VALIDATION OF THE SOFTWARE USED IN DETERMINING THE ENERGY PERFORMANCE OF BUILDINGS (EPB)

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ABSTRACT

Romania currently undergoes a development of the software used in assessing Buildings Energy Performance. In order to grant the free movement of the products and services in the European space, the Buildings Energy Performance software cannot be subjected to a certain design algorithm based on a regularized mathematical model. Therefore it is necessary to develop a pattern which should provide the possibility of testing the commercial software using different design and structuring algorithms. A maximum level of the necessary input data is settled as well as a minimum level of the data resulted from calculations. The assessment of the software is based on a synthetic report including the input data and the values provided by calculations, for a variable number of testing sheets. The software used in assessing the similar commercial products must be based on experimentally validated calculation methods. *The dynamic calculation mathematical models included in the structure of the Validation software do not mark the difference between the seasons (hot-cold) and may be adapted to any initial conditions operating as input data. According to the validation procedure, the mathematical models substantiating the calculation methods specific to the Standard Validation / Attesting Software (PCVE) are experimentally validated by long-term measurements performed on full-scale models, in a controlled microclimate*. The development of the patterns of validating the calculation methods and the software offers a *new approach* of the Buildings Energy Performance Calculation Methodology focusing the regulated contents on the EPB quantification methodological principles, phenomenologically substantiated as well as on providing the calculation support by software attested by the procedure of inter-validation in terms of the Standard Validation Software, experimentally validated. The *new approach* may represent a determining step forward in harmonizing the EPB calculation methodologies

REZUMAT

În prezent, în România se dezvoltă o piață a programelor de calcul destinate evaluării Performanței Energetice a Clădirilor. În scopul asigurării liberei circulații a produselor şi serviciilor în spațiul european, programelor de calcul al Performanței Energetice a Clădirilor nu li se impune un anumit algoritm de calcul bazat pe un model matematic reglementat. Ca urmare este necesară crearea unei scheme care să ofere posibilitatea testării programelor de calcul comerciale care utilizează algoritmi de calcul şi de structurare diferiți. Este definit un nivel maxim al datelor de intrare necesare, precum şi un nivel minim al datelor rezultate din calcule. Evaluarea programelor de calcul se bazează pe un raport sintetic care cuprinde datele de intrare şi valorile rezultate din calcul, pentru un număr variabil de fişe de testare. Programele de calcul utilizate în scopul validării produselor similare comerciale trebuie să fie elaborate pe baza unor metode de calcul validate experimental. *Modelele matematice de calcul dinamic care sunt incluse în structura Programelor de calcul de validare, nu fac diferența între sezoane (cald-rece) şi sunt adaptabile oricăror condiții inițiale cu valoare de date de intrare. Conform procedurii de validare, modelele matematice care fundamentează metodele de calcul proprii Programului de Calcul de Validare / Atestare Etalon (PCVE), sunt validate experimental prin măsurări de lungă durată, efectuate pe modele la scară naturală, cu microclimat controlat.* Apariția schemelor de validare a metodelor de calcul şi a programelor de calcul automat, generează posibilitatea unei *noi abordări* a Metodologiei de calcul a Performanței Energetice a Clădirilor, în sensul concentrării conținutului reglementat asupra principiilor metodologice de cuantificare a EPB, fundamentate fenomenologic, şi asigurării suportului de calcul prin programe de calcul atestate prin procedura de intervalidare în raport cu Programul de Calcul de Validare Etalon, validat experimental. *Noua abordare* poate constitui un

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and in providing a highly accurate computer based management of the EPBD implementation national strategies. This article presents the phases in preparing and finalizing the national pattern of validating the software to be used in drafting CPEA according to the Romanian legislation.

Key-word: mathematical models, experimental validation, standard validation software (PCVE), validation criteria, apartment energy performance certificate, validation sheets

pas determinant către armonizarea metodologiilor de calcul al EPB precum şi de realizare a unui management informatic cu grad ridicat de precizie al strategiilor naționale de implementare a EPBD. Lucrarea prezintă etapele de pregătire şi de definitivare a schemei naționale de validare a programelor de calcul destinate elaborării CPEA, în concordanta cu legislația autohtonă.

Cuvinte cheie: modele matematice, validare experimentală, program de calcul de validare etalon (PCVE), criterii de validare, certificat de performanță energetică pe apartament, fişe de validare

I. GENERAL PRESENTATION

The European Union issued, through the European Parliament, the Directive for Buildings Energy Performance (EPB) (2002 / 91 / EC) in order to obtain the reduction of the carbon dioxide emissions by increasing the buildings energy performance. This Directive was adopted in the Romanian legislation as Law 372 / 2005 and together with the necessity of certifying new and existing EPB entailed the appearance on the market of EPB assessment software. The results of using such software have not been evaluated so far in terms of truthfulness or convergence, which allows a number of discrepancies between the results, obtained and may cause the loss of the experts' trust in these calculation instruments.

In May 2010 (19.05.2010) the European Directive 2010 / 31 / EU was published (further called EPBD) which imposes increased exigencies for EPB mainly by introducing the compulsiveness of erecting buildings with an energy consumption very close to zero starting with the year 2018. The approach of solutions with a very high energy efficiency leads to the use of sophisticated calculation instruments structured according to the dynamic of the heat and mass transfer processes specific to the buildings components.

In this line, the European Directive 2010 / 31 / EU insists in chapter 3 on devising calculation methods meeting the exigencies, methods which will be included in the Calculation methodologies to be adopted at a national or regional level. INCERC Bucharest completed in 2009 a research programme financed by MDRL (currently MDRT – Ministry of Regional Development and Toursim) which revealed the errors generated by the use of certain European standards (SR EN 13770, SR EN 13790, SR EN 13791, SR EN 13792) in terms of the measured values of the main physical dimensions contributing in the EPB assessment.

As concerns the practical use of certain advanced calculation methods, their use in hand calculation is excluded (they may even generate errors), therefore a number of software should be devised and used. Both targets of the existing and new buildings energy-related audit are thus met, namely the high accuracy of the calculations and the reduced time necessary in providing the results. More or less complete procedures are decided both at the European and at the international level for the validation of the software focused on EPB; they are based on dynamic calculation software experimentally validated on modules and as wholes as well.

To resume the idea of what we call a *new approach* of the EPB Calculation methodology, we consider that the currently used form of certain calculation relations, most often taken from European standards and subjected to errors, either because of editing or of conception and therefore generating errors, should be replaced by a phenomenological presentation of the processes, clearly defining the input and output data as well as their degree of accuracy in terms of the type of application the calculation methods address. The actual calculation will be performed by using the software which have been validated and nationally attested by an expert committee coordinated by the central authority in charge with the implementation of EPBD (in Romania, MDRT through DTC). Therefore, the Validation Software should be issued as a Standard, which will be used by the Validation committee in order to validate and attest the software products to be used in the quantitative assessments specific to the new and existing buildings energy auditing.

Another advantage of this *new approach* is the considerable reduction of the number of technical regulations and the simplification of the practical application. *The dynamic calculation mathematical models do not mark the difference between seasons (hot-cold) and are adaptable to any initial conditions working as input data. According to the validation procedure, the mathematical models substantiating the calculation methods specific to the Standard Validation / Attesting Software (PCVE) are experimentally validated by long-term measurements performed on full-scale models in a controlled microclimate. PCVE is then used as a validation / attesting software of any commercial software to be used on the market in the new and existing buildings auditing.* ***PCVE is not a commercial software product****.*

The regulated calculation methodologies include exigencies imposed by the targets, including national parameters concerning buildings microclimate, according to their specificity and concerning the zonal climate. Based on the regulated calculation principles, by using some of the proper provisions of the national and European standards, and following the validation and attesting by comparison to the results provided by the Standard Validation Software, according to the national validation procedures, the EPB software will turn into commercial software to be applied in different ways according to the targets they were issued for (e.g. buildings heating, heating of apartments in a building, new or existing buildings, buildings equipped with unconventional energy sources, air conditioning, condominiums, public buildings, etc.) as well as to the accuracy category of the results provided, mentioned in the technical regulations structure.

The previously described elements prefigure a *new structuring* of the Technical regulations in a European line by using the software instruments and the targeting on the system of exigencies and performance criteria to be met by buildings so as to become real exponents of the Sustainable Development concept. By adopting the MDRT Minister’s Order 1271 / 2010 on the setting up of the committee in charge of validating the Software necessary in issuing the Apartments Energy Performance Certificate (CPEA) for the apartment buildings, Romania joins the countries approaching this modern procedure of performing the buildings energy audit (for building components as well).

A first step (simple, both in terms of social implications and of those associated to EPBD implementation) in this modern line of harmonized attesting at a national level the EPB assessment calculation instruments was the validation of the software to be used in issuing CPEs for apartments in condominiums. The issuers of the software validation / attesting procedures mentioned, among other things, that certain calculation algorithms are not imposed in the validation / attesting software, but (rigorous) restrictions related to the results accuracy are. The required rigorousness represents a testing of the local market, and not only, concerning the devising of quick and accurate calculation instruments.

