TOWARDS SUSTAINABLE HOUSING IN AUSTRIA
Lessons Learned, Measures for Market Deployment and Future Prospects

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1. Background

The reduction of the energy consumption within energy-saving measures, the use of renewable energy resources for substitution of fossil energy sources as well as the reduction of CO_2-emissions in the energy sector have priority in the Austrian energy policy. The sector of building construction is responsible for 25% of the mineral materials flow, 50% of waste generated, and almost 40% of end-use energy consumption. To reduce the heat energy demand in the building sector and therefore also the fuel demand for space heating as well as the CO_2-emissions of the heating devices is the main goal of the Austrian energy and research policy. Present initiatives on the Austrian housing market are focused on the marketing of *energy-efficient* / *sustainable buildings*, including cost-effectiveness and acceptance by occupants and therefore ready for a faster market penetration. The market deployment of sustainable housing is supported both by research programmes and financial support of the Austrian federal and provincial governments. Besides of the *Housing Promotion Act* for sustainable housing special support for biomass-, solar- and heat pump systems are offered to the consumers by the provincial governments in the order of up to 20% of the investment costs.

2. The building sector in Austria

Since 1967 the building standards – related to the building envelope insulation – changed remarkable to lower space heat demand. Fig. 1 illustrates the development of the U-values of the building envelope (average figures) in Austria from 1918 to 2003. Within the better insulation of the building envelope it has been possible to reduce the heat load from 150 W/m² to 40 W/m² and the space heat demand from more than 300 to 60 kWh/(m², year) in the last decades. For illustration, the share of low-energy housing in new building constructions increased remarkable in the last 5 years; from about 5% to 20%.

Energy-efficient housing have been receiving greater attention in recent years as building constructions and efficient heating systems accelerate. Also new building codes have influenced the market for low-energy buildings in the last years remarkable. Characteristically U-values for the building envelope of different building standards are listed in Table 1. In principle, these values can be reached by all building constructions: bricks, concrete and wood with sufficient insulation; Fig. 2.

The changing in the building sector was not only the consequence of public funding, but also because of energy-economic solutions in the building sector as well as in more interest and attention from buyers and tenants for environmentally sound, higher performing, more comfortable and healthier buildings. Realized projects show, that it is possible, to reduce the fuel supply up to 30% compared to „standard“ buildings by better building insulation with nearly the same investment costs. Fig. 3 indicates the possibility to realise low-energy buildings to nearly the same investment costs of “standard” buildings.

Besides of better building envelope insulation, the use of renewable energy technologies increased in the last years. Favourites are solar combined biomass- (pellets) heating systems.

3. The Austrian research and technology programme on “Building of Tomorrow”

The Austrian research and technology programme on “*Building of Tomorrow*” is a part of the Austrian programme on technologies for “Sustainable Development” /1/. It has been developed by the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) with the goal to initiate and support trend setting research, and development projects and the implementation of exemplary pilot projects. The programme pursues clearly defined emphases, selects projects by means of tendering procedures and is characterized by networking between individual research projects and by accompanying project management.

The research and technology programme "Building of Tomorrow" /2/ makes use of the two most important developments in solar and energy efficient building: the passive house and the low-energy solar building method. For the purposes of the "Building of Tomorrow" programme, these energy centred innovations are expanded to take in ecological, economical and social concerns; Fig. 4.

The *Buildings of Tomorrow* are residential and office buildings, and differ from current building practice in Austria by fulfilling the following criteria:

- Higher energy efficiency throughout the whole life-cycle of the building.
- Greater use of renewable energy sources, especially solar energy.
- Greater use of sustainable raw materials, and efficient use of materials.
- Increased consideration of user needs and services.

However, the costs should be comparable with conventional building methods.

To introduce the programme “Building of Tomorrow” the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) at the beginning of the project in the year 2001 initiated an architectural competition of realised projects. Examples for objects received an award are illustrated in Fig. 5.

The *"Building of Tomorrow"* research programme has a planned duration of five years (2000 – 2005), and a total budget of 120 million Euros. It comprises the following elements:

- Technology and component development.
- Development of innovative building concepts for residential and office buildings.
- Setting up and evaluating demonstration projects.
- Market diffusion of the "*Building of Tomorrow”*.

4. Requirements for the design of energy-efficient / sustainable buildings

The overall goal for *Sustainable Buildings* may be:

> “Based on a life cycle analysis sustainable buildings are designed to minimize both direct and indirect adverse impacts on the indoor, local, regional, and global environments”.

Sustainable buildings incorporate sustainable materials and components and use a minimum amount of energy, which should be covered with a high percentage by renewable energy carriers.

Sustainable buildings have some building requirements, but there exist a wide range for architectural design. Nevertheless, sustainable buildings should be attractive in design and function as well as cost-effective; Fig. 6.

To reduce the heat energy demand and therefore also the fuel demand for space heating as well as the CO_2-emissions it is necessary to consider the building envelope and the heating system as an unit.

The design of concepts for sustainable buildings is in practice often limited in time and resources for doing sophisticated analysis of the different options and comparing different technologies and strategies. Nevertheless, the market offer some integrated pre-design tools including energy-, environmental- and economic-analysis, easy to use, fast and user-friendly but also accurate.

The first schematic and conceptual design is always the starting point for generating effective concepts for building energy systems. Advanced components, new materials, advanced technologies and innovative architectural design concepts are available today and have opened a quite new area in the energy conscious building design. Together these have the potential of reducing significantly the energy needs of buildings but at the same time maintaining, or even improving the living conditions and occupant comfort. It is important that these innovative approaches are handled properly in the pre-design phases.

In addition to building or architectural components, there exists a range of energy technologies that could be incorporated into a building, e.g. solar thermal and solar electric, heat recovery and heat pumps, advanced biomass boilers, control and different operating strategies, etc. All these measures influence significantly the building energy performance and should be included in the pre-design.

The design of *Sustainable Housing* requires some special attention to energetically and ecologically aspects, considering also economic solutions. On the basis of criteria's both the members of the design team and the owner have to be encouraged as well as convinced about the design strategies and solutions. Using the *Checklist* all actors can better understand the manifold possibilities to realize sustainable housing with all their benefits. The results of an assessment of different housing designs are documented in Fig. 7; /3/. The *star diagram* may be used to give an indication of the overall performance of the building.

5. Ways to achieve the requirements of sustainable buildings

The elements of *Sustainable buildings* are: Building insulation, renewable energy technologies and heat recovery; Fig.8. The ways to reduce energy demand for space heating are measures on the building envelope within energy-saving building constructions including well-designed elements and systems for "passive" use of solar irradiation via *solar architecture*. The remaining heat demand has to be covered by an efficient heating system on the basis of a high contribution of renewable energy sources; Fig. 9.

The utilization of solar energy in buildings is an important task to achieve the goals for *sustainable buildings*. The use of solar energy includes direct and indirect solar irradiation. Indirect solar energy sources like ambient heat and biomass products are possibilities to overcome the mismatch between solar irradiation and heat demand and therefore are interesting "long-term stores for solar energy" as well as auxiliary energy sources for solar housing.

Today, solar systems for hot water preparation in detached, row and apartment housing have priority.

The implementation of a seasonal thermal storage in buildings with a high-insulating standard is technically possible, but it has to be considered also under economical and environmentally aspects. Experience shows that economical-technology solutions with middle-term stores in combination with renewable energy technologies, which are reliable and easy to handle, are of more importance, at least for near-term applications and commercialisation. Proved technologies are solar combined heating systems with heat pumps, bioenergy technologies and heat recovery systems. Sufficient experience and operational data already exist to achieve the goals for solar advanced (sustainable) buildings and to ensure professionally designed as well as cost-effective solutions with an optimum of performance.

6. Appropriate heating systems for sustainable buildings

Sustainable buildings need energy-efficient heating devices with a high share of renewable energy sources. Favourites for appropriate heating systems are:

- Solar hot water systems.
- Solar–combisystems.
- Heat recovery systems.
- Heat pump systems, especially ground-coupled.
- Advanced biomass heating systems, e.g. pellets-boilers.

In the past decade the demand of fuel for space heating as well as for hot water preparation could be reduced remarkably by energy-saving building constructions and by energy-efficient heating systems. Practical research in and demonstration of low-energy buildings as well as new technologies for the heating of buildings have resulted in a number of economical and marketable solutions in the building sector.

The simplest possible way to utilize solar radiation for space heating in buildings is the so-called passive solar energy utilization: *solar architecture*. This term comprises all physical and constructional design measures in building construction that provide for a direct thermal utilization of solar irradiation falling on the outer surface of a building (walls and windows) or attaining its inside through transparent external construction units. Solar architecture is nothing else but "construction and design fitting the climate". The passive use of solar energy in buildings is bound to the realisation of *low energy buildings*: energy saving building constructions and passive use of solar energy are therefore to be considered as a unity and to be realised in building projects.

Day lighting systems have a high potential for saving electricity for lighting as well as to improve the building quality.

The hot water preparation in new buildings is today standard in Austria. In the area of building renovation, solar systems for hot water preparation are attractive on the market. Especially ineffective heating systems for hot water preparation outside the heating season have been replaced by solar hot water preparation. Thus pollutant emissions through heating (wood-, coal-, oil-boilers) could be reduced and at the same time a high comfort in hot water preparation could be reached. The use of solar hot water systems in multi-family buildings has the advantage of lower specific investment costs and thus also the heat preparation costs for solar hot water preparation can be reduced in comparison with small, decentralized systems.

The economic efficiency of *solar heating systems* (hot water preparation and combined heating) depends mainly on its design. Thus, the optimal design of all components of the system - collector, storage, tanks, pumps, control mechanism, and piping - is essential as well as the design of collector area and storage volume as a function of the daily/hourly heat demand. For the selection of the collector type are responsible the application and the temperature, which has to be reached. For domestic hot water preparation the use of flat plate collectors with selective coating may be the most cost effective solution in many cases. For higher temperatures (process-heat above 80°C) and lower solar irradiation evacuated collectors would be more successful. The use of solar energy for space heating in residential areas can only be justified in the case of *low energy buildings* with a maximum hot water inlet-temperature of 40EC.

