IEA HPP ANNEX 32: ECONOMICAL HEATING AND COOLING SYSTEMS FOR LOW ENERGY HOUSES

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Abstract: Annex 32 in the Heat Pump Program (HPP) of the International Energy Agency (IEA) is dedicated to the application of multifunctional, highly-integrated heat pump systems in low energy houses. Nine countries are co-operating in the Annex 32 to assess and to foster heat pumping technology for the application in residential low energy houses. The projected research work comprises prototyping and lab-testing of new heat pump developments, redesigns of existing units to low energy house requirements, system simulation including the control as well as field monitoring to optimise systems with regard to energy consumption, comfort and cost. Expected deliverables of IEA HPP Annex 32 are concluding design guidelines for the different applications. Moreover, IEA HPP Annex 32 will yield a documentation of the field-monitored systems as optimised best practice solutions with additional information on monitoring techniques and operation control concepts. The paper presents the current state of low energy buildings and respective system technologies with heat pump application and an overview and interim results of the national research contributions to IEA HPP Annex 32.

Key Words: ***multi-functional heat pump systems, low energy houses, field testing***

1 INTRODUCTION

In many countries, the energy consumption of buildings accounts for 40 - 50% of the total energy consumption. Thus, low energy houses with considerably reduced energy consumption are a key strategy to achieve climate protection targets.

Since the mid of the 90ties, the energy consumptions of new buildings were successively lowered by introducing more stringent legal requirements for the space heating energy needs in building codes and directives. This led to the development of buildings with significantly reduced space heating needs down to about 15 kWh/(m^2·a) in houses according to the German passive house standard (http://www.passiv.de). In these houses, the domestic hot water (DHW) heat requirement can reach up to half of the total heat energy requirement. Therefore, the building technology has to be adapted also to the specific requirements of these low- and ultra-low energy houses in order to guarantee an efficient operation and maximise the possible reduction of CO_2-emissions. In fact, system solutions for low energy houses have already been established in some national markets, but developments are not finished, yet.

Annex 32 in the Heat Pump Program (HPP) of the International Energy Agency (IEA) entitled "Economical heating and cooling systems for low energy houses" started in 2006 with the participating countries Austria, Canada, Germany, Japan, the Netherlands, Norway, Sweden, Switzerland (operating agent) and the USA in order to support the further development of heat pump systems for the use in low- and ultra-low energy buildings and to prove the feasibility of new developments.

The objectives of the IEA HPP Annex 32 comprise

- Development of components with an enhanced performance including the highly efficient auxiliary drives suitable for the capacity range of low energy buildings
- Improved system integration in multifunctional layouts, e.g. simplifications of the hydronic layout, the integration of additional functionalities, e.g. space cooling or de-/humidification, leading to robust operating standardised system solutions. This includes new system designs, too.
- Approved functionality and performance factors derived from real-world operation by field testing. The field monitoring yields optimisation potentials of new and marketable system solutions, as well.

2 LOW ENERGY BUILDINGS

2.1 Principles

The principles to achieve low heat requirements of a building are the same in all participating countries. Basically two directions exist: The minimisation of thermal losses and the maximisation of solar gains (passive solar design). Most buildings are a compromise between these two directions.
For the minimisation of thermal losses, the insulation layers of the building are substantially increased up to a thickness of 40 cm with conventional thermal insulation materials (thermal conductivity of 0.04 W/(m·K)). Ventilation losses can be effectively reduced by the air-tightness of the buildings which is approved by blower door testing (typically 0.6 h^{-1} air change at 50 Pa pressure difference). The necessary hygienic air exchange rate is guaranteed by a mechanical ventilation system with heat recovery at a temperature change coefficient of typically 0.8.
On the other hand, larger south-oriented high-quality glazing is integrated in the façade in order to maximise the passive solar gains. For the comfort in summertime, adequate sun protection measures and a reduction of internal thermal gains are required. However, due to growing glazing fractions and higher comfort demands, comfort cooling and air-conditioning become more and more an issue not only in commercial, but also in residential dwellings.

