# Ventilation in the Third Millennium – Challenges and Opportunities

Bach H
University of Stuttgart, Stuttgart, Germany

To predict developments, actually, doesn't suit me at all, especially since most predictions – even the scientifically established ones – do not come true. Usually they only cause worries and rarely stimulate the fantasy. The term "Development" can be meant intransitive or transitive. I would like avoid the intransitive aspect. Therefore I would not like to ask like a market researcher: How will the market *itself* develop? I rather prefer to take up the transitive meaning and would like to ask: In which direction do we have to develop the ventilation technology?

The question for a new development is generally initiated by recognizing the disadvantages of the current praxis. It is characterized by the fact, that experience based concept patterns for HVAC systems are zoomed to the given load situation or even simpler to the space volume. Such concept patterns are most of the time company specific preconceived solutions. Their advantage of a broad applicability is at the same time their disadvantage: system functions which are adjusted to a specific case are rather avoided than emphasized. Since the load calculations and the fundamental requirements are standardized, differences between alternative offers cannot occur – besides the price. By this the way for bad prices is paved! A further disadvantage of the idle concept patterns occurs when boundary conditions and the requirements are changed and the experiences on which the concept patterns are based are not valid anymore. Possible changes at the boundary conditions are e.g. an increased insulation and at the requirements e.g. more comfort and air quality.

But how do we find new concepts which comply with the requirements, and how do we enforce their realization without being forced to unsatisfying primitive solutions by the pressure of the prize?

Since the experience foundation which had been useful so far was not reliable anymore because of all the changes, it was tried to obtain new knowledge – first in the heating technology – with the new possibilities given by the computer based simulation of the system operation. Together with the new methods new ways of looking at things emerge, new questions arise and new answers are produced. In the past we had to rely on field experiments, whereas today we obtain our knowledge by using simulations. In this way we gain more reliable and generalizable knowledge – more reliable because the boundary conditions can be maintained exactly and generalizable because of the reproducibility. This statement is not only valid for the evaluation but also for the methodology and therefore for the conception, the design and finally the market development. The following can be recognized of the so obtained new perspective:

1. Every HVAC system can be **conceptual** structured into three processes: benefits transfer, energy distribution and energy generation (Figure 1 for a heating plant). The new unfamiliar term *benefits* contains all required effects of system functions on the user within the room. The *transfer* – this also a new term in this context – describes the local and the temporal process of adapting to precisely defined requirements in the respective room. Within the remaining processes distribution and generation energy is only generated and distributed dependent on the transfer processes.

2. In the case that the conceptual structure can be applied **technically** to the plant (this is not possible for example at for stove or an air conditioning unit), it is possible to value and therefore to optimize each process for itself. This is shown in Figure 2 for the example of the heating technology. A further subdivision of the benefit transfer like it is given at air conditioning systems with air flow pattern, air transport and air conditioning (Figure 3) reveals further possibilities for the evaluation and optimization with the purpose to meet the benefit requirements as good as possible.

Ventilation includes the two first mentioned subsystems air flow pattern and air transport whereas the air flow pattern has the bigger, even the decisive influence. In the sense of the aspired evaluation possibilities by introducing subsystems it is important to describe the processes which produce the air flow patterns as exact as possible. This means it is important to use terms which characterize the physical processes correctly. There has been a lack with that in the past, so that inexpedient concepts are developed only because of an unclear picture of the air flow patterns.

It has to be distinguished between principles for the load removal and types of air flow patterns like proposed by W. Dittes. For the load removal principles we know three the different possibilities of displacing, diluting and localizing (Figure 4) as. The latter term is new: it means the selective creation of one ore more space zones with the regarding required air conditions ("requirement zones"); for the remaining zones there are only small or no requirements. For the generation of air flow patterns we have also three possibilities: displacing (piston flow), mixing and layering. Whereas the first two to load removal principles can only be realized by the first two types of air flow pattern, it is possible to apply all three types of air flow patterns for the load removal principle localizing (Figure 5): "sectional displacement flow", "sectional mixing flow" and "layer flow". The latter can only be applied for the localizing principle (for this also the term "source ventilation" is used). As it can be seen, the localizing principal can only be realized in the case that there are heat sources in the height of the requirement zone.

