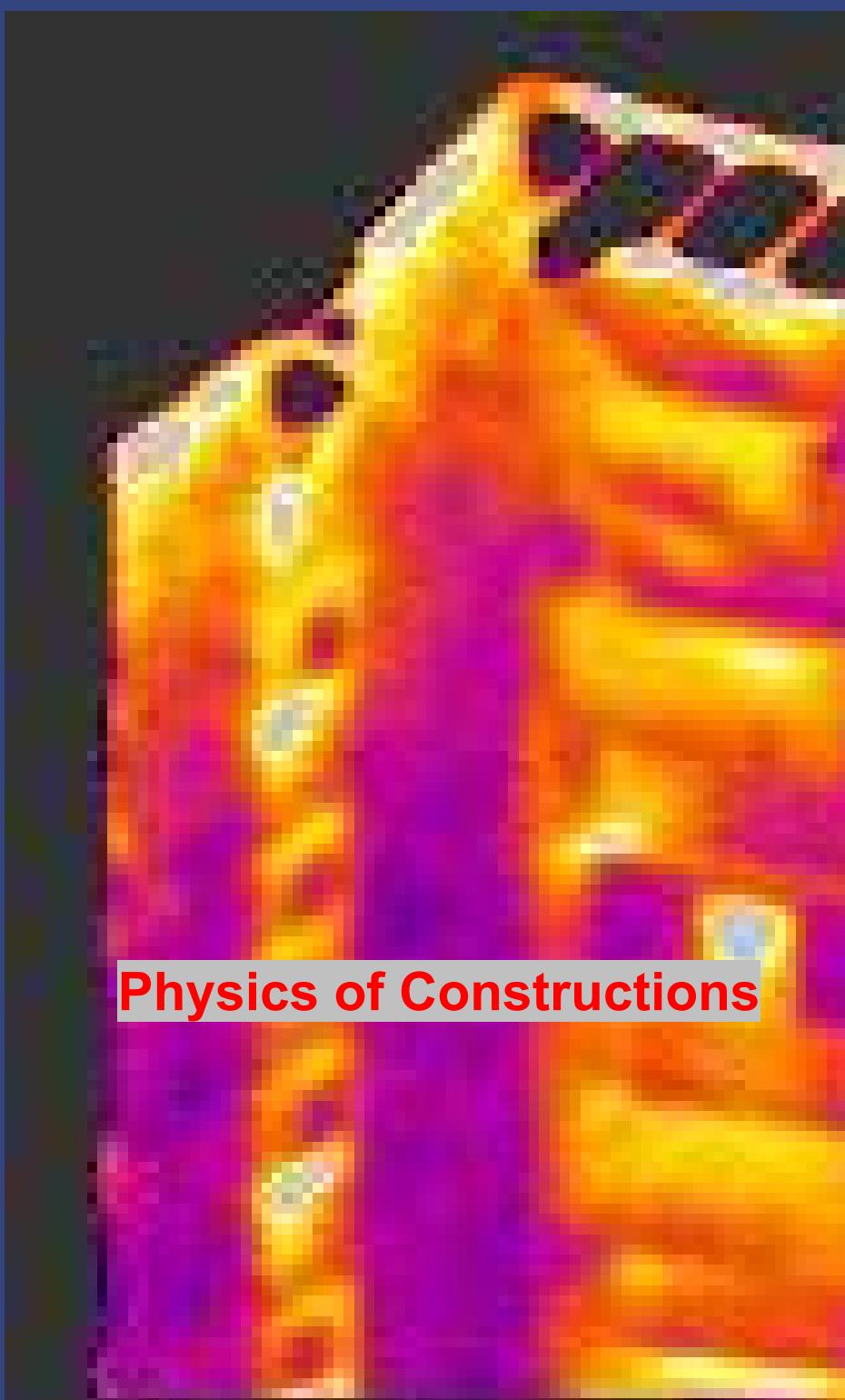


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**Irina BARAN Secretary**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
baran@ce.tuiasi.ro

**Irina BLIUC**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
ibliuc@ce.tuiasi.ro

**Ioan GAVRILĂ**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
gavrilas@ce.tuiasi.ro

**Adrian RADU Team Leader**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
raduadr@ce.tuiasi.ro

**Dan ȘTEFĂNESCU**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
stefanescu@ce.tuiasi.ro

**Maricica VASILACHE**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
maricica@ce.tuiasi.ro

**Cristian VELICU**

Department of Civil and Industrial Engineering  
Faculty of Civil Engineering  
"Gh. Asachi" Technical University of Iași, România  
cvelicu@ce.tuiasi.ro



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## Building system loads and its climatic data

Roman Musil

*Dept. of Microenvironmental & Bldg. Services Engrg., CTU, Prague, 169 34 6, Czech Republic*

### Summary

*This paper is considering application of stochastic models on human factor. It describes energy and environmental loads of buildings and types of data needed to be obtained in practice.*

**KEYWORDS:** Water and electricity consumption, waste production, building occupation, climate dates and its formats.

### 1. TYPE OF ENERGY AND ENVIRONMENTAL BUILDING SYSTEM LOADS

#### 1.1. Water consumption

Consumption of water depends on the type of building and its occupancy during operation. It is necessary to have a respect to behavior of users, to respect their needs, regional practice or hygienic consumer habits by assessment water consumption. It isn't important only total water consumption, but we want to know distribution of fractional water consumption in the time period. On the basis of improvement curves of water consumption for particular types of buildings is possible to design smaller reservoir for warm water and in consequence smaller heat sources. Subsequently it leads to reduction of flow warm water in circulatory pipe and it leads to lowing energy intensity of heating water.

Model of water consumption depends on these characteristics:

- type of building and its purpose
- number of people in the building
- direct water using (for toilet, shower, cooking, garden watering, swimming pool...)
- using water for technical equipment (production processes)

Work objective:

It is necessary to develop models which will correspond with real consumption profile. We have to obtain for practice two formats of data:

- average yearly values ( for overall summary of water consumption)



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- water consumption distribution to time period (for precise design of heating water)

## 1.2. Waste water production

Waste water production is directly linked with consumption of water in most of cases. For most cases flow waste water is equal to consumption of water which means that the sum of warm and cold water consumption in time period is equal to flow waste water in the period. In some cases the water doesn't outflow (for example garden watering) or it outflows with some time-current delay (filling swimming pool, washing up or tidying up). This delay isn't important for us because it is only drainage of waste water from the building. It is important for us to know total production waste water and its quality which can be very different and again it depends on the user.

Waste water is divided on 3 types:

- waste water from toilets which are contaminated and needs biological cleaning
- waste water from wash-basins, baths, showers, roofs,...which is possible considered as almost clean and it is appropriate for recycling and reuse.
- waste water with fat, oil or petrol which needs special wastewater pretreatment.

Recycling possibilities depend on resource of waste water and on using of recycled waste water in building.

Work objective:

We need similar data as like as water consumption.

## 1.3. Production of solid waste

Daily profiles these waste aren't interesting because these waste collection is realized in regulated interval, for example two times a week for household waste or one times a month collection of paper and its following recycling. Average values of waste depend on the type of building, for example in the offices. There is massing more wastepaper than in other buildings over big quantity of computation techniques. It is the most important by this waste their sorting which increases efficiency liquidation of this waste and reduces energy intensity of proper liquidation.

Work objective:

We need average values waste production of solid fabric (paper, special waste, biologically liquidated waste and type of building). These values serve for design temporary storage spaces and collectors equipments.



## *Building system loads and its climatic data*

### 1.4. Electricity consumption

Consumption of electricity depends on occupancy and use of building. User behavior is in this case again the key factor, next key factor is using of control systems which are setup in building service (for example automatic switch of lighting during person absence in interior) or economic running equipment (PC, printers, copiers, ...). This precaution has influence on total consumption of electricity. When lighting is switch off during user's absence or offices equipment is running in economic mode so total profile will be very different from the profile, when real occupation in the building wasn't taken into calculation.

The model should be made from independent part of each specific electricity use:

- lighting
- heating and cooling including additional equipment (circulatory pumps, humidification and cooling boxes)
- ventilation
- computers and other office equipment
- domestic electrical appliances (television, stereo, cleaning equipment, cooking, fridge, freezer)

Work objective:

Created model should copy real energy consumption and should have included all control systems.

## 2. LOADS MODELING

### 2.1. Building occupation

Occupation has very significant effect on energy flows in buildings.

- Directly production, for example heat production of person (in usual situations one person products around 100 watt heat which can represent significant part of need for heating of very good insulated buildings). Direct heat consumption depends on number of person in the building and their activity.
- Indirectly consumption of sources (water, electricity, energy) and production of waste linked with people behavior (for example: opening windows, using water on toilet, switching on electric equipment and lighting). It depends on number of person in the building and probably people behavior in the building.
- Indirectly consumption of sources for associate operation equipment of building (circulatory pumps, sanitation pumps, ventilators, air conditions



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units,...) and emergency equipments, for example lighting. This consumption depends mainly on time of running equipment.

Building or room occupation is independent parameter, user's profile of one need is usually independent on other variables (for example: energy consumption doesn't depend on waste water production). User's profile strongly depends on occupancy and time-current interval.

## 2.2. Models type of people behavior in the building

- fixed profile which depends on time: day, weekday, month (we are taking into consideration leave and arrival time, weekdays plan and holidays)
- stochastic models based on Markov chains, which are giving probably transition from one state to another, are processed on real dates in similar building type.
- empiric models based on obtaining information from real dates of occupancy in similar building.

## 2.3. Description principles of building loads

Buildings loads which depended on human factor we call stochastic processes. Stochastic processes are such process where are physical laws supplying laws of probability which are showing for random time interval probability values. The processes are developing randomly from one to second state and future these states is possible to determine only on the basis probability.

For description these states are using Markov chains which are stochastic processes with final number of states where is time divided on individual time intervals. Markov chains are possible to use only when it discharge following condition: "Future development of process depends only on existent process state and no on its history.

## 2.4. How do we use Markov chains?

Mainly idea this method is building matrixes (Markov matrix) which expressive probability of process in time interval which is going from the one state to another state during next time step. Every element  $P_{ij}(t)$  represent probability of change process from state i in time t to state j in the future time step t+1, which we call "change probability" state i to state j.

Theory of Markov chain gives information to us about probability behavior of process and calculation "static vector of probability". This vector gives probability apparition each state in long-time interval.



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### 2.5. Model

It is necessary to have enough dates in acceptably period which will designate and probability of use. We have to determinate time step about which we interest and we have to be sure that it is possible to obtain data with time results. Because this method use union of discreet states, we need again to group parameters values to final number intervals where every interval is termed represent values (often it is maximum, minimum, or average value from the interval) We can use dates for derivation to transition probability as per cent of incident which we interest and total number of events. Now we have “catalogue” of transition probability from one state to other. Next it is possible use this information for simulation behavior of parameters by simple method which is calling reverse method.

## 3. CLIMATIC DATA, ITS FORMATS AND USE IN THE SIMULATION COMPUTER PROGRAM

Except people behavior in the building, exterior climatic conditions influence energy and environmental building systems loads modeling. It influences consumption of energy for heating and cooling by these exterior conditions. Climatic conditions are simultaneously impulse for user which for example in summer, when it is hot, switches on air-conditioning or ventilator.

In winter user can increase temperature on term regulator in required room or heating sources output. Public notice 152/2001Sb. establishes rules for heating and assessment consumption of energy. This notice fixes start (1. September) and end (31. May) of heating period. Heat supply starts in heating period, when average daily temperature of exterior air goes down below 13°C in two tandems following days and cannot expect increasing this temperature above 13°C for following day. Heat consumption is currently assessing by day-degrees method where we know number of days and average exterior temperature in heating period for every locality.

$$Q_{VYT,r} = \frac{24Q_c \cdot \varepsilon \cdot D}{t_{is} - t_e} [\text{Wh / rok}] \quad (1)$$

where:

$Q_{VYT,r}$  - yearly need of heat [Wh/rok]

$Q_c$  - heat loss of building [W]

$\varepsilon$  - correction factor

D - number of day-degrees [d.K]

$t_{is}$  - average interior temperature [°C]



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$t_e$  - calculating exterior temperature (it is assigned according to locality). [°C]

$$D = (t_{is} - t_{es}) \cdot d \quad (2)$$

where:

$t_{es}$  - average exterior temperature in heating period [°C]

$d$  - number of days in heating period [-].

A Day-degrees pattern shows that it is two-times influenced by climatic dates. Firstly, average exterior temperature and than number of days in heating period are influenced. Number of days in heating period is possible to determine returnly for each heating period.

Nowadays average daily exterior temperature is assessed as:

$$t_{ed} = \frac{t_7 + t_{14} + 2 \cdot t_{21}}{4} \quad (3)$$

Nowadays, when it is going to building-up development from thermal properties aspect of building, this assessment way is unsatisfactory. Using existing average exterior temperature by very good insulated building leads to deviation of calculated and real values. Today, it is setup in some meteorological stations automatic monitoring and writing climatic dates.

By using existing thermal average, it is necessary to make a difference between average daily temperatures, average monthly temperatures and thermal average of individual years. The long-term average values show smaller fluctuations of temperatures. The daily average exterior temperature is assessed from measured values:

$$t_{ed} = \frac{\sum_{e=1}^{e=24} t_e}{24} \quad (4)$$

We can obtain average exterior temperature in heating period  $t_{es}$  from this assessment daily average exterior temperature

$$t_{es} = \frac{\sum_{d=1}^{d=n} t_{ed}}{d} \quad (5)$$

where  $d$  is number of days in heating period.

Using average daily exterior temperature is by using spreadsheet program possible and calculated value of energy consumption is most approached to real energy consumption. Use of average hourly temperatures is possibility of next improvement of energy consumption. The average hourly temperatures for heating



## *Building system loads and its climatic data*

period are used in simulating programs with using climatic databases due to big number of this values (for example: TMY, IWEC, WEA,...etc.)

### 4. TYPICAL METEOROLOGICAL YEAR

It is most significant format of climatic dates. It is a group of meteorological dates with values for typical year which is making from selection month of separate years (long-time measured during 30 or 50 years). Individual selections are linked to typical meteorological year format. Typical meteorological year has two format types: TMY and TMY2. In this formats are including hourly and monthly dates. Every file have to obtain head with title of measured station, WBAN number (this is identification number of station), town, state, time zone, latitude, longitude and camber. For get date it is necessary to know its position in the column, type of date and range their values. Measured dates are divided to groups. A-D is calibration measured dates, E-I is data which isn't directly measured, but it are generating by other inputs or are obtaining from prediction models. Further are data divided to groups (1-9) according to uncertainly of measured or generation where the group 1 has smallest % uncertainly.

#### Mainly dates of meteorological year:

- dry-bulb temperature
- dew point temperature
- relative humidity
- static pressure
- direct solar radiation
- diffusion solar radiation
- global solar radiation
- wind direction
- wind speed
- precipitation
- cloudiness

TMY and TMY2 has different time format and units hence isn't possible change it. Sometimes is directly and complex data hard to obtain or it is available in other format which we need. In this case we have to use for example Weather manager which can analysis and conversation to other dates formats. Among most supported dates formats is:

- TMY Climate Data (TMY)
- TMY2 Climate Data (TMY2)
- Energy plus weather files (EPW)
- Weather data file (WEA)



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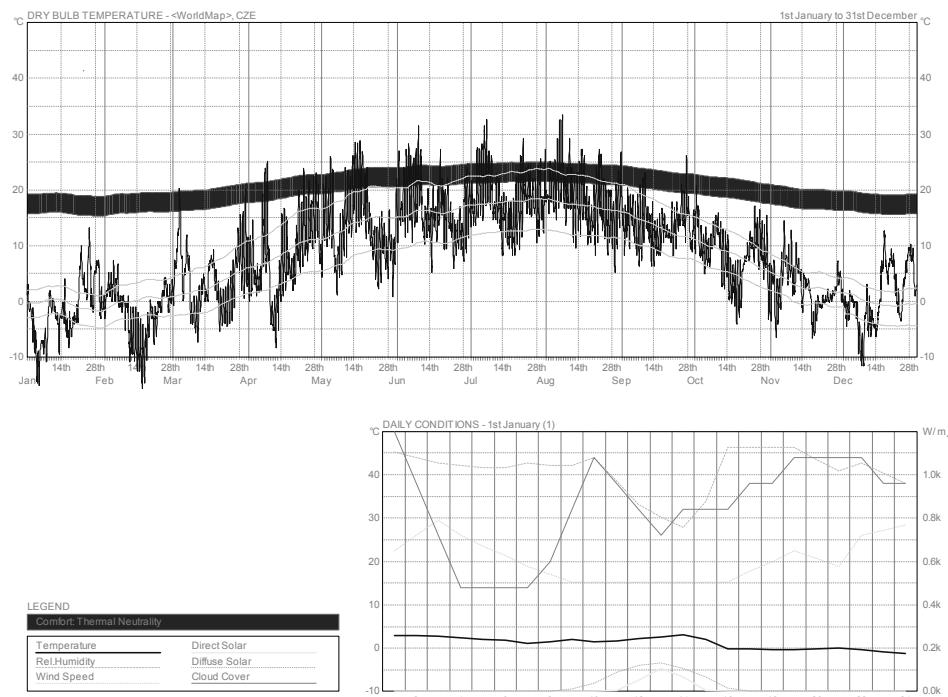


Figure 1. Example of graphic representation TMY which is generation from the Weather data manager

## 5. CONCLUSION

Using input data in simulation calculations is one of the dominant elements which determines the quality of the results and its application in practice. Building facade, its structural solution or acquisition costs, aren't only important by new projects realization. Nowadays, when continually grow energy costs and environmental importance increase, we are essentially more interested in real building service during its lifetime. It is important to consider building working state, already at projection documentation. Simulating programs are used for expectant building behavior. Every simulating program is as good as good are used input data. This paper shows overview of input data which are necessary to compile for characteristic building types.

### Acknowledgements

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## *Building system loads and its climatic data*

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# Physics of Constructions

## Present trends and potentialities in designing of log-houses external walls

Hana Brandejsová and Miloslav Novotný

*Department of Building Structures, Brno University of Technology, Brno, 662 37, Czech Republic*

### Summary

*The paper deals with designing of log-houses external walls with the viewpoint of thermal material characteristics. Timber is the natural material with the specific properties such as volumetric changes caused by drying-out. That fact has to be taken in account already during the design period. Window, door and stairs claim the correct and elaborated details of horizontal log joints.*

*One of the chapters refers to the incorrect solved details of log house.*

*In the contemporary building classification, according to LCA (Life Cycle Assessment), the log houses are ranked in very high position. Energy intensity of the construction life is calculated since the building material production, through the service till the demolition and removal.*

*The report deals with present trends in designing of the external walls of log houses.*

**KEYWORDS:** log houses, external walls, thermal material properties, volumetric changes, round timbers.

### 1. INTRODUCTION

Recently, building of the classic log-houses becomes to be famous. This type of construction is typical especially for Scandinavia and Canada, where roughly 85 % of buildings are built from wood or wooden basis materials. In former times, the wooden houses were fully occurring in the area of Czech Republic but later on, wood had been jostled away by new materials, e. g. steel, concrete, glass. Within the years of wood declining, the original traditions and continuity of for centuries forwarding information had been broken and so we can say, building of long-houses is quite new in our regions nowadays.

That is why the research and progress in designing of problematic details and edification of log-house producers and lay public is so important. Many failures that can occur within the log-house service period are caused by specific wooden characteristics neglected when the structure have been constructing.



*Present trends and potentialities in designing of log-houses external walls*

Timber is as a natural material sensitive to biotic and abiotic damages. These disadvantages are overcharged by relative source availability of sustainable material source, workability, by pleasant feature, and last but not least, by easy way how to dispose.

Lately, there are all over the world increasing demands for usage of environmental friendly and permanent available materials. Just timber is a material that satisfies these requirements.

## 2. EXAMPLES OF INCORRECT DETAILS



Figure 1. Left –Incorrect construction and insulation of gable; Right –Incorrect placing of vertical element (an adjusting screw is missing)



Figure 2. Incorrect corner structure (roughly encircled shapes)



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### 3. DESIGNING OF THE LATERAL GROOVES

#### 3.1. Termal-technical requirements

Recently, still increasing values of thermally technical construction requirements are heavily discussed among the construction specialist. Light framework constructions can be easily insulated by required thickness of insulator. The log-houses have different behavior – timber has a specific ability to accept and eliminate the moisture content in dependence with interior air relative humidity. Against that, totally insulated and closed buildings require to be furnished by forced ventilation system that ensures regular interior air changing and clear the interior air to anticipate the condensation and mould rises at the sensitive places.

Log walls are built up from logs of diameter 350 – 400 mm to meet standard ČSN 730540. The thermal resistance of wall is defined by the log diameter and tree species. However, the lateral grooves are staying the problematic details.

#### 3.2. Insulation material

The lateral joint of two logs has to be designed in such a way to ensure as tight and stable barrier between interior and exterior as possible. The material used for jointing of lateral grooves has to guarantee to thermal-technical properties from the point of view of both thermal resistant and air infiltration. At once, the material has to show shape recovery that means it has to be able to follow the working of wood (swelling and shrinkage). Each log that is inbuilt with moisture content higher than 19 % has to be provided by longitudinal kerf. These kerfs cut on the top of logs show an effective way to control the location of checks as green logs dry. The depth of the kerf shall be at least one-quarter of the log diameter, and shall be no deeper than one half of the diameter.

Primarily, PUR foam was using for sealing of the grooves and notches. This material is shape stable when hardening that means it cannot respond to the woodworking, consequently cracks appear and need to be repair time to time. That is why this material is no more used. Today, two-level insulating is common used; it can be seen on the picture nr.1 - left. The mineral wool is embedded into the continuous lateral groove and protected by joint sealing tapes from both sides. The tapes are made from permanent elastic material on the base of modified rubber foam, which is impregnated to resist UV radiation and eliminate an absorbing power. Such a gasket shall also restrict the water, air and insect infiltration.

Recently, usage of fleece instead of mineral wool is considering in Czech Republic. This natural material has to be necessarily proofed in insect resistance. The subject of further research is a fleece availability and effectiveness within the gaskets problematic.



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For comparison, the incorrect type of groove is shown on the picture nr. 1- right, there is neither notch nor insulation in the groove.

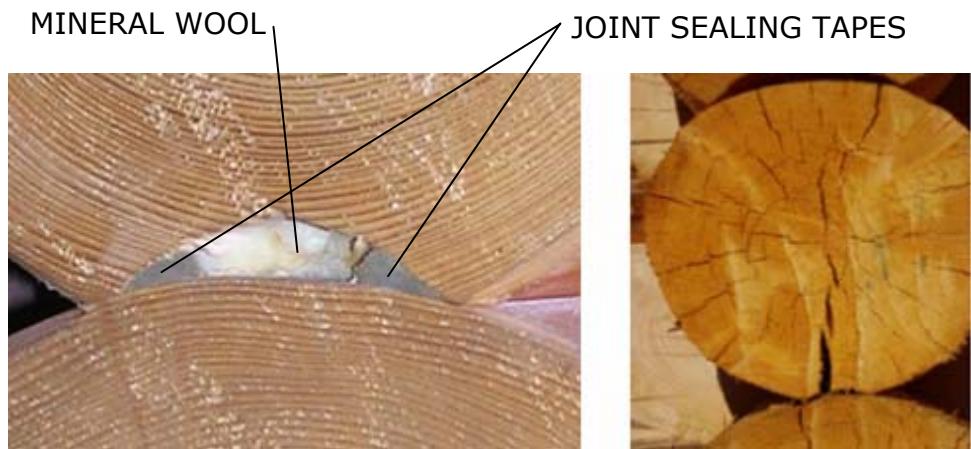


Figure 3. Examples of correct and incorrect groove type

#### 4. MEASUREMENT

To obtain enter values necessary for further design analysis, the thermo vision measurement and surface temperatures measurements of log walls were realized. Shown outputs are from the log wall, where only the pairs of joint sealing tapes protect the grooves. There is no thermal insulation.