2.2 Markets

In some European countries the markets for low energy houses are already in the growth phase.
Figure 1 shows the development of subsidised houses of the Kreditanstalt für Wiederaufbau (KfW - http://www.kfw.de) in Germany and passive houses in Austria. The KfW as German governmental bank has subsidy programs for energy efficient houses. In Germany, there are ~15’000 ultra low energy houses, which comprise ~5’000 passive houses with a space heating requirement < 15 kWh/(m^2·a) and ~10’000 KfW40 houses with the requirement of a primary energy consumption for space heating and DHW < 40 kWh/(m^2·a). Moreover, about 40’000 low energy houses according to the KfW60 requirements (primary energy consumption for space heating and DHW < 60 kWh/(m^2·a)) have been built since the beginning of the millennium (state mid of 2007).
In Austria, the number of built residential passive houses has reached about 1’700 in 2006 with strong increase, see Figure 1 right.
In Switzerland, already about 30% of all new buildings comply with the requirements of the voluntary building label MINERGIE® (http://www.minergie.ch) which defines a good low energy house. Half of these are actually certified according to this label (~8’500 installed dwellings, state 2008). Ultra-low energy houses according to the MINERGIE-P® standard and retrofitting to the MINERGIE® standard are still niche markets. In Norway, a growth from 2’000 low- and ultra low energy houses in the year 2006 to 10’000 in 2007 took place including building in the design and construction phase.

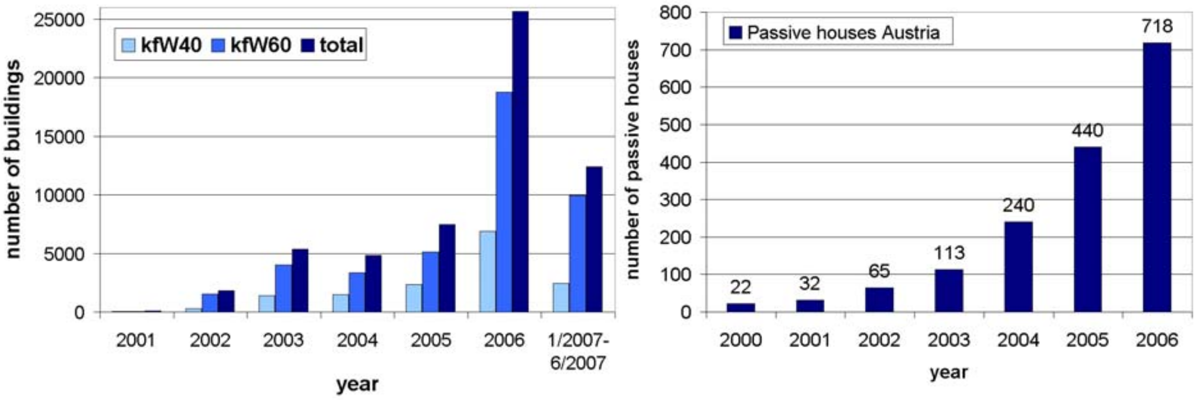


Figure 1: Development of KfW houses in Germany (left) and passive houses in Austria (right)

Other European countries like the Netherlands and Sweden are rather in the market introduction phase.

3 BUILDING TECHNOLOGY IN LOW ENERGY BUILDINGS

Due to reduced heat loads and thereby lower temperature requirements, low energy houses are well suited for system technology which uses low supply temperatures. This is advantageous for the efficient use of heat pumps and solar thermal systems. Actually, in Swiss low energy houses according to the MINERGIE® standard, ~80% of the installed systems for space heating and DHW are based on heat pumps, wood or solar thermal (the latter mainly for DHW operation). In Switzerland, heat pumps established as the standard heating system for new buildings with a market share in single family houses of ~70% in the year 2006.

