Trends in High-performance Buildings and the Role of Ventilation

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ABSTRACT

On the way to the solution of our energy-problems, the conditioning of buildings is the most important sector. We have to create new buildings, that produce more energy than they need in the course of a year, so called plus-energy buildings and we have to perform large-scale retrofitting of existing buildings. Priority must be given to increasing energy-efficiency. Having fulfilled this, the implementation of renewable energy has to be undertaken. To achieve this, new techniques have to be developed, but also the political regulations and the conscience and behaviour of the users have to be seriously taken into account.

In the past a lot of developments have been undertaken to reduce the transmission losses. In future we have to focus on the ventilation and infiltration losses because of the increase in their relative importance. Even in existing buildings the implementation of central ventilation systems with heat recovery is easily possible by using a new system, presented in this paper.

KEYWORDS

plus-energy buildings, ventilation systems, heat recovery in existing building, energy efficiency, renewable energy

1. THE IMPORTANCE OF THE ENERGY EFFICIENT PERFORMANCE OF BUILDINGS IS RECOGNIZED THROUGHOUT EUROPE

The terms 'climate change' and 'energy' are currently dominating TV news and light programs as well as magazines and daily newspapers. The urgency for taking measures to reduce greenhouse gas emissions as well as the adverse dependency on natural gas and oil suppliers is becoming a topic of top priority. Fortunately, the level of public awareness concerning this matter has improved due to the support of the media.

The necessity to reduce the consumption of coal, oil, natural gas and uranium, which has been recognized in the meantime, can be achieved by the following three measures:
1. Reducing the demand
2. Enhancing the efficiency of provision and conversion
3. Increasing the use of renewable energy sources.

Almost 40 % of the total final energy consumption is used for the conditioning of buildings – heating, cooling, domestic hot water production, lighting, ventilation – throughout Europe. More than one third of the final energy consumption is used for space and DHW heating, the greatest share being consumed by private households. This is a quarter of the total final energy!

In contrast to other sectors of energy consumption, additional positive effects are achieved by taking structural measures to save energy costs for heating. The improvement of thermal comfort in buildings in winter as well as in summer is of special importance in this context. In many cases, modernization measures are required to preserve existing buildings and to conserve their value.

Lately, the reduction of demand and the enhancement of the efficiency of provision and conversion have also been summarized by the term 'improvement in energy efficiency'. By introducing this term it was intended to eliminate the misleading expression of 'energy savings' (as from the physical point of view this is impossible) as well as to improve the image of this measure ('to save' evokes rather negative, 'to improve' rather positive associations). A definite classification is not possible in many cases so that the summary by means of the term 'improvement in energy efficiency' is reasonable and continuative as is done for example in the EU Green Book or Action Plan for Energy Efficiency EU [1, 2]. 'Energy-efficient' thus implies low consumption and high efficiency concerning the meeting of demand. It is the amount of energy that is actually needed to secure the designated use.

2. ENERGY EFFICIENCY IMPLIES THE GREATEST POTENTIAL

Special emphasis on the fact that the increased use of renewable energy sources should always be considered in connection with measures to improve energy efficiency can be found in the media and politics. First of all, measures to improve energy efficiency are of considerably higher practical importance than the increased use of renewable energy sources, which is also necessary. In 2006, for instance, renewable energy sources delivered 70 TWh for electricity production and 90 TWh for heat production (with a share of 69 TWh for wood) in the Federal Republic of Germany. Figure 1 shows the shares of the amounts of energy produced by various renewable energy sources.

