ENERGY PERFORMANCE OF FACADES AND BUILDINGS – IEA AS SUPPORT FOR THE EUROPEAN DIRECTIVE?

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INTRODUCTION

Within IEA Task27 the topic of energy performance of advanced windows and facades was taken up in an international cooperation project. Different approaches throughout the various member countries were presented and discussed with the aim to develop the methodologies further and to harmonize the approaches.
This work seemed to fit to the European Energy Performance Directive (EBPD) published in January 2003 as 2002/92/EG, where the topic of a certification of the whole building - building structure and technical building services is being taken up. The directive works on the subsidiarity principle with a harmonised European structure and local national implementations. A methodology for calculating integrated energy performance EP is needed, which can be used for specifiying the minimum requirements on EP of new buildings and for large existing buildings under major renovations, and for energy certification. The EPD shall be fully implemented in January 2006 and due to the tight time frame only little time was left to develop (inter)national integrated methods and certification schemes.
In the following paper the general ideas within the IEA group are presented. These ideas could partially be transported into the national and European standardization groups through individual members, but many other issues had to be respected as well.
Two basic approaches were identified which have different advantages and disadvantages. One is the so-called component performance assessment methodology (CPAM) where the performance of the façade is characterized with physical quantities associated alone with the building element. The second approach is the building performance assessment methodology, where the performance is characterized indirectly via building performance indicators, i.e. the components influence on overall building performance is the meter stick.
Both methodologies and some aspects of the discussion within the standardisation organizations on the way to an European Building Performance standard will be described in the paper.

OBJECTIVES OF A GENERAL ENERGY PERFORMANCE ASSESSMENT METHODOLOGY

The objective of a general energy performance methodology is the evaluation of the energy performance of a building envelope component, either product or development, in the context of real use. The question is not how to characterize the properties of the component with well-defined component performance figures, for instance with heat resistance or total solar energy transmittance, but to give a well-defined but illustrative view of the energy-related benefits of this components in a realistic use condition. Obviously the application and use is not a completely fixed frame. Windows and other envelope products may be used in different contexts. Nevertheless the answer can be representative for typical use. Therefore the definition of typical reference cases and conditions is a part of the work on a general EPAM.
As the target value is the benefit of the user related to energy, the changes in energy consumption have to be determined for different component alternative, if products are to be compared. This quantity, however, is dependent on a number of other factors such as

- building and HVAC-systems
- user patterns, regulations
- climate
- national/local data on energy, building regulations
- building element characterization

In order to allow objective and realistic comparisons there are in principle two alternatives:
define typical reference cases where the factors above are well-defined
use the conditions as specified for a specific building project

The first alternative is mainly interesting to the component producer who wants to demonstrate possible clients or customers the specific advantages of the product in a language they can understand, whereas the second alternative is only possible, if a this specific building project exists. This latter case is probably more interesting to the planning profession or the investors and builders themselves.

The energy related quantities to be considered in an overall energy performance cannot be restricted to an isolated performance figure e.g. heating energy requirement, but must include other indicators as well:

- energy savings heating and cooling
- energy substitution through daylight
- peak load reduction for systems
- thermal and visual user comfort
- air quality

Other indicators such as

- cost
- environmental benefits

may be interesting to the user, but are not strictly related to energy. Therefore we leave them out at this stage.

DEFINITION OF PERFORMANCE INDICATORS

As there is a whole range of performance indicators being discussed, the following definitions shall serve to categorize these different approaches, which should help avoiding misunderstandings.

BUILDING PERFORMANCE INDICATORS BPI

The BPI is a quantity directly connected to energy not only taking into account the well-defined component performance say in a laboratory, but also the use of the product.

Examples are the heating energy consumption or lighting energy consumption usually related to heated floor area or per volume. As facade elements may influence rather different energy consumption, it is difficult to stick to useful energy. For example how should transparent glazings be compared which influence heating, cooling and lighting energy. When CO2-emissions are important, for electricity and gas the rather different transformation and transport losses have to be taken into account as well. Usually therefore the primary energy is taken as a basis for comparison, not final energy bought for the building (See Figure 1). As a consequence the national or even regional energy market has to be defined for a reasonable comparison of building concepts and building product performance. For example, the optimization between solar shading, artificial lighting, heating and cooling energy may result in different solutions, depending on the electricity production in the region considered.

