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MATRIX ROM
3 Politehnicii Street, Bucharest, Romania
Tel. +4021.4113617, +40733882137
e-mail: office@matrixrom.ro
www.matrixrom.ro

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Shared and intake energy related to a building served by a hybrid source - heat pump with boiler

Energie comună și absorbită aferentă unei clădiri deservite de o sursă hibridă - pompă de căldură cu boiler

Florin IORDACHE[1], Mugurel TALPIGA[1]

[1] Technical University of Cvil Engineering Bucharest
Bd. Lacul Tei nr. 122 - 124, cod 020396, Sector 2, Bucharest, Romania

E-mail: *fliord@yahoo.com*, *talpiga.mugurel@gmail.com*

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Rezumat: Evaluarea aporturilor si consumurilor energetice aferente utilizarii pompelor de caldura pentru deservirea cladirilor in ceea ce priveste incalzirea spatiilor si/sau prepararea apei calde de consum comporta 3 etape principale de calcul : evaluarea coeficientului de performanta al pompei de caldura, COP, determinarea temperaturii exterioare de echilibru, teE si calculul puterilor de baza ale pompei: puterea termica livrata la condensator, puterea termica absorbita la vaporizator, puterea electrica utilizata si puterea termica livrata de centrala termica. In lucrarea se prezinta in detaliu evaluarea fiecareia din aceste 4 tipuri de puteri energetice. Procedura de lucru descrisa permite utilizarea programului de calcul al BIN-urilor lunare.

Cuvinte cheie: sursă hibridă, pompă de căldură cu boiler

Abstract: The assessment of shared and consumed energy related to heat pumps for servicing buildings in terms of space heating and/or the preparation of domestic hot water involves 3 main stages of calculation: assessment of the heat pump's coefficient of performance, COP, determination of the external equilibrium temperature , teE and the calculation of the basic powers of the pump: the thermal power delivered to the condenser, the thermal power absorbed by the evaporator, the electrical power used and the thermal power delivered by the heating plant. The paper presents in detail the evaluation of each of these 4 types of energy powers. The described work procedure allows the use of the monthly BIN calculation program.

Key words: hybrid source, heat pump with boiler

1. Introduction

The evaluation of input energy and consumption related to heat pumps to solve the problems of space heating and the preparation of domestic hot water related to buildings has been a constant concern in the authors' research. The current work is based on the evaluation of the COP of the heat pump using the isentropic energy efficiency of the heat pump, ε^{IZ}_{pc}, {1} as the central core. A first step in the calculation of the assessment of energy inputs and consumptions is the evaluation of the COP values of the heat pump in the different situations of the couple of temperatures of the cold, θ_{vp} and hot θ_{cd} environments. A second important stage is evaluation of equilibrium external

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temperature, teE, temperature for which the thermal power delivered to the pump condenser is equal to the required thermal power of the consumer. The third stage is the effective evaluation of the thermal and electrical powers involved in the operation of the source-consumer system on each BIN separately and of the energies on each BIN, for each month and for the whole year, for space heating and/or hot water preparation.

2. Procedure

The procedure that will be presented is based on the evaluation of the isentropic energy efficiency of the heat pump, ε^{IZ}_{pc}. A number of parameters related to the heat pump and the consumer are considered known, such as:

a. The temperatures of the cold and warm environments in which the evaporator, θ_{vp}, and the condenser of the machine are located, θ_{cd}.

b. Isentropic efficiency, η_{iz}.

c. Electrical motor efficiency, η_{el}.

d. Electrical motor maximum power, P_{EL};

e. Building transfer capacities for heating and DHW, H_{inc}, H_{acc};

f. Hot and cold DHW temperatures : t_{ac} si t_{ar};

g. In the case of space heating, account will be taken of the simplified calculation relationship of the heat agent input temperature in the central heating installation.

$$t_T = \left(1 + \frac{t_{T0} - t_{i0}}{t_{i0} - t_{e0}}\right) \cdot t_{i0} - \frac{t_{T0} - t_{i0}}{t_{i0} - t_{e0}} \cdot t_e \tag{1}$$

Heat pump isentropic efficiency will be :

$$\varepsilon^{IZ}_{pc} = U \cdot dt^{-V} \qquad dt = t_{cd} - t_{vp} \tag{2}$$

$$\varepsilon^{IZ}_{pc} = M \cdot \varepsilon^{C}_{pc} - N \qquad \varepsilon^{C}_{pc} = \frac{t_{cd} + 273.15}{t_{cd} - t_{vp}} \tag{3}$$

To simplify evaluation it was proposed relations (3).

Constant values :

$$U = 705.53;\; V = 1.284; \qquad M = 0.9676;\; N = 1.6081; \tag{4}$$

To be possible heat transfer at evaporator respectively condenser, logarithmic temperature differences are:

$$\Delta t = \Delta t_{vp} = \theta_{vp} - t_{vp} \qquad \Delta t = \Delta t_{cd} = t_{cd} - \theta_{cd} \tag{5}$$

Below examples use $\Delta t = 5\ ^{o}C$.

Evaporation and condensing temperatures:

$$t_{vp} = \theta_{vp} - \Delta t$$
$$t_{cd} = \theta_{cd} + \Delta t \quad (6)$$

COP evaluation use ecuation (7)

$$COP = \eta_{el} \cdot \varepsilon_{PC} = \eta_{el} \cdot \left[1 + \eta_{iz} \cdot \left(\varepsilon_{PC}^{IZ} - 1\right)\right] \quad (7)$$

3. External equilibrium temperature evaluation, t_{eE},

The equilibrium external temperature, teE, is defined as the external temperature for which the thermal power delivered to the pump condenser is equal to the required thermal power of the consumer. The case of the space heating consumer and the case of the hot water preparation consumer will be analyzed separately.

a. Space heating

$$COP_E \cdot P_{EL} = H_{inc} \cdot \left(t_{i0} - t_{eE}\right) \quad (8)$$

Simplified form of equation (8):

$$\frac{t_{i0} - t_{eE}}{COP_E} = \frac{P_{EL}}{H_{inc}} \quad (9)$$

In relation (9) the equilibrium external temperature is found only in the left member of the relation, the quantities in the right member being given. An analysis of the correlation between the external equilibrium temperature, teE and the P_{EL}/H_{inc} ratio was carried out and the obtained result is presented below:

$$t_{eE} = -2.4958 \cdot \left(\frac{P_{EL}}{H_{inc}}\right) + 15.361 \quad (10)$$

b. Daily Hot Water production:

$$COP_E \cdot P_{EL} = H_{acc} \cdot \left(t_{ac} - t_{ar}\right) \quad (11)$$

Extracting COP from eq. (11):

$$COP_E = \frac{t_{ac} - t_{ar}}{P_{EL}/H_{acc}} \quad (12)$$

An analysis was made of the correlation between the equilibrium external temperature, teE contained in the left member of the relationship (12) and the right member of the relationship (12) and the obtained result is presented below:

$$t_{eE} = -1.7191 \cdot \left(\left(t_{ac} - t_{ar}\right) \Big/ \left(\frac{P_{EL}}{H_{acc}}\right)\right)^2 + 24.338 \cdot \left(\left(t_{ac} - t_{ar}\right) \Big/ \left(\frac{P_{EL}}{H_{acc}}\right)\right) - 56.032 \quad (13)$$

4. The effective evaluation of the thermal and electrical powers involved in the operation of the source-consumer system on each individual BIN and of the energies on each BIN, for each month and for the whole year, for space heating and/or hot water preparation

For heating:

a. If $\mathbf{t_e} < \mathbf{t_{eE}}$ then $P_{EL} = P_{el\_max}$ and COP vs thermal powers evaluation for each external temperature are:

$$P_{pc} = COP \cdot P_{EL}$$
$$P_{inc} = H_{inc} \cdot (t_{i0} - t_e) \qquad (14)$$
$$P_{ct} = P_{inc} - P_{pc}$$
$$P_{vp} = (COP - \eta_{EL}) \cdot P_{EL}$$

b. If $\mathbf{t_e} > \mathbf{t_{eE}}$ then $P_{pc} = P_{cons}$ and thermal powers evaluation for each external temperature are:

$$P_{inc} = H_{inc} \cdot (t_{i0} - t_e)$$
$$P_{pc} = P_{inc}$$
$$P_{el} = P_{pc} / COP \qquad (15)$$
$$P_{ct} = 0$$
$$P_{vp} = (COP - \eta_{EL}) \cdot P_{el}$$

Daily Hot Water preparation:

a. if $\mathbf{t_e} < \mathbf{t_{eE}}$ than $P_{EL} = P_{el\_max}$ and:

$$P_{pc} = COP \cdot P_{EL}$$
$$P_{acc} = H_{acc} \cdot (t_{ac} - t_{ar}) \qquad (16)$$
$$P_{ct} = P_{acc} - P_{pc}$$
$$P_{vp} = (COP - \eta_{EL}) \cdot P_{EL}$$

b. If $\mathbf{t_e} > \mathbf{t_{eE}}$ then $P_{pc} = P_{cons}$ and:

$$P_{acc} = H_{acc} \cdot (t_{ac} - t_{ar})$$
$$P_{pc} = P_{acc}$$
$$P_{el} = P_{pc} / COP \qquad (17)$$
$$P_{ct} = 0$$
$$P_{vp} = (COP - \eta_{EL}) \cdot P_{el}$$

The energies on BINs are obtained by multiplying the powers with the duration of the BIN. To determine the monthly energy values, the resulting values for the BINs of the respective month are collected.

Definition of energy coverages:

- Heat pump coverage factor:

$$GA_{pc} = P_{pc} / P_{cons} \qquad (18)$$

- Electrical energy coverage factor :

$$GA_{el} = P_{el} / P_{cons} \qquad (19)$$

- Boiler coverage factor:

$$GA_{ct} = P_{ct} / P_{cons} \qquad (20)$$

- Renewable energy coverage factor :

$$GA_{vp} = P_{vp} / P_{cons} \tag{21}$$

5. Results

The evaluation of energy inputs and consumption for a space heating and hot water preparation consumer presented in the previous chapters follows the order in which the calculations must be performed. The first action undertaken is the establishment of the BINs corresponding to the locality where the building for which the calculations are made is located. Establishing BINs is a preliminary step that must be carried out before starting the procedure described so far based on climate data. Enter the data related to the consumer, Hinc, Hacc, the temperature of hot water, tac, and cold water, tar, and the data related to the heat pump: ηel, ηiz, M, N, PEL, and proceed to the first stage of establishing the COP of the heat pump. Next, the external equilibrium temperature, teE, is established, according to the procedure described in point 3. Next is the application of point 4 for the assessment of thermal and electrical powers: Ppc, Pvp, Pel, Pct and their corresponding energies: Epc, Evp, Eel, Ect , obtained by multiplying the powers with the durations of the BINs. In this way, a tabular presentation of the results appears, as the program created by the authors, which also includes the program for creating the BINs that was written in [2], appears. In this way, an automatic calculation tool is obtained that solves the energy aspects related to the implementation of a heat pump with mechanical compression of air-water type values together with the consumer's classic heating plant.

As an example, we present the results obtained with the mentioned program for a building with space heating utility located in Odorheiul Secuiesc. The presented results, as can be seen for the month of December, are extended to evaluate all the year and show the sum of the energies for all months of the year. It can be seen in table 1, which follows in columns 2 and 3, the data of the BINs, (t_e and N_{ore}) for the month of December. In column 2, the values of the external equilibrium temperature, t_{eE}, were placed, further following 4 groups of parameters. For COP calculation (columns 5, 6, 7, 8 and 9), for power evaluation (columns 10, 11, 12, 13 and 14), for energy evaluation (columns 15, 16, 17, 18 and 19) and finally group of degrees of energy coverage (columns 20, 21, 22 and 23)

Example: Odorheiul Secuiesc

Tabel 1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Decembrie	**teE**	**te**	**ore**	**tcd**	**tvp**	**eCpc**	**elZpc**	**COP**	Pcons	Pel	Pcd	Pvp	Pct	Econs	Eel	Ecd	Evp	Ect	GApc	GAel	GAct	GAvp
	oC	**oC**	**h**	**oC**	**oC**				W	W	W	W	W	kWh	kWh	kWh	kWh	kWh				
BIN 1	-4.605	-6.24	59.52	42.891	-11.240	5.838	4.041	3.090	372608	113600	350985	248745	21623.02	22177.63	6761.472	20890.63	14805.3	1287.002	0.942	0.305	0.058	0.668
BIN 2	-4.605	-3.92	178.56	41.309	-8.920	6.260	4.450	3.384	339664	100383	339664	249319.3	0	60650.4	17924.38	60650.4	44518.46	0	1	0.296	0	0.734
BIN 3	-4.605	-1.6	267.84	39.727	-6.600	6.754	4.927	3.727	306720	82291.61	306720	232657.6	0	82151.88	22040.98	82151.88	62315	0	1	0.268	0	0.759
BIN 4	-4.605	0.72	178.56	38.145	-4.280	7.337	5.492	4.134	273776	66225.81	273776	214172.8	0	48885.44	11825.28	48885.44	38242.69	0	1	0.242	0	0.782
BIN 5	-4.605	3.04	59.52	36.564	-1.960	8.040	6.171	4.623	240832	52093.02	240832	193948.3	0	14334.32	3100.577	14334.32	11543.8	0	1	0.216	0	0.805
												Energ. Lunare		228199.7	61652.7	226912.7	171425.2	1287.002				
												Energ. Anuale MWh		1267.241	328.7461	1250.88	955.0089	16.36091				

Nomenclature :
t_e – external temperature, °C;
t_{e0} – design external temperature, °C;
t_{eE} – external equilibrium temperature, °C;
t_{T0} – design maximum turn temperature, °C;
t_T – turn temperature, °C;
t_{i0} – design comfort temperature, °C;
t_{ac} – DHW temperature, °C;
t_{ar} – cold water temperature, °C;
θ_{vp} – evaporation environment temperature, °C;
θ_{cd} – hot environment temperature, °C;
t_{vp} – evaporation temperature, °C;
t_{cd} – condensing temperature, °C;
Δt – logarithmic temperature difference, °C;
η_{iz} –isentropic efficiency, -;
η_{EL} – electrical compressor motor efficiency, -;
ε^{C}_{pc} – Carnot efficiency, -;
ε^{IZ}_{pc} – heat pump isentropic efficiency, -;
COP – Coeficient of Performance, -;
P_{el} – heat pump electrical power consumption, W;
P_{EL} – maximum heat pump electrical power consumption, W;
P_{pc} – condensing power, W;
P_{vp} – evaporation power, W;
P_{ct} – boiler power, W;
P_{cons} (P_{inc}, P_{acc}) – design thermal power consumption, W;
H_{inc} – building heating capacity, W/m^2;
H_{acc} – DHW heating capacity, W/m^2;
E_{pc}, E_{mf}, E_{el}, E_{ct}, E_{cons} – BIN energies; W.h;
GA_{pc} – heat pump coverage factor, -;
GA_{el} – electrical energy coverage factor, -;
GA_{ct} – boiler coverage factor, -;
GA_{vp} – renewable coverage factor, -;
U, V, M, N – procedure design parameters,

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Key factors to have a good sleep quality in bedrooms
Factori cheie pentru a avea o calitate bună a somnului în dormitoare

Cristian PACURAR [1], Adriana TOKAR[1], Marius ADAM[1]

[1] University Politehnica Timisoara
Victoriei Square, no. 2, Timisoara, Romania
E-mail: cristian.pacurar@upt.ro, adriana.tokar@upt.ro , marius.adam@upt.ro

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Abstract. *The indoor air quality in bedrooms is one of the main factors that influence the human performance during these days. Throughout the years, a lot of studies described the relation between the climate comfort and the performance. This study presents the important factors to have a quality sleep with the main effect being daily productivity*

Key words: thermal comfort, productivity, performance, environmental quality, indoor air quality (IAQ)

1. Introduction

An important aspect that could help better inform designers and home builders is understanding sleep quality and our physical sleep environment. The houses should be designed and built that provide an adequate (comfortable) indoor environment for all rooms, but especially for the bedroom, which can be adjusted by the bedroom(s) to suit individual preferences and a lot of people spend up to 87% of their time in indoor environments, be it in residential, academic, or commercial buildings, and another 6% in their vehicles, and thus are continually being exposed to the indoor environment [1]. According to Wong et al. (2007) [2], the acceptance of an environment by its occupants depends on environmental parameters, namely thermal comfort, indoor air quality (IAQ), sound and visual comfort, which are identified to determine indoor environmental quality. In many studies it has been proven that poor IEQ may cause diseases, negatively affecting the workers well-being and reduce its productivity [3]. Many studies held in the last decades have reported the connection between thermal environment and the performance of its occupants [4]. The thermal environment may vary and may affect the performance of workers, affecting their productivity. Sleep is an important factor that affects a person's health and performance. The quality of sleep is very important to perform well at work but also in other daily situations. A good sleep improves our performance, health, and mood.

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2. Content of the paper

A large part of the time we spend indoors is related to relates to the sleeping environment. Sleep is an important factor that affects people performance and health. A good night's sleep is commonly accepted as a significant factor in allowing adequate daytime functioning such as concentration and alertness. The quality of sleep is very important to perform well at work. today there is no clear definition of sleep quality. To understand the significance of sleeping well, a distinction must be made between sleep duration and sleep quality. These two aspects of sleep are uncorrelated and may have different effects on daily functioning. In simpler terms, it means that having longer sleeping duration does not necessarily indicate that sleep quality is good. Similarly, if a person has poor sleep quality, it does not imply that his sleep duration is short [5]. Someone can have short sleep duration with high sleep quality at the same time. In the studies carried out so far, sleep duration is defined as the sleep period from going to bed to waking up in the morning. We can also define it as "time in bed". As for the quality of sleep, the literature frequently cites criteria such as early onset, fewer interruptions, and fewer early awakenings. In other words, sleep quality is correlated with measures of sleep continuity but not with the content (stages) of sleep. As for the quality of sleep, the literature frequently cites criteria such as early onset, fewer interruptions, and fewer early awakenings. In other words, sleep quality is correlated with measures of sleep continuity but not with the content (stages) of sleep. [6] There have been identified a variety of sources that affect sleep quality that include psychological and environmental factors. Psychological factors, often referring to mental health problems, include Autism Spectrum Disorder (ASD), depression, anxiety, ADHD and panic attacks [7]. Life events such as work stress, relationship problems and financial worries can lead to negative thoughts and excessive anxiety, causing one to have difficulty falling asleep. Environmental factors include noise, unfamiliar environments, uncomfortable beds, and pillows, high or low temperatures, bright lights, and nursing at night [8].

The categories of comfort in terms of sleep quality related to the level of expectations the occupants may have been presented in Table 1. A higher level may be selected for occupants with special needs (children, elderly, handicapped, etc.). A lower level will not provide any health risk but may decrease comfort. An optimal level expectation is considered to be IEQIII, representative for an “medium” level of expectation, with heating season temperature with values between 20.0 - 24.0 °C and cooling season temperature with values between 23.0 – 26.0°C. Conform ISO 17772-1 and pr EN 16798-1 minimum total ventilation rate for health is 4 l/s person. This will work for establishing design values for dimensioning of heating and cooling systems by using the lower value in heating season for the heating system and the upper value in cooling season for the cooling system.

Table 1

Categories of optimal comfort in terms of sleep quality related to the level of occupant's expectations

Category	Level of expectation	Heating season (1.0 clo)°C	Cooling season (0.5 clo)°C	Low polluting building l/(s m2)	Minimum total ventilation rate for health l/s person
IEQI	High	21.0 - 23.0	23.5 - 25.5	1,0	4
IEQII	Medium	20.0 - 24.0	23.0 - 26.0	0,7	4
IEQIII	Moderate	19.0 - 25.0	22.0 - 27.0	0,4	4
IEQIV	Low	17.0 - 25.0	21.0 - 28.0	0,3	4

Natural home ventilation uses all the gaps and cracks in the home, along with windows and other passive openings, such as the spaces under doors or those between doors and frames, to allow air to move uncontrollably into the home. These are found in older houses, being most of the time sufficient to dilute the atmospheric pollutants in the rooms and maintain the environment suitable for sleeping. The main advantage of this type of ventilation is the low cost and the fact that they are already present in most homes right from the design stage. However, the disadvantages are many, starting with the fact that this ventilation is uncontrolled, and the ventilation is not uniform. When it comes to room temperature control the system can become particularly expensive. Moreover, the system is not enough to remove pollutants from the air. There is a significant difference between naturally ventilated bedroom and the case when the ventilation is not realized in the room. A comparation between these two cases are presented in the Table 2 below, to see the difference between these two options and which one is more reliable. The option in which a room is naturally ventilated shows a qualitative improvement of the air in the bedroom.

Table 2

A comparation between a naturally ventilated bedroom and without ventilation case

CO_2 level	Measured outside (ppm)	Measured inside	
Evening		Naturally ventilated (ppm)	Without ventilation (ppm)
	400	530	750
Morning	380	1230	1850

Mechanical ventilation uses equipment such as fans, air conditioners, hoods and ventilation systems installed throughout the building to move air around the home. Since a large part of new homes, designed on the principles of energy efficiency, are built airtight to ensure energy savings, the need arises to install mechanical ventilation systems. Mechanical ventilation systems ensure uniform ventilation of the entire home, while the air is purified by filters. Also, a very big advantage is that you can opt for integrated systems at the level of the entire house or for the ventilation of a single room. Moreover, mechanical equipment can be integrated into heating and cooling systems, such as air conditioning units. The main disadvantage of these equipment is their relatively large volume and significant energy consumption, being more expensive than natural ventilation. Another aspect that many people forget to take into account is the air conditioner, because over time a thick layer of dust and dirt is deposited on the internal components of the air conditioner, a very favorable environment for the development of bacteria, fungi and molds. With increasing living standards and expectations for better thermal comfort, more residential homes have air-conditioning systems installed in each bedroom. Primarily, the bedroom air conditioning is to maintain an appropriate thermal sleeping environment by providing a cooling sensation to the occupants. Room temperature that is too hot or too cold can also be disruptive to one's sleep [9].

Another objective of air-conditioning is to dilute the indoor air pollutants by introducing conditioned outdoor air into the room. If there is insufficient outdoor air to dilute the room, the concentration of indoor pollutants will be increased. Thus, enough fresh air intake is critical, but this could in turn affect the energy efficiency of the building. There are not many studies reported regarding the thermal comfort and IAQ issues in bedroom environments.

Sleep quality is closely related to outdoor air pollution, because together with natural ventilation, part of the pollutants is introduced into the bedrooms. Along with the penetration of outside air pollutants, air quality can be indicated by the number of certain pollutants in the air. Air pollution is a complex mixture of solid particles, liquid droplets, as well as gases. It can come from many sources for example: household fuel burning, industrial chimneys, traffic exhausts, power generation, open burning of waste, agricultural practices, desert dust and many other sources.

World Health Organization (WHO) guidelines values for indoor and outdoor air pollutants are presented in Table 3. A few adverse health effects have been associated with exposure to both PM2.5 and PM10. For PM2.5, short-term are associated with premature mortality, increased hospitalizations for cardiac or pulmonary causes, acute and chronic bronchitis, asthma attacks, emergency room visits, respiratory symptoms and restrictions, days of inactivity. Additionally, of all common air pollutants, PM2.5 is associated with the highest proportion of air pollution-related adverse health effects, both in the United States and worldwide, according to the World Health Organization. [10] Short-term exposure to PM10 has been primarily associated with worsening respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD), leading to hospitalization and emergency department visits. Long-term exposure (months to years) to PM2.5 has been linked to premature death, especially in people who have chronic heart or lung disease, and reduced lung function growth in children. The effects of long-term exposure to PM10 are less clear, although several studies suggest a link between long-term exposure to PM10 and respiratory mortality [11]. Research shows that older adults with chronic heart or lung disease, children and asthmatics are the groups most likely to experience adverse health effects from exposure to PM10 and PM2.5. Children and infants are also likely to be affected by inhaling pollutants such as particulate matter because they inhale more air per kilogram of body weight than adults – they breathe faster, spend more time outdoors and have smaller body sizes. In addition, children's immature immune systems may cause them to be more susceptible to PM than healthy adults [12], [13].

Table 3

WHO guidelines values for indoor and outdoor air pollutants

Pollutant	WHO Indoor Air Quality guidelines 2010	WHO Air Quality guidelines 2005
Carbon monoxide	No safe level can be determined	-
Formaldehyde	30 min. mean: 100 μg/m3	-
Naphthalene	Annual mean: 10 μg/m3	-
Nitrogen dioxide	1h mean: 200 μg/m3 Annual mean: 40 mg/m3	-
Polyaromatic Hydrocarbons (e.g. Benzo Pyrene A B[a]P)	No safe level can be determined	-
Radon	100 Bq/m3 (sometimes 300 mg/m3, country-specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 μg/m3	-
Sulfure dioxide	-	10 min. mean: 500 μg/m3 24h mean: 20 mg/m3
Ozone	-	8h mean:100 μg/m3
Particulate Matter PM 2.5	-	24h mean: 25 μg/m3 Annual mean: 10 μg/m3
Particulate Matter PM 10	-	24h mean: 50 μg/m3 Annual mean: 20 μg/m3

Conclusions

The characteristics of thermal comfort and indoor air quality (IAQ) in bedrooms, occupants' perceptions and their impact on sleep quality are not often studied.

Understanding sleep quality and our physical sleep environment is an important aspect that could help to better inform designers and housebuilders.

To improve the quality of sleep increases people's productivity during the day. Societies should be designing and building homes that provide an adequate (comfortable) interior bedroom environment that can be adjusted by the sleeper to suit individual preferences and temperature events.

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[13] EEA, NMVOC: non-methane volatile organic compounds; NOX: nitrogen oxides; PM2.5: particles with a diameter smaller than 2,5 microns; PM10: particles with a diameter smaller than 10 microns; SO2: sulphur dioxide, 2022.

