Universitatea Tehnica de Construcții București

Title research report:

Statistical methods and artificial intelligence methods used to treat data application to the study of nocturnal ventilation

REPORT NO.3

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Contents

I.The purpose and object of study

Our paper aims to outline solutions that would reduce the required energy for cooling buildings, utilizing nocturnal ventilation, and to fiind simplified methods that would facilitate the introduction of simplified perscriptions in curent energy calculation norms.

The main objective of the paper is an analysis of the needs and potential of buildings and equipment, the study of climate predictions for the future, in order to obtain appropriate working conditions, with reduced energy consumption. We will delve deep into the importance of indoor climate control and the use of easily operable openings in the building design.

All these observations are made in order to reduce the energy consumption in buildings.

The paper aims, on the one hand, to examine the theoretical basis of these methods in order to approximate as close to reality as possible, the energy demand for the cooling of the buildings, under the conditions of a passive cooling achieved by the structure elements of the building.

In this analysis we used detailed calculation methods of the energy consumption, ie hourly methods. There has been suggested the hourly calculation method based on thermoelectric analogy which stands for the theoretical grounding of theKoZyBu programme with reference to the o thermo-aeraulic modelling phenomena in buildings.

II. Statistical research

II.1 Preparation of the statistical research stages

Sizes that define the energy performance of buildings:

The heat flow through transmission and for the ventilation of the building;

- The contribution of domestic sources of heat and of the solar heat to the thermal balance of the considered building;

The annual energy demand for cooling to maintain an inside temperature prescribed in the building / area - (in the building);

(Methodology for calculating the energy performance of buildings, 2006)

II.1.1 Defining the database structure

For the statistical survey to which we refer there was first of all built a database entry that includes:

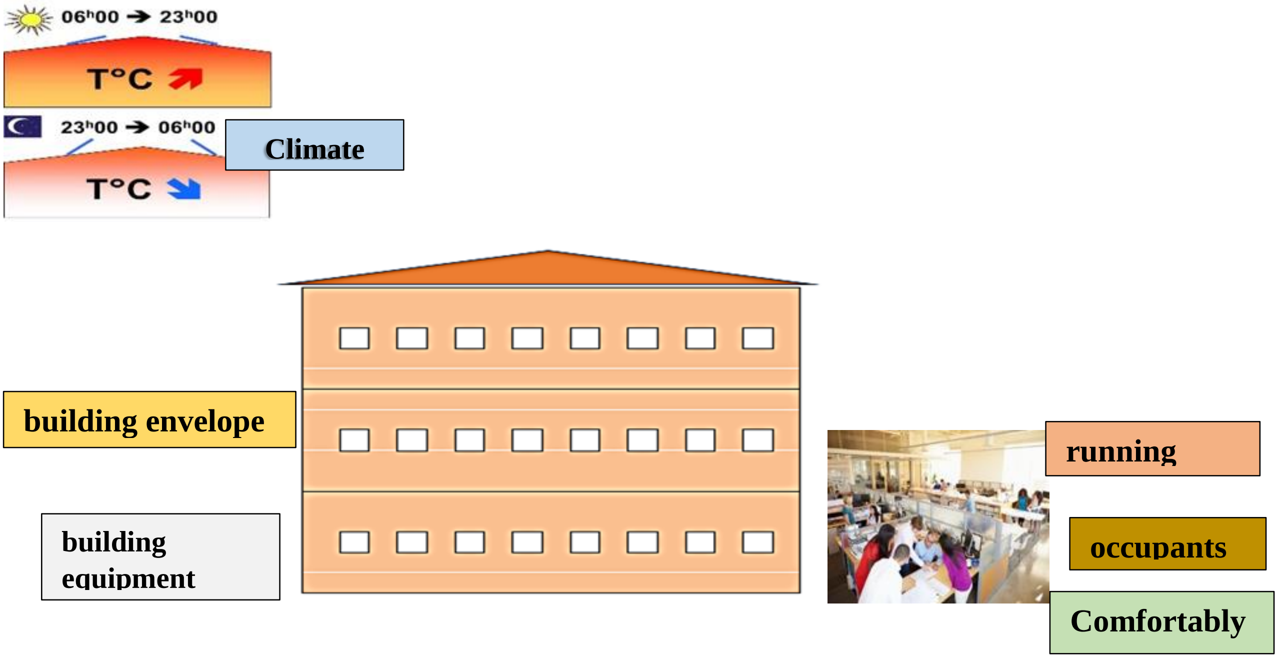
- Climate database

- Technical database

Based on this data and using the KoZyBu software alot of simulations have been achieved .

All output data determined on the basis of simulations were created in the database used in the statistical research.

II.1.1.a. Database entry



1.Climate data:

a) The National Meteorological Administration in Romania shows, on its website, reports of the covered periods and forecasts. (NMA, 2016)

b) For hourly readings of the outside temperatures we used http://www.infoclimat.fr site.

c) For details regarding the position of the sun (azimuth solar height) and horizontal solar flux (direct and diffuse), specific to each location, readings were performed using specialized sites. (Sun Position, 2012)

The simulations are performed using real data from 2012. All analyses indicated 2012 as being above climatic average + 4gr.C, on average.

2. Buildings; office spaces with identical volumes were chosen, with varied geographical positions , tire structure, the height level of the office in the building and the position of the glazing elements versus the cardinal points.

The building is P(groundfloor) + 2, with no basement.