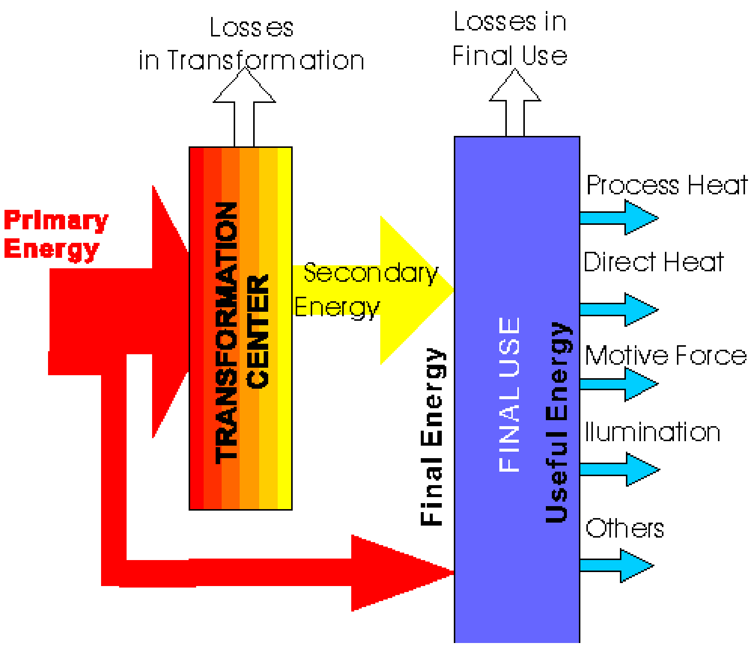

Figure 1: Concepts of primary, secondary, final and useful energy for a building

COMPONENT PERFORMANCE INDICATORS CPI

The CPI is characterized being very much a quantity directly connected to the product without taking into account the use of the product. Mainly the CPI is a single number based on physical measurements or calculations, specific to product, which characterize a specific performance related to energy transport or storage.
Examples are the U-value, the g-value, the visual transmittance and so on in their various specific forms.

BUILDING PERFORMANCE CRITERIA BPC
There are performance related parameters which are not an indicator for energy consumption, but nevertheless influence the energy performance of the component. They describe the comfort for the user, that should be kept in an optimal range.

PARTS OF A GENERAL ENERGY PERFORMANCE ASSESSMENT METHODOLOGY

A general energy performance assessment methodology needs a number of parts contributing to the overall picture. This is very roughly described in the following figure and text parts.

COMPONENT DATA
The first part is a consistent set of BPI describing and characterizing quantitatively the building component physically. The most prominent parameters are the U-value of the component, the total solar energy transmittance g, the visual transmittance tv. The degree of sophistication is of course is dependent on the level needed for building energy calculation. For example, in simplified tools only single number values are needed for this characterization, but for building energy simulation tools like ESP-r you would like to have angular dependent data of total solar energy transmittance g and light transmittance τ_v, and the tool itself for this purpose needs angular optical properties and thermal properties of the glazing layers. Even more advanced models one may perceive in future would probably use even spectral data. Information on frame and edge-seal design is needed to input a linear thermal conductance Ψ.

COMPONENT MODEL
The second part connected to the experimental data therefore is the component model within the simulation routine which may be a part of the EPAM. The simplest so-called trivial component model is just the instruction “Feed in the measured parameter, e.g. U into the calculation”. A more sophisticated model would be the calculation of effective parameters derived from measured data to be fed into the building model. An example is the determination of frame U-value and Ψ -value from frame design according to EN ISO 10077 in order to feed these data in to a simulation tool requiring these parameters. Or an optical glazing calculation tool can be used to calculate effective solar transmittance and absorptance for input to, say, the TRNSYS library from measured optical spectral data using an empirical formula to derive angular optical data from normal incidence measurements.

INTEGRATION MODEL
The third part would be the integration and description of components like windows integrated into the building model. Questions of window-wall connections and shading by window apertures will be treated here. Even if in many cases a so-called trivial model again is employed here in many current energy performance calculations, one should be aware that even in very simplified tools empirical coefficients (e.g. relating TSET g and solar irradiation for solar gain calculation) are an implicit integration model.

BUILDING MODEL
For calculation of the energy consumption we have to define the building including all the information about users, thermal zones, internal gains etc. This part is called the building model.

