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SIMULATING QUALITY IN RELATION TO VENTILATION SYSTEMS : CHALLENGES FOR AN ENERGY PERFORMANCE REGULATION

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Synopsis

Ventilation systems should contribute to good indoor air quality conditions and should be energy efficient. In practice, one often finds ventilation systems which often not give the appropriate indoor climate conditions and/or which consume a lot of energy.

In an increased number of European countries, legislation exists (France, Netherlands,…) or is under preparation (Belgium, Greece,…) putting requirements on the total energy use of the building. Part of this energy use deals with ventilation (thermal energy and fan energy). Various aspects of the notion of quality are discussed and a number of challenges for such energy performance legislation are identified.

1. What is 'quality'?

In principle, one should expect that all buildings are of good quality. However, what exactly is meant by 'quality'? How to guarantee that there is quality? How to stimulate a better quality? In this paper, the discussion is focused on quality in relation to ventilation systems.

All systems, including ventilation systems, can be characterised by a set of performances. The issue of quality is a key area of concern for many industrial sectors. In the framework of the ISO standard 8402, quality is defined as *'Totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs'*. An 'entity' can be e.g. a ventilation component or a ventilation system.

The suppliers are assumed to deliver entities which meet the requirements for quality (Figure 1❶). The customer is in a position to identify his needs (Figure 1❷) with respect to a certain entity. Besides the customer, society can also impose certain performances. These performances (also called the requirements of society) (Figure 1❸) can be specified in standards, regulations,… Ideally, the needs of the customer and the requirements of society should cover all the needs. However, certain needs may not be covered (Figure 1❹).

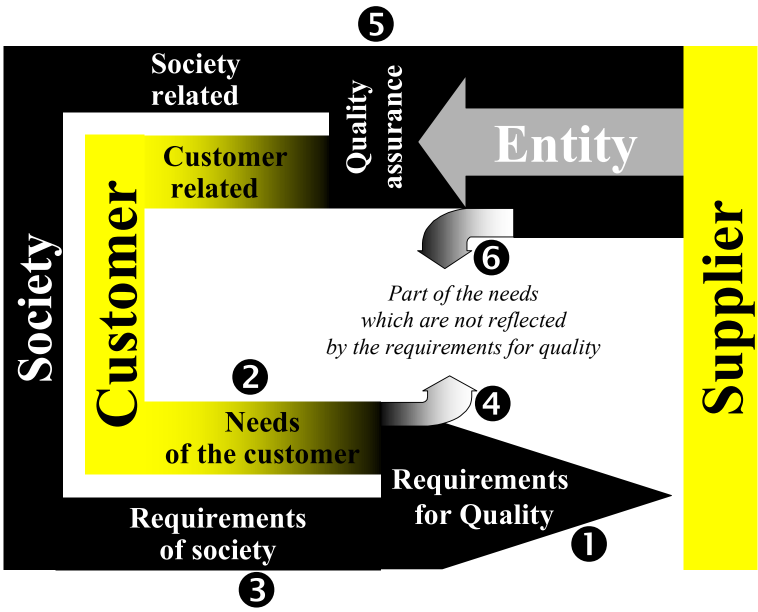


Figure 1: Global context for determining quality and performances according to ISO 8402 (Wouters, 2000)

Based on the requirements for quality, the supplier is assumed to deliver an entity. Quality assurance (Figure 1❺) is in most cases crucial to guarantee compliance with the requirements for quality. Such assurance procedures can be applied by the customer and/or by society. Of course, if certain needs are not covered by the requirements for quality, it is not evident to carry out quality assurance on these aspects (Figure 1❻).

In many industrial sectors, it has become common practice to develop quality schemes in line with figure 1. Often, the role of society in expressing the requirements is relatively limited. However, the role of society can be very important, e.g. in relation to environmental concerns,…

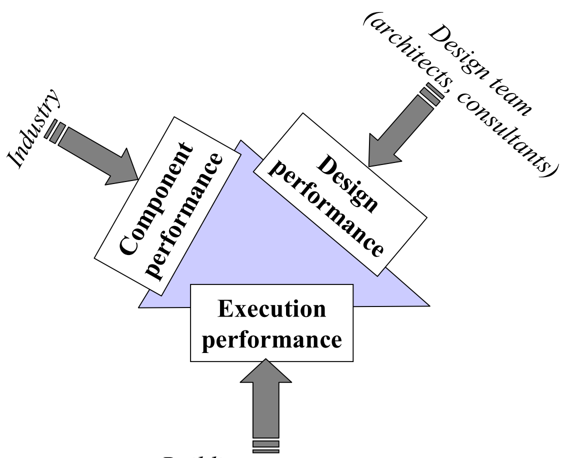
As far as the building sector is concerned, there are requirements for quality for a whole range of products and technologies, e.g. for concrete structures (strength, deformation, material composition,…), for thermal insulation materials,… For certain performance aspects, it is less crucial to clearly state requirements for quality since there is common sense (it are 'implied' needs) with respect to the quality expectation, e.g. water tightness of plumbing, occurrence of internal condensation in double glazing units,…