The solar share of solar supported heating systems (solar-combisystem) – considering energy-economic aspects - depends on the heat demand of the building (space heat and hot water) and the design of the heat distribution system (design inlet-temperature below 40°C) and is of about 20% to 40% for low-energy dwellings. An efficient operation of solar supported district heating plants is only possible when the heat losses in the pipes of the network are - related to the useful heat - small. The number of users and the density of supply are essentially. The requirements for a high density of heat supply are optimal in housing estates with a high density of buildings. Solar-supported small district heating for new housing estates are an important new approach for the utilisation of solar energy in the building sector. Results from solar systems in existing buildings are illustrated in Fig. 10.

The integration of the collectors in the building should consider architectural rules and for the location specific building traditions. In urban buildings, there is not always sufficient suitable and oriented roof area for the installation of solar collectors available. Therefore it is necessary to integrate collectors in the facades. Both solar collector and heat insulation of the building envelope understand a collector element directly integrated in the façade. Constructional and aesthetically attractive solutions without thermal separation are necessary. Also recyclability of the materials used and resource efficiency play a central role. Compared with tilted collector areas, the absorbed solar radiation is reduced by about 25% to 30% as an average. From the energetic point of view, façade integrated collectors are acceptable in solar combined heating systems with an oversized collector area for hot water preparation outside the heating season; Fig. 11.

The operating comfort of biomass boilers could be improved by features of full automatic operation and a similar comfort as oil or gas fired boilers: *woodchips*- and pellets-boilers; Fig. 12. Within series production of small biomass heating systems, especially pellets-boiler cost-effective products are offered on the market nowadays. Pellets offer the possibility to use wood as a fuel without any reduction of convenience in comparison to heating oil or natural gas. Pellets are transported in a tank lorry and pumped dust-free into storage. From there, they are fed to automatically working pellet furnaces. Today, pellets boilers are fully developed in a number of options and environment-friendly in every respect. Heating with pellets is economical at the current price level of heating oil and natural gas. New on the market is a storage-integrated pellets-burner. This compact system supports both high efficient use of pellets and cost-effective installation.

7. Criteria's and directions for sustainable housing

Buildings can be much more *sustainable* on average than they are currently. To achieve this goal, concepts for efficient-energy building design has to be defined and realized within *integrated building planning*, considering energetically, environmentally, economically as well as social aspects.

To meet the goals of energy-efficient buildings and to achieve a sustainable built environment it is necessary to define *common criteria and directions* for the whole building sector and to investigate and present policies and strategies to enhance urban sustainability.

Energy-efficient buildings are characterized with a high insulation standard. To achieve energy-efficient buildings with good thermal comfort and indoor air quality the building envelope has to be optimised. The performance assessment of insulation materials includes the thermal performance and aspects of environmental impacts, durability, and reliability and life cycle cost-effectiveness. Such a method will facilitate selection of components and enable comparative performance to be made.

To reduce the total energy consumption in a building it is necessary to consider more than one of the energy consumers: space heating, hot water preparation, lighting, and household appliances. The development of electricity-efficient household appliances and lighting products is remarkable. Fig. 13 illustrates the share of energy consumers in households, also including private mobility, as well as the development of energy-efficient household appliances.

The main benefit of sustainable buildings is its potential for saving both fuels and CO_2-emissions. Indicators for the quality of housing are both primary energy demand and environmentally relevant CO_2-emissions of the heating system. Characteristically data for the assessment are shown in Fig. 14. Based on the space *heat demand* of a detached house in Austria (Vienna, temperate climate) the *primary energy demand* and the *CO_2-emissions* for different heating systems are illustrated in Fig. 15.

8. Economics of sustainable solar housing

A comparison of costs between existing both housing and energy systems employing different primary energy sources such as oil, gas, nuclear energy and new energy systems with renewable sources of energy is basically a trade-off between capital-intensive projects with low fuel prices and projects with relatively small capital investments and high fuel costs. In general, sustainable solar housing are freer from future fluctuations in energy prices but are more capital-intensive compared with conventional energy systems such as those using fossil fuels. Therefore, capital costs and fuel prices have been the key factors in determining the relative economy of sustainable solar housing.

Specific cost estimates can only be carried out when based on concrete examples and it should be clearly born in mind that cost estimates are basically site-specific.

Based on a planned building project, various questions which are highly relevant for the introduction of the passive house standard in the social housing construction have been analysed /4/; Fig. 16. Background of the project are the published results of already established passive houses, in particular from the CEPHEUS project /5/; Fig. 17. The following points were identified as substantial planning objectives:

- High cost-efficiency
  Extra costs < 75 Euro/m² effective living area
  Construction costs < 1,055, - Euro/m² effective living area
- Low energy consumption - passive house standard
  Heating energy demand < 15 kWh/(m², a)
  Heating load < 10 W/m²
  Air tightness n50 < 0,6/h
  Primary energy demand < 120 kWh/(m², a)
- High user comfort
  Controlled ventilation, acoustics, hygienic, user acceptance.

The costs of the passive house standard for social housing in relation to the low-energy housing standard in Vienna amount to about an extra 73 Euros per square meter of effective living area. Compared to ordinary social housing construction costs this means 7 % extra costs. The improved constructional quality of the building envelope and the highly efficient ventilation in passive houses require additional investments. Standard costs for the construction of social housing on the other hand (1,055 Euro per square meter of effective living) could be kept by optimising components, integrated performance simulation and integral planning.

Extra construction costs for a passive house - per square meter of effective living area, exclusive sales tax, basis 2003 - in social housing are illustrated in Fig. 16.

9. New business opportunities

New technologies and products in the building and heating sector offer new business opportunities. The worldwide markets for buildings are changing. Buyers and tenants are demanding higher performing, more comfortable and healthier buildings. Forward-looking business, communities and energy companies are searching for ways to respond to customer demand. People want houses, offices, apartments and communities in which sound environmental principles are integrated into building architecture and surrounding amenities.

New ideas and products are being developed on the worldwide market to respond to their changing demands.

10. Indicators for the market penetration of sustainable housing

To facilitate more rapid deployment of *Sustainable* Housing, it is important that people understand the advantages of using energy-efficient houses in the context of the full range of their benefits, in contrast to the environmental and other consequences of using energy derived from fossil fuels because of their apparently lower cost.

There is a general need for increased public awareness and understanding of *Sustainability*, especially for the main players involved in planning decisions (planning officers, local communities, pressure groups, etc.). Greater consideration needs to be given to the potentially useful role that *energy-efficient buildings* and *renewables* could play in meeting these targets and of ways of encouraging their development and deployment. Encouragement needs to be given also to increase research in this area and to improve sharing of information’s on this topic.

From the experiences in Austria the main indicators for the market penetration of *Sustainable Housing* are:

- New building standards for energy-efficient housing - in correspondence to the goals of national energy policy - supported with financial measures and
- the acceptance for new building standards and heating systems by consumers.

Main criteria's for *Sustainable Housing* are: Primary energy for building construction and operation (life-cycle-analysis), share of renewable resources, living standard, cost-effectiveness. These criteria's have to be guarantee by planers, architects and building construction firms.

Sustainable buildings have to be characterized by certification considering the terms for *sustainable buildings*. Therefore criteria for sustainable buildings have to be defined and analytical calculation models for the assessment must be available.

Market introduction and dissemination of innovative concepts and technologies in the building sector (high efficient insulation, use of solar energy, mechanical ventilation systems, securing of indoor air quality, etc.) is strongly influenced by different obstacles and supporting factors such as technical, legal, sociological, psychological, ecological and economical ones.

An essential impediment to the market introduction of innovative residential buildings is that most planners, builders, building contractors and residents have only a remarkably low level of specific knowledge concerning energy- and resource-efficient buildings. The lack of information on side of the potential users of a building causes a low demand for such dwellings.

11. Market barriers for Innovative Concepts and Technologies into the Building Sector

Market introduction and dissemination of innovative concepts and technologies in the building sector (high efficient insulation, use of solar energy, mechanical ventilation systems, securing of indoor air quality,...) is strongly influenced by different obstacles and supporting factors such as technical, legal, sociological, psychological, ecological and economical ones.

The results of a quantitative inquiry done with 212 residents of average buildings were contrasted with the views of about 50 representatives of firms who are engaged in either producing or selling certain innovative technologies (P. Biermayr et al /6/). On the other hand, six case studies of already realised innovative buildings based on about 50 qualitative interviews with actors of the relevant target groups were worked out.

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Many actors in the building sector are organised as private enterprises whose main interest is to maximise profit. They usually have no interest in minimised technical systems and because of lack of information they are confronted with additional transaction costs if they would go for innovative concepts. Higher design costs, which cannot be calculated for reasons of competitiveness as well as less material input (and thus less returns) through optimised constructions and minimised technical systems are a big obstacle to more engagement of the relevant actors.

An essential supporting factor concerning the market introduction of innovative residential buildings is the engagement of single technically and / or ecologically motivated actors who push projects forward with a high degree of personal commitment. Further motives on side of the dwellers to choose a highly innovative building are the expectance of a highly comfortable and healthy dwelling environment, but also the wish to present something special to the outer world and thus gaining status. The acceptance of innovative residential buildings is strongly supported by a high level of identification with the building, which mainly depends on the degree of participation during planning and building and the status of ownership.

To achieve more rapid diffusion and further development of innovative residential buildings measures from the federal and provincial governments have to be taken. Regulations prescribing significantly higher insulation standards are expected to be very effective and to play a key role in triggering other technologies whose acceptance and economic application depend on an optimised building envelope. The development of certified standardised single components and complete solutions, for which producers can give warranty, will also speed up the diffusion of innovative buildings. Individual options for the supply of remaining heat demand, which fulfil the criteria of sustainability on the one hand and support a high degree of identification for the user on the other hand, should be offered. Energy savings must have an effect on the energy bill of a resident and must not be weakened by collective billing arrangements in centralised systems. A high degree of personal identification with the building should be one of the major goals when dwellings are allocated within the scope of “social housing”. This can be achieved if the potential future resident may have the choice between an apartment in the innovative building and another apartment in a more “conventional” building. The way how residential buildings are subsidised has to be rethought. Subsidies should be based on a least cost strategy with minimisation of energy consumption and a sustainable supply of remaining heat demand as the major objectives and be harmonised on a national level. Subsidies should only be given if independent information centres whose task is to supply and spread information offensively (which still have to be created) are already integrated in the planning stage of a building.

