First results from Annex 25

« Year round residential space conditioning systems using heat pumps »

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Abstract
Annex 25 started in 1998 and is nearly achieved. Its objectives are to define and show the technical feasibility of new packaged systems for year round residential space conditioning using heat pumps. These systems target only residential dwellings and use either water or air as energy distribution vector. First, each participating country has produced a state-of-art study which contains an analysis of the existing systems, the market and the users' expectations, in order to define a new concept of heating/cooling system. Then demonstration projects have been launched to prove the feasibility and the performance of these systems.

Annex 25 participants :
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The Netherlands : L. Wijshoff (NOVEM), R. Traversari (TNO - MEP)
France : B. Escarnot (Electricité de France)
US : V. Baxter, E. Vineyard (Oak Ridge National Laboratory)

The objective of this Annex 25 is to define and show the technical feasibility of new packaged systems for year round residential space conditioning using heat pumps. These systems (which include all the components used in a heating / cooling system from the heat pump to the inside unit) target mainly new residential dwellings and use either water or air as energy distribution vector. The work carried out within the framework of this Annex cover low initial and operating costs, comfort provided, suitability to customer demands, design / installation requirements, performances, integration in buildings and aesthetics.

The programme is divided into three parts :
- a state of the art study : analysis of existing system, market needs and demand, new concepts
- a co-operation with manufacturers on a new concept,
- demonstration and dissemination.

1. State of the art study

France :
Up to the late 90's, the French heating market has been mainly dominated by direct electric heating (electric static heaters or electric radiant panels), which equip 42% of new residential dwellings. Moreover, very few dwellings (less than 2%) are equipped with air conditioning.
In 1997, EDF decided to launch new commercial offers, including heating and cooling systems using heat pumps, to better respond to customers' needs by improving comfort and

operating costs in new and existing houses (better insulation, high performance electrical solutions). Among the different heat pump systems available on the market, four main types were identified to be part and parcel of EDF offers :

- split system,
- heat pump + air distribution,
- heat pump + fan coil unit,
- heat pump + floor heating and cooling system.

Heating / cooling floor represents the main system installed in France; it can be coupled to an air-to-water heat pump or a ground source heat pump (30% of the domestic market).

An important work has been carried out by EDF and the manufacturers in order to edit guidelines for each system to properly design, dimension, install and maintain an heat pump installation. Although the development of the domestic heat pump market in France is beginning, the increase is quite significant with 8000 heat pumps sold in 2000 for only 1500 in 1998. A lot of work has still to be done on reliability, technical and economical optimisation but above all on heat pump actors' training.

The french contribution to annex 25 focuses only on hydronic systems. Some works have been conducted to improve the existing systems :

- control strategies of the heating/ cooling floor, more especially in summer to avoid condensation,
- performance analysis of fan coil units in order to develop a new prototype for residential dwellings : silent and small.

People’s needs and expectations were investigated through several market studies and opinion surveys. They lead to avenues for new developments : aesthetics and noise levels are the most important criteria. It has been decided to focus on an hybrid system with heating/ cooling floor and fan coil units on the first storey. Indeed it offers an optimal comfort : a more efficient cooling at the upper floor and the heating/ cooling floor aesthetic and heating comfort is kept on the ground floor.

The Netherlands :

In the 90’s the interest in heat pump technology has regained. This interest was based on high expectations for heat pumps as a mean to achieve a more sustainable energy supply infrastructure. The heat pump programme, carried out by Novem, covers heat pump application in residential buildings, commercial buildings, industry and agriculture. The aim was to achieve a 1.6 PJ energy savings by heat pumps in the year 2000 in residential buildings, through close co-operation with all parties involved (builders, architects, installers, developers, utilities and suppliers). A recent evaluation of the activities carried out thusfar has shown that the energy saving target for the year 2000 will not be reached for the residential building sector. The energy saving up till 1998 was 66 TJ, whereas approx. 1200 heat pumps were installed and 3800 heat pump boilers.

The existing systems encountered can be divided into two categories : heat pump systems with cooling as an extra, and air-conditioning systems with heating as an extra. In the first category no systems have been found that have been operational for any considerable time.