Therefore, the interest of the technical regulations moves from devising operating calculation relations, rather simple (manual or table-form calculation) to be used by energy auditors with a rather heterogeneous education in the field (from the hydrotechnics engineer to the building systems engineer), which significantly reduces the calculation accuracy, to defining the exigencies and most diversified performance criteria and to the use of attested commercial software in quantifying the dimensions defined by the national regulations. In fact the adopting of the concept also solves the problem of regional or European harmonizing of the calculation methodologies, as *all the PCVE are granted by the experimental validation in the previously mentioned conditions. The step of regional and European inter-validation of national PCVE will facilitate the issuing of the European Validation Software with national clones used in validating the commercial software.*

As examples of a European approach, the European standards are briefly presented which settle the hypotheses, boundary conditions and procedures of validating the *dynamic calculation methods* for determining the annual energy demand for heating or cooling a building or a part of it. The reason why this analysis on the EPB calculation methods attesting includes the presentation of these standards is the parallel that may be traces between the calculation methods validation and the software attesting process. The European standards under analysis do not impose a certain calculation method or algorithm. But a number of recommendations and minimum requirements are expressed in order to rend the calculation methods acceptable; a number of validation tests and criteria are also defined. In general, these standards provide the elements necessary in validating the calculation methods and are examples of European approaches of this issue.

The committee in charge with the Software validation is a structure currently being set up and it will have to operate similarly with an excellence network so as to be able to ensure the connection to the software validation European system (e.g. PASSYS 1986 – 1993 project) and, most important, to benefit from a PCVE produced locally based on local research, or by purchasing an efficient program (which involves a certain degree of rigidity in functional adapting and limited operation granted by the license), or by performing a hybrid product by experimentally validating the local dynamic calculation Models and by adopting the modular structure of the efficient software products. In this case, the participation on inter-validation programmes within internationally recommended programmes is recommended.

Similarly, as an example of good international practice, the analysis of the NatHERS (Nationwide House Energy Rating Scheme – Australia) software attesting pattern proves that no settled mathematical model or calculation algorithm is imposed, therefore the possibility to attest the software using their own EPB assessment algorithms.

The structure of the Romanian procedure used in validating the CPEA devising software observes similar principles and includes a sensitivity analysis pattern entailing a significant simplification of the PCVA structure, but within very restraint limits of deviation compared to the hourly pace basic calculation model.

II. INTERNATIONAL BENCHMARKS

Internationally, there are a considerable number of software products for the simulation of buildings dynamic behaviour. These software are validated either experimentally in the form of empirical validation, or by inter-validations based on standards like ASHRAE Standard 140 / 2001, NBL BESTEST – 1995, CIBSE (Standard Test for the Assessment of Building Service Design Software). The project TREES – IEEP contr. EIE / 05 / 110 / S12.420021 provides, in section 2 devoted to Thermal Simulation Models, a presentation of the results obtained by using the BLAST, ENERGY PLUS, ESP-r, COMFIE, SIMBAD software, observing the BESTEST validation procedure.

A numerical experiment corroborated with detailed measurements is presented in report [1] – 5 software (VA114, ESP-r, TRNSYS, IDA ICE 3.0 and Bsim were tested in the simulation of the dynamic response of double skin facades). The results obtained were rather highly inaccurate in terms of the experiment and, moreover, prove that as concerns the simulation of buildings characteristics transfer processes, the adoption of simplified models not representing at least the inter-validation type result compared to the experimentally validated product turns into a source of errors by providing results with an unacceptable degree of deviation from the phenomenological reality.

The calculation relations specific to the experimentally validated dynamic models, adapted to the exigencies of a immediately applicable calculation methodology generate the calculation instrument called **Standard Validation Software (PCVE)** in terms of which may be validated, by the inter-validation procedure, commercial software observing the validation criteria exigencies. This article proposes a *new approach* of the EPB Calculation methodology, which will have to update the Mc 001-2006 calculation methodology according to Directive 31 / 2010 / EU, meaning to wave the including of calculation relations (taken either from European standards or from Romanian technical regulations), usually simplified and adapted to highly inaccurate manual calculations. They will be replaced by software validated and attested based on the inter-validation procedure, using the

Standard Validation Software (PCVE) as a reference point; the devising of PCVE is coordinated by the Committee for the validation of software meant for the assessment of the new and existing EPB.

At the CA2 project Ljubljana reunion (September 2010), the report of the committee in charge of revising the European standards adopted a number of recommendations among which is found the devising of calculation methods according to the physical reality, *a recommendation expressly requested by Romania* and included in the recommendations package addressed to CEN.

In view of providing a general picture of the international situation concerning the modality of attesting the software referring to the Energy Performance and the necessary procedures, the current situation in countries with a tradition in the field of EPB was analyzed. We further briefly present the attesting schemes under use and the experience of these countries in implementing the requests concerning EPB of the European Directives.

II.1. UNITED KINGDOM: SAP / RdSAP software approval process

SAP is the acronym of Standard Assessment Procedure and RdSAP is the simplified version of the assessment scheme, usable exclusively for assessing existing residential buildings.

SAP is a nationally addressed scheme / procedure, approved at the government level for the assessment of the energy efficiency and of the impact on the environment of new buildings. The certification schemes based on SAP are currently used in England and Wales; a decision will be taken at the local level on their use in Ireland and Scotland.

II.2. AUSTRALIA: accreditation of software within the national assessment scheme for the energy consumed in dwelling buildings

The thermal assessment programmes, which may be used in assessing the energy consumption in dwelling buildings, were frequently used in providing information of the design quality or to test the compliance to the construction standards.

The national scheme of energy-related assessing dwelling buildings – NatHERS is a governmental Australian procedure meant to facilitate the improvement of lodgings thermal performance, to increase the efficiency of software products in the sector and to promote their use by the Australian industry.

There are separate but interconnected protocols meant to facilitate the use of the software products in regulations in the construction sector (ABCB protocol - Australian Building Codes Board – for software products used in assessing the energy used in dwelling buildings) and for associations accrediting energy auditors.

II.3. SR EN 15265:2005 – Buildings thermal performance. Calculation of the energy demand for rooms heating and cooling. General criteria and validation procedures

The European standard defines the hypotheses, boundary conditions as well as the validation procedures of the dynamic *calculation methods* for determining the annual energy demand for the heating or cooling of a building or of a part of it.

The standard does not impose a method or a calculation algorithm. A number of minimum requirements are expressed so that the calculation methods should be acceptable and a number of tests and validation criteria are defined. In general, the standard provides the elements necessary in validating the validation of the calculation methods for the annual energy demand for heating and cooling and represents an example of European approach on this issue.

The SR EN 15265 European standard does not impose any specific calculation technique for the room heating and cooling energy demand or for a room indoor temperature.

Validation tests

8 validation tests are defined, with different initial parameters.

Validation criteria

The results on heating, Q_{INC} and for cooling, Q_R, (expressed in kWh) reefr to the whole year and are compared to the reference values as follows:

$$rQ_{INC} = \text{abs}\,(Q_{INC} - Q_{INC,\,ref}) \,/\, Q_{TOTAL,\,ref}$$

$$rQ_{R} = \text{abs}\,(Q_{R} - Q_{R,\,ref}) \,/\, Q_{TOTAL,\,ref}$$

where abs (....) is the absolute value.

The results obtained may correspond to three accuracy levels: A, B, C. The validation tests are observed if for each test:

Level A: $rQ_{INC} \leq 0.05$ and $rQ_R \leq 0.05$;
Level B: $rQ_{INC} \leq 0.10$ and $rQ_R \leq 0.10$;
Level C: $rQ_{INC} \leq 0.15$ and $rQ_R \leq 0.15$.

The reference results are indicated in the standard for each test.

II.4. SR EN ISO 13791 : 2005 – Buildings thermal performance. Indoor temperature calculation of a room with no air conditioning in summer. General criteria and validation procedures

This document does not impose any specific method in calculating the indoor temperature of a room. The annexes present methods for calculating the parameters necessary in determining the indoor temperature, according to the hypotheses included in this document.

The results obtained using any numerical solution model should range in the field indicated for each test. The validation procedures refer both to each corresponding thermal transfer process and to the whole solving model.

III. DRAWING UP OF THE PCVA SOFTWARE

In the conditions of EPB software appearing on the market, the results of which have not been assessed in terms of validity or convergence, on one hand and on compliance to the national legislation imposing the issuing of CPEA in the case of any real estate transaction, on the other hand, it is obvious that the validation of the previously mentioned software products is necessary. This activity is regulated by the Minister's Order no. 1.217/ 31.03.2010.

The setting up of the Committee for the validation of the software concerning the issuing of a CPE for the Apartments in the condominiums by MDRT – DTC represents a very significant experiment as it is a signal of normalizing and rendering more efficient the energy audit activity for the buildings in Romania. The success of this experiment will allow the approach, in the near future, of the validation of most complex software products, with a modular structure, meant for the dwelling and public buildings energy audit, by expanding the competences of the validation committee. Besides the testing of the procedural elements, which they themselves are novelty, taking into account the confidential nature of the validation activity, the testing of the software products market represents an important challenge.

In the line of the compulsory exigencies in the case of the validation of any product, the validation committee finalized the PCVA structure and issued a modular mathematical model to meet the high accuracy exigencies imposed by the Order of the Minister of the Ministry for Regional Development and Tourism no. *1217 / 31.03.2010 (in terms of the European validation standards, the 5% deviation is the maximum exigency – class A).* Even if at first sight the high level of accuracy imposed to an activity which in fact does not immediately address the buildings energy efficiency increase, but only the information of the buildings users on the energy characteristics of the occupied or purchased apartments surprises, the target is strongly educational and, moreover, represents a test of capability for the local experts in providing high quality IT products meant for the energy upgrading of all types of buildings.