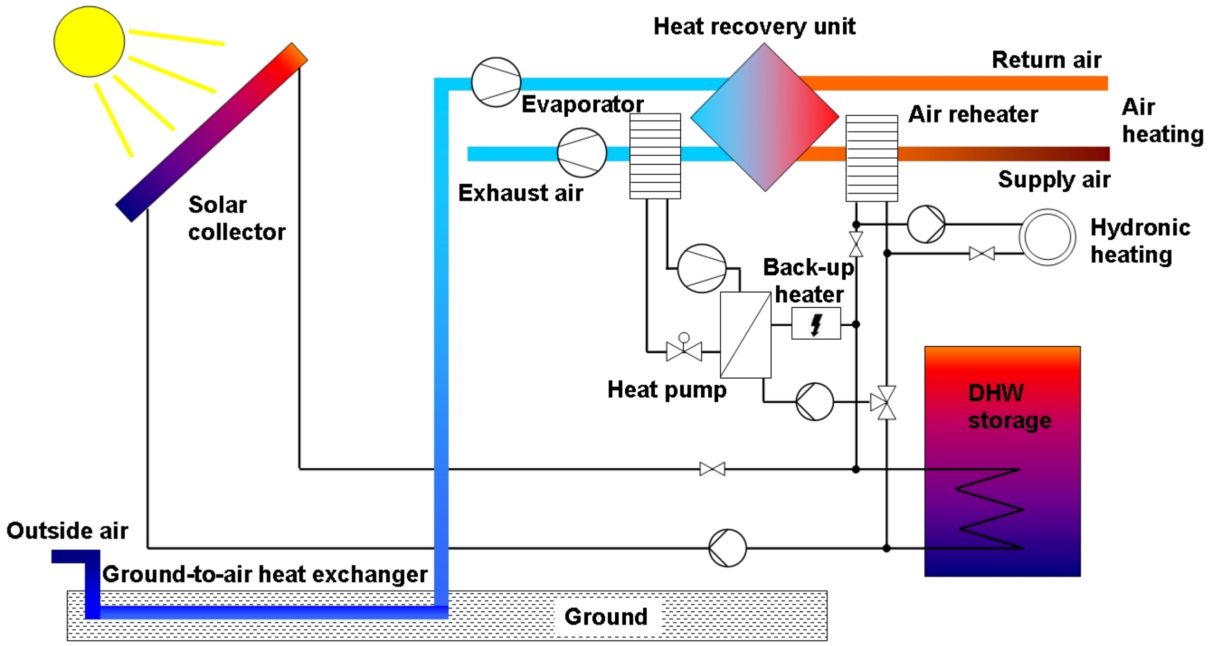


Figure 2: Principle of highly-integrated ventilation compact units with exhaust air heat pump and optional solar collector and ground-to-air heat exchanger

In Germany, so-called compact ventilation systems with exhaust-air heat pump were introduced into the market for passive houses and have a large market share in single family passive houses. The principle layout of the units is given in Figure 2. The core components of these systems are a heat pump and a DHW storage. In most cases, the heat pump is connected to the exhaust air duct of the ventilation system and extracts further heat of the ven-

tilation system after the heat recovery. The heat is used either to reheat the supply air exiting the heat recovery unit or for a hydronic heating system. Moreover, the DHW is produced by the heat pump, in most configurations in alternate operation, e.g. the space heating operation is interrupted while the heat pump reheats the integrated DHW tank.
Optionally, this system configuration is extended by a ground-to-air heat exchanger, which mainly serves to prevent a frosting of the ventilation heat recovery unit. On the other hand, it can be used for precooling the air in summertime, as well. An additional solar collector is mainly used to support DHW production, even though some system configurations would also allow a solar contribution to the space heating.

4 NATIONAL CONTRIBUTIONS TO IEA HPP ANNEX 32

Table 1 gives an overview of national contributions of the participating countries in Annex 32.

Table 1: Overview of national contributions to IEA HPP Annex 32

Country	Institutions	Focus of work in Task 2/3
AT	IWT/TU Graz	• Development A-A or A-W heat pump for the small capacity range. • Prototyping and lab-testing of the best solution of pre-studies
CA	LTE/Hydro-Québec	• Design, construction, monitoring and optimisation of two EQuilibrium low energy houses for cold climate.
CH	IEBau/FHNW	• Design guidelines of energy efficient heat pump systems for space heating and cooling. • Field test of a heat pump system for space heating and cooling
DE	FhG ISE, Viessmann GmbH	• Field testing of more than 100 state-of-the-art residential heat pumps in co-operation with seven manufacturers and two utilities. • Field test of 70 retrofit heat pumps for replacement of boilers in dwellings with high supply temperature requirements with the German Utility E.ON
JP	University of Hokkaido, TEPCO	• Optimisation of systems for moderate climate regarding the capacity range and part load operation • Feasibility studies and field test of ground-source heat pumps for the cold climate zone
NL	SenterNovem, different Dutch market players	• Promotion of market introduction of low energy houses, establishment of certification/subsidy schemes, system development and field tests in the frame of Dutch low energy house projects
NO	SINTEF Energy Research in co-operation with NTNU	• Technology assessment of suited heat pumps for Norwegian low energy houses (cold climate conditions) • Evaluation of the performance of ventilation compact units with exhaust air heat pumps for Norwegian climate • Field test of novel water-water heat pump with the refrigerant propane installed in a passive house
SE	SP and Swedish manufacturers	• Assessment and redesign of Swedish heat pump systems (capacity range, auxiliary consumption) • Further development of Swedish heat pumps for the application in low energy houses (e.g. exhaust air heat pump with hybrid source, combined space cooling/DHW)
US	DOE, ORNL	• Development of a multifunctional heat pump system for space heating, cooling, DHW, ventilation incl. de-/humidification for Net Zero Energy Houses • Prototyping, lab-testing, simulations and field test of the system

In the following, a more detailed outline of the national contributions and interim results is given.