Challenges in peer review, a lesson for improving technical government regulations in the hydrotechnical field

Provocări în evaluarea inter pares, o lecție pentru îmbunătățirea reglementărilor tehnice guvernamentale în domeniul hidrotehnic

Cristian ANGHEL[1], Daniel CORNEA[2], Stefan Ciprian STANCA[3], Cornel ILINCA[4]

[1,2,3,4]Technical University of Civil Engineering Bucharest
Lacul Tei Boulevard Nr. 124, Bucharest 020396, Romania
[1]*E-mail:* cristian.anghel@utcb.ro
[2]*E-mail:* daniel.cornea@utcb.ro
[3]*E-mail:* stefan-ciprian.stanca@phd.utcb.ro
[4]*E-mail:* cornel.ilinca@utcb.ro

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Abstract. *Since hydrotechnical is a broad topic, the peer review process is extremely important in maintaining the quality and validity of technical government regulations.*
Peer review is necessary to improve government technical regulations in the hydrotechnical field, as it is observed from ISI articles on some of these regulations which are characterized by eclecticism.
A primary challenge in peer review is finding specialists who are capable of reviewing technical documents. This challenge is also relevant regarding government regulations. Solutions to this challenge include maintaining a database of academic specialists, incentives to participate, and encouraging collaboration between agencies and academic institutions.
Disclosure of the reviewers' identities and the provision of guidelines for the review process of technical regulations should be a priority of the relevant authorities, as it would promote transparency.
Regulations should be designed as adaptable and responsive to changes and new information in ored to address the dynamic nature of hydrotechnical issues.

Key words: *Peer review; Hydrotechnical regulations; Government normatives; Transparency in regulations; Adaptability in regulations; Regulatory quality; Academic specialists; Ecological flow*

1. Introduction

Government regulation is crucial for operation of society as it safeguards the equity, integrity and efficacy of different domains, including hydrotechnics.

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Subjecting the technical regulations to a critical evaluation by people who possess vast knowledge and experience in the relevant field can be done according to the Peer-review model of articles in internationally indexed scientific journals. [1]

Peer review is an important phase in the scholarly publication process since it makes sure that research publications are of a high enough quality and novelty before they are published. It assists in weeding out subpar research, guarantees precision, and upholds the integrity of scientific publications.[2]

The academic and scientific publishing process includes several forms of peer review. The selection of peer-review methodology is frequently contingent upon the specific academic discipline, the characteristics of the research being conducted, and the editorial inclinations of the scholarly publication or conference in question. The broad nature of academic research is also a characteristic of legislation, the many types of peer-reviews being relevant also for the creation and selection of government normatives. [3]

2. Peer review process

In the following paragraphs some of the most adopted peer review methods are described.

In a single-blind review process, the reviewers possess knowledge regarding the identities of the authors, while the authors remain unaware of the identities of the reviewers. Maintaining impartiality is a widely adopted approach that enables reviewers to evaluate the work in consideration of the authors' background. [4]

The double-blind review entails that both the reviewers and the authors identities remain anonymous. This method of peer review is more stringent and its objective is to eliminate potential biases.

In the context of an open review process, it is acknowledged that both the reviewers and the writers possess knowledge of each other's identities. The purpose of this transparent procedure is to foster accountability and transparency. There are multiple approaches to accomplish this, one of which involves the inclusion of reviewer comments alongside the text during the publication process.

Post-publication review entails that the article is published before the peer review process, as comments and feedback from fellow researchers and readers come after the publication and the article undergoes revisions while being already published.

Collaborative review entails the collective participation of multiple reviewers in the assessment of an article. This methodology has the potential to offer a more extensive and varied evaluation of the task at hand.

Rapid review is a streamlined variant of the peer review process that aims to speed up the publication timeline. Frequently, a more concentrated evaluation of the fundamental components of the text is undertaken in order to expedite the duration between manuscript submission and publishing. [5]

Certain academic journals employ an internal evaluation procedure whereby editors or members of the editorial board evaluate the manuscript prior to its submission for external peer review. The internal review process serves to identify and exclude submissions that may not adhere to the established standards of the publication. [6]

In the pre-publication review process, authors distribute their manuscripts to a group of academics in the respective subject prior to formally submitting them to a journal. This informal evaluation assists authors in refining their work prior to the official submission.

3. Peer review application for government regulations

Rigorous evaluation of scholarly research is at the base of peer review, and can provide significant benefits in the development of governmental normatives.

Peer review would entail subjecting proposed regulations to critical evaluation by individuals possessing extensive knowledge and experience in the pertinent domain. These individuals possess the ability to detect potential flaws, gaps, or unintended repercussions that may not be readily discernible to policymakers who do not possess the same level of specialised knowledge. By utilising the knowledge and expertise of academics and researchers, laws can be formulated with enhanced clarity and efficacy.

Peer reviewers are commonly characterised by their impartiality and objectivity since they concentrate exclusively on assessing the strengths and weaknesses of proposed rules. The impartiality exhibited in this context serves to mitigate the impact of political factors, so guaranteeing that regulations are formulated based on their inherent value rather than being influenced by partisan objectives. This factor enhances the credibility and impartiality of regulatory determinations. [7, 8]

Peer review serves as a tool to ensure the quality of government rules. The implementation of thorough examination conducted by impartial professionals can effectively detect inaccuracies or vulnerabilities in suggested legislation, hence diminishing the probability of incurring expensive errors or unforeseen repercussions. This facilitates the overall efficacy of regulations and their capacity to accomplish their intended objectives.

Academics can greatly contribute the field of government regulations by being involved in the review process. Their inclusion facilitates cooperation and recognition of wider viewpoints and considerations into the formulation of government rules.

The inclusion of the peer-review process in the creation of government regulations enhances transparency and fosters public trust. The act of being transparent and implicating academics in regulatory proposals fosters public trust as it demonstrates a willingness to undergo external evaluation, hence enhancing confidence in the regulatory process.

4. Case study

The case study refers to the methodology for determining ecological flows HG 148/2020.

Until 2020, environmental flow in Romania was assigned a constant value throughout the year, which led to ecological responses such as local extinction for the native species [10,11,12,13]. At the moment, ecological flows are implemented by HG 148/2020 [14].

According to Wei's research [15,16], ecological flow calculation falls into four categories, with the primary approaches shown in table no. 1

Table 1

Ecological flow calculation methods

Categories	Methods	Advantages	Disadvantages
Hydrology methods	Tennant method; Texas method; Flow Duration Curve (FDC) method; Range of Variability (RVA) method; Monthly frequency calculation method.	The methods are simple and convenient and do not require on-site monitoring.	The accuracy of the methods is low, due to single factor.
Hydraulic methods	Wetted perimeter method; The region 2 cross(R2-CROSS) method.	The methods take account of the hydraulic factors.	The methods do not reflect seasonality and needs many rivers topographic data.
Habitat simulation methods	Instream Flow Incremental Methodology (IFIM); Computer-Aided Simulation Model for Instream Flow (CASIMIR); Physical Habitat Simulation Model (PHABSIM).	The theoretical basis is sufficient and meets the requirements of representative species.	The methods consider limited river biological species and find it difficult to reflect the overall situation of river ecosystem.
Holistic methods	Building Block Methodology (BBM); Downstream Response to Imposed Flow Transformations (DRIFT); Scientific Panel Assessment Method (SPAM); Ecological Limits of Hydrologic Alteration (ELOHA).	The methods consider economy, society, ecology, and environment.	The methods require a large amount of data support, with complex calculation.

HG 148/2020 was announced through the publication of an article by the creators of the governmental methodology.

A manuscript prior to the normative HG 148/2020, with authors from INHGA, the institution that developed the normative specifies the following:

1. The discharges are to be calculated using natural or naturalized/estimated flows for a 30-year period (recent records), in order to account for dry, wet, and normal hydrologic years as well as the effects of climate change [17]. According to the World Meteorological Organization's (WMO) a 30-year series is in accordance with hydrological practice recommendations. WMO specifies the reference periods, namely 1931-1960, 1961-1990, 1991-2020;
2. The dynamic component of ecological flow related to hydrological forecasting is considered an original contribution of the article [17];
3. According to a presumption made in relation to the ecological flow calculation, the natural flow supports the habitat needs of the dominant fish species (for each river typology) that have persisted over time (existed prior to 1964, i.e. were mentioned in The Treaty on the Fauna of Romania, Volume 13—Fishes, published by the academician Dr. Petre Mihai Bănărescu), and still exist in light of the findings from the monitoring campaigns run by the National Administration Authority "Romanian Waters" [17];
4. The paper mentions that it takes into account hydrological regimes, which are identified as high, medium and deficient water regimes [17].

It should be specified that the regulation contains all the principles stated in the article, but later some are refuted by the studies carried out by the INHGA and by the response to the addresses of the beneficiaries of the hydrological studies for the ecological flow, thus:

1. The ecological flows provided in the year 2022 to some owners of hydropower works were for the period 1986-2015 and not 1991-2020. The explanations of the author of the study were by quoting by truncation of the normative HG14/2020. It is interesting that after the exchange of these addresses, the hydrological studies for ecological flows for the period 1991-2020 were developed;
2. The dynamic component of the ecological flow is actually a quasi-static one, disregarding the hydrological regime. Thus, longitudinal connectivity is not ensured in the period of low water, for all water intake works, and in the period of high water, longitudinal connectivity is not ensured for reservoirs with annual and multi-annual regularization [18];
3. It does not take into consideration the updated studies requested by ANAR regarding the ichthyofauna, using an old literature from 1964 that studied a few reference rivers and designed the habitats for all of Romania. In the 1964 treaty, it is specified that preferences are actually presented in relation to biotope and zoogeography conditions [19], which cannot replace the current studies and those before the realization of hydrotechnical arrangements. INHGA and ANAR, through an action worthy of a conjurer, misrepresent the scientific reality.

4. The hydrological regime is not given by the average monthly flows according to the statements of the INHGA authors [17], it is given by the average daily flows and the idea of "imitating" a natural hydrograph is completely far from the truth if we analyze a simulation of the application of the ecological flow on river Uz [18].

The ecological state of water bodies, particularly hydromorphological indicators, is seriously threatened by HG 148/2020. The primary criticism, especially for rivers in natural protection areas, is the reduction in flows for unusually extended periods of time, at least eight months each year.

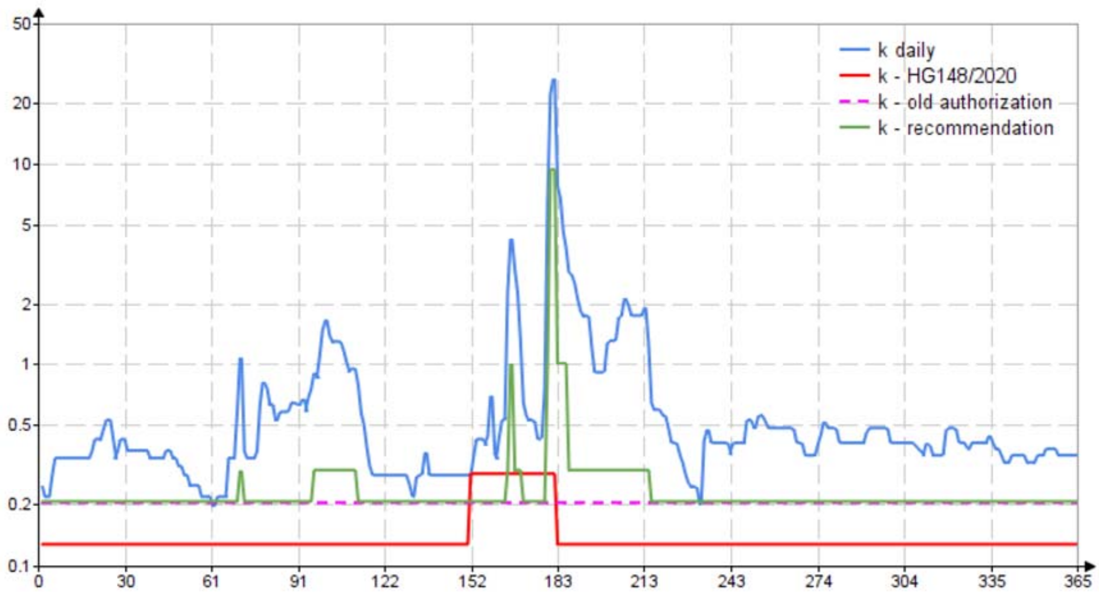

Fig. 1. The values for the ecological flows as a result of the approaches used at the Uz site are shown in a time series for the module of average daily flows.[18]

In addition to these misinterpretations of a "so-called ecological" debit standard, the following wrong practices of INHGA and ANAR overlap:

- Hydrological studies are issued without respecting the right to water on the legal and European principle of first come first served, thus hydrological studies, notices and water authorizations that limit the right to water to some existing uses are issued, such as a few well-known cases: Runcu, Galbenu, Suceava;
- The ecological flow rate is not applied correctly, there are cases in which tables with lower values are taken from the INHGA studies in the authorization, or reference is made strictly to the study without presenting the table with the ecological flow rates, thus the valley of a river is practically dry (the case of Baia de Fier, Gorj county);
- Issuance of wrong rights on water uses by ANAR, which are included in INHGA hydrological studies, which become mandatory;

- Conducting wrong studies on flow rates through similarities with other river basins without considering the global balance of a receiving basin.

These aspects presented above would have been avoided if the technical regulation was carried out with the official participation of technical universities in Romania.

5. Conclusion

In conclusion, it is essential to include academics into the review process of government regulations. By including them as peer reviewers, the regulatory system would be stronger, more efficient and more flexible.

Peer review, at its essence, functions as a means of assessing the credibility of experts, introducing a rigorous evaluation process that guarantees rules are firmly grounded in robust scientific, technological, and professional knowledge. The participation of academics with experience and knowledge in a particular issue can serve as a safeguard against the unintentional dissemination of incorrect information or defective logic, promoting regulations that are both precise and up-to-date with the current developments. [9]

As shown by the case studies, sometimes government regulation can be wrongfully interpreted and can lead to confusion.[18] The peer review process, which can prevent instances such as those shown in the case study, encompasses more than just verifying factual accuracy. The system functions as a diligent protector against mistakes, discrepancies, or uncertainties that have the potential to undermine the comprehensibility and enforceability of regulations. By engaging in thorough scrutiny, academics can make valuable contributions to the development of technical regulations. This, in turn, can promote a climate of adherence to these regulations.

The establishment of transparency and accountability through peer review is crucial for fostering public confidence, which is a fundamental element of an effective government. The public's trust can be fostered by the fact that regulations are subject to examination by impartial academics. The establishment of trust plays a crucial role in creating a strong foundation for the regulatory system, as it leads the public to view rules as the result of well-informed decision-making rather than arbitrary impositions. [20]

Furthermore, the process of peer review will promote the development of adaptation and flexibility within regulatory frameworks. By establishing a consistent feedback loop, it can facilitate the recognition of developing obstacles and the integration of fresh data. The iterative nature of this method will guarantee the ongoing relevance and adaptability of regulations in the face of evolving circumstances, including technical breakthroughs, societal changes, and emerging hazards. Within this dynamic interplay, rules that undergo peer review would transform into living documents that adapt to address the demands of a swiftly evolving global landscape.

The peer review method can enhance the legal defensibility of rules. The endorsement of university examination would confer an additional level of legitimacy that can prove pivotal in instances where regulations encounter legal disputes. The comprehensive evaluation conducted by colleagues acts as evidence of the meticulousness and procedural fairness that underlies the regulatory decision-making process, enhancing the legal credibility of the regulatory system. [21]

Efficiency and effectiveness, which are considered fundamental elements of sound governance, would be enhanced through the proactive function of peer review. Through the implementation of rigorous examination, peer review could serve as a mechanism to minimise regulatory overreach, so ensuring that regulations remain proportionate to their intended objectives. The adoption of this well-balanced approach would effectively reduce the potential negative impact on innovation and economic development, while simultaneously ensuring the protection of public welfare.

Fairness, informed decision-making, and adaptability in the field of hydrotechnics would be some of the benefits that the inclusion of academics as peer reviwers in the regulatory process would bring. This fact would undeniably create a more transparent, inclusive and fair regulatory process.

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A comparative evaluation of floor heating systems performance

O evaluare comparativă a performanței sistemelor de încălzire prin pardoseală

Alexandru DORCA[1], Adriana TOKAR[1], Marius ADAM[1], Dănuț TOKAR[1], Daniel MUNTEAN[1]

[1] Universitatea Politehnica Timișoara
Victoriei Square, no. 2, Timisoara,, România
E-mail: alexandru.dorca@upt.ro, adriana.tokar@upt.ro, marius.adam@upt.ro, danut.tokar@upt.ro, daniel-beniamin.muntean@upt.ro

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Abstract. *Underfloor heating systems ensure maximum comfort through optimal vertical temperature distribution, and the possibility of exact control and programming of the indoor climate. Used as a total heating source, the underfloor heating system will provide all the heat requirements of the space to be heated, provided that the external walls are properly insulated. In the study, two underfloor heating systems were analyzed using the dynamic simulation feature of the HTflux software. Following these simulations, temperature differences will be observed in front of the floor finish depending on the type of system used. The wet screed system heats up significantly faster and reaches a higher temperature by approximately 4.5% compared to the dry screed system.*

Key words: heating floor, wet and dry system, thermal inertia, temperature distribution

1. Introduction

Underfloor heating is a modern option for ensuring thermal comfort in homes, but also in other spaces, such as offices or various buildings. Even if the alternative is modern, thanks to existing new technologies, the underfloor heating procedure has been used since the time of the Romans. Briefly, rooms with tiled or mosaic floors were heated by a fire that was built in a space below. This system in ancient Rome was called hypocaust (Fig. 1), which was based on floor heating and worked by circulating hot air under a double floor and through double walls [1]. The gases were thus directed through channels in several rooms. The hypocaust was one of the first central heating systems on the floor.

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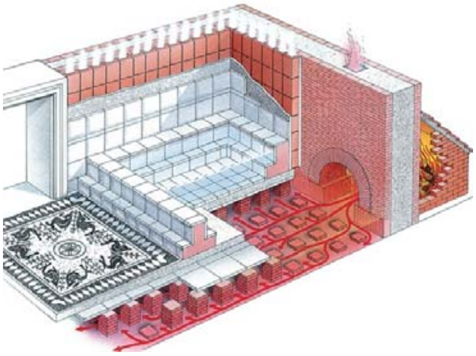

Fig. 1. Warm air circulation using the hypocaust floor heating system [1]

With the reconstruction of Europe that took place after the Second World War, there was an effective development of underfloor heating systems, using a technique of embedding ½" steel pipes without layers of thermal insulation under them. This is how underfloor heating systems were developed, and this led both to the discovery of the advantages of these types of heating systems, as well as to the discovery of the disadvantages caused by the lack of advanced research into the effects of the incorrect use of these heating systems on humans.

Compared to the heating system with radiators mounted on the walls, the floor heating system with hot water is more advantageous. When using an underfloor heating system, the heat is released evenly at the ground level and thus ensures an increase in thermal comfort.

From a practical point of view, the intermittent operation of underfloor heating systems is challenging due to the heating times resulting from the heat capacity of the floor. Therefore, two underfloor heating systems were analyzed in a comparative simulation study.

2. Description of underfloor heating systems

Underfloor heating systems are a prerequisite for the comfort of your own home for a pleasant and enjoyable life. In recent years, underfloor heating systems have started to be used on a large scale in Romania as well.

Studying the underfloor heating system, we will come across 2 variants of it, namely: the wet system and the dry stem, analyzing which is the most efficient.

2.1. Underfloor heating using the wet system

2.1.1. Castellated panel

A castellated panel is formed in the lower part of expanded polystyrene and in the upper part of thermoformed covering film, in which pipe fixing knots are incorporated (Fig.2). The insulation is made of sintered polystyrene, molded to a high density, and then hot-jointed with the help of a special rigid polystyrene film.[2] This process gives the panel greater mechanical resistance and creates a vapor barrier on the surface.

The perimeter strip is placed around the area to be heated, providing a barrier against perimeter heat loss and for screed expansion.

The panels are placed over the concrete slab and interlock to form a continuous layer. Tiles are especially useful where there is a limitation of floor height.[3] The PE-Xa pipe will be clamped between nuts, which fix it and hold it in place, at a suitable mounting step.

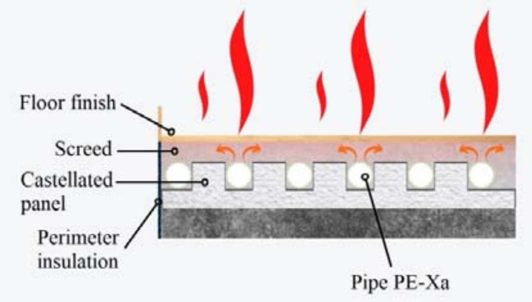

Fig. 2. Floor heating system with castellated panel [2]

2.1.2. Tacker plate

The tacker system shown in Fig. 3 is widely used due to the versatility of installation. Insulation panels are generally supplied from EPS expanded polystyrene, providing additional strength. The panels have a heat-shrinkable foil of high productivity and resistance with excellent tolerance to varied operating conditions.[3] The foil provides a grid reference for proper pipe spacing and fixing and is also waterproof.

The perimeter strip is placed around the area to be heated, providing a barrier against perimeter heat loss and for screed expansion.

Insulating Tacker boards are placed over the entire surface of the floor. The PE-Xa pipes are then laid in the circuits and secured with specially designed Tacker pins, installed with a special gun. These pins are completely fixed in the insulating material, thus preventing the pipe from lifting during the pouring of the screed.

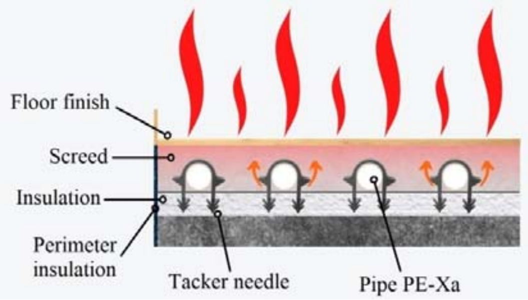

Fig. 3. Underfloor heating system with Tacker plate [3]

2.2. Underfloor heating using the dry system

The dry underfloor heating system is a flexible solution characterized by low construction height and low weight. The system is suitable both for new construction and for the modernization of old buildings. It is quick and easy to assemble and can be started immediately after assembly.

Figure 4 shows the four component elements of the system: polystyrene mounting plate, heat diffusion plates, pipe, and polyethylene film. 12.5 mm fiber-reinforced gypsum boards must be placed over the system. [4] They can be mounted individually or overlapped in two layers. The heat diffusion plate is easy to cut and has preformed channels in which the aluminum heat diffusion plates are placed, and then the pipe is placed.

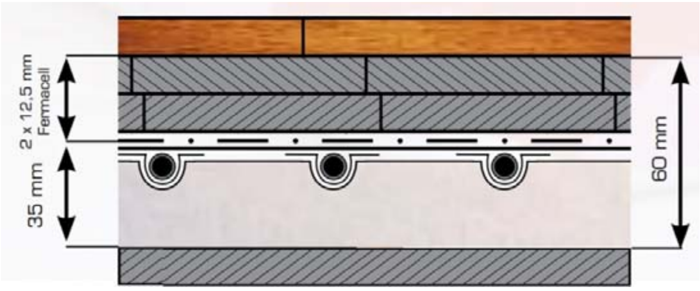

Fig. 4. Dry floor heating system [4]

3. Comparison of underfloor heating systems

In the study presented below, two underfloor heating systems are simulated using the dynamic simulation feature of HTflux.[5] Based on these transient simulations we will observe the temperature differences in front of the floor finish. This temperature distribution always depends on the entire configuration of the heating system, the construction of the floor, and the ambient conditions.

The first configuration represented in Fig. 5 a) is a dry floor heating system, consisting of heat-insulating boards inside which the PE-Xa 16x2 mm heating pipes are placed, and a 25 mm thick dry screed will be poured over them.

The second configuration represented in Fig. 5 b) is a common detail, used for wet systems, where PE-Xa 16x2 mm pipes are directly integrated into a 50 mm thick wet screed. The pipes will be placed on a 30 mm thick EPS insulation board.

Both constructions have a parquet layer on top of 3 mm.

The behavior of a heating system depends not only on the construction of the underfloor heating, but also on the heating device, the length of the pipes, but also on many other factors.[6] In this study, we assumed a constant room temperature of 22ºC and a heating agent temperature on a tour of 40ºC. It was assumed that the heating system was off, which means that the water temperature inside the pipes was close to the indoor temperature. From this initial state, we will start the heating with the so-called step function, suddenly setting the temperature of the heating medium to a level of 40 °C at a certain time.

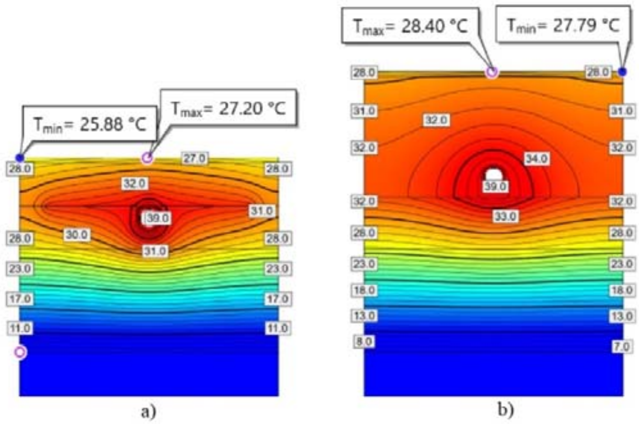

Fig. 5. Temperature distribution depending on the type of underfloor heating system
a) Dry system; b) Wet system

As can be seen, the wet screed construction heats up significantly faster and reaches a temperature in front of the floor finish of approximately 28.40 ºC, thus being 4.5% higher than the dry screed construction.