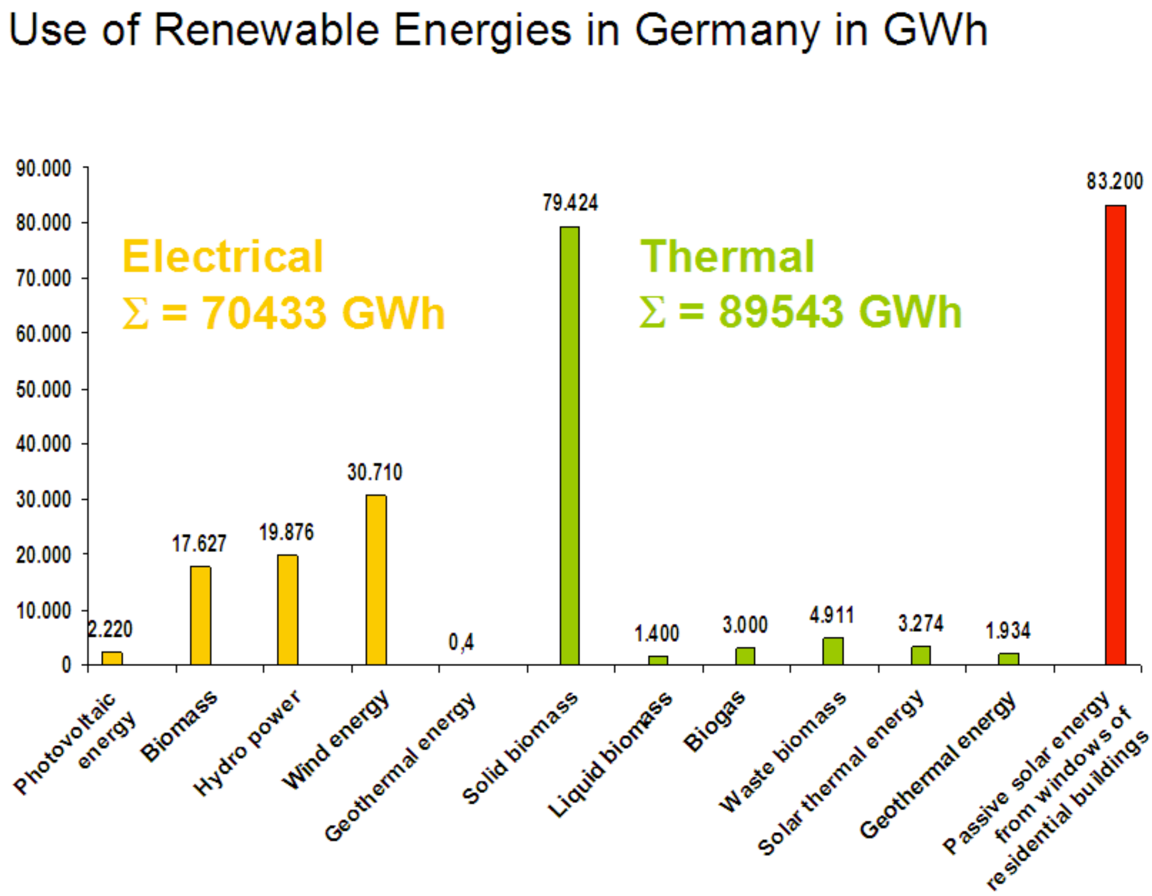

Figure 1: Use of renewable energy sources in Germany in 2006 for electricity (yellow columns) and heat production (green columns) in comparison to the use of passive solar energy in residential buildings [3].

If these amounts are compared to the amounts annually produced by the use of passive solar energy of residential buildings, the result is of the same order (an average amount of 83 TWh). In the process, only solar energy taht is actually usable for heating is considered, the effects of overheating or unused solar energy (due to window ventilation or solar protection devices) have already been deducted.

As fas as existing buildings in the Federal Republic of Germany are concerned, the potential to reduce energy consumption is very large, since the energy performance of the building stock has not been optimized [3-6]. Due to the Thermal Insulation Regulations (and later the Energy Conservation Regulations) requirements for new buildings were enhanced, resulting in the reduction of energy consumption as specified in Fig. 2. The potential of measures to improve energy efficiency is demonstrated in Fig. 3.

3. Regulations of public law

Since 1976 energy-saving building has become more and more important. In the Federal Republic of Germany energy-saving methods were implemented in various energy conservation regulations.