The office has the following interior dimensions:

An area of a 6 x 30 = 180 square meters and a height of 3m => interior volume = 540 m

The orientation of the eight (8) glazing elements is South. The windows are made of plastic , with tight seal and Thermopane glass type.

After analyzing the climatic data (high temperatures with high frequency and the density layout of the office spaces, we defined as being entirely representative the following locations:

- in Bucharest: Latitude .: 44.5N, Long .: 26.13, elevation: 90 m

- in Constanta: Latitude .: 44.22N, Long .: 28.63, elevation: 13 m

- in Craiova: Latitude .: 44.3N, Long .: 23.8, elevation: 192 m

3. The office has benefited, during the working hours, 8-18h, of a ventilation 1.5sch / h and natural lighting. There are no other sources of indoor heating.

4. Occupancy hours 8-18 h.

5.There are 40 working occupants seated. No moisture releases were considered.

6. The simulations had, as case studies, scenarios for which the proposed indoor temperature during the hours of occupancy was 24.5gr.C, 25gr.C.

Appendix 1 shows the geometrical and thermotechnical characteristics of the tire.

II.1.b. The database obtained as a result of simulations

To manage the simulation results we used statistical models. Statistics gives us the ability to make predictions.

The regression process involves two stages. The first relates to the determination of the regression equation, and the second was to use the prediction equation.

To define the criterion variable, I used the parameter Degree days.

II.2 4. The degree days method

The degree days method used for evaluating the posibility of cooling within a environment where air circulates freely.

The principle on which the cooling degree days method is used is similar to the method used in heating degree days method (HDD).

It is a simplified approach to quickly assess how energy consumption can be estimated at the design stage. With this tool the designer will make decisions implicitly favorable both for the buildings and to the users, defining, from the drawing-board, the future thermal capacity, the insulation levels, depending on the tasks.

Cooling degree days are a measure of how much (in degrees), and for how long (in days), the outside air temperature is higher than the equilibrium temperature and in this case the building needs cooling.

By definition, "degree-day" is a function of time that varies with temperature.

I used CDD as an acronym for cooling degree days. The energy demand for cooling is specific to each building, located in the given weather data. We must know how many degrees you have to lose in the timeframe proposed, which is defined by cooling degree days (CDD). CDD represents on the outdoor temperature graph, the area of the surface defined by the temperature diagram and the temperature equilibrium line.

$CDD = \int (\theta e - \theta\ eq)\ dt$.

The balance temperature (θech) is a measure of earnings over which the space no longer provides comfort, therefore, to some extent, it takes into account the different ways in which the building is used. An approach that assumes the equilibrium temperature being the same for all buildings in the study will not give a true picture.

It is necessary to establish what equilibrium temperature characterizes, during summer, a type of a building located in a specific location and how we transfer these observations into a template of work for existing buildings.

II..3 Determining the equilibrium temperature

II.3.1 The calculation relation

The balance temperature is important because it sets the temperature above which the building is overheating (for cooling), implicitly the starting temperature for turning on the cooling systems.

We have shown that to determine CDD, we start from the equilibrium temperature which is actually the label that lists the characteristics and the thermal response of the building under thermal load. Starting from the energy demand of a building that can be expressed as an integral

$$\int QE \, dt = \lambda \int (ext\ \theta - \theta\ eq) \, dt \qquad (2.7)$$

λ = heat transfer parameter

$$CDD = \int (\theta ext - \theta\ eq) \, dt. \qquad (2.8)$$

As such energy demand for cooling is the product between a transfer coefficient and CDD.

θeq equilibrium temperature (^{o}C), calculated on the basis of the energy balance of the building is

$$\theta eq = \theta i - Q_G / U '(° C) \qquad (2.9)$$

Where: θi is the temperature of the point set on the inside (° C)

Q_G is the useful space heat gain (kW)

U 'is the coefficient of heat loss in the whole building (kW x K^{-1})

otherwise writing:

$$\theta eq = \theta i - \frac{\eta * \Phi_{int} + \Phi_S}{H_T + H_V} \qquad (2.10)$$

Where: θi is the interior temperature (° C);

- H_T the heat transfer coefficient of transmission (W / K);

- H_V is the coefficient of heat transfer through ventilation (W / K);

- η is the ussage factor of loss for cooling (-).

The cooling period (specific to each building by H_T) is defined by the outdoor temperatures that are higher than the equilibrium temperature. In the same geographic area different types of buildings will need different balance temperatures and different cooling interval lengths.

Outdoor air temperature does not remain constant, it changes pretty much all the time, the occupancy of the building varies throughout the week, with two days in which the temperature of the premises depends solely on the conductive transfer (the closing elements of the building). To ensure the accuracy of these results we have chosen the equilibrium temperatures for each week specifically.

II.3.2 Statistical methods for determining the equilibrium temperature

This study suggests a steady temperature determination in a situation where we have no data of energy demand, using as starting data the outside temperature, the temperature inside the building without air conditioning systems and the proposed temperature in the period of occupancy.

To study the dependencies of the temperature outside and inside, we turned to statistics, using the regression and correlation analysis. The graphical method revealed a linear relationship between the two parameters, ove dependent (t_int) in relation with the variable one (t_ext), leading to the nonlinear regression model (parabolic Grade 2).

The X-axis contains values of the outside temperatures of the week which are read hourly.

Values on the Y axis, which mark the determined temperatures in the analyzed precinct, are obtained as a result of the simulations performed using the KoZiBu software . These determinations are made in conditions where the air circulates freely inside the precint at certain ventilation rates during the night (2,3,4sch / h at night and 1.5 sch / h day).