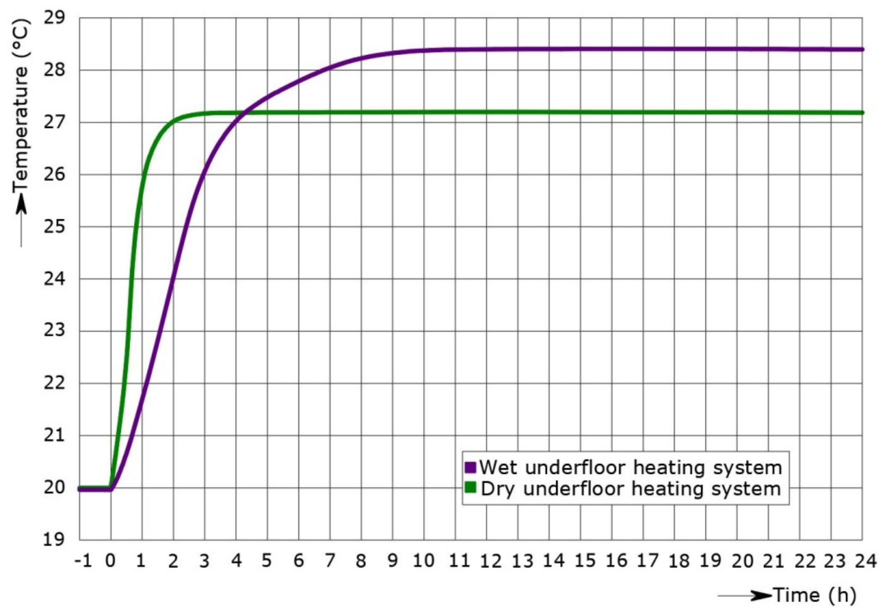

Fig. 6. The maximum temperature on the floor surface during the heating period

In Fig. 6 it can be seen that the dry screed system heats up significantly faster, needing 2 hours to stabilize the temperature, compared to the wet screed system which needs a longer time, of approximately 8 hours to stabilize. The heating times depend to a large extent on the installation heights and the structures of the underfloor heating systems.

It can be seen that the wet system becomes much more efficient over time due to the high temperature on the surface of the finished floor.

4. Conclusions

The dry underfloor heating system has a lower temperature compared to the finished floor, due to the fact that the pipe is integrated into the thermal insulation panels that do not allow the thermal load to be distributed over the entire circumference of the pipe.

The wet underfloor heating system with the Tacker plate becomes the most efficient, due to the greater contact surface between the screed and the pipe, respectively the heat transfer efficiency. In the system with the plate with nuts, the embedment of the pipe in the screed is weaker, due to the nuts that isolate part of the pipe.

Obviously, the dry system has little inertia and is suitable for buildings where people are passing by and spend little time. The wet one is slower, but it is preferable to use it anywhere with a known schedule: residential buildings, halls, schools, etc.

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Energy key performance indicators for research infrastructures equipped with optimized HVAC system

Indicatori cheie de performanță energetică pentru infrastructurile de cercetare echipate cu sistem HVAC optimizat

Răzvan –Silviu ȘTEFAN[1], Radu-Mircea DAMIAN[1], Delia TINCA

[1]Technical University of Civil Engineering of Bucharest, Romania
Lacul Tei Blvd, No 124

Email: razvan.stefan@eli-np.ro, radu.damian@utcb.ro

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ABSTRACT: In the context of the effort to find the right key performance indicator that allows comparing the energy efficiency of the ELI-NP research infrastructure equipped with a unique HVAC geothermal system with other similar infrastructures, the paper presents key performance indicators used to evaluate the energy efficiency of buildings. The end goal is to optimize and make the infrastructure energy efficient while maintaining the operating parameters imposed by the research activity.

Key words: energy key, HVAC System

CONTEXT

Building energy efficiency, together with energy supply security and the fight against energy poverty, are top priorities in the EU's energy and climate change policy.

One of the key principles of the EU's energy policy, according to the European Strategy for the Energy Union, <u>is to increase energy efficiency, decrease reliance on energy imports, cut emissions, and promote economic growth and job creation.</u>

Strategies for cutting energy consumption, utilizing renewable resources extensively, and lowering CO_2 emissions have been and are being developed by stakeholders in the context of the present focus on the efficient use of energy resources. Therefore, evaluating buildings is very important in order to set reference values for energy consumption for different building categories and activities and to categorize them into energy efficiency classes.

There are regional variations in the way that different countries address the energy performance of buildings and other energy-related issues.

The ELI-NP research infrastructure viewed in terms of:

- the complexity of its built environment
- the activity carried out within it - cutting-edge research

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- the HVAC geothermal system with heat pumps units with which it is equipped - the largest in Europe

offers opportunities for studying the behavior of research infrastructures from the point of view of energy consumption, to identifying ways of energy efficiency and equally for studying the optimal control and energy efficiency of shallow geothermal HVAC systems.

Considerations on the energy efficiency of research infrastructures in the context of the high share of energy consumption of HVAC systems in the total consumption

Whereas assessment of the performance of residential buildings or regular buildings is considered in terms of ensuring the comfort of the users at low rates of energy consumption, the environmental parameters are of significant importance for the processes carried out in buildings with specific uses (hospitals, industrial buildings, research laboratories).

Most of the time, a high stability of the parameters is required. At the same time, ensuring the parameters requires high energy consumption.

The share of consumption of HVAC systems in the total energy consumption of these buildings is very high, reaching 70% of the total.

Consequently, HVAC systems represent a significant component in the economics of building energy efficiency measures. It's time-consuming and resource-consuming to optimize their operation when operating manually, and difficult to accomplish. Automatic operating and control systems provide conditions for optimization.

The energy consumption of applied research laboratories, especially those that include clean rooms, is very high. Their reduction is possible through optimization, and a substantial reduction in consumption is possible through the use of renewable energy.

For example, laboratories / research infrastructures typically consume 5 to 10 times more energy per square meter than office buildings.

The use of a research infrastructure is different from the use of a conventional non-residential building. The large equipment, the large built area of the cleanrooms, the need to keep the very high stability of the operating parameters, imply a very high energy consumption for heating, ventilation and air conditioning. Some specialized laboratories, like clean rooms or laboratories with significant technological consumption, can use up to 100 times the energy of an institution or commercial structure of the same size.

Due to the fact that activity carried out inside research laboratories requires high stability of the environmental parameters constraints of the HVAC systems operation must be taken into account. Listed below are some of the requirements and conditions that impose constraints on operation:

- requirements for high relative humidity and temperature stability in most laboratories
- relatively low temperatures in clean rooms
- requirements for high air change rates
- multiple operating conditions
- pressurization requirements

- limited options to use energy recovery strategies to avoid cross-contamination
- the difficulty of anticipating equipment thermal loads and evacuation requirements
- high energy consumption of the process and research equipment.

Key Performance Indicators for evaluating the energy performance of buildings

Most frequently, indicators of the "specific energy consumption" type are used to evaluate the energy performance of buildings, in the case of buildings, they are expressed by relating energy consumption to the area of the building's surface.

Akville et al. extensively discussed the topic in [1] and provided their conclusions on the definition and differential treatment of this indicator. The authors state that despite the frequent use of the Specific Energy Consumption (SEC) indicator when benchmarking with the aim of improving energy efficiency, clear and detailed descriptions of the assumptions on which the SEC calculation is based seem to be missing from both scientific literature as well as international standards.

The authors concluded that the calculation of SEC is based on assumptions that are rarely presented or highlighted after analyzing scientific publications and standards that address and use SEC. Therefore, a significant improvement is needed in terms of the reliability and comparability of SEC, which is impacted by several factors.

In order to critically analyze SEC in relation to industrial energy efficiency, Akville et al. formulate the following conclusions:

- SEC is of greater use if a longitudinal benchmarking (i.e. same company, same sector or same country, over time) is undertaken.
- In order to benchmark correctly, special attention is recommended when using SEC for comparative assessment between companies, sectors or countries,
- The use of SEC for comparisons is optimal in the case of a unitary calculation of it.
- As there is a gap in both research and international standards regarding the use of SEC, a plan for the future use of SEC, accompanied by monitoring activities, would be needed.
- The SEC calculation can be significantly influenced by the conversion factor from primary energy to final energy.
- SEC is a more optimal KPI within the same study when the underlying assumptions are the same.
- The authors also suggest that the abbreviation SEC would be more correct for specific exergy consumption than specific energy consumption. Alternatively, the term specific energy use could be used.
- Before using SEC from other studies, it is recommended to study the assumptions behind the calculations. SEC is a convenient indicator with potential for use in various valuation applications, provided that the assumptions used to make the calculations are appropriate.

Specifically, it is recommended to consider the following aspects:

The origin, availability and quality of the information and data that were used to calculate the SEC

- Accuracy of system boundaries, for example, energy used by main equipment, auxiliary equipment used in production and/or parts thereof
- Conversion factors from primary energy to non-primary energy
- Energy calculation mode
- Other factors such as equipment specifications (i.e. age).

Romanian legislation ("Methodology for calculating the energy performance of buildings, Mc001-2022) that implements European directives, also provides for the use of a "specific consumption" type indicator. Energy classes are defined by utility and by building category, a disadvantage of the methodology being that it does not cover important categories of energy-consuming buildings. For example, the methodology does not treat industrial buildings.

In the United States of America, energy efficiency is a central theme both within the Department of Energy/US Department of Energy (US DoE) and within the Environmental Protection Agency/US Environmental Protection Agency (US EPA). Thus, EPA administers the Energy Star platform, launched in 1992, which together with EPA, provides energy efficiency solutions that deliver cost-saving energy efficiency solutions that protect the climate, improve air quality and protect public health.

Portfolio Manager is an interactive management tool that enables the assessment of the energy consumption of any type of building, all in a secure online environment. Nearly 25% of the US commercial building space is already actively benchmarking in Portfolio Manager, making it the industry's leading benchmarking tool, comparing the energy performance of buildings to similar buildings. [2] The indicator with which buildings are compared in Portfolio Manager is Energy Use Intensity / the intensity of energy consumption / the intensity of energy use or EUI. Essentially, EUI expresses the energy consumption of a building according to its size or other characteristics [3, 4].

For property types in Portfolio Manager, "Energy Use Intensity" - EUI (Energy Use Intensity) is expressed as energy per square meter per year.

It is calculated by dividing the total energy consumed by the building in a year (measured in kBtu or GJ) by the building's total gross floor area (measured in square feet or square meters).

Source Energy represents the total amount of energy / raw fuel that is required to operate the building and includes all transmission, delivery and production losses. Considering the entire amount of energy used provides a complete assessment of the energy efficiency of an assessed building/object.

Site Energy is the annual amount of energy (for heating, lighting, etc.) consumed by a building, as reflected in utility bills.

Energy at the point of consumption can be delivered to a building in one of two forms: primary energy or secondary energy.

Primary energy represents the amount of raw fuel used to obtain heat and electricity (e.g. natural gas or fuel oil used to produce energy at the point of consumption).

Secondary energy is the energy product (heat or electricity) created from a raw fuel, such as electricity purchased from the grid or heat received from a centralized (district) system.

A unit of primary energy and a unit of secondary energy consumed on site are not directly comparable because one represents raw fuel while the other represents transformed fuel.

Therefore, in order to assess the relative efficiency of buildings consuming primary and secondary energy in various proportions, it is necessary to transform these two types of energy into equivalent units of raw fuel consumed to generate a single unit measure of energy consumed at the point of consumption.

Thus, any form of primary or secondary energy consumed at the point of consumption (on site / at the location) is calculated unitarily, because the calculation of energy at the source takes into account the losses incurred in its production, transport and delivery to the building.

To achieve this equivalence, the EPA uses the quantity "source energy".

Portfolio Manager presents/recommends national median source EUI reference values for building types. The median is more appropriate for analysis than the mean (arithmetic mean) for comparing relative energy performance, as it more accurately reflects the middle values of energy consumption for most property types. This data is centralized and published on the platform, the database being continuously updated according to the results of The Commercial Buildings Energy Consumption Survey (CBECS), which is referenced in the Portfolio Manager. This is a national study, conducted by the U.S.

Energy Information Administration (EIA) and collected the information on the building stock in the United States. The U.S. The Energy Information Administration (EIA) is an agency of the U.S. Federal Statistical System that collects, analyzes, and disseminates energy information.

The CBECS study analyzed 11,000 research laboratories totaling
711,000,000 ft2 (approximately 66,000,000 m2).

Energy efficiency of the ELI-NP research infrastructure. EUI assessment

A large HVAC system uses unconventional geothermal energy to provide cooling or heating for the ELI-NP research infrastructure.

The thermal source is a low-enthalpy source that is captured through drilled wells, and then capitalized by heat pumps units. The geothermal system at ELI-NP is installed on a plot with a total area of approximately 27,000 m^2, has a length of 135,000 m and fully provides the energy required for heating and cooling the infrastructure, having an installed capacity of 6.2 MW (4.2 MW heating and 6 MW cooling).

The ELI-NP geothermal HVAC system serves a built-up area of approximately 33,000 m^2.

The energy efficiency of the HVAC system installed at ELI-NP has been monitored, at different degrees of occupancy, after the installation of the research equipment, starting with the testing period and then during the period of conducting the experiments.

The geothermal HVAC system with heat pumps units maintained the stability of the required parameters (temperature and relative humidity). At the same time, the ISO 7 cleanliness class (according to standard 14644) of the clean room in the building housing the high-power laser and the other laboratories was preserved.

The lack of data for similar infrastructures makes it difficult to evaluate ELI-NP. Health infrastructures, more commonly assessed and classified, are somewhat similar in terms of the need for HVAC, but in the case of ELI-NP the rooms housing the research equipment are single-volume rooms with large areas and heights. Moreover, there are areas where the basement of buildings communicates directly with the ground floor. Also an area 8,200 m^2 of research laboratories with high lighting level requirement has no natural lighting. In addition, research buildings have continuous operation, at least in terms of heating/cooling ventilation and air conditioning, the environmental parameters stability in these buildings being mandatory.

Benchmarking the ELI-NP research infrastructure would be relevant if comparisons with similar infrastructures ("peer group of facilities") were possible.

The monthly site electricity consumption of the infrastructure is around 500,000 kWh (technological consumption is included). Figure 1 shows the total electricity consumption of the infrastructure for the year 2022, and the figure 2 shows the data from the year 2022 for the research buildings.

The data source for the total plant consumption is the monthly reading of the electricity supplier. The recorded monthly consumption is relatively constant throughout the year, in winter and summer months being approximately 12% higher than the average consumption, "in money."

Also, the electricity consumption is known for all important consumers in the research infrastructure, individually for buildings and systems, and can be read in real time from the network analyzers installed on the electrical switchboards.

As expected, building heating, cooling and air-conditioning use accounts for the largest proportion of building use, around two-thirds of total energy use.

In 2021 and 2022, three of the five infrastructure buildings were 100% occupied, and the Laser and Laboratory research building had 100% occupancy in 2022.

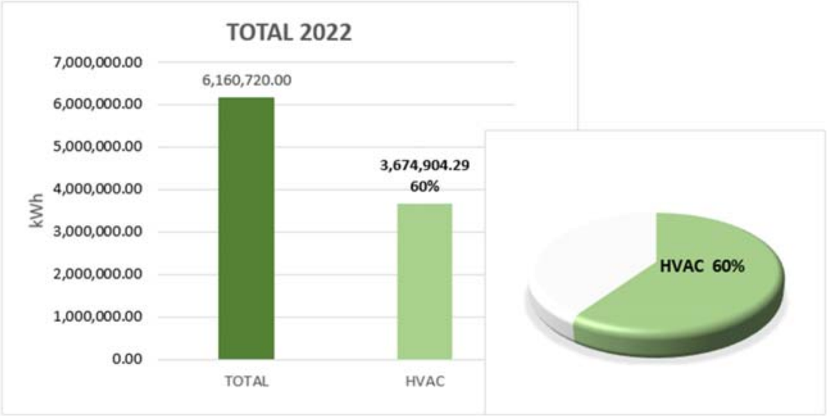

Figure 1 Energy consumption – ELI-NP Research Infrastructure 2022

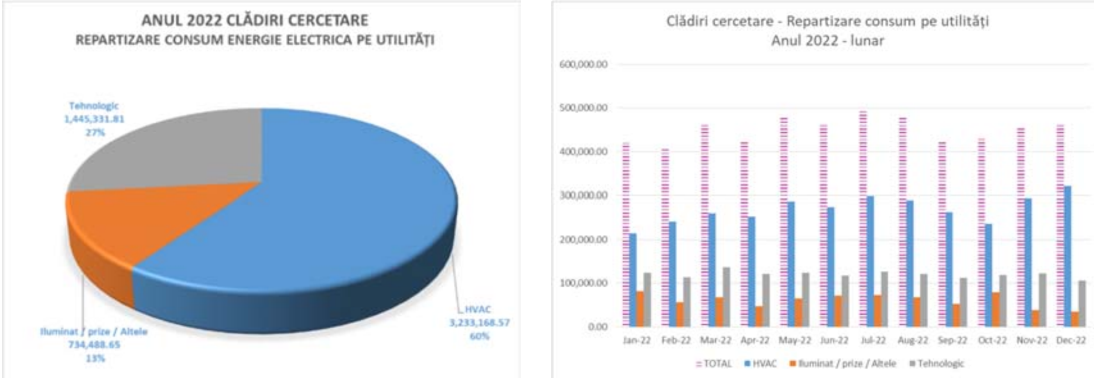

Figure 2 Research Buildings consumption 2022 out of total

Figure 3 shows values of the EUI indicator for the entire ELI-NP research infrastructure, respectively only for the research falls related to the years 2021 and 2022.

In 2021, at around 70% utilization, the EUI of the ELI-NP research infrastructure is less than half of the median EUI of 1,004 kWh/m2/year published on the ENERGY STAR platform, both for the entire infrastructure and for the research buildings. In 2022, the value of the EUI increased, along with the increase in electricity consumption, but without approaching the median value of EUI Energy Star. The conversion factor from site energy to source energy used for calculations is 2.5 according to SR EN ISO 52000-1.

EUI Energy STAR				EUI ELI - NP - Research Infrastructure						
kBTU/sf/an		kWh/m2/an		AN	Conversion factor	Total electrical energy consumption	kWh/m2/an		kBTU/sf/an	
SOURCE	SITE	SOURCE	SITE			kWh	SOURCE	SITE	SOURCE	SITE
318.20	115.30	1,003.79	363.72	2021	2.50	5,495,840.00	405.60	162.24	128.57	51.43
				2022	2.50	6,160,720.00	454.67	181.87	144.13	57.65

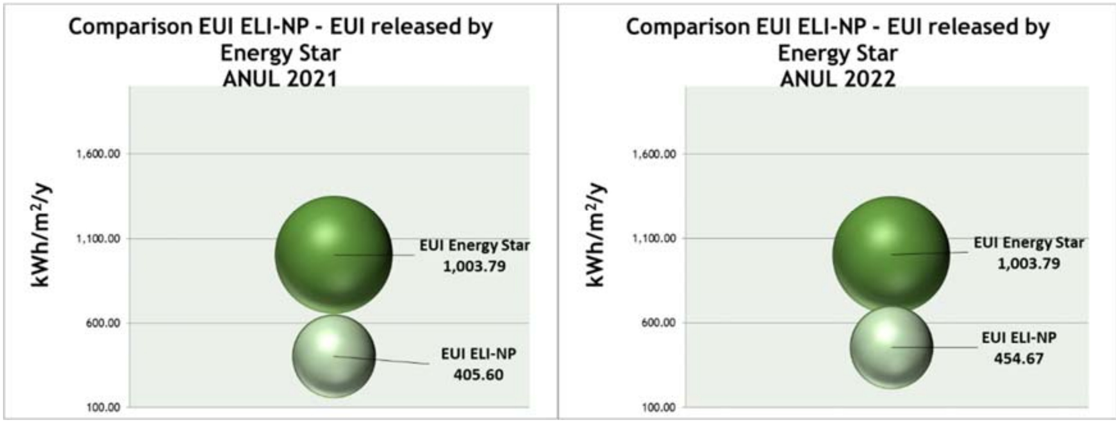

Figure 3 EUI ELI-NP Infrastructure – Comparison with the EUI published by Energy Star

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Harnessing the Energy Potential of Associated Gases from Geothermal Water Deposits in Micro-Cogeneration Power Plants

Valorificarea potențialului energetic a gazelor asociate din zăcămintele de apă geotermală în instalații de cogenerare

Dan Radu Danciu STĂNOIU[1], Emil Valer HERLO, Manuel Valer HERLO[2]

[1.] University Politehnica Timisoara,
Victoriei Square, no. 2, Timisoara, Romania
Email: dan-radu.danciu-stanoiu@student.upt.ro

[2.] S.C. OGAUS TECHNOLOGY S.R.L.
Calea Radnei, no. 149Bis B, Arad, Romania
E-mail: office@ogaus.com

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Abstract: *The paper presents an approach to use the associated gases from geothermal water deposits for electric and thermal energy cogeneration in centralized distribution systems.*

Key words: associated gases, energy sources

1. Introduction

In the current political and economic context, where the diversification of energy sources used to produce electricity and thermal energy is becoming an increasingly prominent advantage and renewable energy sources with as little impact on the environment as possible are becoming more and more necessary, the use of the geothermal water resource that Romania has, is becoming more and more attractive. This is encouraged by the Romanian state and the European Union by allocating substantial non-reimbursable financing in this field.

The paper does not aim to present revolutionary information in the field but to place it in a context that will be of interest for many years.

The paper deals with the basic technological scheme of an installation for separating associated gases from the geothermal exploit its energy potential in thermal power plants. If these gases have high energy potential, they should be preferred for use in high-efficiency cogeneration installations to obtain electrical and thermal energy, water extracted from the deposit to obtain electrical and thermal energy.

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Fig. 1. Distribution of geothermal water deposits in Romania

2. Description of the technological scheme:

The phenomenon of gas release when geothermal water is extracted from the well is scientifically modelled by Henry's law. One formulation of the law is: "*At constant temperature, the amount of gas dissolved in a liquid, at saturation, varies in direct proportion to the partial pressure of the gas in contact with the liquid.*" [1]. Thus, gases are released inside the borehole and also after extracting the water from it, because on the technological route represented in Fig. 2, the pressure is much lower than in the deposit.

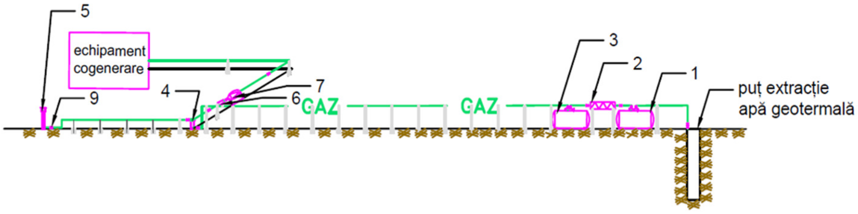

Fig. 2 The basic technological scheme for producing electricity and thermal energy in cogeneration, using aggregates fed with associated gases, with more than 50% methane, from geothermal water well, 1-biphasic separator, 2-heat recovery, 3-buffer vessel, 4-centrifugal liquid separator, 5-torch, 6-conical filter, 7-compressor.

In the technological scheme presented above (Fig. 2), two gas capture points have been provided: one is the well extraction head, and the second is the two-phase separator, where the final degassing of the geothermal water takes place. From the two-phase separator, the geothermal water follows its route to the thermal power plant and then to the reinjection well. If the associated gases extracted in this way have a minimum required methane content of over 50%, they can be exploited by burning them in high-efficiency cogeneration aggregates where electrical and thermal energy will be produced. In this situation, the associated gases follow the technological path presented in Fig. 2.

Fig. 3. Two-phase separator [4]

From the two-phase separator (Fig. 3), the gases, if necessary, pass through a heat recovery unit and then reach the buffer vessel, which will be sized so that when the aggregates are switched on, the pressure does not drop by more than 30% from the nominal value chosen for the operation of the installation [7]. In the buffer tank, it takes place the accumulation of a quantity of gas required for the operation of the installation in good conditions, without flow fluctuations. Also, the condensate collection resulting from the cooling of the gases within the heat recovery unit and the buffer tank itself occurs. The buffer tank will be purged periodically, either automatically or manually. Condensate pans with float can be used, provided they close tightly enough and quickly so that there is no escape of gases into the atmosphere. It is recommended that an automatic air freshener be included in the scheme. After the buffer tank, the gases pass through one or more centrifugal liquid separators, as noted in Fig. 2 with 4.

Fig. 4. Centrifugal liquid separator [5]

Then, the gases reach the compressor, but not before being passed through a conical filter, which protects it from possible mechanical impurities. The compressor (Fig. 5) supplies the cogeneration aggregates with gas at constant pressure and flow rate (the supplier equips the aggregates with filters, pressure regulators, and flame-back protection devices).

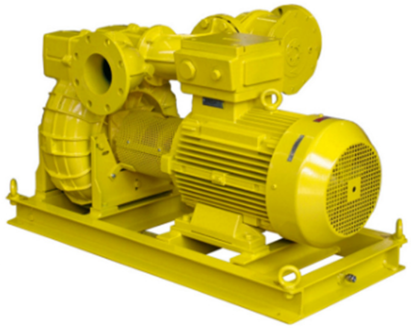

Fig. 5. Gas blower [6]

The cogeneration unit consists of the following primary equipment: a four-stroke thermal engine designed to work optimally with the gas mixture provided by the well, an electric power generator, and equipment for recovering thermal energy released by the engine and from the combustion gases. For this purpose, it is advised that the engines be manufactured following the composition analysis of the gases from the geothermal well and the project's technical requirements. The engine drives the electric power generator. Thus, the engine's power is determined according to the flow rate and the calorific value of the gases extracted together with the geothermal water.

The engine is equipped with heat recovery from the cooling circuit and from the burnt gases discharged to the chimney (Fig. 6 and Fig. 7)

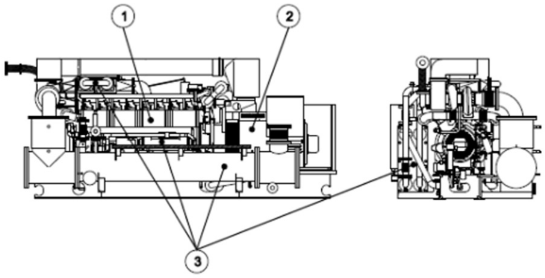

Fig. 6 Cogeneration aggregate [8]
1-Gas engine, 2-Electricity Generator, 3-Heat Exchanger

The engine drives the electric power generator, and the heat produced during the production process is recovered and sent to the thermal power plant.

