# DEVELOPMENTS WITHIN BUILDING TECHNOLOGY & HEATING SYSTEMS IN AUSTRIA

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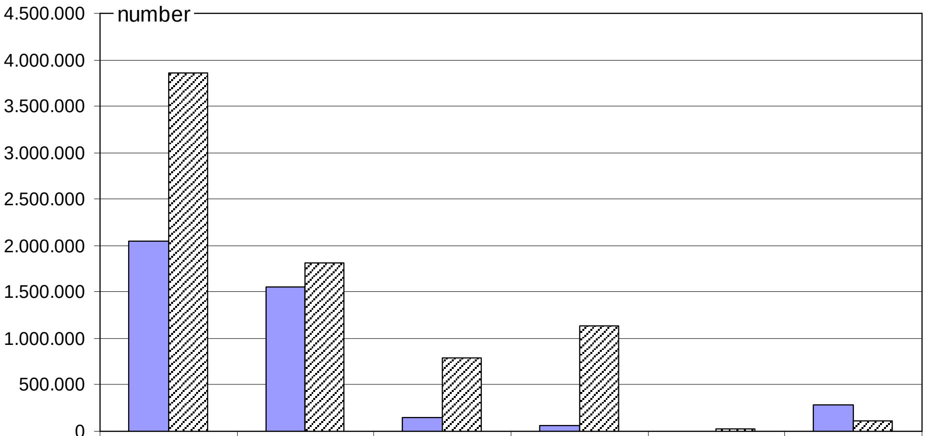
## Introduction

This paper gives an overview of the development and the current situation concerning the building stock and the heating demand of buildings in Austria. Furthermore, figures about the Austrian heat pump market and relevant R&D activities in the field of heat pump technologies are presented. These results are based on the work that was done in Task 1 of Annex 32 “Economical heating and cooling systems for low energy houses” within the Heat Pump Programme (HPP) of the International Energy Agency (IEA) (Heinz et al. 2007).

## The Austrian building stock

The Austrian building stock consists of about 2.05 million buildings (3.9 million dwellings). It is dominated by about 1.56 million one family houses or semi detached houses. This category, called buildings with “one or two dwellings” represents 76 % of all buildings in Austria. Nearly the half (47 %) of all Austrian dwellings can be related to this category. About 50 % of the dwellings are in buildings with “three to ten dwellings” and in buildings with “eleven or more dwellings”. The rest of the dwellings belongs to the category “for associations“ or to the category “non-residential buildings”. As shown in Figure 1 the number of non-residential buildings is one order of magnitude smaller than the number of residential buildings (Statistik Austria, 2006).




| | total | 1 or 2 dwellings | 3 to 10 dwellings | 11 or more dwellings | for associations | non-residential buildings |
|---|---|---|---|---|---|---|
| building | 2.046.712 | 1.557.420 | 142.351 | 61.196 | 3.488 | 282.257 |
| dwelling | 3.863.262 | 1.809.380 | 791.584 | 1.134.782 | 21.663 | 105.853 |

Figure. 1: The Austrian Building Stock classified according to the main use (Statistik Austria, 2006)

## Steady rise of the floor area per capita and the number of buildings and apartments

The average useful floor area, which is available for every inhabitant in Austria, and also the average number of apartments per capita have been increasing for the last decades. According to the last building and apartment count in 2001 an average useful floor area of 38.2 m² was available for each inhabitant (see Figure 2).