The initial number of days for each simulation is 20.

The solution we propose is to use the regression equation in reverse; We start from the Y axis, imposing the condition that the indoor temperature be, in the range 8-18h, the proposed temperature , namely 24.50C.

We exemplify the situation presented in the following graph:

$y = 0.0001x^2 + 0.2155x + 20.356$

For the imposed condition y = 24.5gr.C => equation $0.0001x^2 + 0.2155x - 4.144 = 0$

with root x = 19.06, indicating that the office with the stated data (structure, tasks), can provide indoor the forecasted temperature independently without energy sources, if the temperature is 19.06gr.C (under the circumstances).

This graphical method is very easy to use. The correlation coeficient indicates the correctness of the corelation and offers informaiton for the building's energy management.

(no stands for night, day for day)

Bucharest - 2012, office space on the ground floor of a building

Figure 1. Proposed statistical method for determining the equilibrium temperature , office space on the ground floor, Bucharest 2-6 july 2012 natural ventilation at night 2mc/ h

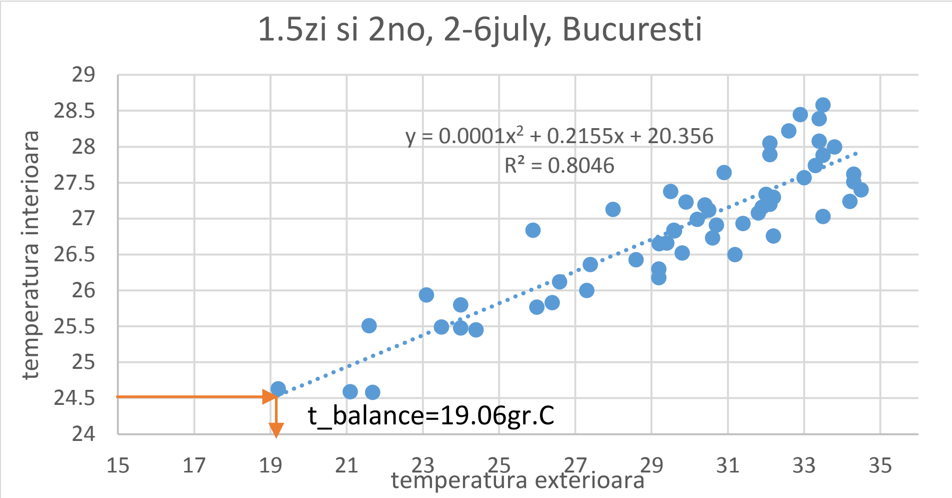
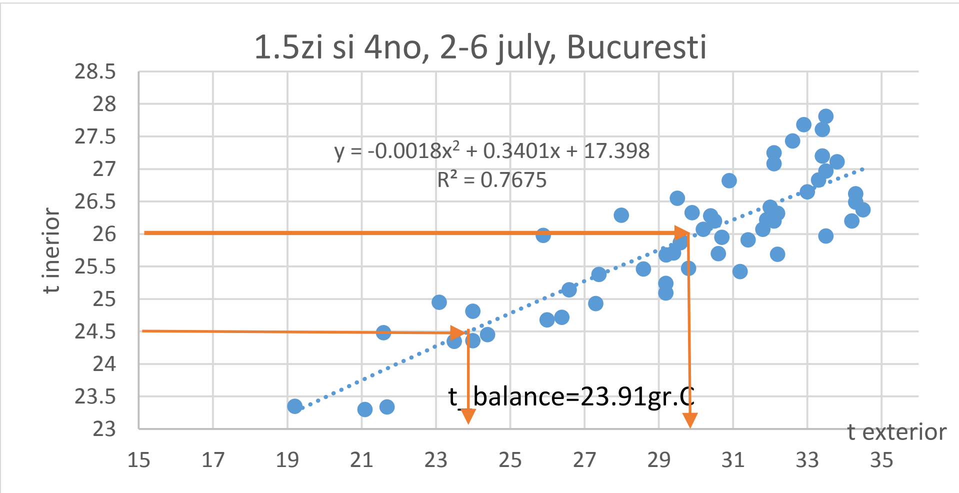


Figure 2. identical with figure 1 but natural ventilation at night 4mc/ h



We impose a higher comfort temperature, eg. 26gr.C, then lead from Y = 26, a parallel axis to the axis of the outside temperature to intersect the correlation curve. We descend perpendicularly on the X axis, obtain the outdoor temperature at which the building, provides comfort in times of occupancy, average ext t / period of occupancy = 30.5gr.C.

An office like the one analyzed in the scenario presented benefiting from a night natural ventilation of 4sch / h, at night, in the summer days when the average daytime temperature does not exceed 30gr.C and the nocturnal one is <20.5gr.C, designed for a comfort temperature of 26gr.C (an equilibrium temperature of 30gr.C) will have a consumption of 0 kWh (cooling energy).