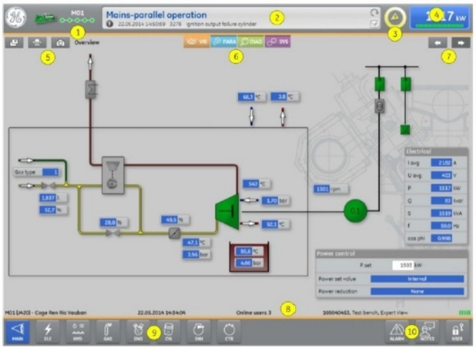

Fig. 7 Basic diagram of cogeneration aggregate [7]

The thermal power plant can be supplied with water heated up to 90°C (Fig. 7). The amount of energy varies depending on the engine load. In general, these types of engines are recommended to operate at least 50% of capacity.

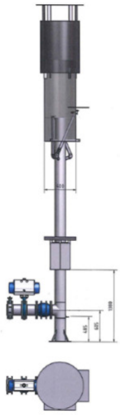

Fig. 8. Torch

Such an installation must also contain a torch (Fig. 8) that takes over the excess gases produced accidentally or when starting/stopping the installation. In general, the torch is equipped with automatic ignition and a device to prevent the flame from returning.

3. Case study: well no. 4628 from Timis County

According to project no. 34300/100, designed by IPROTIM Timișoara in 1990 [2], the well no. 4628 shows a geothermal water deposit with a temperature of 80°C, a flow rate of 10 l/s (36 m^3/h), and an associated gas content of 2.08 m^3 at 1 m^3 geothermal water.

According to the above data, there is a flow of associated gases at a temperature of 80°C, which can be considered. However, according to project 34300/100 [2], following the cooling of the gases and the condensation of the water vapor, we can take into account a 60% lower associated gas flow, as it was established.

$$\frac{G\,gaz\,15^0}{G\,gaz\,80^0} = 0{,}4047 \quad (1)$$

Thus, according to project 28226/090 designed by IPROTIM Timișoara in 1984 [3], the associated gases resulting from the exploitation of well no. 4260 contains methane with a concentration of more than 92% and a lower calorific value of 7100 – 7900 kcal/Nm^3, resulting in an available power which can be estimated.

$$P = \frac{D_{gaz} \times Q_i}{860} \quad (2)$$

Formulas (1) and (2) result in an available power input of 247 kW.

According to the data above, from the catalogue of one of the manufacturers of such machines [8], it can be determined the aggregate with the following characteristics:

- when operating in nominal parameters: delivered electric power 104 kW, thermal power 141/155 kW (depending on equipment), electrical efficiency 37.1%, thermal efficiency 50.4/55.4% (depending on equipment); gas consumption 30 Nm^3/h;
- when operating at 75% of capacity: delivered electric power 78 kW, thermal power 117 kW (depending on equipment), electrical efficiency 35%, thermal efficiency 52% (depending on equipment); gas consumption 24 Nm^3/h;
- when operating at 50% of capacity: delivered electric power 52 kW, thermal power 95 kW (depending on equipment), electrical efficiency 31%, thermal efficiency 56.6% (depending on equipment); gas consumption 18 Nm^3/h.

4. Conclusions

In the context of diversifying energy sources and encouraging the use of local resources as much as possible with as little environmental impact as possible,

geothermal water becomes a valuable asset for the local communities that have it. Where the quantity and quality of the associated gases allow the production of electricity and heat in cogeneration facilities, relatively simple from a constructive point of view, they considerably increase the energy efficiency of the respective installations.
Considering the relatively wide distribution of these resources on Romanian territory, an important number of local communities can be protected from price fluctuations and the uncertainty of access to classic energy sources in the very near future.

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The steps towards an infrastructure with minimal impact on the environment: the ELI-NP model of good practice

Pașii către o infrastructură cu impact minim asupra mediului: modelul de bună practică ELI-NP

Răzvan –Silviu ȘTEFAN[1], Daniel CORNEA[1]

[1]Technical University of Civil Engineering of Bucharest, Romania
Lacul Tei Blvd, No 124

Email: razvan.stefan@eli-np.ro, danielcornea@hidraulica.utcb.ro

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ABSTRACT: The paper presents steps taken to minimise the impact of the ELI-NP research infrastructure on the environment, on a roadmap towards a green facility.

The current crisis highlights the need to invest in strong renewable infrastructure and sparks interest in using cleaner, more sustainable energy sources.
As a result, stakeholders' interest is to maximise the infrastructure's initial potential while simultaneously enhancing key performance metrics and energy efficiency.
The primary aim of the ELI-NP decision makers is to enhance the efficiency of the current infrastructure in order to minimise its energy consumption.
Reducing the carbon footprint of the infrastructure is also a major goal in minimising its effects on the environment. To make the switch to green infrastructure, future investments are scheduled.

Key words: model of good practice, environment

Current state and context of the project

In the subject of photonuclear physics, the Extreme Light Infrastructure Nuclear Physics (ELI-NP) project is a sophisticated research infrastructure in the world, at the moment.

The ELI-NP high-power laser system (also known as HPLS) test results, which were released on March 13, 2019, constituted a significant step towards the establishment of a first-rate research infrastructure. These results verified the achievement of a power of 10 PW.

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The ELI-NP laser system is the most powerful ever created, with two laser beams that each have a power of 10 PW.

The HPLS must function properly under certain environmental conditions. High stability is essential for variables like humidity, pressure, and temperature.

Two research purpose buildings with a high-power laser system (HPLS) and sophisticated experimental sets are supplied with thermal load by the shallow GSHP system. The design of the system, as outlined below, aims to supply the optimum energy consumption while supplying the necessary air exchange rates.

To mention some operating constraints given by the research equipment, the building where the HPLS is located has more than 3000 m^2 of ISO 6 and ISO 7 clean rooms, out of which the laser room has around 2400 m2. The system has to provide or deliver 20 air changes per hour with a vertical air flow of 435,000 m3/h, at a constant temperature of 22°C in order to maintain the required humidity and cleanliness. Only +/- 0.5°C variations are allowed.

To operate the building where combined experiments are carried out, a flow rate of 80,000 m3/h of fresh air is required.

Details of the building that houses the high-power laser system:

- The building houses the HPLS
- The building is technically complex, being served by a wide variety of HVAC equipment.
- The building has high energy consumption.
- The usage and occupation of the building is 100%
- The ambient parameters (temperature and relative humidity) have a high stability, the ambient temperature of 22°C +/-0.5°C is a mandatory requirement for the functioning of HPLS.

Additionally, at present a 1.2 MW photovoltaic system will be installed in the ELI-NP infrastructure, which is anticipated to be finished by the end of 2025.

Milestones towards an infrastructure with minimal impact on the environment

A geothermal HVAC system is being installed in the ELI-NP infrastructure - 2016

When the ELI-NP research infrastructure was designed, it was outfitted with the largest shallow ground source heat pump (GSHP) system in Europe to provide the energy needed for air conditioning, heating, ventilation, hot water, and technological cooling.

Among the considerations that went into choosing this solution for the infrastructure's HVAC and technological cooling were the need to meet the operational parameters within the restrictions set by the cutting-edge research equipment. The infrastructure includes five buildings:

- Two buildings having research laboratories of 11,500 m^2 and 13,500 m^2
- Three buildings for support activities (office building, restaurant, guest house) of 7800 m^2.

The GSHP System was installed on a plot of 27,000 m^2 and has a length of 135 km. The total installed thermal capacity is above 6.2 MW.

The GSHP System is a closed-loop system made of 1070 boreholes with a depth of 120 m each.

The primary and secondary thermal agents are circulated within the closed loop by means of 185 circulating pumps.

The required primary thermal agent (water) is pumped from the manifolds to nine thermal plants equipped with water to water heat pumps that carry out the heating and cooling of the buildings.

The secondary thermal agent (water) for cooling and heating prepared with the water to water heat pumps is delivered to the HVAC equipment (air handling units, fan coil units).

The required thermal load of 6.2 MW is provided by 129 water-to-water heat pumps. In addition, 46 water to air heat pumps directly carry out the cooling or heating of the indoor air in some rooms.

The heating, ventilation, and conditioning of the buildings is performed by air handling units. Energy recovery is used wherever possible.

The shallow GHSP system at ELI-NP is unique due to its size and technical requirements.

The constraints considered in the design and implementation of the GHSP system at ELI-NP are reviewed here:

- precise humidity control requirements in many of the laboratories, low temperature and relative humidity being required
- the high air change rates requirements
- multiple operating conditions
- the pressurization requirements

- the limited options to use the energy recovery strategies, in order to avoid the cross-contamination
- the difficulty to anticipate the equipment thermal loads and exhaust requirements,
- the high energy consumption of the process and of the research equipment

The use of high-efficiency equipment has ensured a good balance of energy recovery and ventilation requirements.

The design of the system is intended to guarantee the required air change rates while minimizing energy consumption.

Since the requirements for heating and cooling are covered by the Shallow Geothermal System with Heat Pump Units (the largest in all of Europe), the infrastructure is free of fossil fuel consumption.

1. Extensive, long-term monitoring of the infrastructure in operation

Extensive, long-term monitoring of the infrastructure in operation is necessary to observe the results in terms of energy efficiency and environmental impact.

Working at full capacity, the Shallow GSHP System and the technological cooling account for almost two-thirds of the electricity consumed.

Surveillance showed that environmental parameters were stable and easy to manage, staying within the limits necessary for the research activity.

The most significant outcomes are those obtained when usage and occupancy are in the vicinity of 100%.

The project's focus is on highlighting the outcomes of the evaluation of the Shallow GSHP System in operation after long-term monitoring.

Four of the five buildings are, at present, occupied with a maximum occupancy rate of 100%.

Digital control of the Shallow GSHP System is done by the DDC system. Continuous monitoring, recording, and adjustment of temperature and humidity is done, and the information is sent to the BMS system.

The activities follow three main directions:

The performance of the Shallow GSHP System is assessed. Metrics considered for evaluation are Energy Intensity Use and the performance coefficient.

The EUI for the infrastructure, expressed as energy per square foot per year, was computed by dividing the total energy consumed by the infrastructure in one year (measured in kBTU or GJ) by the total gross floor area of the building (measured in square feet or square meters).

To evaluate the Shallow GSHP System, its performance coefficient was estimated in the next step, by comparing the electrical energy consumed by the system with the actual thermal load required for the building.

Groundwater and the ground are being observed continuously to determine the effects of the Shallow GSHP System.

Two sets of parameters are being measured, collected and compared with quality indicators of the groundwater set before the commissioning of the facility, to monitor the impact on the ground and groundwater:

- Physical parameters – piezometric levels, temperature (automatically measured on daily basis
- Hydro-geo-chemical and microbiological parameters (water sampling is performed each semester)

Simulations and studies both regarding the evaluation of the thermal loads introduced by the HVAC systems and the long-term response of the ground to the action of these loads, are of particular importance for the determination and evaluation of the possible consequences on the ground and groundwater.

Fine adjustment, optimization, and future optimal control of the shallow GHSP system are possible due to the recordings of operation consumption patterns and the high stability of the ambient parameters.

An important consequence of this fact is that it will be possible to carry out studies and simulations useful for making predictions and forecasts for the behaviour of similar systems, in order to evaluate the impact of the systems on the environment, their continuous innovation and optimization.

2. Optimisation of the geothermal HVAC system in operation

Given that the previously mentioned equipment and constraints have significant energy consumption, achieving the highest energy efficiency with the least amount of environmental impact has been taken into consideration.

Optimizing the operation of large consumers brings significant energy savings. Identifying and implementing efficient and inexpensive optimization techniques can bring great benefits to the society, especially in the long run.

Testing integrated optimization techniques for large shallow GHSP systems is an innovation in itself, and it adds value to the existing ELI-NP shallow GSHP system. Furthermore, the future results could contribute to the development of optimization criteria for large shallow geothermal systems.

Observing the system's performance and consumption patterns over the previous five years, revealed that there is space for improvement in both control and energy efficiency.

To achieve the ideal balance between consumption and technological requirements, the ultimate goal is to optimise the Shallow GSHP System.

Reducing the carbon footprint of the infrastructure is also a major goal in minimising its effects on the environment.

Given that the consumption of the circulating pumps has an impact on the overall performance of the Shallow GSHP System's an experimental optimization methodology is being developed for the circulating pumps operation, to obtain the values of the optimal frequencies of the circulating pumps.

An experimental methodology is under development to optimize the Shallow GSHP System, at the same time.

The optimization of the Shallow GSHP System is in progress. There have been steps taken to obtain an accurate pattern of the system's behaviour and to develop an optimal control strategy.

3. Installing a photovoltaic system

To make the switch to green infrastructure, future investments are scheduled.

At present a 1.2 MW photovoltaic system will be installed in the ELI-NP infrastructure, which is anticipated to be finished by the end of 2025.

The photovoltaic installation for the production of electricity will be connected to the network of the existing medium voltage of the ELI-NP infrastructure without grid discharge

The photovoltaic system will consist of a number of around 2000 PV modules, each of them having the power of 540W.

Photovoltaic panels will have a minimum nominal efficiency of 20.89% in

The system will be equipped with three-phase string inverters of the string inverter.

The installed power of the photovoltaic system will be of around 1.2 MW.

Expected results

Finding the optimisation technique to maximise the performance coefficient of the shallow GHSP system to the maximum value achievable within the limitations imposed by the research activity conducted is anticipated.

Good estimates of the buildings' behaviour with 100% usage and occupancy are possible, at this stage of the project.

A complete and optimized picture of the behaviour of the Shallow GSHP System will be provided by gradually expanding the analysis throughout the entire infrastructure.

The HVAC system and the hydrogeological monitoring station are in their 5th year of operation. By means of the statistics and monitoring, data are available to highlight the real behaviour of the system by comparison with the predictions made based on the physical model.

Data are available regarding the energy consumption of buildings and their systems, as well as the consumption of the processes carried out in the buildings.

The published median source EUI (energy use intensity) for technology and science is 1004 kWh/m^2/year. In contrast, the source EUI of the ELI-NP facility is 489 kWh/m^2/year.

A comparison between the electrical energy consumed and the actual thermal load required for the building yielded an average value of 3.8 for the Shallow GSHP System's performance coefficient.

Groundwater and the ground were also observed for effects of the Shallow GSHP System, but none have been found as of yet.

The heat transfer models will be refined and calibrated based on real data and considering the operation in both directions (yielding or receiving heat from the HVAC system in the environment).

A significant reduction of electricity consumption is anticipated by the end of 2025 as a consequence of the system's optimisation and the installation of the photovoltaic plant.

Experimental measurements and analysis of the parameters that influence the consumption of electrical energy in HVAC systems.

Măsuratori experimentale și analiza parametriilor care influențează consumul de energie electrică în sisteme HVAC.

Marius ADAM[1], Adriana TOKAR[1], Alexandru DORCA[1], Dănuț ToKAR[1] Alexandru FILIPOVICI[1]

[1] University Politehnica Timisoara
Victoriei Square, no.2, Timisoara, Romania
E-mail: marius.adam@upt.ro, adriana.tokar@upt.ro, alexandru.dorca@upt.ro, danut.tokar@upt.ro, alexandru.filipovici@upt.ro

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Abstract. *The building sector is one of the largest final consumers of energy, especially for air conditioning, and research has shown that there is a great potential for energy savings in this sector. The performance of a chiller can vary significantly depending on system partial loads and evaporator and condenser operating temperatures. The condensers of water-only chillers take the heat of condensation from the refrigerant only through the sensible heat of the refrigerant, leading to significant water flows. The outside air temperature and the intensity of solar radiation directly influence the consumption of electricity on the chiller. Having available the values for the solar radiation intensity I [W/m^2] and the outside air temperature t_e [^{o}C], with the help of the proposed mathematical model, validated by experimental measurements, the optimal values for the minimum electricity consumption of the system are obtained, under the conditions which the chilled water temperature is 7/12^{o}C and the indoor air temperature is 27^{o}C*

Key words: *HVAC, energy efficiency, GWP, chiller, cooling, mechanical ventilation, GES.*

1. Introduction

On 12 December 2015, leaders from 55 countries around the world signed the Paris Climate Agreement, which set out an action plan to limit global warming to "well below" 2°C and work towards limit it to 1.5°C. The European Council approved a binding EU target of reducing net domestic greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. In 2020, five years after the Paris Agreement signing, the highest temperatures were recorded and 200 gigatons of CO_2 were emitted. Almost 200 countries have agreed for the first time, at the COP28 Dubai climate change summit, to start reducing global consumption of fossil fuels, but without giving up coal, oil and gas for good.

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The need for immediate action to reach the global emissions cap by 2025 at the latest and reduce global greenhouse gas emissions by 43% by 2030 and 60% by 2035. Globally, the main consuming sectors are construction, transport, industry and others, which group minor activities such as agriculture, forestry and fishing. Consumption in each sector increased, while their shares in final consumption remained constant [3].

Although the energy saving potential remains high in all sectors, there is a particular challenge related to transport, as it is responsible for more than 30% of final energy consumption, as well as construction, as 75% of the Union's real estate stock has low energy performance. The 2020 EU reference scenario foresees 864 Mtoe for final energy consumption and 1124 Mtoe for primary energy consumption, values to be reached by 2030. An additional reduction of 11.7% results in 2030, 763 Mtoe and 992.5 Mtoe. Compared to 2005 levels, this means that final energy consumption in the Union should be reduced by around 25% and primary energy consumption should be reduced by around 34% [4].

A classic ventilation and air conditioning (HVAC) system accounts for approximately 40% of the building's total energy consumption [1]. This is an important consideration because energy consumption for cooling, heating and refrigeration has a substantial impact on the total energy consumption of buildings and countries. Depending on how electricity is generated in each country, its efficient use also has a large indirect impact on climate change by reducing CO_2 emissions.

Global warming potential (GWP) is a value that indicates the degree of contribution to global warming of various greenhouse gases (GHGs). (R-410A: 2,090, R-32: 675) [2]. Lifecycle Global Warming Potential measures the GHG emissions associated with the building at different stages throughout its life cycle.

It therefore measures the building's overall contribution to climate change emissions. This is sometimes referred to as 'carbon footprint assessment' or 'life cycle carbon measurement'. It brings together carbon emissions embodied in building materials and direct and indirect carbon emissions from the use stage [4].

2. Presentation of the work

The objective of this study is to illustrate the optimal control of the ventilation/air conditioning system, whereby for a given cooling load, the total electricity consumption of the system is minimized, while maintaining comfort conditions in the building.

The measurements, which were the basis of the electricity consumption analysis, were carried out in an industrial hall (Fig.1), with an area of 2290 m^2 and a height of 12 m, located in the town of Timisoara, having known the values of the air parameters outside for the summer period, from July, t_e=36,4°C, relative humidity of the outside air, θ_e=25%, according to SR 6648-2 / 2014 and I5-2022.

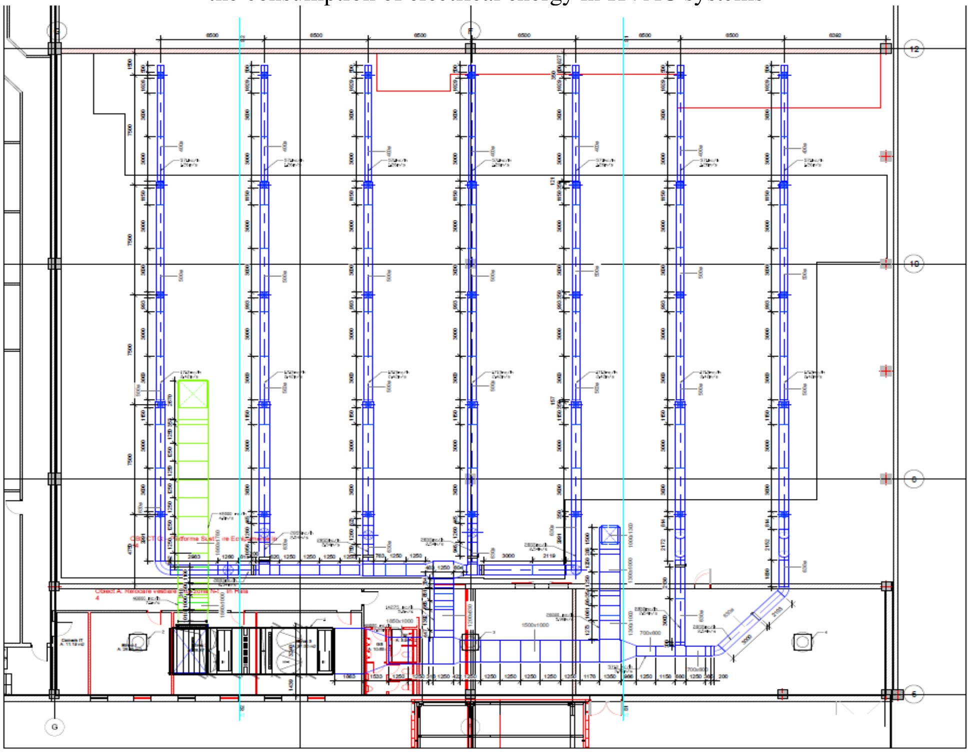

Fig. 1. Industrial hall plan.

The resulting values for the cooling and heating thermal loads are as follows, ΔQ_{Summer}=312 kW and ΔQ_{Winter}=210 kW.

The air conditioning ventilation system consists of a chiller, a cooling tower and an air treatment plant.

For this ventilation/air conditioning system, two controllable parameters were defined (indoor air temperature and chilled water temperature) which were determined so that the electricity consumption was minimal. Controllable parameters were defined as depending on other uncontrollable parameters, such as the outside air temperature and the intensity of solar radiation. The electricity consumption of the ventilation/air conditioning system is the sum of the electricity consumption of the chiller, cooling tower, exhaust and air intake fans from the air treatment plant and heat agent circulation pumps.

3. Description of the ventilation/air conditioning system

The ventilation / air conditioning system that ensures thermal comfort and olfactory comfort parameters for the industrial hall is made up of the following components:

- air treatment plant with fresh air intake, with a flow rate of 48,000 m^3/h;
- water-cooled chiller, net cooling power 337.1 kW, chilled water 7ºC /12ºC, freon 410A;
- open cooling tower, with radial fan, water flow 48m^3/h, electric power 4.3kW;
- 3 air exhaust fans, flow rate 16000 m^3/h;

- water treatment station.

In open cooling towers, the water coming from the cooling system is distributed directly on the spray surface and comes into contact with the air blown through the tower, thus ensuring its cooling by evaporating a certain amount of water. This type of cooling is the most advantageous in terms of efficiency, dimensions, cost and energy consumption. Regarding the risks related to water quality, the volume of water to be managed (water from the cooling tower and that from the cooling network) and the diversity of materials with which it comes into contact must be taken into account. In these systems, the water has high temperatures, which favors microbial proliferation, and the hot spots of the system are favorable areas for stone deposits and corrosion production. The functional diagram for the cooling system is shown in Fig. 2.

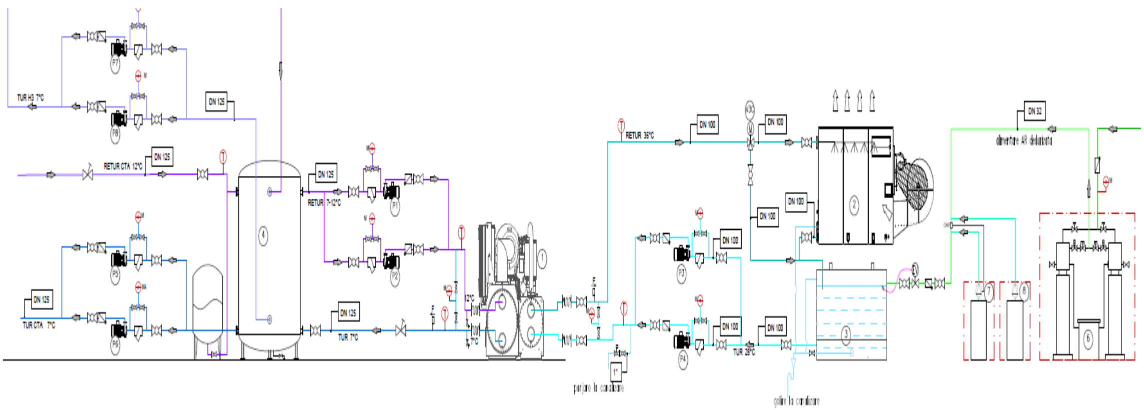

Fig. 2. Cooling system functional diagram.

For ventilation and air conditioning in the industrial hall, an air treatment plant with fresh air intake is used, with an input air flow rate of 48000m³/h. The air treatment unit, for indoor installation, will consist of the following modules:

- multifunctional mixing chamber, with the following connections provided with motorized dampers with proportional actuators (0-10V control), powered by 24 V alternating current:
- fresh air connection (for free cooling from 0 to 100% air flow);
- recirculated air connection in winter (from 0 to 100% air flow);
- recirculated air connection in summer (from 0 to 100% air flow);
- 2 bar steam heating battery, power 225 kW, including steam solenoid valve;
- water cooling coil 7/12°C, power 349.7 kW, including three-way valve with proportional servo motor (0-10V command), powered by 24 V alternating current;
- G4 filters on the fresh air intake side and F7 final filter;
- noise attenuators on air suction and discharge;
- 2 fresh air intake fans, with a total flow rate of 48,000 m³/h, equipped with frequency converters, with a static pressure of 450Pa.

The air evacuation will be done by means of three roof ventilators, equipped with a basic plinth and anti-return valve, mounted in the area of the air treatment plant. The flow rate of air circulated by each fan will be 16000 m^3/h, but these fans will only work when the air treatment plant introduces fresh air (free-cooling mode).

