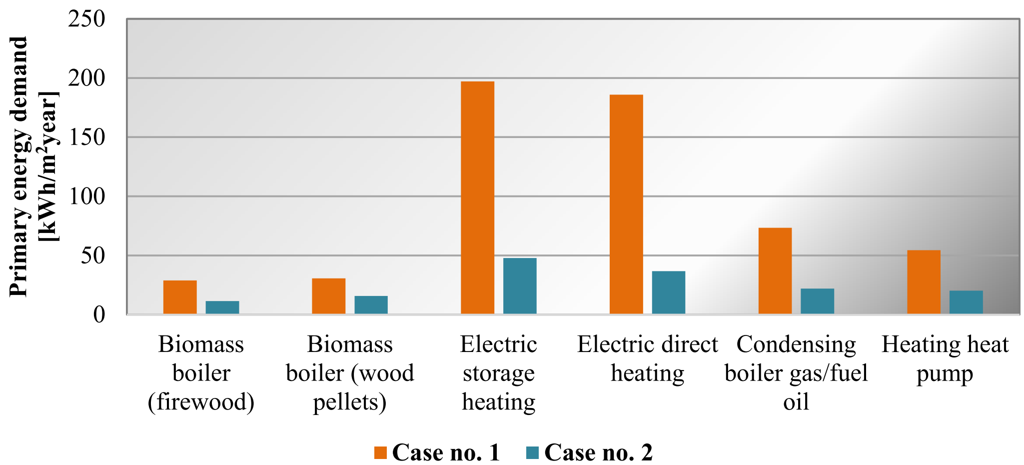

Fig. 7. Primary energy demand for different heating systems

From the results obtained, we noted that:

- Heat pumps record the lowest end energy consumptions for heating, delivering energy savings compared to other heating systems analyzed between 45…73% in case no. 2 and 70…83% in case no. 1;
- In terms of primary energy consumptions for heating, taking into account the following primary energy factor:
  - Electricity 3,
  - Oil, gas 1.1,
  - Biomass wood pellets/firewood 0.2,

  the lowest values of primary energy demand were obtained when using biomass boiler with firewood and wood pellets, and compared to the other heating systems heat pump achieved energy savings of 8…57% in case no. 2 and 25…72% in case no. 1.

Unlike other heating systems, heat pumps can also provide cooling of the building by reversing the operating cycle.

As a result of high performance and energy extracted from the environment, heat pumps reduce energy consumption for heating and cooling buildings and thus contribute to reducing GHG emissions.

4. Conclusions

Due to the fact that buildings in EU cover 40% of energy consumption and 36% of greenhouse (GHG) gas emissions, the heating and cooling sector has significant potential to improve energy efficiency and increase the share of energy from renewable sources, by promoting energy efficient and ecological buildings and heat pumps.

The authors have proposed for analysis a passive-green building designed according to passive standard, using environmentally friendly materials: a family house built on wooden structure and thermal insulation from wood, triple glazing windows with low emissivity (Low-e) and highly insulated wood window frames, most of the windows oriented southward, external shading systems, a high degree of thermal insulation and tightness and domestic heat recovery.

From the simulations carried out using the Casanova software, for different cities and two cases: with or without a domestic mechanical ventilation system with heat recovery (Table 1), we notice that:

- For Helsinki, the city with the lowest minimum temperature of the year (–20.7^{0}C), the energy demand for heating exceeds 100 kWh/m^2·year in case no. 1 and 15 kWh/m^2·year in case no. 2. However, the cooling demand meets the passive standard requirements for both cases;
- For the following cities with a minimum temperature of the year: Bucharest (–16.3^{0}C), London (–6.7^{0}C) and Barcelona (0.20^{0}C), the energy demand for heating in case no. 1 matches the energy efficient buildings;
- For Lisbon with –0.8^{0}C minimum temperature of the year, the energy demand for heating fulfills the passive requirement;
- For all analyzed cities: Helsinki, Bucharest, London, Lisbon and Barcelona, the cooling demand in case no. 1 is below 15 kWh/m^2·year;
- For case no. 2, by using a domestic mechanical ventilation system with heat recovery, the energy demand for heating decreased below 15 kWh/m^2·year (with except of Helsinki).
  The cooling demand increased to maximum 15 kWh/m^2·year for the coldest cities: Helsinki, Bucharest, and London and over 15 kWh/m^2·year for the hottest cities (Lisbon and Barcelona).

In order to meet the requirements of the passive standard (H&C demand up to 15 kWh/m^2·year), while preserving the dimensions and shape of the building, it will be mandatory to change and adjust: the orientation of the building and/or windows, the thickness of thermal insulation, the shading systems etc. according to the climate zone of interest.

By reducing the actual dependency of fossil fuels, by promoting renewable energy sources (RES) and lowering down the finally and primary energy demand, nowadays heat pumps (HP) can play a significant role in decarbonizing the H&C of building sector.

From the simulations we carried out using the Casanova software, with different heating systems for Bucharest city, we noticed the followings:

- Compared to other heating systems analyzed, HP record the lowest end energy consumptions for heating, also delivering important energy savings;
- With respect to the primary energy consumptions for heating, HP achieved important energy savings compared to condensing boiler gas/fuel oil, electric storage heating or electric direct heating.

By using for buildings ecologically materials with high energy performance and ensuring heating and cooling with HP, we will achieve much more significant contributions to decarbonize the heating and cooling sector.

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Efficiency of lighting for lecture halls

Eficientizarea iluminatului în amfiteatre

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Abstract: Fluorescent tubes as well as LEDs have advantages and disadvantages, but it seems that the LED is starting to come out a winner in the attention of consumers.
In this paper we present the advantages that are offered to us by using LED luminaires. WE do this by comparison between, three types of luminaire, 2xT8 36W fluorescent luminaire, 2xT5 28W electronic ballast luminaire and 36W LED luminaire.
The measurements were made with new fluorescent lamps but also with fluorecent lamps that have already been used for a period (approx. 4800 hours). The LED luminaire used for the measurements were used for almost 1300 hours. We compared the measurements made with LED luminaire with the results obtained from measurements of the fluorescent lamps.In both cases even if I used old or new fluorescent luminaires, the results were in favor of LEDs, with a much higher energy efficency.

Key words: LED, fluorescent luminaire, energy efficient, lighting, measurements

Introduction

Fluorescent luminaires have been used and been around us for years. It has been proven over time that they are economical and produce optimal light for workspace and public environments. However, a new method of lighting has attracted attention: LED. [1]

The principle of operation of fluorescent lamp remains the same as that of all conventional discharge lamps: mercury atoms are excited to the point where they irradiate ultraviolet light as they return to a low energy level. This ultraviolet light is transformed into visible light as it passes through the fluorescent tube.

Two other essential components in the operation of fluorescent lamps are the starter and the ballast. When supplied with electricity, the starter allows the electrodes to be brought to the incandescent and then the heating current to be switched off after the lamp has been switched on. The ballast provides and overvoltage at the tube terminals, which is necessary to prime the electric arc in the gas mixture inside and subsequently limits the current through the tube, while allowing its stable operation.[2]

An LED lamp consists of one or more light emitting diodes (LEDs). LED lamps have much longer lifespan and energy efficiency than incandescent or fluorescent lamps, these lamps can reach up to 100000 operating hours and can emit up to 200 lumens per watt, while fluorescent lamps have an efficient up to 100 lumens per watt. [1]

The LED is made of a semiconductor anorganic material. This material is found under solid state in nature, thus making the LED more durable and resilient. When electric current passes through this semiconductor material, the electrons in the material access higher energy levels and begin to emit energy in the form of visible light. [2]

Study case

To observe the differences between three luminaires (two fluorescent and one LED), we made measurements two situation (in the experimental stand also in the work stand). I measured new and old fluorescent lamp in the experimental stand as well as in the working stand (4200 operating hours). The experimental stand 2m x 2m (1.96 m^2) and we used a calculation grid of 40 x 40 cm, while the work stand is the room I205 (lecture hall of the Faculty of Building Service Engineering 56.13 m^2), having a calculation grid of 80x60 cm.

We will compare the luminaires with new fluorescent lamps (T5) with the old ones (T8) as well we are going to compare fluorescent lamps T5 with LED luminaires.

3 different types of lightings (2 different fluorescent lamps and LED light), but were used with more scenarios: - T8 fluorescent lamp cleaned and dirty

- T5 fluorescent lamps, cleaned and dirty
- LED lighting, cleaned and dirty

RESULTS – EXPERIMENTAL STAND

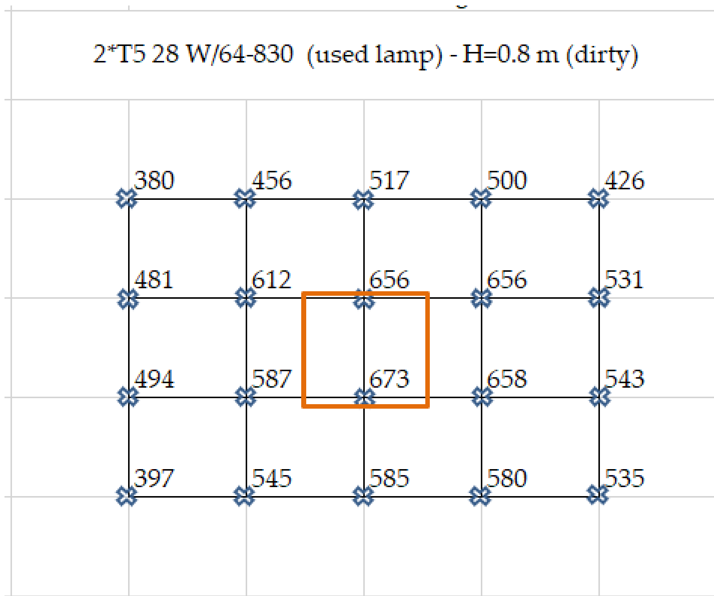

Fig. 1. Measurements 2*T5 (used and dirty lamp).