In order to promote energy-efficient buildings, declaration of energy efficiency and application of minimum requirements to energy performance of buildings, the European Parliament has adopted the directive on "Energy Performance of Buildings" (EPBD) in 2002. The general framework for a methodology of calculation of the integrated energy performance of buildings defined in the directive includes the thermal characteristics of the building and its associated boundary conditions, the heating installation, hot water supply and ventilation as well as air conditioning installations and built-in lighting installations. In addition, the EU Member States are requested by the EPBD to set up minimum requirements on the energy performance of new buildings, based on the aforementioned methodology. Also for large existing buildings that are subject to major renovation, minimum requirements on their energy performance have to be established.
As a consequence for residential buildings, it becomes necessary to make up the balance on their heat use (transmission and ventilation losses, internal and solar gains), heat losses of the heating, and hot water preparation systems. This method has been used for calculations within the scope of the German energy conservation regulation ("Energieeinsparverordnung") and has to be modified to cover not only new but also existing residential buildings. For non-residential buildings this energy balance had to be extended to include the amount of energy for ventilation, cooling, and lighting. The calculation method for the energy balance for non-residential buildings is formulated in the new German standard DIN 18599.
The effects of the different requirements are marked by the upper boundary line in Fig. 2.

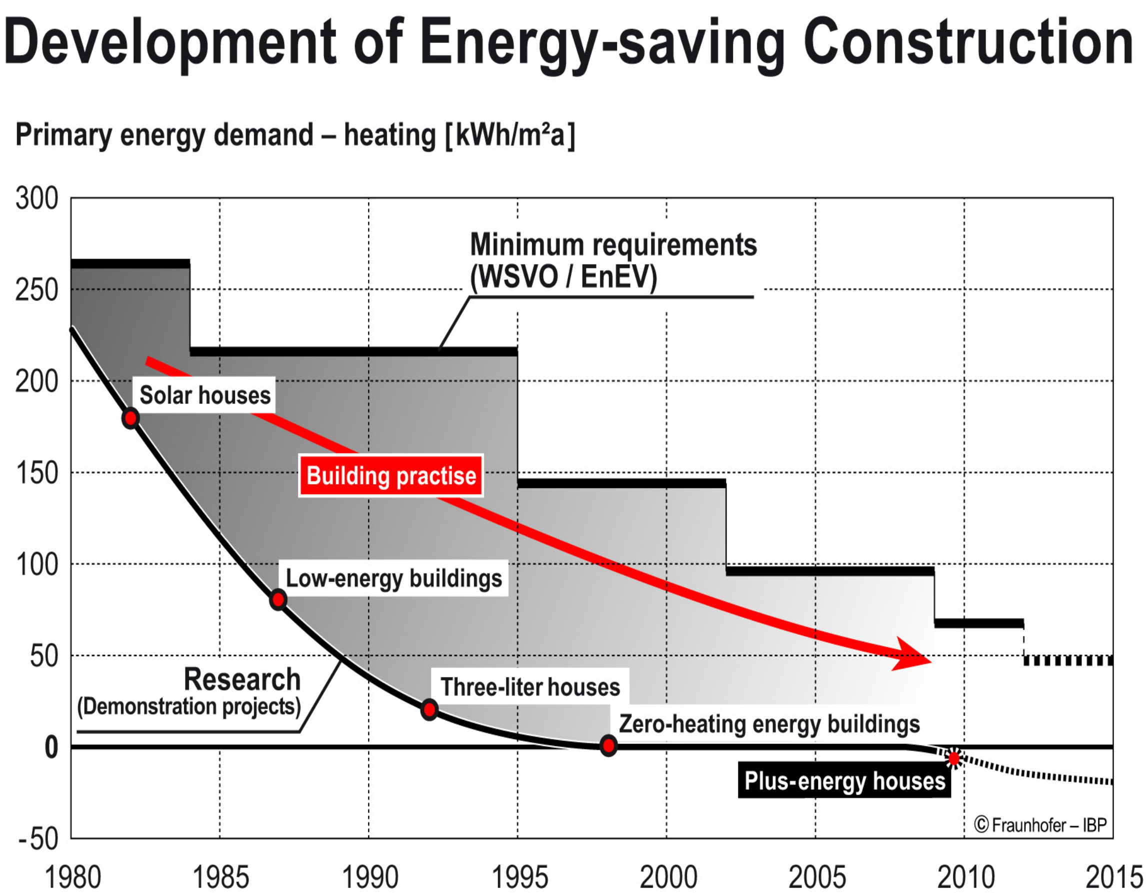

Figure 2: Development of energy-efficient buildings in Germany.

Reasonable lower limit values for the energy demand were shown in demonstration projects (the grey area reflects the building practice for new buildings). Renovation measures performed in existing buildings in the last few years resulted in considerable reductions in consumption.