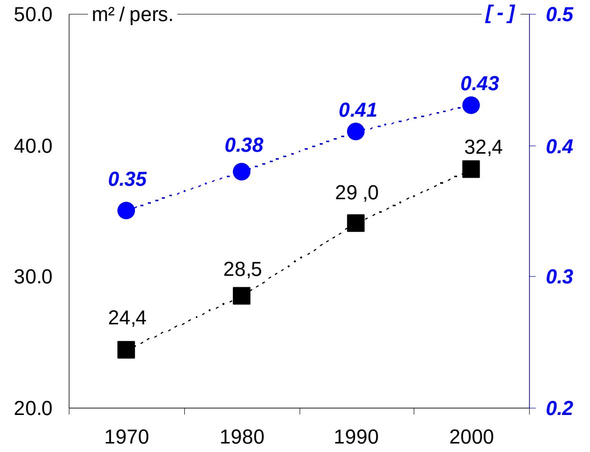


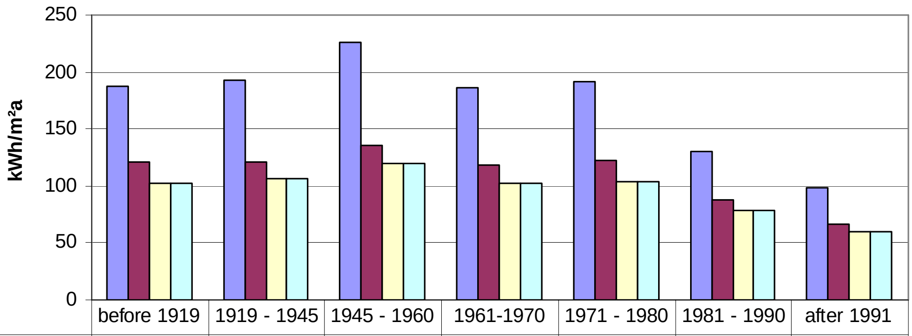

Figure 2: Development of the apartments per capita and the mean floor area per capita in the Austrian building stock

In the period from the year 1991 to the year 2001 there has been an enormous enlargement of the Austrian building stock. In the year 1991 there have been about 1.81 million buildings in Austria. Until the year 2001 this number raised up to about 2.05 million buildings (increase of 13 %). This development of course had an effect on the number of apartments. The number of apartments increased from about 3.39 million apartments in the year 1991 up to 3.86 million apartments in the year 2001 (increase of 14 %). All over Austria there have only been ten counties in which the number of apartments increased by less than 10 % (Statistik Austria, 2004).

## Space heating energy demand of Austrian Buildings

The energy demand for space heating (useful energy) of residential buildings is dominated by buildings with one or two dwellings. The share of the energy demand of multi dwelling buildings is 37 % although about 50 % of all dwellings are located in multi dwelling buildings. This is due to the higher ratio of volume to surface area (compactness) and therefore far less specific energy demand and smaller dwelling size. The average dwelling size for buildings with one or two dwellings is 113 m² floor area per dwelling compared to 70 m² floor area per dwelling for buildings with more than two dwellings (Wirtschaftskammer Österreich, 2006).

The evolution of the energy demand of buildings over the building age is similar for many middle European countries. As shown in Figure 3 buildings with one dwelling built in Austria before 1945 have a specific useful energy demand for space heating per m² of heated floor area of about 190 kWh/(m²a). For dwellings built between 1945 and 1960 this value is 230 kWh/(m²a) (Wirtschaftskammer Österreich, 2006). This period was the time of fast and cheap production of living space after the Second World War. Since then the specific energy demand of buildings steadily decreased due to the first oil price shock in the end of the 1970s. This development was enabled by the availability of more effective insulation materials and advanced window technology, supported by a growing environmental concern. For buildings built after the year 1991 the useful heating demand is in the range of 100 kWh/(m²a), which is already less than half of the values of the period from 1945 to 1960. For multifamily buildings the value was already 60-70 kWh/(m²a) in 1991. The trend is in the direction of even far lower values. With current (2006) building codes and subsidy schemes values of about 50-60 kWh/(m²a) for single (and two) dwelling buildings and 40-50 kWh/(m²a) for multi dwelling buildings are achieved. Houses built according to the Passive house concept (see below) show that the space heating demand can be decreased to 15 kWh/(m²a). The requirements to reach such small heating demands are an optimal thermal insulation of the building envelope and an effective mechanical controlled ventilation using air heat recovery. Thus the energy demand of new buildings decreased drastically in the last 50 years (Wirtschaftskammer Österreich, 2006).