SYSTEM MODEL
If we want to relate different energy use, e.g. heating by gas or oil and lighting by electricity, we have to introduce the system models. Here energy transport and conversion losses are detailed, and primary energy consumption is linked through this to the different end energy use.

GENERAL DATABASE
For these different levels of models a general database is necessary, where data not related to the specific component under evaluation have to exist. Climatic data, building data, user patterns, system data, but even the energy-mix in a country relating electricity to primary energy consumption is needed. These data will be used the same for all assessments of building component energy performance assessment.

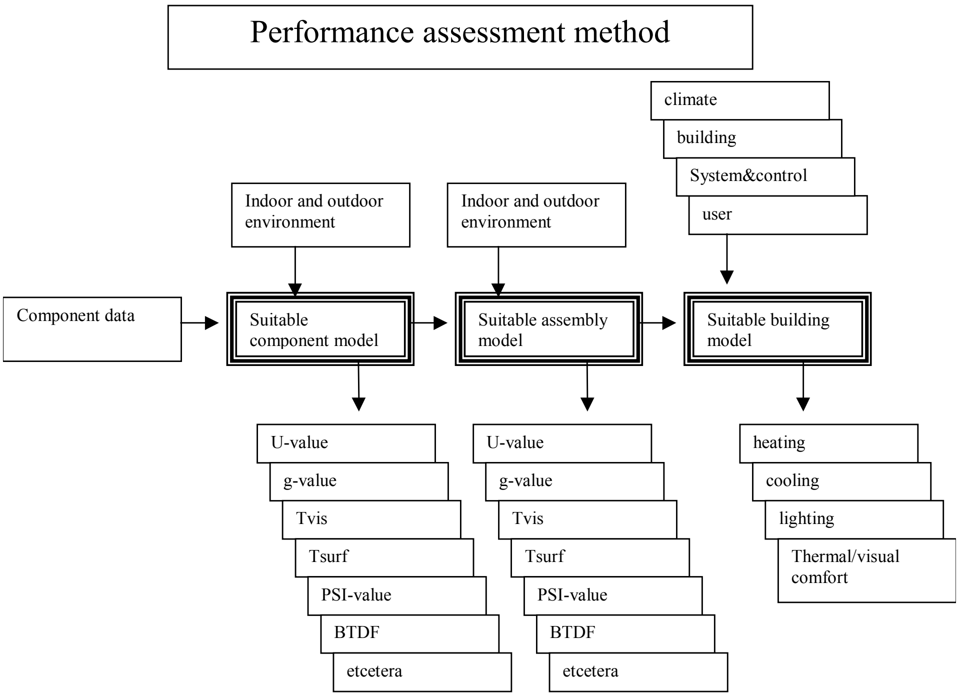

Figure 2: Structure and relation between elements of a general energy performance assessment method

SIMPLIFIED METHODS AND SIMULATION

For heating energy a large number of simplified calculation methodologies exist, based on heating period or monthly calculation, which have proven to give results very close to those of detailed simulation programs, provided the input data are chosen in a compatible way. The European standards EN 832 and EN 13790 deal with such methods. There are small differences in all these methods, mainly connected to boundary conditions (which have to be national), to the level of detail (e.g. some methods thermal bridges may be taken into account explicitly) and utilisation of gains. However the main structure and the main underlying equations are the same.

For cooling energy, however, no such method had been developed. Now within IEA, the Netherlands and Germany rather similar ideas have been proposed in order to treat this issue.

In simulation tools usually cooling and heating energy consumption and power requirements can be investigated easily. However, the number of results and especially the large number of detailed assumptions to be made in an early planning stage (e.g. on user patterns, on control algorithms) make these tools not easy to use. Moreover, results and inputs are not transparent to an outsider, and different algorithms hidden in the various programs complicate the comparability of simulation results. A standardisation of input and algorithms in my opinion seems to be far away. Therefore transparent algorithms – even if simplified – seem to be a necessity. Simulation on the other hand may be used for case studies and for optimisation of a specific building envelope and equipment.

THE REFERENCE OFFICE: A COMMON SCIENTIFIC BASIS

DEFINITION OF “TYPICAL” BUILDINGS

Within a general EPAM for building envelope components a definition of a “typical” building has to be given. As within the Task 27 mainly innovative components related to the use in office type buildings have been considered, it was decided that a reference office should be defined within the project.