Considering advanced renovation technologies and particularly aspects of rising energy costs, a reduction in consumption of about two thirds on average seems to be realistic. This means a savings potential of 724 TWh for the building stock. Figure 3 shows this saving potential in comparison to the benefits from renewable energy sources.

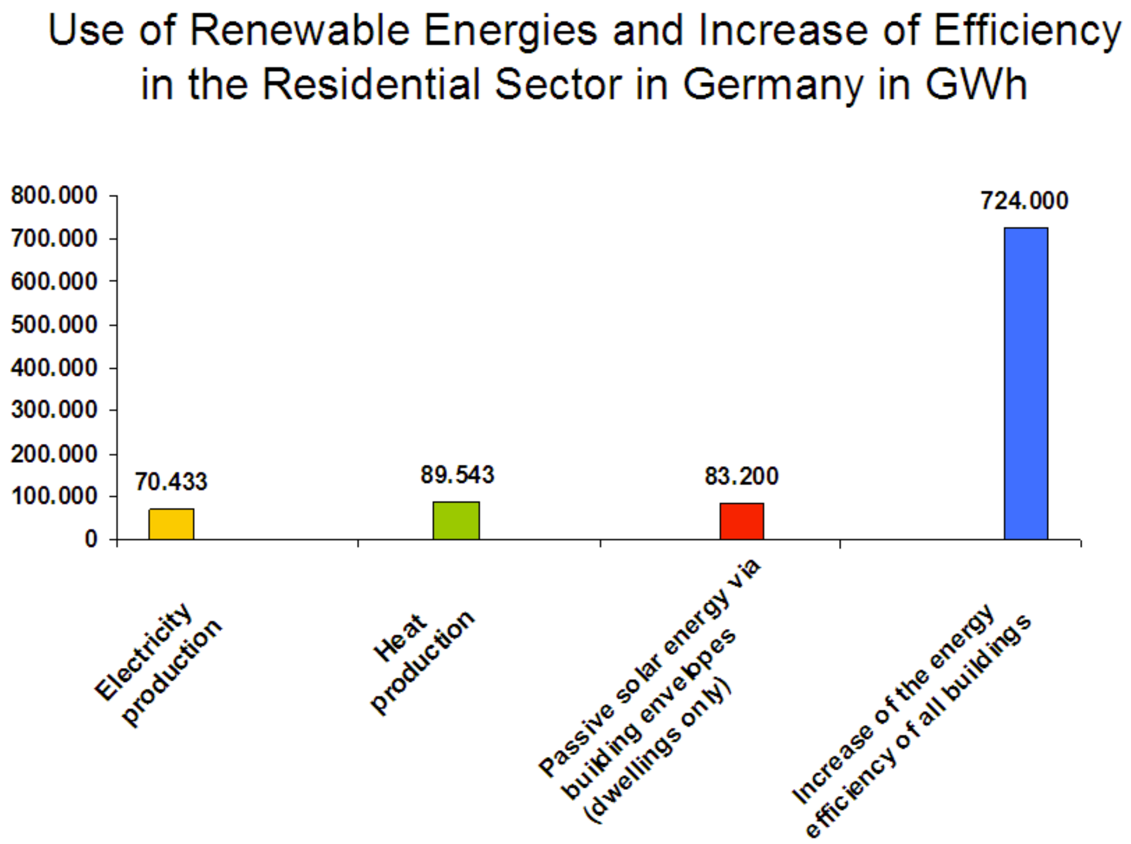

Figure 3: Use of renewable energy sources in comparison to the improvement in energy efficiency in buildings in Germany in 2006, based on a 65% reduction in consumption.

Thus measures to improve energy efficiency comprise a potential which is an order of magnitude higher than the amount presently contributed by renewable energy sources. Improving energy efficiency in buildings is most important to solve energy problems. Regarding measures designed to improve energy efficiency, issues of acceptance are significantly less controversial compared with renewable energy sources such as hydropower, wind and geothermal energy. Furthermore, numerous measures to improve energy efficiency have positive additional effects, e.g. enhanced thermal comfort, increase in value as well as the conservation of existing buildings.