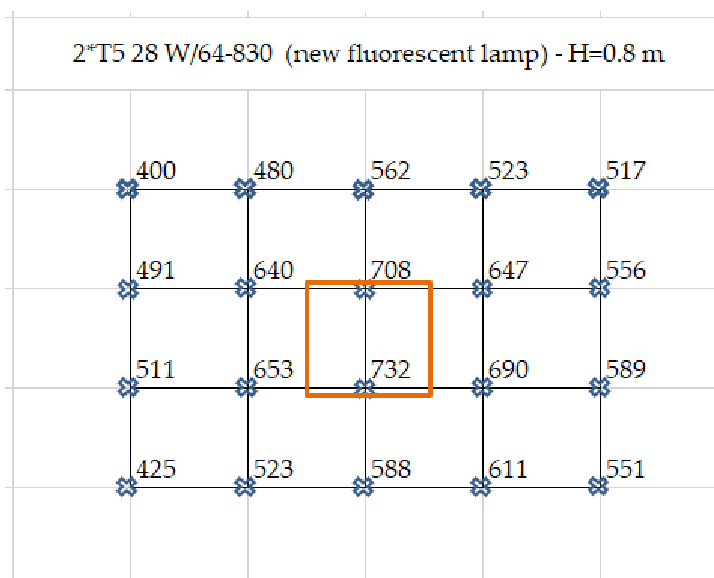

Fig. 2. Measurements 2*T5 (new lamp).

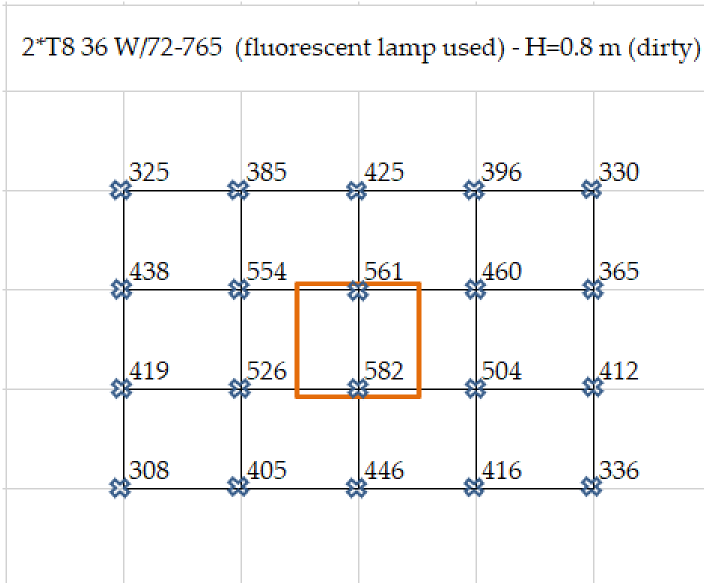

Fig. 3. Measurements 2*T8 (used and dirty lamp).

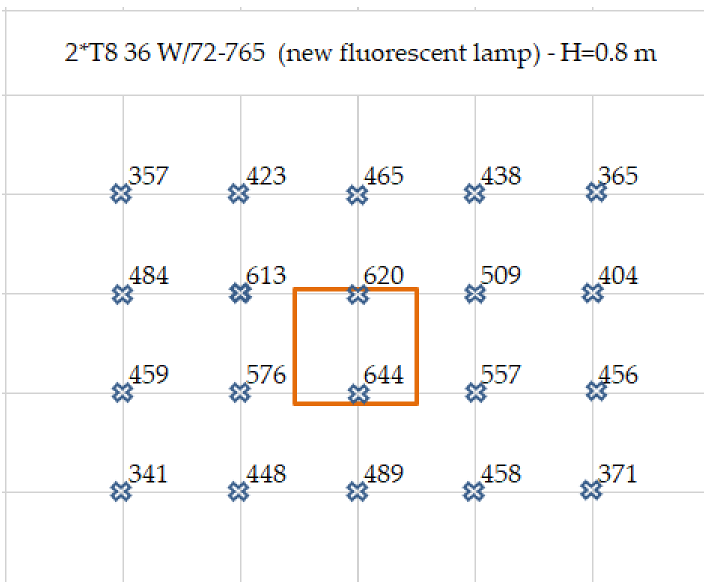

Fig. 4. Measurements 2*T8 (new fluorescent lamp).

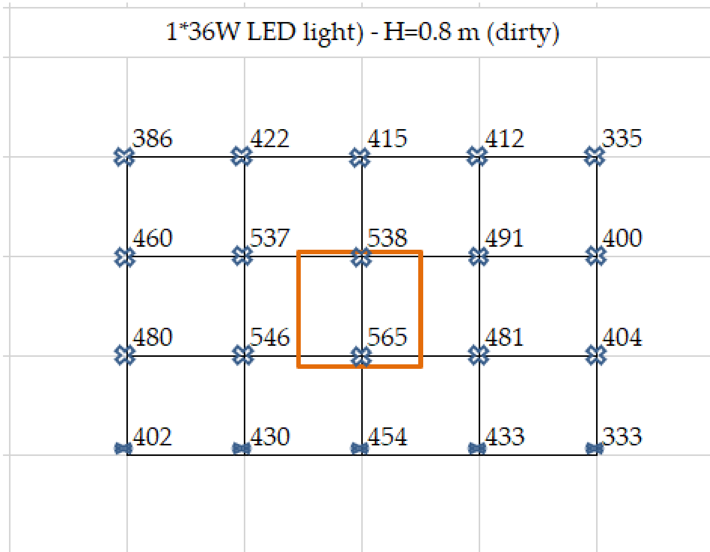

Fig. 5. Measurements LED lighting (used and dirty lamp).

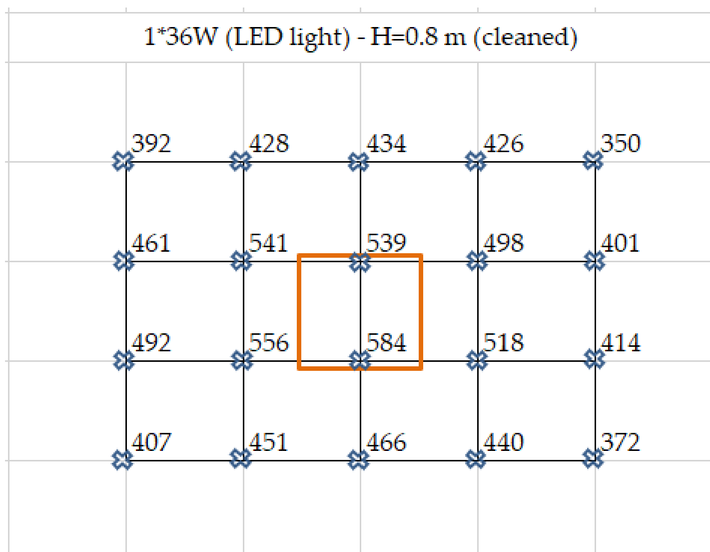

Fig. 6. Measurements LED (used and cleaned lamp).

MEASURED	2*T5 28 W/64-830 used, dirty fluorescent light	2*T5 28 W/64-830 new fluorescent light	2*T8 36 W/72-765 used, dirty fluorescent light	2*T8 36 W/72-765 new fluorescent light	1* Led 36W dirty LED light	1* Led 36W cleaned LED light
Total power per luminaire [W]	64	64	72	72	36	36
Minimum ilumination level [lx]	380	400	308	341	333	350
Maximum ilumination level [lx]	673	732	582	644	565	584
Average ilumination level [lx]	541	570	430	474	446	459
Uniformity [min/average]	0.70	0.70	0.72	0.72	0.75	0.76
Lighting power density [W/sqm/100lx] - 2*2.4=4.8 sqm	2.47	2.34	3.49	3.17	1.68	1.64

Fig. 7. Results of measurements

It can be observed the difference between these luminaires, based on the measurements on the experimental stand, because each luminaire had the same measuring grid and each measurement was made with the same measuring device (TESTO luxmeter).

We can see the difference between the T8 and T5 (both of them were used for 4800 hours) and LED light (about 1300 hours of operation), we can observe the consumption per square meter of each luminaire and we see that the LED luminaire has the lowest consumption of 1.64 w/sqm compared with T8 that have 3.14 W/ sqm, and T5 lamp with a consumption of 2.47 W / sqm.