Last but not least, the ecological relevance of tax systems has to be improved. The inclusion of external costs in the price of fossil energy carriers enables an objective economic comparison between fossil and renewable sources of energy.

12. User Acceptance of Balanced Ventilation Systems in Residential Low-energy Buildings in Austria

To reach very low levels of energy consumption (below 30-40 kWh/(m^2, a)) in residential buildings balanced ventilation systems with heat recovery are needed as energy loss through ventilation and air leakage otherwise would become dominant. In some cases (especially passive houses) even room heating is provided through the ventilation system. Occupants' acceptance of balanced ventilation and attached heating systems will strongly influence the chances of a wide dissemination of very low energy buildings. To find answers and to develop strategies to support a wide dissemination and user-friendlier design of these low energy house technologies solutions, the experiences of users of balanced ventilation systems in low-energy housing have been analysed on the basis of 174 questionnaires and in-depth interviews from residents; (H. Rohracher et al /7/). The aim of this project was to analyse the pre-conditions, which influence occupants' acceptance of ventilation and heating systems.

Successful dissemination will in the long run depend on better matching technical and planning concepts to the needs and expectations of users. The improvement of low energy house technologies has to be organised as a mutual learning process of component producers and users (users in a wide sense, i.e. professionals, companies, building societies, etc.).

The result of quantitative analysis of 144 questionnaires from residents` acceptance of controlled ventilation and heating systems and from in-depth interviews with 30 residents are (Fig. 19):

- Overall satisfaction with balanced ventilation systems is very high (especially in single-family houses where more than 90% of the occupants would again install a ventilation system).
- A significant proportion of the residents interviewed reported negative experiences - predominantly noise (41% even of single-family homes!) and too low humidity levels, or expressed dissatisfaction with the control system.
- Problems and complaints are significantly higher in multi-family buildings, where occupants never took a conscious decision in favour of balanced ventilation and usually did not get enough information about function and usage of this technology. Moreover, many of the blocks of flats investigated are social housing projects, which were built under high cost pressure sometimes resulting in dysfunctional or badly working ventilation systems.
- However, it is a good sign that experiences and satisfaction with balanced ventilation significantly improves towards newer systems, which have been built during the past few years.

Most problems with ventilation systems do not result from inappropriate technical components, but depend on the quality of the planning and construction process, integration of the ventilation system into the general concept of the building (energy concept, design), information of users, cost pressure, balancing of the system after completion etc. Though remarkable learning processes and know-how improvement of specialised planners, architects and building societies can be observed, the majority of relevant professionals does not have sufficient competence and know-how (especially when heating is provided through the ventilation system) to meet high quality standards yet.

Strategies to improve quality and dissemination of ventilation systems in low energy houses therefore will have to focus on several different levels:

a) Improving the socio-economic, legal and organisational context of balanced ventilation technologies, i.e. know-how of professionals (training programmes, certification, quality standards), regulations (acceptable noise levels, the way planning fees are calculated), structure of subsidies for low-energy buildings), moving towards integrated planning processes, shaping the expectations of potential users and building societies through marketing programmes.

b) Systematically integrating experiences and expectations of users of balanced ventilation systems into the further development of the product and of planning concepts. User involvement may take place at a more general level of product development through surveys, focus groups or 'lead user' workshops, or it may be employed at the level of planning, constructing and using buildings, where experienced users from other buildings or prospective users should be more actively involved in the planning process of the building.

c) Taking into account product perceptions of customers who decided against purchasing a balanced ventilation system, when creating marketing and information concepts for producers, installers or energy advice agencies. Non-customer perceptions often remarkably differ from experiences of users. As an example the expected problem of draft is a serious obstacle to have a ventilation system installed, though users or suppliers do not take this problem into account, as it does not exist in reality.

13. Summary

The remarkable market development of sustainable housing and renewable energy technologies in Austria has only been possible because Austrian firms have in co-operation with research centres developed cost-effective technologies, both for energy saving building constructions and solar thermal and heating systems based on renewable energy sources. High quality could be achieved in the solar thermal sector and in advanced environmentally friendly biomass heating systems with optimised combustion technology. Especially test results led to technical improvements in technologies as well as to common standardisation.

Pilot and demonstration systems have made essential contributions and have apparently contributed to partially overcoming the market barriers for innovative building concepts.

Many examples show, that it is possible, to reduce the fuel supply in buildings by better building insulation standards as well as efficient heating systems with nearly the same investment costs.

Under these circumstances the future prospects for the market deployment of *Sustainable Housing* in Austria are favourable.

Literature:

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http://www.hausderzukunft.at/projekt02.htm#pl

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User acceptance of balanced ventilation systems in residential low-energy buildings in Austria.
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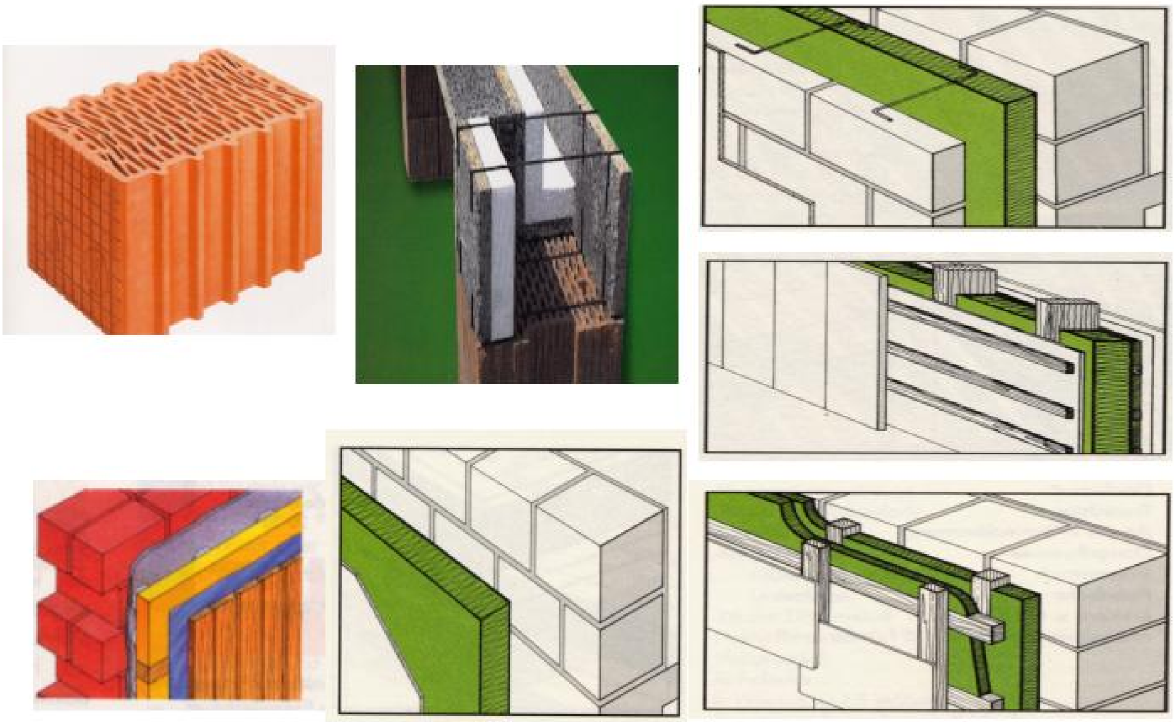
Table 1:
CHARACTERISTICAL U-VALUES FOR THE BUILDING ENVELOPE
U in W/(m², K)

Building Part	Standard (related to Energy Code 2000)	Energy saving House	Low energy House	Passive House
Outside Wall	≤0.40	≤0.25	≤0.20	≤0.15
Outside Window	≤1.80	≤1.30	≤1.10	≤0.70
Upper Floor	≤0.50	≤0.20	≤0.15	≤0.10
Ceiling/Basement	≤0.50	≤0.30	≤0.20	≤0.13

Fig. 1: Market development of building insulation standards in Austria



Ecologically sound building constructions

Ecologically sound building insulation

Fig. 2: Building construction materials
(Mantle concrete: 89% wood & 11% cement and water glass)