There are various measures available to better exploit this potential. The least expensive method, which (in theory) could also be realized most rapidly, is changing the users' awareness. The so-called 'cooling boxes', which can be found at almost every window in many southern European countries, may have high technological efficiency, but they would become unnecessary by applying solar protection devices. Frequently, there is simply no understanding of interrelations.

The energy performance certificate, which was first presented in 1989 [7], having been extended to large sections of the building stock since 2008 (according to the Energy Conservation Regulations of 2007 [8]), will contribute to improve understanding and create more awareness.

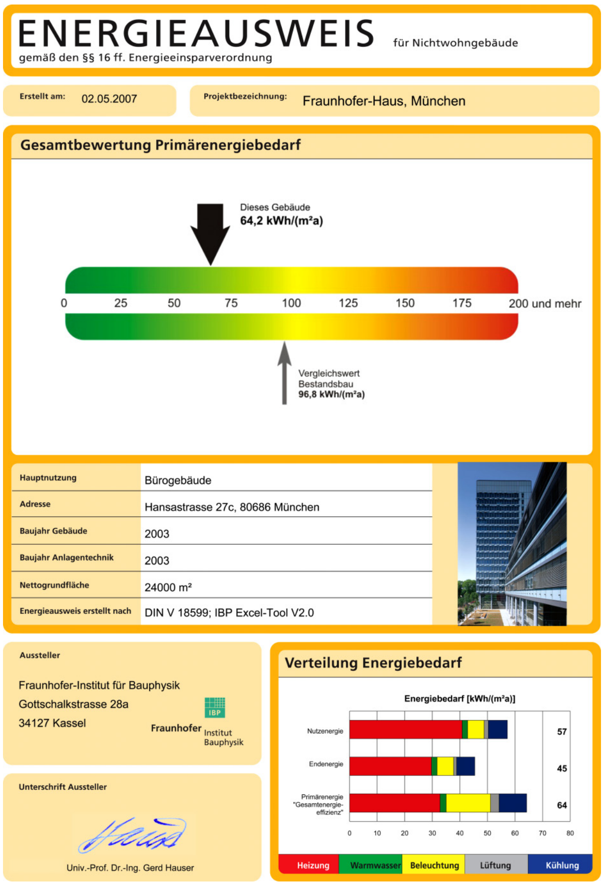

Figure 4: Energy certification of buildings (energy performance of buildings certificate) of the head office of the Fraunhofer-Gesellschaft in Munich.

As an example, Figure 4 shows the energy performance of buildings certificate issued for the head office of Fraunhofer-Gesellschaft in Munich (a non-residential building), giving visitors information on the energy performance of the respective building and an incentive for further consideration. In the meantime, such certificates will be found in any Ministry of the Federal Republic of Germany, being displayed in the entrance area. Energy consumption is becoming a matter of general concern.

The essential purpose for introducing the energy certificate is giving information on the building energy performance and encouraging renovation measures to retrofit existing buildings.

Accordingly, extensive marketing measures should be launched to support the demand-based energy certificate, with the aim of rapidly promoting the energy efficiency of buildings. Energy efficiency must have top priority: Even at this stage, a slogan like 'Energy efficiency – made in Germany" can be effectively applied to support the export trade, see Fig. 5.

Figure 5: Presentation of the label issued by the Federal Ministry of Economics and Technology, introduced on the occasion of the conference "Canada & Germany – A Path to Energy Efficiency"on 12 November 2007.

Activities of the Federal Ministry of Economics prove the great reputation of German energy efficiency products abroad. It is only on the basis of adequate domestic implementations that 'The German way of Life' can be preserved as a competitive advantage and the continuous flow of exports be sustained.