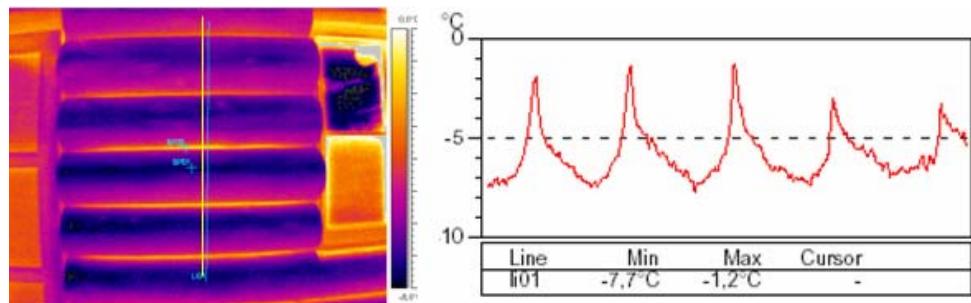


Figure 4. Thermo camera outputs – outside view

From the upper two graphs, the obvious difference between the log surface and groove temperature can be seen.



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The subject of further research is an optimization of groove design with the point of view in thermal engineering.

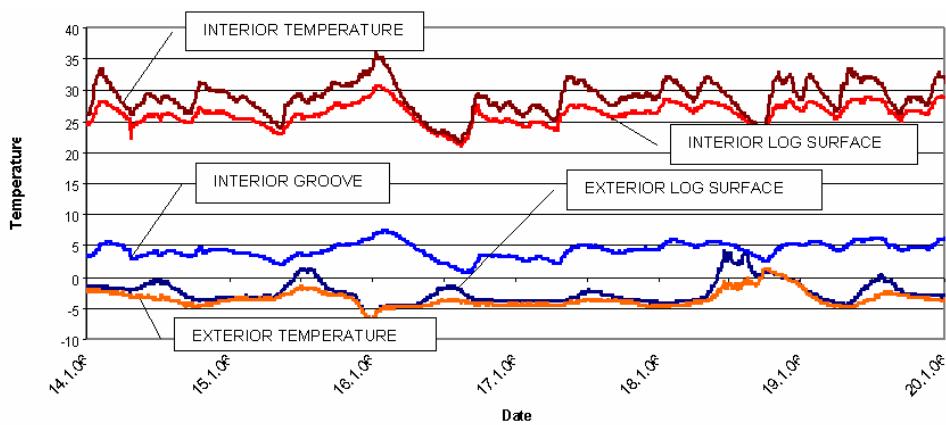


Figure 5. Surface temperature measurement outputs

## 5. ENVIRONMENTAL CLASSIFICATION

Recently, general attitude towards the environment is changing and also the civil engineering sphere is looking towards to original material base comeback. Also within the construction materials and elements classification, the environmental aspects have rising importance beside the technical and economical aspects. Effects on environment caused by usage of definite material have to be considered during the whole life element period.

The international reputable system for material and buildings classification is so called Life Cycle Assessment – LCA. To be the project certificated as an ISO suitable, the requirements of series ISO 14040 should not be omitted. Standards describe methods needed for Life Cycle Assessment generation. These are especially ISO 14040 Goal and scope, ISO 14041 Life Cycle Inventory Analysis, ISO 14042 Life Cycle Impact Assessment and ISO 14043 Life Cycle Interpretation.

In practice this means that the fossil energy consumption used in building constructions should be reduced. The total fossil energy consumption does not only compose of coal and gas but this is a complex question of choice of particular material types, which had been produced with the aid of fossil energy. For that reason, as much renewable sources should be used for the constructing as possible. Wood is undoubtedly ranked among these low energy renewable materials.



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## 6. CONCLUSIONS

From the point of view of recently LCA classification, the log houses are ranked among the energy modest construction. That is because wood is an easy available and renewable material, log houses production is easy while the construction details are finished in correct way, their operation is also quite unpretending and last but not least, they cause minimal environment pollution. Wood is a renewable natural source and that is why is so contradistinguished from other construction materials.

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# Physics of Constructions

## Indoor climate in contemporary buildings

Lenka Másilková

*Dept. of Microenvironmental & Bldg. Services Engrg., CTU, Prague, 166 29, Czech Republic*

### Summary

*Microclimate in contemporary residential buildings is nonconforming, because packaging constructions are too tight. In the aspect of presence of people is the most important thermal-moisture microclimate.*

*To guarantee optimal temperature in an interior can be quite simple, but to achieve optimal relative humidity can be problematic. But mildew emerges from higher relative humidity. It is important to guarantee sufficiency of ventilation air in the rooms, especially in winter period. Winter is the highest-risk period for increasing the relative humidity and following arise of the mildew.*

*This entry is comparing results of intensity of natural ventilation in various types of contemporary buildings.*

**KEYWORDS:** indoor climate, contemporary buildings, relative humidity, natural ventilation, exfiltration, infiltration

### 1. INTRODUCTION

This entry intends to verify the authenticity methodology of computation of buildings ventilation. It especially determines more accurately interdependence parameters of leakage window chink of ventilated room size in the case of meeting existing hygienic requirements and conditions for protecting engineering construction (such requirement is for example moisture outlet).

At computations air change rate was not taken into account effect of under pressure ventilation bathroom and toilet to other rooms. Considering limited range of this article it is impossible to describe all the computations, which we have made. To make the computations more understandable I added a table to the last part of each of them.

Below in the text I am using a help term „diagonally ventilated flat“. Diagonally ventilated flat is a flat, which windows are situated on the opposite sides of building facades. On the contrary not diagonally ventilated flat has windows only on one facade.



## *Indoor climate in contemporary buildings*

As basis of computations all three examples of natural ventilated rooms are taken into account flat 3+1. Disposition of this flat in a panel house has total volume of all the rooms 160m<sup>3</sup>.

## 2. VENTILATION IN CONTEMPORARY BUILDINGS

### 2.1. Problems of heat consumption for ventilation

Almost 4 million people in the Czech Republic live in panel houses. Majority of older panel houses are not corresponding to the standard ČSN 73 05 40 (thermal buildings protection) nowadays. Expensive reconstructions of panel building are passing through – heat cladding facades, changing original wooden windows to plastic, glazing loggia as well. We are packing flats to save money for energy.

But how big is the importance of these changes to the flat natural ventilation? Well, all the buildings are so tight now that the infiltration rate is so minimal – the air supply by the chink in construction's blocking.

Nevertheless each household is producing moisture – by evaporating from the flowers, by cooking, by bathing etc. As far as the draining away of this moisture is not solved, due to it can be inception of moisture and degradation of engineering construction (rot). There is only one possible solution how to reduce relative humidity. It is ventilation, which at the same time ventilates others injurants from the interior (CO<sub>2</sub>, formaldehyde etc.) and ensures the supply fresh air into the flat.

Is it possible to count only on infiltration by window chink in so tight objects?

Does not mean heat cladding facade, new tighter windows, possibly glazed loggia periodical opening the windows for ventilation, so that to ventilate the room actually?

Will not be necessary to wake up each 1,5 hour and perfectly air all the room?

In this entry author presents how much energy do we use up for prescribed necessary hygienic need on air change rate in the room. How does differ from each other the heat consumption for ventilation by infiltration, exfiltration or standard 0,5times air change rate per hour for definite flat in the panel house?

### 2.2. Ventilation by wind with its different speed during the year – INFILTRATION

The main part of the wind effect ventilation in the flat takes not only the wind speed, but the flat position too. We consider a wind speed in variants of 2,5m/s; 5m/s; 10m/s.



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The air change rate in the flat grows according to the velocity of wind. Flats in the ground floor of the buildings are mildly ventilated by wind in comparison with the flats in the upper floors, which are ventilated intensively.

It is valid the rule of wind influence to the buildings. Wind speed is increasing with the building height. And that is why the flat in the eight floor is more ventilated than the flat situated in the first above-ground floor.

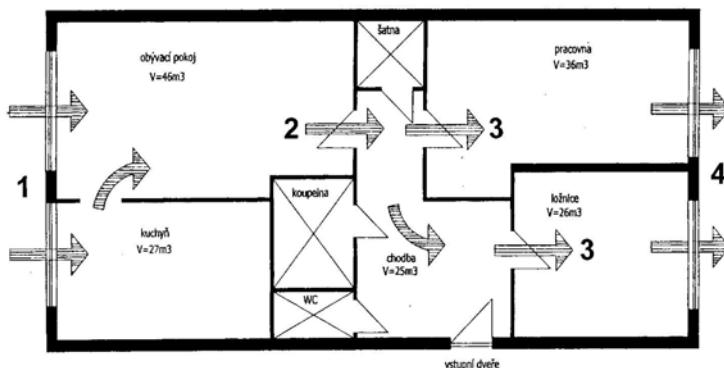


Figure 1. Ground plan of the flat – wind effect ventilation - INFILTRATION

Of course we consider flat position in the computations. We choose different coefficient leakage window chink and variants closed or opened interior doors in the flat in computations as well.

### 2.3. Ventilation by static pressure effect in the stair's shaft – EXFILTRATION

Lower flats are intensively ventilated, namely at not tight openings and chinks in the upper part of stair's shaft. When the inner stair's shaft is connected through the flats on exterior the ventilating air from the lower flats can get into the upper flats namely when

- Entry flat's door is not tight
- Lower flat's windows are not tight or opened

For ventilation by static pressure effect in the stair's shaft is important that

- Upper flats are practically not ventilated from the exterior. But air is pressed from lower flats to upper flats through the stair's shaft (by inner stair's shaft).
- On the contrary lower flats are intensively ventilated by exterior air, the air is sucked up to them under pressure through the stair's shaft.



## Indoor climate in contemporary buildings

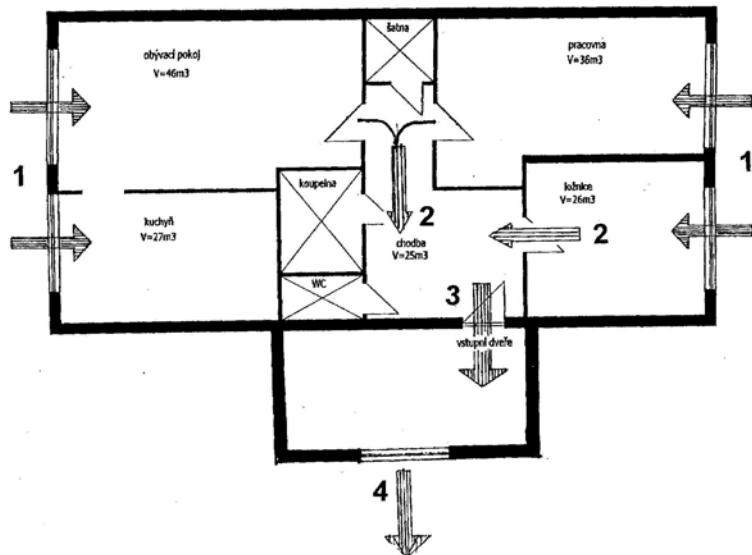


Figure 2. Ground plan of the flat – ventilation by static pressure effect in the stair's shaft - EXFILTRATION

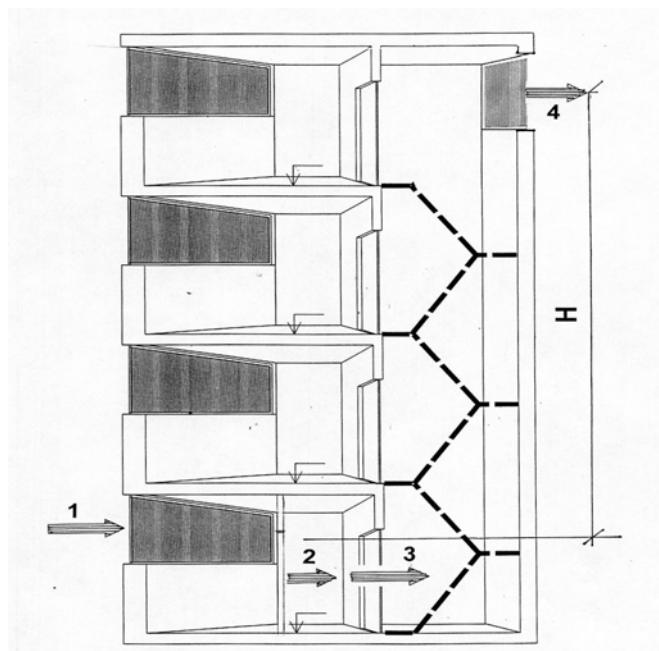


Figure 3. Section across the building – ventilation by static pressure effect in the stair's shaft - EXFILTRATION



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#### 2.4. Ventilation by combination of wind effect and stair's shaft effect

Combination of wind effect and stair's shaft effect compensates fair extremes in upper and lower flats (we do not include this combination in computations)

- Low – small wind effect and up – meaningful stair's shaft effect.
- Up – meaningful wind effect and low – small stair's shaft effect (under pressure against to excess pressure from the wind).

#### 2.5. Ventilation by standard 0,5times air change rate per hour

Hygienic requirement for ventilation by standard 0,5times air change rate per hour lets

- By relatively small total volume of the room and small length window's chink, for example in panel building bigger infiltration coefficient  $i_{LV}$  (classic value coefficient leakage for original wooden windows is  $1,4 \cdot 10^{-4} \text{ m}^2 \text{ s}^{-1} \text{ Pa}^{-n}$ ). From the energetic point of view in panel buildings is not necessary to plant tight windows.
- By relative large total volume of the room in old buildings (high room's headroom) and large length window's chink could be smaller infiltration coefficient  $i_{LV}$  (tightly windows).

### 3. AIR CHANGE RATE – COMPUTATIONS

End computation conditions: we consider a flat with a total volume of 160 m<sup>3</sup> (area with 64m<sup>2</sup> and height of 2,5m).

Rooms are ventilated by natural infiltration or exfiltration effect. MS Excel makes all the computations.

Entry value, inter computations and results are elaborated in well-arranged tables with particular descriptions of quantities, formulas and at the end comparing end values with standard values.

### 4. HEAT CONSUMPTION FOR VENTILATION - COMPUTATIONS

Computations about heat consumption for ventilation are elaborated in three variants air change rate in the flat.



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### 4.1. Heat consumption for ventilation by wind effect – INFILTRATION

When wind speed is higher, than heat consumption need is higher too, we have higher heat consumption to secure the loss during the ventilation.

With the wind speed of 10m/s is used up to 47% heat consumption quantity from total heat quantity.

Table 1. Ventilation by wind effect force with different wind speed during the year

	wind speed	percentage share	hour number	exterior temperature	interior temperature	ventilation air volume	$(t_i - t_e) \cdot 0,36$	power	heat quantity
	c	x	h	$t_{e,m}$	$t_i$	Vv		Q	$Q_c$
	m/s	%	h	(°C)	(°C)	m³/h		W	kWh
1	2,5	30	1800	4	20	20,36	5,76	117,27	211,09
2	5	15	900	4	20	81,46	5,76	469,21	422,29
3	10	5	300	4	20	325,84	5,76	1876,84	563,05
50% = 3000 hours from 6000 hours in heating period									
1196,43									

### 4.2. Heat consumption for ventilation by static pressure effect in the stair's shaft – EXFILTRATION

- To secure the loss during the ventilation is needed the biggest heat quantity, when the exterior temperature is -2,2 °C. It is 55 %.
- At the same time this maximum is raised by the fact that the temperature of -2,2 °C secures 118 days from 240 days in heating period.
- It is 50% of days in the heating period.

Table 2. Ventilation by static pressure effect in the stair's shaft

interior air density	exterior temperature	day number	$(273+t_e)$	$\frac{273}{(273+t_e)}$	$1,293 \cdot \frac{273}{(273+t_e)}$	shaft's height	$(p_a - p_l)$	static pressure	ventilation air volume	power	heat quantity
$p_t(20^\circ\text{C})$ kg/m³	$t$ $(^\circ\text{C})$	x			$p_a(p_l \cdot x^\circ\text{C})$	H	$\frac{p_a - p_l}{kg/m^3}$	$p_t$ Pa	Vv m³/h	Q	$Q_c$ kWh
1.205	-15	6	258	1,058	1,368	15	0,163	24,476	31,53	397,28	57,21
1.205	-9,4	19	263,6	1,036	1,339	15	0,134	20,116	25,77	272,75	124,37
1.205	-2,2	118	270,8	1,008	1,304	15	0,099	14,776	18,84	150,57	426,41
1.205	1,8	52	274,8	0,993	1,285	15	0,080	11,930	15,19	99,52	124,21
1.205	7,4	37	280,4	0,974	1,259	15	0,054	8,081	10,19	46,22	41,04
1.205	11,2	18	284,2	0,961	1,242	15	0,037	5,557	7,11	22,52	9,73
day sum = 250										total heat quantity $Q_{\text{SUMA}} = 782,98$	

### 4.3. Heat consumption for ventilation by standard 0,5times air change rate per hour

- Results are percently agreeing with example 4.2.
- To secure the loss during the ventilation is needed the biggest heat quantity, when the exterior temperature is -2,2 °C. It is 54 %.
- At the same time this maximum is raised by the fact that the temperature of -2,2 °C secures 118 days from 240 days in heating period.



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- It is 50% of days in the heating period.

Table 3. Ventilation by standard 0,5times air change rate per hour

exterior temperature <b>t</b> ( °C )	day number <b>x</b>	interior temperature <b>t<sub>i</sub></b> ( °C )	air change rate <b>n</b> h <sup>-1</sup>	flat volume <b>V</b> m <sup>3</sup>	ventilation air volume <b>Vv</b> m <sup>3</sup> /h	n*V <sub>v</sub> *0,36	temperature difference <b>t<sub>i</sub>-t<sub>o</sub></b> ( °C )	power <b>Q</b> W	heat quantity <b>Q<sub>c</sub></b> kWh
-15	6	20	0,5	160	80	28,8	35	1008,00	145,15
-9,4	19	20	0,5	160	80	28,8	29,4	846,72	386,10
-2,2	118	20	0,5	160	80	28,8	22,2	639,36	1810,67
1,8	52	20	0,5	160	80	28,8	18,2	524,16	654,15
7,4	37	20	0,5	160	80	28,8	12,6	362,88	322,24
11,2	18	20	0,5	160	80	28,8	8,8	253,44	109,49
day sum =		250						total heat quantity <b>Q<sub>SUMA</sub></b> =	3427,80

## 5. CONCLUSIONS

- The highest heat consumption provides ventilation by standard 0,5 times air change rate per hour
- At the same time maximal heat quantity is value, which is needed for perfect flat airing, it means to hold the norm standard 0,5 times air change rate per hour
- Airing by INFILTRATION, with the same entry conditions, air change rate is only 0,175 times per hour
- Airing by EXFILTRATION, the flat is ventilating only 0,115 times

Table 4. Results comparing – computations heat consumption for ventilation

	heat quantity <b>Q<sub>c</sub></b> kWh	percentage share heat quantity	air change rate <b>n</b> h <sup>-1</sup>	
	INFILTRATION	1196	35%	0,175
EXFILTRATION		783	23%	0,115
n = 0,5per hour	3428	100%	0,5	
maximum				

After comparing the results of total heat consumption we are satisfied that maximal heat quantity (that is 55% from total heat consumption) is important to supply when the exterior temperature is -2,2 °C.

This percentage share completely corresponds with percentage share day number during heating period while different exterior temperatures. Day number during heating period while exterior temperature is -2,2 °C, it is to 50%. And it is the same



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in the case of stair's shift effect and standard 0,5times air change rate per hour too. In both cases is used about 55% from total heat consumption.

We are satisfied that room's ventilation by standard 0,5times air change rate per hour is the most energetic expensive.

Total heat consumption for ventilation by standard 0,5 times air change rate per hour is 100%. This energy cost we could theoretically decrease by calculated heating loss by infiltration (35%) and exfiltration (23%). We can decrease total heat quantity by heat quantity from wind effect (infiltration) and stair's shaft effect (exfiltration). Percentage share 58% (35% + 23%) is more than a half needed heat quantity. This result we cannot neglect.

Total air change rate can we compute by this equation (1). Air change rate 0,79times per hour in this case is much more than hygienic requirement presents.

$$\begin{aligned} n_{0,5} + n_{\text{INFIL.}} + n_{\text{EXFIL.}} &= n_{\text{TOTAL}} [\text{h}^{-1}] \\ 0,5 \text{ h}^{-1} + 0,175 \text{ h}^{-1} + 0,115 \text{ h}^{-1} &= 0,79 \text{ h}^{-1} \end{aligned} \quad (1)$$

Because natural ventilation is passing through all the time in parallel with controlled standard 0,5 times air change rate per hour. If we do not accept natural ventilation, the room will be ventilated more than hygienic minimum.

Controlled standard 0,5 times air change rate per hour is the most energy consuming. We can decrease total heat quantity by heat quantity from wind effect (infiltration) and stair's shaft effect (exfiltration). It is computed in second equation (2).

$$\begin{aligned} Qn_{0,5} - Qn_{\text{INFIL.}} - Qn_{\text{EXFIL.}} &= Qn_{\text{TOTAL}} [\text{kWh}^{-1}] \\ 100\% - 35\% - 23\% &= 42\% \end{aligned} \quad (2)$$

We are satisfied that total heat quantity can bee decreased more than to half.

#### Acknowledgements

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## CFD simulation of indoor climate

Ondřej Šikula

*Institute of Building Services, Brno University of Technology, Brno, 602 00, Czech Republic*

### Summary

*The paper presents the experience acquired by the CFD (Computational Fluid Dynamics) simulation of indoor climate in a room heated by a gas space heater. The vertical air temperature difference in room is one of the indoor climate parameters. The simulation presents the non-stationary airflow and the distribution of temperatures in a dwelling room. The main goal of the paper is to identify factors which make a great vertical air temperature difference. Especially in a room which is heated up with high temperature of air. The paper compares results of CFD simulation with the measuring of temperatures and velocities in this room. The results can be considered trustworthy only if proper models of turbulence and radiation are used. The next goal is finding out appropriate turbulence and radiation models which could describe both heat transfer mechanisms in the room. The simulation is solved in the computer program FLUENT.*

**KEYWORDS:** CFD simulations, indoor climate, dwelling room

## 1. INTRODUCTION

### 1.1. Indoor climate

The main goal in the field of environmental engineering is to ensure optimal conditions for work, relaxation and residence of people in buildings. Optimal conditions are created artificially by means of heating, ventilation and air-conditioning systems. In this connection we speak about creation of the indoor climate in buildings which can be distinguished as thermal-technical, lighting, acoustic, etc.