How it is possible now – with the more exact choice of terms and the new order of terms in the direction of the demand evolution – to disclose the desired further evaluation and optimization possibilities and to include them into a methodology which leads to the system concept that is optimally adjusted to the requirements? Here the simulation praxis provides a further general valid knowledge.

3. Every evaluation – especially for energetic purposes – is based on a constant **reference demand** (e.g. heat, coolness, water or outside air, Figure 5). It is given by boundary conditions (e.g. climate, building) and requirements (e.g. benefits). The accuracy of the evaluation depends on the precision of the analysis and the completeness of the given requirements. They are listed in the **specification**. Its

extent depends on the complexity of the regarding task. The specifications will form the foundation of future design and the wide range of argumentation for the found concepts. Standardized requirements (e.g. according to DIN 4701, DIN EN ISO 7730 or DIN 1946) will naturally appear within the specifications as single items, but they won't give any reason for arguing.

Boundary conditions and requirements do not only define the reference demand values for an energetic evaluation. They also provide the design data for the conception e.g. of ventilation system. Fixed prerequisites are the internal heat loads $Q_{0,i}$, the convective thermal air flows $m_{0,K,i}$ at heat sources and surrounding areas as well as the contaminant loads $m_{0,S,i}$. As limiting values within the requirement zone for the contaminant concentration the value $c_{lim}$ and for the comfort the enthalpy difference $(h_{ARB} - h_{ZU})_{lim}$ have to be listed in the specifications. Consequently it follows now:

4. The **system functions** are derived from the boundary conditions and the requirements (Figure 6) corresponding the precision and the variety of analysis, especially and at first for the benefits transfer, to which the distribution and the generation have to be adjusted. So a system concept emerges in a methodical and conclusive way. Varying concepts differ the less, the more detailed the specification is.

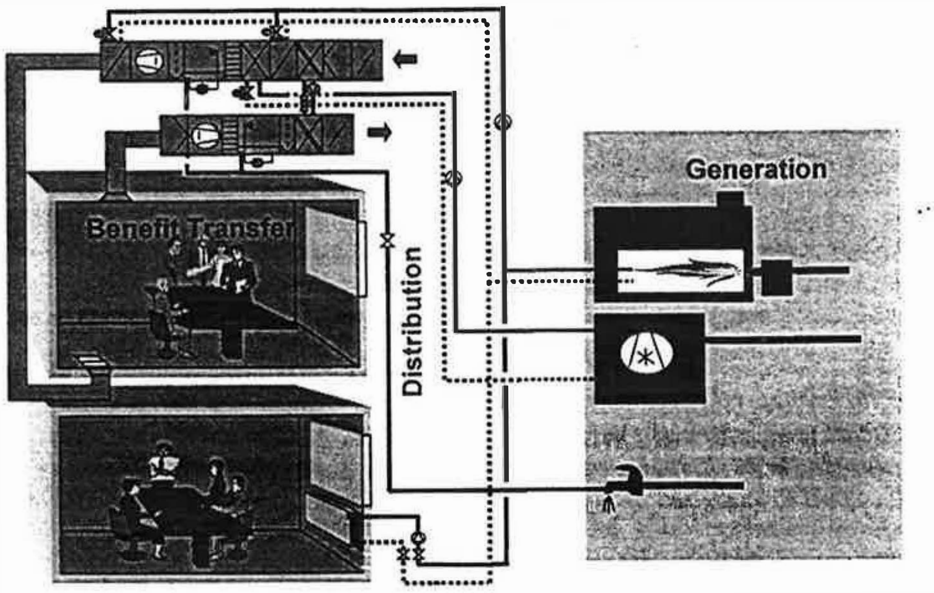
The most important system functions within the subsystem "air flow pattern" (Figure 3) are the chosen load removal principle, the type of air flow pattern and the type of the capture systems as well as the required supply air flow $m_{ZU}$. In case that there are appreciable heat and contaminant sources and that the ventilated room is significantly higher than the requirement zone (with its 2 $m$) then the localizing principle (Figure 4 and 5) should be preferred to the displacing or the diluting principle. For type of the air flow pattern the sectional mixing flow (Figure 5, center) or a layer flow (Figure 5, bottom) can be applied. This needs to be clarified considering the local situation and the financial effort. After that the type of the capture systems together with the capture air flow and the capture efficiency $\eta_S$ resp. $\eta_W$ are determined. The supply air flow is calculated according to the scheme shown in Figure 7: In any case it has to be greater than $\Sigma\ m_{ER,i}$ and it has to cover the thermal air flows $\Sigma\ m_{0,K,i}$ up to the height of the requirement zone (index ARB). If there is a limiting contaminant load factor $\mu_{S,lim}$ (and respectively $\mu_{W,lim}$), it is necessary to check if the firstly calculated supply air flow (Figure 7, top) is sufficient of if it needs to be increased. Eventually a load factor $\mu_S < \mu_{S,lim}$ is obtained which is advantageous. The second subsystem "air transport" depends on the local situation and can be designed with orthodox methods. The optimization of the subsystem air conditioning is more complex depending on the requirements (humidifying, dehumidifying, etc.), particularly the operation throughout the whole year needs to be considered. On this a thesis of E. Reichert will be published. Now it needs to be possible to present the so derived "tailor-made concept" with good arguments ("we do not sell building materials, but highly sophisticated engineering concepts"). For this purpose we must be able :