| | before 1919 | 1919 - 1945 | 1945 - 1960 | 1961-1970 | 1971 - 1980 | 1981 - 1990 | after 1991 |
|---|---|---|---|---|---|---|---|
| SFH | 188 | 193 | 226 | 186 | 191 | 130 | 99 |
| MFH-S | 121 | 121 | 136 | 118 | 122 | 88 | 67 |
| MFH-B | 103 | 106 | 120 | 103 | 104 | 78 | 60 |
| NRB | 103 | 106 | 120 | 103 | 104 | 78 | 60 |

Figure 3: Space heating energy demand per m² heated floor area (useful energy) of single and (two) dwelling buildings (SFH), multi family buildings (MFH, MFH-S: small MFH, MFH-B: large MFH) and non- residential buildings (NRB) in Austria classified by the building age (Wirtschaftskammer Österreich, 2006), Original data source: Jungmeier, et al. (1996)

## The Passive House Concept

The passive house concept is seen as one of the most favourite building concepts for the near future in Austria. The definition of a Passive House is: "A Passive House is a building, for which thermal comfort (ISO 7730) can be achieved solely by postheating or postcooling of the fresh air mass, which is required to fulfill sufficient indoor air quality conditions (DIN 1946) - without a need for recirculated air" (Passive House Institute, 2007).

The term “passive house” was implemented in different federal directives for the granting of subsidies. Although the fraction of passive houses in the total building stock is still very small, the number of houses built according to the passive house standard has increased strongly during the last 10 years (see Figure 4). A special organisation, the IG Passivhaus, cares for the further spread of the passive house in Austria. In the year 2006 there have been more than 1600 documented buildings obtaining the objectives of the passive house concept (calculated values) (IG Passivhaus, 2007). The whole building stock contains about 300 million m², 1 million m² in passive houses (ca. 0.3 %). Other concepts like e.g. the “plus energy house” or the “zero energy house” do exist but are not promoted.

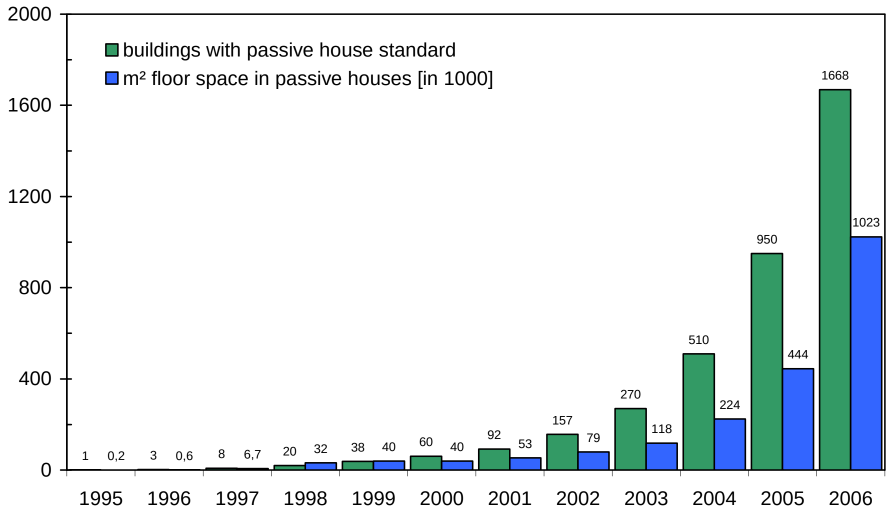



Figure 4: Development of the building stock achieving the goals of the passive house standard (IG Passivhaus, 2007)

## Used energy sources for heating

Space heating and the preparation of domestic hot water account for about one third of the final energy consumption in Austria. Figure 5 shows the energy sources that are used for heating in Austrian dwellings.