The most important barriers for a large scale application of such systems in the Netherlands are the high investment costs, the integration in the design and building processes, the low

price of gas compared to electricity and a possible future limitation to the use of groundwater as a heat source. The possible disadvantages of electric heat pumps, compared to competing options, are largely outweighed by the fact that heat pumps offer a cooling function without extra energy consumption.
The most significant *market segment* for heat pumps is the upmarket, new housing sector. On the basis of this study, the combination that provides heating, hot tap water, ventilation and cooling is the most favourable option for new private housing projects. On-going demonstration projects should help to optimise such a system and to promote heat pumps.

Sweden :
The existing situation shows that the residential sector represents the main market for heat pumps in number of units sold and the forecast for the near future is still promising.
For about 20 years, there are near 300,000 domestic heat pump installations in Sweden. About 45% are exhaust air heat pumps, 25% are ambient air heat pumps and close to 30% are ground-coupled heat pumps. Finally, in Sweden, 55 % of the heat pumps installed in single family houses (especially new systems) are integrated systems for both space heating and domestic hot water. The rest 45 % serves only for space heating.

In order to get a complete picture of market needs and demands, the point of view of different groups of people (users, installers and architects) has been investigated. The user's point of view gives information on their opinion on heat pumps, the service demand and pieces of advice to potential heat pump users (technical and economic character).
Swedish consumers consider heat pump as a feasible option for heating ; this shows clearly that heat pumps have established themselves in the domestic heating market. People who intend to buy a new system seem to apply considerations wider than solely the results of financial calculations : security, flexibility and environmental considerations play also a significant role.

The objective of the swedish participants within on-going developments concern the improvements and optimisation of the system including the heat pump and the heat distribution. Research and development support is also needed to design efficient, reliable and easy to install systems. Training constitutes another good way to provide skilled heat pump actors.

United-States :
A large survey focused on air-distribution in new constructions in the US has revealed large potential energy savings in residential single family home. The problems with residential ducts are considered to result in substantial amounts of energy usage and poor thermal comfort. The US contribution concerns both new and existing dwellings.
Existing and new duct systems were seen to be an average of 43.5 to 66.2 percent efficient, depending on the climate, duct location, duct leakage and duct insulation levels. The potential heating or cooling savings that would be realised if the standard duct systems were retrofitted range between 0.03 to 0.27 Quads. But they could reach 0.07 to 0.74 Quads[1] if more efficient distribution systems were used. Moreover as the energy use is expected to increase over the next 20 years (7.4% per ten years), thus potential savings from alternative efficient distribution solutions will become even more attractive.

[1] 1 Quad = 1.055 EJ = 1 055.10^{15} J

Concerning air distribution, the following improvements have been evaluated : duct sealing and improved installation (proper air flow, proper charge), advanced distribution systems (reduced air flow, high velocity : small ducts). Comparisons have been made between standard air distribution and high-velocity air distribution, completed with field validation.
Two advanced distribution systems, hydronic and high velocity air distributions, are studied and compared by ORNL through modelling and field tests on two houses.