4. Monitoring and analysis of the parameters that influence the consumption of electricity on the chiller

The indoor air temperature was set to the comfort value of 27°C, and the measurements were performed at 15-minute intervals every day from July 2023 in (Fig.3).

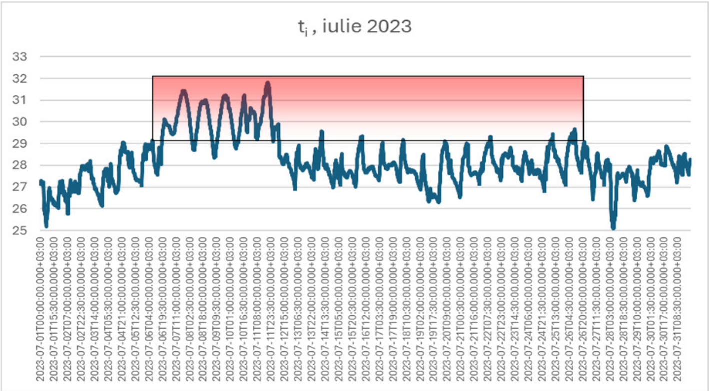

Fig. 3. Variation of indoor air temperature over time

It is noted that between July 6 and July 12, the value of the set indoor air temperature is exceeded by more than 2ºC. This situation is not due to the high values recorded for the outside air temperature or the intensity of the solar radiation, but is caused by the improper operation of the chiller during that period as can be seen from the graphs that follow.

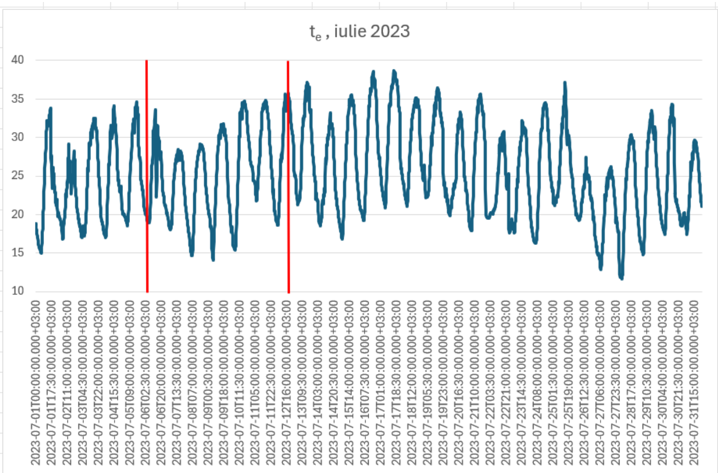

Fig. 4. Variation of outside air temperature over time

For the period July 6 - July 12, the value of the outdoor air temperature is between the minimum values of 14ºC and the maximum of 35ºC (Fig.4). These values are normal for the period of July and do not exceed the values taken into account during the design phase, when choosing the ventilation / air conditioning equipment.

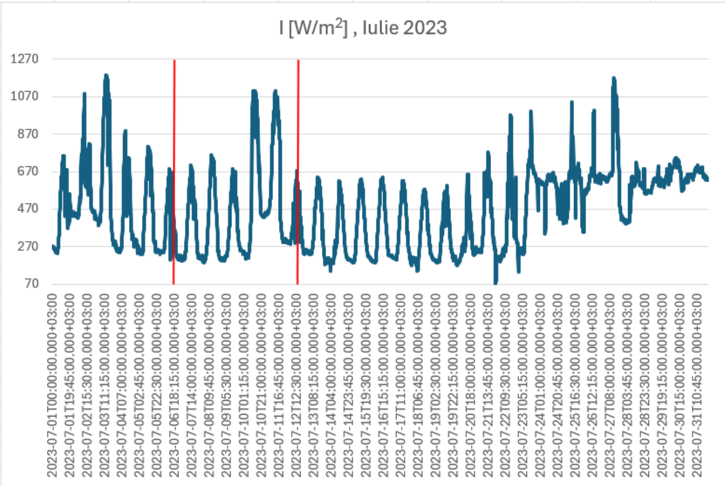

Fig. 5. Variation of solar radiation intensity over time

In the graph in Fig. 5 shows the solar radiation intensity values for the month of July with normal values between 200 W/m^2 and 1100 W/m^2, these values complying with the values of the external calculation parameters from SR 6648-2 /2014.

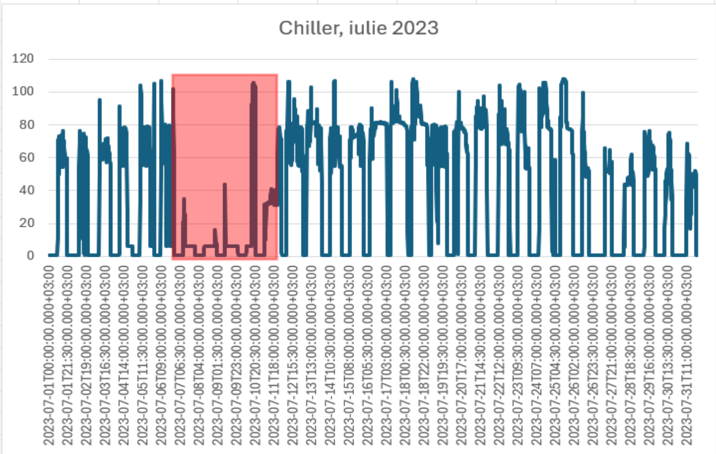

Fig. 6. Variation of electricity consumption on the chiller as a function of time

For the ventilation / air conditioning system used for the industrial hall, analyzing the values recorded for the month of July for the consumption of electricity on the chiller, E_{ch} [kWh] and the values for the outside air temperature, t_e [ºC] (Fig.7.) and the intensity of solar radiation, I [W/m^2] (Fig.8), a strong correlation can be determined between these parameters.

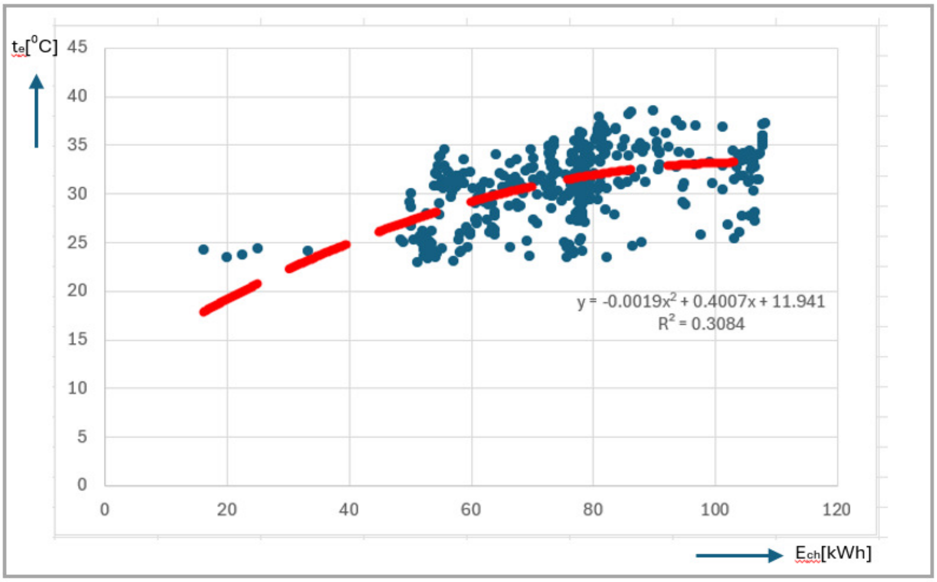

Fig. 7. Variation of electricity consumption on the chiller depending on the outside air temperature

This correlation is valid for chiller operation with chilled water, temperature 7/12ºC and a set indoor air temperature, t_i, of 27ºC ± 2ºC. For the correlation of the outdoor air temperature with the electrical energy consumed by the chiller, a polynomial function of degree 2 resulted and the square of the correlation coefficient being R^2=0.3084.

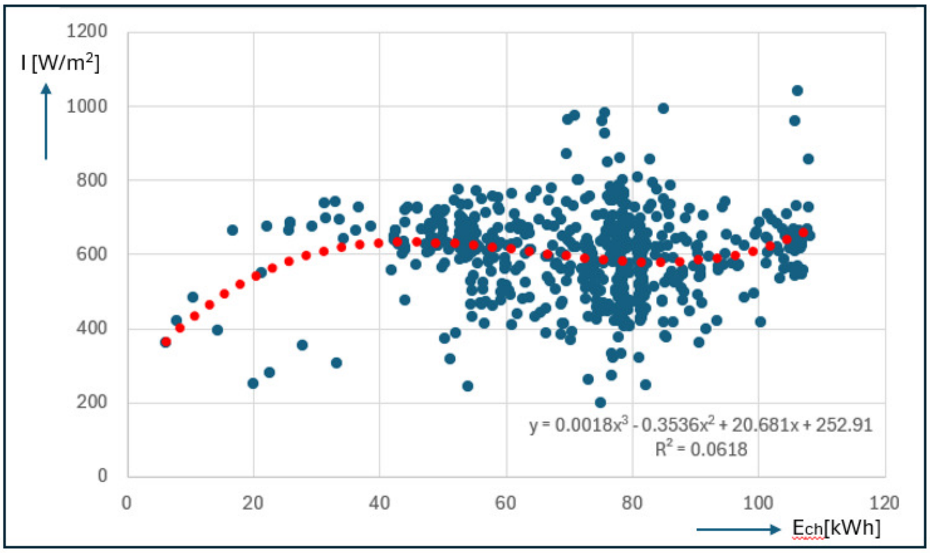

Fig. 8. The variation of electricity consumption on the chiller depending on the intensity of solar radiation

Analyzing the graphs in Fig.7 and Fig.8 shows that the influence of solar radiation is smaller compared to the influence of the outside air temperature on the consumption of electricity on the chiller, for constructive reasons. The industrial hall has a very small glazed area and the building elements with thermal inertia have a high thermal resistance so that heat intakes through insolation are reduced.

Using the two polynomial functions, a minimum value can be determined for the consumption of electricity at the chiller [5] and using the same algorithm, the minimum consumption can be determined for each piece of equipment in the ventilation / air conditioning system.

5. Conclusions

Based on the studies and research carried out, the following main conclusions were drawn:

1) The building sector is one of the largest final consumers of energy, especially for air conditioning, and research has shown that there is a great potential for energy savings in this sector.
2) It is necessary to promote the energy efficiency of buildings, the rational use of energy at the level of buildings, but also the use of renewable energies, with the idea of saving fossil fuels and reducing the level of polluting emissions.
3) The performance of a chiller can vary significantly depending on the partial loads of the system and the operating temperatures of the evaporator and condenser. The condensers of water-only chillers take the heat of condensation from the refrigerant only through the sensible heat of the refrigerant, leading to significant water flows. The outside air temperature and the intensity of solar radiation directly influence the consumption of electricity on the chiller.
4) Having available the values for the solar radiation intensity I [W/m^2] and the outside air temperature t_e [^oC], with the help of the proposed mathematical model, validated by experimental measurements, the optimal values for the minimum electricity consumption of the system can be obtained, in the conditions in which the chilled water temperature is 7/12^{o}C and the indoor air temperature is 27^{o}C.
5) In the future, the authors propose an extension of the mathematical model that estimates the electricity consumption of the ventilation/air conditioning system so that it takes into account several controllable variables such as the thermal inertia of the building, the total opaque surface and the total glazed surface

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High-strength cellular glass made by an effective unconventional technique

Sticlă celulară de mare rezistență realizată printr-o tehnică neconvențională eficientă

Lucian PAUNESCU[1], Sorin Mircea AXINTE[2,3], Enikö VOLCEANOV[4,5]

[1] Cosfel Actual SRL
95-97 Calea Grivitei, sector 1, Bucharest 010705, Romania
E-mail: lucianpaunescu16@gmail.com

[2] Daily Sourcing & Research SRL
95-97 Calea Grivitei, sector 1, Bucharest 010705, Romania
E-mail: sorinaxinte@yahoo.com

[3] University "Politehnica" of Bucharest, Faculty of Applied Chemistry and Material Science
1-7 Gh. Polizu street, sector 1, Bucharest 011061, Romania
E-mail: sorinaxinte@yahoo.com

[4] University "Politehnica" of Bucharest, Faculty of Science and Materials Engineering
313 Independence Splai, sector 6, Bucharest 060042, Romania
E-mail: evolceanov@yahoo.com

[5] Metallurgical Research Institute SA
39 Mehadia street, sector 6, Bucharest 060543, Romania
E-mail: evolceanov@yahoo.com

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Abstract. *The manufacture of cellular glass using recycled residual glass as the basic raw material had the objective of obtaining a porous material with excellent thermal insulation properties and, at the same time, achieving a relatively high compression strength for construction applications. The work is original due to the type of heating adopted (unconventional) and the own solution chosen to obtain the maximum heating efficiency without affecting the quality of the final product (partially direct heating with microwaves and partially indirect heating by thermal radiation). The energy efficiency of the process (specific consumption below 1 kWh/kg) was remarkable.*

Key words: *cellular glass, recycled residual glass, borax, calcium carbonate, microwave.*

Rezumat. *Fabricarea sticlei celulare utilizând sticlă reziduală reciclată ca materie primă de bază a avut ca obiectiv obținerea unui material poros cu excelente proprietăți termoizolante și, în același timp, realizarea unei rezistențe la compresiune relativ înaltă pentru aplicații in construcții. Lucrarea este originală datorită tipului de încălzire adoptată (neconvențională) și propriei soluții alese pentru a obține eficiemța maximă de încalzire fără afectarea calității produsului final*

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(parțial, încalzire directă cu microunde și parțial, încălzire indirectă prin radiație termică). Eficiența energetică a procesului (consum specific sub 1 kWh/kg) a fost remarcabilă.

Cuvinte cheie: sticlă celulară, sticlă reziduală reciclată, borax, carbonat de calciu, microundă.

1. Introduction

Important climate changes due to the destruction of the protective ozone layer of the planet through the excessive emissions of greenhouse gases in the atmosphere have seriously sensitized specialists from all over the world in the last decades. Sources emitting CO_2 have been drastically reduced especially in large fossil fuel-consuming industries and thus, a new global policy of intensive recycling the waste, whose annual generation is in an alarming increase has received special attention [1]. Waste recycling is important due to the energy saving required to produce these materials and implicitly, the reduction of CO_2 emissions during their manufacture. Recycling aims both at the reintroduction of waste into the production circuit as well as their use for the manufacture of new material types.

The construction materials industry is one of the main industries affected by the current international policy and especially, the manufacture of cement as the basic material for making the construction concrete [2].

Among the recyclable wastes (plastics, metals, glasses, rubber, paper and cardboard, textiles, etc.), the residual glass plays an important role in the production of construction materials [3].

Recently, several techniques for manufacturing porous materials with high mechanical strength for construction applications have been experimentally tested.

Assefi et al. [4] used residual alkaline battery and sodium carbonate as expanding agents to sinter/expand LCD waste screen from TV device. The porous ceramic material had high compression strength (18.7 MPa), high flexural strength (6 MPa), but relatively low heat conductivity (0.22 $W \cdot m^{-1} \cdot K^{-1}$) and an acceptable value of apparent density (0.85 $g \cdot cm^{-3}$).

Cellular glass with high compression strength was experimentally made [5] from photovoltaic module waste (80 wt. %), clay (10 wt. %), and 10 wt. % eggshell (with high calcium carbonate content). The temperature of the process was 900 °C. The compression strength reached 12.8 MPa that corresponded to a heat conductivity value of 0.121 $W \cdot m^{-1} \cdot K^{-1}$.

A modern raw hollow sphere technique was applied by Qu et al. [6] in the process of sintering at 680-800 °C and foaming in several stages of recycled residual glass. Specimens of cellular glass with fine porosity and homogeneous structure, apparent density within the limits of 0.129-0.229 $g \cdot cm^{-3}$, porosity between 91-95 %, heat conductivity in the range of 0.055-0.077 $W \cdot m^{-1} \cdot K^{-1}$, and compression strength up to 5.92 MPa were obtained.

König et al. [7] tested making the cellular glass from cathode-ray-tube (CRT) panel glass utilizing carbon and MnO_2 as pore-forming agents. The sintering temperature range was between 700-800 °C. Apparent density had very low values (up to 0.131 $g \cdot cm^{-3}$) and also the heat conductivity (up to 0.042 $W \cdot m^{-1} \cdot K^{-1}$).

Experiments performed through factorial designs were presented in the paper [8]. Cellular glass specimens with high porosity (up to 92 %) and bulk density within the limits of 0.16-0.79 $g \cdot cm^{-3}$ were obtained using sodium hydroxide (NaOH) as an effective expanding agent. In this experiment, NaOH and borax contents as well as the sintering temperature value were the variable elements. The role of NaOH was to reduce the density value of the cellular product and slightly increase the proportion of open porosity.

The methods of making the cellular glass mentioned above included conventional heating techniques. Heating through converting the electromagnetic wave power into heat is recognized in the scientific world as a fast, economical and environmentally friendly process [9]. Although electromagnetic waves were discovered 80 years ago, their main area of application included communications and radars. The advantages in terms of energy have been highlighted so far only in industrial and domestic processes involving low drying and heating temperatures. Although experimental research on the mechanism of heating through this unconventional method is revealed more often in the literature lately [10-12], the industrial application in processes that require high temperatures is still not known.

Under these conditions, the Romanian companies Daily Sourcing & Research SRL and Cosfel Actual SRL have jointly initiated small-scale research on making different types of cellular products using recycled residual glass or alumino-silicate waste subjected to partially or completely direct heating at high temperatures (800-1150 °C). One of the papers of the authors' team presented in the literature refers to results of the experiment aimed at making porous cellular glass with relatively high mechanical strength [13]. Mixing recycled post-consumer container glass (90-94 wt. %), borax (5 wt. %) as a fluxing agent due to its relatively high Na_2O content, $CaCO_3$ (1.5-5 wt. %) as a pore-forming agent, and water (8.5 wt. %) as a binder, they were obtained by sintering/expanding at 820-851 °C cellular glass specimens with apparent density between 0.60-0.90 $g \cdot cm^{-3}$, heat conductivity in the range of 0.081-0.105 $W \cdot m^{-1} \cdot K^{-1}$, and compression strength within the limits of 2.5-6.2 MPa. The partial direct microwave heating technique using a ceramic tube of SiC and Si_3N_4 with the wall thickness of 3.5 mm for protecting the material against the destructive effect of microwave flow through completely direct contact with it led to obtaining heating rates between 15.9-17.0 °C/min and homogeneous structures of the foamed product with pore size between 0.5-3 mm depending on the mixture composition.

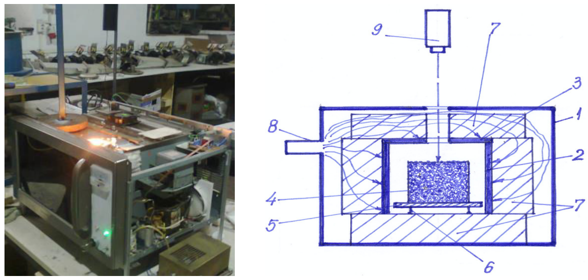
Maintaining the unconventional microwave heating system of the mixture based on residual glass, the current paper aimed at testing the correlation between the amounts of borax and $CaCO_3$ as fluxing and respectively, expanding agents introduced into the starting mixture. Except for its role as a flux material due to its rich-Na_2O content, borax significantly contributes to improving the mechanical strength of the foamed product due to the high level of boron in its composition. Thus, by increasing the proportion of $CaCO_3$ addition that improves the pore size, a higher borax content can compensate for the decrease in mechanical strength. The aim of the work was the experimental determination of the optimal ratio of borax and $CaCO_3$ so that the cellular glass to have heat-insulating and mechanical properties suitable for its use as a construction material.

2. Methods and materials

The method adopted for the manufacture of cellular glass is based on the sintering and expansion of the material mixture in powder state by heating to temperatures at which the pore-supplying agent releases a gas that is trapped in the form of bubbles in the thermally softened material. The heating method is unconventional using the microwave field emitted by a single emitting source (magnetron) placed in one of the side walls of the microwave oven. Since initial tests showed that soda-lime-silica type glass powder is unsuitable for the microwave foaming process by direct heating due to the serious destruction of the structural configuration, it was necessary to adopt an original solution of positioning a protective screen made of microwave susceptible materials between the source and the material. The thickness of the screen wall (2.5 mm) proved optimal to provide a predominant microwave field that penetrates the screen and comes into direct contact with the material. Partially absorbed in the wall mass, heats it up quickly. The hot wall transmits the heat through thermal radiation and thus, the material is heated by a double effect (partially direct and partially indirect).

The direct heating has a high energy efficiency and is based on the conversion of microwave power into heat through the contact of the waves with the material. The start of heating takes place in the central area of the irradiated material and the heat propagation occurs volumetrically in its entire mass from the inside to the outside [11, 12]. The process is fast and economical and is completely different from the conventional heating.

The microwave equipment is an 800 W-oven currently used in domestic applications, constructively and functionally modified for high temperature operations. The rotating mechanism at the base of the oven was abolished, an insulating bed made of ceramic fiber mattresses (resistant up to 1200 °C) being deposed in this space. The material subjected to heating and expansion was freely placed on this bed and was protected on the sides and on top by a ceramic tube made of SiC (80 %) and Si_3N_4 (20 %) with the outer diameter of 125 mm, height of 100 mm and wall thickness of 2.5 mm (purchased from China) as well as a lid made of the same material with the thickness of 6 mm provided with 30 mm-central hole. The outer surfaces of the ceramic tube and lid were thermally insulated with the same type of ceramic fiber mattresses. A radiation pyrometer installed above the oven on a metal rod at 400 mm allowed monitoring the temperature evolution of the sample (over 680 °C, when the ceramic material began to emit thermal radiation detectable by the pyrometer). The upper metal wall of the oven was also provided with an axial hole of 30 mm. As a whole, the microwave equipment (Fig. 1) was designed according to an original own concept within the two Romanian companies mentioned above and was presented in several previously published works [14-16].



a b

Fig. 1. Microwave equipment

a – overall image of the equipment; b – functional scheme: 1 – microwave oven; 2 – ceramic tube; 3 – ceramic lid; 4 – pressed material; 5 – metal plate; 6 – metal support; 7 – ceramic protection; 8 – waveguide; 9 – pyrometer.

The materials that composed the mixture prepared for making the cellular glass were: residual glass recycled from post-consumer commercial colourless containers as the main raw material, borax as a fluxing agent, $CaCO_3$ as a pore-supplier agent, and water addition as a binder.

Residual glass processing meant selection by colour, washing, drying, breaking, grinding in a ball mill, and sieving, the selected grain sizes being below 100 μm. The oxide composition of residual glass included 71.7 % SiO_2, 2.0 % Al_2O_3, 11.8 % CaO, 1.1 % MgO, and 13.2 % Na_2O, according to determinations performed in the Metallurgical Research Institute Bucharest with AXIOS-sequential type X-ray fluorescence spectrometer.

Sodium tetraborate (borax) in powder form is a mineral from the borate class with the chemical formula $Na_2[B_4O_5(OH)_4]\cdot 8H_2O$ [17]. The crystallization water is removed by heating to 100 °C and at over 400 °C the anhydrous product is obtained. Theoretically, the composition of borax contains 30.8 % sodium oxide (Na_2O) as one of the most effective fluxing materials and 69.2 % boric oxide (B_2O_3), boron significantly influencing the mechanical strength of the product that includes boron in its composition.

Probably, one of the cheapest and frequently used pore-forming agents in the processes of making the glass foam [18], $CaCO_3$ was chosen for this experiment. By decomposing this carbonate slowly starting at about 750 °C and rapidly continuing up to about 900 °C [19] carbon dioxide (CO_2) is released and contributes to the pore-formation process and calcium oxide (CaO) enters the composition of the glass molten. $CaCO_3$ had very fine grain size (under 20 μm) commercially purchased at these dimensions.

A number of four experimental versions were adopted to test the variation influence of the mixture component weight proportions on cellular glass specimen features. Table 1 centralizes the four manufacturing recipes, in which residual glass had values within the limits of 88.9-92.4 wt. %, borax represented between 5.9-9.5 wt. %, $CaCO_3$ had increasing values (like also the borax) in the range of 1.7-2.6 wt. %, and water addition as a binder (to facilitate pressing the dry powder mixture) was used in a constant weight proportion of 8 wt. %.

Table 1

Composition of experimental versions

Composition	Version (g)			
	1	2	3	4
Residual glass	92.4	90.9	89.4	88.9
Borax	5.9	7.1	8.3	9.5
$CaCO_3$	1.7	2.0	2.3	2.6
Water addition	8.0	8.0	8.0	8.0

Common methods were used for investigating the cellular glass specimen features. Apparent density and porosity were measured by applying the Archimedes' method according to ASTM D792-20. Determining the heat conductivity was carried out by heat-flow method (ASTM E1225-04) [20]. The measure of compression strength was performed with TA.XTplus Texture analyzer. The common method of immersion of the sample under water was utilized to measure the water-absorbing ability (ASTM D570). Microstructural aspects of samples were examined with ASONA 100X Zoom Smartphone Microscope.