For indoor climate aspects as well as for energy efficiency aspects, it seems less evident to count on implied needs. This is in particular the case for ventilation systems.

The reasons are multiple :

- The needs are often not evident : under what conditions should a certain IAQ level or air flow rate be achieved, what is the required ductwork airtightness, what level of energy efficiency is required, what are the required acoustical performances, what under- or overpressures are allowed in buildings,…
- The customer is often not able to (easily) identify non-compliance. Therefore, precise requirement levels in combination with correctly stated procedures are crucial.

Practice shows that, unless such requirements and procedures are applied, one often finds performances which are (substantially) below reasonable performance levels. In particular, the global quality of a mechanical ventilation system is not only the result of the individual component performances nor of the quality of the design. In practice, it is the combined quality of the design, the component performances and the execution (figure 3).Figure 2Figure



2 : Crucial aspects for achieving mechanical ventilation systems with good performances

Therefore, the designers, the industry and the building contractors are concerned. In the case of mechanical ventilation systems, it appears that the quality of execution is often of extreme importance. Moreover, the interaction between those 3 aspects (e.g. how can optimisation of design and/or components influence the impact of the quality of execution) has been studied.

In general, but in particular in the case of ventilation systems, it is not possible to make a judgement of quality and/or performances unless the requirements of quality (by the customer, by society) are well identified. Given the fact that many customers have no or very vague requirements and that often the requirements of society are weak, many ventilation systems are poorly performing but are still accepted by the customers and by society.

2. Influence of assumptions on quality requirements for natural ventilation devices

2.1 General

The aim of natural ventilation devices is to guarantee, within certain limits, the possibility for an acceptable indoor air quality. One should recognise that requirements concerning natural ventilation devices (the ‘requirements for quality’) are not only determined by the expectations with respect to the indoor air quality (see Figure 3, left part) but also by a whole range of other assumptions:

- First of all, several assumptions (see Figure 3, middle part) have to be made for translating IAQ requirements into air flow rate requirements. These assumptions are the same for mechanical and natural ventilation strategies.
- Then, there are a number of specific assumptions (see Figure 3, right part) needed in order to derive requirements concerning the natural ventilation devices. These assumptions (stated or implied) include :
  - Assumptions concerning boundary conditions :
    - Climate related data (temperature, wind, local shielding,…)
    - Building data : airtightness, leakage distribution,…
    - Occupants: occupancy profile, window use, reaction on draught,….

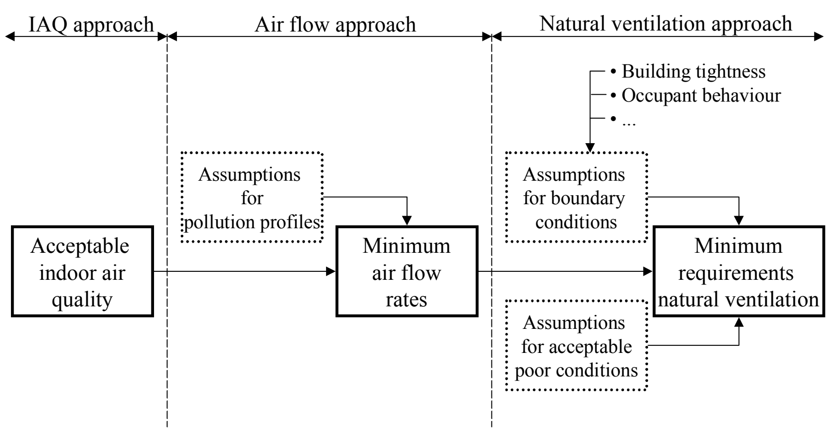


Figure 3 : From IAQ to requirements on natural ventilation : a succession of assumptions

- Assumptions concerning acceptable periods of rather poor indoor air quality: With a natural ventilation system one cannot guarantee an excellent indoor climate under all weather conditions. Therefore, maximum allowable deviations should be defined.

