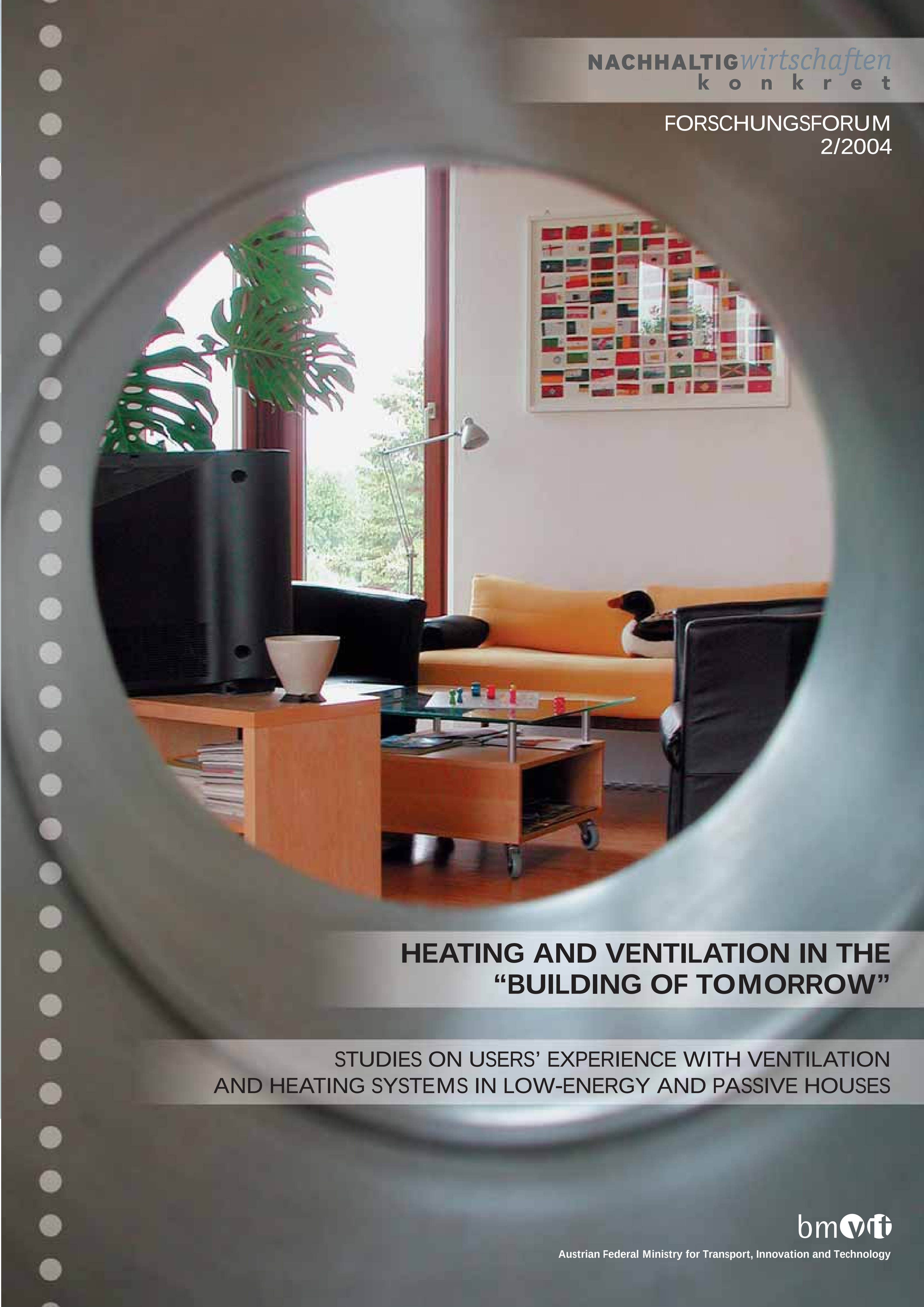

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# HEATING AND VENTILATION IN THE "BUILDING OF TOMORROW"