5. to **evaluate** objectively and to emphasize each system function for itself. The value analysis is predestined therefore as a method: Functions which are derived from definite and limiting requirements are checked with TRUE/FALSE-decisions (constriction of the scope of possible variations). Only the functions related to

desired requirements (like most possible economical and energy saving operation, low environmental impact, highest possible comfort, etc.) give a evaluation by using weighting and performance factors. The more functions have to be evaluated, the wider becomes the argumentation basis, the more significant are the differences between the alternatives and the smaller is the price influence. Since a comprehensible evaluation exists with the value analysis, the client is relieved of the constraint to look only on the price (he could to it by now, but he doesn't have credible arguments).

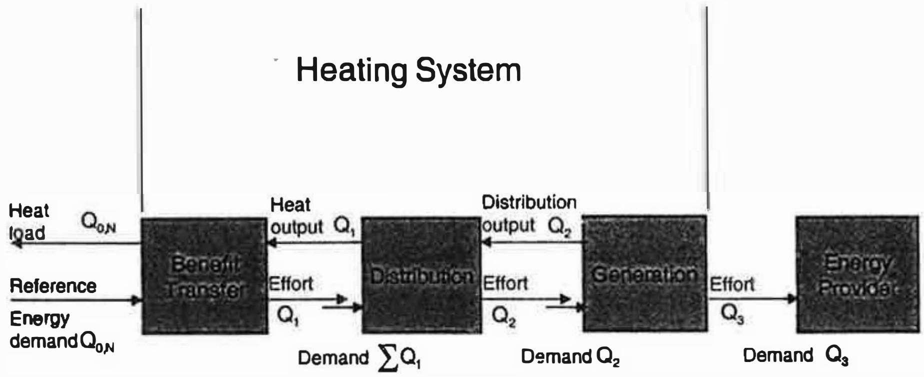
To minimize the energy demand is one of the most important system functions. It also has a major influence on other functions like for instance to increase economy or to minimize the impact on the environment. The development of the energy demand within a system (see Figure 3) shows, how strongly the single processes depend on each other and on the reference demand. This can be shown for heating system particularly easy. Here the mentioned performance factors for all three processes – benefits delivery, distribution, generation – can be expressed with effort numbers which are simple to determine. For air conditioning systems the evaluation is more complicated, because there is more than one benefits transfer process. Additionally to that these different benefits transfer processes occur with varying and throughout the year distributed frequencies.