4. ELEMENTS OF THE ENERGY EFFICIENCY INCREASE

To improve energy efficiency in the field of buildings, a great variety of technical measures are available:

- **Reduction of transmission losses**
  - additional insulation
  - use of advanced energy efficiency windows
  - reduction of thermal bridges
  - coating of surfaces
  - reduction of the surface-to-floor area relation

- **Reduction of the ventilation losses**
  - sealing of air leakages
  - measures to obtain demand-controlled ventilation
  - use of mechanical ventilation systems
  - ventilated facades, earth ducts

- **Increase of solar gains**
  - glazing with high solar transmittance
  - glass annexes
  - transparent insulation, hybrid transparent insulation
  - solar collectors, photovoltaics

- **Increase of the efficiency of heat generation**
  - heating
  - domestic hot water
  - control systems

- **Increase of daylight availability and the efficiency of luminaires**
  - transparent or translucent building envelopes with high light transmission values
  - systems for daylight redirection
  - control systems

- **Measures to avoid cooling**
  - solar protection
  - night ventilation systems
  - thermally activated building components
  - heat storage capacity/ application of phase change materials

Most of these measures have already been widely realized and passed practical testing. Regarding both details and comprehensive new solutions, there is still a great amount of development and research work to be done to achieve systems with clearly higher efficiencies at lower costs. To prevent building damages and the deterioration of thermal and acoustic indoor comfort, an integral approach considering all processes related to building physics is required. Novel systems for managing renovation measures, designed to reduce the usual trouble between users and persons charged with executing these measures, are also part of these innovations. In this context, the so-called 'modernization holidays' may be mentioned as a vision, allowing to perform the trouble-free energy retrofitting of a complete building during the three-week vacation of the occupants. As the role of ventilation is of special importance here, it will be dealt with in the next chapter.

5. THE ROLE OF VENTILATION

By using the aforementioned elements, new buildings in Germany have to fulfill at least a maximum value of primary energy demand, depending on the type of building as shown in Fig. 6 and a transmission transfer coefficient of the envelope. The assumed ventilation rate complies with German standard DIN V18599.

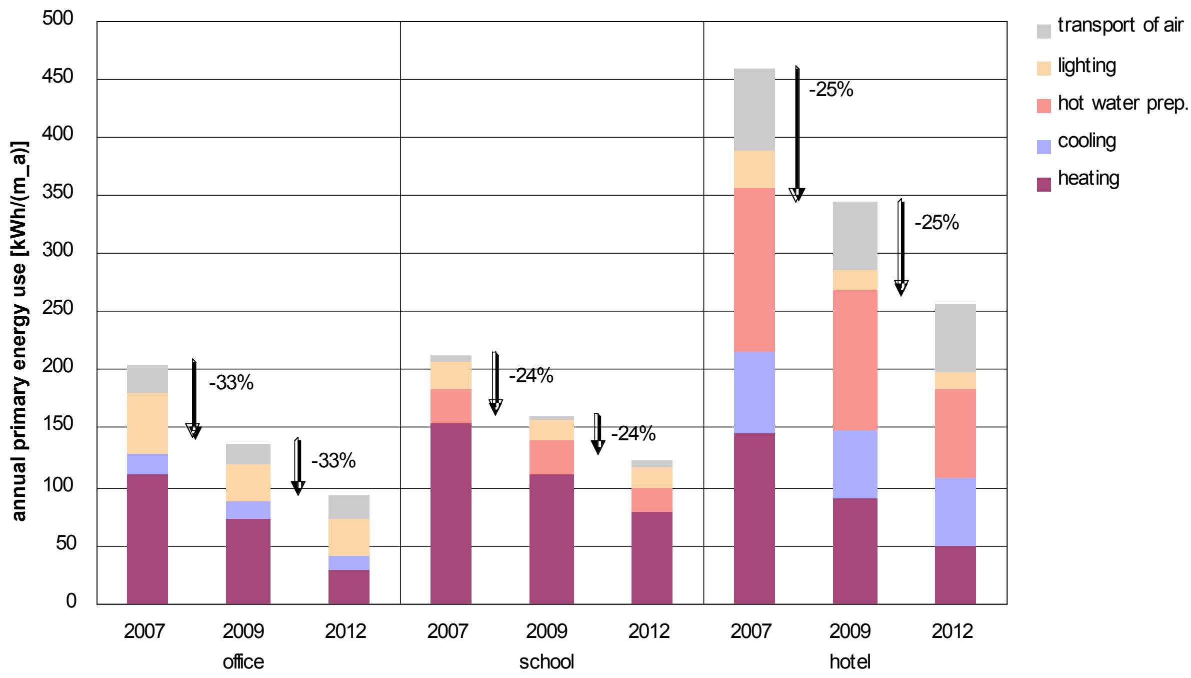

Figure 6: Maximum values of primary energy demand for different building types according to the German energy regulations as of 2007, 2009 (and 2012, probably)

According to the heat balance for the different building types and regulation demands shown in Fig. 7, the role of ventilation is strongly increasing compared to the other elements of the balance.