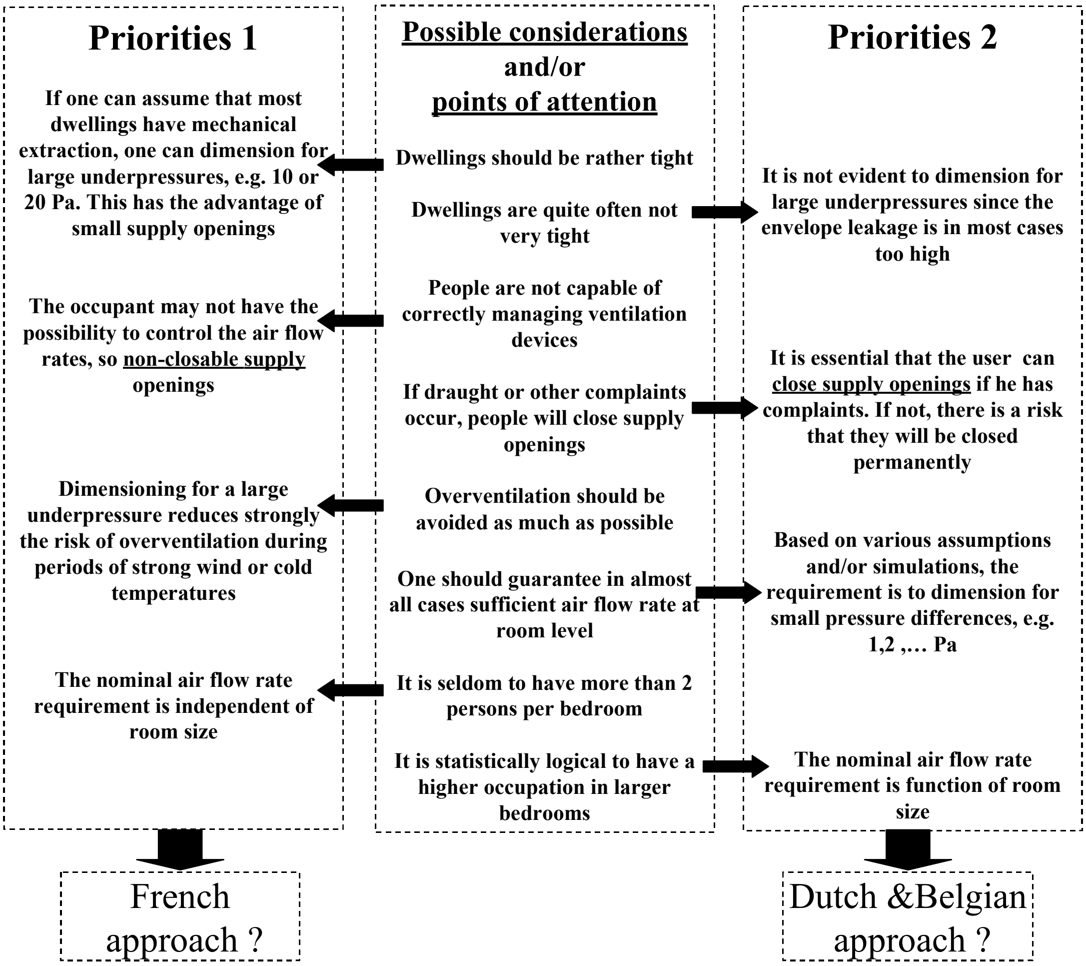


Figure 4 : Example of how, for a given set of rather logical considerations and points of attention, differences in priorities lead to completely different requirements for quality

To illustrate the previous statements, the philosophy is applied to the requirements for quality for natural air supply openings. In Figure 4, one finds in the middle of the figure a series of possible considerations and/or points of attention. Basically, all of them seem to be quite reasonable but they don't lead to the same requirements.

In the left part of the figure, a series of considerations is used for defining a set of priorities (which will result in a series of requirements). In the right part of the figure, the same is done with the other considerations taken as priorities. Both sets of priorities look rather reasonable, but the consequences for the ventilation characteristics are completely different. The left set is quite well in line with the underlying assumptions for the requirements for quality in France, whereas the right set is quite close to the requirements for quality existing in the Netherlands and Belgium.

Either set of priorities can be considered as a set of needs which defines the quality of the components. It is not possible to make a ranking of both quality concepts.