## STUDIES ON USERS' EXPERIENCE WITH VENTILATION AND HEATING SYSTEMS IN LOW-ENERGY AND PASSIVE HOUSES

bmvit
Austrian Federal Ministry for Transport, Innovation and Technology

# HEATING AND VENTILATION SYSTEMS IN LOW-ENERGY AND PASSIVE HOUSES FROM THE USER'S PERSPECTIVE

***Ventilation unit with countercurrent heat exchanger and integrated heat pump.***

*In 1999, the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit) launched the research and technology program "Nachhaltig Wirtschaften", which aimed to effectively stimulate the restructuring of the economy towards sustainability. Various research and development projects as well as demonstration and diffusion measures, which give new impetus to innovation in Austria's economy have since been supported within the scope of a number of subprograms. The "Haus der Zukunft" subprogram aims to develop marketable building components and concepts (for new construction and renovation) that meet the following criteria: Reduction of energy and materials consumption, promoting the use of renewable energy sources, using renewable and ecologically sound raw materials, taking into account social aspects, improving the quality of life as well as costs that are comparable to those of conventional building construction.*

In recent years, housing construction (both, new construction and renovation) showed a clear trend towards low-energy standards and passive house design, respectively. Important goals of this type of building construction consist in the reduction of end-use energy requirements (space heating, domestic hot water, electric appliances etc.) and in providing excellent dwelling conditions with a view to indoor air quality, coziness, comfort, and a healthy environment. The energy need for space heating should not exceed 15 kWh/m$^2$/yr for a passive house and 30 – 70 kWh/m$^2$/yr for a low-energy house.

One of the pivotal components of the technical equipment in passive houses consists in a controlled ventilation system with heat recovery, which minimizes heat loss and, at the same time, provides for the necessary air change needed for hygienic reasons. In some cases (especially with passive houses), the major part of space heating is also taken over by the ventilation system.
In addition to the concept of air heating only, houses with a very low heating energy demand offer many different possibilities of combining the ventilation system with various types of supplementary heating systems (direct electric heating, supplementary hydraulic system), including well adapted combined systems using wood fired stoves (e.g. tile stoves).

**Experts expect that, in five or ten years, buildings with very low energy consumption and integrated ventilation systems will be standard design.**

While the design of recent installations is relatively well developed already, technological and economic aspects still show a high potential for improvement (price-performance ratio, improved control system, ease of installation).
The future diffusion of these building designs will strongly depend on the level of acceptance, by potential occupants, of the components used for the technical equipment of those buildings. One decisive factor in this context refers to the adaptation of the new systems to the individual needs of the users.
In order to attain a high acceptance on the market we have to develop heating and ventilation systems that take into account recent experience and that provide for a broad range of user behavior.

Three studies within the "Haus der Zukunft" subprogram analyzed the state of technology used for ventilation and heating systems in low-energy and passive houses as well as occupants' and experts' statements concerning their experience with these systems.

STUDY 1
**Akzeptanzverbesserung von Niedrigenergiehauskomponenten**
DI Mag. Dr. Harald Rohracher
(Project Leader)
Interuniversitäres Forschungszentrum für Technik, Arbeit und Kultur (IFZ) Graz

The objective of this sociological investigation consisted in the analysis of the level of acceptance and of the experience made by users concerning controlled ventilation systems and the corresponding heating systems as well as to develop strategies toward a broader and more user-friendly dissemination of these technologies.

STUDY 2
**Benutzerfreundliche Heizungssysteme für Niedrigenergie- und Passivhäuser**
Ao.Univ.Prof. DI Dr. Wolfgang Streicher
(Project Leader)
Institut für Wärmetechnik, TU Graz

This study evaluated various heating and ventilation systems for multifamily dwellings and office buildings built to low-energy and passive house standards, respectively with a view to indoor climate, possible range of user behavior, primary and end-use energy demand, cost, space requirement as well as proneness to faulty installation and operation.

STUDY 3
**Technischer Status von Wohnraumlüftungen**
DI Andreas Greml, FHS Kufstein/Tirol
(Project Leader)

This project evaluated 92 existing domestic ventilation systems in Austria with a view to technical performance and viability in practice. A comprehensive survey of the technical aspects of these installations (successful concepts and control strategies, potential for improvement, faults etc.) presents the results of this study.