Let me summarize:
In the sense of the goals of our society with its growing requirements we have to develop the HVAC market in a direction, so that the variety of functions of our systems can be understood by the clients and also by the public and finally be wanted. Thereby the design and the presentation of the benefits transfer is particularly important. The reference demand must become conscious as the given target – it's not us or our systems who produce the consumption! The relation effort to demand is our standard.




**Demand Evolution of an HVAC System**

Figure 1




Effort Numbers: $e_1 = \frac{Q_1}{Q_{0,N}}$ $e_2 = \frac{Q_2}{\sum Q_1}$ $e_3 = \frac{Q_3}{Q_2}$

Demand Evolution $Q_{0,N} < Q_1 < Q_2 < Q_3$

Figure 2

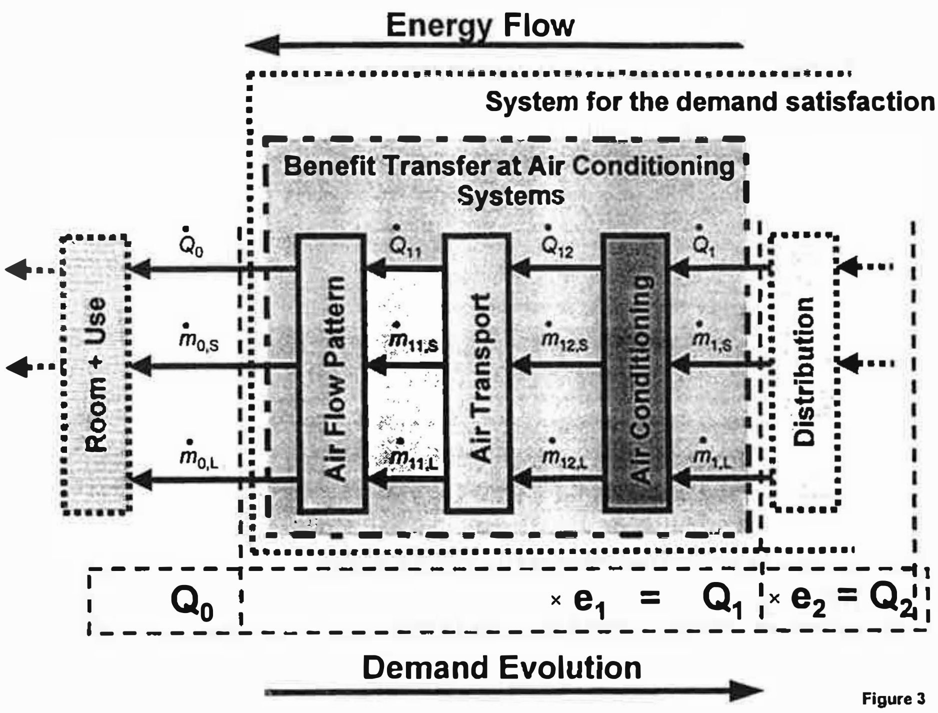



Figure 3

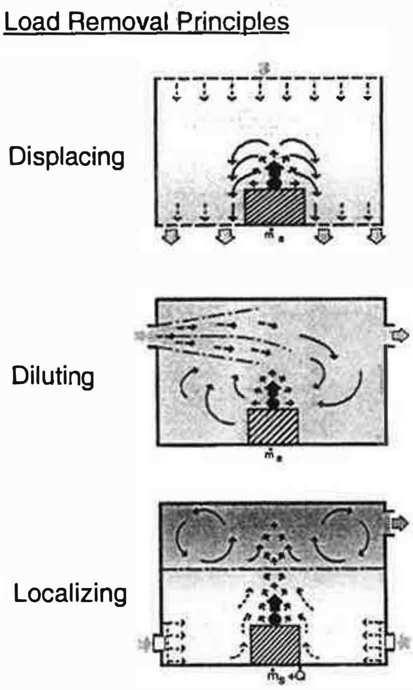



Figure 4

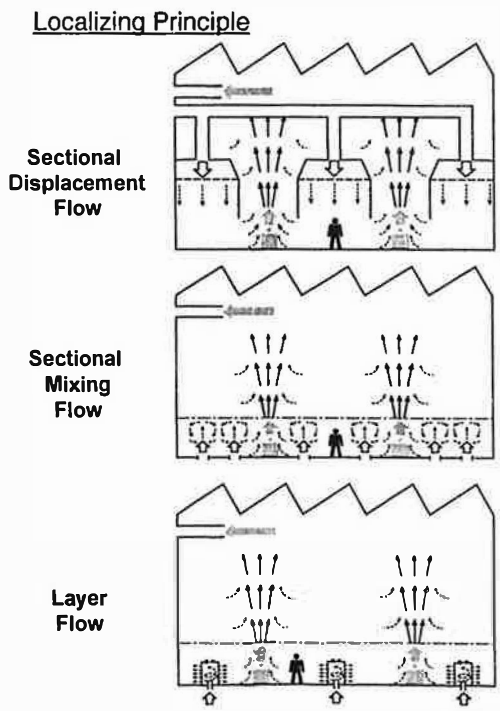



Figure 5

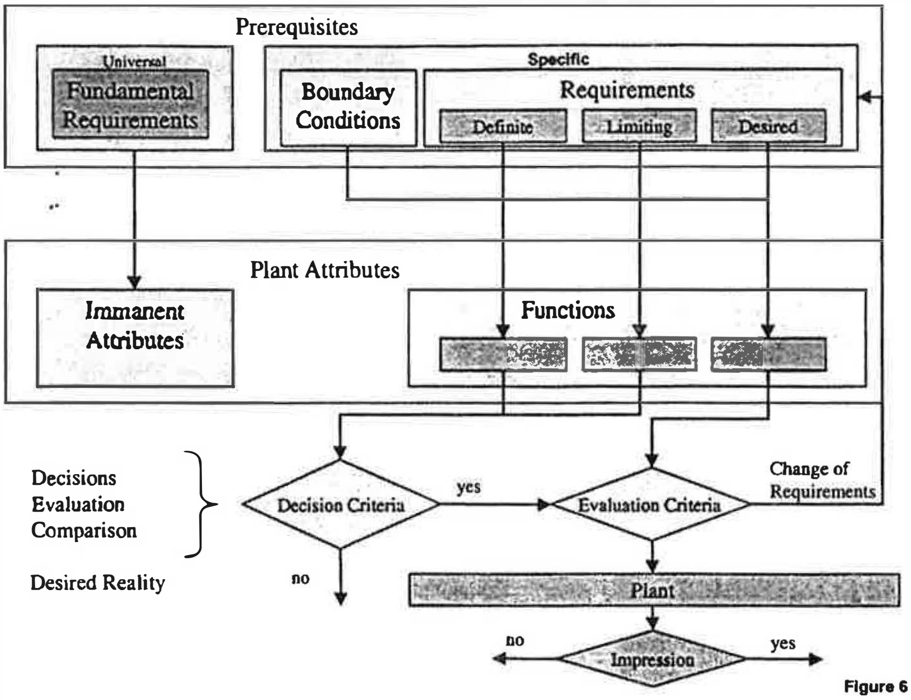
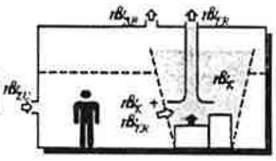



Figure 6

## Localizing Principle

**Minimal Supply Flow**

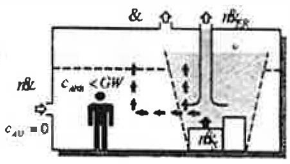
$$\dot m_{ZU} \ge \sum \dot m_{ER,j} + \sum \dot m_{K,j}$$



**Supply Flow determined by:**

**Contaminant Load**

$$\dot m_{ZU} \ge \frac{\dot m_S}{c_{lim}}(1-\eta_S)\mu_S$$



**Heat Load**

$$\dot m_{ZU} \ge \frac{\dot Q(1-\eta_W)\mu_W}{(h_{ARB}-h_{ZU})_{lim}}$$

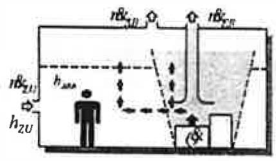


Figure 7