RESULTS – work stand

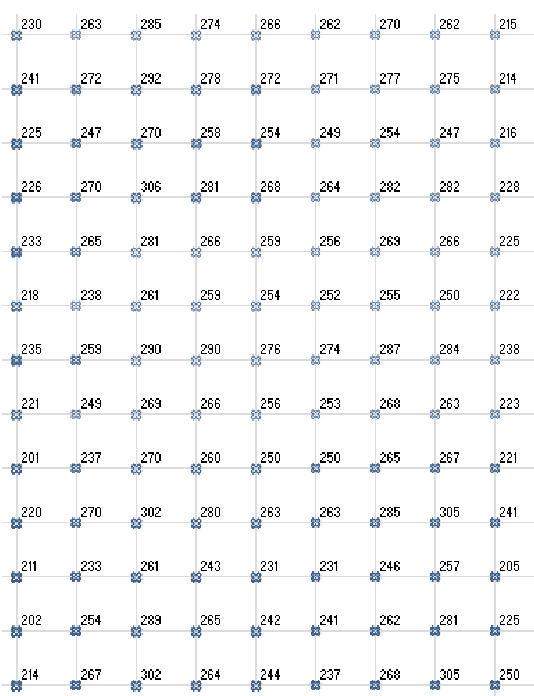

Fig. 8. Measurements in the classroom 2*T8 fluorescent luminaire

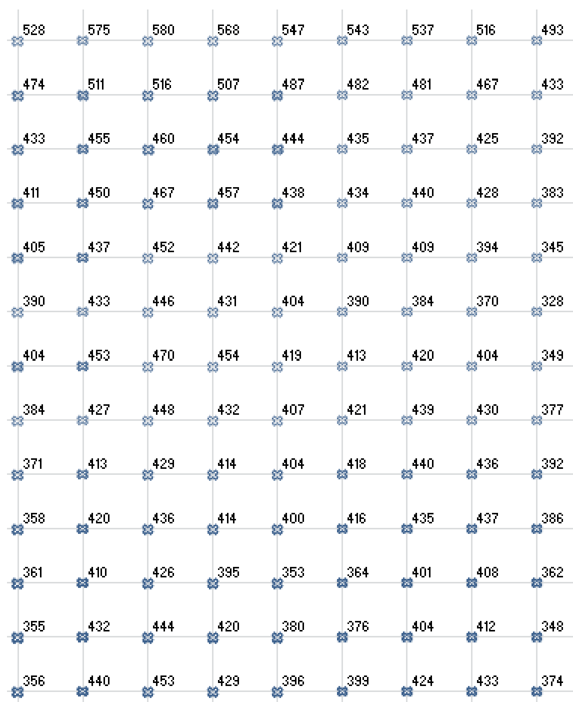

Fig. 9. Measurements in the classroom 2*T5 fluorescent luminaire

Efficiency of lighting for lecture halls

MEASURED	2*T5 28 W/64-830 new lamp)
Total power per luminaire [W]	768
Minimum ilumination level [lx]	328
Maximum ilumination level [lx]	580
Average ilumination level [lx]	428
Uniformity [min/average]	0.77
Lighting power density [W/sqm/100lx] - 6 * 9=54 sqm	3.32

Fig. 10. Result of measurements for new T5

MEASURED	2*T8 36 W/72-765 (used, dirty lamp)
Total power per luminaire [W]	864
Minimum ilumination level [lx]	201
Maximum ilumination level [lx]	306
Average ilumination level [lx]	256
Uniformity [min/average]	0.79
Lighting power density [W/sqm/100lx] - 6 * 9=54 sqm	6.25

Fig. 11. Result of measurements for used T8

Measurements were made in the working plan (I205 lecture hall from the Faculty of Building Services Engineering), with a calculation grid of 80 x 60 cm.

The measurements were made with used T8 4800 operating hours) and in new T5 luminaires. In the case of old T8, we have consumption of 6.01 w/sqm and the lighting level is at half, i.e. on average 250 lx respectively with 500 lx

Fig. 12. Representation of lecure hall I205 of the Faculty of Building Services Engineer in Dialux EVO program

Conclusions

Following the measurements in the experimental stand we can see that the luminaire equipped with LEDs are superior in terms of energy efficiency and lighting.

The energy efficiency of LED luminaires is 43.03% higher than T5 fluorescent luminaire and 93% higher than T8 fluorescent luminaires.

If we refer to the Faculty of Installation Engineering with has an area of 4776 sqm we can calculate for each scenario the energy consumption using new lamps. For the T5 lamps we have a consumption of 24.45 kW, for the lamps equipped with T8 a consumption of 37.77 kW, while the LEDs have a consumption of 19.53 kW.

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Intruziunile de rădăcini în conductele de canalizare

Root intrusions in sewer pipes.

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Rezumat. *Intruziunile de rădăcini în conductele de canalizare amplasate în subsolul orașelor reprezintă o defecțiune destul de frecvent întâlnită pe parcursul operațiunilor de diagnosticare imagistică. Este considerată o defecțiune gravă, care trebuie remediată într-un timp relativ scurt, întrucât poate conduce chiar la colapsul conductei. Sunt prezentate cazurile în care apare acest tip de defecțiune, cu exemple și ce metode de remediere există.*

Cuvinte cheie: intruziuni de rădăcini, conducte de canalizare, diagnosticare imagistică

Abstract. *Root intrusions in sewer pipes buried in the subsoil of urban areas represent a common fault found during CCTV inspection of sewer mains. It is considered a serious fault which must be addressed in a short period of time, or else it can lead even to the collapse of the pipe. Manifestations of this type of fault are presented, with examples, along with the means of remediation.*

Key words: root intrusions, sewer mains, CCTV inspection

1. Introduction

During an extensive research activity the author had access to the CCTV inspection archive of the local provider of water and sewerage services. After studying a considerable amount of footage and printed inspections reports, the faults found were classified in several categories but for this paper the focus will be on root intrusions. The fault appears when trees are planted too close to the alignment of the sewer pipe. There were cases found both in sewer mains and in sewer laterals. Although initially is a fault with a slow progress, ignoring it could result in the impossibility of usage of the sewer section due to total blockage of it or even worse it could lead to the collapse of the sewer pipe. The fault mechanism is simple. Trees in the vicinity of the sewer pipe will grow more and more and will develop stronger and wider roots. If the root filaments meet in their path a sewer pipe, they will get in the cracks found on the pipe wall and/or in the junctions between two consecutive segments of pipe. As they grow, the root filaments will gain in diameter and will become stronger, opening even more the cracks in the pipe's wall, hence the potential collapse of the pipe. In other instances, the root filaments will not get very thick in diameter but will branch inside the pipe creating a dense obstacle in the way of the residual waters. Real dams may form in the pipe starting from these points of root intrusions because debris and sediments will accumulate here.

2. Inspection reports

In the studied materials (footage and printed inspection reports) there were found 9 instances of root intrusions. All of them were in concrete pipes of round section with diameters of 300 and 400mm. As a matter of fact, the material of the pipe's wall may facilitate this type of fault especially if is a material prone to cracks, like concrete. In sewer pipes made of plastics the fault is far less common. These pipes may be affected only if the roots grow thick enough right next to the pipe and deform it severely. In table 1 are presented the cases of root intrusions found.

Table 1

Cases of root intrusions

No.	Place	Street	Sewer segment	Fault location	Pipe material	Cross section	Diameter (mm)
	1	2	3	4	5	6	7
1	Cluj-Napoca	A. Densușianu	nr.3 - downstream	+17,40m	concrete	round	400
2	Cluj-Napoca	I.B. Deleanu	nr.21 - upstream	+32,00m	concrete	round	300
3	Cluj - Napoca	Mălinului	nr.14 - downstream	+3,00m	concrete	round	300
4	Cluj - Napoca	Mălinului	nr.14 - downstream	+4,10m	concrete	round	300
5	Cluj - Napoca	Mălinului	nr.14 - downstream	+12,00m	concrete	round	300
6	Cluj - Napoca	Mălinului	nr.14 - downstream	+13,10m	concrete	round	300
7	Cluj - Napoca	Mălinului	nr.14 - downstream	+18,70m	concrete	round	300
8	Cluj - Napoca	Mălinului	nr.14 - downstream	+19,10m	concrete	round	300
9	Cluj - Napoca	Mălinului	nr.14 - downstream	+19,90m	concrete	round	300

Please note that in the above table the fault location is given in the usual manner for sewer CCTV inspection. Namely, is measured from the insertion point of the CCTV robot in the sewer pipe which is the starting manhole for the inspection. So, if we take for example the first line of the table, the fault is located at 17 meters and 40 centimeters from the manhole in front of the building having the street number 3 on the A. Densuşeanu street. In the following two images are examples taken from the sewer pipes.

Fig. 1. Root intrusions in concrete sewer pipe [1], [2].
The roots are starting to branch already.

Fig. 2. Root intrusions in concrete sewer pipe [1], [2].
In this case the fault is in a more incipient state, the roots are long but not as branched out as in the previous image.

From Table 1 it can be observed that faults presented in the first two lines of the table are singular cases of root intrusions but the rest of 7 instances are all on the same sewer section, on Mălinului street. In this case some ornamental trees are planted along the sewer pipe path, and three of these trees have their roots in the sewer pipe. It can be observed that first two faults are close together, the roots belonging to the first tree, the second group of two faults are close – the roots belong to the second tree and the last three faults are close one of another – the roots belong to the third tree.

5. Remedial measures

What can it be done in case root intrusions are found in the sewer pipe? It depends on severity of the fault. The first step would be to remove de roots by cutting them with special tools. In this respect there are available several types of cutting heads that can be fitted on robots like those used for CCTV inspection. Figure 3 and 4 present such equipment. These robots are also useful in implementation of some rehabilitation techniques like CIPP – Cured In Place Pipe. For this reason, we can observe in figure 3 a connection for compressed air.

Fig. 3. Maxwell 250 - robot for cutting roots inside pipes from DN100 to DN250[3]

These robots have a pretty narrow domain of diameters in which they can work, for example Maxwell 250, as the name implies, goes up to 250mm. Maxwell 400, presented in figure 4, goes only up to 400mm and so on.

Fig. 4. Maxwell 400 - robot for cutting roots inside pipes from DN150 to DN400[3]

Another option would be to use the pressure of the water to do the cutting. In this respect there are available special designed cutting nozzles. These jetting heads work well in smaller diameter pipes. For example, Warthog jetting nozzle is available for different sizes and flows of water, please see figure 5.

a b c

Fig. 5. Examples of jetting nozzles. [4]
a – Warthog jetting nozzle small 1/2" (50-75 lpm) with cutting head;
b – Warthog Mini ½" jetting nozzle (45-80 lpm); c – hydraulic rootcutter

The first example in figure 5 requires a flow of water of 50 to 75 liters per minute and the second example requires 45 to 80 liters per minute. There are other kinds of cutters using the pressure of water, like the Hydraulic Rootcutter [4]. This is using the water pressure to rotate a head with serrated curved blades, much like a saw blade. Using any of these heads will result in a quantity of debris consisting of small fragments of roots which must be washed away from the pipe.
The second step of the intervention would be to locally repair the pipe employing a trenchless repair technique such as CIPP or by applying a layer of centrifugally cast

concrete or other local repair methods. If the fault is serious, it may require the replacement of the pipe segment.