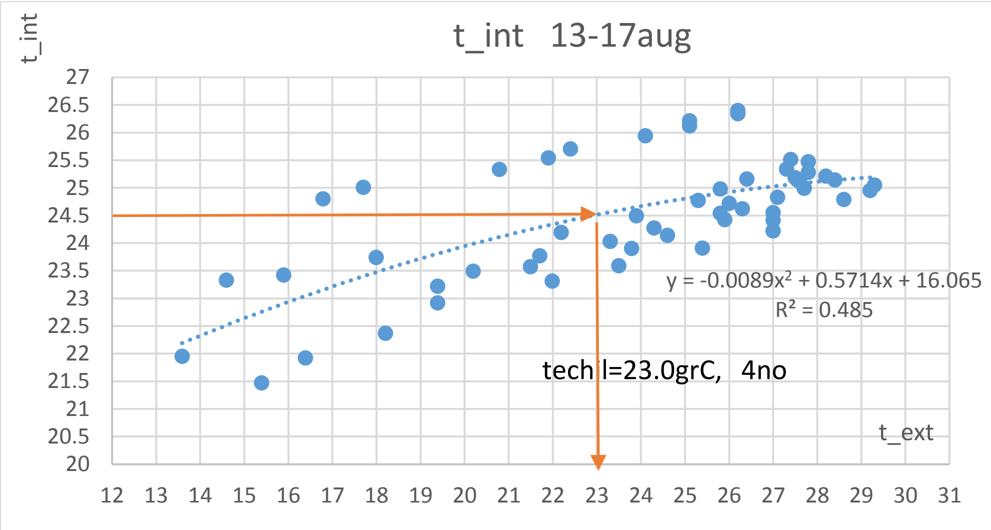
The 30gr.C value has a high frequency of occurrence in the summer months.

We vary the flow of natural nocturnal ventilation (1, 2, 3, 4sch / h) and draw correlation diagrams for each scenario proposed and use the regression relationship (parabolic grade 2) to determine the equilibrium temperature

Table 3: proposed statistical determination to determine t_equil for an office situated downstairs, the natural night ventilation 2sch / h_Bucuresti August 13 to 17

In the week of 13-17 august, in Bucharest, if the building is cooled by 4sch/h, it can provide the comfort temperature required of 24.5grC between 8 am and 18.

Figure 3. 3 is identical, natural night ventilation 4sch / h



II.4 CDD parameter determination (cooling degree days)

In order to determine the cooling degree days parameter we initially applied the method set forth by the Directorate of Climatology of France "method of professionals" (Climatology, 2005):

To reduce the time, after establishing the equilibrium temperature, by applying the graphical method we used the http://www.degreedays.net/ site, mentioned in the EU report and https://www.wolframalpha.com. (Kemma, 2015)

Currently there are countries which admit generalizations for geographical areas, defining referential values for the equilibrium temperature , which is a constraint, the equilibrium temperature depending on the building exterior wrap, usage, the external loads specific to the climate or to the geographical position.

Reaching this step we make a correlation with data obtained that reflects the energy demand for the cooling of the office space which is subject to various conditions.

We display table 8 which shows the cooling consumption in parallel with cooling degree days. In the table the values are shown for the five days of the week occupancy (CDD = Σgrade on 5days and the consumption = Σ 5 day, l, m, mi, j, v)

In August 2012 Bucharest had temperatures which,used in a responsible way, can lead the consumption for cooling closet o 0.

In order to graphically view the CDD area and to understand the mechanisms by which we can reduce it, we display the temperature graphs in parallel with the consumption graphs for cooling, for a target temperature of 24.5gr.C.

Table 1: cooling consumption [kWh] vs CDD pt.birou downstairs Bucuresti_iulie, August 2012

Brick tires, ground without basement, glazed south **Bucharest, June, July, August 2012** room occupancy time period 8/18 l, m, m, j, v t_int_pr= 24.5gr.C												
Iunie iulie	t med **zi/** 10ore tmed **no**	Nr.sch. aer	**cons racire [kWh]**	techi gr.C	**CDD**		t med **zi/** 10ore tmed **no**	Nr.sch. aer	**cons racire [kWh]**	techi gr.C	**CDD**	august
18-	28.4	1.5zi	110	15.3	59.9		30.5	1.5zi	339	<0	140	6-
22	21.6	si 1n					24.4	si 1n	327			10a
iun		si 2n	77	28.1	9.8			si 2n	318	10.3	89	
		si 3n	67.2	30.4	4.84			si 3n	336	13	75.5	
		si 4n	59.75	31.4	3			si 4n	311	14.8	66.5	
25	23.6	1.5zi	0	23.3	7.82		23.7	1.5zi	96	_		13-
29	19.7	si 1n					17	si 1n	47			17
iun		si 2n	0					si 2n	18	13.5	42.4	Aug
		si 3n	0					si 3n	6	20	15.9	
		si 4n						si 4n	2	23	7.8	
2	29.6	1.5zi	241	0	135		30.2	1.5zi	296	_		20-
6	21	si 1n	209	10.8	81.3		21.1	si 1n	256			24
iul		si 2n	186	19.1	40.2			si 2n	227	_		Aug
		Si 3n	169	22.2	26.6			si 3n	206	21	35.3	
		si 4n	155	23.9	20			si 4n	190	23.7	25.1	
9	0	1.5zi	316	37.7	126		24.3	1.5zi	170			27-
13	20	155	306	29.5			17.46	si 1n	121			31

iul	37.7	286	317	77.9	64.7
	29.5	112	292	55.3	55.7
	77.9	324	286	66.5	37.7
16	55.3	234	194	7.8	126
20	66.5	311	163	25.1	
iul	7.8	2	140	49	59.3
	25.1		124	16.6	42.8
	49	52	112	19.4	29.5
23	30.7	1.5zi	323	im	133
27	26.3	si 1n	323		
iul		si 2n	324	im	
		si 3n	324	10.7	90.4
		si 4n	324	13.2	77.9
30iul	29.1	1.5zi	281		
3a	23	si 1n	264		
		si 2n	252	6.2	102
		si 3n	242	13.4	66.3
		si 4n	234	15.6	55.3