3. Results and discussion

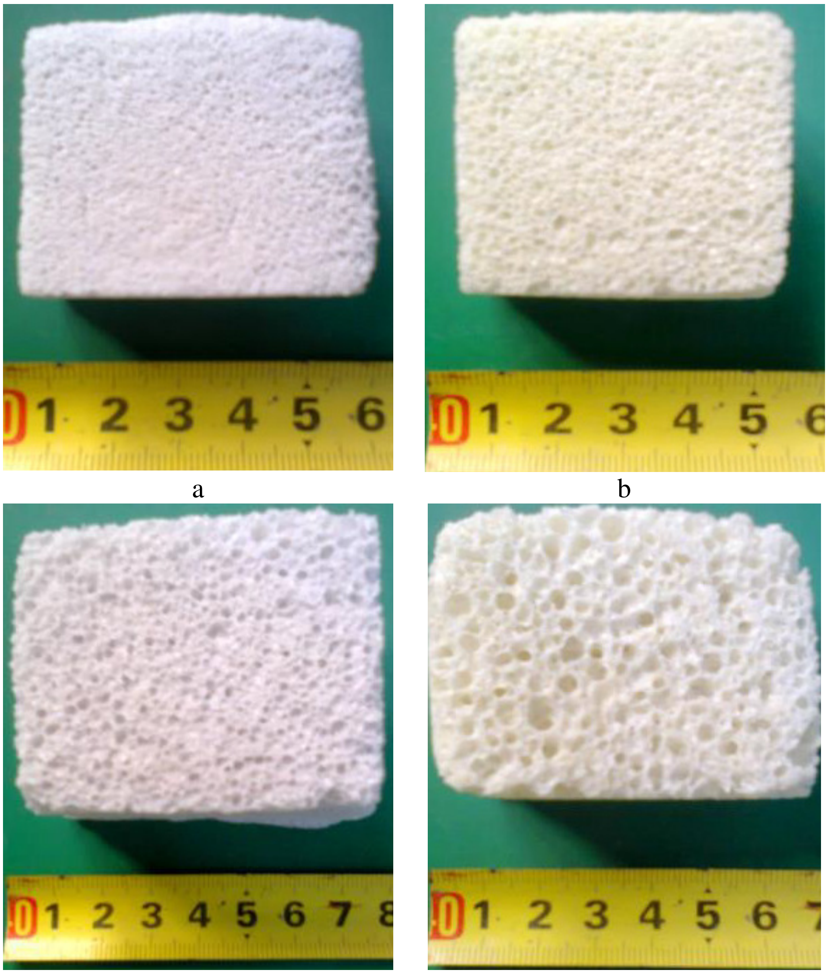
The simultaneous increase in the amounts of borax and $CaCO_3$ with approximately opposite effects on the hardness and mechanical resistance of the foamed product and respectively, on its insulating properties (density, heat conductivity, and porosity) influenced the functional parameters of the manufacturing process (Table 2). Thus, the value of sintering/expanding temperature slightly increased from version 1, with the lowest contents of borax and $CaCO_3$ (834 °C), to version 4, with the highest contents of borax and expanding agent (842 °C). Implicitly, the heating duration increased within low limits from 31 to 40 min. Compared to the results obtained in an almost similar paper, the process being also carried out by the non-conventional method of microwave heating [13], the heating rates reached significantly higher values between 20.6-26.3 °C/min and influenced the considerably lower level of specific energy consumption (between 0.84-1.08 kWh/kg).

Table 2

Functional parameters of the process

Parameter	Version			
	1	2	3	4
Dry raw material/cellular glass amount (g)	430/ 386	430/ 385	430/ 387	430/ 386
Sintering/expanding temperature (°C)	834	837	839	842
Time heating process (min)	31	33	36	40
Average rate (°C/min) - heating - cooling	 26.3 5.4	 24.8 5.5	 22.8 5.4	 20.6 5.5
Specific energy consumption (kWh/kg)	0.84	0.89	0.97	1.08

Appearance images of cellular glass specimens made in the four versions are shown in Fig. 2.



a b

c d

Fig. 2. Appearance of cellular glass specimens
a – specimen 1; b – specimen 2; c – specimen 3; d – specimen 4.

Examining the four pictures in Fig. 2, it can be easily observed that the use of increasing weight proportions of both borax and $CaCO_3$ (according to the data in Table 1) led to changing in the macrostructural aspect of specimens. A structure characterized by low pore sizes corresponded to version 1 (5.9 wt. % borax and 1.7 wt. % $CaCO_3$), while a more coarse structure including much wider and less uniform pores corresponded to version 4 (9.5 wt. % borax and 2.6 wt. % $CaCO_3$).

The application of physical, thermal, mechanical, and morphological (microstructural) investigation methods of each cellular glass specimen has allowed the determination of their characteristics. The results are shown in Table 3.

Table 3

Characteristics of cellular glass specimens

Characteristic	Version			
	1	2	3	4
Apparent density ($g \cdot cm^{-3}$)	0.55	0.51	0.46	0.41
Porosity (%)	75.0	78.1	80.6	82.9
Heat conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	0.106	0.100	0.093	0.084
Compression strength (MPa)	4.2	6.0	4.3	4.0
Water-absorbing (vol. %)	0.7	0.9	1.1	1.1
Pore size (mm)	0.1-0.4	0.2-0.4	0.3-1.0	0.6-1.9

According to the data in Table 3, it was found that the characteristics indicating insulation properties (apparent density, heat conductivity, and porosity) have followed a relatively uniform downward slope, in the case of density (between 0.55-0.41 $g \cdot cm^{-3}$) and heat conductivity (between 0.106-0.084 $W \cdot m^{-1} \cdot K^{-1}$) and respectively, a uniformly increasing slope (between 75.0-82.9 %) in the case of porosity. An uneven evolution of the porous material property under the compression stress was noted. Thus, in the case of version 2 the highest compression strength value was reached (6.0 MPa), after which versions 3 and 4 recorded much lower values (4.3 and 4.0 MPa, respectively).

The explanation of this situation was investigated by also examining the microstructural aspect of cellular glass specimens shown in Fig. 3, in the context in which the content of borax has continued to increase as well as the content of $CaCO_3$.

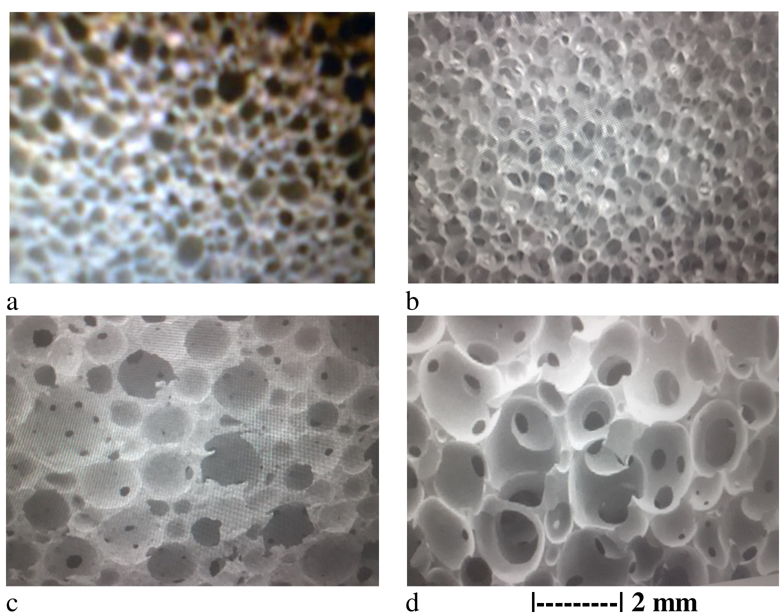


Fig. 3. Microstructural images of cellular glass specimen sections
a – specimen 1; b – specimen 2; c – specimen 3; d – specimen 4.

The cross-section of the four cellular specimens revealed that except for the specimen corresponding to version 1, all other specimens were characterized by microstructures also containing open pores together with closed pores. This type of microstructure represents the case where a cell communicates with other neighbouring cells by perforating the neighbouring wall or through connecting bridges. Usually, a microstructure with partially open pores favours the decrease of porous material apparent density, but at the same time its compression strength should significantly decrease, as it happens in the case of experimental versions 3 and 4. Versions 1 and 2, due to the lower content of $CaCO_3$ as an expanding agent, had fine microstructures, generally with closed pores, in which the formation of open pores was hardly possible. The purpose of the experiment, as noted above, aimed to determine the correlation between the amounts of borax, that contribute to increasing the mechanical strength of the foamed material and $CaCO_3$, that contributes to the pore-formation. Both addition materials had increasing amounts in the four versions. Analyzing the data in Table 3, it can be concluded that the specimen manufactured in version 2 with 7.1 wt. % borax and 2.0 wt. % $CaCO_3$ by sintering at 837 °C using partially direct microwave heating is the optimal version.

The thermal insulation properties of the optimal product were excellent (apparent density of 0.51 $g \cdot cm^{-3}$, heat conductivity of 0.100 $W \cdot m^{-1} \cdot K^{-1}$, and porosity of 78.1 %), while the compression strength reached a high value (6.0 MPa) for this cellular glass type. Water-absorbing was very low (0.9 vol. %) and the material pores were homogeneous and low (pore size between 0.2-0.4 mm). The manufacturing method chosen by authors proved to be fast, "clean", and economical, the specific energy consumption being determined by counting at 0.89 kWh/kg. Cellular glass produced in this way is suitable for the use as thermal insulation material in construction and recycling the residual glass for its manufacture solves both the acute global problem of wastes, as well as increasing the ceramic material resistance to fire, water, and the attack of rodents, insects, bacteria.

4. Conclusions

The work concerned the non-conventional manufacturing of cellular glass from recycled residual glass, combining the heat-insulating and mechanical properties of cellular products. Usually, obtaining low values of the apparent density and heat conductivity also leads to low values, inappropriate for construction applications, of the product compression strength. In general, the pore-providing agent is responsible for obtaining a porous structure. In the case of the current experiment, $CaCO_3$ was chosen for this purpose. The correlation between the amount of the pore-providing agent and the amount of the additive used to improve the mechanical strength (borax) was the challenge of this work. In parallel, the effect of the use of electromagnetic waves leading to energy efficiency increasing for the heating process was a method successfully applied in the last 7-8 years by the Romanian companies Daily Sourcing & Research and Cosfel Actual, although the world industrial producers are not yet interested in this heating mode. The work tested the manufacture of cellular glass under conditions of simultaneous increase in the content of borax and $CaCO_3$ within the limits of 5.9-9.5 wt. % and respectively, 1.7-2.6 wt. %. The fairly close results of the four experimental versions indicated that the optimal solution was that of using 7.1 % borax and 2 % $CaCO_3$, which provided the opportunity to reach the highest value of the compression strength (6.0 MPa) corresponding to the apparent density of 0.51 $g \cdot cm^{-3}$. Water-absorbing had very low values (0.9 vol. %) and also the pore size between 0.2-0.4 mm. The technical solution of using microwaves in the effective process of non-conventional heating for the manufacture of cellular glass has proven excellent and this fact has been recognized by specialists. The Romanian companies utilizing microwaves on a small scale intend to expand the capacity of the experimental equipment to values closer to those industrially required.

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Interior hydrants - approach

Hidranți interiori - mod de abordare

Florin BUMBAR[1], Remus RETEZAN [1], Adrian RETEZAN [2]

[1] SC SOMIAL CONSTRUCT SRL
Com. Dumbrăvița, Str. Petofi Sanor 1C, Jud. Timiș, Romania
E-mail: florin.bumbar@somial.ro, remus.retezan@somial.ro

[2] AIIR-Filiala Banat Timișoara, Romania
E-mail: adrian_retezan@yahoo.com

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Abstract. *The paper signals aspects regarding the functional efficiency of the interior fire hydrants provided by the whole water source, power supply network and the H_{ii} system/installation.*

Key words: interior hydrants fire range

1. Introduction

Burning [1], also called combustion [benga], is a chemical reaction with heat release (external) between a fuel (solid, liquid, gaseous) and air-oxygen from the air-(oxidizing agent), it can also be light generators (flame).

Fire is a self-maintained burning process, carried out without control (the case of burning controlled "guilty" by human development/progress, energy generator, but also by disputes at present). The causes of a fire, conditioned by the existence of a combustible material of an oxidizing agent (air practice) and a „surse" (external or own) triggering, the, can be (with reference to constructs):

a) Open fire supervised;
b) Of a technical nature - short circuits, cooking appliances, stoves, boilers, soldering appliances, cutting, welding, etc;
c) Self-ignition;
d) Natural (globular lightning);
e) Negligence (cigarettes, etc.).

All fires (regardless of their kind/type) are generating danger for:

a) Man, through burns, asphyxia, poisoning with the products of burning;
b) Environment, by pollution;

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c) Company, through the damages produced for individuals, legal entities, patrimony assets, etc.) due to fire, but also to the restoration/removal of the “tracks”, respectively to interventions.

Preventing fires is a general obligation [2], valid for all (from simple citizen to specialist and decision-making personnel) for all situations where the presence of the material was combustible, the oxidising agent and the trigger source are likely to be met. If, however, the fire is initiated, its extinguishing is the duty of all, depending on „position” of each and/or the duties they have.

2. Content of the paper/approach to the work

For buildings, fire prevention and control is from the moment of conception, respectively of the design to which the architect contributes by providing the functionality of the materials (depending on the destination), then the structurist by ensuring the strength and stabilization and finally (but not after all) the installer by predicting the types of installations and their operation mode, the, Their insurance involves a real collaboration between the three specialists, based on knowledge and compliance of the legislation, technologies and materials available and, only in the end, on the economic and financial aspect, having, constantly in view of the beneficiary/user, that is, the man.

The fire intervention methods are multiple, depending on the needs dictated by the destination and the functionality of the building and the combustible material and/or exposed to fire.

In the work is approached a particular case, that of the interior hydrants (combustible materials „enable”, as water extinguishing agent) to combat/extinguish fires. Fire (complex combustion process as progress and effects due to the factors that determine it) has an evolution characterized by the phases:

a) Initiation/occurrence of the outbreak;
b) A slow burning (smoldering);
c) Development („seize power”);
d) Intense/generalised/stabilised burning;
e) Regression/slow extinguishing.

Indoor hydrants are mainly used because water is used in the form of compact jet or spray jet, due to its large heat absorption capacity/reducing the temperature in the burning area and „choking” fire through „curtain” vapor created. The compact jet is used to dislodge some building elements thus isolating part of the building from flame/fire. The provision of installations with internal hydrants [3] is of limitations and localization, fire extinguishing, respectively cooling of the building elements, dilution and dispersion of hot smoke and flue gases) aiming at the protection of people, and, goods in the fire area, as well as intervention personnel.

3. Installations with internal hydrants

Construction/buildings and their fire compartments with their premises and facilities, classified according to fire safety scenarios, when in case of fire, the, water is allowed and the interior hydrants are considered, it is necessary to make/exist a specific system/installation.

Indoor fire-fighting installations with internal hydrants [4] can be:

a) Common to indoor cold water supply facilities, requiring the elimination of stagnation of water in the network by linking the oval end to a water consumer (sanitary object with frequent use, the, idem for an installation, or the creation of a fictitious/recircular consumer); the water source in this case is common, the public network or the own source (drilled well, etc.) of the building;

b) Separate/unique, the water source may be the public network, fire-fighting water tank (ensuring pumping operating pressure or, less often gravitational) – measures to avoid stagnation of water remain valid.

Basically, the fire-fighting installations with internal hydrants consist of:

a) Water supply network, branched, ring or mixed, fuction of concrete/objective situation;
b) Functional system of interior hydrants, which involves the establishment of:
c) (each consisting of connecting piece, tap, discharge hose, discharge pipe, hose winding hose reel, metal box/niche) taking into account the protected lens;
d) (set for known objectives in detail (including „space furnishing") or only „in principle" (with the possibility of change „ furnishing").

Obs. The H_{ii} number and the R range are taken into account and based on knowledge of situation plans and hydraulic characteristics, hydrant types, etc, that is, taking into account the combustibility characteristics of the materials requiring the number of simultaneous fire fighting/extinguishing jets, as well as the operating time.

The facilities with fire extinguishing/combating systems have as purpose:

- Preventing/preventing the onset of large fires;
- Ensuring the conditions for the rescue of persons and goods;
- Stopping propagation (protection) in adjacent spaces of incendiils.

The efficiency of the H_{ii} system shall be ensured also taking into account the functional ensemble – water source, network, indoor hydrant system.

The water source has its specific particularities.

- If the water source is public network, the pressure is not known, is „assumed" (value given „cover" by the water distributor);

When the water source is a water tank from which, by pumping, the internal hydrants are fed, the variation of the flow and pressure (in the end, the water supply, la H_{ii}) is influenced by the characteristics of the pump and the grid (the intersection of the two determines the finishing point). It is important to know how to ensure water in the tank.

The stagnation of water leads to the degradation of qualitative characteristics (physical, chemical, biological, bacteriological and organoleptic sensibles). For recirculation it is recommended to know the whole of the water consumers of the general objective (building, building etc.).

The network has its route „forced" of objective/beneficiary (arrangement of premises, space, the nature of the materials, equipment, installations, activities related to them and the size of the fire compartment can be branched, ring or mixed). Changes/changes (imposed to change the space destination) of the flow will proceed, as appropriate, to the corresponding modification of the parameters.

For the H_{ii} installation of special importance, in the functional context, it must be given to the determination of the range, defined by the length of the compact water jet and the horizontal protection of the length of the hose „unfolded" [5]. The length of the compressed jet is chosen/set according to the flammability and the calorific value of the materials that can generate the fire (not from the „generosity" the designer. Horizontal hose projection ($L_{fc}=\alpha L_f$; $\alpha=0{,}5\div0{,}9$; account shall also be taken of „obstacles" technology/furniture positioning).

Positioning/placement of the H_{ii} requiring two jets may have, depending on the size and shape of the protected fire space/compartment and its furnishing, solution:

a) in series or in doubling (Fig. 1)

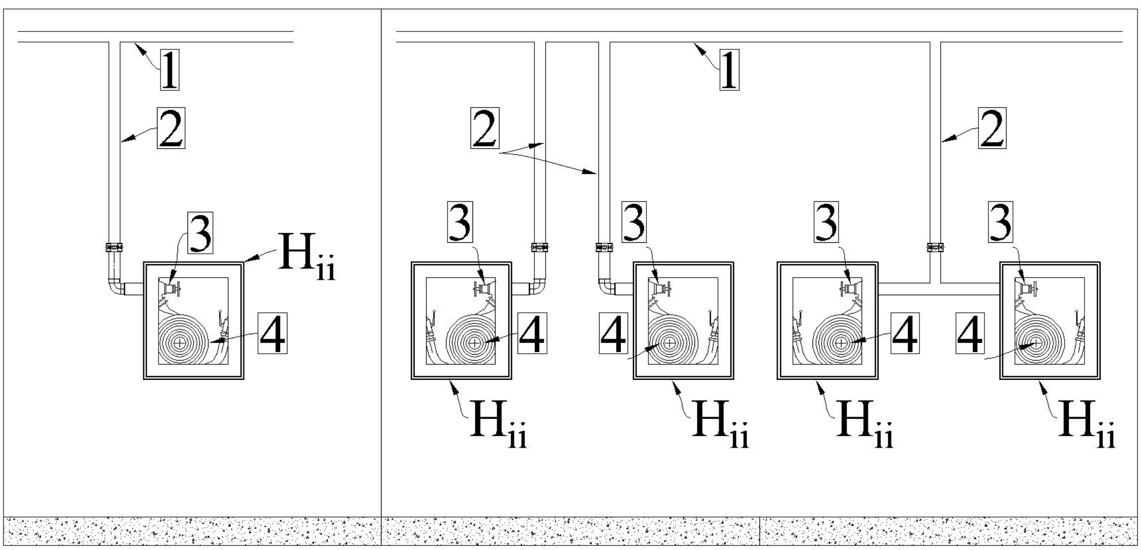

Fig. 1. Solution in series or in doubling
1-network/column; 2-connection; 3-valve; 4-hose

In the design it is indicated to take into account the most unfavorable situations and data, namely the type of interior hydrant (hose connection part, hose type – flat/semi-rigid – discharge pipe, the type of the interior hydrant (hose connection, the type of the hose flat/semi-rigid, specifying nominal diameters, minimum and maximum debits, minimum/working pressures, maximum/breaking), by researching the manufacturer's declaration of conformity (received from the certified distributor of products).

In case of interventions in existing networks (change of space destination and/or of the beneficiary with specific activities) there may be situations of changing the mounting position, a supplementing or reducing the number of H_{ii} and requiring a comparative analysis of the existing situation with the new one required, which will decide on the chosen variant (newly needed).

It is recommended to inform on the maintenance of the existing installation – maintenance, revisions, repairs [6].

4. Conclusions

The first and most important measure to combat fire is its prevention, In the case of buildings follows the rapid intervention of extinguishing/locating the fire by calling – as appropriate/endowment – to foam extinguishers or interior fire hydrants.

Preventing fires through measures/actions to prevent the initiation and spread of fire also means ensuring conditions for saving people and goods. The first step in fire prevention is made by the entrepreneur (be it how „simple”) followed by the designer and the executor of the building who must comply with the principles and regulations in force, helped by the certified bodies in whose duties are (and) market surveillance of equipment, installations, materials. The next step (maybe the most important) is fire prevention education, but also first intervention in case of outbreaks.

Interior hydrants, when they can be used, it is desired to provide the necessary extinguishing intensity, at the site of the fire, and, this is achieved through a well-defined functional system with a (safe) water supply network and a hydrant system that meets the requirements (number, number, range extinguishing flow) efficiency.

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Analysis of Phase Change Material in Room Wall for Thermal Regulation: A Computational Fluid Dynamics Approach

Analiza materialului cu schimbare de fază în peretele unei camere pentru reglarea termică: O abordare prin CFD

Cătălin-George POPOVICI[1], Emilian-Florin ȚURCANU[1], Vasilică CIOCAN[1], Nelu-Cristian CHERECHES[1], Sebastian-Valeriu HUDIȘTEANU[1], Ana Diana ANCAȘ[1], Marina VERDEȘ[1], Marius-Vasile ATANASIU[2], Dumitru Doru Burduhos NERGIS[3]

[1] Technical University "Gheorghe Asachi" of Iasi, Faculty of Civil Engineering and Building Services, Department Building Services, D. Mangeron 67 str., 700050, Romania;
[2] Technical University "Gheorghe Asachi" of Iasi, Faculty of Mechanical Engineering, Department of Mechanical Engineering and Road Automotive Engineering, D. Mangeron 67 str., 700050, Romania;
[3] Technical University "Gheorghe Asachi" of Iasi, Faculty of Materials Science & Engineering, Department of Technologies and Equipment for Materials Processing, D. Mangeron 67 str., 700050, Romania;

E-mail: florin-emilian.turcanu@academic.tuiasi.ro

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Abstract. *The integration of phase change materials (PCMs) into building structures has become a focal point for researchers aiming to enhance thermal comfort and energy efficiency in buildings. This comprehensive article delves into the analysis of PCMs embedded in room walls, emphasizing their role in thermal regulation and the innovative application of computational fluid dynamics (CFD) in evaluating their performance.*

Keywords: Phase Change Materials (PCMs), Thermal Regulation, Sustainable Building Design, Temperature Stabilization, Energy Conservation

1. Introduction

Phase Change Materials (PCMs) are innovative substances that play a pivotal role in energy storage and thermal management. By undergoing phase transitions, typically from solid to liquid or vice versa, these materials can absorb or release significant amounts of energy at predefined, consistent temperatures. This characteristic makes PCMs exceptionally effective in applications where temperature regulation and thermal energy storage are critical.[1]

One of the most compelling attributes of PCMs is their ability to undergo phase transitions at specific, predetermined temperatures. During the melting process, a PCM

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can absorb a substantial amount of latent heat without a significant increase in temperature. Such properties are invaluable in diverse applications, from medical heating pads that deliver controlled warmth to innovative cooling technologies for telecommunications infrastructure and even in advanced textiles designed for thermal comfort in bedding and clothing. [2]

The focus of this project is a computational investigation into the incorporation of PCMs within the structural fabric of buildings, specifically within a room's wall for enhanced thermal regulation. The model considers a square-shaped room, where one of the walls comprises a three-layered composite structure: Brick on the exterior, a layer of Trimethylolethane/water PCM blend, and Concrete on the interior.

The external brick layer is subjected to a constant heat flux of 100 W/m², simulating solar radiation or external thermal conditions. The selection of materials—Brick, Trimethylolethane/water PCM, and Concrete—is critical. Each has been chosen for its specific thermal properties, particularly their low thermal conductivity, which is essential for attenuating the rate of heat transfer and thus stabilizing the internal temperature. [3]

To analyze this system, the study employs a three-dimensional (3D) computational domain replicating a square room with dimensions of 3 meters per side, where each wall layer is uniformly 10 cm thick. The geometry for this simulation is meticulously crafted using Design Modeler software, establishing a precise framework for subsequent analysis. Ansys Meshing software facilitates the generation of a structured mesh grid across the domain, comprising 193,500 elements, ensuring detailed and accurate simulation results. [4]

This project aims to illuminate the potential of PCM-enhanced walls in moderating indoor temperatures, ultimately contributing to the fields of energy efficiency and sustainable building design. By harnessing the thermal inertia provided by PCMs, the study anticipates demonstrating a significant moderation of indoor temperature variations, offering a pathway to more energy-efficient and comfortable living and working environments. [5]

2. Material and method

Simulation Model

The core of our simulation hinges on the Solidification and Melting model, a sophisticated computational tool designed to accurately represent the phase change processes within the Phase Change Material (PCM). This model is adept at simulating the intricate energy exchange that occurs during the transition between solid and liquid states, providing a realistic depiction of PCM behavior within the wall structure. [Fig. 1]

Computational Approach

For the computational fluid dynamics (CFD) analysis, we employed a pressure-based solver, chosen for its effectiveness in handling incompressible fluid scenarios, which aligns well with the characteristics of the PCM in its liquid phase. The pressure-based solver is renowned for its robustness and accuracy in simulations where the fluid density remains relatively constant, which is pertinent to our study as we examine the thermal dynamics within the PCM-enhanced wall. [Fig. 1]

Time-dependent Analysis

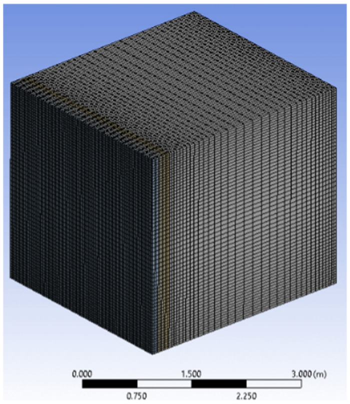
Understanding that the thermal interactions within the wall are inherently time-dependent, our simulation was conducted in a Transient mode. This approach allows us to capture the dynamic nature of the heat transfer and phase change processes over time, offering a detailed temporal resolution of the PCM's thermal response to external and internal temperature variations. [Fig. 1]

Gravitational Effects

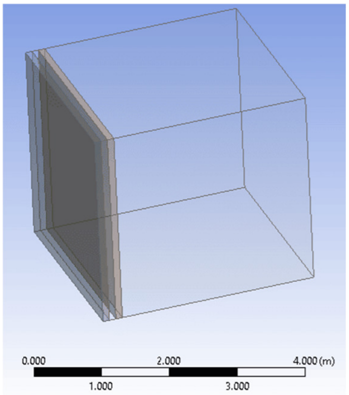
In the context of this simulation, the gravitational forces have been deemed negligible. This assumption is justified by focusing on the thermal interactions driven primarily by heat conduction and phase change phenomena rather than convective flows that would be significantly influenced by gravity.