The substantial part of HVAC designer's work constitutes the ensuring of the proper thermal and moisture microclimate in buildings. During winter and transition periods this problematic is ensured by the field dealing with heating systems. The humidity factor is in practice often omitted, therefore only the thermal component of indoor climate is observed. For simplification the problematic of the indoor climate creation during winter and transition period is focused on residential buildings. Factors creating the thermal microclimate within the room are especially temperature, intensity of thermal radiation and air



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turbulence level. The characteristic feature of all these factors is their distinctive time and spatial variability. These physical factors are present in all parts of the room and form the indoor climate of the room. By means of computer simulations and practical measurements can be proven and shown that the state of indoor climate generally varies at individual points of the room and different time periods as well.

Practically it is important to observe the thermal microclimate within spaces occupied by people. This area is designated as the inhabitant's zone.

### 1.2. Vertical distribution of temperatures as a thermal comfort factor

One of the factors influencing the quality of indoor climate in a dwelling room is the vertical distribution of temperatures. From now on the article deals with this factor. Already the old literature gives attention to this topic. For example [1] recommends the maximal temperature difference between the position of a head ( $t_{1,7}$ ) and an ankle ( $t_{0,1}$ ) to be 2,0 K for standing person and 1,5 K for sitting person from the point of view of thermal comfort. In Table 1, there are stated the ascertained vertical temperature differences for various types of heating according to [1]. The legal regulation for working environment requires the maximal vertical temperature difference to be 3 K, see [5].

Table 1. Maximal vertical temperature difference for standing person

Type of heating	Temp. difference between $t_{1,7}$ a $t_{0,1}$
Hot water heating – sectional heating element	1,5
Hot water heating – convector	2,7
Local heating – tiled stove	3,8
Warm-air heating	5,5

The requirement for thermal uniformity is easy to satisfy in case of floor heating, well-designed warm-air hating, etc. Generally we can say that the requirement on vertical temperature distribution is easily reachable when the temperature of the heating surface is not too much higher than the temperature of air.

Problematic situations occur by heating systems which produce high temperature in the vicinity of the heating surface. Around very hot heating surfaces (approximately  $> 90^{\circ}\text{C}$ ) occurs intensive flow of high air temperature caused by the thermic lifting force. Consequently the vertical temperature difference in the room is greater. Similar situation happens while heating with warm-air heating systems.



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## 2. DESCRIPTION OF THE PROBLEM AND SOLUTION

This article deals with the theoretical and experimental assessment of vertical temperature distribution in a room. We investigate the influence of the heating system with large heating surfaces and high temperatures on the vertical temperature distribution. The problem was solved theoretically and experimentally on a model room in a brick house heated by a gas space heater. The goal is to find out if the requirement on maximal vertical temperature difference according to [1] between the position of a head and an ankle can be satisfied especially at non-stationary conditions.

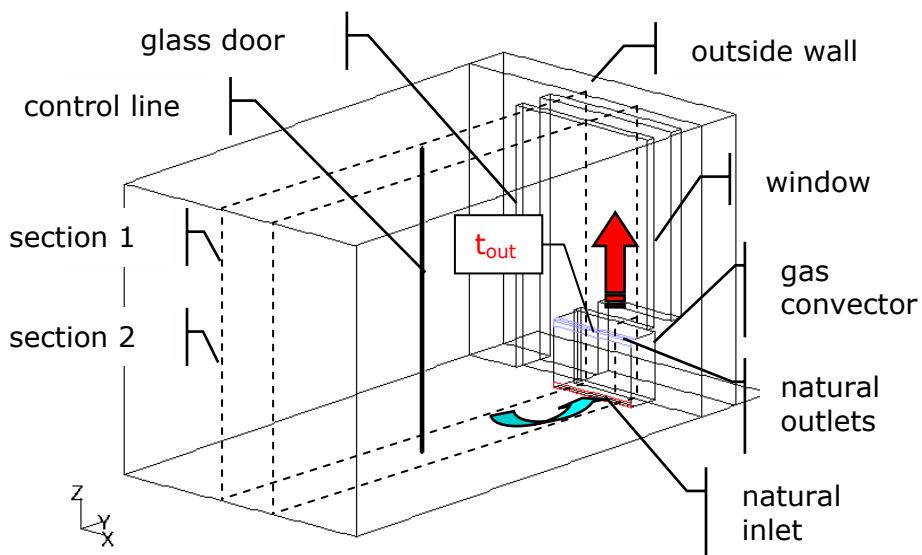


Figure 1. Geometry

Numerical simulation of the airflow and the heat transfer is carried out in the computer software FLUENT on a simplified three-dimensional model of the room.

### Theoretical solution

Theoretical solution is based on CFD simulation of the room created in the software Fluent. The calculation is solved for non-stationary conditions and three-dimensional case. The temperature boundary conditions of the model correspond to the condition of the day when the experimental measurement was done. For turbulence calculations the RNG k – e model was used. The heat transfer by long-wave radiation was solved by DO (Discrete ordinates) model.



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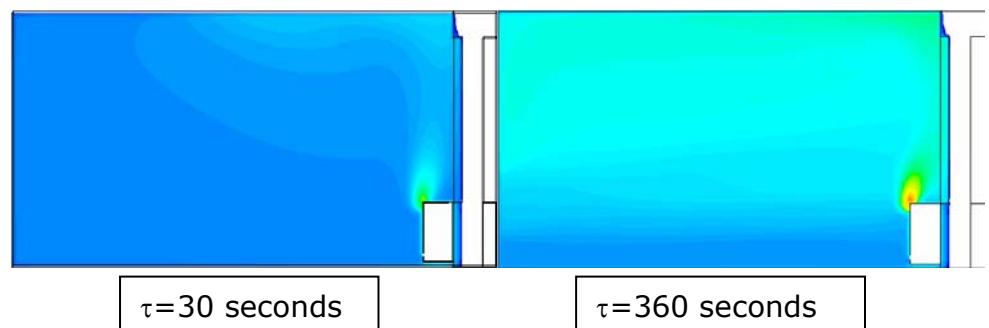


Figure 2. Unsteady temperature fields

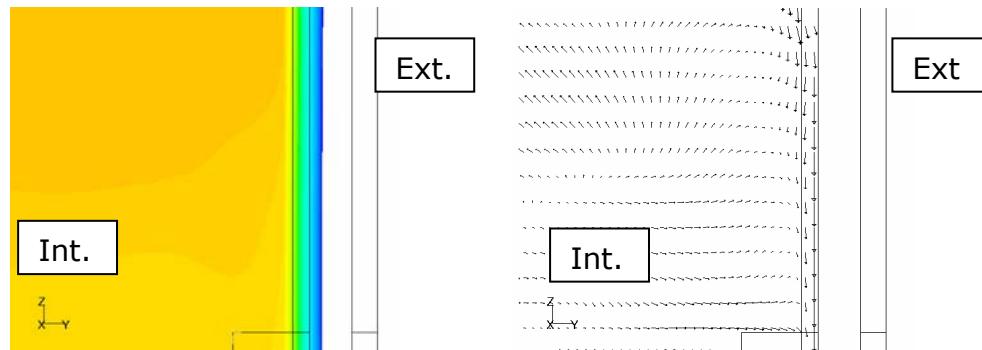


Figure 3. The creation of dropping airflow - section Nr. 1

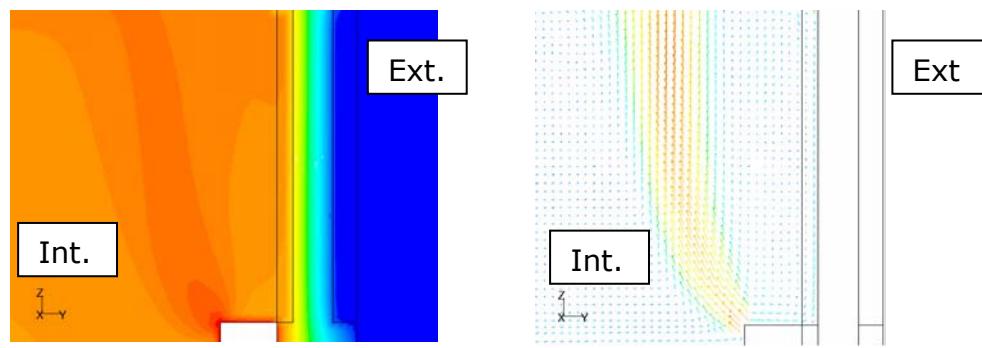


Figure 4. The shading out of dropping airflow - section Nr. 2

Simulation solution enables the illustration of temperature and velocity fields in the analyzed model room.



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### 3. EXPERIMENT

#### Methods

The experimental measurement was taken in the winter period of 2005/2006 and was divided in two parts. First of all were measured vertical temperatures in eight height points in the symmetry plane of the room. At the same time the velocity and temperature of air coming out of the gas space heater was measured and recorded. Further the monitoring of temperature fields of building structure surfaces was performed by the digital thermal-vision camera IR FLEXCAM.

The aim of the temperature, velocity and thermal-vision measurements was the identification of some indoor climate parameters and partially the verification of the numerical simulation results. The measurements proceeded as follows. First the model room was pre-heated (see the first temperature wave at Figure 5).

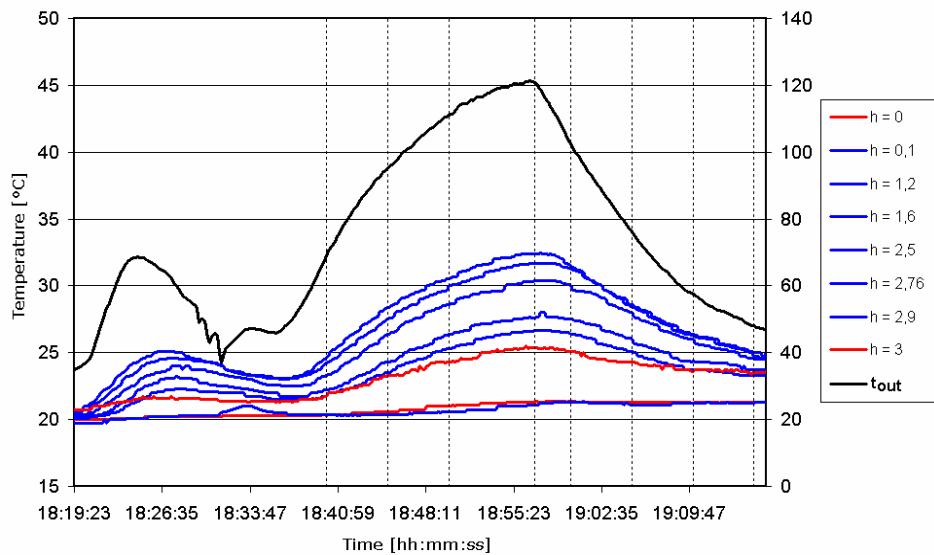


Figure 5. Time flow of the experiment

By this pre-heating the “start” temperature profile of the room was obtained (see the black vertical temperature distribution profile at Figure 6).

By gradual heating the maximal temperature profile was obtained (see the black vertical temperature distribution profile at Figure 7). After shutdown of the gas space heater the temperatures decreased (see the left vertical temperature distribution profile at Figure 7).



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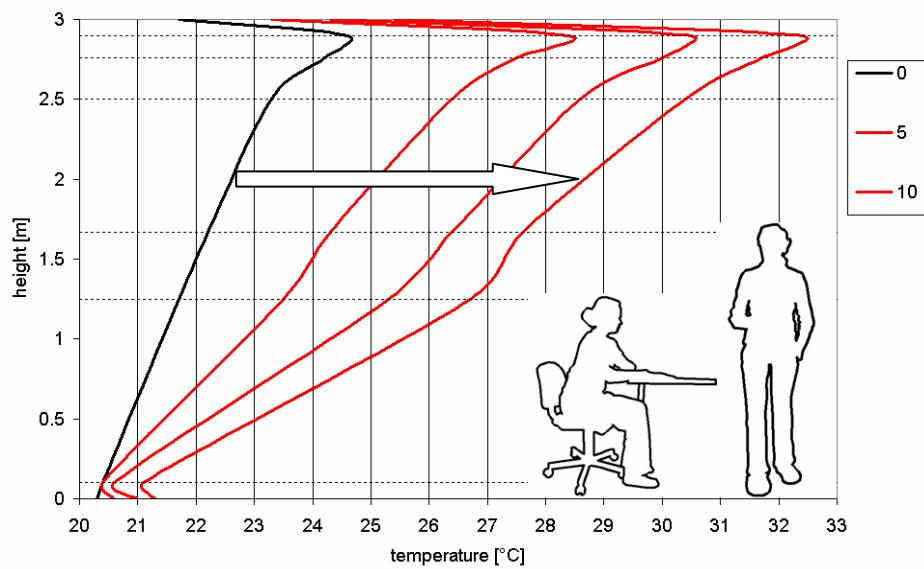


Figure 6. The vertical air temperature difference; warming-up

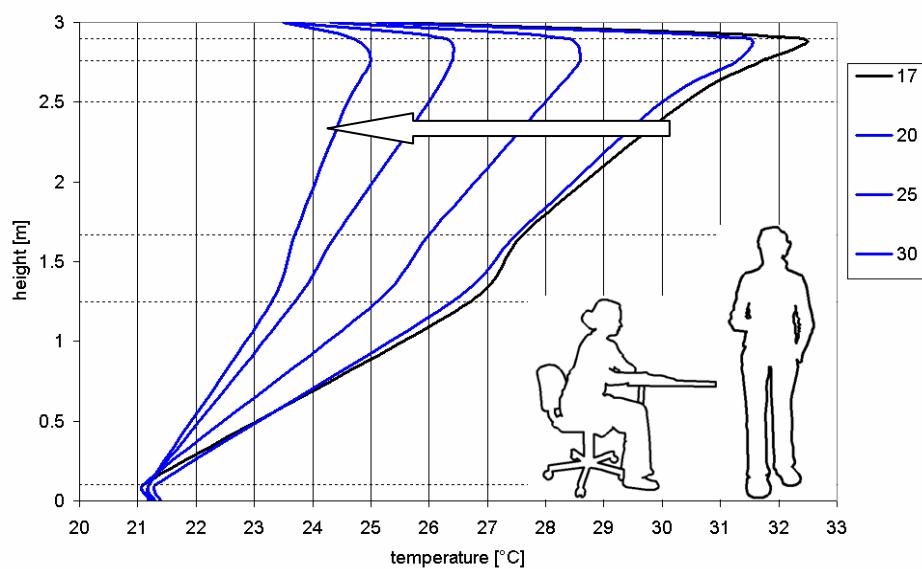


Figure 7. The vertical air temperature difference; cooling



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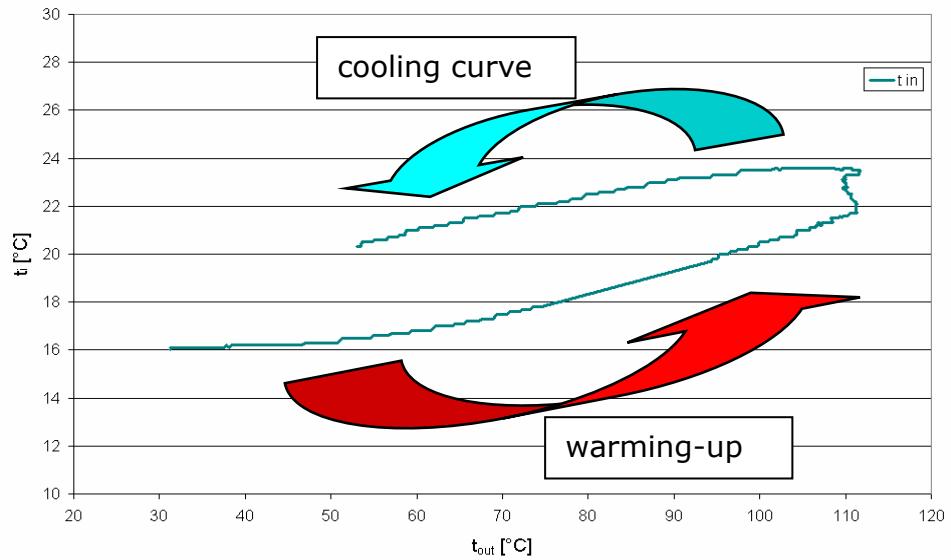


Figure 8. Warming-up and cooling of the interior air temperature  $t_i$  and its dependency on the air temperature coming out of the gas space heater  $t_{out}$

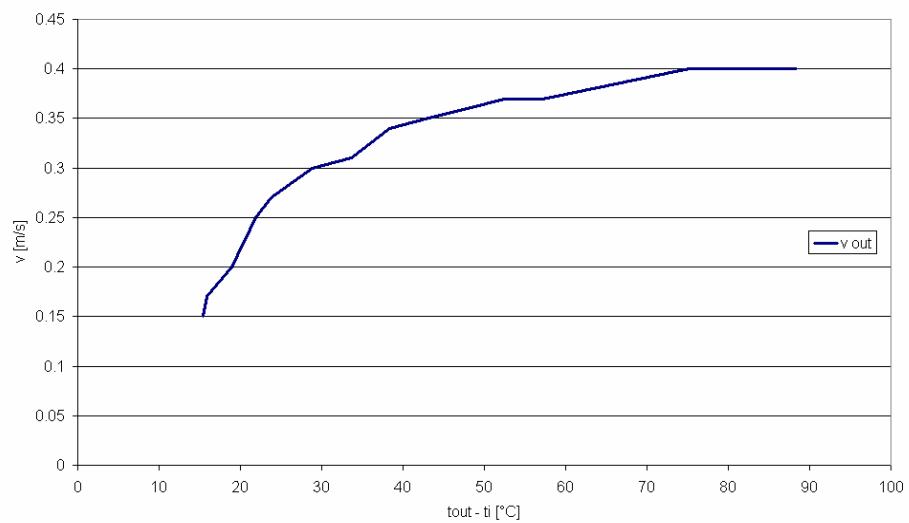


Figure 9. The dependency of the air velocity coming out of the gas space heater on the difference of air temperatures coming out of the gas space heater  $t_{out}$  and the interior air temperature  $t_i$



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Also the temperature and velocity of the air coming out of the gas space heater and the interior air temperature were continuously measured. The output temperature on the gas space heater reaches its maximal values up to 120 °C. From the measurement follows that the requirement on the vertical temperature difference between the position of a head and an ankle for standing person was just satisfied at the "start" temperature profile. In all remaining phases the requirement was substantially over-ranged.

At Figure 9 is shown the dependency of the air velocity coming out of the gas space heater on the difference of air temperatures coming out of the gas space heater  $t_{out}$  and the interior air temperature  $t_i$ .

Figure 8 illustrates the process of pre-heating and cooling of the interior air temperature  $t_i$  and its dependency on the air temperature coming out of the gas space heater  $t_{out}$ .

#### 4. CONCLUSIONS, DISCUSSION OF RESULTS

Above mentioned and described results prove the unfavorable influence of heating systems with high heating surface temperatures on the state of thermal indoor climate in residential rooms.



Figure 10. Surface temperatures

Reasons of great vertical temperature difference in the room are following:

- The formation of dropping airflows at the vicinity of cool surfaces (Figure 10) as a result of insufficient thermal insulation properties of the envelope constructions and high air infiltration of the window and door joints
- Insufficient or no shading out of the dropping cool airflows (Figures 3 and 4)
- High temperature (Figure 5) and velocity (Figure 9) of the air coming out of the gas space heater ( $t_{out}$ ).



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It is not easy to satisfy the requirement on vertical temperature distribution in the room in cases as the one described here. Experimental measurement proves that the worst situation from the point of view of temperature distribution is while dynamic changes of heating system, particularly while heating of the room (Figures 6 and 7).

The results of non-stationary numerical simulation do not correspond precisely to results of the experimental measurements. Nevertheless in principal the simulation results correspond to the measurements and so they give us objective image of thermal processes which take place in the observed model room.

#### Acknowledgments

Numerical calculation in the FLUENT software was performed in conjunction with the company Sobriety Ltd.

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# Physics of Constructions

## Computer modeling and simulation of carbon dioxide indoor concentration

Hana Doležílková

*Dept. of Microenvironmental and Bldg. Services Engrg., CTU, Prague, 166 29, Czech Republic*

### Summary

*Indoor pollutant concentration is more significant for human health than the outdoor atmosphere because people spend most of their time in buildings. There is pollutant concentration enhancement, relative humidity, mould reproduction and rise of environment not corresponding to human organism needs because of insufficient ventilation. Indoor air quality depends on many factors. Carbon dioxide is the most important indoor pollutant whether the pollutant source is presented only by people. There is overview of software enabling carbon dioxide modeling and simulation and also program CONTAM 2.4 using in my paper. It means multizone modeling where at the single zone is obtained carbon dioxide concentration thanks to geometry, openings, ventilation and pollutant sources interpolation. There were chosen three spaces for simulation of occupied flat. The results show that CO<sub>2</sub> concentration run is similar to interior occupation. Increasing time of concentration to constant value and decreasing time of concentration to ventilation air concentration depend on room volume.*

**KEYWORDS:** indoor air quality, computer modeling and simulation, carbon dioxide

### 1. INTRODUCTION

The aim for thermal losses lowering directed to limiting natural ventilation by windows. Tight windows have insufficient infiltration. They are unsuitable from the hygienic point of view. It leads to pollutant concentration enhancement relative humidity, mould reproduction and rise of environment not corresponding to human organism. So it is necessary to ensure sufficient mechanical ventilation.

In spite of minimal ventilation, the poor window sealing of old windows ensured sufficient ventilation rate, but it led to higher thermal losses. The residential space ventilation should ensure taking away of the depleted air, pollutants, moisture and smell to ensure the pleasant microclimate in rooms.



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Sufficient ventilation is important for a construction itself as well. High relative humidity can cause water vapors condensation in colder places – thermal bridges – and thereby increase mould rise risk.

## 2. ANALYSIS

### 2.1. Indoor air quality

Indoor air quality depends on many factors, especially on: outdoor air quality, air amount per person or ventilation rate, ventilation plant, amount of air pollutants, that sources are: inhabitants and their metabolism, inhabitants' activities, construction materials, social settlement, flat cleaning and housekeeping. Pollutants influencing indoor air quality are: carbon dioxide CO<sub>2</sub>, carbon monoxide CO, nitrogen oxides NO<sub>x</sub>, sulfur oxides SO<sub>x</sub>, formaldehyde, VOC, asbestos, dust, ozone, hydrocarbons, odors, radon, relative humidity, acaridae and microorganisms. Microorganisms are able to reproduce and multiply their negative influence on inhabitants' health during certain indoor conditions. Some of the chemical compounds presented in the indoor air belong among potential or evident human carcinogens.

Classic Pettenkofer normative 25 m<sup>3</sup>.h<sup>-1</sup> per person is based on the request to abolish unpleasant body odor evoking strain of depleted air by adhering carbon dioxide concentration 700 ppm. Pettenkofer normative is still a basic value for standards of most developed states. ASHRAE standard is based on it as well.