An approach shared by all the standards used as standard documents in validating simplified calculation methods is the analytical or numerical approach on the characteristics transfer processes at the level of the thermodynamic outline which defines the occupied spaces and the envelope adjoining both the occupied spaces and the natural environment, *without imposing a calculation method*. *Informatively*, some European standards recommend certain numerical solving models (e.g. SR EN 15255 : 2005 – Buildings thermal performance – determination of the sensitive cooling load – General criteria and validation procedures), but very importantly emphasizing that the indicated methods (Annex A) refer to a *simplified approach* on the calculations.

The INCERC researches performed in the period 1972-2009 generated experimentally validated dynamic calculation relations, included in the INVAR (1993) dynamic software and in the Dynamic Calculation Model [2] experimentally validated on the buildings operating as laboratories CS1 Campina, CS3 Bucharest and CE INCERC Bucharest plus Block M28 (44 apartments). The dimensional diversity of the buildings represents an additional credibility argument. The building dimensions are a condition of the experimental validation in the case of large spaces of the class of atriums or buildings with envelopes characterized by special processes of the natural / forced convection type [1]. In the previously mentioned cases, the use of criterion-based equations in view of determining the convection heat transfer coefficients may generate significant errors which, even if they do not significantly influence the buildings thermal response, they influence the air velocity field and at the same time the variation of the noxious substances concentration in permanently or temporarily occupied spaces. They represent special cases but are not excepted by the structure of the ***modular mathematical model***, but are included in special calculation modules connectable to the mathematical model basic structure.

The experimental validation of the above mentioned calculation mathematical models [2] covered two stages, as follows:

- ***validation of the calculation sub-models*** concerning the characteristics transfer processes, mainly in the case of the conduction heat transfer and of the heat transfer by short wave radiation heat transfer (visible spectrum) and by long wave radiation (remote infrared spectrum) and of natural or forced convection heat transfer;
- ***validation of the global empirical type***, referring to the comparison of the hourly or sub-hourly values of the intensive and extensive thermodynamic parameters (temperatures and thermal flows) by using the average statistic indicators, the square mean deviation (RMDS) and the standard square mean deviation (CV-RMSD) as a maximum admissible value specific to any of the quantified parameters.

The phases covered in order to validate the Romanian dynamic calculation models are further briefly presented:

The main ***sub-model*** which was tested and experimentally validated is that of the ***conduction heat transfer*** through over-ground and underground flat building components (building-soil boundary) which are or not affected by thermal bridge type disturbances. The calculation model developed by INCERC is the Unitary Thermal Response (RTU) [2] of homogeneous and composite structures to Dirac impulse type loads. The composing model of the random real loads with RTU is convolutional and was tested by long-term experiments on real buildings, starting with the CS1 Campina Passive Solar House (1974-1978) [3] and further on the CS3 Solar House of Bucharest (1982-1988) [4], Block M28-4 Aleea Arinii Dornei, Bucharest (1993-1998) [5], [6] and on the CE INCERC Bucharest Experimental Building (2003-2009) [7], [8], [9], [10]. The sub-model of the ***conduction heat transfer*** was tested in parallel by the inter-validation procedure using the ANSYS Numerical software (2003-2009) [2]. The results of the experimental validation as well as the numerical inter-validation attest the assessment accuracy by using the RTU model, both of the temperature field in composite flat structures with linear or non-linear material characteristics and of the thermal flow density. Based on the RTU method, implemented in the INVAR software, the real thermophysical parameters values of the envelope structures for Block M28 and of the CE INCERC Bucharest and ANVINTEX Bucharest buildings were identified, based on the use of the reversed modelling procedure [11].

The results obtained are used as input data in the structure of the ***spaces thermal balance sub-model*** which includes the inside energy variation of the inside building components under the control of the $Bi = f(Fo)$ function, with reference to the variation in time of the thermal wave which modifies the building components inside energy [12]. The emphasizing of a virtual climatic parameter, the virtual outdoor temperature specific to the structures as wholes [2] allowed the development of the thermal balance sub-model of spaces in controlled microclimate conditions as well as in conditions of free variation of the air indoor temperature and implicitly of the resulting indoor temperature, air conditioning lacking. A significant methodological advantage is the virtual outdoor temperature invariant in terms of the variation of the resulting indoor temperature, associated to the use of the models specific to the steady-state heat transfer in processes characterizing the transient heat transfer.

The use of similitude modelling allowed the devising, experimentally validated, of a ***heat one-phase heat transfer sub-model at the building-soil boundary*** as well as the phenomenologically based determination of the design outdoor temperature, specific to buildings systems dimensioning, both transposed in applied technical regulations (Mc 001/1-2006 and SR 1907 / 1 – 1997).

The ***fourth sub-model tested and experimentally validated is that of composite heat transfer at the outside boundary of flat structures adjoining the natural environment*** in the form of third rank boundary conditions (short/long wave thermal radiation and convection in open spaces). Calculation relations of the equivalent outdoor temperatures were devised and the simplified sub-model was validated; the latter was characterized by a daily mean sunlight coefficient where the $\overline{c}_s$ daily mean value may be used instead of function $c_s\left[y(\tau), z(\tau)\right]$ defined in space and time, in view of assessing the equivalent outdoor temperature hourly values specific to the opaque, respectively glazed areas.

Another ***sub-model*** extensively usable mainly in the case of using air as a space air conditioning vector is that ***concerning spaces convective correspondence*** characterized by air different temperature. A semi-empirical calculation relation was devised, based on the scale analysis used for the Prandtl equations of the thermal and hydrodynamic boundary layers developed at the surface – indoor air boundary, which offers the possibility of quantifying the intensity of the heat transfer between convectively corresponding spaces, according to the rooms' geometric characteristics and to the temperature difference between them. The calculation relation profits by the experimental validation on the support of CS3 Bucharest Solar House [13]. The sub-model of the spaces convective correspondence solves the problem of the influence of architecturally solving the issue of the air-conditioned spaces where cooling convective systems are used.

The use of the ***sub-models validated experimentally and by the numerical inter-validation procedure*** allowed the transition to the ***global calculation model for the occupied space, based on the empirical experimental validation procedure*** [8], [9], [14]. The experimental support of the full-scale physical model type and the buildings geometrical diversity grants credibility to the results provided by the global model. Moreover, it is considered that the experimental validation on a full-scale model in a controlled microclimate represents the maximum possible validation for an engineering calculation method [15]. We consider that the three experimental buildings in the INCERC Bucharest patrimony (CS1 Campina, CS3 Bucharest and CE INCERC Bucharest) plus the Block M28 (44 apartments) monitored in the heating thermal system and in four apartments on different floors of the building provided, in the period 1972-2009, data that facilitated the empirical validation of the calculation sub-models as well as of the integral model.

The question rises naturally, if a simplified approach may become a method of validating certain alternative calculation methods; the answer is negative. An example may be the cooling degrees – days method which generates significant errors compared to the results provided by measurements and by using the hourly pace detailed calculation model [16]. Therefore we consider that the approach on the validation of the software meant for the new and existing EPB assessment should cover a few phases, as follows:

- to issue a detailed calculation model with hourly and sub-hourly time pace, on phenomenological bases (called preliminary calculation model – MPC);
- to experimentally test the results provided by the preliminary calculation model (MCP) by

long-term measurements on a full-scale physical model and in conditions of free and / or controlled microclimate – results accuracy assessment by the validation statistic indicators M – mean, RMSD – mean standard deviation and CV-RMSD – standard mean square deviation;

- to compare the statistic indicators resulting from the dynamic model simulation to those resulting from measurements in terms of certain accuracy degrees imposed to the deviation between the previously mentioned parameters;

- to adapt the mathematical model (corrections mainly of the coefficients operating as material properties or of the material characteristics – thermophysical parameters with a linear or non-linear response in terms of temperature) and to generate the adapted calculation model (MCA);

- to experimentally test the results provided by the adapted calculation model (MCA) by long-term measurements on a full-scale physical model and in conditions of free and / or controlled microclimate – assessment of the accuracy of the results in terms of the validation statistic indicators M – mean, RMSD – mean standard deviation and CV-RMSD – standard mean square deviation;

- to adopt the standard validation calculation model (MCVE)[*)];

- to define the maximum admissible error classes according to the exigencies of the technical regulations;

- based on the results provided by the sensitivity analysis applied to the detailed multi-parametric models, the *simplified calculation models* may be devised; *they must be limitedly applicable in well defined sectors according to the regulated errors classes (MCS)*. These simplified calculation models **do not operate as validation calculation models**.

As concerns the calculation models implemented in the software so far issued in Romania (according to the producers' statements in public presentation materials [17], they all are simplified models structured according to the technical regulations in force (either NP 048-2000 or Mc 001-2006). The validation of the calculation models and implicitly of the software should refer to classes of test solutions specific to the heat transfer dynamic processes in the occupied spaces. From the point of view of the elements presented in this article, and especially of the accuracy degree imposed to the results by the law, the probability for a current software devised in Romania, with no minimum methodological adaptations, to pass the validation tests is extremely low. In order to raise the possibilities of promoting the first software for the EPB *accurate* assessment, an additional simplified calculation model (MCS) was devised, which represents the phase of the *sensitivity analysis*, further called MV0. This model was structured based on the regulations in force, but with *adaptations applied to both calculation models*. This additional processing of the Model of Calculating the Validation and of generating the Validation Software for Apartments (PCVA) ensures that the exigencies required by the law are met. It is thus actually created a possibility that the software become eligible from the technical point of view by adapting the calculation models according to the indications in the document presented by the web page of the Validation Committee (http://www.incerc2004.ro/Comisie_Validare/Comisie_validare.htm) and by the INCERC Bucharest web page (www.incerc2004.ro)

Taking into account the considerations above, the first two phases necessary in working out the PCVA were covered as follows:

- the comparative analysis of PEA on the support of apartments of different architectural and constructive configurations, using the regulated calculation methods;

- the analysis of the results concerning the experimental validation of the detailed calculation methods carried out within the research projects financed by MDRL (currently MDRT – Ministry of regional development and tourism) in the years 2008-2009 and by ANCS in the years 2007-2010 by the PNCDI 2 national research programme as well as by means of the Core Programme (2007-2009).