Analytical Environment

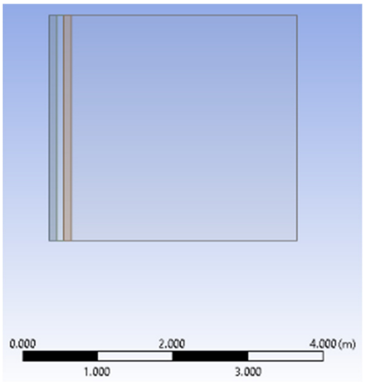
The simulation environment is meticulously configured to replicate the operational conditions to which the PCM wall would be subjected. The transient nature of the simulation demands a time-stepped approach, meticulously cataloging the evolution of temperature distribution and phase change progression within the PCM and adjacent materials. [Fig. 1]



a)



b)



c)

Fig. 1. a) Mesh, b) Geometry, c) Layer of PCM

3. Results

Interpreting Simulation Data Visualizations

The two-dimensional visualizations derived from our simulation offer an in-depth view of the thermal and fluid dynamics occurring within the wall structure, providing a solid foundation for our analysis. The detailed contours and vector fields that illustrate variables such as water pressure, temperature, turbulence kinetic energy, and fluid velocity allow us to comprehend the nuanced interactions between the wall components and the indoor environment. These visualizations are not merely graphical outputs; they are windows into the complex thermal behavior of the system, enabling us to correlate specific design choices with their thermal outcomes. [Fig. 2]

Analyzing PCM Performance

The finding that the Trimethylolethane/water PCM blend requires approximately six days to transition fully from solid to liquid phase is significant. This prolonged phase change duration is indicative of the material's substantial thermal storage capacity, a feature that is essential for its role in thermal regulation. Such a capability allows the PCM to act as a thermal buffer, absorbing heat when available and releasing it gradually, which is critical for reducing thermal shock and enhancing comfort levels within the building. [Fig. 2]

Understanding Temperature Dynamics

The gradual increase in interior temperature, despite external heat flux, underscores the effectiveness of the wall's multilayer composition in thermal resistance. The inherent low thermal conductivities of Brick, PCM, and Concrete are pivotal in this respect, minimizing heat ingress and stabilizing indoor temperatures. This aspect is particularly noteworthy because it suggests that the building's dependency on external heating or cooling can be substantially reduced, which is a direct indicator of improved energy efficiency. [Fig. 2]

Energy Storage and Strategic Release

The PCM's function as an energy reservoir is a cornerstone of our discussion. This ability to cyclically absorb and release energy equips the building with a form of passive temperature regulation, minimizing the need for active thermal control systems. In essence, the PCM wall acts autonomously, responding to thermal stimuli with minimal external intervention. This characteristic not only demonstrates the PCM's utility in energy conservation but also exemplifies a move towards more autonomous building thermal management systems. [Fig. 2]

Broader Implications for Energy Efficiency

The broader implications of our findings for building energy efficiency are profound. By integrating PCMs into building envelopes, we can potentially transform the way buildings interact with their thermal environment. The decrease in HVAC system dependency not only lowers energy consumption but also contributes to reducing peak load demands on energy infrastructure, which is vital for the sustainability of urban energy systems. Moreover, the implications extend beyond energy savings, affecting aspects such as building design, occupant comfort, and even architectural aesthetics.

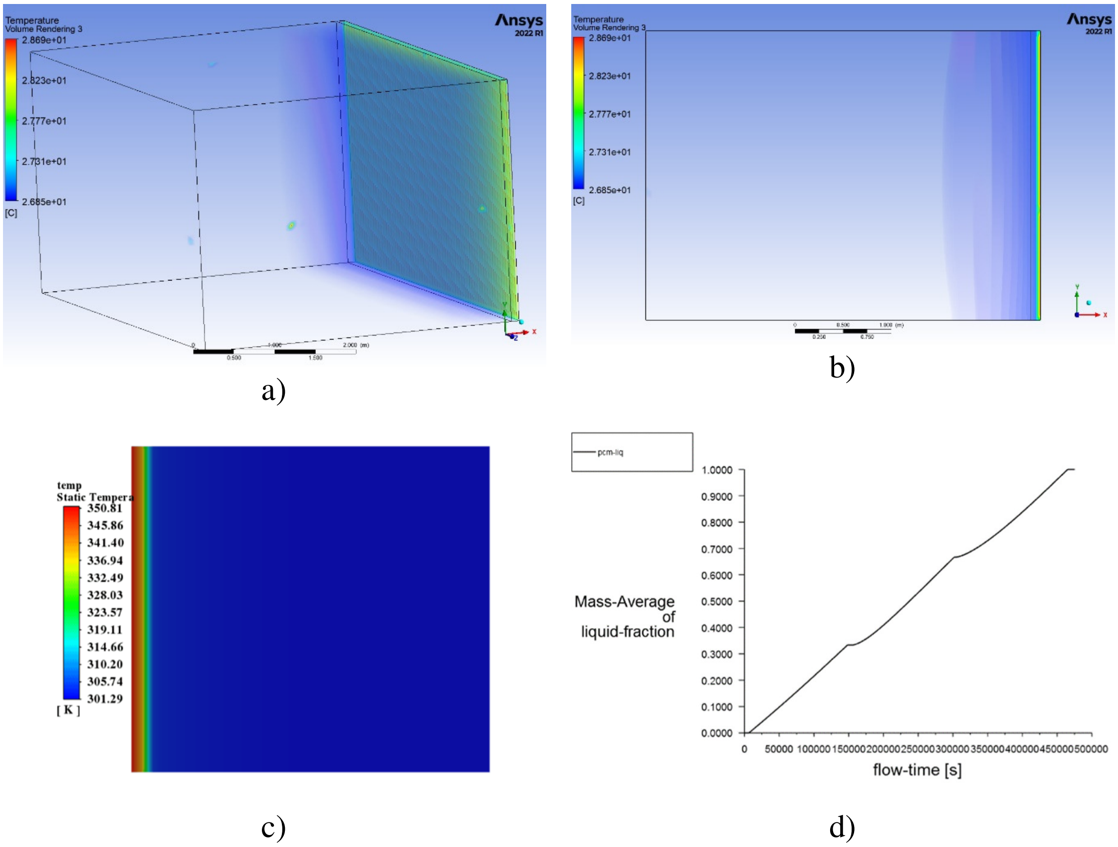


Fig. 2. a), b), c), d) Temperature contours and Mass-Average of Liquid-fraction

4. Discussion

The computational fluid dynamics (CFD) simulation offered a thorough investigation into the role of Phase Change Material (PCM) in enhancing building wall efficiency, focusing on how this material influences thermal regulation. Utilizing two-dimensional visualizations, the study illustrated the variations in water pressure, temperature, turbulence kinetic energy, and velocity, providing crucial insights into the thermal interactions facilitated by PCM integration within the wall. The simulation's significant revelation was the temporal aspect of the PCM's response to thermal inputs, showcasing that the Trimethylolethane/water blend needed around six days to achieve a complete phase transition from solid to liquid. This transition underscores the PCM's ability to store and later release thermal energy, thus stabilizing internal temperatures over extended periods and diminishing the impacts of external temperature changes.

The analysis spotlighted PCM's efficiency during high heat intake periods, demonstrating its capacity to evenly absorb and release heat, ensuring stable and comfortable indoor temperatures without constant mechanical intervention. This feature is particularly advantageous for maintaining uniform indoor climates and reducing energy dependency. The simulation also highlighted how the integration of low-conductive materials like Brick, PCM, and Concrete contributes to the building's thermal inertia, enhancing the insulation effect and preventing rapid temperature shifts.

By interweaving PCM into the building's fabric, the simulation validated a progressive strategy in architectural design, emphasizing material innovation combined with sophisticated simulation methodologies to confirm PCM's real-world applicability. This integration not only acts as a safeguard against thermal extremes but also fosters energy efficiency, offering dual benefits of improved indoor comfort and sustainability. The findings advocate for PCM's broader adoption in construction, heralding a step forward in achieving more energy-efficient and environmentally responsive building designs.

5. Conclusion

This study underscores the detailed simulation results furnish us with a deeper understanding of the practical applications and benefits of incorporating PCMs in building structures. They validate that PCMs can act as a key technological enabler for energy-efficient building design, offering a proactive solution to energy storage and thermal regulation challenges in modern construction practices.

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Lidar vs Thermal Camera: monitoring building energy losses - bibliographic review

Lidar vs Camera termică: monitorizarea pierderilor de energie în clădiri - studiu bibliografic

Floarea - Maria BREBU[1], Alina-Corina BĂLĂ[1], Cosmin-Constantin MUȘAT[1]

[1] University Politehnica Timişoara
Square Victoriei, no. 2, Timisoara, Romania
E-mail: floarea.brebu@upt.ro, alina.bala@upt.ro, cosmin.musat@upt.ro

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Abstract. *Today, energy efficiency plays a key role in achieving climate change targets. Globally, countries are trying to reduce emissions and provide renewable and sustainable energy resources. As most rely on non-renewable sources as their primary source of energy, it is important to adopt ways to be energy efficient with what is currently affordable [1]. In this article we present a bibliographical survey of the literature on this emerging topic, providing an in-depth study and analysis of works published over the last two decades. Within each research area, an overview of several recent applications of the use of two innovative technologies LIDAR and thermal camera is presented: regional classification of environmental data, providing relevant data needed for reporting the energy efficiency of a building, including the use of artificial intelligence algorithms.*

Key words: *LIDAR, thermal image, energy, losses, buildings*

1. Introduction

Energy efficiency plays a key role in achieving climate change targets. Globally, countries are trying to reduce emissions and provide renewable and sustainable energy resources. As most rely on non-renewable sources as their primary source of energy, it is important to adopt ways to be energy efficient with what is currently affordable [1]. In recent changes made by the European Union (EU) to the "Energy Performance of Buildings Directive" require buildings to be more energy efficient. on the new challenges of climate change and other global events [2].

These proposed goals can be achieved through innovative technologies that provide quick and simple energy inspection solutions [1]. Among these modern technologies that can help provide the relevant data needed to report the energy efficiency of a building are:

- LiDAR - Light Detection and Ranging is ideal for acquiring the accurate data needed for an energy efficiency report.

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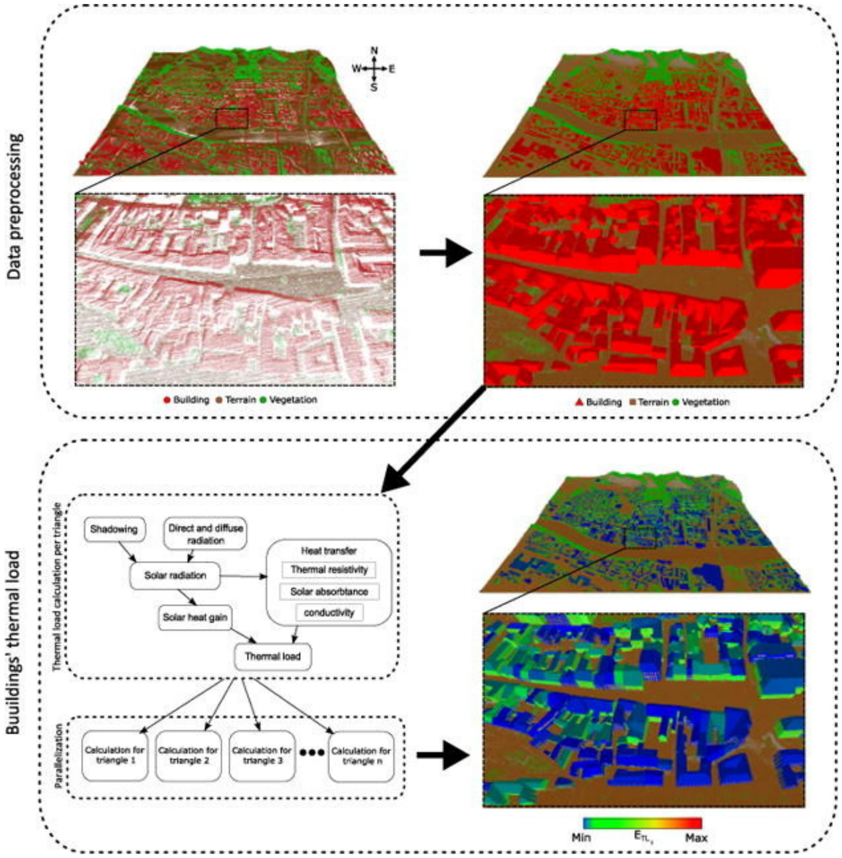

Fig. 1. Collection of thermal images using an infrared camera in the built environment [3]

• Thermal imaging - thermal imaging cameras detect thermal signals that highlight areas of heat loss, moisture penetration and insulation deficiencies.

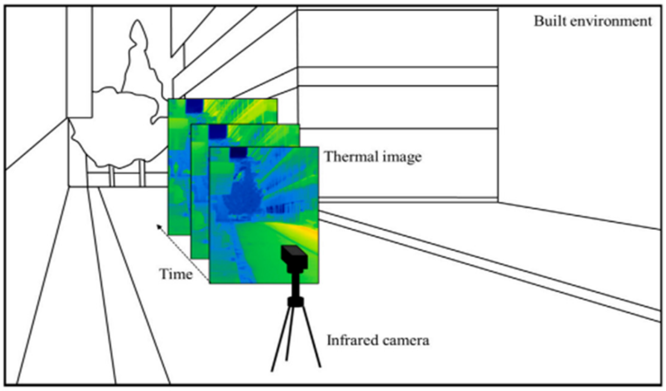

Fig. 2. Collection of thermal images using an infrared camera in the built environment [4]

In this literature review, we aim to conduct an analysis of energy loss monitoring in buildings using two innovative techniques, LIDAR, and thermal imaging. To know the extent of this research field, we searched the term "thermal comfort" in the electronic databases: Springer, Elsevier, Scopus, Scopus, reasarchgate.net, Web of Science, Crossref.

Thus, this literature search on this emerging topic will review some of the recent best practices in building energy efficiency using innovative technologies, considering the learning process and properties of these data for a complete understanding:

- How much progress has been made in monitoring building energy losses?
- What are some of the best practices in this regard?
- How can we process, access, manipulate and display the data?
- What are the opportunities for future research around spatially explicit energy loss efficiency?

2. Methodology and results

The literature selection in this research report started in a first step from the questions listed in the previous section, thus identifying that innovative LIDAR and Thermal Images technologies are future areas in the analysis, visualisation, and monitoring of buildings in terms of energy losses.

The bibliographical review conducted in this research report aimed to inform us about the problems that have been solved so far in terms of making buildings more energy efficient. This led to a bibliographic selection by keywords: lidar, thermal image, energy, losses, buildings, and published in databases such as: Springer, Elsevier, Scopus, reasarchgate.net, Web of Science, Crossref.

Also, for the selection of the bibliographical articles, it was considered that they must be published in peer-reviewed journals, be part of research projects in our proposed research area and present best practices in the literature.

Also, for the selection of bibliographical articles, it was taken into account that they should be published in peer-reviewed journals and present best practices from the literature.

Articles were selected that met the following criteria: published between 2017-2023, published in major journals or conferences on this emerging topic. Based on these criteria, 10 scientific articles were identified, detailed in Table 1. These literature studies were classified in Table 1 and according to the application problems solved in the field using the two technologies: lidar and thermal camera.

Table 1

Bibliographic review classification table

Item	Item from references	Article	Publications /Year	Information extracted in the research report
1.	3.	Directiva privind performanț a energetică a clădirilor	2021	• With the strive to reduce energy emissions, the EU has ambitions to be climate-neutral by 2050. One of the steps they have taken is to revise its Energy Performance of Buildings Directive (EPBD) for 2022/23. • The EPBD is legislation aimed at promoting improvement in the energy performance of buildings within the European Union.

Item	Item from references	Article	Publications /Year	Information extracted in the research report
				Previously, the target for renewable energy used by the EU was 32% by 2030. Efforts to cut emissions even further have led to a revision of that target to an ambitious 45%.
2.	4.	Large-scale estimation of buildings' thermal load using LiDAR data	Energy and Buildings Volume 231, 15 January 2021, 110626, https://doi.org/10.1016/j.enbuild.2020.110626	• The proposed method is performed in two stages. First, the LiDAR data and buildings' metadata are preprocessed to generate high-resolution 3D building models that are represented by a triangle mesh. Thermal load of buildings throughout the year is then calculated per-triangle in a parallelised manner, while considering local micro-climate and shadowing from surroundings. Parallel design of the estimation enables significant speed-up of large-scale workloads, while maintaining accurate shadowing estimation. • In experiments, the method was applied over a part of the city of Maribor, where heating and cooling loads were inspected in addition to other factors of thermal load estimation. Yearly thermal load calculation with an hourly time-step for 4,817 buildings with over 9.17 million triangles took about 8 min on a modern GPU.
3.	5.	Infrared thermography in the built environment: A multi-scale review	Renewable and Sustainable Energy Reviews Volume 165, September 2022, 112540, https://doi.org/10.1016/j.rser.2022.112540	• presents a review on major contributions in infrared thermography to study the built environment at multiple scales
4.	6.	An innovative approach to check buildings insulation efficiency using thermal cameras	Ain Shams Engineering Journal 13 (2022) 101740, https://doi.org/10.1016/j.asej.2022.101740	• introduces on-going research that develops a hybrid thermal LIDAR system for rapid thermal data measurement and 3D modeling of buildings, which will allow "virtual" representations for the energy and environmental performance of existing buildings. • This research aims to stimulate the decision makers to improve their buildings by providing reliable and visualized information of their building's energy performance using the developed hybrid thermal LIDAR system
5.	7.	Innovations in Building	Review of Infrared	• discusses the fundamental principles of infrared thermography, the different types of

Item	Item from references	Article	Publications /Year	Information extracted in the research report
		Diagnostics and Condition Monitoring: A Comprehensive	Thermography Applications. Buildings 2023, 13, 2829. https://doi.org/10.3390/buildings13112829	infrared approaches, and the condition monitoring of buildings using infrared imaging techniques. It also discusses research showing how infrared thermography has been applied to recognize and solve different building-related problems. • The article highlights the potential for infrared thermography to advance while also acknowledging its current limits. Infrared thermography is predicted to become an even more effective technique for building diagnostics with the development of more sensitive cameras and the incorporation of artificial intelligence.
6.	8.	Energy Efficiency Assessment for Buildings Based on the Generative Adversarial Network Structure	Eng 2023, 4, 2178–2190. https://doi.org/10.3390/eng4030125	• proposes a method for improving the accuracy of the measured outside temperature on buildings with different surrounding parameters, such as air humidity, external temperature, and distance to the object. • A model was proposed for improving thermal image quality based on KMeans and the modified generative adversarial network (GAN) structure. It uses a set of images collected for objects exposed to different outside conditions in terms of the required weather recommendations for the measurements.
7.	9.	Quantification of heat energy losses through the building envelope: A state-of-the-art analysis with critical and comprehensive review on infrared thermography	Building and Environment Volume 146, December 2018, Pages 190-205, https://doi.org/10.1016/j.buildenv.2018.09.050	• This study starts from the common approaches for the U-value evaluation (analogies with coeval buildings, the calculation method, the *in-situ* measurements and the laboratory tests), with the underlying standard procedures and the most important advantages, problems, and potential sources of errors defined by the literature
8.	10.	Visualising urban energy use: the use of LiDAR and remote	Visualization in Engineering (2017) 5:22 DOI 10.1186/s403	• Authors explores the potential for using remotely sensed data from a combination of commercial and open-sources, to improve the functionality, accuracy of energy-use calculations and visualization of carbon emissions.

Item	Item from references	Article	Publications /Year	Information extracted in the research report
		sensing data in urban energy planning	27-017-0060-3	• Paper presents a study demonstrating the use of LiDAR (Light Detection and Ranging) data and aerial imagery for a mixed-use inner urban area within the North - East of England and how this can improve the quality of input data for modelling standardized energy uses and carbon emissions.
9.	11.	Thermal image building inspection for heat loss diagnosis	IOP Conf. Series: Journal of Physics: Conf. Series 1297 (2019) 012004 IOP Publishing doi:10.1088/1742-6596/1297/1/012004	• Article presented thermal imaging inspection for building applications it is powerful and non-invasive method for monitoring and diagnosing the condition of buildings. With a thermal imaging camera, you can identify problems early.
10.	12.	Thermographic methodologies used in infrastructure inspection: A review—Post-processing procedures	Applied Energy Volume 266, 15 May 2020, 114857, https://doi.org/10.1016/j.apenergy.2020.114857	• In this work, an exhaustive review is performed regarding the most recent and important practical thermographic procedures for infrastructure applications, focusing on the post-acquisition stage, due to the lack of an in-depth analysis regarding the most recent and used algorithms.
11.	13.	LiDAR point-cloud mapping of building façades for building energy performance simulation	Automation in Construction, Volume 107, November 2019, 102905, https://doi.org/10.1016/j.autcon.2019.102905	• introduces a semi-automated BEPS input solution for existing building exteriors that can be integrated with other related technologies (such as BIM or CityGML) and deployed across an entire building stock.

In the following we will summarize from the most relevant articles presented in Table 1, the most relevant applied research in terms of the progress of infrared thermography and LIDAR systems in terms of technical analysis for building energy performance diagnosis and the incorporation of artificial intelligence algorithms. Within each research area that will be presented below, we will discuss the major features that are relevant to building energy loss monitoring, including, key challenges regarding the

accessibility and reliability of the information recorded by the two techniques LIDAR and thermal camera.
A review of the main contributions of infrared thermography to the study of the built environment at several scales are presented by the authors in paper 4. From the classification, most of the studies reviewed have been carried out to assess the thermal performance of buildings or to detect building defects using images collected by an infrared camera [4].

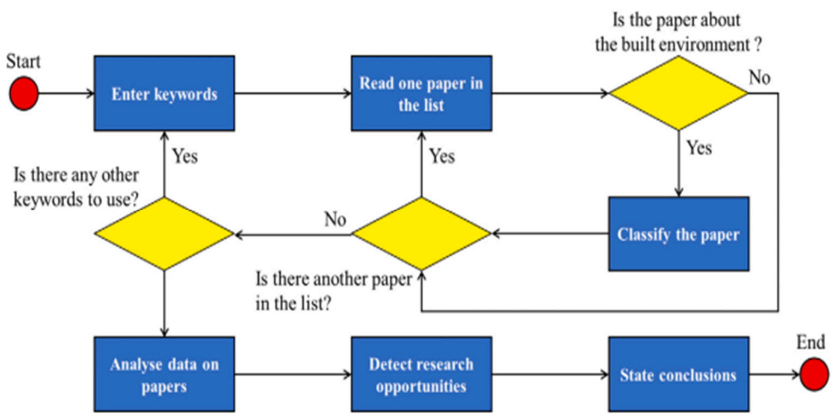

Fig. 3. Workflow used to review papers on infrared thermography for the built environment. [4]

Finally, the authors propose to monitor a city's energy consumption and improve its sustainability that thermal images be integrated into Internet-of-Things and digital twin platforms [4].

Future directions for the use of thermography in buildings are presented in Articles 5 and 6. The authors present the innovation side of thermography in terms of energy efficiency by identifying thermal leaks and insulation deficiencies, contributing to specific retrofit efforts, and thus reducing energy consumption and greenhouse gas emissions [5], [6]. In contrast to the other literature studies, the authors of paper 7 propose a method to improve the accuracy of outdoor temperature measured on buildings with different environmental parameters, such as air humidity, outdoor temperature, and distance to the object. A thermal image quality improvement model based on KMeans and modified generative adversarial network (GAN) structure has been proposed. This method improves the diagnosis of thermal deficiencies in buildings [7].

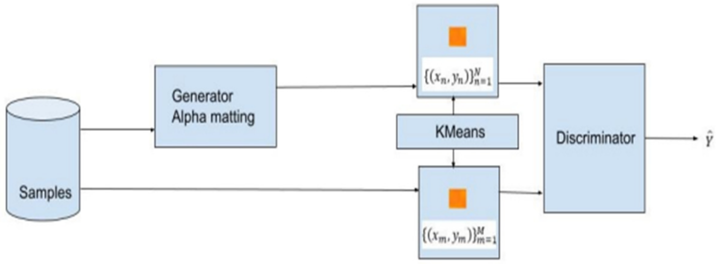

Fig. 4. Schematic representation of an adapted GAN. [7]

The SEMANCO project presented by the authors in Article 9, was developed to convert LIDAR datasets into accurate and consistent urban data to be used in COBie-compliant BIM tools, as well as specific energy-related information fields, to achieve an energy-related ontology (Corrado et al., 2015). This is achieved by creating a formal vocabulary according to the Ontology Web Language specification to assess the energy performance of an urban area [9].

Fig. 5. Developed SEMANTIC tool for Urban Energy Model [9]

3. Discussion

In this research, thermal imaging and LIDAR inspection for building applications are powerful and non-invasive methods for building condition monitoring and diagnosis. Through these methods, heat loss through the building surface is exemplified, in conjunction with heat loss calculation, provides a technical and economical solution to the problem of thermal discomfort in buildings. The different thermal behaviour between defects and undamaged areas allows the detection and thermal characterisation of surface and subsurface defects, which must be considered when maintaining a structure in optimal conditions. Infrared thermography and LIDAR technology are among the most suitable non-destructive techniques to measure these thermal behaviours, represented on temperature maps of the infrastructure analysed by thermal imaging, regardless of the size of the structure. In addition, they are also used for thermal characterization of structures for such important purposes as the energy study of buildings [10].