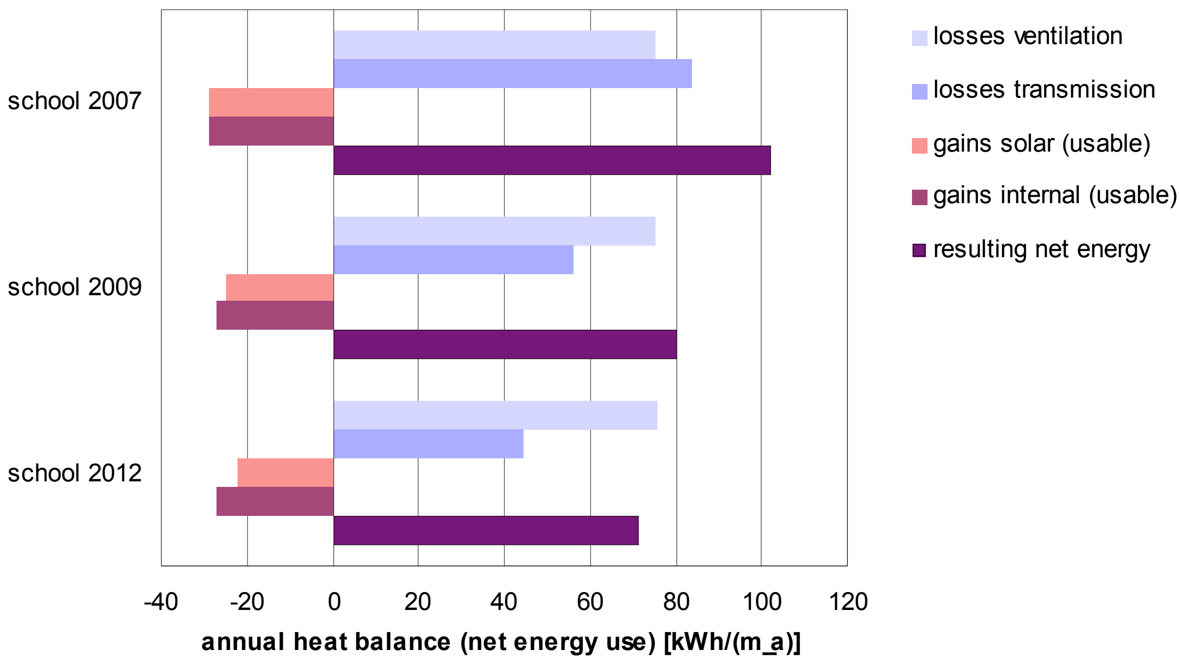

Figure 7: Elements of the heat balance of one building (school) in Figure 6.

From an energy point of view, the optimal ventilation rate would be equal to 0, but this, of course, is not realistic [10] because of the different functions of ventilation, like

- removal of humidity, odours, and pollutants
- oxygen transfer.

These functions could be optimally fulfilled at a very high ventilation rate, which would cause high energy demand, in turn. That's why the optimum value for the ventilation rate is under strong discussion.

The best way to solve this conflict is to have a system that produces high ventilation rates without implying too many energy disadvantages - heat recovery. The heat recovery degree of those systems can be higher than 90 %, as it was measured for the system represented in Fig. 8 [11, 12].