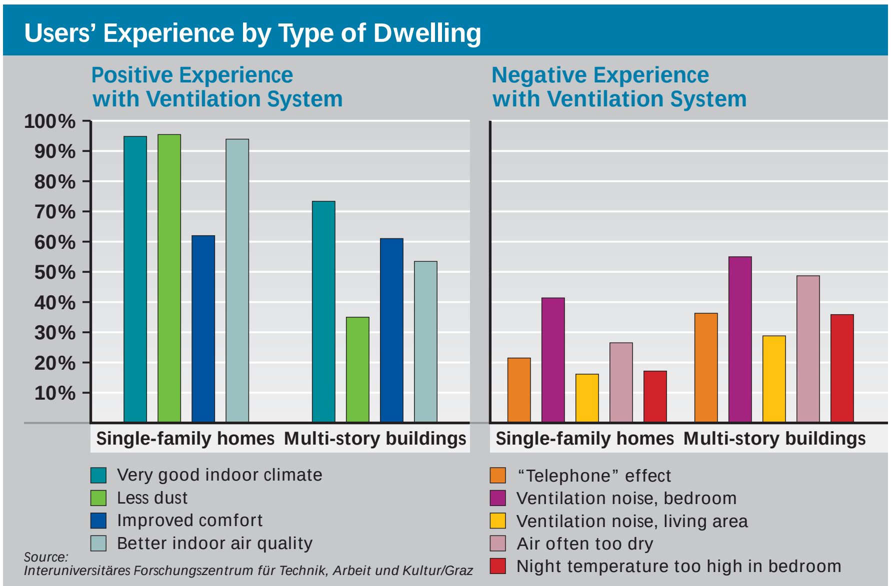
STUDY 1

PROJECT

# IMPROVING THE ACCEPTANCE OF COMPONENTS FOR LOW-ENERGY HOUSES

*The level of acceptance of controlled ventilation systems as well as the perfect interaction of ventilation and heating systems in low-energy houses will play a decisive role in the diffusion of this type of building design.*

The project included an exemplary acceptance study among occupants of low-energy houses with controlled ventilation system. For this purpose, researchers collected data on the experience of 144 users by means of standardized questionnaires and, in addition, conducted 30 open interviews. This also included "non-users", i.e. persons who after in-depth study of the topic decided not to buy such a ventilation system.




In addition, interviews with experts served to discuss the barriers to and chances of the diffusion of controlled ventilation systems. Apart from presenting the results of this investigation the study also proposes strategies towards an improved involvement of users in the technology development process.

Key motives in buying a ventilation system relate to the aspects of energy saving and protection of the environment; indoor air quality and convenience also play an important role.

In general, the degree of users' satisfaction with ventilation systems is quite high for single-family homes (almost all users in this category said they would install the same system again). Concerning multi-story buildings the situation seems to be more problematic because occupants of these dwellings did not consciously decide in favor of such a system; furthermore, cost pressure sometimes made contractors install systems that do not work well. In this context, users also complain about inadequate information about function and proper handling of the system.

Problems frequently addressed by occupants of single-family homes (SFH) and multi-family homes (MFH) include: noise emissions (41 % SFH), dry air (49 % MFH), and limited controllability of the ventilation system (48 % of all users). It is encouraging that users' satisfaction clearly increases with more recent installations.

The interviews with "non-users" yielded interesting results. The disadvantages of a ventilation system this group anticipated referred primarily to technical aspects such as poor operation, restriction of "natural" ventilation (windows), insecurity concerning maintenance as well as high costs. Users of single-family homes did not mention these shortcomings, occupants of multi-story buildings, however, confirmed that these problems do exist. Draft, which non-users considered a very serious problem, was not an issue in practical use, though.

It has been shown that most of the problems occurring in controlled ventilation of dwellings were not associated with bad design of technical components. While there is still potential for improvement and cost reductions concerning this technology, the abovementioned problems usually result from poor planning or inadequate installation, inadequate integration of the system into the whole building, insufficient information for users, cost pressure, or inadequate adjustment of the system after installation.