The so-called base case variations have been defined in order to cover in a controlled manner the number of variations. For instance, offices with completely glazed, with medium and small window area are defined. Thus new office buildings with a large glazing fraction can be similarly treated as the renovation of an old building with small window area. This is important as for instance shading elements must be more efficient in the types with large glazing fraction.

USER PATTERNS - CONTROL STRATEGIES

In the same document is a number of assumptions listed connected to user patterns and control schemes, influencing the momentary gain and comfort situation, e.g. lighting needs and ventilation of fresh air. This time schedules are taken from empirical investigations. It has to be born in mind that such patterns may differ to some extent from country to country. The Northern European office use does not include a Spanish siesta, for example.

SHORT DESCRIPTION OF THE REFERENCE OFFICE

Within IEA Task 27 and in cooperation with the European project SWIFT (Switchable Façade Technology) [2] we have developed a reference office, describing a "typical" office configuration. This reference office includes data on geometry, building components and materials, heating, cooling, ventilation and lighting technology [3]. Moreover, it does not only specify a single cases, but defines so-called base variations. With these base variations well-defined building cases may cover rather different building types existing in reality. For instance glazing fractions prescribed allow the change from a whole in the wall façade to a fully glazed façade. Different thermal insulation standards for external walls and windows are given in order to reflect different building ages. As the complete description covers many details given in a separate document, only some examples are given to show the level of description.
It is hoped that using this description many different systems and technologies can be compared on a unique an unambiguous basis trough different climate zones. The use of the reference office is a scientific instrument, but for manufacturers it may serve to detect the qualities and problems of certain products and product ideas. The reference building simulations could be used in a kind of benchmarking scheme for new product developments.

Climate data are specified and have been distributed for South, Central and Northern Europe, using the weather data of Rome, Brussels and Stockholm. Of course other climate data can be used for simulations, but this selection provides a good overview of climate dependent performance.

The topics covered in the documents are:

- **Location**
- **Geometry**
- **Constructions**
    - thermal properties
    - Roof
    - Floor
    - Ground floor
    - Intermediate floor
    - Opaque part of facade
    - Internal walls
    - Internal doors
    - Internal glazing
    - Windows
    - Other construction properties
    - Solar radiation properties opaque surfaces
    - Thermal radiation properties opaque surfaces
- **Air infiltration**
- **Use of the building**
    - Occupants and working schedules
- **Equipment**
    - Lighting
    - Air exchange between office module and corridor
    - HVAC system
    - Operation period
    - Mechanical ventilation
    - Heating and cooling
    - Installed heating and cooling power
    - Setpoints
- **Detailed data for (day)lighting**
    - Geometry
    - Properties
    - Occupants
    - Electric lighting
    - List of measurement points in the room for luminance and illuminance
    - List of outdoor environment points for luminance from sky and ground
- **Reporting**

Examples of the detailed description are given below. It has to be emphasized that due to the need of coupling heating, cooling and lighting the description of the reference office includes data for building energy simulation and daylighting simulation tools.

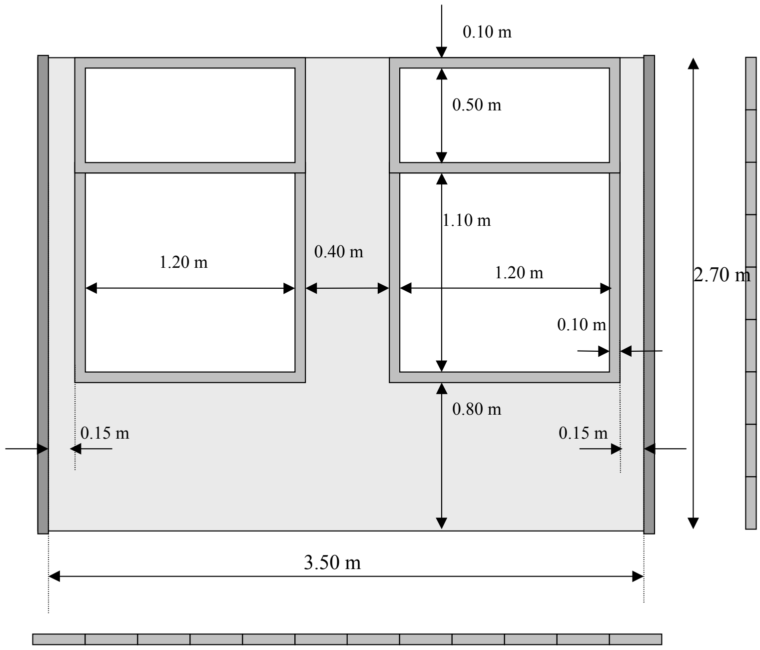

Figure 3: Facade layout of an office cell

For detailing the building constructions tables are being used. For the successive constructions the data, giving the properties of the successive layers, are presented:

Layer thickness	d (m),
Thermal conductivity	λ (W/(m.K))
Thermal resistance	R (m^2K/W)
Specific mass	ρ (kg/m3)
Specific heat	C_p (J/(kg.K))

Also the overall thermal resistance R (m2K/W) is presented.and the U-value is given, based on surface heat transfer coefficients of 8 W/(m2.K) (inside) and 23 W/(m2.K) (outside).

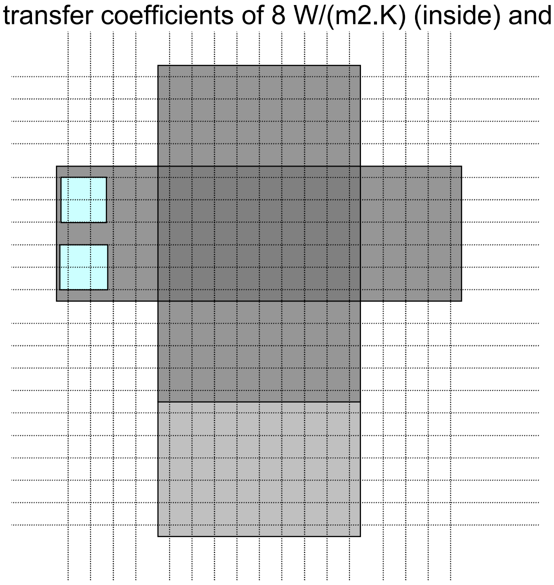

Figure 4: The 228 Positions of luminance measurements at the walls, ceiling and floor for daylighting simulations

In addition to the reference office a reference dwelling has also being developed, which exists in a draft form[4].

CONTRIBUTION OF IEA TASK 27 TO THE WORK ON THE EU DIRECTIVE

The work presented up to now gives a basis for specific discussions in the national member states, however it should be mentioned that the level of detail and specifications of the building elements, of the assessment methodology is too complex for the objectives of the directive.

For this aim simplified methodologies have to be studied and developed. Whereas for heating the monthly method of EN832 [5] and (new) the upcoming EN 13790 [6] on the calculation of the energy performance of buildings is known, methods on a similar level are needed for ventilation, cooling and lighting. Probably monthly methods are the best compromise between simplicity and precision.

A second element of the performance assessment is the description of building technology in the different areas. For heating and domestic warm water equipment the German DIN 4701-10 [7] is a start for such a description. This work has to be extended and fitted into separated but linked energy balances of the building rooms and the technical equipment.

Work within IEA Task K27 had been useful in several aspects:

a) Development of new approaches to simplified calculation methodologies
b) Evaluation of existing methodologies an cross-checking with detailed simulation
c) Developing acceptable simplification of the boundary conditions of calculation procedures (for instance developing simple performance indicators for solar shading devices, daylighting elements, latent heat storage, and other elements)

Although IEA works on a different level than the national experts, a link between IEA and standardization has been established in some countries, which is useful for the exchange of ideas and harmonization of the work.

EXAMPLE CASE STUDY: COOLING ENERGY

As an example of the powerful approach we show the control optimization of an switchable facade(gasochromic glazing) using the reference office. Lighting, heating and cooling energy is takien into account simulateously. The Table gives the overall yearly consumption for three different glazings.

Table Annual heating and cooling energy demand for different glazing options
HM: Heat mirror double glazing (U=1.3 W/m2K, g=62%)
SC: Solar control double glazing (U=1.1 W/m2K, g=33%)
GC : Gasochromic glazing (U=0.9 W/m2K, g=48%/18%)

	Heating energy q_H [kWh/m^{2}a]			Cooling energy q_C [kWh/m^{2}a]		
climate	HM	SC	GC	HM	SC	GC
Rome	3.7	5.5	4.9	45.5	24.2	15.2
Brussels	16.6	20.3	17.2	16.3	6.8	3.4
Stockholm	33.8	39.4	33.1	18.8	7.3	3.1

When the control strategies were optimized it could be shown that the switching according to room temperature would be the most energy efficient (Figure 6). Switching should occur about 2 degrees below the cooling set point (Figure 5). However, because we assume that a user would manually operate a system according to visual comfort, i.e. glare, and glare from the direct sun cannot be reduced sufficiently, manually operable blinds are recommended for that case.