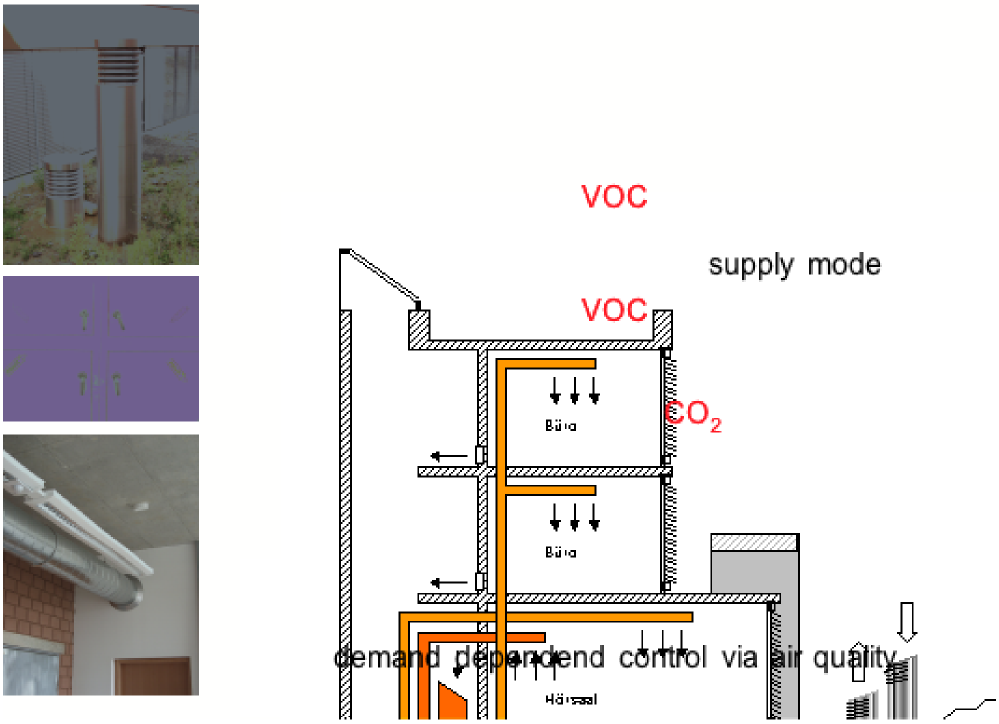

Figure 8: Schematic presentation of a ventilation system with heat recovery installed at the "Zentrum für Umweltbewusstes Bauen" (Center for Sustainable Building, ZUB) at Kassel, Germany.

In the very important case of building modernisation, the implementation of the ducts of mechanical ventilation systems is very often problematic, even in new buildings. To solve that problem, the author is just testing a very inexpensive system, which is shown in Fig. 9.

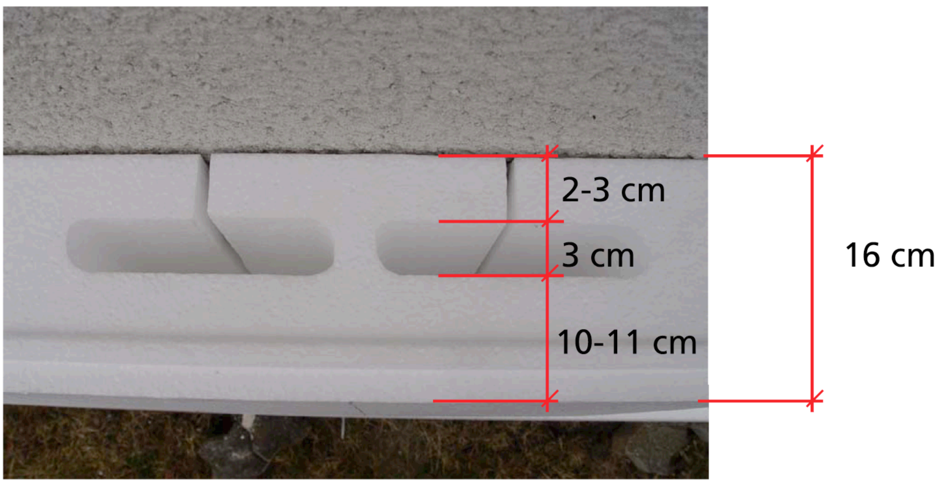

Figure 9: Insulating-material integrated air-duct according to patent.

6. BUILDINGS MUST UNDERGO "TEST RUNS"

Besides the energy efficient design and construction of a building, the energy efficient operation of buildings is also required. Buildings featuring extensive building services engineering need to be given special attention, since their operation is often not energy efficient at all; rather, considerable reductions in consumption would be possible at relatively low cost.

Extensive monitoring to determine and analyse essential parameters will identify weaknesses in the operating procedure. Technologies such as Radio Frequency Identification (RFID), which are already available or are to be expected in the near future, allow wide-range applications.

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