In the bibliographical studies, an exhaustive analysis is carried out on the most recent and important practical thermographic procedures for infrastructure applications, focusing on the post-procurement stage, due to the lack of an in-depth analysis on the most recent and widely used algorithms. Specifically, the theoretical side of these thermal image processing techniques are described, classifying them according to the corresponding theoretical post-acquisition approach used: qualitative and/or quantitative analysis [11].

4. Conclusions

So, we can conclude that thermography and LIDAR technology are useful methods for monitoring building energy losses because they are non-contact, two-dimensional and three-dimensional and real-time information is obtained to monitor the energy performance of buildings.

In contrast to existing approaches, the open research possibilities presented in this paper enhance the use and manipulation of neighbourhood energy analysis and integration with other visualization tools allows unfamiliar users to access customized and versatile information [9].

In addition, the trend of performance improvement in thermal image processing algorithms and LIDAR technology seems to continue a positive trend for the coming years by including artificial intelligence algorithms.

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Stability Criteria in Plant Structures

Criterii de stabilitate în structurile plantelor

Houssam KHELALFA[1,2*], Khaoula KHELALFA[3]

1. *Civil Engineering and Environment Laboratory (LGCE), University of Jijel, Jijel, Algeria*
2. *Faculty of Engineering and Technology, Selinus University of Science and Literature (SUSL), Bologna, Italy.*
3. *University of Mentouri Brothers, Department of Biochemistry and Cell and Molecular Biology, Faculty of Nature and Life Sciences, BP, 325 Ain El Bey Road, Constantine, Algeria*

Corresponding email address: khelalfahoussam@gmail.com

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Abstract:
This article explores the intricate relationship between plant structure and stability, shedding light on the fundamental aspects that enable plants to withstand environmental forces and maintain an upright position. Delving into the realms of geotechnical biology, we dissect the genetic, environmental, and biological influences shaping plant structures. From the physical perspective, we examine how plant structures facilitate water absorption, nutrient transport, and resistance to environmental stress. Emphasizing the crucial role of root systems in anchoring and providing stability, we navigate through the evolutionary adaptations of different plant structures in response to varying environmental conditions. The concept of stability is elucidated, encompassing factors such as root structure, stem strength, flexibility, and biomass distribution. The influence of growth environment, including soil composition and moisture levels, on plant stability is highlighted, alongside the importance of external factors like wind, rain, and animal activities. The article concludes by emphasizing the need for a multidisciplinary approach, involving insights from plant biology, geotechnical engineering, and structural mechanics, to enhance the stability and resilience of plant structures.

Keywords: Geotechnical Biology, Bio-Inspired Geotechnics, Plant, Soil, Equilibrium System, Safety Factor (SF)

1. Introduction

The field of Bio-Inspired Geotechnics offers a new and innovative approach to understanding and solving geotechnical challenges, by exploring the solutions found in nature [1-3]. However, Bio-Inspired Geotechnics only represents one aspect of the geotechnical coin, as a more comprehensive understanding of geotechnical challenges can be achieved through the integration of geotechnical knowledge and biological inspiration. The other side of the coin is represented by Geo-Interaction Biology, which sheds light on the interplay between geotechnical and biological systems and

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the impact this interaction has on geotechnical challenges. By combining both perspectives, we can gain a more comprehensive understanding and develop innovative, sustainable solutions. Uncovering both sides of the geotechnical coin is crucial in making meaningful progress in both fields.

Plants play a pivotal role in slope stability [4-8] and contribute significantly to the delicate balance of biological ecosystems [9-11]. Recognizing their importance in preventing soil erosion and enhancing environmental resilience has been a focal point in previous botanical literature [12-18]. Extensive research has delved into the intricacies of plant biology, exploring genetic, environmental, and growth-related factors that shape various plant structures [19-38]. While this body of knowledge has enriched our understanding of plant life processes, the specific role of plants in geotechnics and environmental biology, particularly their stability factors, remains a critical frontier. However, the application of this knowledge in the context of slope stability and environmental biology introduces a new dimension. The stability of plants, including factors such as root structure, stem strength, and flexibility, emerges as a critical consideration in geotechnical engineering. Understanding how plants resist mechanical stresses becomes imperative not only for assessing slope stability but also for comprehending their broader ecological impact.

This article aims to bridge the gap between botanical studies and the practical implications of plant stability in geotechnics and plant biology. By exploring the intricate interplay between plant structures and their ability to withstand external forces, we seek to inspire transformative advancements in both scientific understanding and practical applications. The discussion will navigate through the multifaceted landscape of geotechnical biology [39], shedding light on the urgency of addressing environmental concerns through interdisciplinary collaborations and innovative strategies.

2 Plant Structure and Stability:

Plant structure refers to the physical arrangement of tissues and organs in a plant, including roots, stems, leaves, flowers, and fruits. These structures play important roles in the survival, growth, and reproduction of the plant. From a physical perspective, plant structure affects the plant's ability to absorb water and nutrients, transport materials, and withstand environmental stress [40]. For example, roots absorb water and nutrients from the soil, stems transport water and nutrients from the roots to the leaves, and leaves use light energy to produce food through photosynthesis. From a biological perspective, plant structure is important because it provides the plant with support and allows it to perform its life processes [41]. The root system provides anchor and stability to the plant, while the stem provides structural support and the leaves perform photosynthesis. Flowers and fruits attract pollinators and disperse seeds, allowing the plant to reproduce. From an evolutionary perspective, plant structure has evolved over time to optimize the plant's ability to survive and reproduce in its environment. Different plant structures have evolved in response to different environmental conditions, such as light availability, water availability, and herbivore pressure.

Stability of plants refers to the ability of a plant to maintain its upright position and resist falling over or being toppled by external forces such as wind, rain, or animals. There are several factors that contribute to a plant's stability, including its root structure, stem strength and flexibility, and the distribution of its leaves and branches [42]. A plant's stability can be influenced by its growth environment, including soil type and composition, moisture levels, and light conditions. A plant that is not stable may lean or bend, which can affect its growth and health. In some cases, an unstable plant may require staking or support to prevent it from falling over. Unstable plants may also be more susceptible to damage from wind, rain, or animal activity. To maintain plant stability, it is important to consider factors such as soil structure and fertility, light availability, and water management. Additionally, regular pruning and proper training can help promote stability and improve the overall health and appearance of the plant.

3. Concepts of Stable and Unstable Equilibrium System:

In the context of equilibrium systems, there are several types of instability that can occur. These instabilities arise when the equilibrium state of a system is perturbed, leading to a loss of stability and potentially causing the system to deviate from its original state. The different types of instability include [43, 44]:

- ✓ **Static instability:** This type of instability occurs when a small disturbance or perturbation causes a system to move away from its equilibrium position. In static instability, the system is unable to return to its original equilibrium state even after the perturbation is removed. An example of static instability is a vertical column that buckles or collapses under a compressive load.
- ✓ **Dynamic instability:** Dynamic instability refers to the loss of stability in a system due to the amplification of small disturbances over time. It occurs when the response of the system to an external perturbation becomes increasingly divergent or chaotic. An example of dynamic instability is the fluttering or oscillation of a flag in response to wind.
- ✓ **Hopf bifurcation:** Hopf bifurcation is a type of instability that occurs in dynamic systems characterized by oscillatory behavior. It occurs when a system transitions from a stable periodic orbit to a stable limit cycle as a parameter crosses a critical value. Hopf bifurcation leads to the emergence of sustained oscillations or limit cycle behavior in the system.
- ✓ **Saddle-node bifurcation:** Saddle-node bifurcation is a type of instability that occurs when a system undergoes a sudden and irreversible change in its stability. It happens when a stable equilibrium point collides with an unstable equilibrium point and ceases to exist. This results in the creation or destruction of equilibrium points in the system.
- ✓ **Pitchfork bifurcation:** Pitchfork bifurcation is another type of instability that occurs in dynamic systems. It involves the splitting or merging of equilibrium points as a system's parameters change. Pitchfork bifurcation can lead to the emergence of multiple stable equilibrium states or the disappearance of stable equilibrium states.

Understanding the different types of instability is important in various fields of study, including physics, engineering, and biology. It allows researchers to analyze the behavior of complex systems, predict their response to perturbations, and develop strategies to maintain stability or induce desired changes.

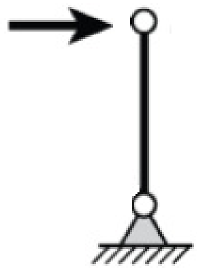

Figure 1: Determinacy of Plant Equilibrium System.

In the context of plants, stable and unstable equilibrium states refer to the balance or imbalance between the external forces acting on a plant and the internal forces generated within the plant's structure (figure 1). A plant can be considered similar to a structural column, where the equilibrium state represents the balance between the stabilizing and destabilizing forces.

The stable equilibrium state of a plant occurs when the combined effect of the internal and external forces maintains the plant in a balanced position. In this state, the plant remains upright and structurally sound, with the internal forces (such as the root system and stem strength) effectively countering the external forces (such as gravity, wind, or other external loads). The plant is able to withstand these forces and maintain its position without significant deformation or failure.

On the other hand, the unstable equilibrium state of a plant occurs when the external forces acting on the plant exceed its internal stabilizing forces. This results in an imbalance that can lead to the plant losing its upright position and potentially collapsing or experiencing structural failure. Factors such as strong winds, heavy rain, or animal activities can disrupt the equilibrium and push the plant into an unstable state.

To ensure the stability of a plant, it is important to consider both the internal and external factors that affect its equilibrium. The structural properties of the plant, including its root system, stem strength, and overall architecture, contribute to its ability to maintain stability. Additionally, understanding and mitigating the impact of external forces, such as wind or excessive loading, can help prevent the plant from reaching an unstable state.

By studying the stable and unstable equilibrium states of plants, we can gain insights into their structural behavior and develop strategies to enhance their stability. This knowledge is vital for various applications, including plant engineering, landscaping, and ecological conservation, as it allows us to design and manage plant systems that can withstand external forces and maintain their structural integrity.

4. Structure and Stability of Plants:

Structure and stability are key aspects of plants' physical characteristics and play a crucial role in their ability to withstand environmental forces and maintain an upright position.

Structure refers to the **arrangement** and organization of the different **parts of a plant**, including roots, stems, leaves, and flowers. It encompasses the overall architecture and **spatial distribution** of plant components. The structure of a plant is influenced by **genetic factors**, **environmental conditions**, and **growth patterns**. These structures play important roles in the survival, growth, and reproduction of the plant. From a physical perspective, plant structure affects the plant's ability to absorb water and nutrients, transport materials, and withstand environmental stress [45]. For example, roots absorb water and nutrients from the soil, stems transport water and nutrients from the roots to the leaves, and leaves use light energy to produce food through photosynthesis. From a biological perspective, plant structure is important because it provides the plant with support and allows it to perform its life processes [46]. The root system provides **anchor** and stability to the plant, while the stem provides **structural support** and the leaves perform photosynthesis. Flowers and fruits attract pollinators and disperse seeds, allowing the plant to reproduce. From an evolutionary perspective, plant structure has evolved over time to optimize the plant's ability to survive and reproduce in its environment. Different plant structures have evolved in response to different environmental conditions, such as light availability, water availability, and herbivore pressure.

Stability, on the other hand, refers to the **ability** of a plant to **resist mechanical stresses**, such as **wind**, **gravity**, or **external forces**, **without collapsing** or losing its **integrity**. It is closely related to the strength and rigidity of the plant's structural elements. There are several factors that contribute to a plant's stability, including its root structure, stem strength and flexibility, and the distribution of its leaves and branches [47]. A plant's stability can be influenced by its growth environment, including soil type and composition, moisture levels, and light conditions. A plant that is **not stable may lean or bend**, which can affect its growth and health. In some cases, an unstable plant may require staking or support to prevent it from falling over. **Unstable plants** may also be more susceptible to **damage** from wind, **rain**, or **animal activity**. To maintain plant stability, it is important to consider factors such as soil structure and fertility, light availability, and water management. Additionally, regular pruning and proper training can help promote stability and improve the overall health and appearance of the plant. These factors Could summarized as following:

✓ **Stem and Root Strength:** The mechanical properties of stems and roots, such as their **rigidity**, **flexibility**, and **resistance to bending** or breaking, directly impact the overall stability of the plant. The structural strength of stems and roots is influenced by factors such as tissue **density**, fiber arrangement, and lignification.

✓ **Tissue Elasticity:** Elasticity refers to the ability of plant tissues to deform under stress and return to their original shape once the stress is removed. Elastic tissues help absorb and dissipate mechanical forces, enhancing the plant's stability. The elasticity of plant tissues is influenced by factors such as cell wall composition, water content, and structural arrangement.

- ✓ **Biomass Distribution:** The distribution of biomass within a plant affects its stability. A well-balanced distribution of biomass, with sufficient mass in both above-ground and below-ground parts, helps maintain stability and prevents toppling or uprooting.
- ✓ **Root-Soil Interaction:** The interaction between roots and soil plays a critical role in plant stability. Roots anchor the plant in the soil and provide mechanical support. The strength and extent of root anchorage depend on factors such as root architecture, root diameter, root penetration depth, and soil characteristics.

5. Criteria of Plant Structure

Stability of plant structure may described as the power to recover equilibrium or Resistance to sudden change, dislodgment, or overthrow. Moreover, a stable structure shall remain stable for any imaginable system of loads. The stability of a structure is of the following types:

- ✓ **External Stability;** For a structure to be externally stable, the reactive forces should be non-parallel & non-concurrent.
- ✓ **Internal Stability;** An internally unstable system can change its shape without any deformation of its members.

It is necessary to establish stability criteria in order to answer the question of whether a structure is in stable equilibrium under a given set of loadings. Stability theories are formulated in order to determine the conditions under which a structural system, which is in equilibrium, ceases to be stable. More generally the following should be determined:

- ✓ the equilibrium configurations of the structure under prescribed loadings.
- ✓ which amongst these configurations are stable.
- ✓ the critical value of the loadings and what behavioural consequences are implied at these load levels.

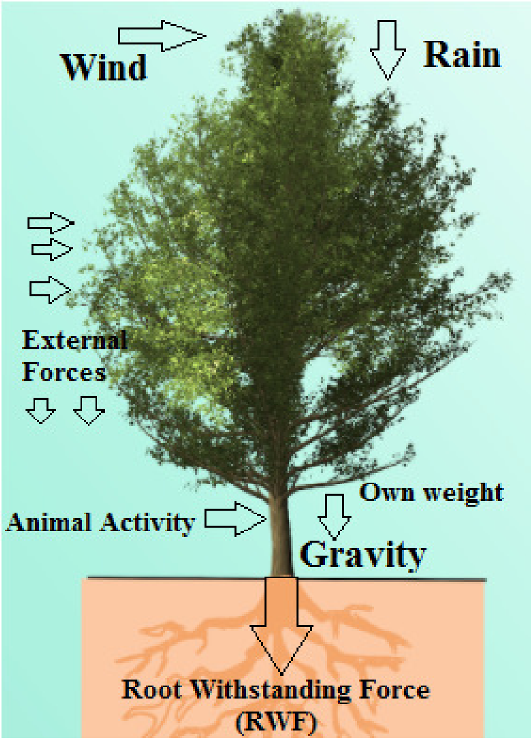

Figure 2: Forces Influencing Plant Stability: Internal and External Factors.

In the figure (2), we present the main internal and external forces/stresses that contribute to the stability of a plant. The stability of a plant is determined by the balance between stabilizing forces, such as gravity and root withstanding force (RWF), and destabilizing forces, including wind, rain, animal activities, and other external forces.

Gravity is a fundamental force that acts vertically downward, exerting a stabilizing effect on the plant by keeping it firmly rooted in the ground. The weight of the plant's structure and biomass contributes to its stability, preventing it from toppling over.

Root withstanding force (RWF) is another crucial internal force that provides stability to the plant. Roots anchor the plant in the soil, resisting the overturning forces caused by wind and external disturbances. The strength and extent of root anchorage directly influence the plant's ability to withstand these destabilizing forces.

On the other hand, external forces such as wind, rain, other external forces and animal activities can pose challenges to plant stability. Wind exerts horizontal forces on the above-ground parts of the plant, potentially causing swaying or bending. Rainfall, especially during heavy downpours, can increase the weight of the foliage and induce bending or even uprooting. Animal activities, such as grazing or digging, can disrupt the root system and compromise stability.

Understanding the interplay between these internal and external **forces** is crucial for assessing and enhancing plant stability (**Equation. 1**). By considering the balance (**SF**) between **stabilizing** and **destabilizing** forces, researchers and practitioners can develop strategies to promote plant stability, optimize root systems, and mitigate the risks associated with external forces.

$$\mathbf{SF} = \frac{\sum \textbf{stabilizing forces}}{\sum \textbf{destabilizing forces}} \quad \textbf{(1)}$$

If ; **SF >1;** Stable System,

If ; **SF< 1**; Unstable System.

In the equilibrium system of a plant structure, there are several potential instability failures that can occur. These include:

- ✓ **Buckling:** Buckling can also occur in plant structures, particularly in tall and slender plant parts such as stems or branches. When subjected to excessive compressive forces, these plant elements can buckle, resulting in a loss of stability and structural failure.
- ✓ **Breakage:** Breakage refers to the failure of plant parts due to excessive tensile or shear forces. It can happen when the applied forces exceed the strength or structural integrity of the plant tissues, causing them to fracture or snap.
- ✓ **Uprooting:** Uprooting is a common instability failure in plants with extensive root systems. It occurs when the anchoring roots are unable to withstand external forces such as wind or water flow, leading to the uprooting of the entire plant from the soil.
- ✓ **Tipping:** Tipping refers to the tilting or leaning of a plant due to unbalanced forces acting on it. This can happen when the weight distribution of the plant or the external forces applied to it are not evenly distributed, causing the plant to lose its vertical stability and tip over.
- ✓ **Collapsing:** Collapsing occurs when the overall structural integrity of the plant is compromised, leading to a sudden collapse or failure of the entire plant structure. This can happen due to a combination of factors, such as weak stem or root structure, excessive loads, or external disturbances.
- ✓ **Collapsing**, **Sliding**, **Overturning**, **Planar Slip**, **Circular Slip** and **Settlement**: These failure modes involve the overall instability or movement of the plant-soil system. They can occur when the soil's strength or stability is compromised, leading to soil failure and subsequent plant movement or collapse. Geotechnical analysis methods, such as limit equilibrium analysis, slope stability analysis, or numerical modeling techniques, can be used to assess the risk of these failure modes. Factors considered include soil properties, such as shear strength and cohesion, as well as external loads, soil water content, and the plant's weight and geometry.

These instability failures can be influenced by various factors, including environmental conditions (such as wind, rain, or soil properties), plant growth stage, structural design, and the mechanical properties of plant tissues. Understanding these failure modes and their underlying causes is essential for plant biologists and engineers to develop strategies for enhancing the stability and resilience of plant structures. It's important to note that the design and calculation of these failure modes require a multidisciplinary approach, combining knowledge from plant biology, geotechnical engineering, and structural mechanics. Field observations, laboratory testing, and numerical simulations can help in quantifying the factors involved and evaluating the stability and safety of the plant-soil system.

6. Conclusion:

In conclusion, this article has provided a detailed examination of the stability criteria in plant structures, unraveling the complexities that govern their ability to resist mechanical stresses and maintain equilibrium. From the fundamental principles of plant structure to the factors influencing stability, we have traversed the interdisciplinary landscape of geotechnical biology. Understanding the internal and external forces contributing to plant stability, along with the potential instability failures, is essential for both plant biologists and engineers. The multidisciplinary approach involving plant biology, geotechnical engineering, and structural mechanics is crucial for designing strategies that enhance the stability and resilience of plant structures. By gaining insights into the stable and unstable equilibrium states of plants, we can contribute to advancements in plant engineering, landscaping, and ecological conservation, ensuring the sustainable and robust growth of plant systems in diverse environments.

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Challenges and advantages in recovering waste energy from flue gases from biomass boilers

Provocări și avantaje în recuperarea energiei reziduale din gazele de ardere de la cazane cu funcționare pe biomasă

Daniel BISORCA[1], Adriana TOKAR[1], Danut TOKAR[1], Daniel MUNTEAN[1]

[1]University Politehnica Timișoara
Square Victoriei, no.2, Timișoara, România
E-mail: daniel.bisorca@upt.ro, adriana.tokar@upt.ro, danut.tokar@upt.ro, daniel-beniamin.muntean@upt.ro

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Abstract. *Currently, the burning of biomass for energy purposes is carried out with a low yield due to the fact that the chimney emits hot gases into the atmosphere that have a residual energy potential that can be used for energy purposes. The political context of the European Union and the ambitions to solve the problem of greenhouse gas emissions, relaunch new challenges both for the research community and for equipment manufacturers to offer viable solutions to increase the energy efficiency of plants that use biomass for energy purposes.*

Key words: Biomass flue gas recovery system, flue gas purification system, energy efficient biomass boiler

Rezumat. *În prezent, arderea biomasei in scop energetic se realizeaza cu un randament scazut datorita faptului ca pe cosul de fum sunt emise in atmosfera gaze fierbinti care au un potential de energie reziduala posibil a fi folosita in scop energetic. Contextul politic al Uniunii Europene si ambitiile pentru solutionarea problemei emisiilor gazelor cu efect de sera, relanseaza noi provocari atat pentru comunitatea cercetatorilor cat si pentru producatorii de echipamente pentru oferirea de solutii viabile pentru cresterea eficientei energetice a instalatiilor care folosesc biomasa in scop energetic.*

Cuvinte cheie: Sistem de recuperare a gazelor de ardere din biomasă, sistem de purificare a gazelor arse, cazan de biomasă eficient energetic

1. Introduction

Considering the ambitious objectives of the European Union to reduce greenhouse gas emissions, in addition to the first step that must be taken, namely the attempt to use renewable energy sources, it is also necessary to try to increase the efficiency of combustion plants by using energy which until now was considered as residual energy and was discharged into the atmosphere in the form of hot gases [1], [2].

The article presents the issues that need to be solved for the sustainable and efficient use of waste energy from the flue gases of current biomass burning plants.

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The article also presents the major advantages of using mixed systems for the recovery and purification of combustion gases resulting from the combustion of biomass. This is particularly important for the energy utilization of biomass grown on former industrial lands that have been contaminated over time with various materials resulting from industrial, mining or energy processes.

2.Theoretical notions regarding the technological challenges and advantages resulting from the recovery of residual energy from combustion gases from boilers operating on biomass

The main problem of plants that capitalize on the energy potential of biomass is primarily represented by the fact that they have to maintain a high temperature of the flue gases discharged into the atmosphere in order to pre-encounter the problems that may appear on the flue gas exhaust system: the deposition of soot, tar or the appearance of acid condensation on the inner surface of the gas ducts, situations that can cause clogging of the gas ducts and the appearance of the phenomenon of chemical corrosion of the gas ducts or the chimney.

It is precisely this high temperature of the flue gases discharged into the chimney, which causes a low global yield at the biomass combustion plant, and therefore economically efficient solutions must be found to extract as much energy as possible from the flue gases that are going to be discharged into the flue and to use this recovered energy for energy purposes to increase the overall efficiency of the combustion plant and implicitly reduce carbon dioxide emissions.

Considering the constructive complexity of the equipment that can extract and energetically utilize the residual energy of the combustion gases from the biomass boilers, in the current conditions, they can become effective only in the situation where the beneficiary of the plant has a cheap source of biomass, for example, biomass grown on lands that cannot be exploited for agricultural purposes due to their industrial history.

However, this biomass can be contaminated with various chemical elements extracted from the soil in which it was cultivated and thus, the residual heat recovery systems can also fulfill the role of purifier of the gases that will be discharged into the atmosphere.

Considering the diversity of the respective biomass fuels: logs, wood waste, wood chips, pellets or sawdust and implicitly their quality in terms of calorific value, ash content or moisture, chemical composition and moisture content of flue gases depends on each case and must be analyzed and known before starting the design process of the waste energy recovery system.

It is also indicated to carry out a representative energy balance for an annual operating cycle of the combustion plant to determine the energy potential that is possible to be recovered and to carry out on the basis of this potential the cost-benefit analysis of a potential energy recovery plant from the combustion gases.

The use of flue gas energy recovery equipment for boilers operating with biomass involves:

- the use of corrosion-resistant materials;

- the use of automatic systems for periodic cleaning of the recovery system;
- the use of flue gas monitoring plants;
- the use of combustion gas flow and purification schemes so that, depending on their composition, they can be put in contact with various solutions with the role of neutralizing and retaining potentially toxic substances;
- implementation of a complementary system for exhausting and dispersing combustion gases into the atmosphere to compensate for the decrease in kinetic energy and gas temperature in the recovery system;
- the preparation and evacuation of residues so that they do not present a potential hazard for the surrounding environment.

To further increase the energy efficiency of the recovery system, an absorption heat pump can be used to extract thermal energy from the flue gas circuit and raise the parameters of the heating agent so that it can be used for space heating or preparing domestic hot water [3].

In order to have an energy with as little carbon footprint as possible, the electrical energy required to drive the heat pump and the heat recovery system, is preferably obtained in as a high as possible percentage from a system combining photovoltaic - electrical energy storage system.

3. Conclusions

In the future, all the problems raised in this article will need to be studied in order to find effective solutions to be offered to equipment manufacturers so that technological progress determines the most efficient use of energy resulting from biomass burning.

Also, the developed technology will be able to allow the safe use of cultivated biomass, on contaminated land, for energy purposes with a positive impact on both local communities and economic agents that own such land. By growing biomass on land with an industrial history, other land can be made available for agricultural use.

Through a good collaboration of all the factors involved, biomass producers, energy consumers, the population of communities, the efficient use of biomass for energy purposes can lead to a model of good practice for the sustainable use of energy resources and in a wider sense and to achieving the objectives of the European Union to reduce greenhouse gas emissions.

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