4.1 Austria

Austria is represented by the Institute of Thermal Engineering of the Graz University of Technology. The national project of Austria is dedicated to the development of an integrated air-to-air or air-to-water heat pump in the capacity range of 3 - 5 kW, preferentially using a natural refrigerant, e.g. CO_2 (R744) or propane (R290). As first step, the following system layouts have been defined:

1. Reverse operating air-to-air heat pump with an air-heating/cooling system
2. Brine-to-water heat pump with a hydronic space heating/cooling system
3. Reverse operating brine-to-water heat pump with hydronic space heating/cooling system

Presently, the preferred system configuration is layout 2, due to that

- the Austrian people prefer surface heating system to air-heating systems due to preference of warm surfaces and scepticism to restricted power of air-heating system
- a passive cooling option is preferable to an only active cooling option

A first evaluation of the refrigerants R744 and R134a for system 2 and the respective operation modes, which has been performed in the software EES (2007), delivered the following results:

- in DHW-only mode, the refrigerant R744 has an ~15% higher COP than R134a
- in space heating-only mode, the refrigerant R134a yields an ~12% higher COP
- in combined space cooling/DHW summer operation, R744 has the advantage of an ~20% higher COP than R134a
- in space cooling-only mode, R744 exceeds R134a by ~9% in COP

In order to evaluate the necessity of an integrated space cooling option, load evaluations have been performed with the result that the cooling hours are restricted and can be further reduced by a use of a ground-to-air heat exchanger. Therefore, it is dubious to integrate a cooling function in the system layout, since the layout can be simplified without a cooling option. After the definite decision of the system layout and the refrigerant, the selected system will be investigated in more detail by

- construction of a prototype and lab-testing
- more detailed modelling of the heat pump
- detailed simulation of the system and its dynamic interaction with the heating system and the building (Dynamic simulations in TRNSYS (2007))

Depending on funding, arsenal research may join the Austrian Annex 32 team in 2008 to contribute a year-round field monitoring of ventilation compact units with exhaust air heat pump (see Figure 2) in the frame of the Task 3.

4.2 Canada

Canada is represented by Hydro-Quebec, one of the largest utilities in Canada. In the Canadian project, field monitoring in the frame of the EQuilibrium Housing Pilot Demonstration Initiative and NOVOCLIMAT Program takes place (CMHC 2007). EQuilibrium housing integrates high-performance, energy-efficient passive solar design and commercially available on-site renewable energy systems such as solar heating as well as air- and ground-source heat pumps.
EQuilibrium housing also incorporates the principles of occupant health and comfort, affordability, resources conservation and reduced environmental impacts.
Two houses in the Québec province will be investigated by year-round field monitoring. The first house has been instrumented, and field monitoring has started in the beginning of 2008. The construction of the second house has been finished in December 2007 and is instrumented in the first quarter of 2008.

4.3 Germany

As the German contribution, the Fraunhofer Institute of Solar Energy Systems (FhG-ISE) performs a large field test in co-operation with seven German heat pump manufacturers and two utilities. More than 100 air-to-water and ground-to-water heat pumps and some water-to-water heat pumps are monitored for two years, for some systems the monitoring is continued for another two years. Presently, 78 field objects have been instrumented, which comprise 56 ground-coupled systems (65% vertical borehole and 35% horizontal ground collector), 15 air source heat pumps (40% exhaust air and 60% outside air) and seven water-to-water heat pumps.
The field plants are single family houses with floor areas in the range of 120-350 m^2 (average floor area of 192 m^2). The emission systems are mainly floor heating systems and only some radiator heating systems. The refrigerants used in the pilot plants are in 85% of the systems R407C, in 10% R404A and in 5% R410A.