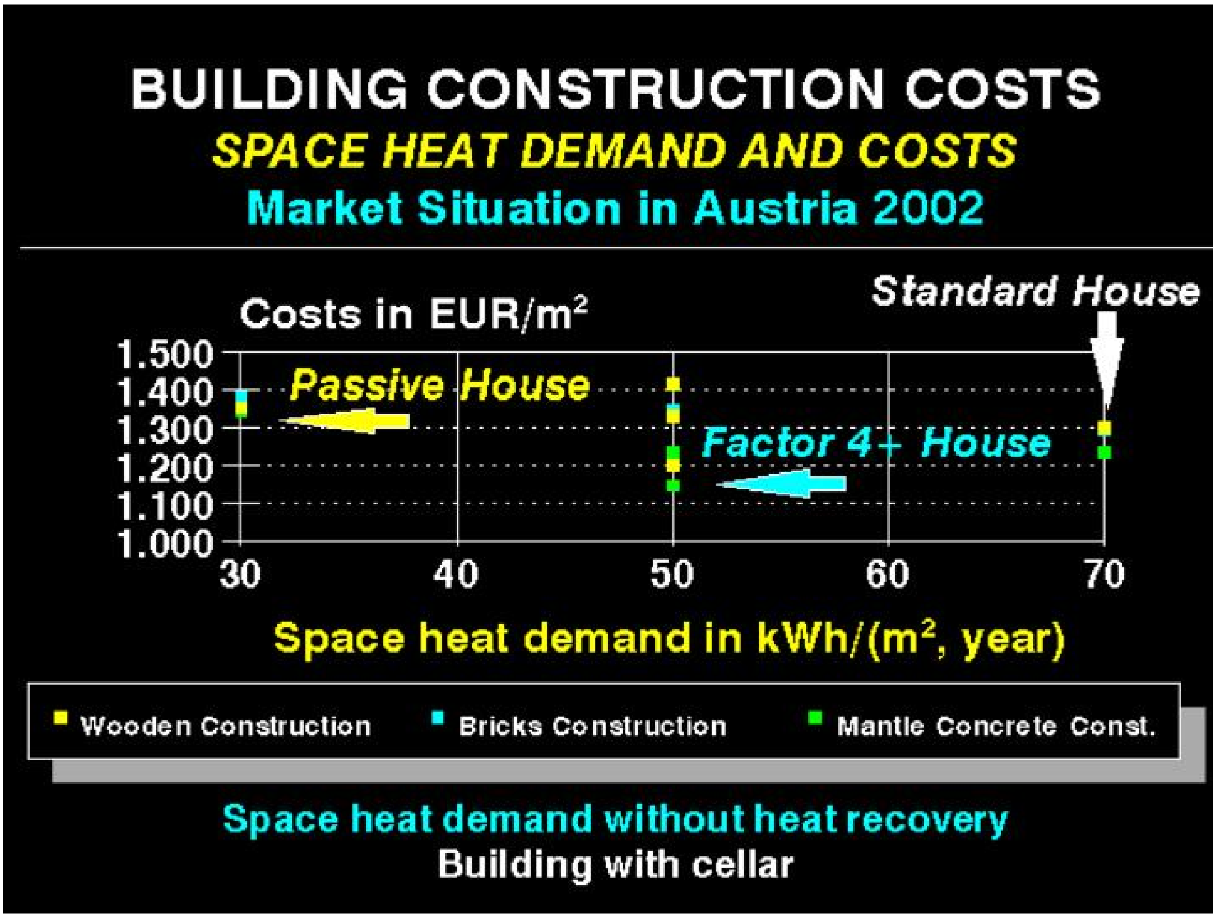


Fig. 3: Building construction costs

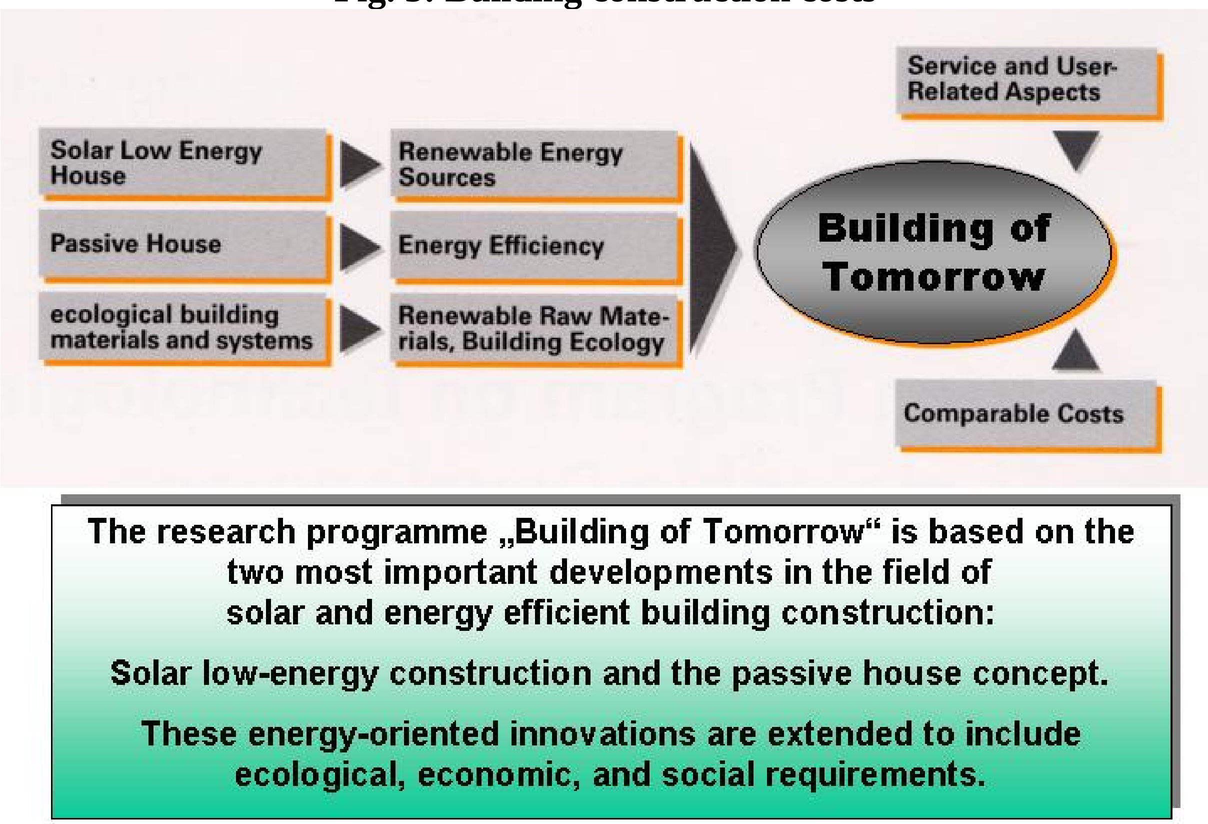
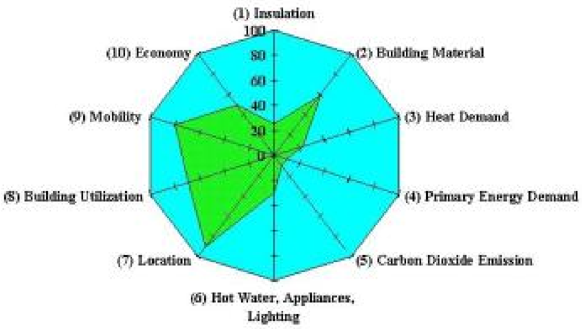


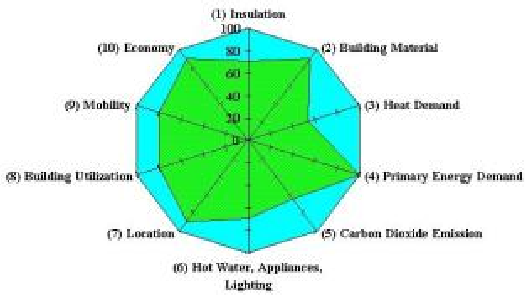
Fig. 4: The Austrian research programme “Building of Tomorrow”

Fig. 5: Austrian architectural housing competition "Building of Tomorrow"

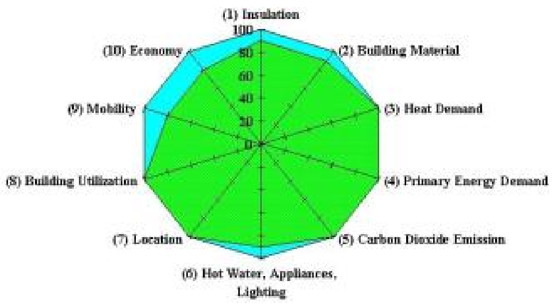
Fig. 6: Building constructions for Sustainable Housing



Standard-Building, oil burner



Low Energy Building, biomass heating system



Passive Building, heat recovery with heat pump

Fig. 7: Check-list for building assessment

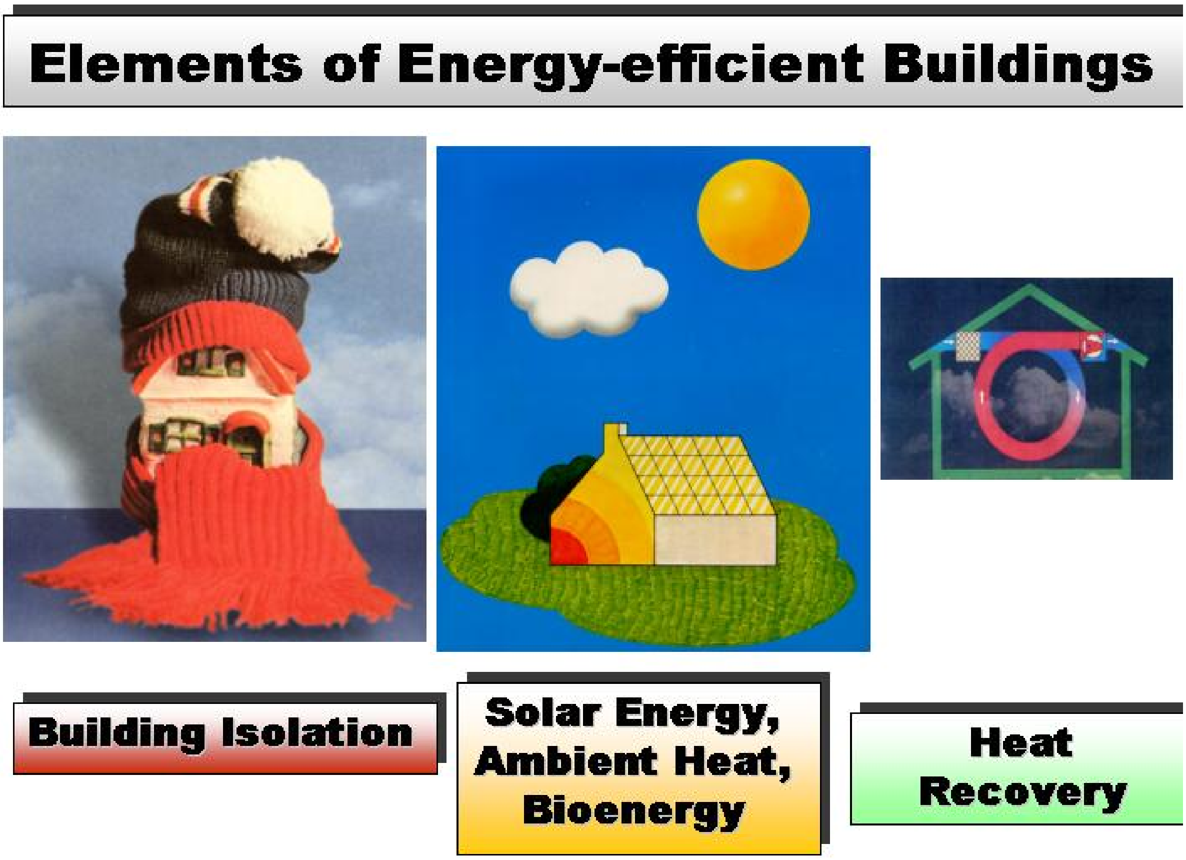
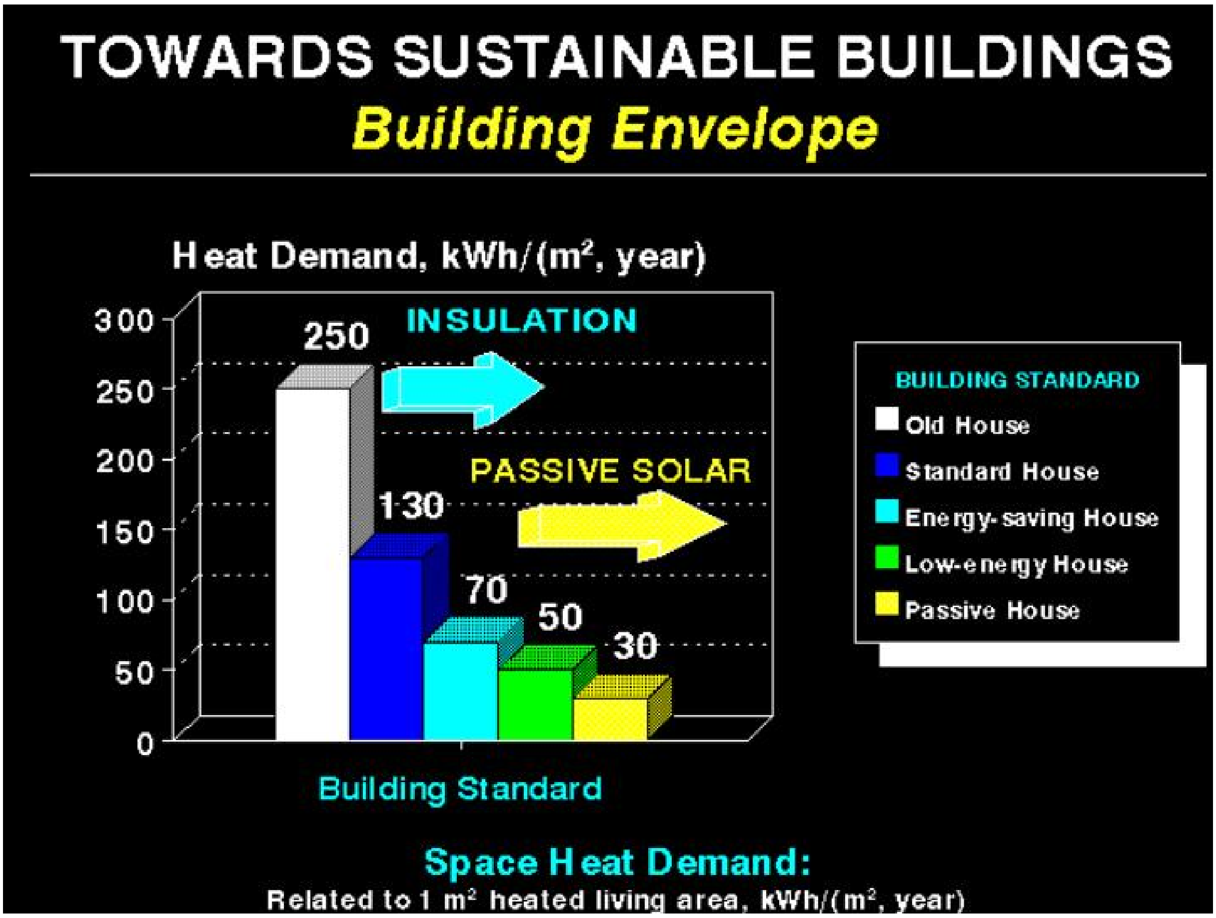