3. Energy Performance Standardisation and Regulation

An increasing number of countries consider Energy Performance (EP) standardisation and regulation as an attractive approach for achieving a more energy efficient built environment. Several European countries have already enacted such EP based regulation (the Netherlands, France,…), or are preparing one (Greece, the Flemish Region,…). The discussion in this paragraph focuses on the challenges to be met for creating an environment which really stimulates the design and construction of energy efficient buildings with good indoor climate conditions and which, moreover, stimulates ventilation systems with good performances. A distinction is made between the EP standardisation aspects (5)and EP regulation aspects (6):

- The standardisation aspects focus on the EP determination method (calculation procedure);
- The regulation aspects focus on the implementation of an EP standard into legislation.

The authors consider Energy Performance standardisation and regulation as the right track towards environmental and societal quality:

- An Energy Performance standardisation and legislation has a real potential for a substantial improvement of not only the outdoor environment (less pollution due to energy use in buildings) but also of the indoor environment (especially summer comfort and indoor air quality) (see also 4). This is surely valid for new buildings but an EP approach can also be helpful for a large part of the renovation market.
- Moreover, such EP approach can lead to substantial improvement of the living conditions of many people and therefore have a positive benefit for the whole society.
- Finally, it can be an effective strategy for dealing with the difficulties faced by individual decision makers in formulating both obvious and special project requirements.

4. No Energy Performance without acceptable indoor climate

The authors believe that an EP approach which does not pay attention to appropriate indoor climate conditions, is not on the right track. Therefore, an EP approach must have as basic idea a correct assessment of the energy efficiency of a building for an agreed level of indoor climate conditions, whereby particular attention is given to thermal comfort in summer, indoor air quality and visual comfort (**Figure 5**). It implies that a meaningful approach cannot only be based on a procedure which aims to limit the (normalised) energy use (❶) of a

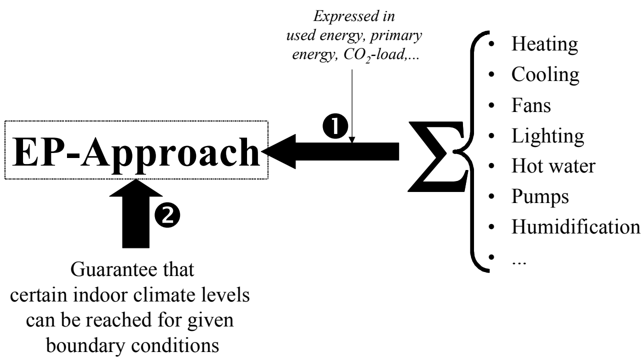


Figure 5: The EP number of a building includes all building related energy consumption (under normalised conditions) and assumes appropriate indoor climate conditions

building. It should be accompanied by appropriate procedures that guarantee that acceptable indoor climate conditions (❷) can be achieved for given boundary conditions, such as climate, occupancy, etc.

5. Challenges for an Energy Performance standardisation

To realise an EP approach which really achieves environmental and societal quality, a whole range of challenges have to be dealt with, including those listed in **Figure 6**:

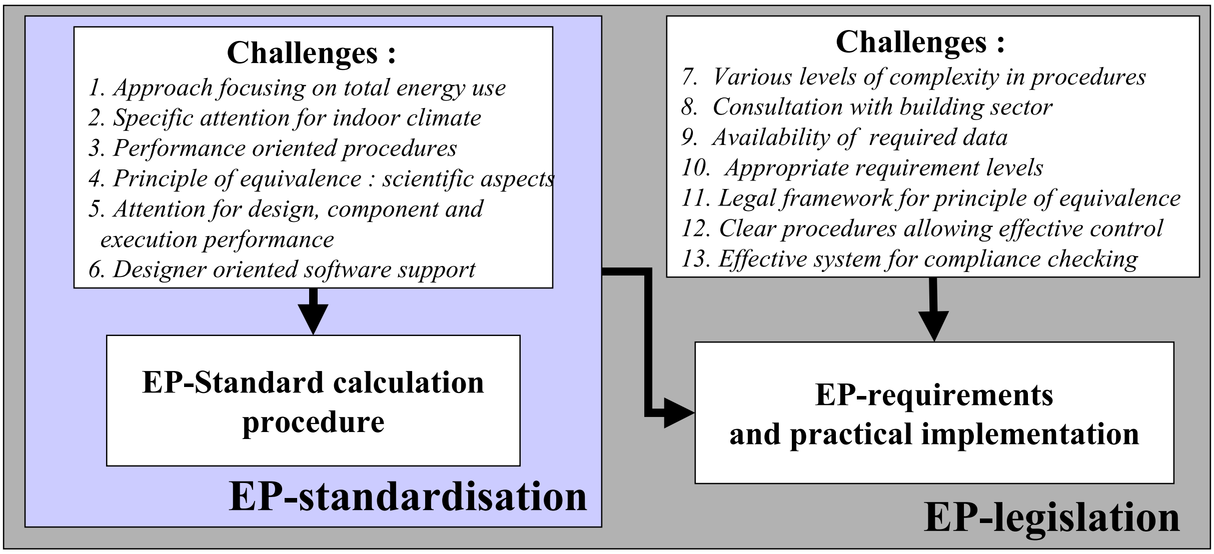


Figure 6: Challenges for and interaction between EP standardisation and legislation