si 2n	90	13	73.9	Aug
si 3n	67	16	58.9	
si 4n	52	18	49	

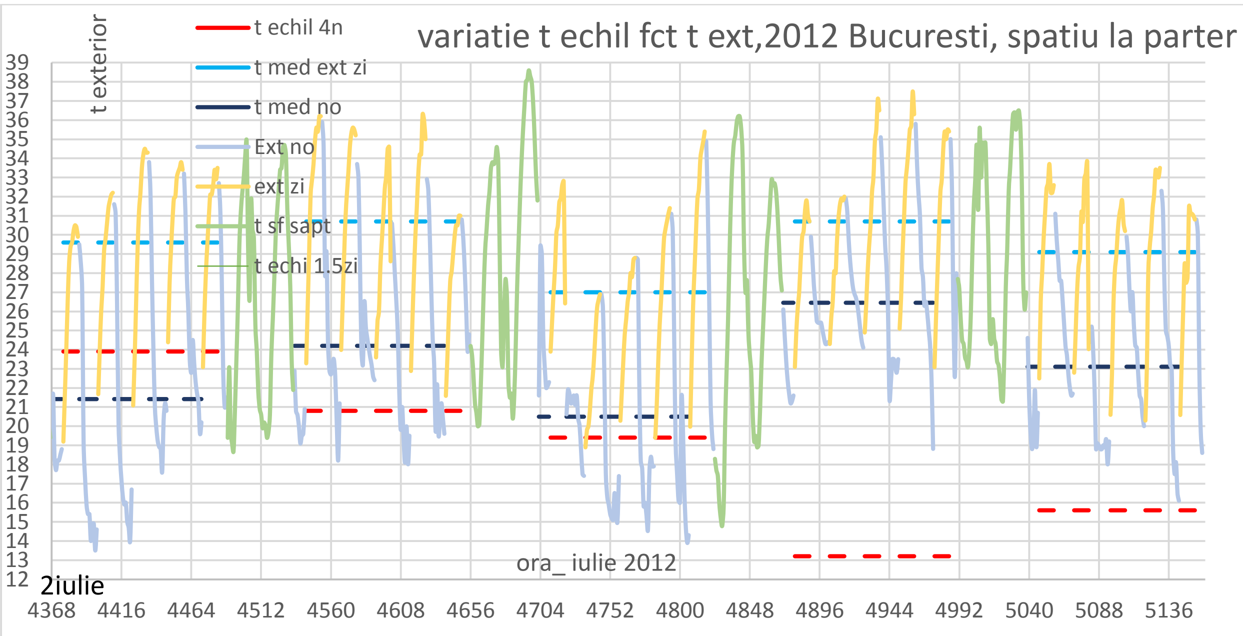


Figure 4: The weekly steady temperature variation in maximum and minimum media reported in July 2012 at a ground-floor office in Bucharest

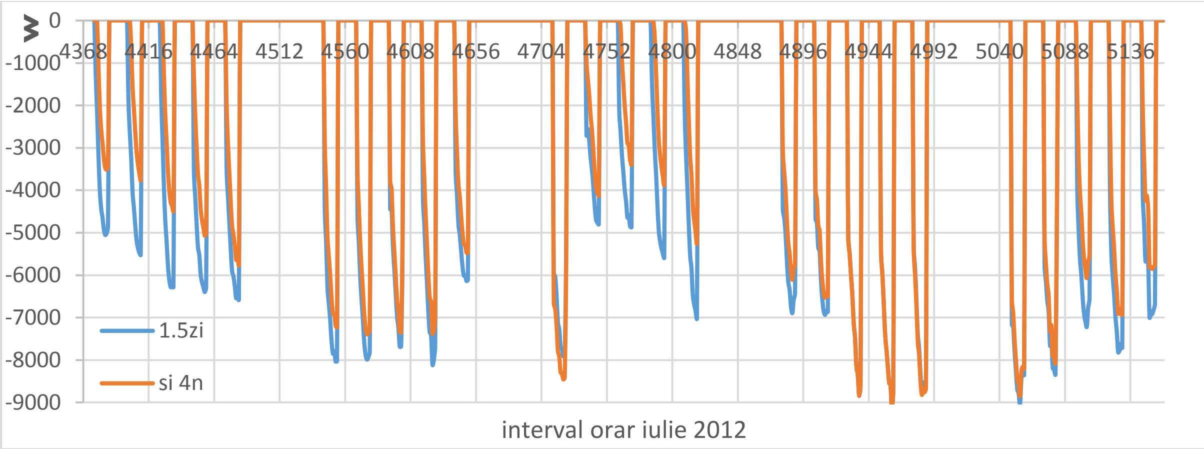


Figure 5: The variation of the energy demand per day compared with natural night ventilation (4vol / h) in July 2012 Bucharest office downstairs