A comparison of the heating period 1996/97 and 2001/02 shows a significant reduction of about 50% of the dwellings heated with coal. There was also a reduction of electrical energy (-16.6%) and wood (-4.5%). The use of oil and particularly gas (+24%) and district heating (+41%) has increased strongly. Gas is the energy source with the highest share in this sector since the heating period 1999/2000.

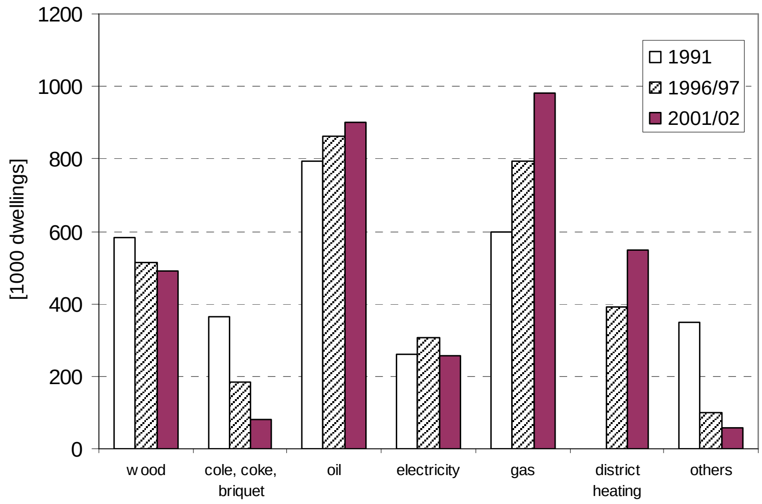



Figure 5: Energy sources used for heating in Austrian dwellings (Remark: In 1991“others” includes “district heating”) (Energiebericht 2003, Statistik Austria, 2004)

# The Austrian Heat Pump Market

The Austrian heat pump market started after the second oil price shock, stimulated by tax reduction measures for energy saving investments by the Austrian government and supported mainly by the Upper Austrian Energy Corporation (OKA). After reaching a peak in installations the market collapsed, was stabilised on a lower level, dropped again and is now recovering, as it can be seen in Figure 6. This figure shows the evolution of the number of annually installed systems over the years parted into four applications: indoor pool dehumidification, ventilation, heating and domestic hot water preparation. It can be seen that in the first 25 years the main part of installed systems were for domestic hot water preparation. In the last 5 years the number of installed systems for heating is increasing while the number for domestic hot water preparation is nearly constant. Also the fraction of ventilation systems is increasing due to the application in passive houses.

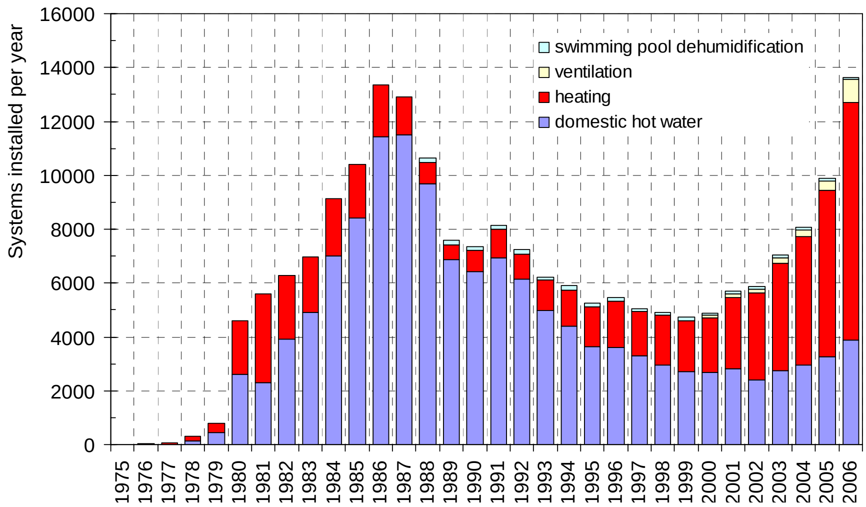



Figure 6: Heat pump market in Austria 1975-2006, systems installed per year (Faninger, 2006)

Figure 7 shows the evolution of the fractions of heat sources used for heat pumps from 1989 to 2005 in Austria. The preferred heat source is the ground. Used heat exchangers include horizontal ground collectors (depth 1.2 to 1.8 m), ditch collectors (depth 2 m) or probes (depth up to 150 m). For horizontal collectors both brine and direct expansion systems are used (see the market shares in Figure 8).