1. *An EP approach must focus on the overall energy consumption:* The total energy consumption of the building and its installed appliances has to be considered, whereby certain assumptions have to be made with respect to various boundary conditions (climate, occupancy,…)

2. *Special attention to indoor climate:* An EP approach must pay explicit attention to the indoor climate conditions. Of particular interest is the thermal comfort in summer and the indoor air quality (see 4).

3. *Performance oriented procedures:* As much as possible, the whole EP approach must be based on a performance oriented approach. This does not necessarily mean that the whole calculation procedure must be expressed in performance terms, but that the method is founded on a performance based philosophy. This is especially crucial to allow for the application of the principle of equivalence.

4. *Open platform for innovation : coherent scientific philosophy with respect to the principle of equivalence:* From the start, the whole EP philosophy must take the principle of equivalence into consideration. It means in practice that for most processes, one should have a correct philosophy for allowing in a later phase a correct assessment of the principle of equivalence.

5. *Attention for design, component and execution performances*: It is important to have not only good component performances but also a good design and a correct execution. Therefore, an EP approach should pay attention to these 3 aspects. As far as legislation is concerned, the execution aspects can only be included in the assessment if proof of

compliance is required after construction ('dossier as built'). Examples in relation to ventilation are : building airtightness, ductwork airtightness, control of air flow rates.

6. Support by means of designer oriented software

6. Challenges for an Energy Performance legislation

An Energy Performance legislation specifies the minimum performance level, using the agreed Energy Performance standard as determination method or, if not fully covered by the standard, use can (partly) be made of the principle of equivalence. To have an effective approach, a whole range of requirements have to be met, e.g. :

7. *Various possibilities in proof of compliance with required performance level, with specific attention to simplified procedures for simple projects*: Especially for small projects and/or projects with very classical techniques and/or in a market which makes little use of specific consultancy on building physics, there may be a need for a simpler procedure than the standard EP calculation (see Figure 10, left part). Such approach is in principle almost purely descriptive. The other extreme is the approach which is required for applying the principle of equivalence. It may require detailed calculations going far beyond the standard EP calculation (see Figure 10, right part) and it is mainly performance based.

8. *The preparation procedure for the legislation should include consultation with all stakeholders:* Implementing an EP legislation should be preceded by consultation of the various partners in the building community: designers, manufacturers, building contractors, consumer organisations,… This is important for various reasons: to inform, to obtain feedback on the applicability in practice,….

9. *Availability of required product data and default values:* Reliable and well defined product data are essential inputs for applying an EP procedure. This means that, first of all, there must be appropriate determination procedures (preferably CEN standards). Moreover, industry must make these data available. As far as possible, there also should be default data for most products and systems, whereby these default data should be an underestimation of the real performances.

10. *Requirement levels which are sufficiently performance oriented and achievable by the market:* An EP regulation can contribute to a better environmental and societal quality if the levels of requirement are sufficiently severe for stimulating better building design, technology and execution and if these levels are achievable by the market. Therefore, the authors believe that a gradual increase of the requirements is strongly recommended (Figure 7).

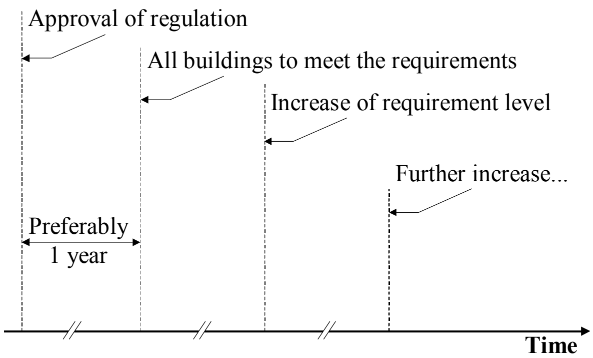


Figure 7: Gradual increase of the requirements

- In a first phase, the building sector must become familiar with the new approach.Therefore, sufficient time should be allowed between the adoption of the new legislation and its effective application on new buildings. One year seems to be appropriate;

- Later on, the requirements can/should be gradually increased. This has e.g. been done in the Netherlands where the required EP coefficient (based on NEN 5128) was at the start 1.40 (1996), then it became 1.2 (1998) and since January 2000, it has become 1.0.