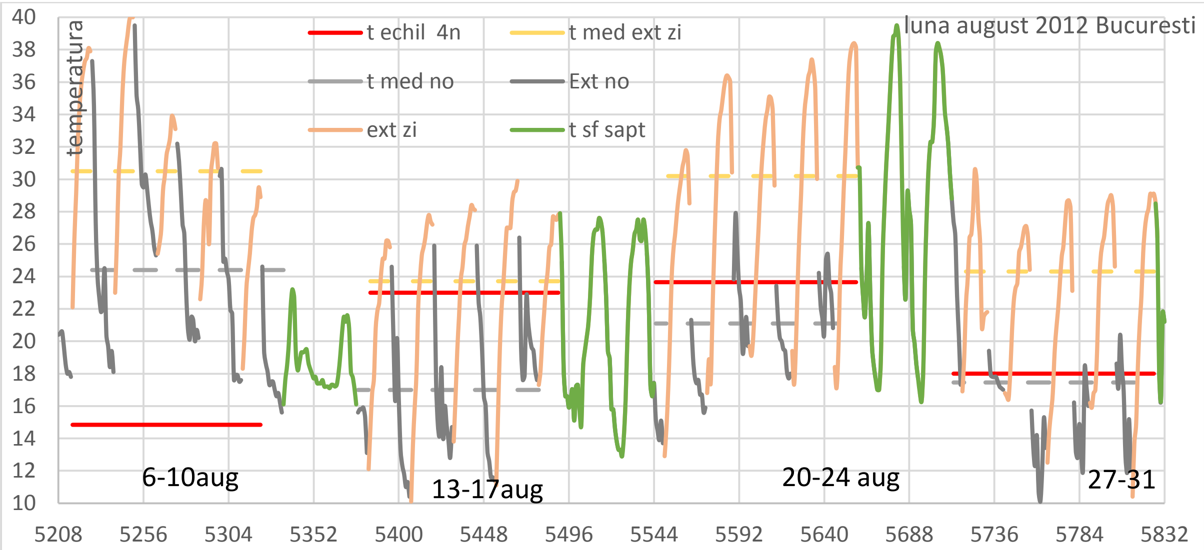


Figure 6: identical for August fig.4

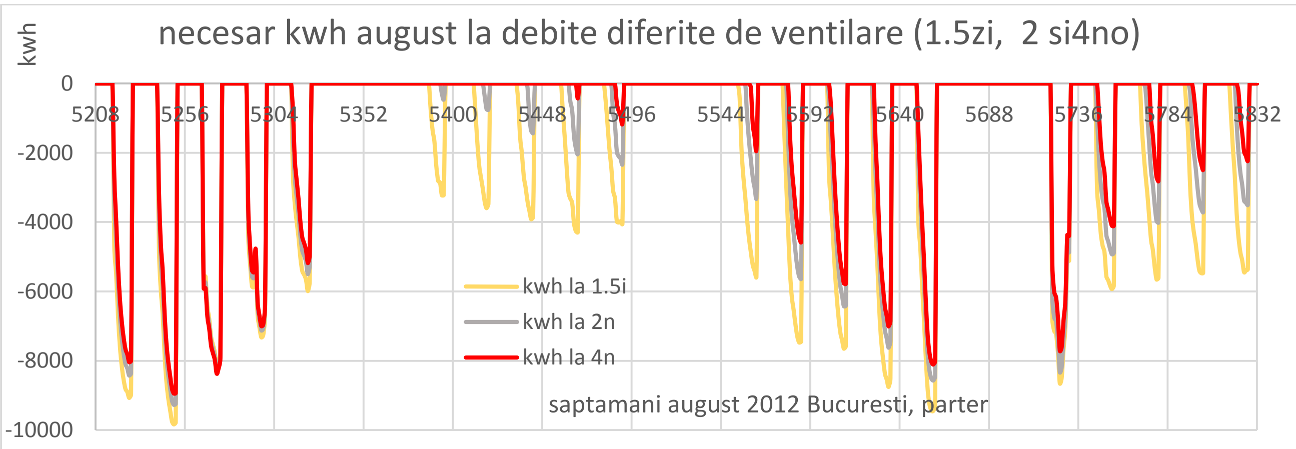


Figure 7: identical for August fig.5

We follow the obtained values for the validation of the determinations accuracy:

- Simulations have revealed energy needs for cooling, 0 kwh in the week of 13 to 17 August

- For the same periods , the cooling degree days values (CDD), show values close to 0, as can be seen in the table

The correctness of the determination of the equilibrium temperature is very important for a correct result of CDD.

III. Expected values

In the chart below, we present, for the southern part of Romania, in 2012, where, with a proposed comfort temperature of 24.5 gr.C, the influence of the difference in the day / night temperature on the report t_equil / _ext t_aver day .:

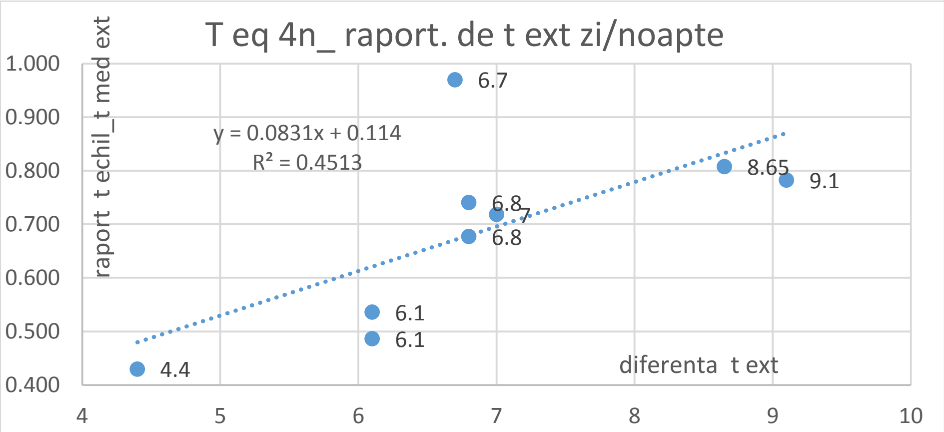


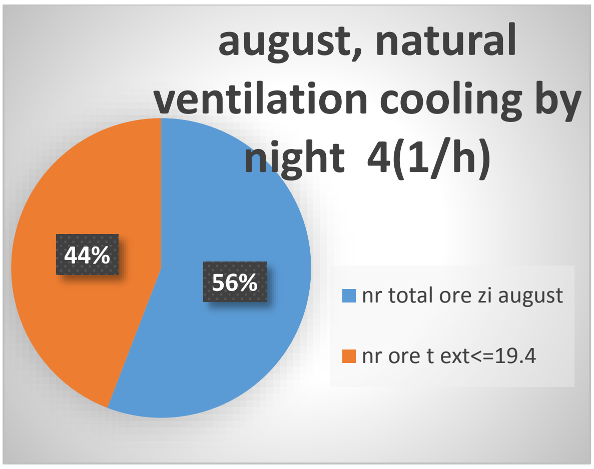
Figure 8: equilibrium temperature/ t ext office reported to the temperature difference night day on the ground floor, Bucharest seasonal cooling in 2012

We can observe that in general the difference between day and night temperatures is above 6gr.C to ensure an equivalence ratio t / t ext toward unity.

If we accept indoors s higher temperature than (25-25.5gr.C), the equilibrium temperature increases , thus CDD will approach 0 more easily.

The analysis pointed out that each week is characterized by a certain equilibrium temperature, which is very important in terms of energy savings.

In terms of natural cooling, in the night ventilation scenario with 4vol / h,it denotes an improvement of 76% compared to the lack of nigth ventilation, but the fact that for 10% of the working time a comfort temperature of 24.5gr.C is ensured , this asks for random cooling methods.



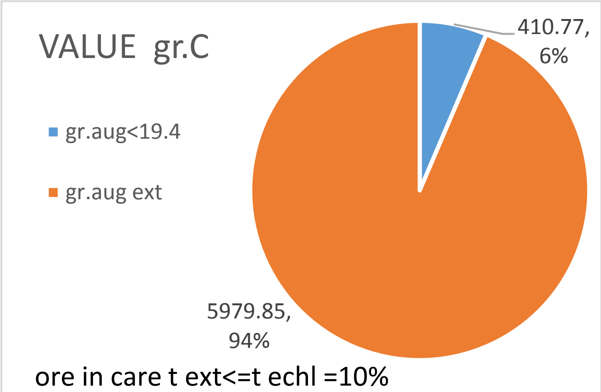


Figure 9: nocturnal natural cooling, ground floor office in Bucharest in August 2012 time

A more accurate determination of the equilibrium temperature will facilitate the programming of the sensors to help the buildings become "smart".

III.2 Statistical method for determining the performance lines

The performance lines have been used for many years, and are well documented as a management tool (eg McVicker [1946] Harris [1989] Levermore [1989]).

The performance lines are graphics of the monthly energy consumption in relation to monthly degree days.

The performance line is the instrument usually used to show how the power consumption varies according to the weather; it gives credible clues about the response of the building.

For the data expressed in the case of the office on the ground floor of a building in Bucharest we draw the CDD graph / cooling energy consumption and the trend line achieved as the regression line of the compliance between the two variables. The performance line obtained shows how power consumption varies depending on the weather, the CDD.

Y = a + b CDD

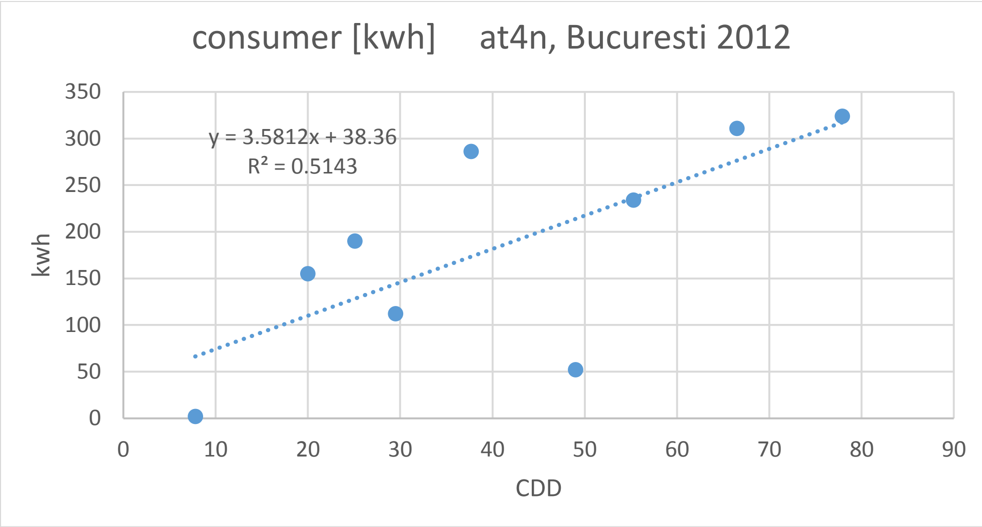
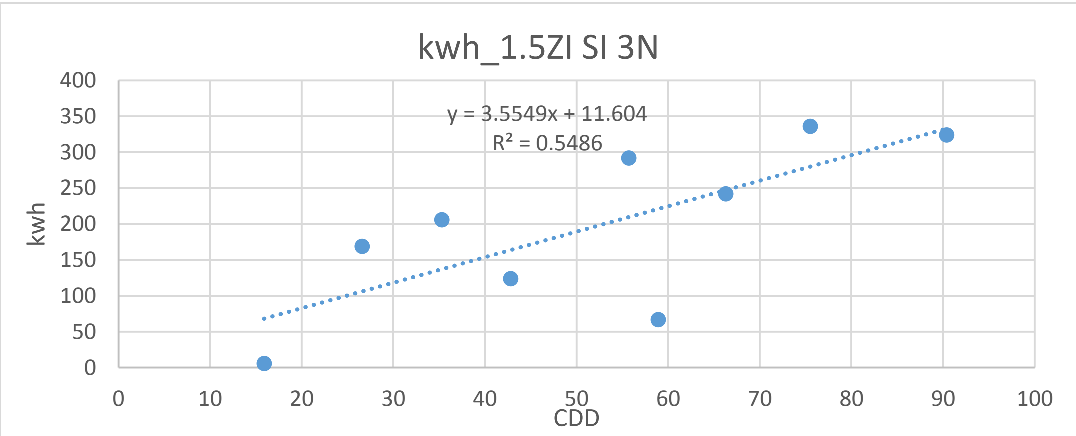