Fig. 8: Elements of energy-efficient / sustainable buildings



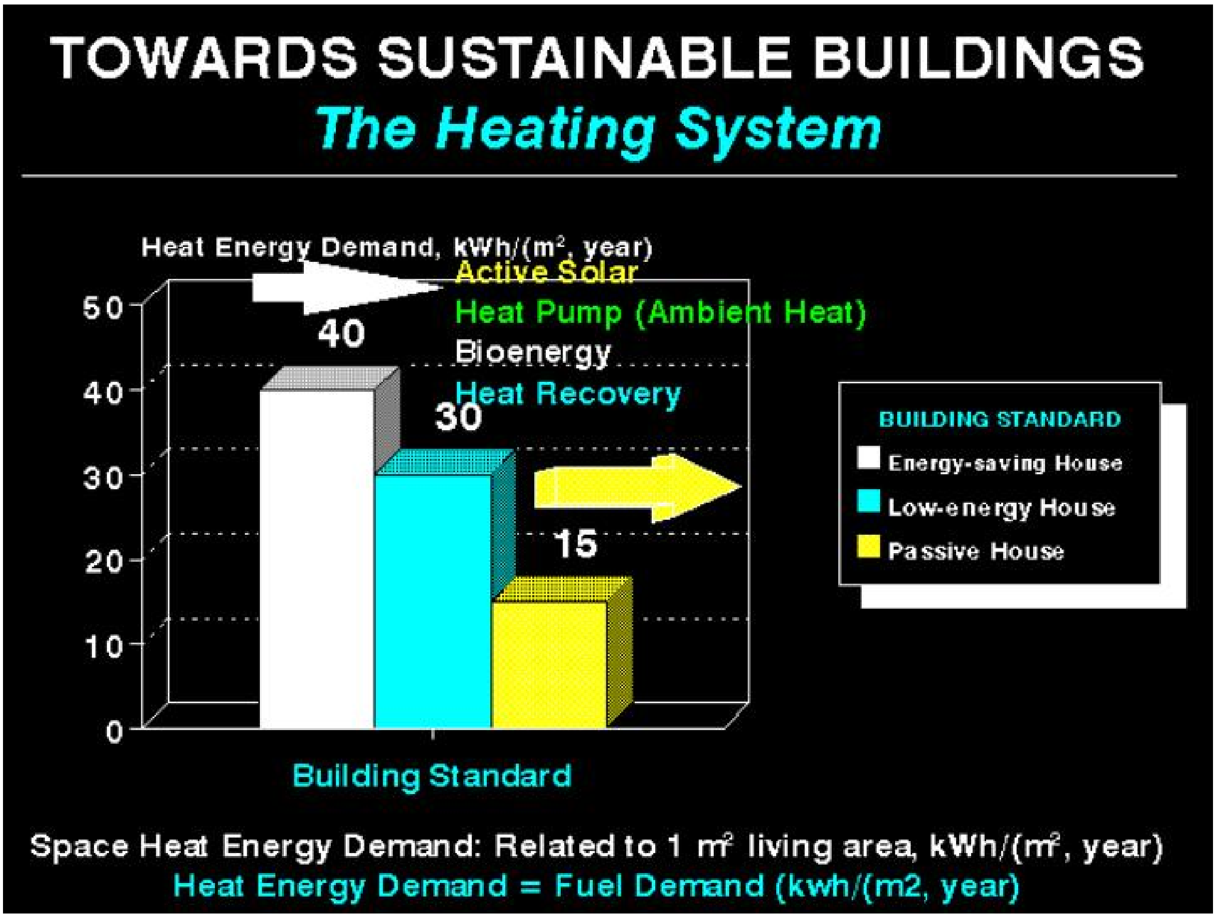


Fig. 9: Ways to design sustainable buildings

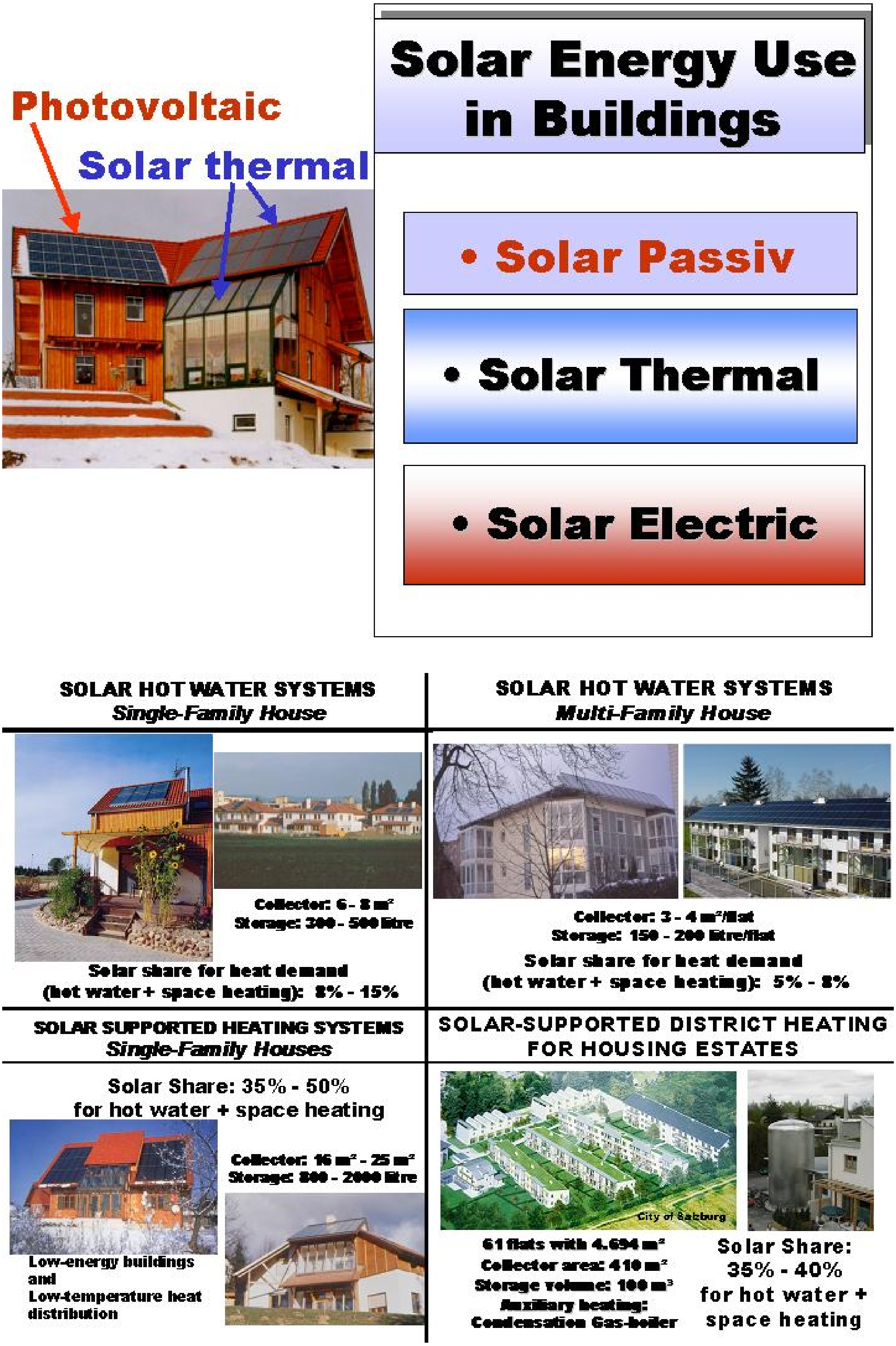


Fig. 10: Solar energy utilisation in buildings