[*)] The imposed MCVE characteristic deviations in terms of the measured values are under 3%.

A strong confirmation of this methodological approach is represented by the conclusions of the final report of the CA 2 meeting in May 2010 in Ljubljana, concerning recast of European standards, subject of EPB. We emphasize that the empirical validation of calculation methods, is the third option of a total of 15 options with a positive score of + 5,40, based on the responses of 25 Member States. The followings are the conclusions of the mentioned final report, with reference to this issue [18].

III.1. Characteristics of the regulated calculation methods

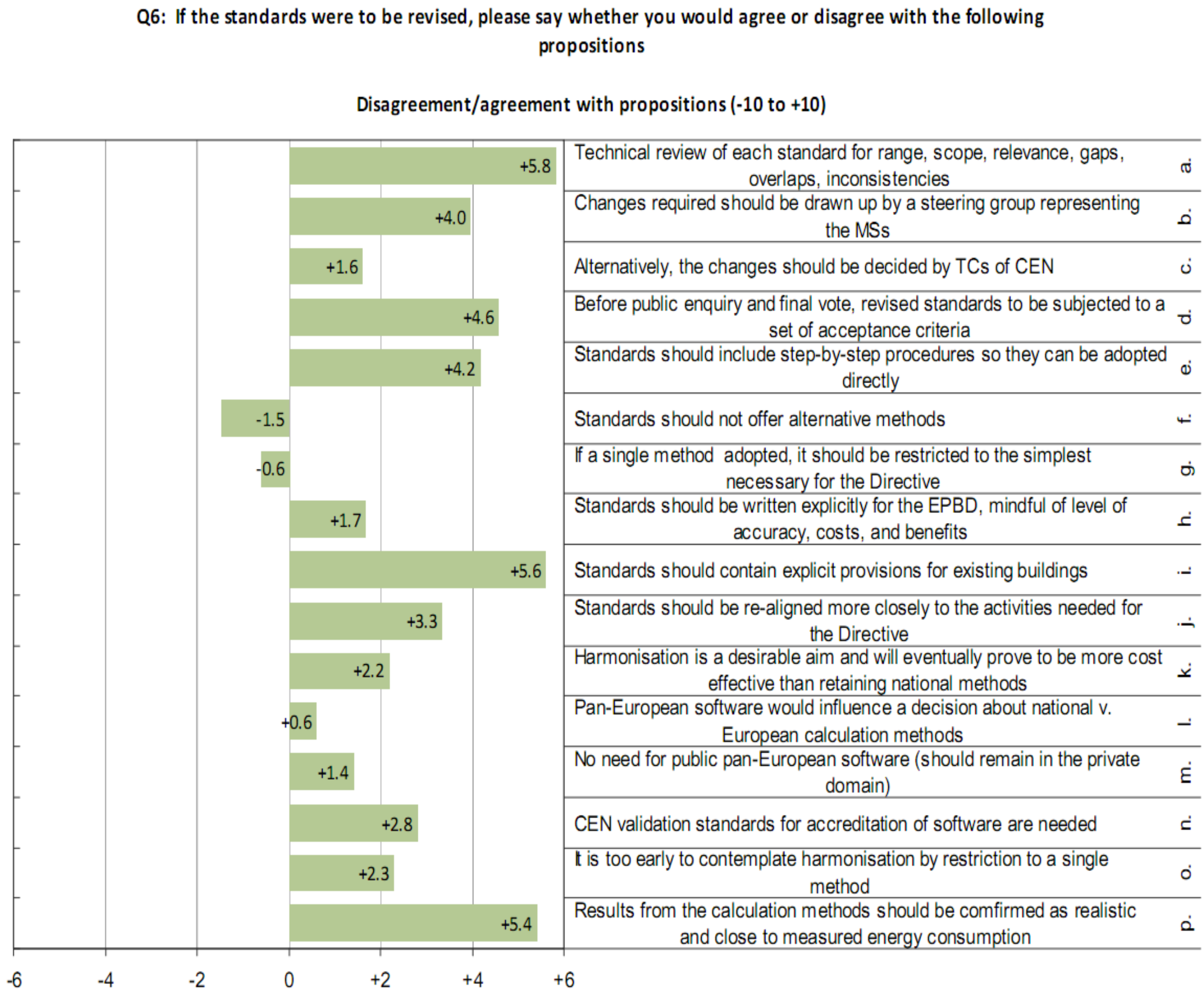
The compared analysis of the regulated calculation methods is presented, emphasizing their defining characteristics and the differences between them.

III.1.1. Mc 001 / 4-2009 and the Calculation and the Calculation abstract (Mc 001 / 5-2009) – continuous heating

a. The calculation model is one-zonal seasonal, with no correction of the operating temperature according to the normal conditions of the heat in occupied spaces and approaches a two step procedure as follows:

a.1. The first is a preliminary step based on the conventional assumption of defining the heating season, according to SR 4839 /97, which provides the preliminary duration of the heating season;

a.2. The second step defines the actual duration of the heating season in terms of meeting condition (1.23) chapter II.1.5.11.2 of Mc 001 / 2-2006;



b. Determination of the seasonal heat demand of the occupied space, by using a few simplifications as follows:

b.1. The equality between the air mean temperature and the operating indoor temperature is admitted (this hypothesis might be admitted in the case of spaces with adiabatic envelope);

b.2. Assessment of the intensity of the heat transfer to the building secondary spaces only in the case of a difference of at least 4K between the occupied space mean indoor temperature and the temperature in the secondary spaces zones;

b.3. Limiting of the solar radiation influence on the heat consumption specific to the occupied spaces by considering the energy inputs exclusively through the glazed areas and by using correction coefficients taken from the EN 13790 standard;

b.4. The influence of the cumulated energy inputs (sun and indoor activities) on the heat consumption of the occupied spaces is considered in the calculations by introducing the "heat inputs using factor" based on simplified, semi-empiric algorithms;

b.5. The simplification represented by the fact that condition (1.23) chapter II.1.5.11.2 of Mc 001 / 2-2006 is adopted; it represents a thermal balance relation specific to a period of 24 hours written according to the steady-state thermal conditions, which leads to significant deviations from the phenomenological reality;

b.6. The thermal balance of the envelope and of the secondary zones spaces (useful in applying the simplifying hypothesis b.2) is of the steady-state type, integrated by linear overlapping of the dissipated heat quantities with the energy input type ones, for an (undefined) period of the heating season, and the reference outdoor temperature is the outdoor air temperature, namely the temperature of the environments adjoining the occupied space if condition (1.23) is not met. This approach requires the iterative calculation for determining the heating season duration;

b.7. The calculation method is not completed by proving the convergence and stability of the iterative solution.

c. The thermal conditions of the secondary zones spaces (technical basement, staircase) are a consequence of using the relations specific to SR EN 13770: 2003 and C 107 / 5-2005 which overlook the effect of the heat sources in the previously mentioned spaces and use steady-state thermal balance relations which are improper for environments of the soil type, characterized by a considerable and variable thermal capacity in terms of the thermal flow "lines".

d. The *seasonal heat demand of the occupied spaces of a building* (or of a part of a building) is determined according to the annual mean values of the outdoor temperature and of the indoor one, to the value of the factor of heat inputs use and to the heating season duration.

e. The global energy-related effect specific to the heating systems equipping the building is presented (in chapter II.1.6, Mc 001 / 2-2006) in the form of additional heat consumptions of the systems, as follows:

- effect of the heating system emission characteristic;
- effect of the heat supply adjusting characteristic;
- effect of the distribution characteristic; it is associated to the heat carrier line;
- effect of the heat source characteristic.

f. The annual heat demand (consumption) of the building is determined as the sum of the heat demand specific to the occupied spaces and of the so-called "heat losses" of the heating system.