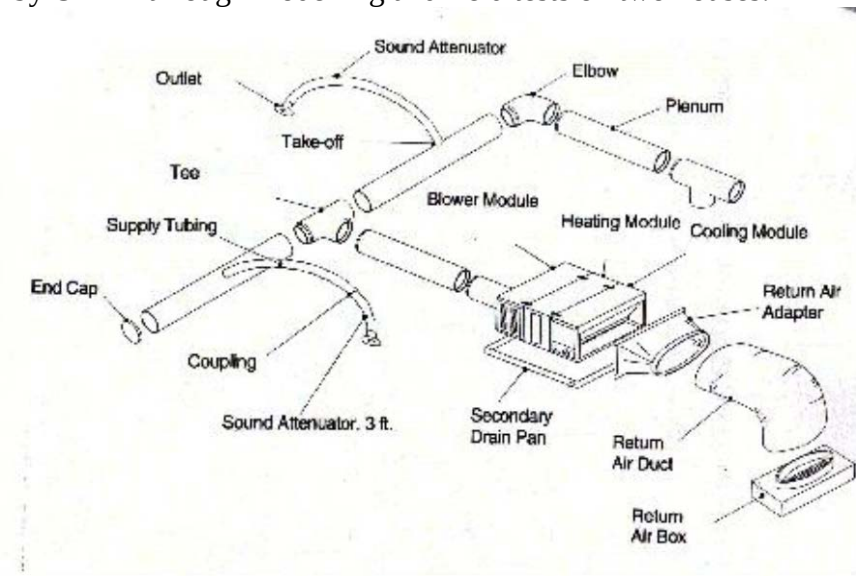

Figure 1–1 : High velocity air distribution system

2. Demonstration projects

2.1. France

EDF Research and Development carries out many on-site field tests, in order to validate the systems or to communicate on demonstration projects.
The costs are really competitive compared to boilers ; the best results were obtained with ground source heat pump, although they were installed in colder areas (COP=3.2 / 30kWh/m²).
In this annex, France focuses on a combined system (fan coils + heating/ cooling floor) ; measurements have been made on a 199m² house in the south of France.

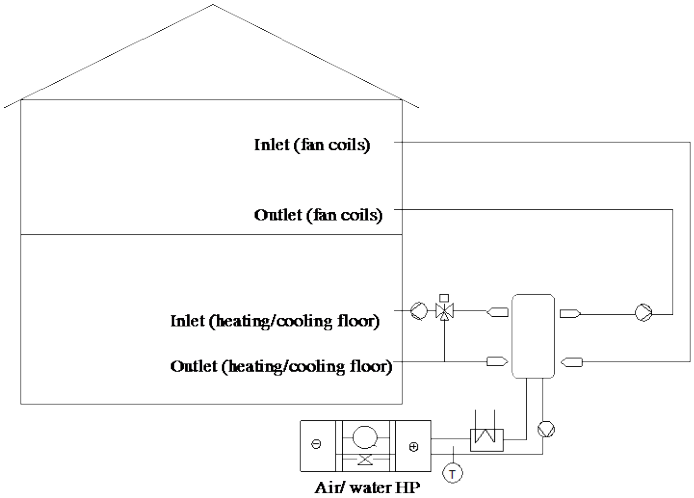

Figure 2–1 : Combined system (heating/ cooling floor + fan coils)

The first results indicate a good comfort during the heating season as well as during the cooling season ; the inside temperature in the bedrooms has not exceed 26°C even during the

warmest days (outside temperature around 35°C during several days). The higher cooling power of the fan-coils at the upper floor has been really appreciated, since the house's windows are all facing south.
Another lesson concerns the important consumptions of the pumps (24% of the heating and cooling consumption), which constitute a major way to improve the installation's seasonal performance. It is especially true for combined solutions that require several pumps. Other field tests prove that the consumptions can be divided by 3 if the pump is enslaved to the ambient thermostat.
A co-operation with the manufacturers will be necessary to implement this improvement on their systems.

2.2. The Netherlands

The number of heat pump projects is increasing. Several large projects (300 to 3000 new houses) using heat pumps are presented by Novem.
Specific measurements are made on attached single houses with the Itho/TNO heat pump system used for heating, cooling (passive or active) and domestic hot water. The heat source consists of a ground source heat exchanger and a solar collector ; during the summer, the soil is regenerated by the solar collector. Moreover, the heat pump capacity can be controlled on 3 steps (33%, 60% and 100%).
The first results are really encouraging ; indeed, the hot water can be produced at 62°C without backup heating with an excellent COP of 3. The average COP reached for the total installation is around 3 to 3.5 (heating + hot water) depending on the house.