However, if automatically the façade would be operated using vertical irradiance or glare as switching criterium, only 10% increase in primary energy consumption (due to higher cooling loads) would result.

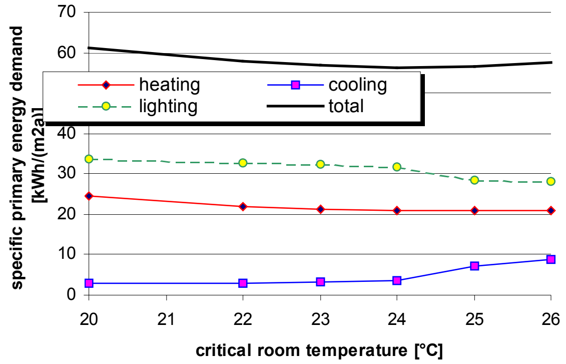

Figure 5 Primary energy consumption for the case of a gasochromic facade, reference office, Brussels, South-North orientation, switching according to room temperature set point (minimum consumption for 24°C set point)

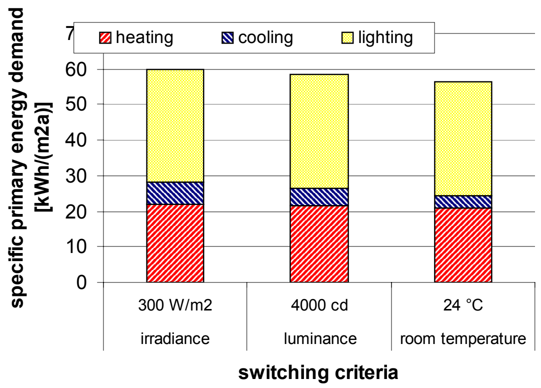

Figure 6: Primary energy consumption (conditions as in **Fehler! Verweisquelle konnte nicht gefunden werden.**)
Different control strategies

As the cooling energy demand is small when the gasochromic façade is investigated, one might be interested whether natural or passive cooling could be sufficient to avoid overheating of the building. This is certainly not the case for Rome. In extreme periods the ambient temperature is very high even at night time. Thus cooling by nighttime ventilation is not effective. However, first simple strategies of increasing nighttime ventilation in Brussels or Stockholm reduced the number of overheating hours substantially with only a few hours above 27°C (for comparison: double low-e glazing without night time cooling around 700 hours above 27°C). For a real building project passive cooling options should be optimized of course, e.g. by increasing accessible ceiling mass, or by using earth-to-air-heat exchangers.

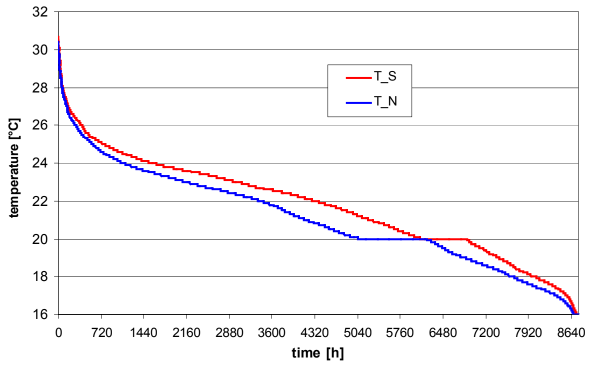

Figure 7: Distribution of room temperatures in reference office with increased night ventilation compared without cooling device (climate Brussels)

CONCLUSION

IEA Task 27 provides a scientific background for the simplified building performance assessment needed for the European Union as well as for advanced studies. It has developed methods and data which may be used to give support on specialized issues. It may serve as a basis for international discussion and exchange of ideas to harmonize the national approaches, which is a fundamental objective of the EU. However, the main role in this field belongs to the standardisation bodies in the national countries as well as CEN in Europe. As a scientific basis for future studies the useof the international reference office is highly recommended to create intercomparability of results. The data can be downloaded from [2].

ACKNOWLEDGEMENT

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