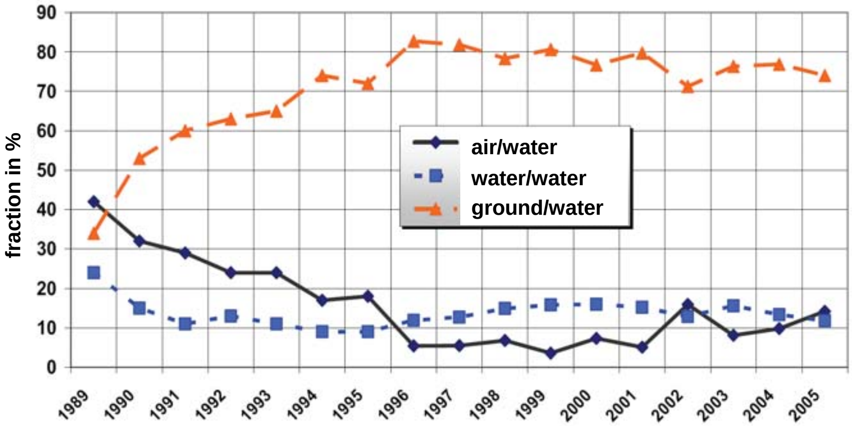



Figure 7: Fractions of used heat sources for heat pumps used in space heating systems in Austria from 1989-2005 (Faninger, 2006)

In 2004 the main share of heat pumps were brine/water systems (52 %). Nevertheless, there is also a share of about 22 % of direct expansion systems installed. For these systems a higher SPF can be achieved due to the fact that the working fluid is used directly as the heat carrier from the ground to the heat pump. The decrease of the fraction of direct expansion systems in the last years (see Figure 8) is caused by the circumstance that there are more brine/water systems available on the market, and advantages with respect to the installation at the site.

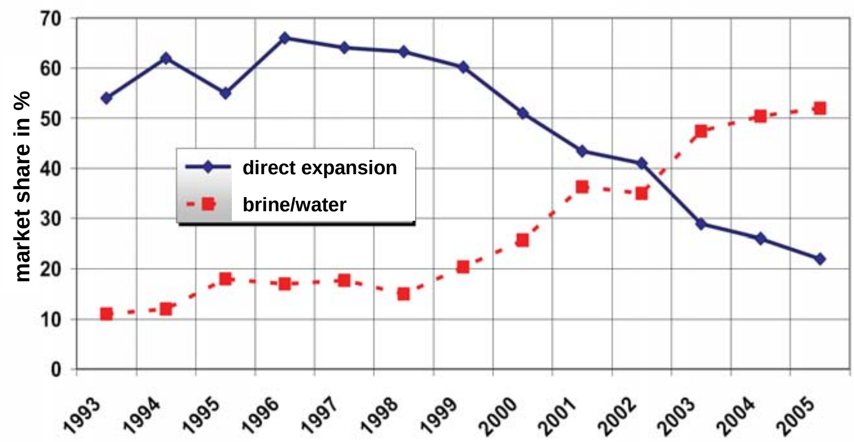



Figure 8: Ground coupled heat pump systems - market shares of direct and indirect (brine/water) systems for space heating in Austria from 1993-2005 (Faninger, 2006)