III.1.2. NP 048-2000 – continuous heating

a. The calculation model is multi-seasonal with monthly and sub-monthly time pace, but not shorter than 5 consecutive days and covers two successive phases, as follows:

a.1. To determine the temperatures specific to the indoor environment corresponding to the main zone and to the outdoor environment of the occupied space main zone, as follows:

a.1.1. Reduced indoor temperature including the thermal effect of the heat indoor inputs on the resulting indoor temperatures;

a.1.2. The volume mean temperature of the air in the occupied space, different from the resulting indoor temperature and determined from the condition of achieving the standard resulting indoor temperature value (different from the operating temperature used in the European standards) in any conditions of performing the envelope of the main zone space;

a.1.3. Equivalent mean outdoor temperatures specific to the opaque / glazed components of the envelope and which include the solar radiation effect;

a.1.4. Reference outdoor temperature, which depends on the intensity of the heat transfer by transmission through the opaque and transparent envelope components (including that to the secondary zones, regardless of their temperature compared to the mean resulting indoor temperature).

a.2. To determine the heating season duration, based on the equality of the temperatures mentioned by items a.1.1. and a.1.4. and on the value of the degree-days Corrected Number (by integrating in time the function generated by the difference between the two temperatures) of the occupied space main zone;

a.3. To determine the main *zone annual heat demand* according to the degree-days Corrected Number and by adopting certain correction coefficients which take into account the following elements:

a.3.1. The normal conditions of heat supply to the occupied space (by adopting a correction function specific to lowering the resulting indoor temperature during the night);

a.3.2. The effect of adopting the steady-state heat transfer through the envelope opaque components (correction proper for short periods of time, under 120 consecutive hours, but improper for monthly calculation periods (namely, over 120 consecutive hours));

a.3.3. Existence of open balconies in the building main zone (in the units forming the building).

b. The *heating systems efficiency* values are presented in the following sequence:

- heat supply adjustment efficiency;
- distribution efficiency associated to the heat carrier flow line;
- heat source efficiency.

NOTE: The emission efficiency (mentioned in regulation Mc 001-2006) is used in correspondence with a whole number numerical coefficient ($f_{ta} > 1$) the function of which is to correct the indoor temperature in terms of the space thermal gradient in the occupied spaces, which is a consequence of the operation of different indoor heating systems. The numerical coefficient also corrects the value of the air volume mean temperature and therefore the value of the resulting indoor mean temperature.

c. According to the annual heat demand and to the heating system efficiency, the *annual heat consumption for spaces heating and EPB* are determined (for the whole building or for parts of the building, namely apartments).

III.2. Conclusions of the pre-standardizing research programme

1. The main target of the research activity performed by INCERC Bucharest in the period 2008-2009 [8] was to test and experimentally validate the detailed calculation model *with hourly pace*, which is the reference model. The calculation model testing and validation were performed in a period of 57 days (06.01-04.03.2009) by measurements on the CE INCERC Bucharest building. The heat demand hourly values provided by the measurements attest the accuracy of the hourly calculation model. The mean deviation of 1.45 % between the measured values and those calculated validates the hourly calculation model. This article presents a phenomenological analysis of the heat transfer functions synthesized as functions

t_{ev} (τ), which attests their phenomenological objectivity at the macro as well as at the hourly level.

2. The next target is represented by the experimental validation and testing, on the support of the CE INCERC Bucharest experimental building, by comparing the monthly / seasonal calculation models to the hourly time pace calculation model and to the values resulted from measurements, in order to assess the occupied spaces heat demand in the cold season (resulted from the sensitivity analysis applied to the hourly pace model).

3. The monthly pace mathematical model (NP 048-20001[1)]) is based on the structure of the NP 048-2000 calculation method with modifications according to the method presented as alternative calculation method, revised, in the calculation methodology of EPB Mc 001 / 2-2006, chap. II.5.

4. The seasonal pace calculation method, specific to regulation Mc 001 / 2-2006 cannot be adapted to the operational conditions of CE INCERC Bucharest because the building is equipped with a ventilated solar space and the above mentioned regulation does not refer to such equipments of the buildings.

5. The calculation error per season between the measured heat demand and the one calculated by the NP 048-20001[1)] monthly pace method was of 0.61%, a value confirming the accuracy and the phenomenological nature of the NP 048-2000 method.

6. The second phase was meant to complete the analysis by numerical case studies focused on the condominium type conventional block and an office building with North and South directed facades, completely glazed. The glazing is heat insulating with selective properties (low-e) and the geometry of the two buildings is identical. The hourly pace calculation methods (reference calculation method), the monthly pace calculation method, NP 048-2000[1)] and the seasonal pace calculation method Mc 001 / 2-2006 were used in parallel (the test buildings are not equipped with elements not allowing the use of these methods).

7. The calculation synthesis is presented in table 1, with reference to the annual heat demand / consumption values of the apartment building (block).

8. The conclusion of item 7 is also valid in the case of the office building. The results for this case are further synthetically presented (table 2).

9. The simulation mathematical models specific to ventilated solar spaces were validated; they are used in calculating the hourly variation of the free temperature in the occupied spaces (hot season, natural ventilation and controlled mechanical ventilation; the mathematical model for calculating the artificial cooling in conditions on controlled mechanical ventilation was also validated.

Table 1.

Dimension	INCERC calculation hourly pace	Calculation NP 048[1)]-validation	Diff.	Deviation [%]	Calculation Mc 001	Diff.	Deviation [%]
Dz [days]	216.0	199.3	– 16.7	– 7.7 %	220.8[2)]	4.8	2.2 %
Sinc [m²]	1 858.0	1 858.0	0.0	– 0.0 %	2 393.8[2)]	535.8	28.8 %
Vinc [m²]	5 016.0	5 016.0	0.0	– 0.0 %	6 409.0[2)]	1 393.0	27.8 %
Qinc [MWh/year]	171.5	165.9	– 5.6	– 3.3 %	228.3[2)]	56.8	33.1 %
Qs_inc [MWh/year]	192.2	186.0	– 6.2	– 3.2 %	272.2[2)]	80.1	41.7 %

[1)] Compared to the revised calculation model, **the following modifications were operated**, which generate the **Monthly pace calculation method**:

- the correction coefficient generated by the use of the steady-state conditions of heat transfer (0.96) through opaque building components, was waved and its value so becomes unitary;
- the coefficient of correcting the volume mean temperature value f_{ta} >1 was waved and the heating units **emission efficiency was adopted** (determined according to Mc 001/2-2006).

[2)] The one-zone calculation model (Mc 001/2-2006, chapter II.1.5.11.2) are used following the verification of the conditions mentioned in Mc 001/2-2006, chapter II.1.5.3.2.1.

Table 2.

Dimension	INCERC calculation hourly pace	Calculation NP 048[1)]-validation	Diff.	Deviation [%]	Calculation Mc 001	Diff.	Deviation [%]
Dz [days]	214.0	179.6	– 34.4	– 16.1 %	184.6[2)]	– 29.4	– 13.8 %
Sinc [m²]	1 858.0	1 858.0	0.0	0.0 %	2 393.8[2)]	535.8	28.8 %
Vinc [m²]	5 016.0	5 016.0	0.0	0.0 %	6 409.0[2)]	1 393.0	27.8 %
Qinc [MWh/year]	165.4	166.2	0.9	0.5 %	204.3[2)]	39.0	23.6 %
Qs_inc [MWh/year]	184.9	185.9	1.0	0.6 %	243.0[2)]	58.2	31.5 %

The third phase consisted in devising a simplified software based on hypotheses verified by numerical tests, repeated and significant both quantitatively (number of tests) and qualitatively (3% maximum accepted error) by comparison to the results provided by the experimentally validated detailed calculation methods. The calculation methods worked out following the experimental validation on the support of a laboratory building and of a number of blocks of flats are hourly or sub-hourly pace detailed methods and entirely meet the extremely severe validation criteria imposed by the square standard deviation values (RMSD criterion) and of the standardized deviation (CV-RMSD) between the values of the measured and calculated parameters (temperatures and thermal flows). It is emphasized that the calculation methods do not refer to a certain configuration of the building or to an operational time. These are methods meant for any type of building and to the entire operational year (winter-summer).

The detailed calculation methods represented models of validating simplified models with an applicability limited to the target requested by the Minister's Order of the Ministry for Regional Development and Tourism no. *1217/31.03.2010*, but within the error limits imposed by this order. In fact the major simplification was the calculation time pace, and the verdict, the error of the seasonal EPB compared to the similar value resulted from the integration of the hourly values provided by the detailed method, in the validation period.

In the case of the apartments (and of certain types of buildings as well) a simplified calculation model with monthly and sub-monthly time pace (not shorter than 120 consecutive hours) resulted. It results, from the previously presented elements, that the calculation method proper to the determination of PEA.Inc is the monthly or sub-monthly pace calculation method (NP 048-2000[1)]) which becomes the MV0 method, in the case of apartments, experimentally validated. We have to emphasize that the use of method MV0 in special conditions of buildings energy-related configuration or in climatic conditions different from those of Romania may generate errors, in which case either the hourly pace calculation method will be used, or an alternative method, resulted from the use of the validation procedure of a method resulted from the sensitivity analysis proper to the new application conditions. In all the situations, the basic calculation model with hourly pace, experimentally validated is fundamental.

We also mention that the major problem in the case of buildings is EPB associated to the occupied spaces air conditioning. The use of hot water and of the power necessary for the occupied spaces lighting, in the case of apartments, profit, from the point of view of determining the associated EPB, of the current regulations provisions (Mc 001-2006), as they are activities highly subjective from the users' point of view. In this case as well as in that of buildings air conditioning (but to a much lower effect

[1)] Compared to the revised calculation model, **the following modifications were operated**, which generate the **Monthly pace calculation method**:

- the correction coefficient generated by the use of the steady-state conditions of heat transfer (0.96) through opaque building components, was waved and its value so becomes unitary;
- the coefficient of correcting the volume mean temperature value f_{ta} >1 was waved and the heating units **emission efficiency was adopted** (determined according to Mc 001/2-2006).

[2)] The one-zone calculation model (Mc 001/2-2006, chapter II.1.5.11.2) are used following the verification of the conditions mentioned in Mc 001/2-2006, chapter II.1.5.3.2.1.

on EPB), the calculation of PE is compared to a normal situation which in the case of apartments leads to significant simplifications according to the provisions of the previously mentioned document.