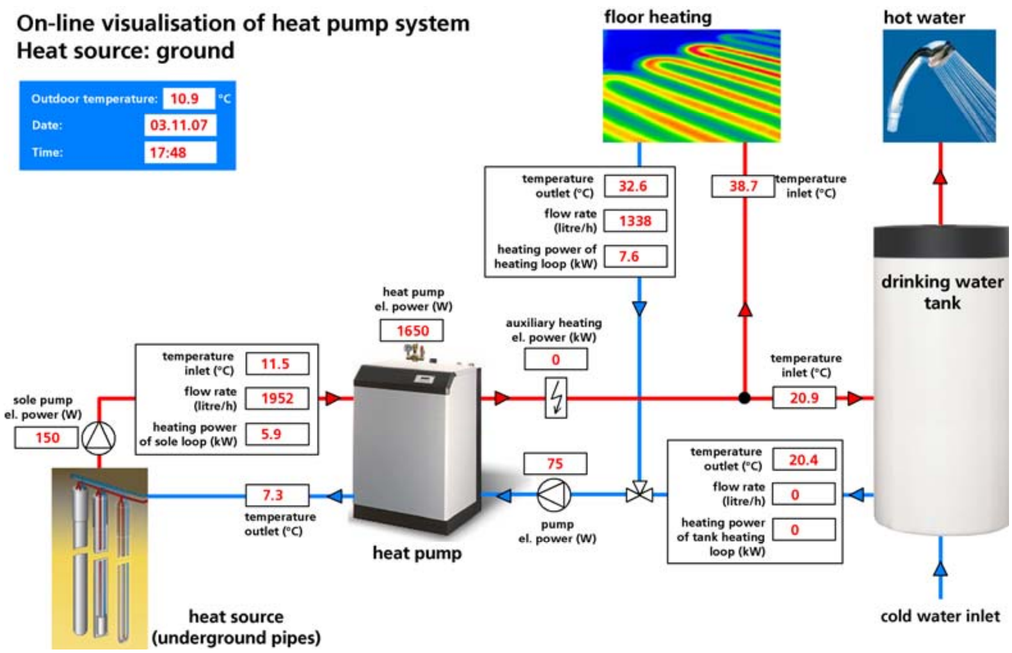


Figure 3: Online visualization of a monitoring plant in the German field test (source: Fhg-ISE)

For the involved manufacturers, an online visualization of the system performance is accessible on the internet. Figure 3 shows the website of a system in online visualisation.
A first evaluation of the field test results show an average performance factor of 3.8 (evaluation of 22 ground-source heat pumps), an average performance factor of 3.0 for air-source heat pumps (5 heat pumps evaluated) and an average performance factor of 3.4 for water-to-water heat pumps. However, these results are just first evaluations, since these values are based on different operation times and do not reflect seasonal values.
Actualised information on the project can be found on the project website in German at http://wp-effizienz.ise.fraunhofer.de.
Moreover, another field test of about 70 systems in co-operation with the German utility E.ON is dedicated to the retrofitting of boilers with a heat pump in heating systems with high supply temperature requirements (project website in German at http://wp-im-gebaeudebestand.de)

4.4 Japan

The Japanese national team has a large number of different institutions comprising three universities, four organisations and 16 companies.

The Japanese national project is dedicated to future heat pump developments for the northern cold climate of the Hokkaido Island and the moderate climate zone of the Tokyo area, in which 80% of the Japanese population live.
In the Hokkaido area the common heating system are oil boilers. Therefore, two field tests are conducted with ground-coupled heat pumps in low energy houses situated in the Hokkaido area. The first field test, described in Takeda-Kindaichi et al. (2007), resulted in good seasonal performance of 4.5 (system boundary heat pump and source pump) with a low temperature emission system layout to design supply temperatures of 30°C. Including an installed 3 kW PV-system, the CO_2-emissions are estimated 60% less than in case of a standard oil boiler system. The second field test has started at the end of 2007.
For the moderate climate zone, the standard systems are single and multi-split room air conditioners. For the application of these units in low energy houses, load calculations with the Japanese standard calculation method SMASH (2000) and dynamic year-round simulations with TRNSYS (2007) have been performed.
Calculation and simulations show that these systems are designed to a rather high capacity. Therefore, the part load operation is quite determining for the year-round performance. If systems are designed smaller, the energy consumption of the system can be reduced. Thus, based on these results, a new method for the design of room air conditioners for low energy houses will be elaborated.

4.5 The Netherlands

The Netherlands is represented by SenterNovem, co-ordinating a national team of stakeholders in the low energy house market like project developers, building companies, manufacturers of HVAC technology and research institutes.
The Dutch market of low energy houses is still in the market introduction phase. One reason for that is that the Dutch housing market is a push market, so that any house on the market is sold, which leads to a general low quality in terms of thermal insulation and air-tightness. However, some smaller project developers are now propagating high quality buildings. So, the Annex 32 contribution of the Netherlands is mainly dedicated to promote the market introduction of low energy houses and respective system technologies. The intention is to link the market developments of low energy houses and heat pump systems.
In detail, the following items are investigated:

- Development of information courses together with 'Bouwend Nederland' and S.B.R. Amersfoort B.V. for project developers and building companies
- Analysis of calculation models and development of new models
- Development of a set of parameters for a new subsidy scheme, set-up through tendering for low energy houses and demonstration projects
- Development of criteria for certification of systems and integrated building technology developments
- Setting-up of parameters to monitor the technology as well as the building process
- Support for the development of new technology within two Dutch companies manufacturing heat pumps and ventilation systems
- Development of a set of standard architectural details for building