## Heat Pump Research / Systems under development

In Austria several companies and research institutes work on the improvement of heat pump systems. For example, at the moment following topics are focused on:

a) Reduction of the supply temperature

b) Speed control of ground coupled heat pumps

c) $CO_2$ as heat carrier

d) Alternative heat sources

ad a) Reduction of the supply temperature

In Austria an increasing share of ground-coupled heat pump systems is in operation with SPFs of 4 and higher. These SPFs sound great and everybody expects a highly sophisticated design of the heat pump units used in these installations. But the explanation for these high SPFs is relatively simple: it is the approach to consider the complete system consisting of the building, the heat distribution system, the heat pump and the ground coil, linked by the system control in a way that optimum efficiency as well as comfort can be achieved for the consumer. This is a result of improved compressors, properly sized ground coils and low-temperature hydronic heat distribution systems with design temperatures of 35°C (at a typical design temperature of -12°C), which is possible in houses with specific heat loads lower than 60 W/m$^2$ in combination with a floor heating system. Nowadays, one can see the tendency to further reduce the supply temperature (below 30°C, "ultra-low-temperature" heat distribution systems) which results in a higher SPF. Of course, this demands relatively large heat transfer areas as well as low heat loads, i.e. low-energy buildings.

ad b) Speed controlled compressors for ground coupled heat pumps

Usually ground coupled heat pumps have an on/off capacity control, i.e. the heating capacity of the heat pump – when it is running – is almost constant during the heating season. A variable speed compressor helps to match better the heat demand of the building (compare Figure 9). This may result in a reduced electricity consumption and a higher SPF.

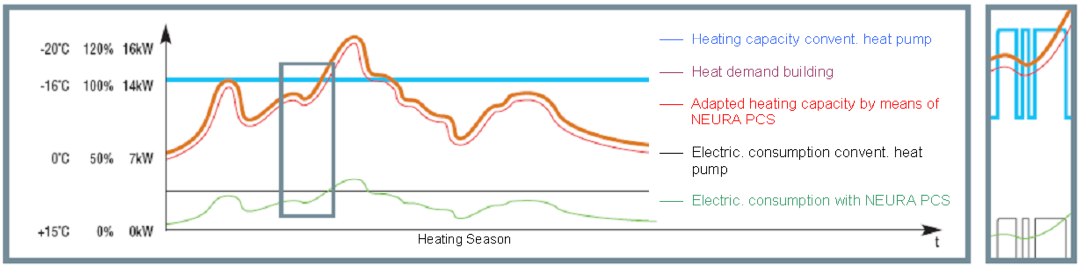



Figure 9: Neura PCS- Power Control System (source: http://www.neura.at/download_de/WP_Europa.pdf)

ad c) $CO_2$ as heat carrier

In principal two heat source systems for ground coupled heat pumps are used (see above): direct expansion (evaporation) systems, in which the refrigerant evaporates directly in the ground heat exchanger, and secondary loop systems, with brine as the heat carrier from the ground to the heat pump. However, the former systems have been discussed to be harmful to the environment in the case of leakage and the latter ones demand an electrically driven circulation pump which reduces the SPF.

A small Austrian company developed – in close cooperation with the Institute of Thermal Engineering – a $CO_2$ probe based on the closed two-phase thermosyphon principle as alternative to brine based systems (compare Figure 10).