Figure 10: a)Performance Line for office on the ground floor, Bucharest, 2012 cooling season nocturnal ventilation 4h^{-1}

b) nocturnal ventilation 3 h^{-1}



We drew the performance lines for the space on the ground floor, Bucharest, July, August 2012.

At the moment, we are in the situation in which if all the other factors are constant values, the energy consumption for the cooling of the space is proportional to the outside temperature changes.

It follows that such energy is proportional to the degree days.

Therefore, in theory, a chart outlining the building energy consumption, in conjunction with degree days has shown a straight line of the form: Y = a + b CDD where a is the y-axis intercept and b is the slope of the line.

The coefficient shows us what the value of Y is when X is zero. Instead, the coefficient b (slope of regression) shows how much Y is influenced when X increases by one.

Analyzing the performance line for 4n and 3n, the slope is about the same, the obvious change is for the point a- which is the building at point 0 of the test.

"A" shows the efficiency of the cooling if we would also cool the building the night before the test with 4 h^{-1}.

IV. Conclusions

Our study was done in extreme conditions of temperature, for representative buildings, in the southern part of the country.

1. If 2012 has temperatures with 3-4 degrees C above the normal, and a building with high inertia succeds, in August, in using only about 50% of the time the natural night ventilation (4vol / h) as cooling during working hours, it is obvious that a good night air management is very important in the cost management of a building.

2. Case studies have shown that the supplementation of the glass area on the eastern side increases consumption.

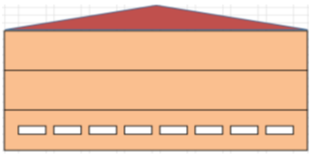
The shading of the glazing has revealed both in practice and in studies that it protects the building against the solar load.

3.The temperature curves show that in summer, the outside temperature is still high even after 6 PM, the cooling occuring in the morning, after 1-2 AM, which is the range in which we must apply the natural night ventilation .

4. If the final consumer understands that investing in knowledge is a bank for the future, for himself as well, he will find the right levers.

APPENDIX 1: Tire geometric characteristics and ventilation

Office building; GVP brick masonry, insulation polystyrene 10cm



Office downstairs

Description locking element	orientation position	area calculation [mp]	Layers components(i->e) material	thickness [m]	R gr.C mp/W
Opaque exterior wall PE	S ext	76.32	mortar var	0.005	2.9505
			mortar var si ciment	0.015	
			caramida GVP 950	0.29	
			polistiren	0.1	
			mortar var si ciment	0.02	
Interior wall (P int)	to staircase	18.72	mortar var	0.005	0.59225
			mortar var si ciment	0.015	
			caramida GVP 950	0.25	
			mortar var si ciment	0.015	
			mortar var	0.005	
Opaque exterior wall (PE)	E ext	18.72	mortar var	0.005	2.9505
			mortar var si ciment	0.015	
			caramida GVP 950	0.29	
			polistiren	0.1	
			mortar var si ciment	0.02	
Interior wall (P int)	aisle access	87.93	mortar var	0.005	0.59225
			mortar var si ciment	0.015	
			caramida GVP 950	0.25	
			mortar var si ciment	0.015	
			mortar var	0.005	
Ceiling (Pf_cp int)	intermediate ceiling	180	mortar var	0.0015	0.71379
			beton BA 2400	0.14	
			polistiren	0.018	
			mortar ciment	0.05	
			polistiren	0.004	
			parchet	0.012	
Floor (PLs_cp)	planseu ground floor parter	180	parchet	0.012	1.6355
			polistiren	0.004	
			mortar ciment	0.07	
			beton BA 2400	0.15	
			polistiren	0.05	

			izolatie hidrofuga umplutura pietris	0.015 0.2	
usi (U)	spre culoar acces	5.67	lemn	0.08	0.625
feretre (FE) tocarie PVC+geam TMP	S ext	17.28	geam int aer	0.004 0.02 0.004	0.55

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