Referring again to the first phase of the analysis comparing the results provided by the calculation methods worked out in time and currently regulated, as well as these results and MV0, a case study was carried out in order to emphasize the differences occurring following the use of the regulated calculation methods and the calculation method proposed and included in the MV0 structure. The support of the case study is a block of apartments in Bucharest. The block has 36 apartments identical in terms of volumetry. The analysis refers to 11 cases with the following differences:

- location of the apartment in terms of the building floors;
- location of the apartment in terms of the facades cardinal direction;
- location of the apartment in the middle of the facade or in the corner;
- constructive solution of the staircase space;
- constructive solution of the technical basement;
- quality of the heat insulation of the heat carrier pipes.

The partial results substantiating the validation / invalidation decision of the Software (in this case of the calculation model used) refer to the following elements:

- The deviation of the PEA values (Apartment Energy Performance), expressed in kWh / m^{2}year, determined by using the regulated calculation models in force (Mc 001 / 4-2009 and NP 048-2000), but not experimentally validated, in terms of the values determined by using the PCVA calculation model, experimentally validated, compared to the reference deviation imposed by order 1217 / 31.03.2010, item 3, of maximum 5%;

- The deviation of the mean corrected thermal Resistance of the apartments envelope, expressed in m^{2}K / W, determined by using the regulated calculation models in force (Mc 001/4-2009 and NP 048-2000), but not experimentally validated, in terms of the values determined by using the PCVA calculation model, experimentally validated, compared to the reference deviation imposed by order 1217 / 31.03.2010, item 3, of maximum 5%.

The final result refer to the whole package of validation sheets and is determined as a function formed of the previously mentioned partial results, by the following relation:

$$I.V.package\ method = \sum_{i=1}^{i=11}\left(\prod_{j=1}^{j=2} I.V._J\right)$$

where i is number of the validation sheet ($j \in [1, 11]$), j – tested physical dimension, namely:

j = 1 – PEA [kWh / m^{2}year];

j = 2 – R.mean. [m^{2}K / W];

and $I.V._J$ is value of the validation index for each of the two tested physical dimensions (the validation index has a binary value, 0 or 1).

The synthesis of the results obtained is presented in table 3.

The following symbols are used in identifying the apartment's position: P – ground floor (above the technical basement); EC – common floor; UE – highest floor (under the terrace); M – middle of the facade; C – corner.

These symbols are accompanied by the indication on the vertical facades cardinal direction, according to the classical symbols (N, NE. E, SE, S, SV (W), V, NV).

Table 3 presents the deviations resulting following the use of the calculation models mentioned in the structure of the regulated calculation methods without the adaptations presented in the validation procedure, deviations which automatically lead to the non-attesting of the software.

The values in table 3 confirm again the main reasons for the inaccuracies generated by the two calculation methods, namely:

- the existence of correction numerical coefficients, unconfirmed experimentally, in the case of the NP 048-2000 Method;
- the restrictive use of the solar radiation influence exclusively on the glazed areas, the improper use of the adiabatic surface decision if the temperature difference of 4K between the occupied space and the secondary zones is

Table 3.

Synthetic table of the PEA.Inc. validation sheets

Sheet no.	Position apart.	Orientation	Physical dimension	Dev. NP [%]	Dev. Mc [%]	Dif. dev. NP [%]	Dif. dev. Mc [%]	I. V. NP 048-2000	I.V. Mc 001/4-2009
1	EC - M	S	q.inc. [kWh/mp.an]	6.269	17.006	1.269	12.006	0	0
			R.med. [mp.K/W]	0.000	68.443	– 5.000	63.443	1	0
2	EC - M	N	q.inc. [kWh/mp.an]	6.612	27.589	1.612	22.589	0	0
			R.med. [mp.K/W]	0.000	67.024	– 5.000	62.024	1	0
3	EC - C	SV	q.inc. [kWh/mp.an]	6.656	16.064	1.656	11.064	0	0
			R.med. [mp.K/W]	0.000	55.955	– 5.000	50.955	1	0
4	P - C	SE	q.inc. [kWh/mp.an]	6.692	41.915	1.692	36.915	0	0
			R.med. [mp.K/W]	0.000	108.395	– 5.000	103.395	1	0
5	P - M	S	q.inc. [kWh/mp.an]	6.746	15.989	1.746	10.989	0	0
			R.med. [mp.K/W]	0.000	46.165	– 5.000	41.165	1	0
6	P - C	SE	q.inc. [kWh/mp.an]	6.784	9.848	1.784	4.848	0	0
			R.med. [mp.K/W]	0.000	46.080	– 5.000	41.080	1	0
7	P - C	SE	q.inc. [kWh/mp.an]	6.404	39.542	1.404	34.452	0	0
			R.med.[mp.K/W]	0.000	108.395	– 5.000	103.395	1	0
8	P - C	SE	q.inc. [kWh/mp.an]	6.654	12.854	1.654	7.854	0	0
			R.med. [mp.K/W]	0.000	39.202	– 5.000	34.202	1	0
9	EC - C	SE	q.inc. [kWh/mp.an]	6.736	13.167	1.736	8.167	0	0
			R.med. [mp.K/W]	0.000	56.250	– 5.000	51.250	1	0
10	UE - C	SE	q.inc. [kWh/mp.an]	6.900	4.970	1.900	– 0.030	0	0
			R.med. [mp.K/W]	0.000	43.799	– 5.000	38.799	1	0
11	UE - M	S	q.inc. [kWh/mp.an]	6.772	5.192	1.772	0.192	0	0
			R.med. [mp.K/W]	0.000	53.432	– 5.000	48.432	1	0
Reference deviation [%]		5						I.V.NP - package 0	I.V.Mc - package 0

not exceeded, the overlooking of the difference between the indoor temperature and the indoor air temperature and the adopting of a seasonal calculation model, not confirmed experimentally, for Method Mc 001 / 4-2009.

NOTE:

The comparison of the results provided by the two calculation methods includes an inconsistency, assumed by the authors, referring to the different temperatures of the occupied spaces, with reference to the normal situation of using heat in apartments, when the Mc 001/4-2009 calculation method does not include the adopting of the day-night differentiated thermal conditions, as it is used in the NP048-2000 model. The achieving of the identical indoor thermal conditions is reflected in the lowering of the consumptions determined by using the Mc 001/4-2006 method as a result of using the correction coefficient $C_R < 1$. The result of the comparative analysis, which also includes the equalizing of the occupied spaces temperature level, is presented in table 4 and in the diagram in fig.1. The influence of the successive simplifications which affects the calculation model included in Mc 001/4-2006 methodology and especially, in this case, the overlooking of the solar radiation impact on the heat transfer through the envelope opaque components are emphasized.

The analysis of the results presented in table 3 emphasizes the error generated by admitting the simplification to consider adiabatic a surface dividing two environments characterized by temperatures the difference of which is lower than 4K. Cases 4 and 8, marked in the table refer to two situations of considering the floor above the basement, namely not thermally insulated (case 4) and thermally insulated (case 8). In case 4, the temperature difference between the occupied space and the basement is of 2.6°C, which leads, according to Mc 001 / 2006, to the annulment of the thermal flow dissipated through the floor to the basement and, therefore, to a high energy performance, specific to the analyzed apartment (91.6 kWh / m^2). In case 8, the temperature difference between the occupied space and the basement is of 4.4°C which leads to considering the thermal flow dissipated through the floor to the basement and, consequently, to an energy performance lower than that of the apartment in case 4 (114.59 kWh / m^2). The paradox of the conclusion comes from its correlation to the condition of the floor above the basement. The error generated by assuming a simplification proposition which is phenomenologically unacceptable is more than obvious.

The following elements were emphasized:

- unacceptable deviations between the results provided by NP 048-2000 and Mc 001 / 4-2006 (structured based on Mc 001 / 2-2006 method which in fact takes the methods of the European standards issued until 2005);
- unacceptable[1)] deviations between the results provided by each of the previously mentioned methods and the results provided by MV0.

Taking into account this conclusion and the fact that the potential producers of software products meant for the CPEA issuing will probably be focused on the calculation methods regulated as calculation models (while this is not an obligation of performing and attesting the software products), the possibilities of shortly adapting the calculation models included in the regulated methods were analyzed and, by the validation procedure, an easily usable guide for adapting the regulated methods is proposed. By this minimum intervention on the calculation algorithm already known, the qualification of all the software products devised in this line is ensured.

The criteria of adapting the calculation models specific to the technical regulations in force are the following:

- the square standard deviation (RMSD) in terms of all the analyzed case studies (11);
- the standardized value of the square standard deviation (CV-RMSD) for all the analyzed case studies (11).

If the theoretical standardized value is equal to 0, a single adapting coefficient may be applied, which leads to the calibrated calculation model. The more

Table 4.

Statistic index	NP 048-2000	Mc 001 / 4-2009	Mc. 001 / 4-2009 (cor.)
Deviations mean [%]	6.6567	18.5578	22.5404
RMSD [%]	0.05396	8.965	14.7954
CV-RMSD [–]	0.008106	0.48307	0.65040

1) In terms of the maximum admitted errors based on the Ministry of Regional Development and Tourism no. 1217 / 31.03.2010.