Fig. 11: Façade collectors

Fig. 12: Pellets boilers

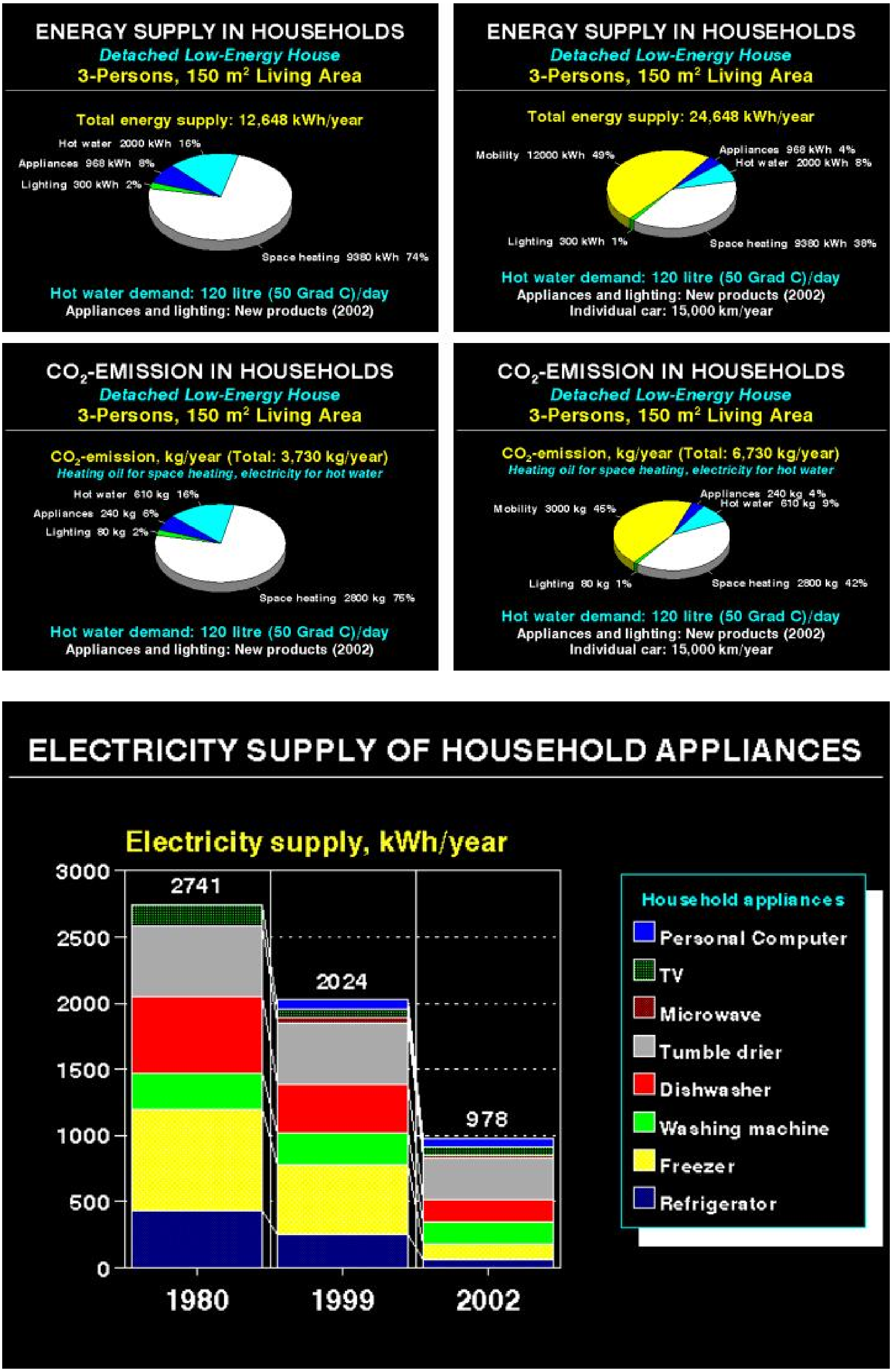


Fig. 13: Energy supply in households

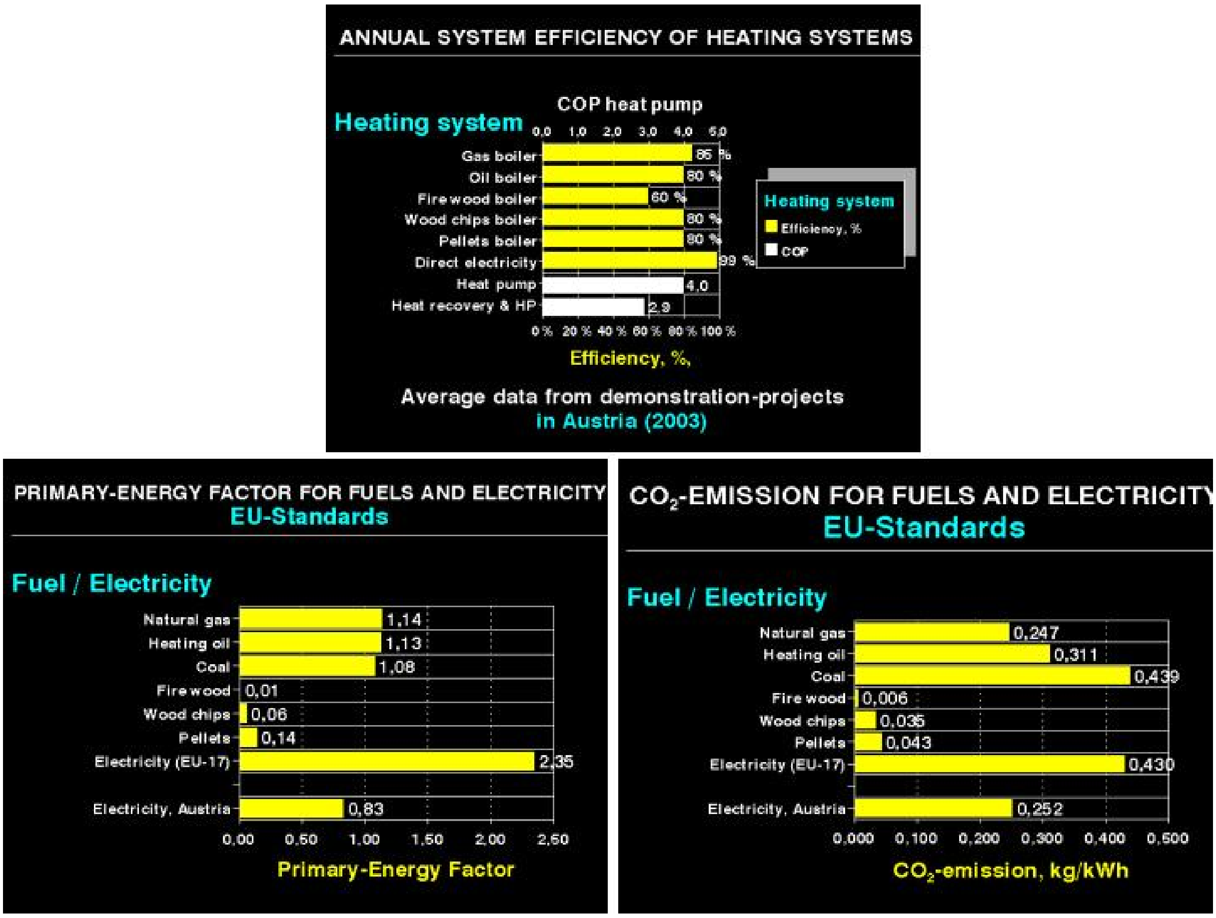