6. Conclusions

Root intrusions is a fault specific for sewer pipes. It affects especially pipes made of materials prone to cracking. It can degenerate into more serious faults like pipe collapse if not addressed in early stages. It is possible to render inoperable the affected pipe section by creating dams inside the pipe. Presently there are means for removal of the root that penetrated the pipe wall, either using electrically powered cutting and milling heads mounted on sewer robots or by employing hydraulic cutting heads in an operation called "jetting". If a local repair method is not applied soon after cutting the roots, CCTV inspections should be carried out on regular bases to observe if the roots are growing back inside the pipe. This outcome is very probable if a local repair is not done. A further direction of research would be the use of chemical substances locally, in the pipe, to inhibit the growth of the roots back into it. After the use of such inhibitors if a local repair is done, the risk of future root penetration would be greatly reduced. Another aspect to be taken in consideration is to plant the trees far enough from the sewer pipe pathway, but this applies, of course, to the trees younger than the pipe.

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Study Regarding the Negative Effects of Industrial Wastewater Discharges

Studiu privind efectele negative ale deversărilor de ape uzate industriale

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Abstract. *The purpose of this article is to better comprehend the impact of industrial waste waters discharges on the water cycle, in order to better understand current trends and the magnitude of the environmental strain posed by industrial wastewaters. It also examines the various regulatory frameworks that restrict and influence industrial wastewater discharges. An assessment of industrial wastewater discharges in Cluj-Napoca, Romania is carried out, taking into account the types of monitored industrial units, the monitored quality indicators, and their compliance with the EU and Romanian environmental regulations.*

Key words: industrial wastewater, pollution, wastewater discharges monitoring.

1. Introduction

Insufficiently treated or untreated wastewater is one of the main causes of pollution and degradation of water bodies. Therefore, the main practical measure to protect the quality of surface water is wastewater treatment, which involves collecting the wastewater through sewage systems and transporting it to the treatment plant, from where it is usually discharged into a surface water body.

The composition of industrial wastewater and the concentration of pollution differ considerably depending on the type of activity of the industrial agent.

Also, the types of hazardous substances that can be found in industrial effluents differ depending on the existing industrial production process and the state of the treatment and production facilities.

Water abstraction for industrial purposes in European Union represents about 54% of the total uptake for human activities [1]. Thus, water discharges from industry create significant pressures on water bodies both quantitatively and qualitatively.

In most cases, these waters show a substantial deterioration of all quality properties and therefore cannot be discharged safely into a surface water without prior treatment.

Figure 1 shows an overview of the industrial water cycle, starting with the water uptake from a body of water - freshwater catchment – and presents three possible variants of discharging the industrial effluent (A, B and C) depending on the existing industrial production process: direct release, direct release without treatment, indirect release.

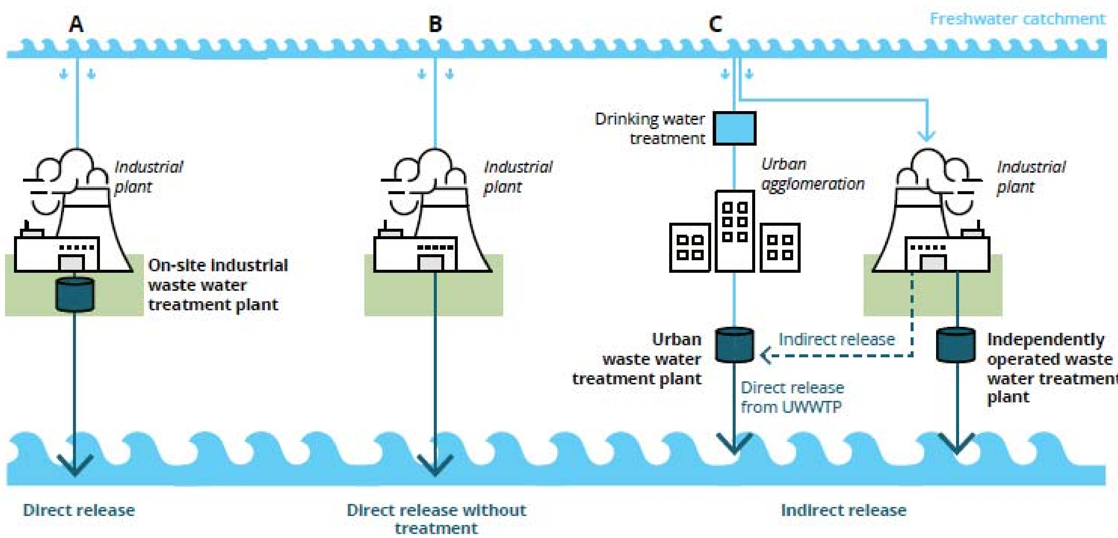

Fig. 1. Wastewater treatment cycle [1].

The first scenario, variant A, applies to the case of effluents from certain industrial processes which require a specific treatment, that is not usually available in the urban wastewater treatment plants, and thus need to be treated to meet the quality standards before being discharged back into a surface water.

In the next scenario (B) the wastewater has a low pollutant concentration and can be discharged directly into the surface water because it meets the quality standards, which are presented in the next section.

As seen in the last scenario (C), there are some industrial processes that release wastewater streams which cannot be discharged directly into the surface waters because they do not meet the quality standards, or the industrial operator does not have the necessary treatment facilities and chooses to discharge the effluent into a municipal sewer system to be subsequently treated in an urban wastewater treatment plant.

Wastewater treatment facilities of industrial or economic operators must be sufficiently effective to prevent dangerous effects on humans or the environment. This applies both to the direct release and indirect release of industrial effluent. In the latter case, a pretreatment at the industrial/ economic operator is still necessary and must be sufficiently efficient to prevent the harmful effects on the sewerage and the wastewater treatment plant.

2. European Policy Framework for industrial Wastewaters

To have an overview of the legislation in this field, we will present the European directives and the relevant Romanian legislation and other legislative elements regarding the prevention and combating of accidental pollution and restrictions regarding the evacuation in the municipal sewerage system.

The discharge of industrial wastewater is regulated in Europe both directly, through environmental legislation for industry, and indirectly through water regulations.

The most relevant directives are the Water Framework Directive (2000/60/EC), the Urban Waste Water Treatment Directive (91/271/EEC), the Groundwater Directive (2006/118/EC) and the Environmental Quality Standards Directive (2008/105/EC). These directives regulate aspects that will influence industrial wastewater generation and management.

The Water Framework Directive establishes a series of mechanisms for the protection of all water resources in the EU. It applies to rivers, lakes, groundwater, and transitional coastal waters and it aims to ensure that all aquatic ecosystems meet the ‘good ecological status' and the 'good chemical status' and it also sets deadlines for this objective. The first deadline was set to 2015, although a large proportion of the water bodies in Europe have failed to meet it, and the latest deadline is set to 2027.

The Urban Waste Water Treatment Directive represents the main instrument for regulating the operation of waste water treatment plants in the EU. Its main objective is to protect the water environment from the adverse effects of discharges of urban waste water and from certain industrial discharges.[4]

Directive 2010/75/EU, named the Industrial Emissions Directive represents the main instrument for regulating pollutant emissions from industrial operations [5]. By decreasing harmful industrial emissions across the EU, the IED strives to establish a high degree of protection for human health and the environment. In Europe, the IED currently oversees 31 industrial sectors and approximately 50 000 installations.

The IED distinguishes between "direct" and "indirect" environmental emissions, with the latter occurring after separate treatment. Permit limit values for direct releases of certain pollutants are typically more stringent than those for indirect releases. For some compounds, this may be done to guarantee that pollution levels in the effluent do not harm the sewer system or degrade the performance of the urban wastewater treatment plant.#

In most cases, industrial wastewater discharged into surface water must be sufficiently treated to prevent adverse effects on surface water bodies. In the EU, the directives presented above provide a guide to industrial wastewater discharges into surface water, using water quality standards, emission limit values and the concept of best available technology.

All the European directives mentioned above are already transposed into national Romanian regulations. Among the most important national legislative acts that regulate the discharge of industrial wastewater in Romania can be mentioned:

- Water Law no. 107 / 25.09.1996 with subsequent amendments and completions
- Decision no. 188 of February 28, 2002 - that comprises NTPA-001/2002, which establishes loading restrictions for contaminants in industrial and urban wastewater discharged into natural receptors and NTPA-002/2002 on the conditions of wastewater discharge in urban sewerage networks and directly in the treatment plants
- Decision no. 570 of August 10, 2016, Program for the phasing out of discharges, emissions and losses of priority hazardous substances and other measures for major pollutants
- O.M. no.161 / 16.02.2006 Norm on the classification of surface water quality in order to establish the ecological status of water bodies
- Decision no. 472 of June 9, 2000 - measures for the protection of the quality of water resources, with subsequent amendments and completions

3. Negative effects of industrial wastewater discharge

We will investigate the effects of these discharges on the ecosystem to have a better knowledge of the impact of industrial waste waters on the environment.

Industrial wastewater discharges into sewage systems must be managed to avoid the following:

- **Harmful effects on the health of operational employees and those exposed to wastewater and sludge.**

Humans may be exposed to hazardous substances during sewage system operation and maintenance, as well as throughout the treatment process. Exposure to hazardous or explosive volatile compounds is a potential concern. Discharges of potentially harmful compounds must be avoided or limited to a level that does not endanger the effluent being released into the sewage system.