Table 1. Software for indoor environment modeling and simulation

Name	<b>IDA Indoor Climate and Energy</b>
Characteristic	a tool for simulation of thermal comfort, indoor air quality and energy consumption in buildings
Inputs	building geometry, thermal characteristics, internal loads and schedules, heating and cooling equipment and system characteristics
Results	zone heat balance, including specific contributions (sun, occupants, equipment, lights), ventilation, heating, cooling, surface transmissions, air leakage, cold bridges and furniture, solar influx, air CO <sub>2</sub> and moisture levels, air and surface temperatures, comfort indices, PPD and PMV
Name	<b>IAQ-Tools</b>
Characteristic	indoor air quality analysis including troubleshooting "sick" buildings, ventilation and filter design, design for contaminant source control, only simple-zone modeling
Inputs	filter effectiveness, air amount, pollutant production, indoor and outdoor pollutant concentration, contaminants: airborne solid contaminants (asbestos, lead, and particulates), gases (ammonia,



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	carbon dioxide, carbon monoxide, ethane, formaldehyde, hydrogen sulfide, methane, nitrogen oxides, ozone, propane, radon, and sulfur dioxide), bioaerosols (bacteria, fungi, and molds), tracer gases
Name	<b>COMIS</b>
Characteristic	air flow distribution model for multizone structures; takes wind, stack and HVAC into account; allows for crack flow, flow through large openings, and single-sided ventilation
Inputs	air-flow network, operating schedule, weather data, pollutant sources
Results	available graphical
Availability	<a href="http://www-epb.lbl.gov/comis">http://www-epb.lbl.gov/comis</a>
Name	<b>BSim2002</b>
Characteristic	indoor climate and energy conditions, design heating, cooling and ventilation plants, the geometry of the rooms created in the model graphic editor or imported from CAD drawings, room or rooms are attached to thermal zones by drag and drop in the tree structure of the model BSim 2002 includes standard libraries for: constructions, materials, glass, window frames, people loads, schedules, the user can define new
Inputs	climate data, constructions and materials, heating, cooling, internal loads, moisture load, ventilation systems, automatic control strategies
Results	available weekly, monthly or periodical basis, in tabular or graphic form
Name	<b>CONTAM 2.4</b>
Characteristic	multizone indoor air quality analysis and ventilation, flowing among particular rooms during natural, hybrid and mechanical ventilation, wind pressure on building facade
Inputs	the quantity airflow and pollutant production, schedules, outdoor pollutant concentration, geometry of zones, ventilation
Results	pollutant concentration, airflow – infiltration, exfiltration, flowing among particular rooms
Availability	<a href="http://www.bfrl.nist.gov/IAQanalysis/CONTAMWdesc.htm">http://www.bfrl.nist.gov/IAQanalysis/CONTAMWdesc.htm</a>

## 2.2. What pollutant is the most critical?

Pollutant production generating indoor as a result of people presence is possible to describe physically and to model. The shortness of the air oxygen, whose consumption is also possible to describe physically, can have the negative influence on indoor environment as well. Air amount is 1,06 m<sup>3</sup>.h<sup>-1</sup> per person for the minimal O<sub>2</sub> concentration, 8,38 – 9,96 m<sup>3</sup>.h<sup>-1</sup> per person for the optimal relative humidity and 22,5 m<sup>3</sup>.h<sup>-1</sup> per person for the acceptable CO<sub>2</sub> concentration. The highest amount of ventilation air is necessary for the acceptable CO<sub>2</sub> compliance concentration.



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### 2.3. Carbon dioxide

Carbon dioxide is the most usual air pollutant. Human metabolism, respiration and thermoregulation are the main sources of this pollutant. Respiration is adversely influenced by higher carbon dioxide concentration - already above 15 000 ppm. If its concentration in indoor air enhances above 30 000 ppm, most of people will have headache and dizziness. Concentration above 60 000 – 80 000 ppm leads to lethargy and losing consciousness. According to Czech Government order 178/2001 Sb. maximum acceptable CO<sub>2</sub> concentration is 25 020 ppm [5].

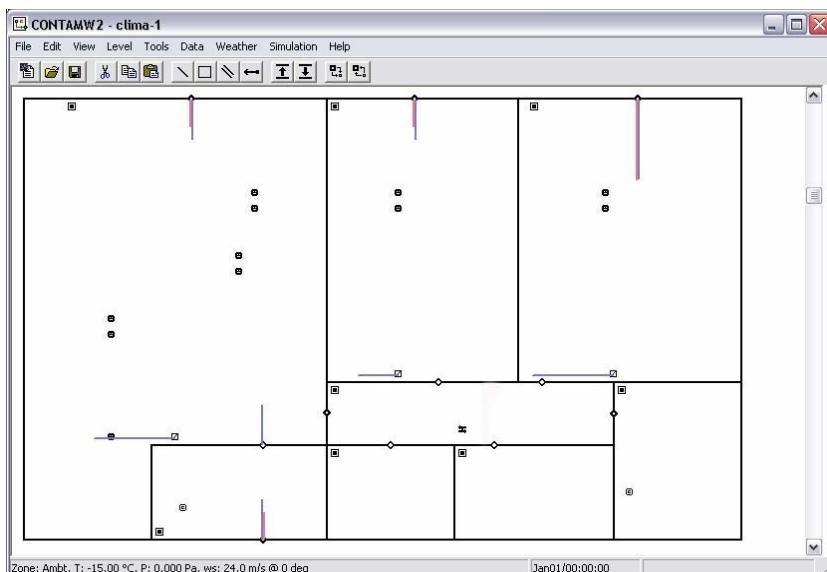


Figure 1. The plan of observed flat

### 2.4. Software for indoor environment modeling and simulation

Software for indoor air quality modeling and simulation are described in Table 1. There are described main characteristics, inputs and results, if the program is multi-zone or simple-zone.

## 3. METHOD - MATHEMATICAL MODEL IN PROGRAM CONTAM 2.4

There were chosen three alternatives for simulation of occupied flat. Alternative no. 1 presents flat occupation during weekday, e.g. when mother and her child are at home all the day and father is at work.



*Computer modeling and simulation of carbon dioxide indoor concentration*

Alternative no. 2 presents weekend, when all family is at home.

Alternative no. 3 describes weekday whit visit in the evening. The plan of the observed flat shows Figure 1.

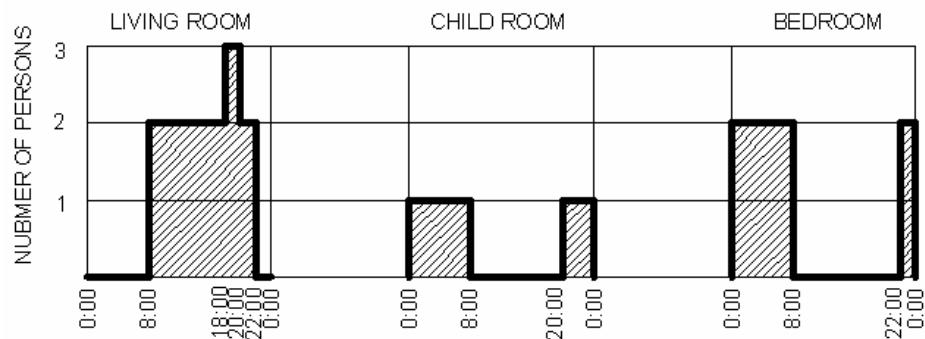


Figure 2. Particular zone occupation for alternative no. 1

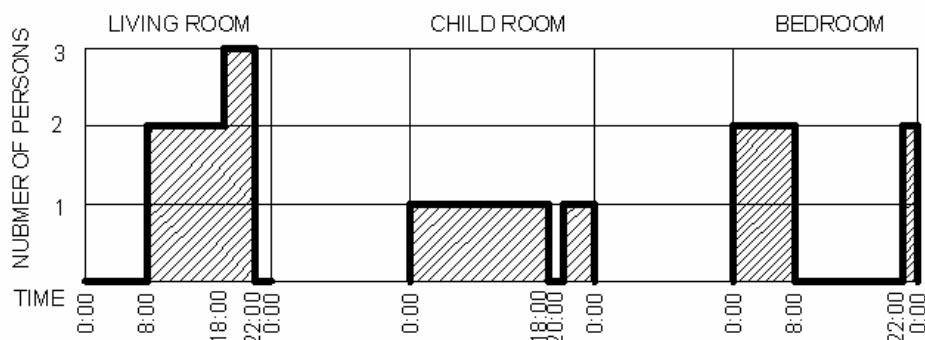


Figure 3. Particular zone occupation for alternative no. 2

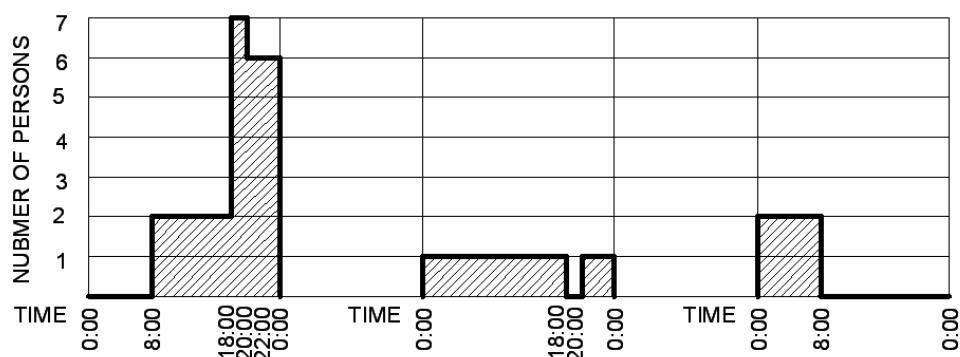


Figure 4. Particular zone occupation for alternative no. 3



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The observed rooms were presented by a living room and a bedroom, their occupation is stated in Figures 2, 3 and 4.

The detected indoor pollutant is carbon dioxide. It was counted with outdoor carbon dioxide concentration 350 ppm and respiration production 19 l.h<sup>-1</sup> per person. Ventilation air amount for particular spaces is stated in Table 2.

Table 2. Ventilation air amount

Zone (room)	Ventilation air amount		
		[m <sup>3</sup> .h <sup>-1</sup> ]	[m <sup>3</sup> .h <sup>-1</sup> per person]
Living room	Alternative no. 1 and 2	68	22,5
	Alternative no. 3	155	
Child room		22,5	22,5
Bedroom		45	22,5

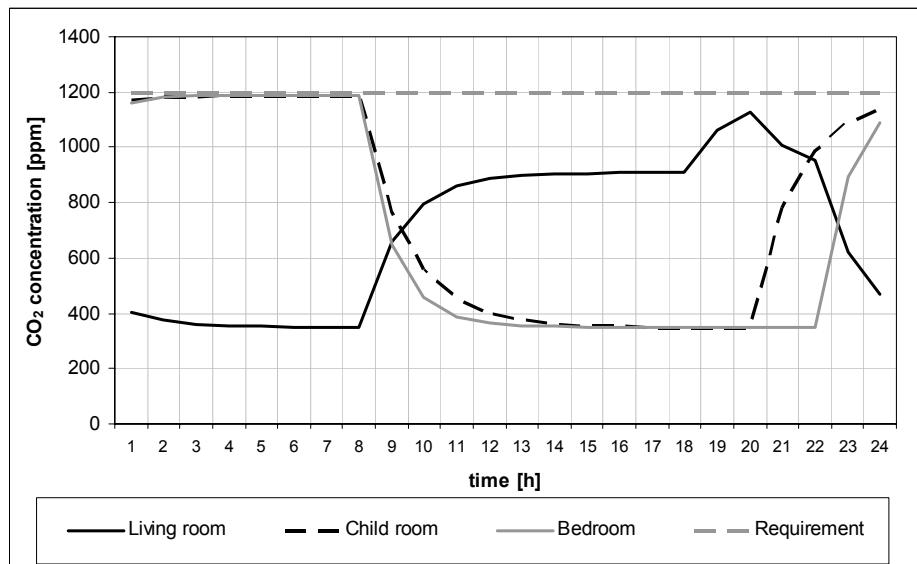


Figure 5. Carbon dioxide concentration runs for alternative no. 1

#### 4. RESULTS

The carbon dioxide concentration in particular rooms was calculated by program CONTAM 2.4. Figures 5, 6 and 7 show carbon dioxide concentration runs. The results show, that CO<sub>2</sub> concentration run is similar to interior occupation, increasing time of concentration to constant value and decreasing time of concentration to ventilation air concentration depend on room volume. From



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concentration runs is distinct, that ventilation air amount  $22,5 \text{ m}^3 \cdot \text{h}^{-1}$  per person is the necessary air amount for ensuring maximal carbon dioxide concentration 1200 ppm according to EN CR 1752 for Class “C”.

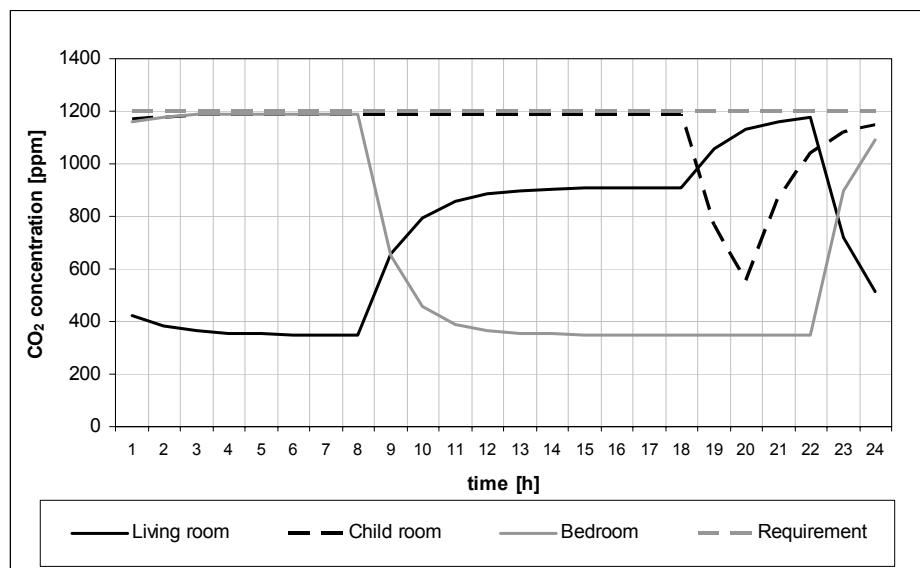


Figure 6. Carbon dioxide concentration runs for alternative no. 2

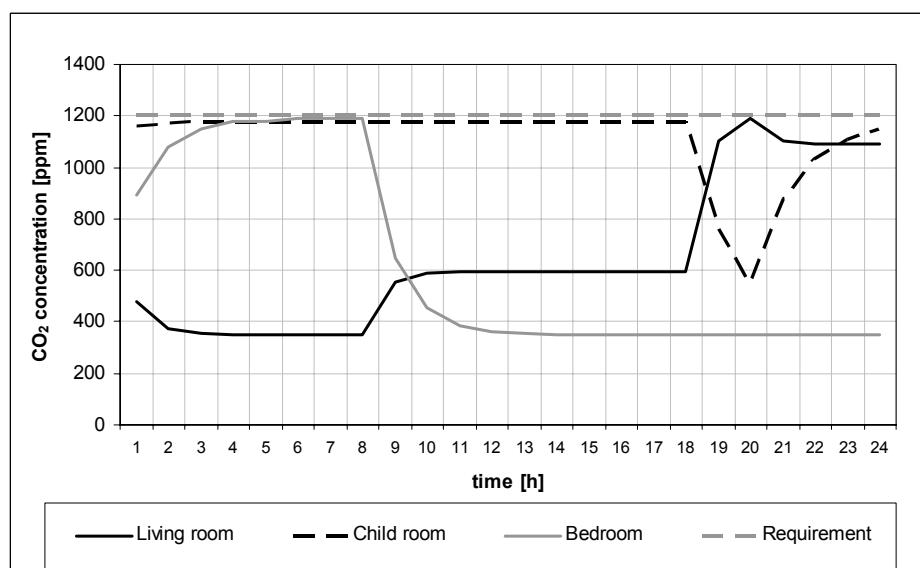


Figure 7. Carbon dioxide concentration runs for alternative no. 3



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## 5. DISCUSSION

The concentration dependence of CO<sub>2</sub> on supplied air amount for alternative no. 3 shows Figure 7. The maximum CO<sub>2</sub> concentration is 1200 ppm at supply 155 m<sup>3</sup>.h<sup>-1</sup>, it is much higher than in previous alternatives, and this is only for case of a visit. If it would be 68, maximal carbon dioxide concentration will be 2000 ppm for four hours. There is a question, if the short-term exceeding of concentration has an effect for ventilation design. During steady-state air return with more people than expected in the interior causes higher pollutants production. The constant return air volume increases energy losses if the room is empty. The ideal solution is while CO<sub>2</sub> sensor is in each room and air amount is controlled by actual demand.

## 6. CONCLUSIONS

It was documented that CO<sub>2</sub> concentration is the critical criterion for ventilation air amount design. The results show, that CO<sub>2</sub> concentration runs is similar to interior occupation. Simulation in program Contamw 2.0 showed, that necessary air amount per person for ensuring maximal CO<sub>2</sub> concentration 1200 ppm is 22,5 m<sup>3</sup>.h<sup>-1</sup> per person. It was established that, Pettenkofer normativ 25 m<sup>3</sup>.h<sup>-1</sup> per person is valid.

### Acknowledgements

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## Maîtrise de l'énergie dans les logements

Valentin Pavel<sup>1</sup>, Maricica Vasilache<sup>2</sup> et Monica Chereches<sup>3</sup>

<sup>1</sup>Departement Installations pour Constructions, Université Technique "Gh.Asachi", Iași, B-dul D.Mangeron 43, 700050, Roumanie

<sup>2</sup>Departement Génie Civiles, Université Technique "Gh.Asachi", Iași, B-dul D.Mangeron 43, 700050, Roumanie

<sup>3</sup>Institut National de Recherche dans le Bâtiment (INCERC), Iași, Rue Anton řesan 36, Roumanie

### Résumé

L'article présente une analyse sur les sujets suivants: évolution de la consommation de l'énergie au niveau national dans les derniers 30 ans; évolution de la consommation spécifique de l'énergie dans les bâtiments; évolution des réglementations techniques concernant l'énergétique du bâtiment; considérations sur l'acquis communautaire dans le domaine concerné. L'analyse sera réalisée de la perspective des deux étapes distinctes: 1974 – 1990 – caractérisée par une économie centralisée et influencée directement par l'augmentation du prix du pétrole et de l'énergie sur le marché international et 1990 – 2004: la transition de la Roumanie vers une économie de marché.

KEYWORDS: énergie thermique, combustible fossile, économie énergétique

### 1. INTRODUCTION

Depuis le 1 janvier 2007 la Roumanie est membre titulaire de l'Union Européenne. C'est le début d'une étape où il faut adopter des solution complexes pour réduire les décalages existants, dans tous les domaines de la vie sociale, politique, économique etc. face aux autres pays de l'Union

Une des questions c'est le problème de l'énergie. Nous voulons présenter une série d'éléments de liaison entre les notions ENERGIE et BATIMENT, dans une perspective qui fait référence à l'intervalle de temps du premier choc pétrolier des années '70 jusqu'au 2004.

Les estimations suivantes seront liées, en principe, aux trois ans importants: 1974, 1990, marqué par le changement du régime politique et 2004.



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## 2. LES BATIMENTS

En Roumanie existe un fond locatif relativement grand, qui, aux termes de référence en discussion, avait les valeurs suivantes [1], [2]:

- 1974 – 3.984.400 dont environ 35% avec chauffage central;
- 1990 – 7.948.000 dont environ 42% avec chauffage central;
- 2002 – 8.110.407 dont environ 50% avec chauffage central.

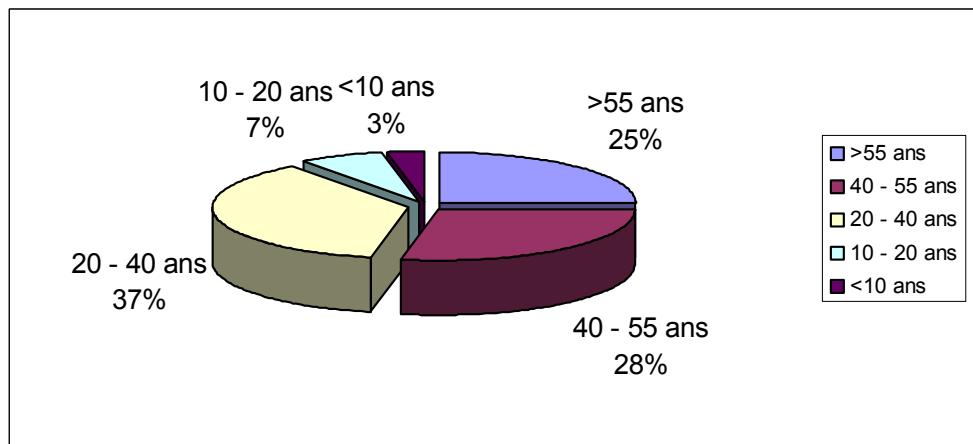


Figure 1 : La structure du fond locatif en Roumanie

Conformément aux donnés du dernier recensement de 2002, 52,5% des logements sont situés dans le milieu urbain.

La majorité des logement de Roumanie se trouve dans des bâtiments vieux de 15 à 55 ans, caractérisés par un degré réduit de protection thermique et de usure avancée. La structure du fond locatif en fonction de la vieillesse est illustrée dans la figure 1.

Pour comparaison, en 1995, dans les pays de l'Union Européenne, les 150 mille logements résidentiels, sont distribués de la manière présentée dans la figure 2. Comme élément spécifique on peut remarquer le pourcentage de 97% du font locatif appartenant au secteur privé, ce qui représente une valeur importante, en comparaison avec la situation d'avant 1990. Ça signifie que le nombre des Roumains qui habitent des logements loués est très réduit.

En même temps, environ 56% des bâtiments résidentiels de l'UE sont occupés par des propriétaires. Cet aspect a une signification particulière par rapport à l'implication du propriétaire (et usager dans le cas de Roumanie) dans les activités liées à la maîtrise de l'énergie dans les logements [1].



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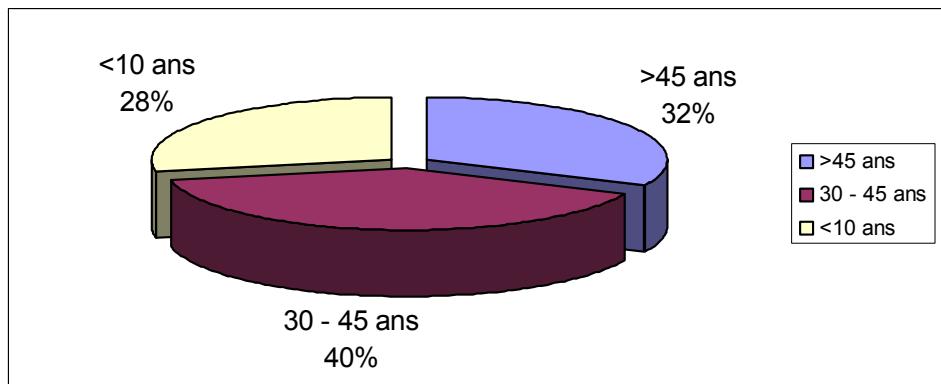


Figure 2 : *La structure du fond locatif en UE*

### 3. EVOLUTION DU DEGRE DE PROTECTION THERMIQUE DES BATIMENTS

Après le début de la crise énergétique de 1973, la préoccupation pour améliorer le degré de protection thermique des éléments de l'enveloppe des bâtiments, a connu une évolution particulière, dont le but était la maîtrise de l'énergie et en même de réaliser la satisfaction des exigences de performance concernant le confort thermique.