Coping with the complexity of heating and ventilation systems for low-energy and passive houses requires integrated planning processes involving close cooperation of planners and contractors. In addition, a mutual learning process between manufacturers and users is called for in order to facilitate the integration of users' experience into the technology design process.

STUDY 2

# USER-FRIENDLY HEATING SYSTEMS FOR LOW-ENERGY AND PASSIVE HOUSES

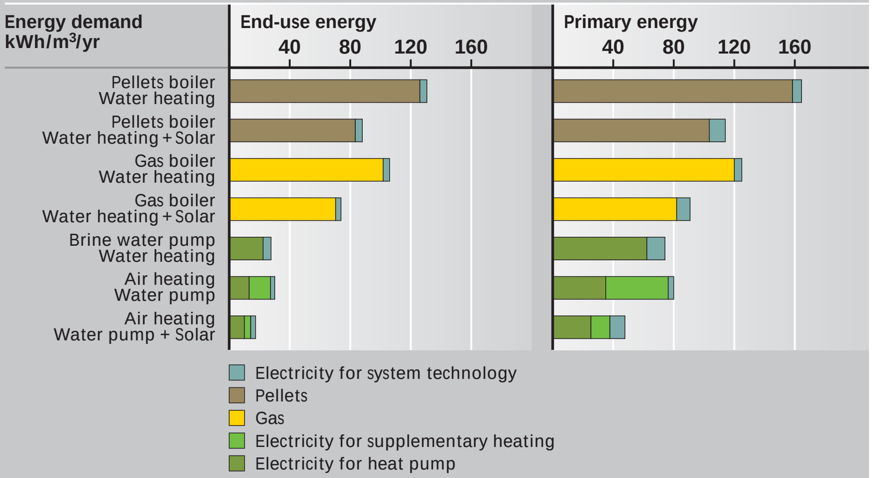
Heating systems for low-energy and passive houses have to meet different specifications than those for conventional buildings. In a "Building of Tomorrow", user behavior, passive solar gains, and interior heat sources have a much greater influence on thermal energy demand. The present project gives an outline of the special requirements, and researchers developed a comprehensive assessment method and tested and evaluated various heating systems for low-energy and passive houses.

## METHOD

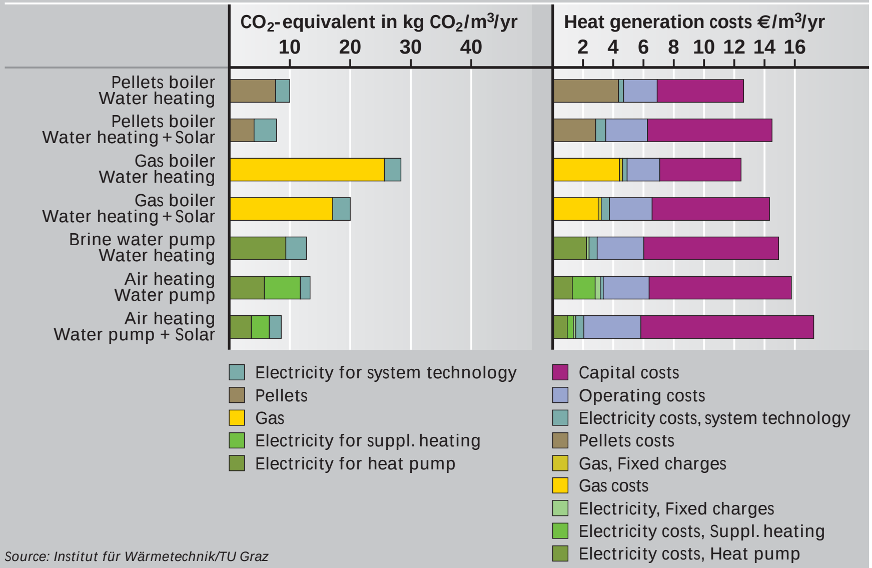
The first step consisted in building two multi-family passive houses on the model of two houses used in the TRNSYS simulation program conducted within the scope of the EU-project "CEPHEUS"; results from the simulation were then compared with energy measurements performed under real-life conditions. Results for the indoor air temperature profile were very similar to the outcome of the simulation. However, it also turned out that even minor changes in sensitive parameters have a decisive impact on the results. Thus, raising the indoor temperature from 20° C to 22.5° C increases the heating requirement by 28 %.