11. *Legal framework for the application of the principle of equivalence:* Given its importance as a measure for correctly assessing innovative approaches, a legal framework for proof of compliance of the alternative proposal as equivalent with the EP requirement is needed. The authors believe that it is not realistic to expect from a communal civil servant to correctly assess such approaches and, therefore, an assessment procedure at a higher level is required.

12. *Legal framework requiring proof of compliance after construction:* Given the building practice in certain countries, proof of compliance with the regulation should be given upon termination of the works (and not only at the moment of the request for building permit) and this for the following reasons:

- It allows to pay attention to the execution aspects.
- The motivated architects are in a stronger position to impose the desired performance.
- The motivated builders know quite well the composition of their building. They will have the possibility of checking the conformity between the dossier 'as built' and the reality.
- The material manufacturers and the building contractors are in a stronger position.
- As a result, the governmental officials will no longer be the only inspectors, since motivated building owners, architects, material producers, building contractors and possible purchasers of the building are becoming able to carry out the inspection.
- The risk of non-compliance with the regulations is strongly reduced and this will lead to more energy efficient buildings and a better environmental performances.
- Finally, a dossier 'as built' is at the same time an ideal basis for energy certification.

13. *An effective system for checking compliance with the regulation:* A legislation that is based on a proof of compliance after construction strongly enlarges the number and type of persons who can check the works. Nevertheless, there is still a major role for the administration to set up a framework for carrying out random checks and for taking appropriate measures in case of non-compliance.

7. Energy Performance Standardisation : an open platform for innovation and creativity

As shown by numerous studies in the past, cost-effective innovation with respect to indoor climate and energy efficiency is not a guarantee for its large scale application by the building sector. Many users are not able to correctly assess the benefits of certain innovations. Moreover, creative solutions for improving the indoor climate and/or energy efficiency are not always understood by the decision makers. An EP approach has the potential to stimulate innovation and to promote creative solutions.

In **Figure 8**, various possible actions (all aiming to improve the energy efficiency of a building) are compared with respect to their investment and the energy savings (in EP terms). In principle, an EP approach must allow to assess all relevant technological improvements, therefore a situation as presented for 'measure' E should not occur. As far as the various measures have no other advantages, an EP approach will orient the market to those measures with the best 'investment-energy savings'-ratio, which corresponds in **Figure 9** to those measures with the steepest slope.

A major advantage for governments is that one can focus on a single global requirement and that the market forces can determine the most attractive options.

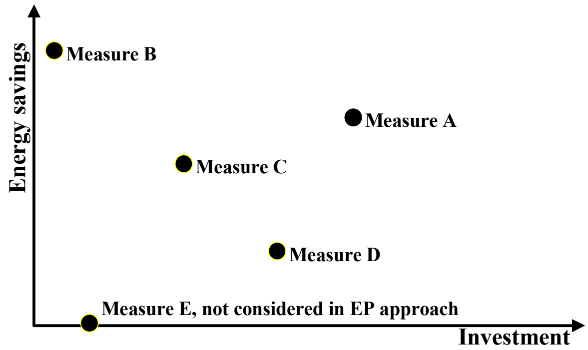


Figure 8: Comparison of various measures

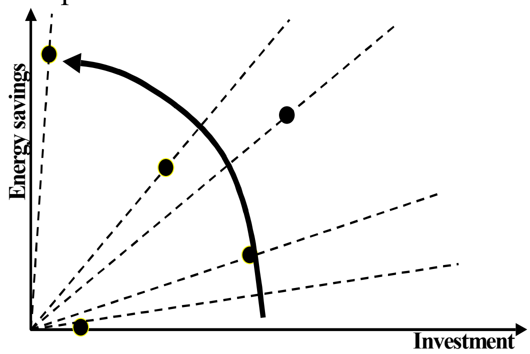


Figure 9: An EP approach stimulates the use of cost-effective measures

8. The philosophy of equivalence

The standard procedure of an EP approach must be capable of dealing with most applications. However, it is impossible to include in a standard all possible concepts:

- Innovation is a continuous process and results in new components, systems and design principles. All of them cannot be foreseen at the moment when the standard procedure is developed.
- The standard procedure should not be too complicated.

In such circumstances, it is important that one can make use of an alternative procedure for proving compliance with the objectives of the legislation (Figure 10). Such proof is to a large extent performance based.