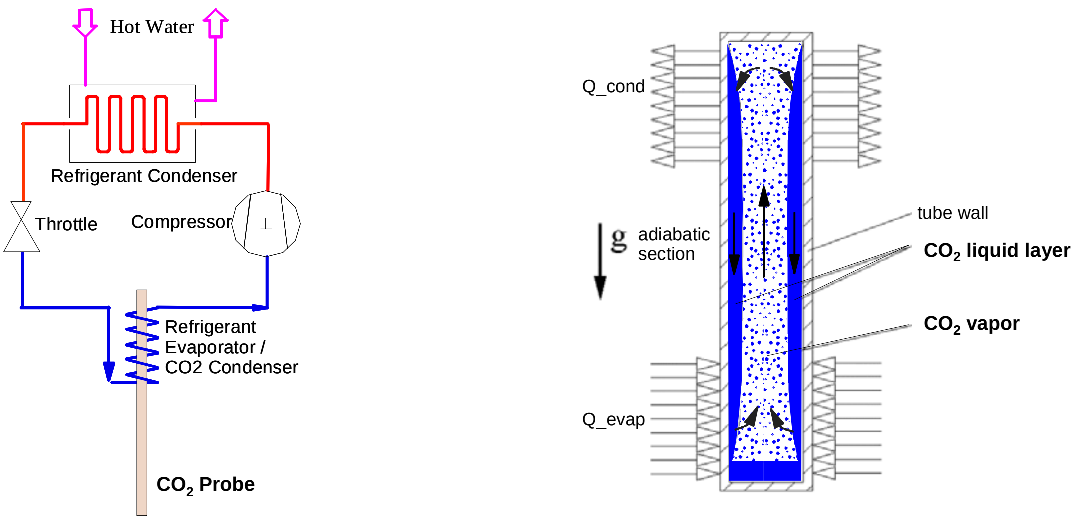



Figure 10: System layout (left) and working principle of a $CO_2$ probe, i.e. closed two-phase thermosiphon (right)

The market introduction of the $CO_2$ probe took place in the year 2001 and up to now some hundred systems have been installed. If one compares these systems with brine systems following advantages can be summarized:

- the self-circulation (instead of forced circulation by a pump) leads to a reduction of the electricity consumption and potential defects of the pump are eliminated,
- $CO_2$ offers favourable heat transfer characteristics (phase change at almost constant temperature and high transfer coefficients), and
- last but not least $CO_2$ is absolutely harmless to the ground in the case of a leakage.

More information about $CO_2$ probes can be found in Rieberer (2005).

The advantages listed above as well as the successful market introduction of the $CO_2$ probe initiated research activities on a “$CO_2$ collector”. The $CO_2$ collector is also based on the thermosyphon principle and shall be used as horizontally installed heat source system for ground-coupled heat pumps. For the first analysis of the suggested system a test rig has been designed and constructed at the Institute of Thermal Engineering. The R&D work is still going on.

ad d) Alternative heat sources

A development by the Austrian company “PREFA Aluminium Products” (Schranzhofer and Streicher, 2006) uses an aluminium roof where drained water is preheated and used as the heat source of a heat pump for space heating and the preparation of domestic hot water. The whole roof area is used as a solar panel, whereby the gained low–temperature energy is stored in an underground rainwater cistern. This storage is designed as an ice storage and supplies the closed heating circuit of the building via a heat exchanger and a connected heat pump. The system is currently being developed for residential buildings and will, in a second step, be extended to industrial buildings. The new system should also provide the possibility of being mounted on already existing buildings.

## Conclusions and Outlook

In Austria with current building codes (2006) and subsidy schemes space heating demands of 50-60 kWh/(m²a) for newly built single (and two) dwelling buildings and 40-50 kWh/(m²a) for multi dwelling buildings are achieved. Furthermore, more than 1600 passive houses with a heating energy demand < 15 kWh/(m².a) are already built and a further growth is expected for the next years. The heat pump market is also increasing in Austria, especially in the application of space heating.

The R&D acitivities concerning heat pumps focus on $CO_2$ as natural refrigerant, alternative heat sources, speed control of compressors and the reduction of the supply temperatures of space heating systems in order to achieve higher SPFs.

In the framework of IEA HPP Annex 32 integrated heat pump systems for the low-capacity range of 3-5 kW - adapted to the heating needs of low energy houses - are analysed at the Institute of Thermal Engineering. The work comprises an evaluation of different refrigerant cycles with different refrigerants, among others $CO_2$, which will deliver the best refrigerant choice for the low capacity application. Another boundary condition for the choice of the system is the availability of components on the market. A prototype of the most favourable layout will be constructed and tested in the laboratory.

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