Fig. 14: Characteristically data for the assessment of buildings

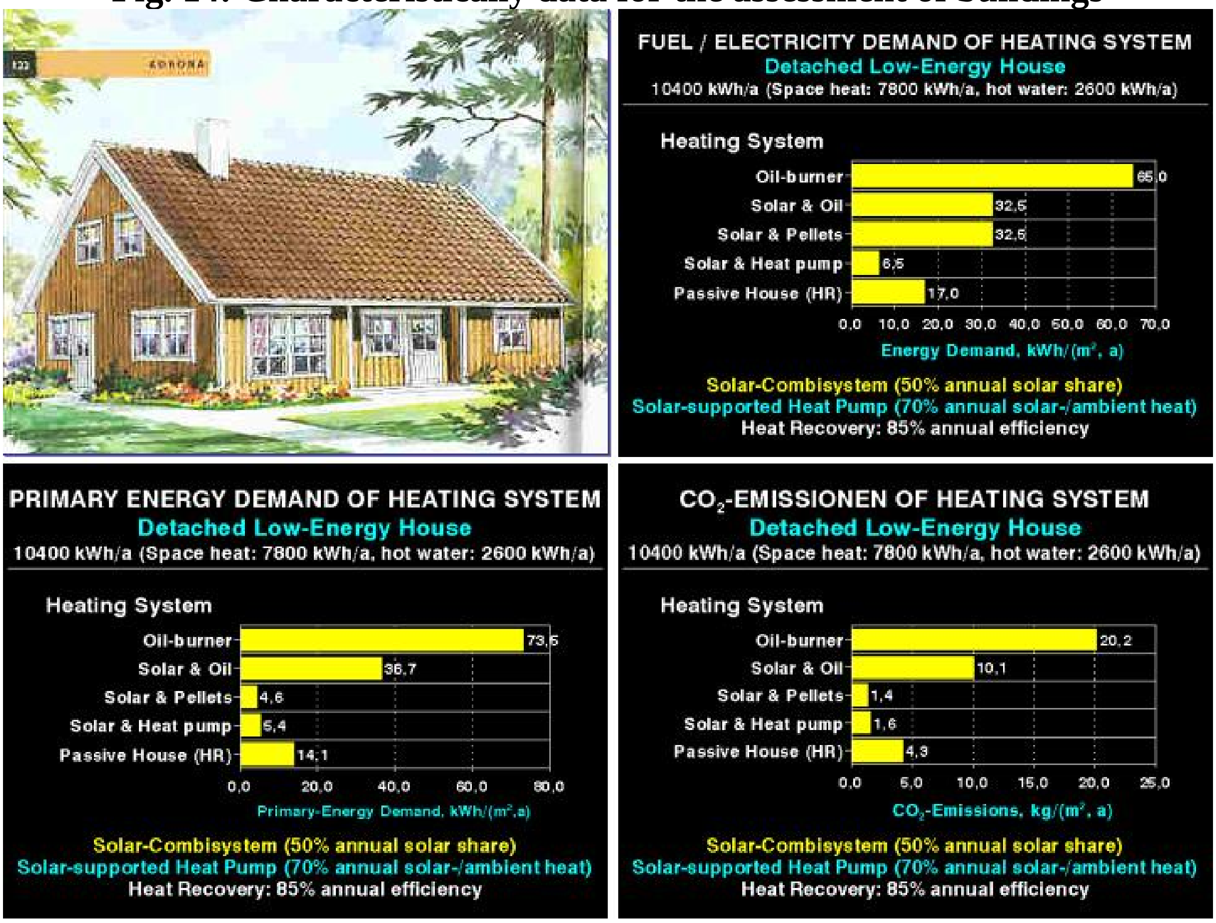


Fig. 15: Energetic and environmentally assessment of buildings

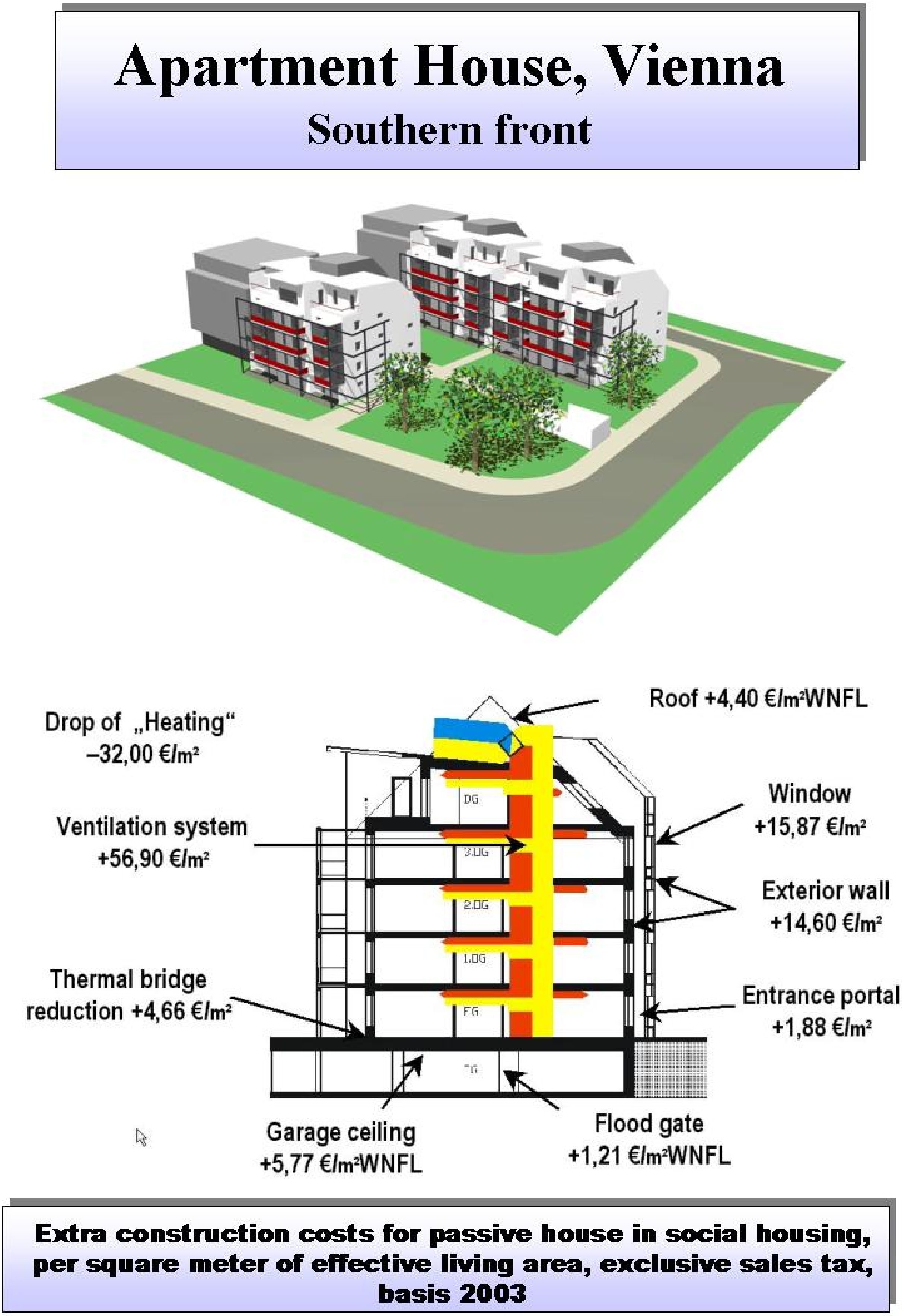
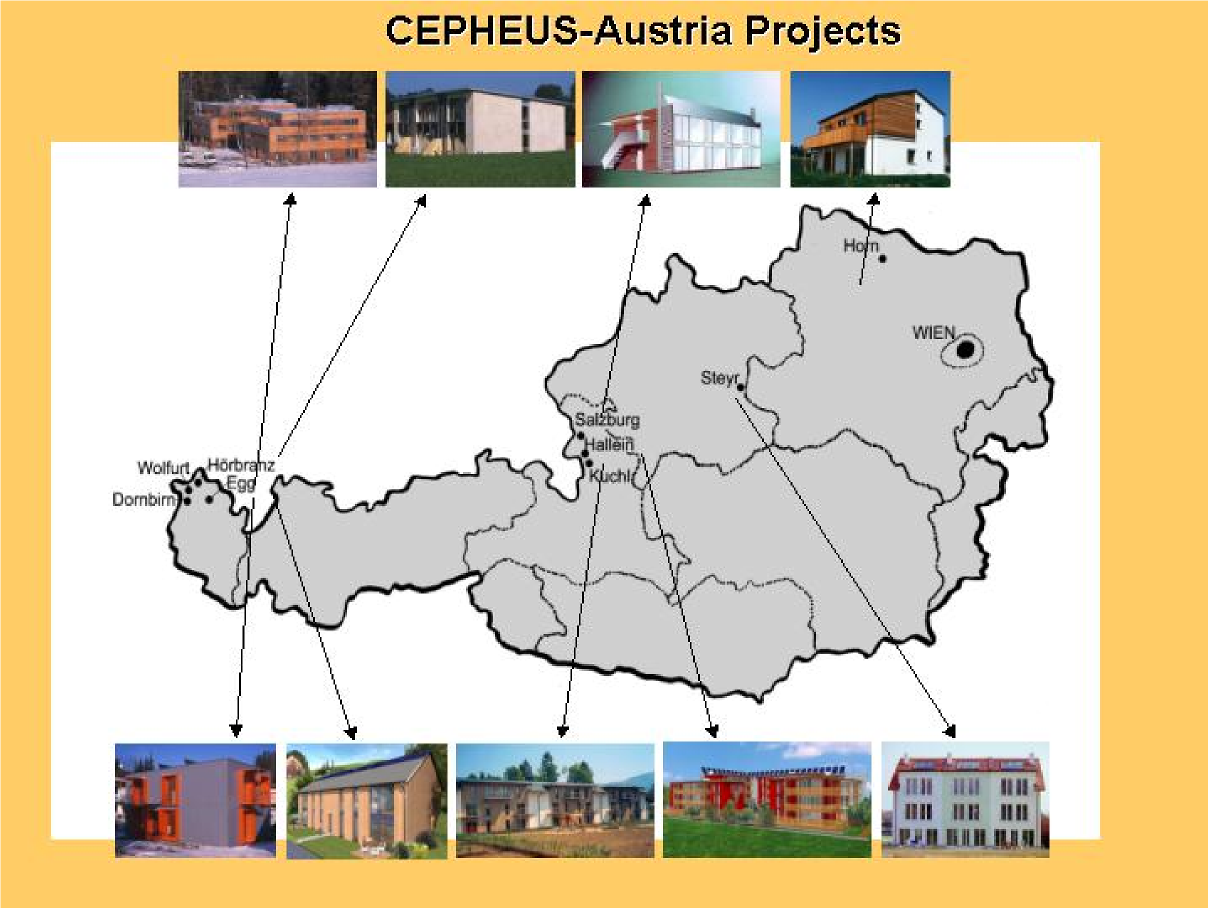