**Comparison of Simulated Heating System without Domestic Current**
(Standard Variant, Reference Building 1, 3 Dwelling Units)

**End-use and Primary Energy Demand of Simulated Heating Systems without Domestic Current**




**$CO_2$-Equivalent Emissions, and Heat Generation Costs**




*Source: Institut für Wärmetechnik/TU Graz*

Interviews conducted among occupants of 53 dwelling units (multi-family passive and low-energy houses) as well as measurements performed by Austrian researchers within the EU-project "CEPHEUS" (2001) served to identify patterns of user behavior. Two reference buildings (a row house with three dwelling units and a multi-story building with twelve dwelling units) were selected for more detailed analysis. Subsequently, researchers analyzed nine different heating systems for these types of building, their characteristics, advantages and disadvantages as well as space requirements: four air heating systems and five systems using water as a heat transfer medium; types of heat source included a decentral exhaust air heat pump, central geothermal heat pump, central pellets- and gas-fired boiler, as well as decentral stove, and tile stove.

A detailed simulation program was used to test four of the system concepts presented in the study (decentral air heating with heat pump, central brine heat pump with water heating, central gas-fired and central pellets-fired boiler with water heating) concerning their characteristics, end-use and primary energy demand, $CO_2$-equivalent emissions, heat generation costs and with a view to their sensitivity to different patterns of user behavior. In addition, researchers conducted a sociological study (interviews and analysis of relevant literature) to ascertain the level of acceptance for the various heating and heat distribution systems.

## RESULTS

Using results from the interviews, researchers defined a desired indoor air temperature of 22.5° C for the simulation program. The lowest energy demand was identified for the decentral air heating system with heat pump, domestic hot water storage and solar installation, followed by the central brine heat pump/water heating system.

The lowest $CO_2$-equivalent emissions, however, were identified for the central pellets boiler/water heating system. Central boiler variants without thermal solar installation performed best concerning heat generation costs. Operating costs of decentral air heating systems were comparable to those of brine heat pump/water heating systems. However, on account of the additional costs for air distribution the capital costs are considerably higher resulting in the highest heat generation costs as compared to other systems. However, this system comes with a controlled ventilation system, which is not included in the other systems and has to be paid for separately.

As a general finding the study demonstrated that each system had its specific strong points / weak points profile and that an overall assessment depends on the type of building and the specific needs of the individual user. An analysis of the interviews has shown that most users do not consider the type of heating system a decisive factor, provided the installation is easy to handle, reliable, and does not require a lot of maintenance. In most cases, problems concerning acceptance – irrespective of the type of heating system used – were associated with poor planning and installation (sizing, control system etc.)

STUDY 3

## DOMESTIC VENTILATION SYSTEMS: STATE OF TECHNOLOGY

This project evaluated 92 domestic ventilation installations in Austria with a view to technical performance and viability in practice. The study focused on intake and exhaust systems with heat recovery. Crucial factors for the further diffusion of domestic ventilation systems include good design and professional installation of the system. The project aimed to contribute to the further improvement of controlled ventilation systems and to a positive market trend by highlighting exemplary concepts, but also faults and shortcomings.

In order to create a basis for an objective evaluation researchers developed a catalog of various quality criteria, and analyzed in how far the various installations fulfilled these criteria. For this purpose, researchers conducted interviews with users, carried out a measuring program (air mass flow, pressure drop, sound level...) and evaluated the individual components of the installations.

The study includes the catalog with 55 quality criteria and a detailed documentation of the tests as well as a general overview of the essential technical aspects of ventilation systems. Thus, the report may serve as a guideline for the planning, sizing, and installation of such systems in the future.

Respondents rated some 80 % of the tested installations as "very good" or "good". The main reason for discontent was the noise emitted by some ventilation systems. A technical evaluation has shown that the fan units themselves rarely gave rise to criticism. In most cases, problems were associated with overall design, the use of inadequate components, and with the control system.