- **Harmful effects on the sewage system**

The following are some of the consequences of industrial wastewater discharge on the sewerage system: corrosion, blockage, deposition of fine suspensions that obstruct the flow, and a foul odor. Sewer system corrosion is a well-known problem. Corrosion can be caused by acids, bases, chlorides, and sulfates in the system. Sulfate corrosion is usually linked to the transition of sulfates into sulfides, an anaerobic process that occurs in the sewer system. In the sewer system, disagreeable scents are primarily induced by hydrogen sulfide generation, but ammonia and other volatile organic compounds (mercaptan and metal sulfide, for example) can also cause unpleasant odors. Anaerobic conditions inside canals, sulphate concentrations, and easily biodegradable organic substances all contribute to sulfur formation.

- **Harmful effects on wastewater treatment facilities**

The effects of industrial wastewater on treatment facilities include inhibition of the biological treatment process, bad odors, corrosion of some treatment plant components. The biological treatment stage in wastewater treatment plants is mainly based on the concept of activated sludge. Activated sludge biodegrades or eliminates a wide spectrum of organic molecules, including potentially hazardous chemicals, under normal operating conditions. However, if non-biodegradable poisonous compounds are present in excessive concentrations, or if the concentration (loading) of toxic biodegradable compounds exceeds the removal ability of activated sludge, this biological activity may be adversely affected.

Within an activated sludge unit, the following biological processes occur water line, aerobic respiration (degradation of organic compounds under aerobic conditions), nitrification (aerobic oxidation of ammoniacal nitrogen in nitrites and nitrates), denitrification (anoxic reduction of nitrates to free nitrogen), biological phosphorus removal, sludge line, anaerobic sludge fermentation

The most sensitive process within the water line is nitrification, which is a key indicator for wastewater toxicity. Aerobic respiration inhibition is thought to be a less sensitive mechanism than nitrification. Inhibition of aerobic respiration, on the other hand, indicates the presence of hazardous substances. Inhibition of the sludge fermentation process within the sludge line could indicate the presence of hazardous chemicals for anaerobic fermentation. Anaerobic processes are more sensitive than aerobic processes in general. It is a well-known fact that unpleasant scents created by volatile organic and inorganic substances cause problems. Sulfides, mercaptan, and methyl sulfides are some of the substances that have been found in treatment plants and cause a disagreeable odor. Such issues may arise because of some industrial discharges of volatile compounds. Many of Europe's treatment plants have implemented procedures to limit the discharge of volatile chemicals into the atmosphere. Chemical dosing, covering areas of the station, and ventilation or treatment / purification of vented air are examples of these measures.

If the composition of wastewater (e.g. sulfate and chloride levels) encourages corrosion and concrete basins and/or equipment and pipes are not designed for a specific composition of wastewater, corrosion of concrete basins or specific equipment in treatment plants may occur.

- **Dangerous impacts on receiving surface waters**

The overall environmental impact of the effluent discharged from a wastewater treatment plant on the receiver body of water is determined by the effluent's qualities. Most small wastewater treatment plants treat solely household wastewater, but medium and large wastewater treatment plants treat both domestic and industrial wastewater.

The following compounds may reduce effluent quality:

• Toxic compounds for life in the aquatic environment
• Bioaccumulative substances
• Potentially toxic substances that biodegrade slowly in natural environment

Toxic compounds that are not readily biodegradable, such as substances that are not sufficiently biodegraded in the treatment plant or that are not significantly absorbed in the activated sludge, may cause ecotoxicity to the effluent.

4. Case study in Romania – assessment of industrial wastewater discharges in Cluj-Napoca

The primary economic sectors in the Cluj County area are industry, agriculture, trade, and construction and all of these are contributing to the wastewater outflow.

The following figure shows the percentage distribution of active local units operating in various national economy activities in Cluj County, according to the National Institute of Statistics [6].

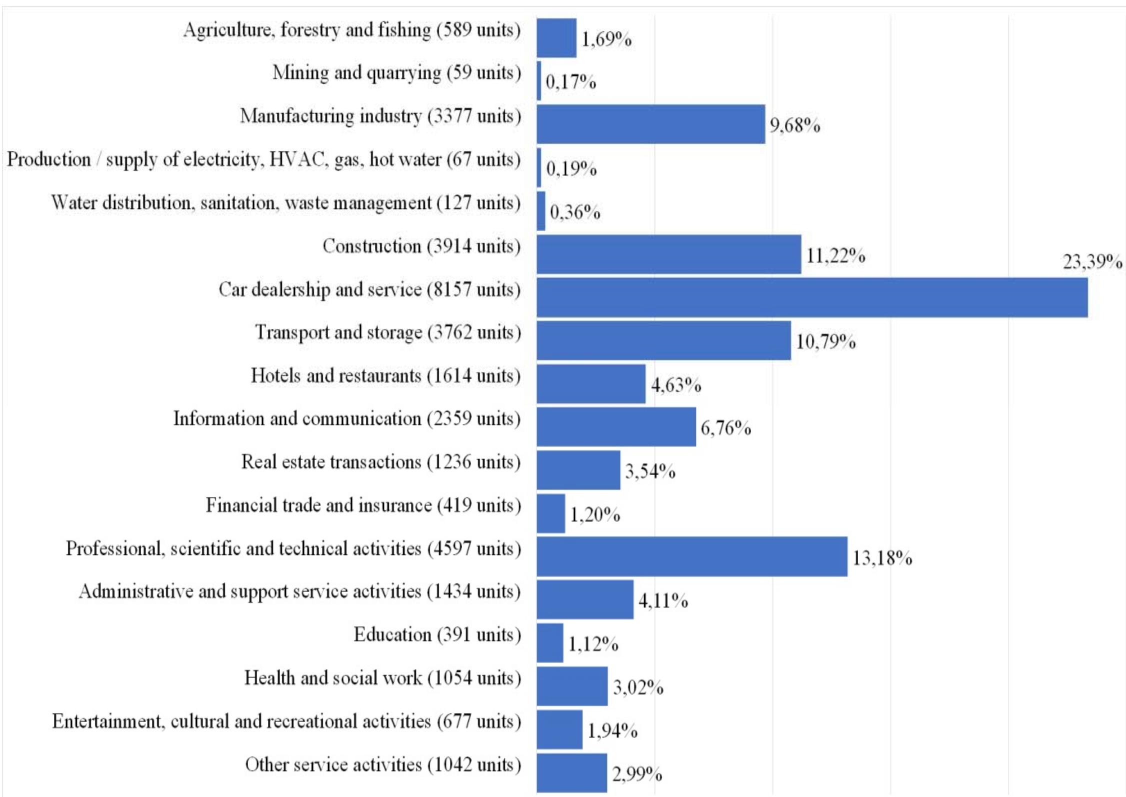

Fig. 2. Percentage distribution of active local units operating in various national economy activities in Cluj County.

All existing industries in Cluj-Napoca area can be connected to the municipal waste water treatment plant, provided they comply with the requirements defined by NTPA 002/2002. For most industries, connecting to the municipal sewerage network represents the most cost-effective option.

On the sewerage system, the amount of water collected from potential polluters' connections is monitored, especially for the economic agents who may have significant impact on the quality of the wastewater collected in the system due to the large volumes of wastewater evacuated or the high pollutant concentrations (table 1).

Table 1

Pre-treatment facilities and monitored wastewater quality indicators depending on the activity profile of the economic agents in Cluj-Napoca

Activity profile	Number of monitored units	Treatment facilities	Monitored indicators
Tourism	20	Clarifiers and grease separator	pH, CCO-Cr, CB05, MTS, NH4+, SE, detergents
Fuel station	14	Clarifiers and separator of petroleum substances	pH, MTS, SE, CCO-Cr
Car wash	11	Grit removal, clarifier and hydrocarbon separators	pH, MTS, SE pH, CCO-Cr, CB05, MTS, NH4+, SE
Bakery	11	-	pH, CCO-Cr, CB05, MTS, NH4+, SE
Shop and supermarket	11	Clarifiers and oil separators and petroleum substances	pH, CCO-Cr, CB05, MTS, NH4+, SE, P, detergents
Car dealership and service	11	Clarifiers and separators of petroleum products	pH, CCO-Cr, MTS, SE
Heavy industry	5	Clarifiers	pH, MTS, SE, CCO-Cr, NH4+
Concrete station	5	Clarifiers	pH, MTS
Textile and footwear industry	4	Clarifier, neutralizing chamber	pH, CB05, MTS, NH4+, MTS, SE, detergents
Farms and butchery	3	Monobloc mechanical-biological pre-treatment plant, separator of petroleum substances and Clarifiers	pH, CCO-Cr, CB05, MTS, NH4+, SE, P, detergents
Mining processing	3	Clarifiers and separator of petroleum substances	pH, MTS, Al, NH4+
Restaurant	3	Clarifier and grease separator	pH, CCO-Cr, CB05, MTS, NH4+, SE, P, detergents
Meat processing	3	Clarifier	pH, CCO-Cr, CB05, MTS, NH4+, SE
Metal fabrications	2	Neutralizer, clarifiers	pH, MTS, SE, Ni, Zn
Industrial fittings	1	Clarifiers and separators of petroleum products	pH, CCO-Cr, CB05, MTS, SE
Seafood processing	1	Monobloc mechanical-Biological pre-treatment plant	CCO-Cr, CB05, NH4+, SE, P