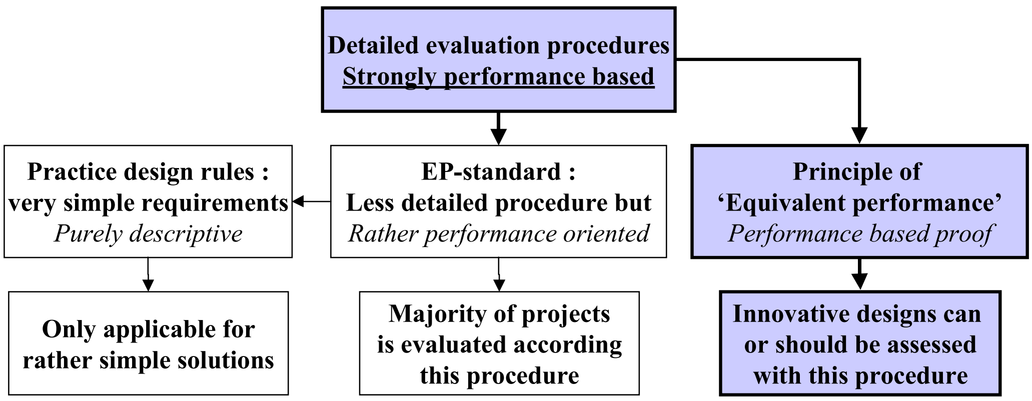


Figure 10: Principle of equivalence : essential part of a coherent EP approach

For a good understanding of its relevance, the motivation given in the Netherlands for the principle of 'Equivalent Performance' is very helpful (taken from TNO, 1996):

'The Dutch Building code specifies the technical minimum requirements for buildings. In most cases, the determination methods described in the standards are sufficient for proving compliance with the performance requirements. However, it is possible that new technological solutions emerge, that don't fit in the 'straitjacket' of the respective performance requirements. Because of its innovative character, the requirements may not be tailored to this type of solution. In such case, 'plan B is put into action': the application of the determination of equivalence in the Building Decree. This in order to prevent rigidity in the legislation and in order to allow 'unusual' solutions. Based on this,

municipalities – mayors and town councillors- can approve solutions that deviate from the given performance requirement, yet without performing below the prescribed minimum performance level. The 'chosen' solution is then at least of a similar level.'

9. The EP approach: a powerful concept to be treated with care

Seen from a distance, the EP approach almost has only but advantages. However, specific attention is needed with respect to the performance assessment of certain (in most cases innovative) technologies (Figure 11). There must be a rather good correlation between the real performance improvement of a certain technology and the EP predicted improvement (❶). In Figure 11, the 2 technologies for which a major difference is found (underestimation (❸) or overestimation (❷)) will disrupt the market functioning. As mentioned before, an EP approach which is not able to treat certain technologies (❹) is not at all acceptable.

An example to illustrate the challenges is demand controlled ventilation. In Figure 12, various types of strategies are considered. For each of them, the performance improvement is presented in qualitative terms. It seems quite logical to assume that *timer control* gives the smallest improvement, the absolute level of improvement depends on the assumptions of user pattern and use of the timer control. *Presence control* will give in practice in most cases a better performance. The benefits may depend on the type of presence detection and the related control strategy. *CO_2-control* will give a further energy saving since it takes into account the building airtightness, room volume and the density of occupation. One can even imagine more refined control strategies, e.g. based on multiple gas sensors. A good EP approach must be able to differentiate correctly between these various technologies.

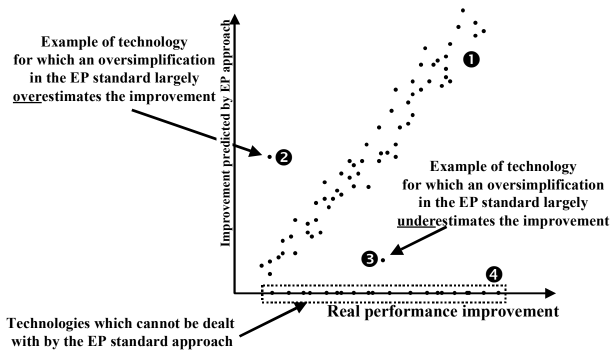


Figure 11: Real performance improvement versus the one predicted by the EP procedure

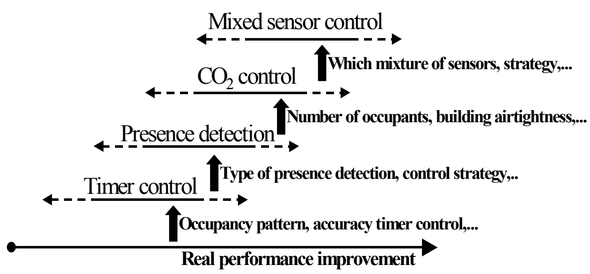


Figure 12: Various technologies of demand controlled ventilation with different impact on energy use

In Figure 13, a qualitative analysis is made of the cost-benefit relation for 3 types of demand controlled ventilation. The assumed relative cost increase of the 3 technologies with respect to a constant air flow system is given on the vertical scale (e.g. cost increase due to presence detection about twice the cost increase of timer control).