4.6 Norway

The Norwegian participation is a co-operation of SINTEF Energy Research and the Norwegian Technical University NTNU at Trondheim. In focus is the development of efficient system technology for the increasing Norwegian market of low energy buildings (see chapter 2.2) considering the specific Norwegian cold winter climate.
In Task 2, different feasibility studies for the application of heat pumps in low energy buildings have been made, in particular concerning ventilation air heat pumps and the application of marketable central European systems under Norwegian boundary conditions. Venti-

lation compact units with exhaust air heat pumps as shown in Figure 2 are a system type to be investigated in more detail are. The focus of the investigation is the feasibility of an application of these units at the cold outside air temperature.
In Task 3, a year-round field monitoring of a novel water-to-water heat pump prototype using the refrigerant propane is accomplished. The development started with a theoretical analysis of the heat pump followed by lab-testing of a prototype. Meanwhile, the heat pump prototype system has been installed in an ultra-low energy house of 170 m^2 in southern Norway. The heat pump of the capacity of ~3 kW is designed to entirely cover the heat demand of the building, which has a design heat load of 2.4 kW incl. DHW.
Actualised information on the Norwegian contributions and the situation of low energy buildings in Norway can be found on the Norwegian Annex 32 project website at the URL http://www.energy.sintef.no/prosjekt/Annex32 (in Norwegian).

4.7 Sweden

The Swedish national team consists of SP, the Technical Research Institute of Sweden, the three Swedish heat pump manufacturers Nibe AB, Thermia Värme AB and IVT AB and several building companies. In Sweden, the low energy house market is in the beginning and adequate system technologies are still missing. A preliminary study of SP has shown that heat pumps are a viable option for low energy houses at the boundary conditions of the Swedish climate and energy prices. However, marketable components and systems are not adequate for the application in low energy houses, since

- the size and energy output is too high
- the total efficiency of auxiliary components like pumps and fans is too low
- the prices are too high and the units yield too low COP-values in the low capacity range.

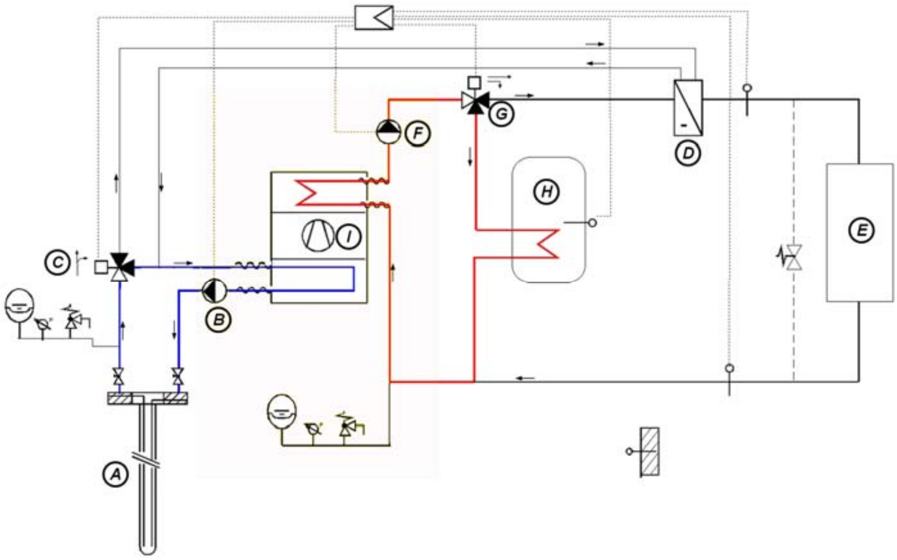
Therefore, product development is needed and consequently, the focus of the Swedish national contribution to Annex 32 is the examination and redesign of Swedish heat pumps for the application in low energy houses. An evaluation of different heating systems for low energy houses shows that for the southern Swedish climate, exhaust-air heat pumps are a feasible option, while for the northern Swedish climate ground-coupled systems are the preferred system.
The product development comprises prototyping and lab-testing of the new layouts and redesigns of existing units. Concerning the real-world operation of systems, existing field monitoring results will be scanned with regard to their relevance for the low energy house application. Moreover, smaller field tests of one or two of the developed prototypes are to be performed.