Activity profile	Number of monitored units	Treatment facilities	Monitored indicators
Abrasive material	1	Clarifiers and separators of petroleum products	pH, CB05, MTS, NH4+, SE
Metal coatings	2	Neutralizer and Clarifiers	pH, SE, Ni, Zn
Beauty	2	Neutralizer, clarifiers and grease separators	CCO-Cr, CB05, MTS, NH4+, SE
Ceramics	2	Clarifiers	pH, MTS, SE
Research	2	Clarifiers and separators of petroleum products	pH, MTS, SE, NH4+
Industrial park with canteen	2	Grease separators	pH, CCO-Cr, CB05, MTS, NH4+, SE,P
Printing	2	Pre-treatment micro station	CCO-Cr, CB05, MTS, NH4+, SE
Chemical industry	1	Clarifiers and separators of petroleum products	pH, CCO-Cr, CB05, MTS, NH4+, SE
Industrial warehouse and park	1	Clarifiers and separators of petroleum products	pH, MTS
Building materials	1	-	pH, MTS, Al
Metal sintering	1	Clarifiers and separators of petroleum products	pH, MTS, SE, CCO-Cr
Cake shop	1	-	pH, CCO-Cr, CB05, MTS, NH4+, SE, P
Plastic material	1	-	pH, MTS, SE
Furniture	1	Clarifiers	pH, SE, CCO-Cr
Dairy industry	1	Mechanical-biological treatment plant	pH, CCO-Cr, CB05, MTS, NH4+, SE,P detergenți
Chemical laundry	1	Clarifiers	pH, SE, P, detergenți
Spirt industry	1	Storage tank, clarifiers, neutralizer	pH, CCO-Cr, CB05
Rolling stock repairs	1	Grit removal, clarifiers and hydrocarbon separators	pH, MTS, SE
Pharmaceutical packaging	1	-	pH, MTS, SE, CCO-Cr
Manufactured items	1	Clarifiers	pH, SE, Ni, Zn

According to the findings of the physico-chemical analyzes of the industrial wastewater discharged by the economic agents from the Cluj-Napoca area, some industrial units exceed the limits established by NTPA 002/2002 (figure 2). However, due to the reduced quantity of industrial wastewater discharged, respectively due the effects of dilution in the sewerage network, there is no significant overall impact on the sewerage system and on the processes of the municipal wastewater treatment plant.

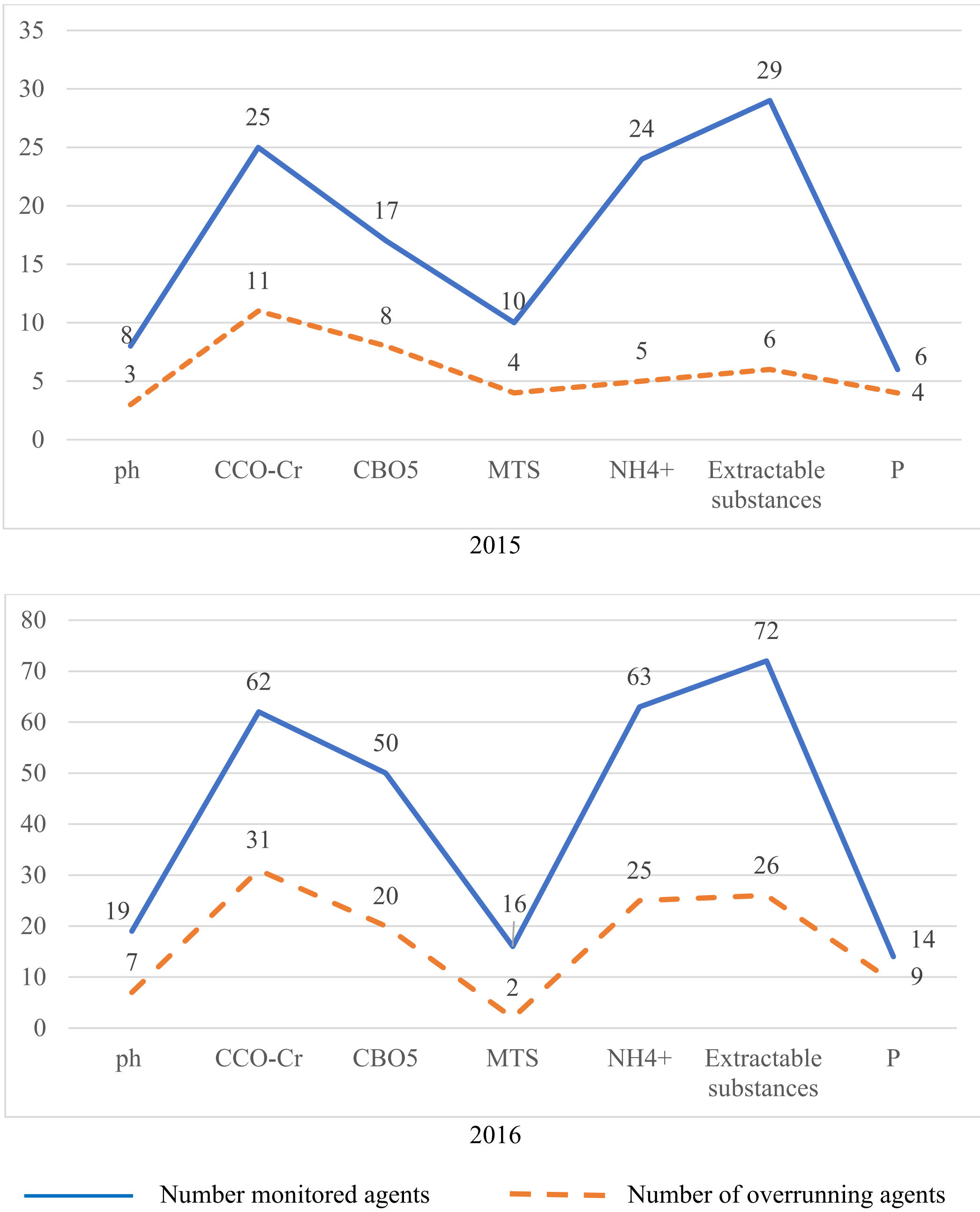

Fig. 2. The economic agents that registered exceedances for the monitored indicators

Based on the results of the economic agent monitoring and the impact on the wastewater treatment plant, it is considered that no adjustments in the wastewater treatment plant's technological flow or the construction of additional treatment plants are required. However, the economic operators who have consistently exceeded the values imposed for different quality indicators should adopt wastewater pre-treatment solutions to fall within the limits of NTPA 002/2002.

5. Conclusions

In general, industrial wastewater discharged into surface water must be properly treated to prevent adverse effects on receptors. EU directives and national legislation provide a guide for the management of industrial wastewater discharges into surface waters, indicating limit values for pollutants and using the concept of the best available technology.

The results presented in this article show that the water discharged by economic agents into the municipal sewer is, with some exceptions, in accordance with the standards imposed by NTPA 002/2002, however, improvements are needed, both in terms of pretreatment facilities at economic agents, as well as regarding the monitoring program.

The problem that economic agents face is not due to a lack of legislation in this field, which has been in place for a long time, but rather to the fact that budgets for provision and maintenance of wastewater facilities have always been limited or unavailable.

In the case of wastewater treatment plants, their operators must take a set of measures to minimize the impact of industrial wastewater discharged into municipal sewerage networks.

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School Lighting Measurements Campaign in Romania

Campanie pentru Iluminatul Şcolar în România

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Abstract. *Lighting levels for educational buildings in Romania has evolved in time due to the development of various lighting technologies, from the incandescent to light emitting diodes. The measuring campaign found that the majority of the educational buildings are using fluorescent and LED light sources. Results showed that the majority of the college classrooms have a lower mean illuminance value (119 lx – 243 lx) than the recommended level of the SR-EN 12464-1 of 300 lx. In case of classrooms for adult education (208.88 lx – 413.45 lx), the illuminance levels are below the 500 lx recommendation. The highest mean illuminance level was calculated at Onisifor Ghibu College – 625 lx, which is the result of implementing new state of the art LED technology. Uniformity in all educational buildings is below the 0.6 ratio, revealing uneven light distribution. The colour correlated temperature of the light sources has a wide variation, from 3000 K – 10000 K, indicating that there are no clear instructions on how to choose this light source feature. Colour rendering index of the luminaires is mostly below the 80 Ra values recommended by the norm. This campaign's audit can be useful for the public authorities in order to have a clear situation of the existing lighting systems and about improvement possibilities in future refurbishment projects.*

Key words: school, lighting, campaign, illuminance

1. Introduction

As many municipalities are willing to replace existing, fluorescent lighting with new LED solutions, it is important to perform a survey of existing lighting characteristics to see if they are in line with the norms in place and to see if new ones perform better. Adequate and appropriate lighting enables pupils and students to perform visual tasks efficiently and accurately. The degree of visibility and comfort required in educational buildings have a central role for comfort and well-being, regardless of the type of activity and duration. Therefore, it is important to evaluate the educational buildings across Romania, to determine whether the lighting conditions are met with the existing lighting systems.