En Roumanie, dans la période d'avant 1973, c'étaient en vigueur des réglementations de protection thermique copiées du modèle soviétique. Pour la **résistance totale au transfert thermique,  $R_o$** , les valeurs prévues étaient :

- 0,88... 1,06 m<sup>2</sup>·K/W pour les parois;
- 1,18...1,73 m<sup>2</sup>·K/W pour les toits.

Surprenant, en 1973, sont imposées des valeurs diminuées pour le degré de protection thermique des éléments de clôture avec environ 26,4%, à une température intérieure de référence de  $t_i = 20^\circ\text{C}$  (figure 3).

Cette situation s'explique par l'inertie bureaucratique du système qui a appliqué les normes, élaborées avant le début de la crise mondiale du pétrole, quoique la réalité était totalement changée.

À peine en 1978 ont été modifiées, en Roumanie, certaines normes. De cette manière, la température intérieure de référence est diminuée à  $t_i = 18^\circ\text{C}$  et les valeurs de  $R_o$  seront:

- 1,16... 1,25 m<sup>2</sup>·K/W pour les parois;
- 1,46...1,63 m<sup>2</sup>·K/W pour les toits.



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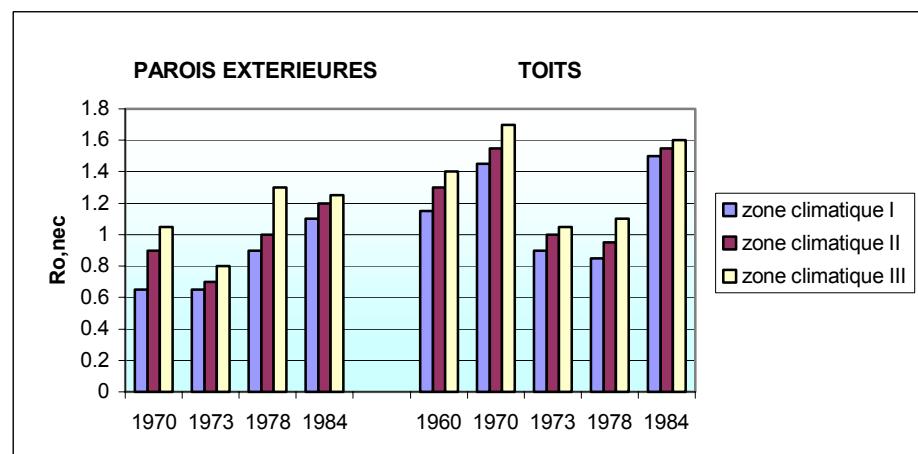


Figure 3 :Les valeurs de  $R_o$  1970 - 1984

Dans plusieurs pays européens, dès 1976 les réglementations concernant le degré d'isolation thermique étaient modifiées. Par exemple,  $R_o$  était:

- $1,20 \dots 1,80 \text{ m}^2 \cdot \text{K/W}$  pour les parois (figure 4);
- $1,30 \dots 1,4 \text{ m}^2 \cdot \text{K/W}$  pour les toits (figure 5).

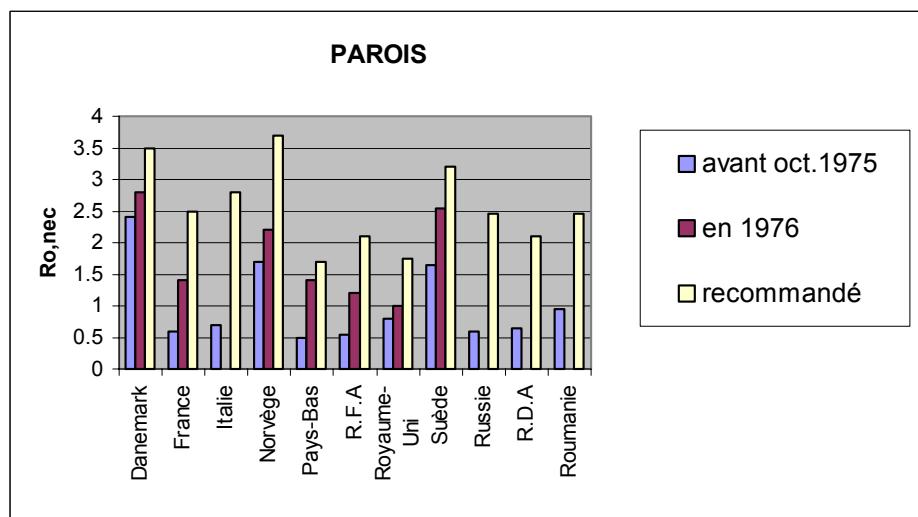


Figure 4 :  $R_o$  pour les parois

Ces valeurs ont été augmentées dans la période 1980-1985, en arrivant à  $R_o = 1,8 \dots 3,8 \text{ m}^2 \cdot \text{K/W}$ .



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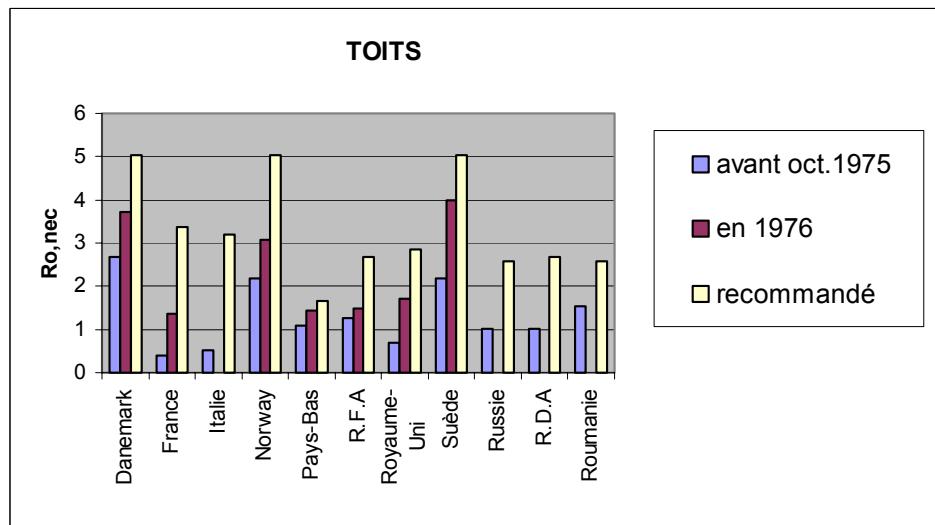


Figure 5 :  $R_0$  pour les toits

En Roumanie, l'année 1984 représente l'année qui apporte un changement remarquable dans les normes: l'adoption du **coeffcient global des pertes de chaleur G** [ $\text{W}/\text{m}^2\cdot\text{K}$ ]. Sont imposées des valeurs normées pour  $G_N = 0,315 \dots 0,610 \text{ W}/\text{m}^2\cdot\text{K}$ , ce qui correspondent à des valeurs de  $102 \dots 200 \text{ kWh}/\text{m}^2\cdot\text{an}$  pour la consommation spécifique.

Juste en 1997, par les nouvelles normes, est imposé l'usage des solutions pour les éléments de construction, avec un degré de protection thermique amélioré.

Il est aussi imposé le terme **R'** – la résistance moyenne corrigée sur le bâtiment, pour chaque type d'élément, dont les valeurs sont:

- $1,40 \text{ m}^2\cdot\text{K}/\text{W}$  pour les parois extérieures;
- $3,00 \text{ m}^2\cdot\text{K}/\text{W}$  pour les toits;
- $1,65 \dots 4,50 \text{ m}^2\cdot\text{K}/\text{W}$  pour les planchers - bas;
- $0,50 \text{ m}^2\cdot\text{K}/\text{W}$  pour la menuiserie extérieure.

Actuellement en Europe, les valeurs du degré de protection thermique **R'** sont augmentées de plus:

- $2,5 \dots 3,2 \text{ m}^2\cdot\text{K}/\text{W}$  pour les parois extérieures;
- $3,60 \dots 4,20 \text{ m}^2\cdot\text{K}/\text{W}$  pour les toits;
- $3,0 \dots 5,0 \text{ m}^2\cdot\text{K}/\text{W}$  pour les planchers;
- $0,62 \text{ m}^2\cdot\text{K}/\text{W}$  pour la menuiserie extérieure.

Donc, du point de vue des normes techniques, le degré de protection thermique imposé aux bâtiments de Roumanie, conduit à des consommations énergétiques dans le secteur tertiaire, situés près des valeurs envisagés dans les pays européens.



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#### 4. PRODUCTION ET DEPENSE ENERGETIQUE. POTENTIEL DE CONSERVATION DE L'ENERGIE

En ce qui concerne la production et la consommation énergétique il faut faire l'observation que les données officielles publiées avant 1990 ne peuvent pas être prises en considération qu'avec un grand degré d'approximation. Par ailleurs, la consommation usuelle de la population, était affectée par des coupures fréquentes dans l'alimentation avec énergie électrique et thermique, surtout pendant l'hiver. Ainsi, la température de l'air intérieur se diminuait fréquemment jusqu' aux valeurs situées environ 10-11°C.

Après 1990, la situation a changé radicalement, les chiffres publiés reflétant, assez précisément la réalité.

Dans le tableau 1 [3] sont présentées les évaluations concernant la consommation d'énergie thermique et électrique de la période située après le changement du régime. *Note: les données statistiques publiées, disponibles sont de 2003 et font référence à 2002.*

Tableau 1 Consommation énergétique nationale 1980 - 2002

Consommation énergétique nationale									
	U.M.	1980	1985	1990	1992	1995	1997	2000	2002
Consummation énergétique totale	10 <sup>9</sup> MJ	911,1	934,3	548,5	827,9	988,6	1314,6	1176,7	1158,4
Énergie électrique	mil kWh	63900	71200	58558	49178	42817	33913	30354	31784
Énergie thermique	10 <sup>12</sup> Kcal	163,7	161,9	65,9	142,5	92,05	125,7	90,17	106,16

Les valeurs du tableau reflètent l'évolution contradictoire de la Roumanie. D'un côté, la forte chute de l'économie du milieu des années '90 a influencé la consommation d'énergie électrique, surtout en industrie. De l'autre côté, la diminution dd l'usage d'énergie thermique, a été déterminé (sauf les variations climatiques) par la paupérisation de la population, spécialement urbaine, qui, étant dans l'impossibilité de payer les factures pour l'énergie, de plus en plus grandes, a réduit la consommation, parfois même jusqu'au renoncement au chauffage et au ECS.

Un autre phénomène de masse, a été le renoncement, dans les zones urbaines, à l'énergie thermique livrée par le système de chauffage centralisé et, en revanche, le montage des centrales individuelles à gaz, dans les appartements. Cette dernière solution a réduit la consommation de chaleur et la facture, mais avec des effets



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négatifs sur l'environnement et sur l'équilibre hydraulique du réseau de chauffage urbain.

Le montage des centrales individuelles a eu comme effet positif le fait que certains propriétaires d'appartements ont amélioré la protection thermique des logements, ce qui a constitué un bon exemple pour le reste de la population.

Par ailleurs, une série de projets pilotes ,réalisés en Roumanie, ont démontré qu'on peut assurer un niveau acceptable pour le confort thermique avec une consommation énergétique diminuée avec 20-25%, qui a été couplé avec un éclairage adéquat avec une puissance installée 4-5 fois diminuée.

Une étude scientifique réalisée pour les pays récemment adhérés à l'UE [4] ou candidats, indique des ressources importantes concernant le potentiel de conservation de l'énergie (figure 6).

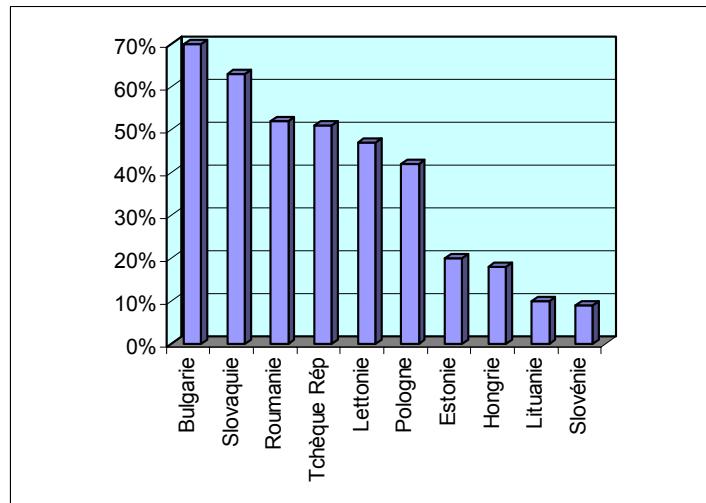


Figure 6 : Potentiel de conservation de l'énergie

## 5. SOURCES D'ENERGIE, MAITRISE, PERFORMANCE DES BATIMENTS, LEGISLATION

La Roumanie est confrontée à deux problèmes majeurs : d'un côté la diminution sévère des réserves d'énergie, ce qui implique des importations de plus en plus grandes, de l'autre côté un fond locatif avec des performances énergétiques modestes .



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La stratégie économique du développement durable impose la promotion de l'efficacité et de l'usage rationnel de l'énergie dans les bâtiments.

En Roumanie, les stratégies pour réaliser l'efficacité énergétique dans les bâtiments ont comme modèle, en lignes générales, le modèle des pays européens développés.

Les problèmes majeurs concernant la découverte de sources de financement, imposent d'établir les priorités et les mesures de réhabilitation et de modernisation énergétique des bâtiments ayant des dépences grandes d'énergie.

L'activité de réhabilitation thermique a comme but l'amélioration des performances thermiques des éléments de l'enveloppe et en même temps, l'augmentation des performances des installations de chauffage et d'eau chaude ménagère.

Les principales mesures concrètes nécessaires pour la réhabilitation thermique sont:

1. interventions au niveau des éléments de construction extérieures qui constituent l'enveloppe du bâtiment (isolations thermiques, menuiserie, étanchéités);
2. montage des compteurs d'eau et d'énergie au niveau du bâtiment;
3. gestion individuelle des utilités, par le montage dans les appartements des systèmes pour la répartition des coûts ;
4. isolation thermique des conduits dans les sous-sols;
5. montage des équipements thermiques performants (chaudières, échangeurs pour ECS, corps de chauffe etc.);
6. remplacement des robinets défaillants par des robinets modernes.

Pour que toutes les solutions pratiques soient appliquées usuellement il est nécessaire une législation appropriée.

Premièrement a été élaboré la **Loi de l'efficience énergétique (199 /2000)** qui a créé le cadre nécessaire pour l'élaboration et l'application d'une politique nationale de maîtrise de l'énergie conformément à la **Carte de l'Energie**.

Ensuite, l'**OG 29/2000, Ordonnance gouvernementale concernant la réhabilitation thermique du fond construit existent et la stimulation de l'économie d'énergie thermique**, a établi, à partir du 1 mai 2005, l'obligation de réaliser le **Certificat énergétique du bâtiment** comme acte officiel par lequel sont attestés les performances du bâtiment à un moment donné. Par ailleurs, un acte similaire devient obligatoire dans les pays de l'Union Européenne à partir du 4 janvier 2006.

A été élaboré, aussi, une série de réglementations par lesquelles on établit les méthodologies de réalisation des activités d'expertise et d'audit énergétiques (conformément avec la Directive du Conseil 93/76 EEC concernant la réduction de



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l'effet sur l'environnement - limitation des émissions de CO<sub>2</sub>- par l'amélioration de l'efficacité énergétique).

Par conséquent, la réhabilitation thermique des bâtiments suppose principalement les étapes suivantes d'intervention:

- I. *l'expertise énergétique;*
- II. *l'audit énergétique;*
- III. *le projet d'exécution des travaux de réhabilitation thermique;*
- IV. *l'exécution des travaux d'intervention pour la réhabilitation thermique.*

Toutes les actions et les activités mentionnées sont en concordance avec la **Directive 2002/91/EC** [5] qui réalise le cadre commun pour la promotion de l'amélioration des performances énergétiques des bâtiments, particulièrement dans les secteurs résidentiel et tertiaire. La *Commission Européenne* propose l'assistance des autorités et des organisations des états membres dans leur action de dissémination des informations concernant la performance énergétique des bâtiments et par des campagne d'information (co) financées par des programmes communautaires, de constituer un support dans l'action de sensibiliser et de mobiliser les facteurs de décision, des spécialistes et de la population.

Le programme **Intelligent Energy - Europe- Décision 1230/2003/EC**[5] – c'est un instrument d'application des principes du *développement durable* dans le domaine de l'énergie, ayant comme objectifs généraux: la sécurité de la livraison de l'énergie, la compétitivité et la protection de l'environnement. Ce programme est structuré sur 4 domaines spécifiques:

- SAVE** – l'usage rationnel de l'énergie et le management de la demande d'énergie;
- ALTENER** – des sources nouvelles et régénérables et diversité de la production de l'énergie;
- STEER** – aspects énergétiques dans le secteur des transports;
- COOPENER** – promotion des sources régénérables d'énergie et l'usage rationnel de l'énergie au niveau mondial;

## 6. CONCLUSION

En Roumanie, pour satisfaire des exigences imposées par ces types de projets européens il est nécessaire de réaliser l'implication de tous les spécialistes du secteur bâtiments (énergie, construction, architecture, génie urbain, fournisseur d'utilités, institutions financiers, etc.) dans un processus intégré et unitaire au niveau local et régional, mais avec un impact au niveau européen et global.



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## Quality of the inside environment and the energy efficiency of buildings

Irina Bliuc<sup>1</sup> and Irina Baran<sup>2</sup>

<sup>1</sup>Faculty of Architecture, Technical University "Gh. Asachi" Iași

<sup>2</sup>Faculty of Civil Engineering, Technical University "Gh. Asachi" Iași

### Summary

*The assurance of the indoor environment quality, having in view the hygiene and comfort aspects, has today a special importance in the present energy context. This means the energy consumptions decreasing, especially those from fossil fuels and the promotion of the renewable energy resource, having in view the diminution of the pollutants emissions with green house effect at the planetary scale.*

*In this context, it is imposed more and more the "energy efficiency" concept or the "energy efficient building" one in the buildings conception and also in the certification and rehabilitation process.*

*Starting from the criteria that are defining the indoor environment quality, this paper wants to present the main passive measures that may lead to this aim, with examples of real achievements met in the literature.*

**KEYWORDS:** energy consumption, energy efficiency, indoor environment quality, thermal insulation, indoor comfort

### 1. INTRODUCTION

The main role of a building is to ensure for the inhabitants a healthy, pleasant and comfortable environment, and as possible independent of the outside conditions, such as meteorological or acoustical conditions.

The present requirements concerning this aspect are much more restrictive than those accepted during the previous historical periods, because of the changes in the nature and complexity of the internal and external actions that are occurring on the buildings, on one hand, and because of the inhabitants' requirements evolution, on the other.

To fulfill these requirements, directly connected to the energy consumption, is as important as the stability and safety requirements, or the architectural or the environmental framing aspects.



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The energy used for the buildings operation is dedicated to the achievement of a healthy and comfortable inside environment, respectively to the heating of spaces during the cold seasons of the year or to the cooling during the warm season, to the lightening and ventilation. Before the period of the energy crisis, period in which the assurance of the environment quality was exclusively an equipments problem, it was generally accepted the idea concerning the direct relation between the energy consumption and the inside environment quality, which means that an increase of the energy consumption leads automatically to the increase of the inside environment quality, in general, and especially of the comfort, and conversely. The energy consumption decreasing has as consequences the inadequate life and comfort conditions. It is even accepted a ineluctable conflict between a low energy consumption and a healthy and comfortable environment.

The researches focused on the identification of some strategies and solving ways of energy problems, and recently of the environmental issues, in the sustainable development concept frame, have shown that through an interdisciplinary and multicriterial approach of the buildings concept is entirely possible an architectural quality, an agreeable comfortable and healthy inside environment, and a low energy consumption too.

All these attribute define an **energy efficient building**.

A complex analysis of the connection between the energy consumption and the inside environment quality at the dwellings and administrative buildings has been achieved in the frame of the European Project HOPE (Health Optimization Protocol for Energy Efficient Buildings) with 14 participants from 12 European countries, during 2002-2005 /1/. There were studied more than 160 buildings from the administrative and dwelling sector, half of them having a low energy consumption. The investigation means a general inspection, a discussion with the building superintendent and questionnaires distributed to the inhabitants.

The results have been invalidated the theory concerning the direct relation between the energy consumption and the quality of the inside environment. This made possible to frame the buildings into 4 categories:

- - buildings with high energy consumption and a good quality inside environment;
- - buildings with a high energy consumption and a low quality of the inside environment;
- - buildings with low energy consumption and a low quality of the inside environment;
- - buildings with low energy consumption and a good quality of the environment.

In this way it was noticed that the consumed energy does not depend on the inside temperature value, on the climate conditions and the ventilation rate, but in a grater



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measure, on the architectural and constructive solutions and the way of use. There was recorded an important dissatisfaction percentage and even SBS symptoms in buildings that consume a high quantity of energy for mechanical ventilation, but it is not paid attention to the moisture, occupation degree or noise protection. On the other hand, the buildings with low energy consumption, natural ventilated, present a healthy and comfortable inside environment.

## 2. THE INDOOR ENVIRONMENT QUALITY

The inside environment quality, a decisive factor concerning the health and well being of the inhabitants, is influenced by the air composition (regarding the chemical, physical and comfortable and healthy pollutants) and by comfort (with the main components, acoustic, thermal and optical)

### 2.1 Air composition. Indoor pollution sources

A building may present risks for the inhabitants' health, depending on the presence of chemical and physical pollution sources or ensure favorable conditions for the microorganisms' development.

The main sources of pollution in buildings may generate:

#### a. Chemical pollutants

The chemical synthetic products are parts of our environment. They are met in food, water, air, being emitted by building materials, furniture, domestic products, etc. The effects of the chemical pollution on health are multiples and are going from simple sense perception to very serious effects that may affect the respiratory, nervous or the gastro-intestinal system. Certain chemical pollutants are framed in the cancerogenic substances category. If the individual toxicity of the greater part of these pollutants is known, practical it is not known almost anything about their toxicity when they are in a combination or they have low concentrations, as they are frequently met in the inside air of the buildings where we live and work.

#### b. Physical pollutants

The main physical pollutants met in the inside environment are the excessive moisture, the radon, the dust, the fibers (especially asbestos), the electric and magnetic field of low and high frequency. The presence of these pollutants may cause different symptoms, from the dryness of the respiratory ways, to the memory loss and concentration difficulties and cancer diseases.