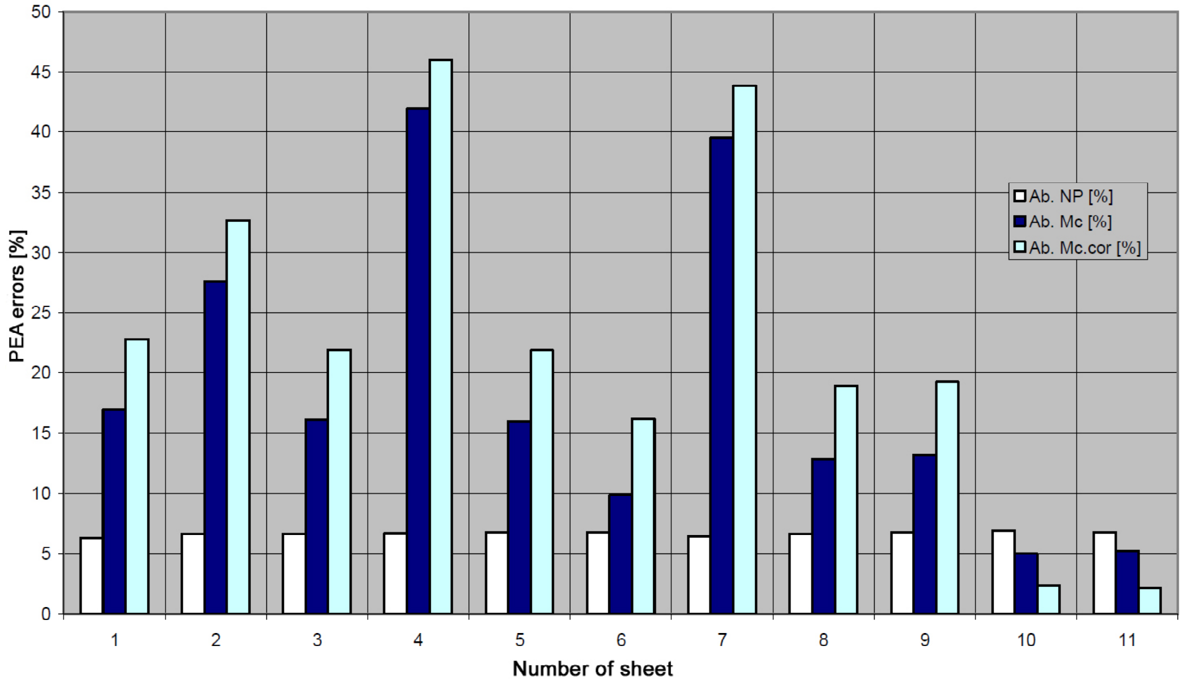


Fig. 1. Errors module variation in terms PCVA

the CV-RMSD value deviates from value 0, the more difficult the calibration of a model is and the *procedure of adapting the "closest" model* is adopted, with reference to the statistic validation criteria. The results of the analysis are presented in table 4 and in fig.1:

It results that an immediately adaptable calculation model, by adopting certain coefficients from the Mc 001-2006 technical regulation as well, is that of the NP 048-2000 Technical regulation which, by the adaptations performed, becomes PCVA.

The last test, of final validation, was represented by the compared analysis of the results obtained by applying PCVA and the initial validation model, MV0. The result attests the accuracy of the calibration by using the mean value of the 0.021 % deviation and by using the CV-RMSD value of 0.00000208, both actually insignificant. Therefore, the PCVA model was adopted, which resulted from adapting the models of the regulations in force, in terms of which the results provided by the software subjected to validation and attesting are analyzed.

The diagram in fig.2 presents the logical diagram of the procedure used in adopting the calculation model included in the **PCVA** structure (with reference to occupied spaces heating).

By this activity, one of the targets of proper and impartial functioning of the Validation Committee is accomplished, namely the devising and use of a calculation model which does not favour any regulated calculation method and which allows the rapid adaptation on one of the regulated methods to the accuracy exigencies specific to validating the software meant for CPEA issuing, by taking certain physical dimensions useful for the other regulated method as well.

IV. CHARACTERISTICS OF THE (PCVA) SOFTWARE FOR VALIDATING THE SOFTWARE MEANT FOR ISSUING THE ENERGY PERFORMANCE CERTIFICATE OF THE APARTMENTS IN APARTMENT BUILDINGS

IV.1. Aim

The **exclusive** assessment of the Energy Performance of an Apartment (PEA) located in a block of flats (apartment building) and, based on the resulted value, the issuing of the Apartment Energy and Environment Energy Performance Certificate (CPEA).

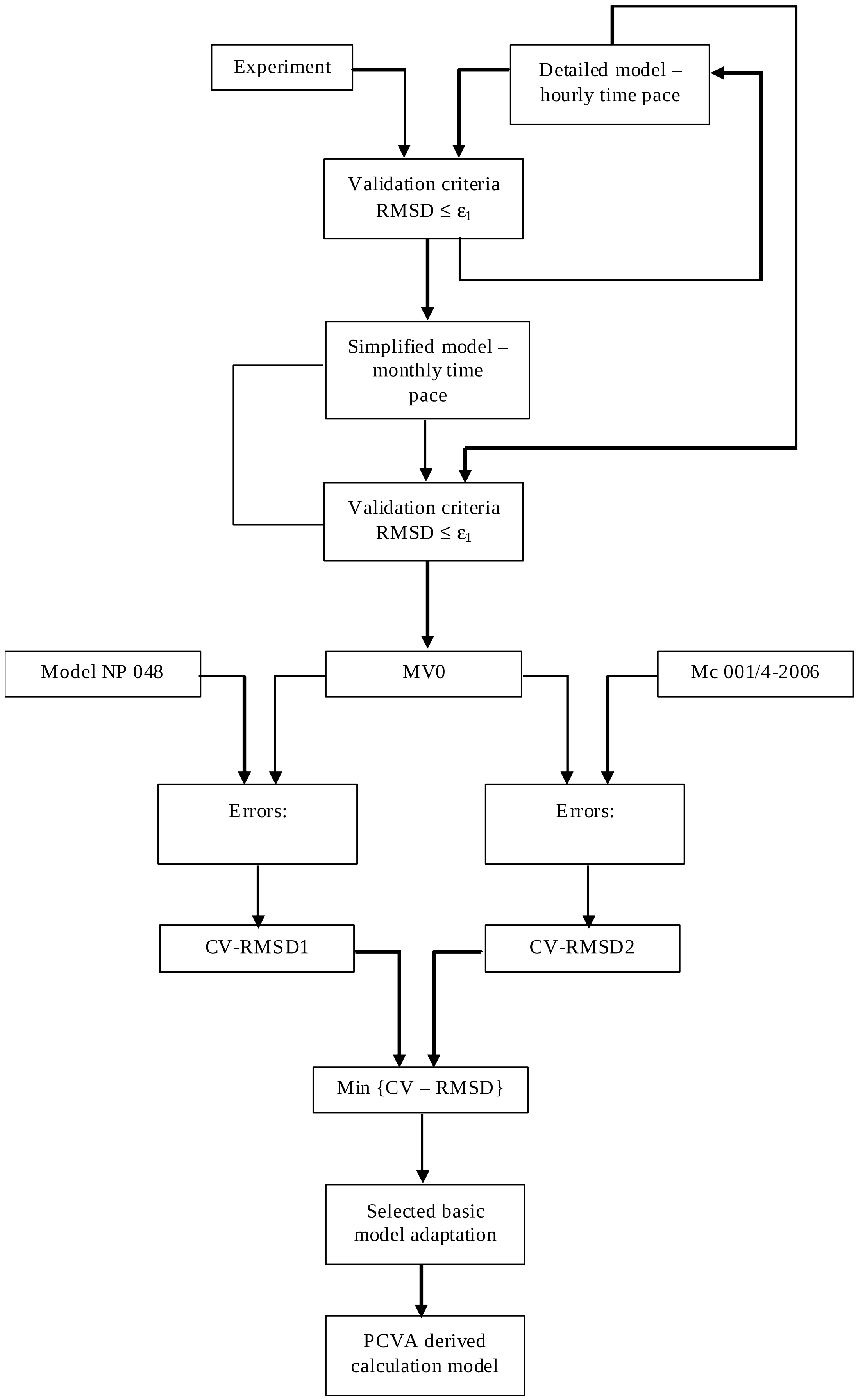


Fig. 2. Logical diagram of the PCVA. Inc. structure determining procedure

IV.2. Target

IV.2.1. Main target

PEA assessment on components as follows:
IV.2.1.1. Dwelled spaces heating
IV.2.1.2. Domestic hot water preparation and use
IV.2.1.3. Dwelled spaces lighting

IV.2.2. Related targets

IV.2.2.1. Apartment belonging to an energy class (A…G) according to the energy consumption values per utilities, according to item IV.2.1.

IV.2.2.2. Apartment belonging to an energy class (A…G) according to the sum of the energy consumption determined according to item IV.2.1.

IV.2.2.3. Penalties evaluation

IV.2.2.4. Energy-related mark (grade) of the apartment (20…100)

IV.2.2.5. CPEA issuing

IV.3. Limit of use: only for the target mentioned in item IV.1.