There are many methods of how to evaluate the lighting system in a building, such as the analytic hierarchy method used by Leccese, F. et al. [1] which reveals that adequate lighting levels in a classroom are dependent on other factors aside for the illuminance levels on the main task areas, such as luminance distribution, glare, daylight availability, flicker and circadian effects. The results exposed inadequate lighting solutions, compared to the current trends. Bellia, Laura, et al. [2] have demonstrated that HDR imaging technology can be a useful tool in order to evaluate the EN 12464-1:2011 requirements and other lighting parameters which are relevant for the users' eye, at a school in Naples, Italy. According to Motta Cabrera and Zareipour [3], there is a possibility to achieve energy savings up to 70%, if lighting waste patterns are identified and avoided, in typical classrooms across Canada, by using data association mining. This tool can be used to determine association rules and understand these waste patterns. Rucinska and Trzaski [4] have concluded that it is necessary to consider the efficiency of the lighting systems during the buildings design process, as well as the suitable window parameters, which will have an impact on the energy balance, due to the high share of lighting demand in schools. Lighting control systems are also a key parameter in achieving energy savings, by mixing daylight and electric light in indoor spaces. Kaminska and Ozadowicz [5] have shown that there is a possibility to further reduce the energy consumption by 24% on educational buildings in Poland, by using complex KNX-based automation systems and taking daylight into account. Lassandro, Paula, et al. [6] developed a tool in the form of a virtual tour that can aid the decision-making process for retrofitting solutions in schools, correlated with students' post-occupancy evaluation surveys. Dascalaki, Elena G. and Vasileios G. Sermpetzoglou [7] have analyzed the energy performance of 135 Hellenic schools and revealed that using lighting control systems and energy efficient lighting fixtures would reduce energy waste and contribute to the reduction of energy demand. Another study from Doulos, L.T. et al. [8] made in schools from Greece, highlighted the importance of combining high efficiency luminaires with daylight controls to fulfill near Zero Energy Buildings (nZEB) requirements for educational buildings. This could also be applied in Romania, due to the operation time during daytime, when there is an abundance of natural light. S. A. Ghita and T. Catalina [9] made an IEQ assessment of 3 schools in Valcea County, where it was found that the illumination level was below the recommendations of the SR EN-12464:2011 [10] for indoor workplaces, with a range between 44 lx as the lowest mean illumination level and 281 lx as the highest mean illumination level. Another IEQ study of 5 classrooms for students diagnosed with learning challenges and attention disorder in the Slovak Republic made by Vilcekova, S., et al. [11] revealed that the illumination levels were low and caused visual discomfort. Energy reduction can be achieved by using smart lighting control systems, such as the one proposed by de Rubeis, T., et al. [12] with a wireless communication protocol. Such a control system can reduce the energy consumption by almost 70% and has a lower payback period when compared to existing control systems on the market. Castilla, N., et al. [13] focused their study on students' subjective assessment of the university classrooms and the results showed a clear connection between light and space. It is important to place students and teachers in the center of the lighting design process.

Most educational buildings in Romania were constructed before 1990 and since then, the lighting recommendations have changed as technology evolved. Nowadays, there is a steady direction towards energy efficient public buildings and the educational sector will have an impact in the process. Before the use of European norm SR EN-12464:2011 there was the Romanian norm STAS 6646 [14] (first version in 1966 and the next one in 1987) and the Romanian regulation PE 136/1988 [15]. For example, the illuminance level in classrooms was 300 lx at a height between 0.85-1m from the floor, on a horizontal plane. In 1966, the illuminance recommendations of Romanian standard 6646 were depending on the type of lamps: lower levels for incandescent lamps and higher levels for fluorescent lamps. For administrative offices, a local supplementary lighting was necessary, in the form of a table lamp. From Table 1 we can see that there was a difference in the recommended values depending on the lamps and these values are lower than those in SR-EN 12464.

Table 1

Recommended values according to Romanian norm STAS 6646-66 (valid until 1987) for schools, high-schools, universities and research institutes

Room	Illuminance value		Height of the task area
	Fluorescent lamps	Incandescent lamps	
Professors office, secretary	200	75	0.85-1m
Classes, lecture halls	300	100	0.85-1m
Laboratory	300	150	0.85-1m
Drawing and art classes	400	200	0.85-1m
Libraries	300	150	0.85-1m
Administrative offices (x)	200	75	0.85-1m
Sport halls	200	75	0
Staircases and corridors	200	75	0

Uniformity for civil buildings was supposed to be 0.5 and for passageways, corridors and staircases 0.25. Emergency lighting was not compulsory for schools,only for rooms with more than 100 people (lecture halls) and for passageways and staircases used by more than 50 people (all the schools and universities). Illuminance level for emergency lighting was supposed to be 0.2 lx. In 1988, a new recommendation was set with the Romanian normative PE136/1988 with a single recommended illuminance level, regardless of the type of lamp, as displayed in Table 2.

Table 2

Recommended values according to PE 135/1988 for schools, high-schools, universities and research institutes

Room	Illuminance value	Height of the task area
Professors office, secretary	150	0.85-1m
Classes, lecture halls	300	0.85-1m
Blackboards	300	1.5m on vertical surface
Laboratory	300	0.85-1m
Drawing and art classes	400	0.85-1m
Libraries	300	0.85-1m
Administrative offices	150	0.85-1m
Sport halls	100	0
Staircases and corridors	50	0

Comparing Table 1 and 2, it can be observed that the recommended values for fluorescent light sources were lowered in 1988 for some spaces (professors and administrative offices, sports halls, staircases and corridors), as a consequence of energy rationalization in all spaces. Also in Table 2, the illuminance level for blackboards is introduced, for the first time. This is an indication of increased lighting quality in the classrooms, by combining the horizontal illuminance with the vertical blackboard plane.

In this campaign, a direct method of evaluating lighting systems and how it affects the spatial illuminance, colour-correlated-temperature and uniformity has been developed. It is based on the illuminance measurements in the classroom, using a portable light spectrometer. Compared to other methods, it has the benefit of obtaining results from a calibrated tool, developed particularly for lighting applications. Other methods such as the ones who use HDR images can also be useful, but there is a possibility to have wide deviations, due to potentially unbalanced calibrations. Furthermore, it is our goal to examine classrooms with electric light only.

The campaign will help to create a database of lighting conditions in classrooms, as exemplified in Table 4, by taking precise measurements in the majority of the educational buildings across Romania. Furthermore, we can obtain a pattern of illuminance levels, which are useful in order to understand what solution is required in each type of classroom. The preliminary results of the measurement campaign indicate that the illuminance level in the Technical University of Cluj-Napoca’s classrooms is approximately 37.72% less than the recommended value of 500 lx. In the case of the examined schools, the level varies between 4.21% and 59.89% below the reference value of 300 lx. There are 3 classrooms with values higher than the reference value at Onisifor Ghibu, Mihai Eminescu and Nicolae Balcescu College, with 625 lx, 359 lx and 329 lx. The uniformity ratio is also below the value of 0.6, in the majority of the cases. As for the colour rendering index, the results indicate that half of the investigated spaces have a value above 80 Ra.

The structure of the paper after introduction contains the detailed description of the method, then it continues with a presentation of the results. Moreover, there is a conclusion section based on the results and observations obtained from the examined spaces. Finally, the future work section is describing the following steps in order to have a complete evaluation and proposed lighting solution.

2. Method

The measurement method has been applied in several high schools from Brasov and Cluj-Napoca (Andrei Saguna College, Unirea College and Johannes Honterus College - Brasov, Anghel Saligny College, Energetic College, Mihai Eminescu College, Nicolae Balcescu College, Onisifor Ghibu College – Cluj-Napoca). The Faculty of Building Services Engineering in Cluj-Napoca, was also part of the campaign. The measurement method used is based on the application of the calculation formula for lighting levels, from the SR EN 12464-1[9] standard, by generating a grid with points of interest, and then to determine by means of a portable light spectrometer, the lighting level for each of these points. The focus of the measurements in each of the educational institutions is in classrooms and gyms. The requirements of the existing lighting standard for indoor workplaces are detailed in Table 3.

Table 3

Types of Activity in Educational Buildings and lighting parameters according to SR-EN 12464-1:2011

Room Type	Em [lx]	U0	Ra	Specific Requirements
Classrooms for primary and secondary courses	300	0.6	80	Lighting should be controllable
Classrooms for evening courses and adult education	500	0.6	80	Lighting should be controllable
Gyms (general use)	300	0.6	80	EN 12193 has to be followed for specific training conditions

After defining the types of activities in each room examined within the educational institutions, the information obtained will be centralized in a table and will be compared with the parameters recommended by the SR EN 12464-1:2011 standard.

To determine the illuminance level in the examined spaces, a calculation tool was developed, starting from the SR-EN 12464-1:2011 recommendations of defining a measuring grid. All the relevant parameters which contribute to the final definition of the grid are exemplified in Fig.1.

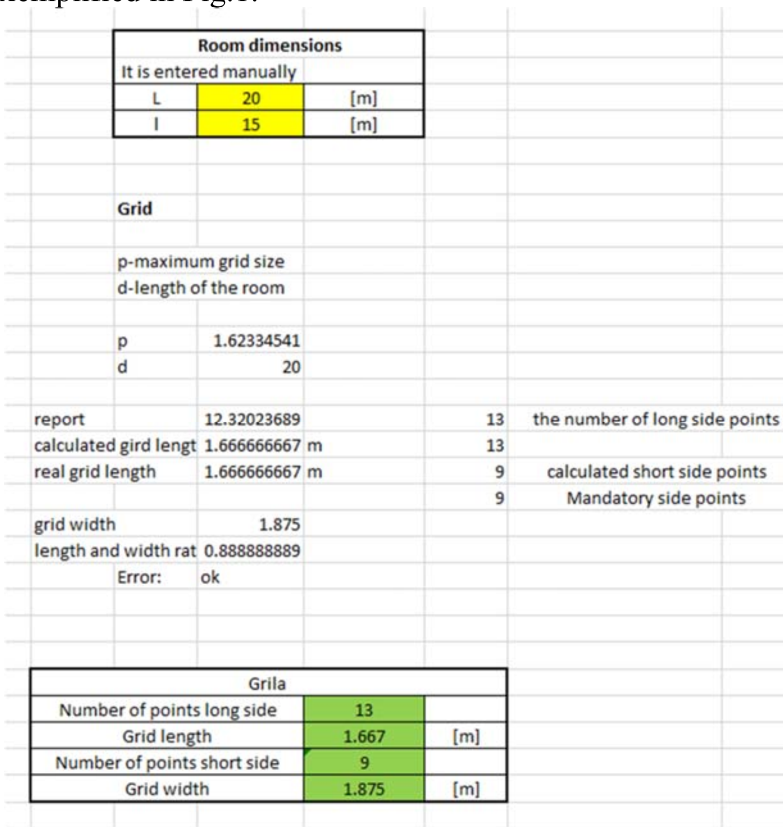

Fig. 1. Grid calculation parameters.