- The slope of the arrows in the left figure is a measure for the cost-benefit ratio (constant air flow system as reference). The uncertainty in the slope for the various technologies should be limited (minimising ❶❷❸).
- If one wants to compare the cost-benefit relation of one technology with respect to another one (e.g. presence detection instead of timer control), the right figure is more appropriate. The vertical line in range '❹' corresponds with an approach which gives the same energy benefit to timer control as to presence detection. If this is the case, there is no benefit at all to replace the 'cheap' timer control with the 'more expensive' presence detection.

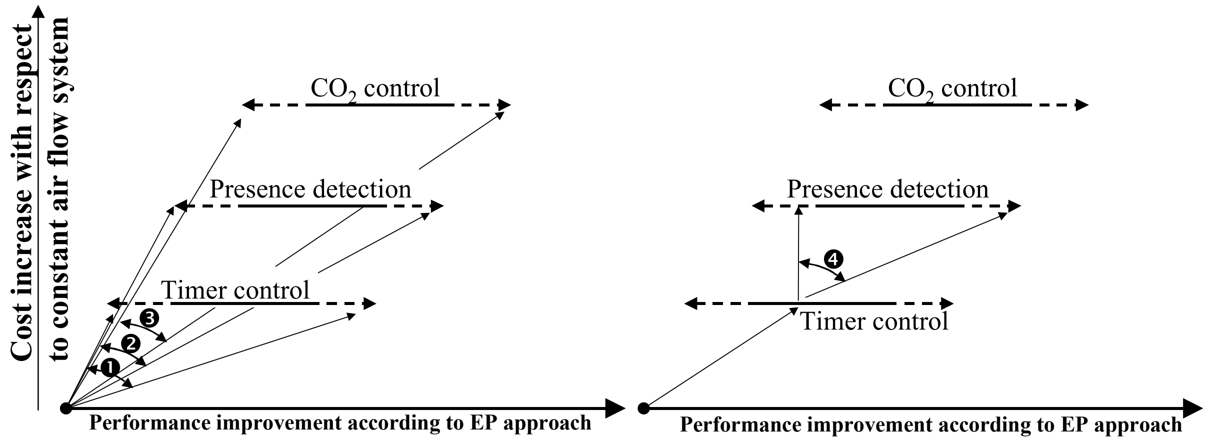


Figure 13: Qualitative cost-benefit of various demand controlled ventilation strategies

Therefore, the EP approach must correctly evaluate changes in technology, as illustrated in the above example.

10. Conclusions

- To allow for a discussion about quality, it is important that stated and implied needs be well identified. Because of the increased complexity, it is less evident to count on implied needs. This is illustrated in the discussion on quality of natural ventilation systems.

- An Energy Performance standardisation and regulation is probably the most effective approach for at the same time improving the indoor climate in buildings (especially thermal comfort in summer and indoor air quality) and increasing the energy efficiency.

- A successful implementation requires that a whole range of conditions have to be met. Among these, the co-operation of the professional sectors involved is of paramount importance for the success of the regulation.

- Several European countries are working in a similar way towards an overall Energy Performance regulation. Exchange of information and collaboration would be most useful and may be a start for European standardisation.

11. References

1. *WOUTERS P.*
   Quality in relation to indoor climate and energy efficiency : an analysis of trends, achievements and remaining challenges. PhD thesis UCL, Louvain-La-Neuve, July 2000.
2. *TNO*
   'Equivalence and quality declarations in relation to the prescriptions with respect to energy performance', TNO report 95-BKR-R1611, Delft, 1996 (in Dutch)
3. *ISO International Standardisation Organisation*
   ISO 8402, Quality management and quality assurance – vocabulary, ISO, Geneva, Switzerland, 1994
4. *DELMOTTE C. and WOUTERS P.*
   Mechanical ventilation systems: How to improve the performances. TIPVENT Source book (to be published 2001)