Fig. 16: Constructional extra costs for the passive house standard /4/



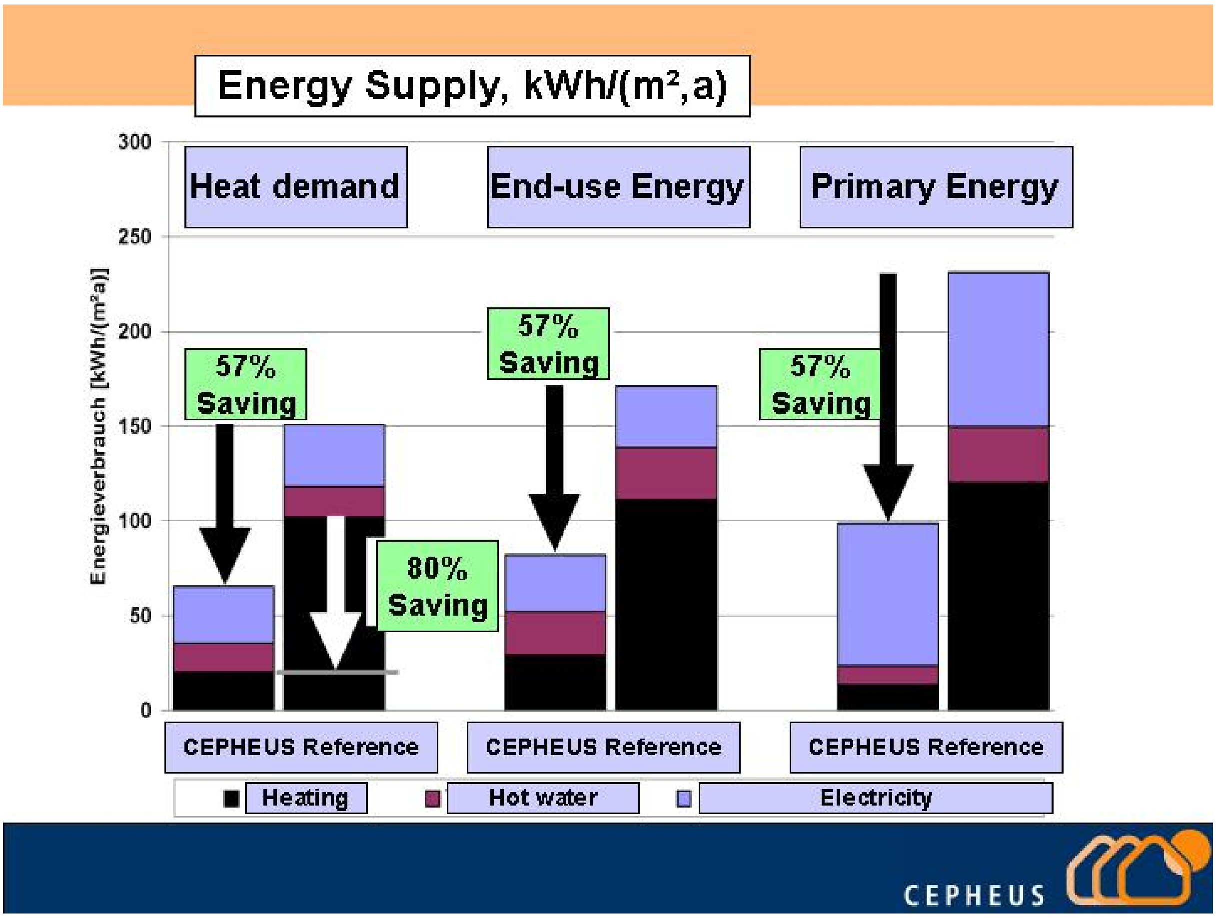


Fig. 17: Results of the research programme CEPHEUS /5/

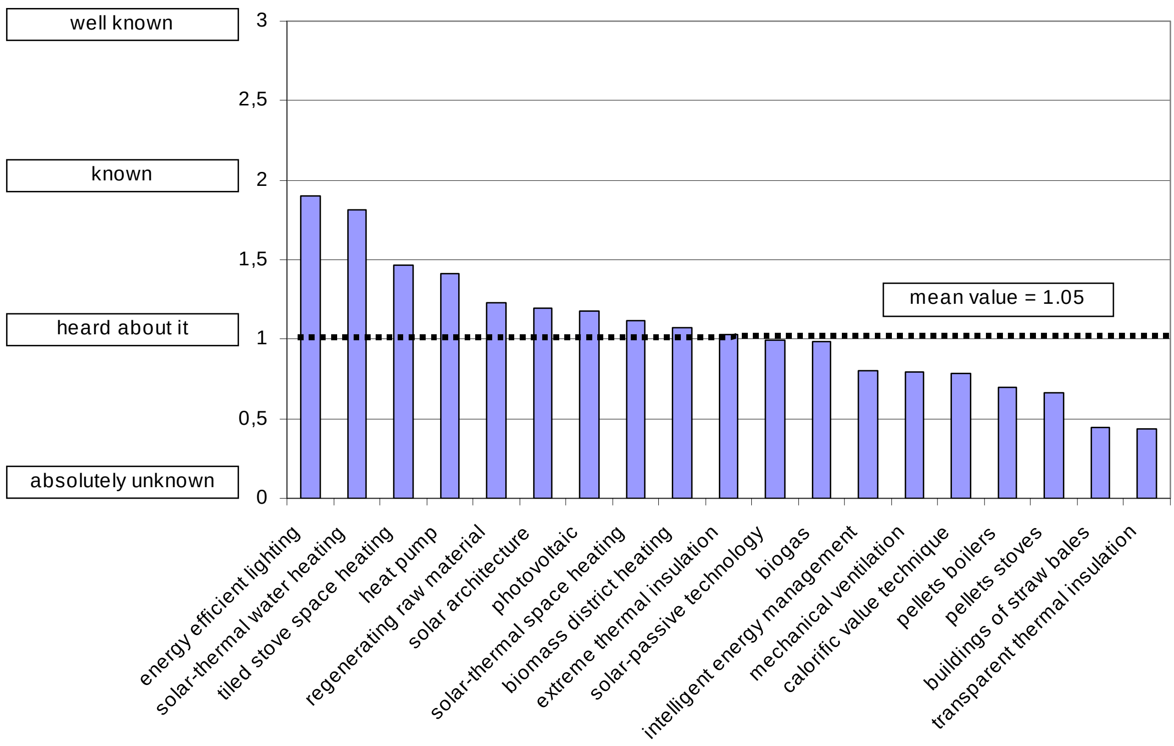
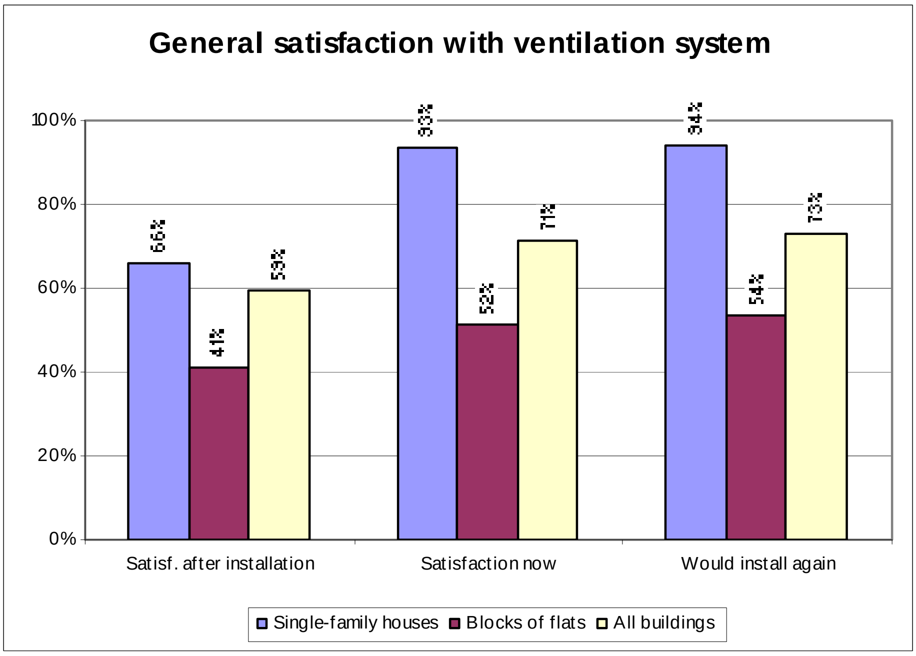
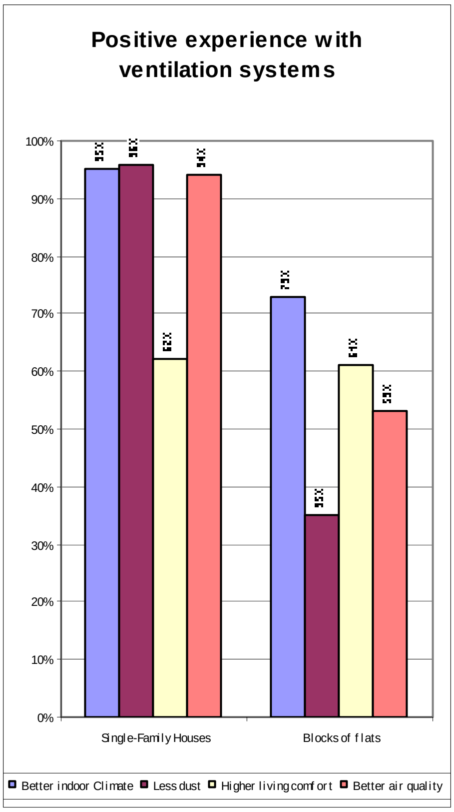
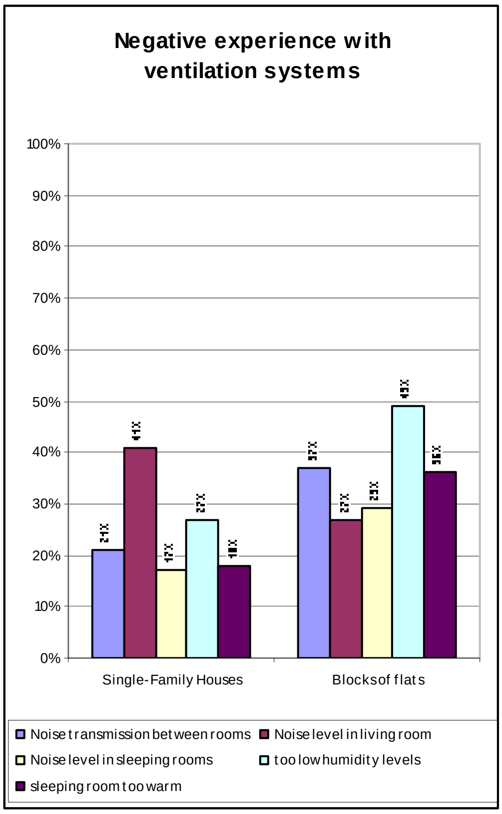


Figure 18: Name recognition rating concerning innovative technologies (n=212)







POSITIVE EXPERIENCE WITH VENTILATION SYSTEM				
Age of system	**Good indoor climate**	**Less dust**	**Higher living comfort**	**Better air Quality**
less than 1 year (n=35)	97%	70%	97%	97%
1 to 3 years (n=22)	100%	63%	85%	94%
3 years and older (n=20)	78%	57%	83%	81%

Experiences with ventilation system in relation to age of product

Fig. 19: User acceptance of balanced ventilation systems in residential low-energy buildings in Austria