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### *c. Biological pollutants*

In this category of biological pollutants are included the microbes, viruses, bacteria, pollen and smells that are developing in the interior air and are coming from the human beings, animals, acarians, beetles, room plants, mould, etc. They can cause allergies, affections of the respiratory ways, the most vulnerable being the children and the old people. The risks concerning these pollutants are as much important as the concentration is higher.

A good quality of the air means the knowing of the pollutants sources, the decreasing to the minimum possible of the emissions and continuous exhaust of the pollutants by ventilation.

## 2.2. The comfort

Generally speaking, the comfort means a thermal, acoustic and optical comfort. The perception of the comfort level implies a certain subjectivism degree, but in the same time is the result of the simultaneous action of objective factors, measurable, as architectural, constructive or operation factors.

If the assurance of the acoustic comfort is not directly connected to the energetic factor, the thermal and optical comfort assurance during the whole year requires certain energy consumption for heating, lightening and air –conditioning.

### *a. The thermal comfort*

The thermal comfort is achieved by:

- - the assurance of a mean operative temperature, as a result of air temperature, of border surfaces, of moisture and air speed, in concordance with the activity nature and the inhabitants cloths;
- - the asymmetry limitation of the radiant temperature and temperature gradients to acceptable values;
- - the situations avoiding in which the inhabitants are coming in contact with surfaces too cold or too hot;
- - the avoiding of air currents ( limitation of air speed).

All these requirements must be fulfilled in winter conditions and summer as well.

### *b. The visual comfort*

The optical comfort is get by the assurance of a lightening adopted to the activity nature in the visual field, avoiding the contrast too strong, especially the blindness. The used light spectrum must be continuous, and the color temperature must be adapted to the lightening. The natural lightening is comfortable in the measure in which its intensity may be controlled.



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### *c. The acoustic comfort*

The acoustic comfort may be ensured by avoiding the annoying noises, by decreasing of their intensity at source or by acoustic insulation to the air noise or the impact one. The admitted noise level has values connected to the activity nature (intellectual, rest, health caring)

## 3. STRATEGIES AND WAYS OF ACHIEVEMENT OF A HEALTHY AND COMFORTABLE INDOOR ENVIRONMENT WITH LOW ENERGY CONSUMPTION

The decreasing of the necessary energy consumption for a healthy and comfortable environment may be achieved by adopting passive measures, associated with minimum energy consumption, integrated in the architectural and constructive conception of the building. For example, the equipments for the mechanical ventilation or air-conditioning, correct conceived and operated could contribute to the assurance of a healthy and comfortable environment, is framed in the active measures category, while the thermal protection or the controlled ventilation are active measures.

In general, the measures for the thermal comfort assurance with low consumption contribute (or does not affect) to the air quality.

One of the measures that intervenes in meeting the both requirements categories, in certain circumstances in a contradictory way, is the ventilation, that reduced under a level aiming an energy saving, becomes insufficient from an air quality point of view or condense risk.

### 3.1. The thermal insulation of the envelope

This means the rational use, in the building envelope structure, of some materials that hinder the heat transmission from inside to outside, during winter, and from outside to inside during summer.

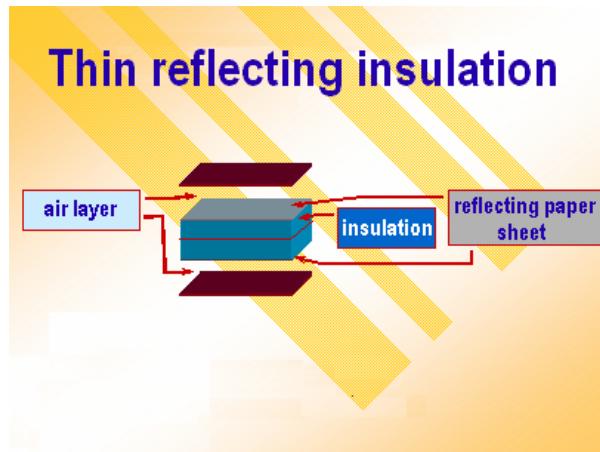
The usually used materials for thermal insulation have low thermal conductivity and density. They have an organic or inorganic nature and they are presented in forms of blocks, plates or mattresses. Their proprieties and application fields are in general well known, and also the constructive solutions where are included: light homogeneous structures, compact stratified structures, ventilated structures, green roofs, walls with translucent insulation, etc.

There are also materials with high thermal characteristics that are not well known in the usual practice:



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- insulation materials in form of thin layers associated with reflecting sheets, having the role of reflecting the infrared radiation and in this way they suppress the heat transfer through radiation;
- insulation materials under vacuum get by air exit from a fibrous or cellular support packed in a air tight sheet; from all these the silicon nanogel has special proprieties, being less conductive than the air at normal pressure;



a.



b.

Fig.1. Thermal insulation of high efficiency a. thin reflecting insulation; b. exceptional insulations /2/

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The thermal insulation efficiency requires its continuity on the whole envelope surface. Any physical or geometrical discontinuity generates a thermal bridge characterized by additional thermal losses, condense risk and lack of comfort. These thermal bridges must be avoided as much possible or treated in a suitable way when they could not be avoided.

### 3.2. The shape and orientation of the building

The contact area between the building and the outside environment influences both heat losses and gains. A smaller external surface increases the thermal insulation efficiency, the compactness index being one of the most important parameters in establishing the energy indicators.

The glazed surfaces correctly dimensioned and oriented contribute to the decreasing of heat losses and solar gains utilization.

The adequate orientation toward the dominant winds and the cardinal points is important for the air infiltration control and for the assurance of a convenient route of the air circulation during summer for spaces air conditioning.

### 3.3. Thermal mass and inertia

The thermal inertia represents the building capacity to maintain an inside temperature as much closer to the outside temperature in the absence of a heat or cooling source. This means the envelope and partition elements capacity to damp and diphase in time the external temperature fluctuations and the fluxes generated by the solar radiation and internal gains.

The thermal inertia has two components:

- - the transmission inertia concerning the opaque elements is get by their damp and diphase capacity and intervenes depending on the temperature variation and external fluxes;
- - the absorption inertia concerning the elements being in contact with the indoor air and intervenes depending on the energy flux that are crossing over the glazed areas or are resulted from the using process.

An important inertia get by disposing the layers with high mass to the interior is adequate to the continuous heating. The discontinuous heating regime requires a low inertia that enables the rapid heating or cooling. This is get by placing to the interior the insulation layer or by plating the internal surfaces with a thin layer of thermal insulation material associated with a thin layer of light material as the wooden paneling, plastic material or gypsum cardboard.



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### 3.4. Ventilation

The role of ventilation is complex and consisting of air refreshing by exhausting the polluted inside air and replacing it with fresh air and of comfort assurance, especially during summer. The energy saving requirements and mainly the air conditioning requirements have generated a reorientation toward the controlled natural ventilation, not only in the dwelling case, but also in the public multistoried buildings case. The references present many examples of public, multistoried buildings, new or rehabilitated, where the ventilation is achieved by a natural way (fig.2). There have been developed some systems that emphasize the stack effects by architectural elements utilization such as the internal courtyard or atrium or by rational use of solar energy and wind pressure (active façades, double-peau façades).

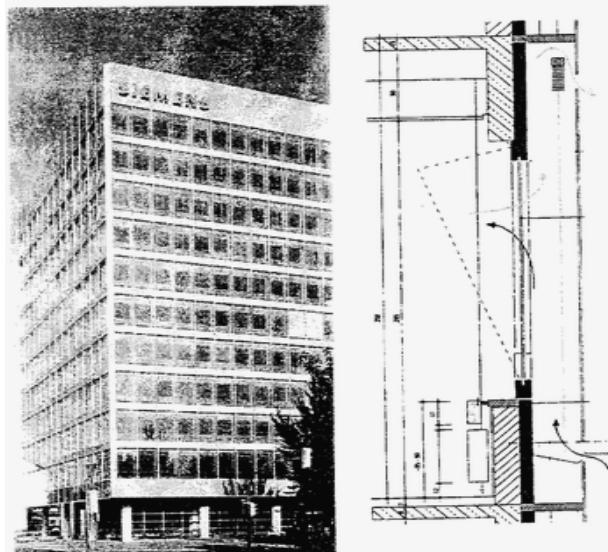


Fig.2. Natural ventilation of tall buildings with double façades (Siemens building, Dortmund) /2/

### 3.5. The climatic advantages of the ground

The important thermal mass of the ground generates a progressive attenuation of the yearly and daily temperatures variations of the outside air, associated with a diphase in time. These can be used to the underground constructions achievement, to the conception and achievement of seasonal storage systems of solar energy and



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some preheating/precooling systems of fresh air introduced in buildings by ventilation process.(Fig.3.).

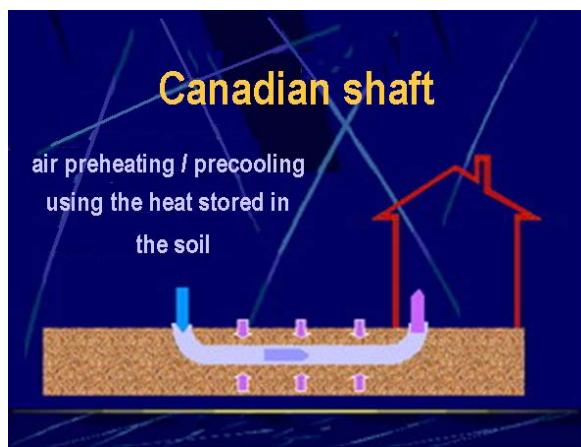


Fig.3. Preheating/ precooling of air by passing through the ground/2/

### 3.6. Solar energy utilization

Passive systems of solar energy utilization consisting of greenhouse spaces, greenhouse walls, solar façades of different types, etc. have penetrated in the basic vocabulary of contemporary architecture. Their working is based on the greenhouse effect, thermal inertia, air circulation by natural thermal convection. A high level of development consists of the introduction of the photovoltaic panels in façades of high performance.

The utilization of these principles has as a result the elaboration of some complex solutions and systems based on the summation of many more effects and on the integration in the general architectural conception. The passive systems of solar energy utilization associated with systems of taking over the polluted air, of air conditioning by using some heat switch ground-air, or cooling systems with evaporation for summer conditions lead to important energy saving in ecological buildings, with real adaptation qualities to the fluctuations of the outside environment parameters.

The technological progresses in the constructions materials and products offer to the designers' complex technique solutions, with high efficiency like: translucide thermal insulations, thermal insulated windows with selective optic proprieties, active façades involved in the spaces ventilation, photovoltaic surfaces, etc.



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### 3.7. The energy decreasing by lightening

The decreasing of the energy used for lightening implies the increasing of the using time of the day light, which is obtained by different architectural measures: the best shape and dimensions adoptions for windows, the avoiding of windows obstruction by trees, equipments and buildings, coloring the opposite surfaces to the windows in light colors, the enlarging the windows to the exterior to increase the aria of visible sky. The placing in front of the windows of some anidolic systems, consisting of mirrors with a certain shape and construction, having the role of concentration and directing the spot light toward arias less lighted, during a certain day period. In this way, it is obtained an uniform lightening and a decreasing of the time using of the artificial light.(Fig.4.)

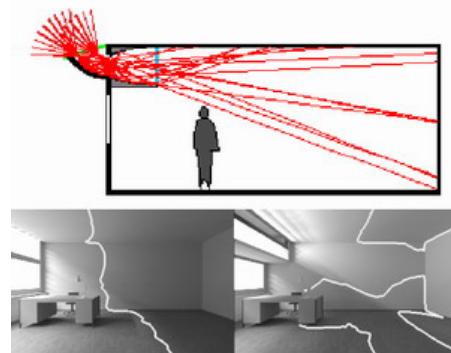


Fig.4. Efficient systems for a natural lightening/2/

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## Sustainable development in Civil Engineering under the climate change and the increasing cost of the energy

Adrian Radu, Laura Dumitrescu

*Civil and Ind. Engineering Department, Technical University "Gh. Asachi", Iasi, 700050, Romania*

### Summary

*The climatic changes, the reduction of the energetic dependency and the increasing price of the fossil fuels are acting together requiring important changes in civil engineering.*

*The article is presenting some data in order to increase the sensibility of the building specialists because during the next decades the climatic changes will grow up throughout the world and in Romania, too.*

**KEYWORDS:** climate change, sustainable development, civil buildings, construction.

### 1. GENERAL FRAME

The climate progressive change was considered in the middle of the last century as scientific hypothesis. Now it becomes certitude.

In this context, the Kyoto Protocol (1997) established important targets in order to reduce the emissions of greenhouse gases (GHGs).

Every day, new information about the possible dangerous consequences of the warming climate can be found on internet and mass-media.

A review of this data established by the specialists in the atmosphere's physics and meteorologists is presented considering the interest for civil engineers and architects.

### 2. CLIMATE CHANGE

Climate changes are the great danger which the humanity confronted in the past milleniums, threatening the environment, the global economy, our way of life, security and safety (Figure 1). Global warming, regional anomalies, tropical



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temperatures, increase of the seas' levels, floods, etc. are expected in the next decades /1/.

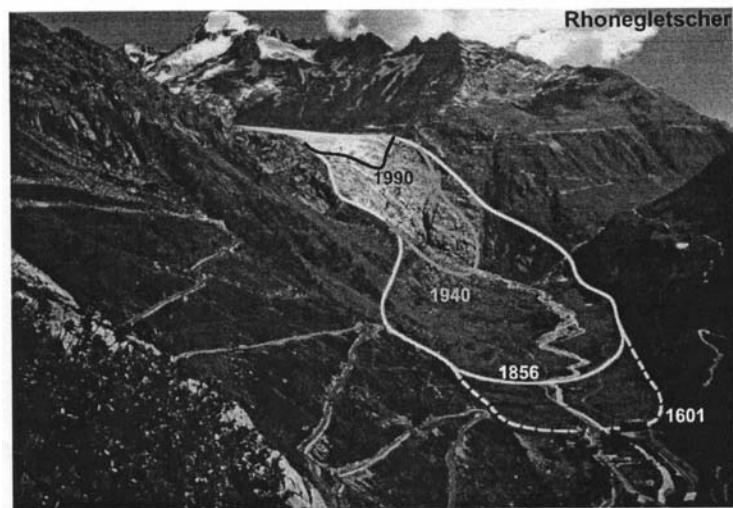


Fig. 1 – The progressive fount of the Rhon's glacier /2/

### 3. THE NATURAL ENERGY RESOURCES DEPLETION AND INCREASE OF THE ENERGY COST

Natural deposits constitute in millions of years. Now, the combustibles are consumed very quickly (at the geologic scale of time) – figure 2.

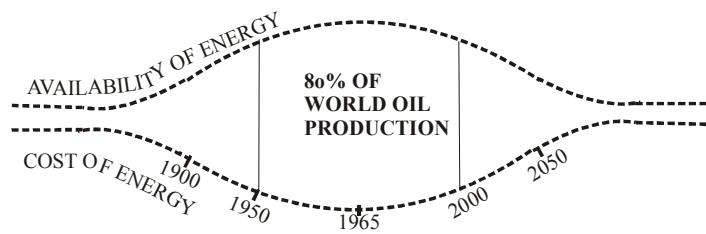


Fig. 2 – The end of the low-cost energy era /3/



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## 4. WORLD-WIDE SUSTAINABILITY CONCERNMENTS AND SOLUTIONS

- Factor 4; E.U.Weizsäcker (1995);
- Kyoto Protocol (1997);
- World Meteorological Organization Declaration (2004);
- Joint science academies' statement: Global response to climate change, addressed to the G8 Gleneagles Summit (2005) – figure 3;

- Climate change is real
- Most of the warming in recent decades can be attributed to human activities
- Reduce the courses of climate change
- Prepare for the consequences of climate change

Fig. 3 – The academies' statement basic ideas /4/

- „2000 Watt-Society“ /2/ to be reached in 2050 (figure 4);

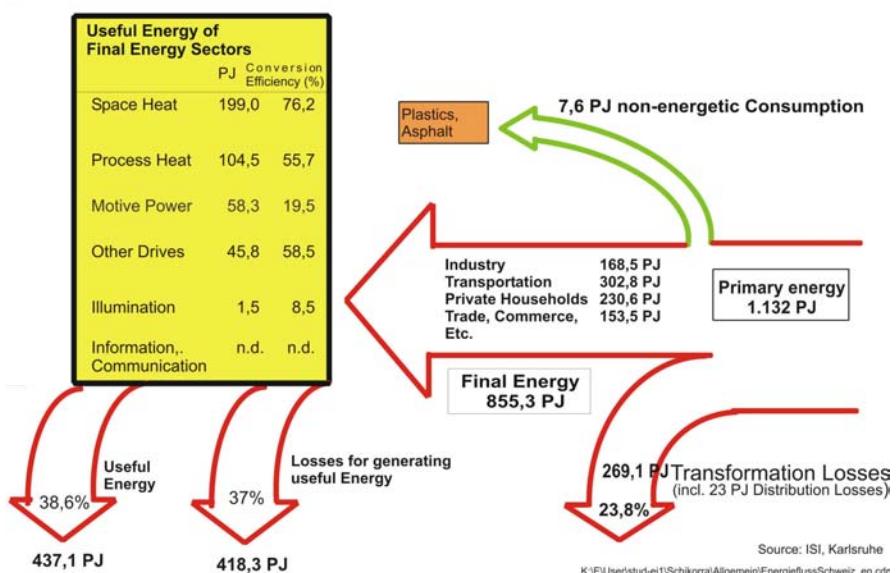


Fig. 4 – Swiss energy flow diagram in 2001 /5/



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- „Faisons vite ça chauffe. Plus de bien être en consommant 2 fois moins”; CITEPA, 2005 /6/

## 5. NEW OBJECTIVES FOR THE SUSTAINABLE DEVELOPMENT IN CONSTRUCTION

The contribution of a small country as Romania to the world sustainable development through the diminution of the GHGs emissions is certainly very important as an expression of solidarity with the countries from UE and with all the subscribers of the Kyoto Protocol. However, in absolute value, our contribution is relatively small, like a drop in a basin, proportional with the population and the economical potential of our country. Decisive to the world level are only G8 countries, China, India and Brazil. Therewith, the measures that are carried out in Romania concerning the decrease of fossil fuel consumption in all areas have very important consequences to the country and population level, and the adaptation at the consequences of regional climatic modifications, for all economic sectors of agriculture, transports, and construction, is a vital problem, national specific, of maximum importance and urgency, without of which the sustainable development will become impossible. Here are only some priority objectives for constructions, but exists much more possible measures of adaptation, which should be studied.

The fields periodic exhibited to inundation must be identified further. If they can not be protected, the dwellings could be moved on new sites in the frame of a systematic action. There when this thing is not possible, the buildings must be rebuilded, so that the first floor should remain free, to permit casually the pass of the waters. Something similar exists in tropical countries besides rivers and in Siberia, where the apartments of condominiums don't get in touch with the permafrost, in order to not warm and thaw it. Is not too important as the walls not to be from adobe masonry or another forms of stabilized earth, how much is obligatory to be protected against water and composed accordingly to rains, storms and earthquakes. In different zones of the country it should be prepared concreted platforms, lead to utilities, on suitable sites destined for the placement of victims of calamity. Based on guide projects, it should be benefic to begin the manufacture of some light modules and which can be rapidly installed, when necessary.

- The modification of the temperature shall have probably an important effect of heating. The inertia and the thermal protection, the ventilation and the utilization of the capacity of warm storage in the earth are ways of that could permit the achievement of comfort conditions in warm season, without using electric fittings of conditioned air. In the cold season, the same measures have only favorable effects. Concomitantly, are necessary collectors and



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photovoltaic panels, so that the buildings to dispose of a high level of energetic autonomy.

- Generally, the eolian regime will be modified, raising the risk of some storms with increased intensity and tornadoes. In present, the big majority of roof structures and roof coverings do not correspond to a raised level of wind action. The climatic loads and constructive systems should be revised. The windows and the additional external thermal insulations are, also, subjected to wind and hail disaster.
- The resistance structures and the nonbearing closing elements are, as a rule, designed to resists at seismic actions, what does not make them always resistant to the increased climatic actions too.
- The migration of some pests towards North (for instance termites), involves other protective solutions.

## 6. CONCLUSIONS

The difficult problem of adapting at the climate change raises numerous challenges for civil buildings practitioners. The necessary actions in civilian buildings include higher thermal efficiency through thermal rehabilitation at the level required by C-107 or even more, the extension of the C-107 requirements in rural environment, the use of renewable energy sources (solar, geothermal, biomass), new effective constructive solutions, education of people, etc. . An enormous effort should start immediately.

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## Terminologie spécifique pour le développement

Adrian Radu<sup>1</sup>

<sup>1</sup>Faculté de Constructions et Installations de l'Université Technique „Gh. Asachi” Iași, Boulevard Dimitrie Mangeron 43, 700050, Roumanie

### Summary

*For the sustainable development in civil engineering, a specific terminology is needed to serve as a basis of the new concepts implementation.*

**KEYWORDS:** sustainable development, civil engineering, materials, human footprint, virtual mass.

### 1. INTRODUCTION

Au début de siècle et millénaire, la civilisation industrielle, arrivée au niveau de la globalisation, ayant les pouvoirs gigantesques que lui donnent les sciences et les technologies, est toutefois confrontée avec de sérieux problèmes. Adaptés à l'actuelle situation, mais conservant toute leur signification dramatique, les mots de Hamlet sont appropriés au moment, sous la forme „exister ou non plus exister”. La sauvegarde est encore possible, seulement par la voie du développement durable. Elle est unanimement considérée comme l'unique „sortie de secours” pour éviter un effondrement assez proche, en interrompant les processus d'autodestruction et ainsi de se soustraire à la triste destinée des civilisations précédentes, après avoir connu de longues étapes d'éclatants succès. Evidemment l'humanité est menacée par plusieurs dangers (pandémies, météorites, séismes, volcans, accidents nucléaires, etc.), mais ceux qui découlent par la dégradation du milieu environnant et l'épuisement des ressources sont les plus importants, car ils affectent toute la planète et sont pratiquement irréversibles. Le développement durable renonce à la lutte avec la nature pour l'amitié avec elle en essayant de réparer ce qui est encore possible. C'est une attitude de solidarité par dessus les limites d'une génération, qui peut prouver la maturité de l'actuelle civilisation à l'époque de la globalisation et des recherches extraterrestres. Des changements profonds sont urgents, ceux qui concernent les technologies étant les plus importantes. Sur cette voie, avant tout, il est nécessaire de penser autrement et de changer d'attitude dans l'esprit „thinking globally, acting locally”. Tout est à faire en marchant, très rapidement. Les enfants doivent apprendre et les adultes aussi, pour qu'ils ne deviennent pas d'un jour à l'autre, incompatibles aux exigences du lieu où ils travaillent.