IV.4. PCVA structure

IV.4.1. PEA assessment for apartments heat supply (PEAInc):

IV.4.1.1. Input data (maximum necessary);

IV.4.1.2. Calculation section for determining the geometric characteristics of the apartment and of the envelope components adjoining the natural environment and the built environment in the building secondary zones (areas and volumes);

IV.4.1.3. Calculation section for determining the real thermal characteristics (thermal coupling coefficients, ventilation rate, significant indoor and outdoor temperatures, thermal flow indoor releases) of the apartment;

IV.4.1.4. Calculation section for determining the geometric characteristics of the building secondary zones (staircase, technical basement, attic) and of the envelope components adjoining the natural outdoor environment, the built environment of the main and secondary zones as well as of the building (areas and volumes);

IV.4.1.5. Calculation section for determining the real thermal characteristics (thermal coupling coefficients, ventilation rate, significant indoor and outdoor temperatures, thermal flow indoor releases) of the secondary zones;

IV.4.1.6. Calculation section for determining the indoor temperatures of the secondary zones (staircase, technical basement, attic);

IV.4.1.7. Calculation section for determining the thermal flow dissipated in the secondary zones space because of the equipments flowing hot fluids;

IV.4.1.8. Calculation section for determining the corrected significant temperatures of the indoor environment (reduced indoor temperature) and of the outdoor environment (reference outdoor temperature) of the apartment;

IV.4.1.9. Calculation section for determining the apartment heat demand (monthly mean value or during at least 5 consecutive days);

IV.4.1.10. Calculation section for determining the apartment heating season duration;

IV.4.1.11. Calculation section for determining the apartment seasonal heat demand;

IV4.1.12. Calculation section for determining the efficiency of the system / indoor heating system and the total efficiency of the system / indoor heating system;

IV.4.1.13. Calculation section for determining the seasonal heat consumption for the apartment heating;

IV.4.1.14. Calculation section for determining PEAInc.

IV.4.2. Assessment of PEA for apartments domestic hot water preparation and supply (PEAAcc)

According to the provisions of Mc 001 / 2-2006 chapter II / 3, with the simplifications indicated as specific to the apartments.

IV.4.3. Assessment of PEA for apartments lighting (PEAIl)

According to the provisions of Mc 001 / 2-2006 chapter II/4, with the simplifications indicated as specific to the apartments.

IV.5. Section for the software validation

IV.5.1. Comparison between the value of the mean thermal resistance of the apartment envelope components according to PCVA and to the software subjected to the attesting procedure (attesting procedure according to order 1217/ 31.03.2010)

IV.5.2. Comparison between the apartment PEAInc value, according to PCVA and according to the software subjected to the attesting procedure (attesting criterion according to order 1217/31.03.2010)

IV.5.3. Comparison between the apartment PEAAcc value, according to PCVA and to the software subjected to the attesting procedure (attesting criterion according to order 1217/31.03.2010)

IV.5.4. Comparison between the apartment PEAIl value, according to PCVA and to the software subjected to the attesting procedure (attesting criterion according to order 1217/31.03.2010)

IV.5.5. Comparison between the apartment PEA value, according to PCVA and to the software subjected to the attesting procedure (attesting criterion according to order 1217/31.03.2010, item 3)

IV.5.6. Issuing of the compared analysis sheet (Table 5)

IV.5.6.1. Determination of the absolute value of the percentage deviation between the value determined according to PCVA and the value determined according to the software subjected to the validation procedure

Table 5.

No.	Physical dimension	Value acc. to PCVA	Value acc. to PC	Deviation absolute value, VAA [%]	Deviation maximum admissible absolute value, VAA0*) [%]	Deviation value [%]	Validation index IV
0	1	2	3	4	5	6	7
1	$\overline{R}\,[\mathrm{m^2K/W}]$	V_{PCVA}	V_{PC}	$\left\lvert\frac{V_{PCVA}-V_{PC}}{V_{PCVA}}\right\rvert\cdot 100$	5	$VAA-VAA_0 \le 0$ $VAA-VAA_0 > 0$	1 0
2	$q_{INC}\,[\mathrm{kWh/m^2an}]$	V_{PCVA}	V_{PC}	$\left\lvert\frac{V_{PCVA}-V_{PC}}{V_{PCVA}}\right\rvert\cdot 100$	5	$VAA-VAA_0 \le 0$ $VAA-VAA_0 > 0$	1 0
3	$q_{ACC}\,[\mathrm{kWh/m^2an}]$	V_{PCVA}	V_{PC}	$\left\lvert\frac{V_{PCVA}-V_{PC}}{V_{PCVA}}\right\rvert\cdot 100$	5	$VAA-VAA_0 \le 0$ $VAA-VAA_0 > 0$	1 0
4	$q_{IL}\,[\mathrm{kWh/m^2an}]$	V_{PCVA}	V_{PC}	$\left\lvert\frac{V_{PCVA}-V_{PC}}{V_{PCVA}}\right\rvert\cdot 100$	5	$VAA-VAA_0 \le 0$ $VAA-VAA_0 > 0$	1 0
5	$q_{TOTAL}\,[\mathrm{kWh/m^2an}]$	V_{PCVA}	V_{PC}	$\left\lvert\frac{V_{PCVA}-V_{PC}}{V_{PCVA}}\right\rvert\cdot 100$	5	$VAA-VAA_0 \le 0$ $VAA-VAA_0 > 0$	1 0

*) Values according to order 1217/31.03.2010, item 3.

IV.5.6.2. Drawing up of the compared analysis synthetic table

IV.5.6.3. Determination of the I.V. validation index

IV.5.6.4. PC validation (col.7):

$$\sum_{i=1}^{i=5} IV_i = 5 \text{ – validated software}$$

$$\sum_{i=1}^{i=5} IV_i < 5 \text{ – not validated software}$$

V. CONCLUSIONS

1. In order to ensure the free circulation of products and services, the software for the Energy Performance of Buildings (EPB) do not have to observe a certain calculation algorithm based on a regulated mathematical model. Therefore, it is necessary to devise a diagram/scheme which should provide the possibility of testing the commercial software using different calculation and structuring algorithms. A maximum level of the necessary input data is defined, as well as a minimum level of the data provided by the calculations. The software assessment is based on a synthetic report including the input data and the values provided by calculation, for a variable number of testing sheets.

2. An alternative variant is to provide the self-validation sheets. They may be structured so that to help the software producer in identifying the error sources in the software structure (e.g. SR EN 15265:2008 allowing a localizing of the errors in the calculation model concerning the thermal inertia, indoor inputs, and solar inputs calculation).

3. The accepted errors differ according to the adopted validation scheme. Therefore, NatHERS requests for the buildings heating / cooling load a statistic assignment of 95 % of the results with a tolerance of 5 % or 10 % according to the object of the analysis. SR EN 15265 concerning “EPB – calculation of the energy demand for rooms heating and cooling. General criteria and validation procedures” specific to three degrees of accuracy: A (5 % tolerance for the heat / cold demand), B (10 % tolerance) and C (15 % tolerance). PCVA according to the Minister’s Order of MDRT 12471 / 2010 imposes the single error of 5% to all the physical dimensions under testing.

4. In all cases the software validation and attesting is in charge of national bodies appointed by the central authorities (in Romania’s case, by MDRT, by DTC). It is recommended to turn the Validation committee into a PCVE issuing coordination body in the form of a network / excellence center meant to coordinate and manage the preliminary phases in issuing PCVE, including the regulation of the validation activity by adopting and adapting the most modern systems used in Europe and all over the world.

5. A distinction is made between the calculation methods validation schemes and the software validation schemes: the calculation methods validation based on experimentally validated dynamic mathematical models does not imply the validation of the software which are highly complex in terms of the operational characteristics and those concerning the final information providing. For this reason, the validation committee newly set up in Romania may fall into the first category of calculation methods validation. The committee will have to involve computer experts when the next validation phase is approached, with reference to the highly complex software, useful in the energy audit of public or commercial buildings with very low energy consumption and useful in the design of the new buildings energy configuration.

6. The appearance of the calculation methods validation schemes and of the software generate the possibility of a *new approach* of the Buildings Energy Performance calculation Methodology, meaning the focusing of the regulated contents on the EPB quantification methodological principles, phenomenologically substantiated, on indicating certain coefficients and thermophysical parameters, climate and microclimate parameters, according to the buildings use conditions, air quality characterization, transparent and opaque envelope components, energy referentials, values specific to the economic efficiency analysis on the building lifetime, etc. As concerns the calculation as such of the energy and economic performance indicators, it profits of the validated and attested Commercial software.

7. This new approach will provide the following advantages compared to the current one:

- volume reduction and increase of the technical regulations rate of use;
- reduced working time for calculations and longer time for the expert analysis of the technical solutions specific to the new buildings or to the upgrading of existing buildings;
- the *proper* use of the technical regulations will depend to a small extent on the degree of technical education of the buildings energy auditors;
- the training courses for the buildings energy auditors and their attesting examination will be restructured in the line of improving the degree of use of the learning and examination computer methods;
- the degree of transparency and objectivity of the professional training and examination will increase by promoting on the market the training software products;
- the products of architecture, buildings energy design discipline will be imposed, as one of the main beneficiaries of EPB quantification computerization;
- the costs of the buildings certification documentation and of the energy audit report will be reduced.

8. The *new approach* may be a significant step toward the harmonization of the EPB calculation methodologies and towards a computerized management with a high degree of accuracy of the EPBD implementation national strategies.

9. The *new approach* leads to the modification of the specificity of the training and specializing courses addressed to the applicants (who want to become professionals), namely to the updating of the knowledge level of the buildings energy auditors.

10. This article presents the phases in the preparation and completion of the national scheme of validation of the software meant for the CPEA issuing, according to the Romanian legislation.

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