4.8 Switzerland

Switzerland is represented by the Institute of Energy in Building of the University of Applied Sciences Northwestern Switzerland. The Swiss national project is dedicated to the derivation of standard system solutions for energy efficient space heating and cooling with heat pumps in low energy houses, including a passive cooling function.
As first system configuration, a ground-coupled heat pump system with floor heating emission system and self-regulation effect in single family houses according to MINERGIE® has been investigated by simulations in co-operation with Huber Energietechnik AG.
The control boundary condition presumes a year-round activation of both the space heating and cooling functions without manual switch of the user. Details on used models, considered parameter variations and the boundary conditions applied are given in the final report (Afjei et al. 2007).
Results on the system configuration, the design, control and comfort boundaries comprise the following essential recommendations:

4.8.1 System configuration

The recommended configuration in terms of hydronic simplicity and robust operation is depicted in Figure 4. The design does not enable simultaneous space cooling and DHW operation due to the results listed in chapter 4.8.2.



- A vertical borehole heat exchanger
- B source pump
- C diverting valve
- D heat exchanger free cooling
- E floor emission system
- F sink pump
- G switching valve DHW
- H DHW storage

Figure 4: Recommended standard system solution for ground-coupled heat pump for space heating, DHW and passive ground-cooling

4.8.2 Design

- A common design of the vertical borehole heat exchanger for space heating is sufficient for a passive space cooling operation. Active cooling by the heat pump in not required in most cases, if shading, night-time ventilation and ground-coupled cooling are combined.
- The capacity of the system for cooling operation depends on the design of the heat exchanger free-cooling (denoted D in Figure 4):
  With a large heat exchanger designed to 1 K temperature difference, 94% of the space cooling demand can be covered, while with a design to 3 K, only a fraction of 66% of the cooling demand can be covered.
- Simultaneous operation of space cooling and DHW yields only marginal performance gains of about 1.7% due to a short term storage of the produced cold during DHW operation in the ground. Thus, hydronic complexity for simultaneous operation is not justified.

4.8.3 Control and comfort

- In automatic activation of the cooling mode, a dead band of about 12 hours between the space heating and space cooling operation can prevent an increasing heating demand due to counter-heating effects caused by the thermal mass of the emission system.
- A moderate cooling curve for the control of the space cooling operation enables comfortable indoor temperatures. In combination with shading and night-time ventilation, an indoor temperature below 28°C can be reached even in extreme summers. Moreover, the outside air temperature based cooling curve minimizes the risk of condensation on the floor, i.e. a dew point control is not required for most regions in Switzerland.

Since November 2007, field monitoring of a system similar to the simulated one is performed. The system is installed in the Cosy Place, the first ultra-low energy multi-family house according to the Swiss standard MINERGIE-P® in the canton Basel City.
Further simulation studies to be conducted in Annex 32 comprise different space heating and cooling emission systems and air-source heat pumps.

4.9 USA

The contribution of the USA is dedicated to the development of an integrated heat pump (IHP) for Net Zero Energy Houses (NZEH) as a co-operation of the space conditioning program of US governmental Department of Energy (DOE) and the Oak Ridge National Laboratory (ORNL). In a feasibility study, the IHP proved to be the most promising system for NZEH, covering the functionality for all building services of space heating (SH), DHW production, ventilation and space cooling (SC) including humidification and dehumidification (DH). The principle of the IHP is depicted in Figure 5 left, the ground-source prototype in Figure 5 right. A description of the components and functions of the unit is given according to Vohra et al. (2007)
Three loops are interacting, one refrigerant, one DHW and one ground heat exchanger.