**The most common shortcomings in overall design include:**

- Noise emissions occurring on account of insufficient sizing of cross sections of air ducts, filters, or valves or inadequate soundproofing.
  In order to avoid this nuisance, users often reduce airflow, which, in turn, causes inadequate operation of the system.
- Airflow in dwellings, i.e. air change in individual rooms is not optimal with some systems.
- In many cases, adaptation of air volume performance is not adequate.
- Calculated air volumes are insufficient, especially in areas like bedroom, kitchen, and bathroom.
- In many cases, the possible impact of ventilation systems on fireplaces has not been taken into account.
- Integration of the range hood into the ventilation system and ducting exhaust air directly to the outside may cause problems.
- Sizing of vents is frequently insufficient or these are located in the wrong place or are lacking at all.

***Blower unit of a ventilation appliance.***

Other problems were identified with the design of individual components and with inadequate planning and installation, which caused acoustic emissions, pressure loss, excessive power consumption, and problems with regulation and control of the system.

On balance, the study has shown that while the requisite components for high-quality ventilation systems are available, planning concepts for and realization of the installation still have a considerable potential for improvement. Substantial cost savings could be achieved through better coordination of the various contractors involved.




# STRATEGIES TOWARD THE FURTHER DEVELOPMENT AND DIFFUSION OF VENTILATION SYSTEMS

The experts interviewed within the scope of the study “Akzeptanzverbesserung von Niedrigenergiehauskomponenten” anticipate that buildings with very low energy requirements and integrated ventilation systems will be more widespread in the future. At present, however, there is still a great potential for improvement at the technical, economic, and social levels. Therefore, strategies for the further dissemination of these concepts will have to focus on three different fields:

### System concepts and installation

Users’ needs seem to suggest a trend towards backup heating systems. Only 16 % of users participating in the study rely exclusively on the ventilation system for space heating, 44 % combine space heating via ventilation system with a supplementary heating system. So far, there is no standard solution for these combinations, and builders often plan and install individual solutions. Thus, there is great need for further development in this field.
Control options for the regulation of these systems, too, have not yet been fully developed. Optimization of user interfaces and IT networking of the various controls as well as options for single-room regulation may contribute to the further improvement of ventilation systems.

### Socio-economic background

Apart from strategies toward better product marketing, improved know-how and training opportunities for planners and contractors as well as close cooperation in integrated planning processes are of great importance in this context. Public grants may also serve as a positive signal for the diffusion of the technology.

### User involvement and information

It is highly important to systematically incorporate users’ experience and to take into account the needs of potential users. At the level of technology development this may be facilitated by means of surveys, focus groups or “lead user” workshops. Close cooperation with builders, who are an important link to the users (concerning information and consultancy) is also highly important.

## PROJECT SPONSORS

**Akzeptanzverbesserung von Niedrigenergiehauskomponenten**
DI Mag. Dr. Harald Rohracher (Project Leader), Interuniversitäres Forschungszentrum für Technik, Arbeit und Kultur (IFZ), Mag. Dr. Michael Ornetzeder, Zentrum für Soziale Innovation (ZSI) et al., Graz 2001

**Benutzerfreundliche Heizungssysteme für Niedrigenergie- und Passivhäuser**
Ao.Univ.Prof. DI Dr. Wolfgang Streicher (Project Leader), DI Richard Heimrath, Institut für Wärmetechnik, TU Graz, DI Alexander Thür, DI Dagmar Jähnig, AEE INTEEC, Mag. Jürgen Suschek-Berger, IFZ, et al., Graz 2004

**Technischer Status von Wohnraumlüftungen**
DI Andreas Greml, FHS Kufstein/Tirol (Project Leader), DI Ernst Blümel, AEE INTEC, DI Roland Kapferer, ENERGIE TIROL, Ing. Wolfgang Leitzinger, arsenal research, Kufstein 2004

All three studies were conducted within the scope of the “Haus der Zukunft” subprogram. www.HAUSderzukunft.at

## INFORMATION PUBLICATIONS

The final reports on the above-mentioned studies have been published in issues 26/2001, 15/2004, and 16/2004 of the bmvit series “Reports on Energy and Environment Research” and are available from:
www.NachhaltigWirtschaften.at

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