It is also important to know the dimensions of the space, which must be introduced manually. The calculation tool generates a virtual grid which covers the entire space, distributing the points of interest on both the length and width of the room. The calculation tool generates a virtual grid which covers the entire space, distributing the points of interest on both the length and width of the room. An example of a calculated grid is shown in Fig.2, which shows the length of the grid as columns and the width of the grid as rows.

The measuring points indicated by the calculation tool will be marked in space. Usually, the measurements should be performed in empty space, but in our case, all the classrooms were filled with furniture and other items. Due to the fixed position of the benches, the positions have to be adapted to the existing conditions and it may have an impact on the results. Finally, the portable light spectrometer is placed on a tripod, at the required height, depending on the workplane requirements. In our case, the measuring device was fixed at 0.8m from the ground in all classrooms and at ground level for the gym. All the measured results were recorded and filled-in the calculation

			Door								
Masuratori iluminare	Column 1 [lx]	C 2 [lx]	C 3 [lx]	C 4 [lx]	C 5 [lx]	C 6 [lx]	C 7 [lx]	C 8 [lx]	C 9 [lx]	C 10 [lx]	C 11 [lx]
Row 1	29.86	120.93	86.56	153.35	167.6	160.5	157.48	136.73	129.44	116.13	68.42
Row 2	216	185.71	188.65	190.69	194.35	198.65	202.24	188.63	183.53	151.28	104.79
Row 3	359.45	210.29	149.66	126.91	149.6	126.82	141.67	113.82	118.23	103.49	79.66
Row 4	144.39	238.08	208.83	208.99	196.51	204.76	209.09	191.1	182.83	181.31	100.46
Row 5	109.18	236.8	224.93	244.82	286.5	276.5	299.87	265.63	235.46	157.11	74.4
Row 6	118.87	197.95	215.27	227.34	248.87	283.2	319.29	316.66	260.52	192.6	131
Row 7	106.13	174.56	189.91	195.28	208.19	251.77	279.89	262.22	249.55	202.47	142.34
Row 8	117.65	139.92	157.02	184.32	186.42	224.25	261.92	212.71	215.93	176.33	138.34
Row 9	45.45	114.48	143.81	142.72	151.07	188.27	179.22	176.46	144.47	114.25	94.53
	Window		Window			Window			Window		

Fig. 2. Example of a generated grid with results.

tool. Then, in order to determine the average illuminance in each space, we applied the arithmetic mean of all measured points. The uniformity is also calculated based on the ratio between the minimum measured value and the calculated average value.

The measurements were done using a GL SPECTIS 1.0 Touch + Flicker [16]. This portable light spectrometer, as displayed in Fig. 3 can be used to evaluate various colorimetric and photometric parameters, such as color-correlated temperature of the light source, the color rendering index, the illuminance value and also the flicker level of an existing lighting installation. It is also possible to compare results from a light source, the color rendering index, the illuminance value and also the flicker level of an existing lighting installation. It is also possible to compare results from a lighting calculation from software such as DIALux Evo [17] or similar, with the existing parameters, after the lighting systems implementation. It is also possible to generate comprehensive lighting reports that can be used for the lighting industry and even for the end users.

3. Results

In this chapter, the measurement results are presented. The lighting parameters, either measured or calculated in the areas of interest, depending on the type of activity will be centralized and will be compared with the minimum values prescribed by the

Fig. 3. GL SPECTIS 1.0 Touch + Flicker Spectrometer.

SR-EN-12464-1:2011 standard. The values in Table 4 represent the existing situation in the educational institutions that were studied.

Table 4

Measured and calculated lighting parameters of the educational spaces

School	Room type	Em	U0	CCT	Ra	Light Source
Andrei Saguna College - Brasov	Class-01	179.58	0.166	5182	77.1	T8 FL
	Class-02	243.2	0.333	3464	85.1	T8 FL
	Class-03	188.66	0.212	5457	71.4	T8 FL
Unirea College - Brasov	Class-01	121.5	0.096	9514	82.1	T8 FL
	Class-02	119.18	0.306	10088	82.1	T8 FL
Johannes Honterus College - Brasov	Class-01	251	0.361	5869	73.3	T8 FL
	Class-02	168.32	0.372	6047	74.9	T8 FL
	Class-03	180.24	0.258	5594	72.3	T8 FL
	Class-04	549.99	0.294	3581	81.4	T5 FL
Faculty of Building Services UTCN - Cluj-Napoca	Class-01	413.45	0.611	3703	83.4	T8 FL
	Class-02	250.1	0.52	5595	72.1	T8 FL
	Class-03	316.78	0.48	3467	81.4	T8 FL
	Class-04	328.25	0.415	3582	82.7	T8 FL
	Class-05	350.95	0.537	5576	72.4	T8 FL
	Class-06	208.88	0.394	5599	71.8	T8 FL
Anghel Saligny College – Cluj-Napoca	Class-01	234.41	0.415	5092	75.2	T8 FL
Energetic College – Cluj-Napoca	Class-01	247.32	0.457	4068	79.56	T8 FL
	Class-02	314.71	0.238	3784	81.3	LED
Mihai Eminescu College – Cluj-Napoca	Class-01	359.3	0.404	4789	80.7	LED
Nicolae Balcescu College – Cluj-Napoca	Class-02	329.43	0.506	3654	78.1	T5 FL

School	Room type	Em	U0	CCT	Ra	Light Source
Onisifor Ghibu College – Cluj-Napoca	Class-01	625.56	0.297	3370	83	LED

When reporting to reference values in the standard, it can be observed that not all the measured or calculated parameters in the classrooms are simultaneously fulfilled, as displayed in Table 5. The illumination level in the classrooms of the 8 studied schools meets the recommendations in the proportion of 40.11% in the most unfavourable case (Unirea College – Brasov), and the most favourable case at Onisifor Ghibu with a value of 625.56 lx which is more than double of the recommended level. In the university classrooms' case, the illuminance level is fulfilled at an average of 62.28%. In the case of uniformities, there are major differences from the most favorable case (Nicolae Balcescu College – Cluj-Napoca) in the proportion of 85% and the least favorable college located at 33.50% (Unirea College-Brasov).

Table 5

Comparison of Lighting levels, uniformity and colour rendering index in studied classrooms

Educational Building	Avg Em (lx)	Em/Enorm (%)	Avg U0	U0/ U0 norm (%)	Avg CRI
Andrei Saguna College - Brașov	203.81	67.93%	0.237	39.50%	77.87
Unirea College - Brașov	120.34	40.11%	0.201	33.50%	82.10
Johannes Honterus College - Brașov	287.39	95.79%	0.321	53.54%	75.48
Faculty of Building Services UTCN - Cluj-Napoca	311.40	62.28%	0.492	82.13%	77.30
Anghel Saligny College – Cluj-Napoca	234.41	79%	0.415	70%	70.26
Energetic College – Cluj-Napoca	281.01	94%	0.352	59%	76.34
Mihai Eminescu College – Cluj-Napoca	359.3	120%	0.404	68%	72.44

Nicolae Bălcescu College – Cluj-Napoca	329.43	110%	0.506	85%	78.1
Onisifor Ghibu College – Cluj-Napoca	625.56	209%	0.297	50%	83

Abbreviations in Table 4 and 5 – Em (mean illuminance); Avg Em (average mean illuminance per schoom); lx (lux); Enorm (reference illuminance); U0 (uniformity); U0norm (reference uniformity); Avg CRI (average colour rendering index); CCT (colour correlated temperature); Ra (colour rendering index); T8/T5 FL (T8/T5 fluorescent tube); LED (light emitting diode).

4. Conclusions

The lighting parameters measured in the educational buildings across Romania are below the requirements of the SR EN 12464-1:2011 for indoor workplaces. The majority of the university classrooms have a lower illuminance level, 37.72% less than the recommended level of 500 lx. After analysing the illuminance levels in school classrooms in Brasov, the average results are 32.07% (Andrei Saguna College), 59.89% (Unirea College) and 4.21% (Johannes Honterus College) less than the reference value of 300 lx. For Cluj-Napoca, the results are either below the reference value (Anghel Saligny College – 21%; Energetic College Class 01 – 17%) or above (Energetic College Class 02, Mihai Eminescu College, Nicolae Balcescu College and Onisifor Ghibu College). Furthermore, in all cases, the uniformity ratio is situated below the mean value of 0.6, indicating that the overall illuminance distribution is uneven. Regarding the Colour Correlated Temperature, there is a wide variation of values from 3000 to 10000 K. This variation is a clear indication that there are no clear instructions on how to choose the lighting source. Regarding the lighting control systems, in the educational institutions of this campaign, there were On/Off type switches installed, with the only exception at Onisifor Ghibu College, which has implemented a lighting control system capable of dimming the luminaires according to daylight availability, movement and presence sensors. Using dedicated lighting control systems and energy efficient luminaires could significantly increase the quality of the visual comfort and reduce energy consumption.

The results obtained from this measurement campaign will be used to create a expand a database of existing lighting conditions in classrooms, having the illuminance levels, uniformity and colour rendering index measurements in the majority of the educational buildings across Romania. With these results, we can generate a pattern that covers the electric lighting conditions in each type of classroom, which will further help the process of designing a new lighting solution. It is also useful for the public authorities as an updated information database regarding the status of the existing lighting systems.

5. Future Work

We aim to collect further relevant data about the lighting systems in educational buildings across Romania in order to have a deeper database of the existing situation. Moreover, we aim to develop a lighting proposal that will meet the recommendations of the lighting standard, provide visual comfort and reduce the energy consumption. It would also serve as a guide for the public authorities in the decision-making process, before opting to implement new lighting solutions.

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