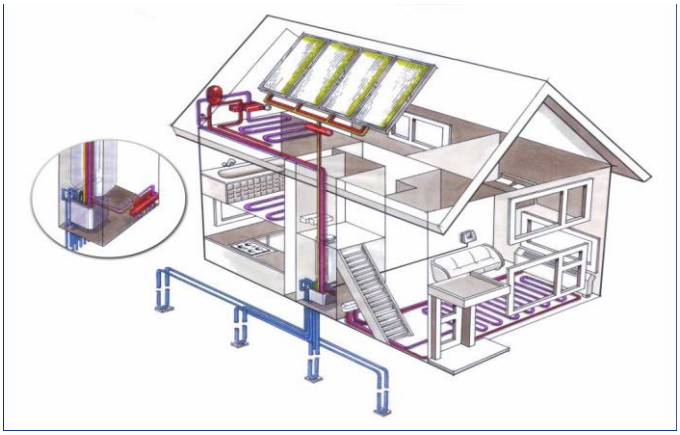

Figure 2–2 : Itho / TNO system

2.3. Sweden

The Swedish market for heat pump is mainly focused on retrofit houses. Therefore, KTH is measuring a ground source heat pump that is replacing a coal/oil burner in a retrofitted house (190m²). The heat pump installation is used for heating (existing radiators + heating floor), domestic hot water and cooling (fan coil). The ground source serves also for the passive cooling which is still quite rare on the domestic market.
A water-to-water heat pump is installed and coupled to a 83m deep bore hole. The heat pump preheats the hot water at 48°C ; then the auxiliary heater is set off to reach 60°C.

The passive cooling has been able to maintain a real comfort in the house during the summer, with an inside temperature around 25°C during the peak cooling loads (brine temperature of 10°C).

The regeneration of the soil is quite fast, probably because of the presence of ground water. In May, the soil temperature was nearly the same as at the beginning of the heating season.

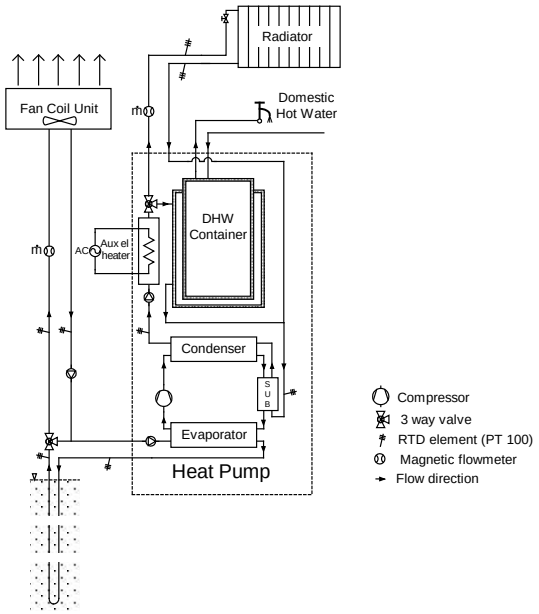

Figure 2–3 : Schematic layout

2.4. US

A field validation on a 156m² house has been initiated in 1999 to complete the study of high velocity air distribution. The duct surface area is approximately 40% to 50% less than a conventional system and the air leakage rates is extremely low.

The measurements have confirmed the simulations' results ; the distribution efficiency is clearly increased up to 85%.
Another field test is conducted on a 400m² house equipped with hydronic distribution and fan coil units ; the main objectives concern the comparison of air system and hydronic distribution and the study humidity control. The distribution efficiency varies from 88% to 93% (versus 44% to 66% for conventional air system). Further measurements are planned to study the temperature stratification and the comparison of convective and radiant heating.

These results illustrate the potential energy saving by replacing standard duct distribution with efficient solutions, such as high velocity or hydronic distribution.

3. First conclusions

Although the systems are quite different from one country to the other, depending on economical, climate or cultural differences, the same conclusions are brought out from the different contributions :

- the feasibility of such new or improved heat pump systems has been proved,
- they enable to reach high performance for both space heating and hot water which represents a considerable amount of energy savings,
- finally, the comfort is clearly improved with such systems, especially in summer but with limited extra consumptions.

Complete results from annex 25 should be available soon and should contain :

- the state-of-the-art study in each country (achieved),
- the results from on site field tests,
- the main guidelines and lessons learned on how to design or to install the heat pump system that each participant has chosen.