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Sous la pression de la situation actuelle on construit une base de pensée correcte et on adopte des points de repère synthétiques d'orientation ayant un rôle catalyseur dans l'activité professionnelle des ingénieurs. Leur importance est exceptionnelle dans le secteur des bâtiments et des travaux publics car ils sont faits pour durer le plus long temps. D'habitude on ne peut pas créer de nouveaux mots et de vieux termes reçoivent des significations nouvelles qui ne figurent pas encore dans les dictionnaires. De cette manière, on a adopté l'expression „développement durable”. D'autres termes ou expressions moins connues sont: masse (poids) virtuel, dématérialisation, matériaux écologiques, énergie englobée, énergies primaire, énergie secondaire et finale, matériaux énergophages, maisons passives, audit, etc.

## 2. MASSE ET POID VIRTUEL

Tout objet a une masse de  $m$  (kg) mais sa production implique l'utilisation de matières premières ayant une masse totale  $m_1$ . De plus on utilise aussi une quantité d'énergie qui est obtenue grâce à de combustibles fossiles non renouvelables ayant une masse  $m_2$ . De cette manière apparaît la masse virtuelle  $m_v$ , qui résulte après avoir déduit la masse  $m_3$  des déchets récupérables :

$$m_v = m_1 + m_2 - m_3 \quad [\text{kg}]$$

C'est une modalité inaccoutumée mais utile, car elle mesure l'importance de l'agression de chaque technologie de production. Un indicateur d'impact spécifique se présente sous la forme suivante:

$$i = m_v / m \quad [-]$$

ayant un domaine de variation très large. A titre d'exemple, pour la fabrication d'un „cip” de 2 grammes qui va être monté dans une calculatrice ou dans un autre dispositif électronique, on utilise plus de 1700 grammes de matériaux, le rapport „ $i$ ” étant 850 /1/. Pour une auto,  $i = 2$ . Une valeur minimale est possible pour les briques de terre crue (adobes) séchées au soleil. On obtient une appréciation meilleure en considérant aussi la durée d'utilisation „ $t$ ” du produit jusqu'à son usure morale ou physique. qui peut être de 5 à 10 ans pour les appareils électroniques mais qui arrive et dépasse la cinquantaine pour un bâtiment. La valeur de cet indicateur corrigé a l'expression:

$$i' = \frac{i}{t} \quad [\text{kg/kg} \cdot \text{a}]$$

Peu de données statistiques concernant ces indicateurs existent. Une correction supplémentaire peut être faite en tenant compte de la nocivité de la masse virtuelle par l'épuisement des ressources naturelles et la pollution du milieu environnant. Dans un récent article, Eric D. Williams de l'Université de Tokyo vient d'écrire:



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„The environmental footprint of the device is much more substantial than its small physical size would suggest”. Si on prend en considération la consommation pendant la durée d'utilisation le résultat devient impressionnant.

Une telle voie d'analyse pourrait donner des indications bien utiles dans les domaines du bâtiment et des travaux publics. Tout d'abord on devrait établir une liste des valeurs  $m_v$  pour divers matériaux et par la suite pour plusieurs types de constructions y compris ce que l'on consomme ultérieurement pour des travaux de réparations capitales. Le résultat, divisé par durée moyenne de vie donne seulement l'indicateur partiel  $i'$  auquel on doit ajouter l'indicateur exprimant l'effet de la consommation annuelle d'énergie. De cette manière l'indicateur final pour les constructions serait

$$i_c = i' + i_e \quad [\text{kg/m}^2 \cdot \text{a}]$$

C'est une opération laborieuse mais justifiée car elle nous ferait connaître la masse virtuelle des constructions pour lesquelles nous savons que la masse réelle est d'environ 200...300 kg/m<sup>3</sup>.

### 3. DEMATERIALISATION

Cette expression est récente et elle a été proposée ayant en vue le fait que l'utilisation de plus en plus intense des matériaux et des combustibles fossiles a pour effet la dégradation du milieu naturel et l'épuisement des ressources qui ne sont pas régénérables /2/. On entend par dématérialisation la diminution des quantités de matériaux introduites dans le circuit de production industrielle et de génération de l'énergie. C'est ainsi que l'on a adopté l'expression „décarbonage de l'énergie” par l'utilisation des ressources renouvelables. L'idée se reflète dans les déclaration du „Club pour le facteur 10” /3/ qui argumentait que cette décroissance doit être égale à 10, ce qui donne lieu à des controverses car certains apprécient qu'elle devrait être 100 fois et d'autres bien plus petite. On peut faire une liaison avec la proposition de Weiszäker /4/; après 50 années, quand la population de la Terre va passer de 6 à 9 milliards et les besoins vont être égalisés, la survie imposera que l'efficience soit accrue au moins 4 fois.

Pour un produit quelconque sont importants l'indicateur d'impact ainsi que la quantité produite chaque année et on doit actionner pour : des conception améliorées, des technologies efficientes, utilisation des ressources régénérables ou disponibles en quantités illimitées, diminution des consommation spécifiques pendant l'exploitation, emploie des déchets et récupération des matériaux provenant des objets après leur utilisation. Tous ces objectifs sont importants pour le progrès technique.



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Par son volume, la production d'énergie à partir de combustibles fossiles constitue un domaine où l'utilisation est particulièrement importante. Un exemple intéressant est donné par l'Islande, pays où l'on entreprend de produire de l'électricité en utilisant l'eau chaude des geysers et, avec elle, de l'hydrogène pour alimenter les transports en commun. On y développe aussi des centrales hydroélectriques avec l'eau des glaciers qui fondent à vitesse accélérée. Bientôt, les islandais espèrent devenir des exportateurs de hydrogène pour la propulsion des bateaux. En France, en Allemagne et en Japon on développé intensivement les piles à combustible qui utilise du hydrogène pour obtenir de l'électricité sans ignition et sans dégager des gaz à effet de serre.

L'objectif de la dématérialisation peut être une impulsion pour des changements favorables en industrie. Voilà deux exemples banaux. Chez les anciennes autos Dacia, à présent hors de fabrication, mais encore rencontrés sur nos routes, les tuyaux d'échappement et les silencieux doivent être remplacés chaque année à cause du phénomène de corrosion. Quelques 30 kilos de métal et amiante, sans tenir compte de la masse virtuelle, se transforment périodiquement en déchets et sont perdus. Pendant 20 ans d'utilisation de l'auto, leur masse arrive à être égale à celle de la carrosserie. Beaucoup d'exemples similaires existent et leur identification peut constituer un sujet de début pour tout enseignement ayant cet objectif. Dans le domaine des préoccupations pour un développement durable, la dématérialisation doit être assurée par l'amélioration de la conception des éléments constitutifs et de la qualité des produits livrés au marché. On peut remarquer que bien de fois la dématérialisation vient en contradiction avec la rentabilité du fabricant. En partant d'une qualité inférieure, il dépense moins et vend plus, en transférant les conséquences défavorables à l'acheteur et au milieu environnant d'où sont prélevés les ressources et où s'accumulent les déchets. La contradiction entre l'économique et l'écologique devient manifeste quand on fait des analyses partielles, sans prendre en compte les dépenses qui concernent l'utilisation et l'entretien le long de la durée de vie (LCA – life cycle assessment). Le problème doit être examiné dans son ensemble et dans un mécanisme économique conçu pour être favorable au développement durable.

La dématérialisation est un argument pour mettre en valeur les déchets de béton, métal, briques, verre, papier, compost, etc. Ce problème devient très actuel car à l'occasion des travaux pour la réhabilitation thermique on détruit certains éléments de l'enveloppe, figure 1. Une action bien plus réprouvable existe quand certains éléments sont délibérément détruits pour être volés et vendus après aux centres de collection en vue du recyclage.



A. Radu



Figure 1. Pour assurer une protection thermique meilleure, une grosse quantité de matériaux est rejetée



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## 4. MATERIAUX ECOLOGIQUES

Les matériaux écologiques sont ceux qui ne causent pas des dommages au milieu environnant et aux hommes. Les plaques d'amiante-ciment, les sabots de frein en métal amiante, les roches radioactives, certaines peintures, les sources de COV (composants organiques volatils), etc., ne sont pas des matériaux écologiques. Par assimilation de la dénomination de „charbon blanc” pour designer d'énergie hydroélectrique, on parle de „matériaux blancs” quand ils sont régénérables. De même, par emprunt, on utilise aussi l'expression „matériel vert” pour caractériser ceux qui comme les plantes ne dégagent pas du CO<sub>2</sub>. C'est le cas du bois qui absorbe du CO<sub>2</sub> pendant la période de croissance. Quand il brûle, il restitue la même quantité dans l'atmosphère et pas plus. Tout de même, quelques autres substances nocives sont émises.

## 5 ENERGIE ENGLOBEE, MATERIAUX ANTHROPOPHAGES ET BATIMENTS A FAIBLE CONSOMMATION D'ENERGIE

En parlant de leur production industrielle, il y a un „prix énergétique” pour chaque matériau (figure 2). Si ce coût est grand, on adopte le qualificatif „énergophage”, pour sensibiliser le public. Pour une appréciation correcte, il est nécessaire de caractériser les produits pour leur entière durée de vie. Ce fut une erreur de limiter pendant les années 1970-1980 l'utilisation des meilleurs matériaux d'isolation thermique (polystyrène expansé, laine minérale) en les considérant énergophages, sans tenir compte de leur efficience pour réduire les pertes de chaleurs dans les bâtiments. A son tour, l'aluminium qui réclame beaucoup d'énergie pour être produit, présente l'avantage d'être autoprotégé contre la corrosion. Alors il peut être utilisé à nouveau. Un jour il sera possible que tout le nécessaire d'aluminium soit couvert de cette manière. On doit retenir que pour confectionner une feuille d'aluminium il faut avoir recours à 170 MJ/kg tandis que en disposant d'aluminium recyclé, 15,6 MJ/kg sont suffisants. C'est-à-dire à peu près 10 fois moins.

Les études statistiques effectuées dans les pays industrialisés mettent en évidence le poids considérable de l'énergie consommée par les bâtiments civils (figure 3), situation qui se reflète dans le haut niveau des dépenses et des émissions de CO<sub>2</sub>. Une analyse effectuée en grande Bretagne /6/, met en évidence la répartition suivante de la consommation annuelle d'énergie : constructions 46%, industrie, transports et agriculture 44%, industrie des matériaux de constructions 10%.



# Physics of Constructions

A. Radu

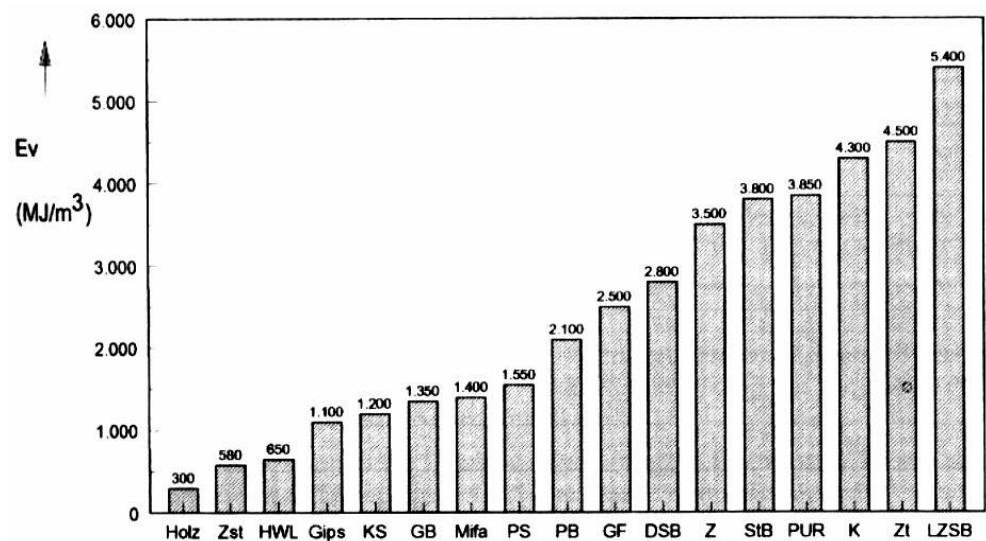


Figure 2 Energie englobée ( $E_v$ ) dans divers matériaux de construction, d'après /5/ : Holzbois ; Zst- isolation thermique (cellulose); HWL- plaques agglomérées; Gips- plâtre; KS- silico-calcaire; GB- béton cellulaire; Mifa- laine minérale; PS- polystyrène expansé; PB- béton léger; GF- laine minérale; DSB- béton dense; Z- brique céramique; STB- béton armé; PUR- écume de polyuréthane; K- chaux (MJ/t); ZT- ciment (MJ/t); LZSB- béton léger avec des adjuvants poreux. Ces indicateurs évoluent avec le temps

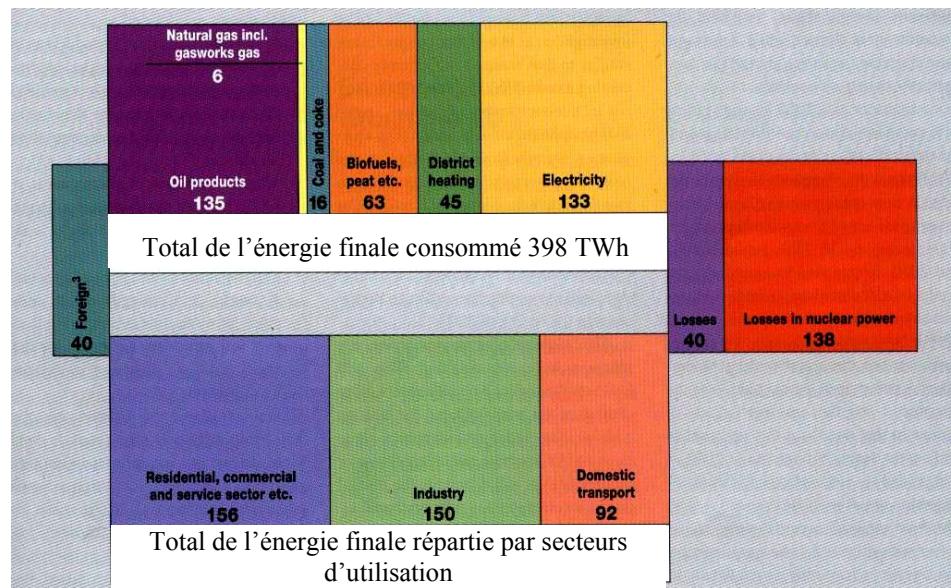


Figure 3 Répartition de la consommation d'énergie en Suède /2/. On peut constater que les secteurs résidentiel et tertiaire représentent 39% du total



# Physics of Constructions

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La figure 4 présente, pour quatre types de bâtiments, une comparaison entre l'énergie englobée et celle consommé pendant 25 années d'exploitation. L'analyse fut effectuée en 1975 en Grande Bretagne et il faut observer que depuis, la consommation en exploitation a été diminuée et celle englobée s'est accrue à cause du renforcement de la protection thermique.

En général il existe une préoccupation progressive par diminuer la consommation d'énergie dans les bâtiments civils, qui était d'environ 200...300 kWh/m<sup>2</sup>·a pour ceux réalisés avant 1970, vers 75 kWh/m<sup>2</sup>·a à présent et même moins. On essaye aussi de réaliser des immeubles écologiques qui vont jusqu'à les faire devenir fournisseurs de petites quantités photovoltaïques installés sur les toitures. On peut distinguer :

- les bâtiments à consommation réduite d'énergie finale (*low energy houses*) d'environ 50 kWh/m<sup>2</sup>·a pour chauffer les espaces ;
- les bâtiments énergétiquement positifs (*positive energy houses*) qui fournissent de l'énergie au réseau énergétique public.

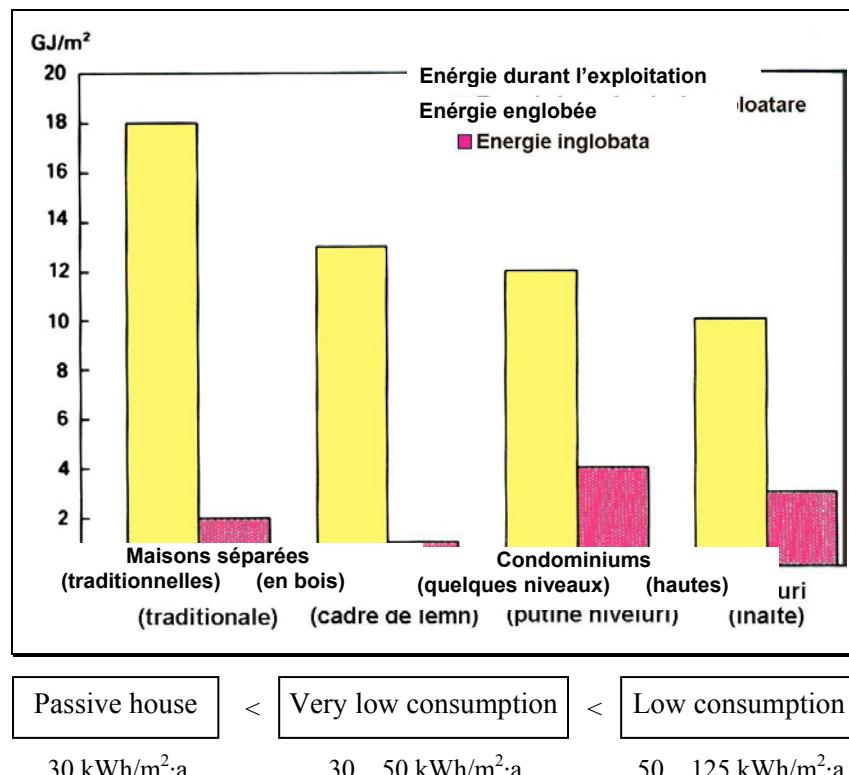


Figure 4 Comparaison entre l'énergie utilisée pendant 25 années d'exploitation et celle pour la réalisation des logements Grande Bretagne /6/



A. Radu

En Allemagne on parle aussi d'une catégorie d'immeubles ayant une consommation finale d'environ 20...30 kWh/m<sup>2</sup> a dénommés „Superniedrigenergie Häuser”. Par analogie avec les véhicules routiers, en partant de l'équivalence énergétique (1 ℓ de combustible liquide pour kWh), ces immeubles sont appelés maisons à 2 ou 3 litres /1/. C'est une modalité efficiente de gagner l'intérêt de la population familiarisée avec les combustibles liquides pour des maisons écologiques.

## 6. AUDIT ENERGETIQUE

Le mot anglais „audit” (lat. auditio) signifie révision comptable, balance économique ou constatation. Aux Etats-Unis, il a été introduit pour l'obtention des subventions offertes par un programme pour la conservation de l'énergie et des emprunts bancaires. A présent il signifie l'identification et la quantification des fuites d'énergie dans l'industrie ou les bâtiments on précise que l'audit énergétique établit les entrées d'électricité, gaz, pétrole, charbon ou vapeur et les modalités par lesquelles elles sont utilisées pour illuminer, chauffer, conditionnement de l'air ou production /7/. L'audit est connu aussi sous le nom de „diagnostic thermique”.

L'audit énergétique doit établir des possibilités efficientes pour économiser l'énergie et la diminution des dépenses à cet effet. Dans les règlements techniques roumains on établit trois composants de l'audit :

- **l'expertise thermique** qui établit les caractéristiques termotechniques des bâtiments (éléments de construction et installations) et les besoins d'énergie pour satisfaire les exigences d'utilisation normale ;
- **le certificat énergétique** qui, en partant de l'expertise thermique, établit la qualité énergétique du bâtiment et accorde un qualificatif. Il est obligatoire dans maintes situations ;
- **l'audit énergétique** pour lequel on présente des solutions pour réduire la consommation d'énergie dans le bâtiment.

## 7. CONCLUSIONS

Sous la pression du temps qui s'écoule et du réchauffement climatique le développement durable doit se concrétiser en actions ayant des effets multiples et surtout concernant la réduction des besoins d'énergie obtenues à partir de combustibles fossiles. A cet effet la responsabilité des ingénieurs et architectes est énorme. La recherche scientifique pourra contribuer au développement des énergies régénérables, mais des solutions techniques pour la conservation de l'énergie existent et doivent être appliquées avec l'appui de l'état car les bénéfices



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apparaissent non pas seulement ou on doit investir. Les changements nécessaires doivent être réalisés dès maintenant. Autrement il sera trop tard car les gaz à effet de serre persistent très longtemps dans l'atmosphère terrestre. En même temps, il faut trouver les moyens de s'adapter aux changements climatiques déjà inévitables. La transition vers le développement durable et un processus d'ampleur planétaire, réalisable par coopération de tous les pays, car les effets sur le milieu environnant ne connaissent pas les limites imposées par les frontières des états. C'est peut-être l'aspect le plus important de la globalisation. Nous sommes tous dans l'unique et le même bateau.

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## New approaches and achievements in sustainable construction. Synthesis

Laura Dumitrescu

Civil and Ind. Engineering Department, Technical University "Gh. Asachi", Iasi, 700050, Romania

### Summary

*The climatic changes, the reduction of the energetic dependency and the increasing price of the fossil fuels are acting together requiring important changes in civil engineering.*

*The article is presenting a documentary synthesis concerning some new approaches and achievements in sustainable construction, considering the interest for civil engineers and architects.*

**KEYWORDS:** sustainable construction, climate change, energy consumption, civil buildings.

### 1. INTRODUCTION

Climate changes will have serious impacts on the planet's life conditions but the modifications are difficult to predict in detail.

The effects could be catastrophic: increase in temperatures, droughts and floods affecting the health and lives of millions of people and causing the loss of several species of flora and fauna. A rise in sea levels will threaten the existence of regions where millions of people live and will delete from the map some of the most beautiful sites in the world.

By reducing global greenhouse gas emissions as of today and in the longer term, we can and must avoid the worse effects of climate change. It is the major environmental challenge of the 21st century.

### 2. THE CERTIFICATES CONCERNING ENERGY SAVING

The certificates concerning the energy saving shows the diminishing of final energy use, so that to contribute to the decrease of fossil fuels consumption and to the diminution of GHGs emissions. The objective established by the European



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Union is that until 2050, these emissions will be 4...5 times decreased in order to limit the climatic changes.

Also, this will contribute to reach the aim of saving the energy, and so on as the raised prices of fuels, heat and electricity. With their help, "the deposits" neglected by final energy saving of different construction, transport, trade and industrial consumers will be turned to good account.

The use of thermal and electric energy in residential and social buildings is far away of being optimized. The means for touching this aim exists but are not utilised in sufficient measure because of the habitudes established through one century of cheap energy.

The energy savings from fossils sources is concordantly with the environment protection and with the decrease of maintenance expenses.

Given as examples /1/:

- home equipments, fridges and new washers from A and B classes, consumes with approx. 30...50% less energy than those time-worn;
- the use of termopan windows combined with curtains and the attenuation of outline thermal bridges diminish the losses of heat from houses with across 7%, the replacing of one old heating station with a new one with condensation and a distribution thermal protected permits savings of more than 15%, the supplementation of thermal insulation of the walls contribute with 10...15%, and the installation of a programmable thermostat with another 7%. An individual solar collector reduces with 50% the heat necessary for preparing the warm water.

The occidental press pointed out the population preoccupation for climatic modifications. In Europe this is considered the principal present-day problem.