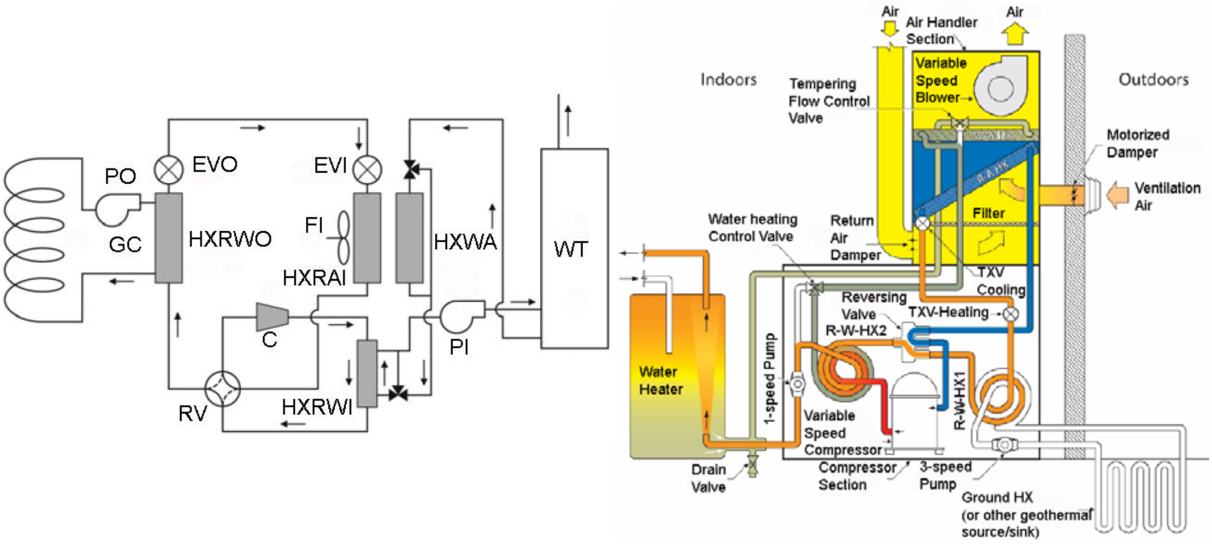


Figure 5: Principle of the ground-source IHP (in simultaneous space cooling/DHW mode) and sketch of the prototype (in dehumidification and water heating mode) (source Vohra et al. (2007))

Electrical energy consuming components are one variable speed compressor (C), one variable speed indoor blower (FI) and two pumps – one single speed pump (PI) for the DHW loop and one multiple-speed pump (PO) for the ground heat exchanger loop (GC).
Four internal heat exchangers (HX) are included to meet the space conditioning and water heating loads:
One refrigerant-to-air (fan coil, HXRAI), one water-to-air (tempering, HXWA), and two refrigerant-to-water (domestic hot water interface, HXRWI, and ground coil interface, HXRWO).
Further components shown are the reversing valve (RV) and a refrigerant expansion valve (EV) depicted as separate indoor (EVI) and outdoor EVO expansion valves, which could also be replaced by a single, bi-directional EV.
Outdoor ventilation air is drawn through a duct with flow control damper (see Figure 5 right), mixed with recirculating indoor air and distributed to the space via the blower, FI. The heat exchanger HXWA (see Figure 5 left) uses hot water, that is generated by heat recovery in the space cooling and dehumidification modes and stored in the hot water tank (WT), to temper the circulating air stream, as needed, in order to meet space neutral temperature requirements. Modulation of compressor speed and indoor fan speed can be used to control both supply air humidity and temperature as required. With this arrangement, water heating and air tempering can be accomplished simultaneously.
The air-source IHP concept is similar, but the GC loop including the pump PO and the heat exchanger HXRWO items are replaced by an outdoor refrigerant-to-air HX and variable speed fan.

Based on a prototype, lab-testing for different operation modes and test conditions have been carried out to set the parameter of the DOE/ORNL Mark VI Heat Pump Design Model (Rice and Jackson 2002). After this calibration of the model, it has been integrated in the dynamic simulation environment TRNSYS (2007). With the TRNSYS/HPDM combination, annual energy simulations have been carried out for the typical climates of the USA: Atlanta (mixed-humid), Houston (hot-humid), Phoenix (hot-dry), San Francisco (marine) and Chicago (cold).
The baseline system consists of individual systems to deliver the same energy services, namely an air-to-air heat pump, an electric storage water heater, a stand-alone dehumidifier and a whole-house ventilation system. For the efficiencies of the baseline system, common market or minimum requirements have been set.
The simulations of the air-source IHP version showed ~46-67% energy savings potentials compared to the baseline system. For the ground-source IHP version, the simulations resulted in energy savings in a range of ~52-65%. Initial cost analyses (based on equipment costs and electricity prices of 2006) yielded estimated simple paybacks about 5 to 10 years for the air-source IHP and 6.5 to 14 years for the ground-source IHP (with vertical borehole HX) compared to the baseline system in a NZEH application.
As outlined, the present target of the developments was the NZEH application. However, up to now, nearly no NZEH exist in the US market, so further research is dedicated to explore particular niche markets and adapt the concept to today's housing market. Necessary modifications for this adaptation may include the elimination of one or the other function and the substitution of components in order to achieve a less expensive system.

5 CONCLUSIONS AND ACKNOWLEDGEMENTS

As described in chapter 4, the main activities in the national contributions to IEA HPP Annex 32 are dedicated to

- the development of new system concepts and redesigns in connection with prototyping and lab-testing
- system assessments by simulation and derivation of optimised standard system solutions
- field testing of existing and new system solutions

The expected deliverables of the Annex 32 are thus

- new system concepts and components with lab-tested improved performance
- design recommendations and guidelines
- standardised system solutions for different applications
- documented best practise systems including monitoring concepts and energy balancing for operation control

Actualised information and publications on IEA HPP Annex 32 are accessible on the Annex 32 website at http://www.annex32.net.
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