### 3. NEW STRATEGIC REPORT „CLIMATE – ENERGY”

On January 24, 2006 within the framework of European Union has been published a strategic report concerning the use of coal and the implications concerning the climate and the energy. The report /2/ emphasis that:

- the coal reserves represent 63.7% from total resources of fossils fuels, towards 18.2% oil and 18.1% natural gases. The biggest coal reserves are in USA (27% from the total), followed by Russia (17%), China (13%), India (10%), Australia (9%) and South America (5%);
- the weight of the coal in the world production of electricity is of 40%, and in the production of steel of 70%;



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- two thirds from the world consumption are fated of electricity production, and 90% from the growth of coal consumption is bound currently by the production of electricity;
- the coal is the strongest emissions of CO<sub>2</sub> provider, through the sequestration of CO<sub>2</sub> it can be obtained decreases of 80 – 90% of the emissions due the production of electricity.

The report presents previsions concerning the production of electricity and the emissions of CO<sub>2</sub> accordingly, having as horizons the years 2030 and 2050, based on two scenarios of technological evolution, in report with a reference scenario. Those two scenarios examine the impact of the most efficient procedures of coal burning in the electricity producer stations.

Compliant to the reference scenario, the world CO<sub>2</sub> emissions will grow with 56% in 2003 - 2030, and those connected with electricity production shall be tripled within 2050.

The main conclusion of the report is that the resort to coal reserves is not reconcilable with the mitigation of the greenhouse effect only in the conditions of a major technological jump for sequestration to which permit the decrease of CO<sub>2</sub> emissions. The European Union, beside other big world countries, will make the necessary efforts concerning the research area, and the mechanisms and regulation examination able to permit the realization of some competitive and efficacious coal stations.

## 4. GERMANY AND SWITZERLAND

The meaning of the term 'low-energy house' has changed over time, and will certainly change in the future.

In Germany a Low Energy House (*Niedrigenergiehaus*) has a limit equivalent to 7 litres of heating oil for each square meter of room *for space heating* annually (50 kWh/m<sup>2</sup>a). In Switzerland the term is used in connection with the MINERGIE® standard (42 kWh/m<sup>2</sup>a).

The MINERGIE standard has been widely accepted in Switzerland. Today, more than 1500 buildings in Switzerland comply with it without legal enforcement. Also, more than 1000 dwellings have been built according to the Passive House standard in Germany and Austria /3/. In Switzerland, the Passive House standard just begins to spread. MINERGIE and Passive House standard differ in their methods. However, both aim to realize comfortable and economically attractive buildings with very low energy requirements and to assure the quality of such buildings (figure 1).



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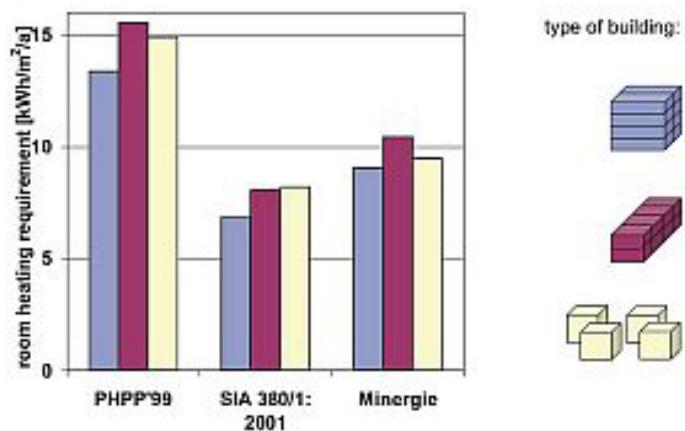


Fig. 1 – Room heating energy requirement calculated according to the methods used by the Passive House standard (PHPP'99), by Swiss code SIA 380/1 and by SIA/MINERGIE for the reference buildings (same net area, different geometry). The results differ because different reference floor areas are used, and because of differences in boundary conditions and standard values. (source: [www.empa.ch](http://www.empa.ch))

Low-energy buildings typically use high levels of insulation, energy efficient windows, low levels of air infiltration and heat recovery ventilation. They may also use passive solar building design techniques or active solar technologies.

## 5. FRANCE

France supports the objective of two-fold diminution of the world emissions of GHGs until 2020. It is often said: „Faisons vite, ça chauffe!”.

For the building sector, the following measures /4/ are proposed:

- in the cold season, an average temperature of 19 °C should be assured in all rooms, except the ones from sanitary sector or for old people and small children. The rooms vacant for more than 24 hours or 48 hours should be warmed at 16 °C and 8 °C, respectively;
- in the warm season, the passive cooling techniques should be preferable. If air-conditioning installation are used, their energy use should be at moderate level, and the indoor/outdoor difference of temperature should be bellow 6 °C;
- before authorizing the building modernization works, a preliminary study must be made regarding the possibility of renewable energy use.



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The Climate Plan is an action plan drawn up by the French Government to respond to the climate change challenge, firstly by 2010 (complying with the Kyoto Protocol target), and, secondly, beyond this date.

The government has devised certain forms of action concerning direct emissions: these constitute 23% of the Climate plan's efforts and are directed at both new and existing homes. Indirect emissions are incorporated into the Climate Plan's energy section. The following initiatives /5/ have been devised:

- fiscal measures, such as the improved tax credit for efficient appliances, increased to a maximum of 25% and 40% for appliances using renewable energy, a market that is enjoying growing success;
- an energy efficiency diagnosis, incorporating the building energy label, will be compulsory as of 2006 to identify potential energy savings;
- heating regulations, created for the first time, concerning the most substantial renovations on all existing buildings.

## 6. CONCLUSIONS

Climate changes have already had and will continue to have impacts on human life, ecosystems and the economy of all countries. The costs associated with global warming will be colossal.

A decrease in greenhouse gas emissions well in excess of Kyoto objectives is necessary before the end of the century.

It is possible to reduce the impacts of climate change, but this requires immediate long-term action.

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## Réhabilitation thermique, exigences, normes, mise en oeuvre

Maricica Vasilache

*Faculty of Civil Engineering, Technical University "Gh. Asachi", Iași, 70050, Romania*

### Résumé

*Au moment actuel l'humanité est confrontée avec un problème très important représenté par les changements climatiques. Déterminés partiellement par l'activité humaine, basée sur les énergies produites avec les hydrocarbures, ce phénomène impose des mesures de limitation des dépendances des ressources.*

*La réhabilitation thermique est aussi une exigence imposée par l'usage des bâtiments pendant la saison froide ou chaude, pour la maîtrise de l'énergie et l'économie des ressources.*

*Le travail présente l'état de choses en Roumanie concernant les lois, les normes et les difficultés d'application dans le domaine réhabilitation thermique.*

MOTS CLÉ: changements climatiques, développement durable, économie d'énergie.

### AVANT – PROPOS

Jamais durant les dernières décennies on n'a discuté tant sur l'énergie et son prix. Personne n'a imaginé que les combustibles fossiles seront si couteux, que l'équilibre budgétaire dépendra de l'importation du pétrole et de gaz naturel, que la production et l'usage de l'énergie contribue aux changements climatiques et que les énergies renouvelables pourraient être si nécessaires, mais avec tant de problèmes technologiques et économiques. Pour l'instant la plus accessible forme d'énergie c'est l'énergie économisée. Par conséquent, l'idée de maîtriser l'énergie s'est imposée de plus en plus. Au début, elle a été la condition préliminaire pour l'usage rationnel de l'électrique utilisée pour le chauffage des bâtiments et ensuite pour toutes les autres formes d'énergies y compris le solaire, l'énergie éolienne, le biogaz, l'énergie géothermale. Après, elle est devenue une nécessité déterminée par les coûts très élevés des énergies résultées des sources conventionnelles, mais aussi par suite du fait que même les énergies nouvelles - renouvelables sont d'autant plus chères, par les investissements, qui devraient être subventionné (solaire photovoltaïque, pompes à chaleur ou solaire thermique).



# Physics of Constructions

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De cette manière, la maîtrise de l'énergie dans les bâtiments neufs et aussi dans l'existant après la réhabilitation thermique est devenue une exigence très importante en Roumanie. On introduit ainsi une direction supplémentaire obligatoire de préoccupations pour les concepteurs – architectes et ingénieurs. Pratiquement, l'activité suppose parcourir une „feuille de route” au niveau national avec des points obligatoires (fig 1). C'est un circuit continu, en amélioration graduelle mais qui finit au moment où une des étapes 1...11 n'est pas assurée.

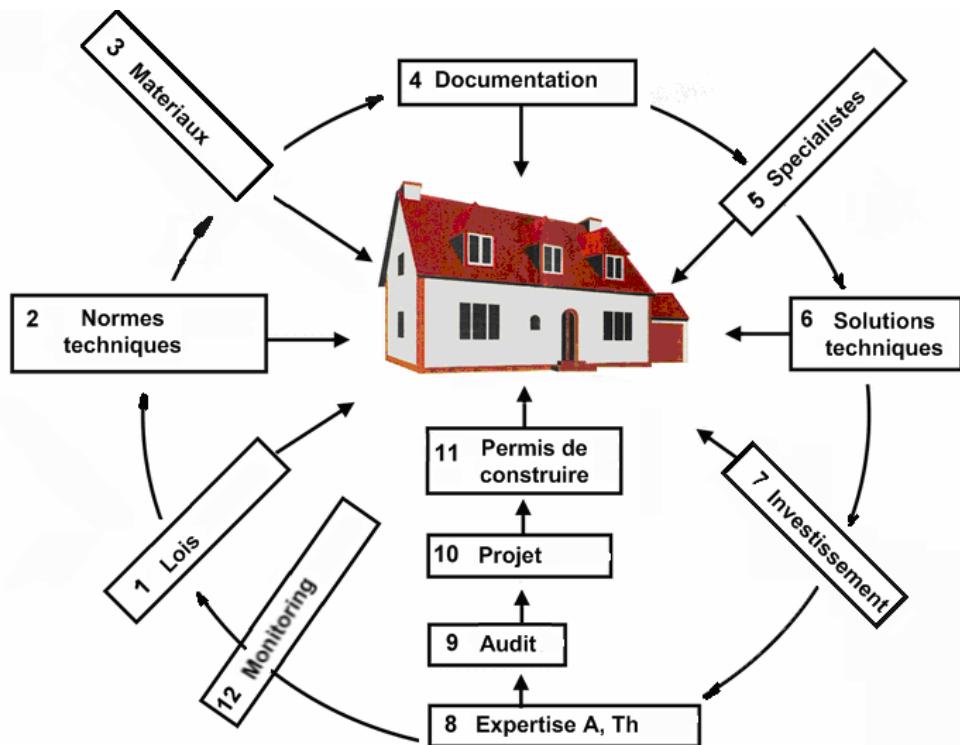


Fig. 1. Feuille de route pour la réhabilitation thermique des bâtiments existants

Il est utile de mentionner que sur le plan européen, où la durée de vie des bâtiments est de plus 100 ans, le problème d'adaptation aux changements climatiques fait l'objet de vastes et variés études/ Koen Steemers, CISBAT, 2005 / tenant compte de quelques aspects:

- les changements continueront au moins 40...60 ans, temps nécessaire pour que la réduction de la dépendance de combustibles fossiles commence avoir effet;
- les températures seront plus hautes pendant l'été et plus basses pendant l'hiver par l'accentuation des extrêmes imprévisibles, caractéristiques pour le climat continental excessif;



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- dans ce contexte et sans considérer le prix élevé de l'énergie électrique et thermique, il est nécessaire que tous les constructions s'adaptent à ces conditions.

Koen Steemers met en évidence 3 directions d'action: mesures d'atténuation des changements climatiques, mesures d'adaptation des bâtiments et mesures d'éducation des usagers. Il constate aussi que les concepteurs devraient adopter entre autres: de supplémenter avec 5...10% les charges de vent, pluies intenses, résistances aux rayonnements hv, des côtes de fondation plus profondes, une efficacité thermique supérieure et une ventilation naturelle améliorée pour éviter l'usage de l'air conditionné avec l'électricité.

## 1. LÉGISLATION

A cette date il y a une série de lois en vigueur:

- Lois 199/2000 concernant **la maîtrise de l'énergie**;
- Lois 325/2002, concernant **la réhabilitation thermique** des bâtiments existants et **stimulation de la maîtrise de l'énergie thermique**;
- Lois 211/16 - 2003 concernant **l'application des mesures spécifiques pour la réhabilitation des bâtiments à plusieurs étages**;
- Lois 372/13 - 2005 concernant **la performance énergétique des bâtiments**.
- OG 29/2000 – **Certification énergétique des bâtiments** – pour attester la classe énergétique au moment de l'expertise (niveau de protection thermique de l'enveloppe, l'efficacité de l'installation de chauffage, pour l'eau chaude ménajère, la dépense spécifique d'énergie produite avec les combustibles fossiles etc.). Ce document sera, en perspective, un instrument légal d'évaluation des constructions dans le cas d'achat – vente, location, hypothèque etc.

Pour les spécialistes et aussi pour le grand public il serait nécessaire de concentrer les lois, ordonnances, guides, standards, normes d'application et méthodologies, trop nombreuses, devenant peu accessibles pour être mise en oeuvre.

En même temps, la législation roumaine devra s'adapter aux décisions de l'Union Européenne concernant la maîtrise de l'énergie obtenue du pétrole, gaz naturel, ou charbon et l'usage des sources renouvelables.

Essentiellement, tous ces règlements techniques concernent l'évaluation des bâtiments du point de vue efficacité énergétique par l'expertise thermique, nommée aussi le diagnostic thermique et énergétique et le certificat énergétique, document synthétique nécessaire pour le classement des bâtiments. Outre ce certificat énergétique il y a aussi le certificat concernant l'économie d'énergie,



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necessaire pour imposer la maîtrise de l'énergie par les grands fournisseurs de combustibles.

## 2. NORMES TECHNIQUES

Entre 1998 et 2007 ont été publiés les norme techniques spécifiques aux travaux de réhabilitation thermique, une base complexe pour adapter les bâtiments aux exigence de performance améliorées face aux normes nationale antérieures:

- C 107 /0 -02 Norme pour la conception et l'exécution des travaux d'isolation;
- C107/1.....7 -97...2005 Norme pour le calcul des éléments de l'enveloppe, le transfert de masse, la stabilité thermique et le coefficient global des pertes de chaleur;
- La série NP 048, 049, 047- 2001...2007 concernant l'élaboration de l'expertise thermique, le certificat énergétique et l'audit;
- La série des guides et les méthodologies spécifiques pour l'expertise, le certificat et l'audit: GT 036-02, MP 024 – 02, GT 037- 02, NP 060 – 02, SC 007 – 02, SC 006 – 01, MP 019 – 02.

Généralement, la réhabilitation thermique proposée dans l'audit suppose un nombre réduit de solutions techniques pour l'enveloppe et les installations sans imposer l'usage des énergies renouvelables et le monitoring permanent des bâtiments après la réhabilitation thermique.

L'ensemble des normes techniques fait référence à:

- la prise en compte des ponts thermiques dans l'évaluation de la résistance thermique des éléments de l'enveloppe (murs extérieurs, toit, menuiserie, plancher bas etc.);
- l'évaluation globale avec le coefficient des pertes de chaleur  $G/G_1$ . Il est possible de valorifier la créativité technique pour adapter les façades (fig. 2.).

Dans le cadre des programmes de coopération internationale ont été réalisés des traveaux démonstratives dans plusieurs villes de Roumanie, suivi par un programme de monitoring dans l'hiver suivant.

Ont été évidenciées des aspects concernant l'usage des logements et le nécessaire adapté d'énergie thermique. Le monitoring du bloc 7, rue Tabacului a relevé entre autres la diminution excessive de la ventilation naturelle à cause de la menuiserie étanche, la manque d'intérêt de la part des fournisseur d'énergie thermique pour le contrôle des livraisons. Les normes actuelles contiennent des références sur les énergies gratuites et leurs utilisation.



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Fig. 2. Foyer T14 Tudor Vladimirescu. Façade isolée avec polystyrène expansée, et POLyALPAN, des bow-windows légers pour valorifier l'effet de serre. Les autres fenêtres ont 3 vitres.

Un autre aspect fait référence au quantum :

- de la **dépendance de l'énergie primaire** – tenant compte que pour l'énergie finale il y a des pertes en amont à la source, la transformation et la distribution. Au niveau national compte seulement la dépense d'énergie primaire et en liaison directe avec ça;
- **l'émission de gaz à effet de serre (GES) et d'autre polluants (SO<sub>2</sub>, NO<sub>x</sub>, COV, poussières, etc.).**

Une préoccupation spéciale doit être accordée aux bâtiments avec compacité réduite qui ont des dépendances énergétiques spécifiques plus importantes que ceux plus compactes, dans les conditions du même degré d'isolation thermique.

Dans la période suivante sera nécessaire de réaliser des bâtiments avec des consommations très réduites d'énergie, avec autonomie énergétique ou actives du point de vue énergie.

#### Bâtiments neufs

L'hypothèse de concevoir une construction efficace seulement par la disposition des couches d'isolants thermique est déficiente. Il faut aussi considérer :

- l'orientation de la construction ;



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- la forme ;
- la menuiserie et l'éclairage naturel ;
- la ventilation rationnelle et le risque de condensation ;
- les solution de protection thermique ;
- l'usage de l'énergie solaire ;
- l'efficacité des équipements et des installations de chauffage ;
- les possibilités de réglage, contorisation et d'automatisation.

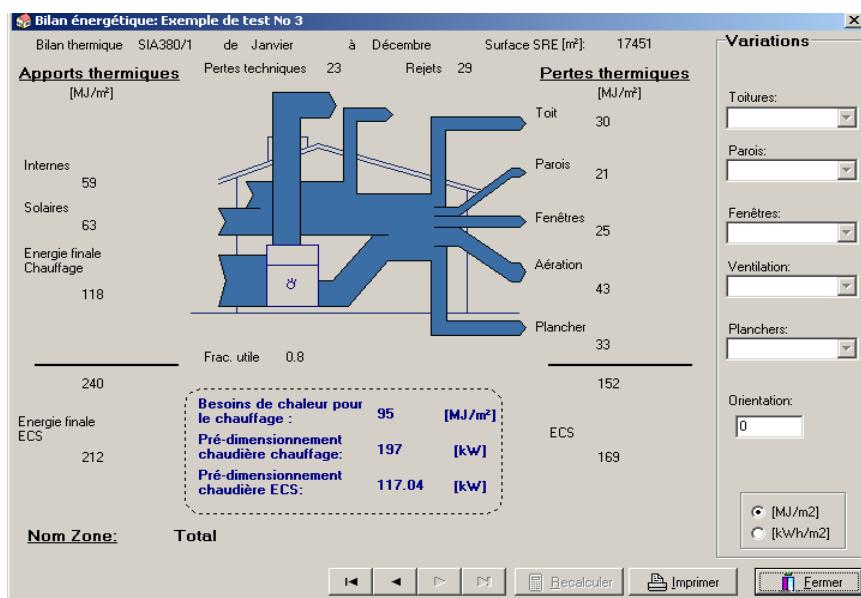


Fig. 3. Bilan énergétique d'un bâtiment (Logiciel Lesosai 5.5) – EPFL, CH

La plupart des concepteurs ignorent ce domaine, en se limitant à la satisfaction de l'exigence de sécurité structurelle. La connaissance des normes est superficielle et le respect de ces réglementations n'est pas trop importante pour obtenir le permis de construire.

La perception du grand public, concernant la réhabilitation thermique fait référence à la menuiserie étanche avec vitre isolante ou le montage des centrales thermiques individuelles.

Pour convaincre les propriétaires des immeubles et les locataires que le certificat énergétique est essentiel il faut:

- présenter, en forme claire, intuitive, accessible les indicateurs de la dépense énergétique. L'expression en kWh est meilleure, mais insuffisante, car on fait la liaison avec l'électricité. Pour cette raison, en Allemagne, le résultat final est exprimé en litres de combustible ( $1\text{kWh} \approx 0,1$  litre) et de cette manière „la



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maison de 3 litres” est facilement remarquée, car tous les familles possèdent au moins un auto;

- présenter en détail la structure de la consommation .

Tenant compte du fait que l’objectif c’est l’autonomie énergétique par rapport au combustibles fossiles épuisables et polluants, il faut que les niveaux de performance imposés par C 107 soient améliorés assez vite.

## 3. MATÉRIAUX ET SOLUTIONS TECHNIQUES

L’usage des matériaux performants de protection thermique est imposé par les exigences de confort et économie d’énergie mais aussi par la réserve de capacité portante de l’ossature.

## 4. SPECIALISTES

La formation de spécialistes pour l’audit énergétique des constructions existantes est basée sur deux directions les constructions et les installations et les équipements.

En même temps les principes d’économie d’énergie doivent être appliqués aussi dans les bâtiments neuf, à l’occasion de leur conception.

## 5. SOLUTIONS TECHNIQUES

Les solutions à appliquer sont précisée dans le rapport d’audit, pour réaliser une certaine économie d’énergie. On inclue les solution pour les éléments oppaques, vitrés et les installations mais aussi l’usage des énergie renouvelables.

### Problèmes spécifiques des spécialiste

Les certificats énergétiques sont le résultat d’un volume appréciable de calculs pour établir la performance du bâtiment existant. L’audit est plus difficile, spécialement pour les constructions monumentales ou avec des façades spécifiques à l’architecture locale (fig. 4).



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Fig. 4 Façades spécifiques sur lesquelles on ne peut pas opérer des modifications par des travaux de réhabilitation thermique.

## 6. INVESTISSEMENTS

Il y a des sources de financement et des facilités fiscales comme les allocations budgétaires, les fonds des sociétés fournisseurs de combustibles, des fonds ARCE etc.



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## 7. PROJETS

Les projets techniques de réhabilitation thermique applicables après l'expertise structurelle et l'audit énergétique suppose des spécialistes concepteurs pour adapter l'ossature et l'enveloppe aux exigences actuelles.

## 8. MONITORING

Les opérations spécifiques supposent la réalisation d'investigations complexes. Les aspects de référence sont:

- satisfaction des exigences de confort thermique et d'économie d'énergie;
- correction des ponts thermiques;
- réduction de l'effet sur l'environnement;
- risque de condensation dans la masse des éléments protégés avec des isolats très épais, ayant une perméabilité réduite aux vapeurs;
- ventilation des unités fonctionnelles équipées avec menuiserie étanche.

## 9. CONCLUSIONS

Entre 1990 – 2006 le coût de l'entretien des logements s'est amplifié 5 fois par rapport aux revenus, qui sont multipliés par 1,5. Dans ce contexte la supportabilité des usagers est très réduite. En même temps seront éliminés les subventions pour le chauffage des logements. Donc, sont justifiés les travaux de réhabilitation thermique.

Il faut avoir une politique cohérente au niveau du gouvernement dans le domaine de l'économie de l'énergie par la stimulation des investissements dans ce domaine et la réduction de la dépendance énergétique des importations.

En Roumanie, dans le domaine des constructions les spécialistes en audit énergétique auront à analyser environ 75% du fond construit existant pour l'adapter aux exigences actuelles.

La diminution des consommations de ressources d'énergie dans tous les secteurs d'activité et la maîtrise de l'énergie dans les bâtiments sont des éléments fondamentales du développement durable et une preuve de solidarité humaine au delà des limites imposées par l'espace et le temps.



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