

REDUCTION OF CO₂ EMISSIONS BY HEATING RESIDENTIAL BUILDINGS WITH LOW-COST HEAT PUMPS

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ABSTRACT

The heating by a heat pump provides the chance for reduction of CO₂ emissions at the heating of residential buildings. The minimizing of investment costs serves for a higher acceptance for this technique. An important point of view is the combination of a heat pump with reduced capacity with a cost-efficient additional heating as a mono-energetic system.

There are two technical concepts of the low cost heat pump: Compact heat pump unit with a vertical earth probe with brine, reduced heating capacity and additional electrical heating. All the possible requirements can be realized by such a heat pump unit. If there is no demand for cooling in the summertime the vertical earth probe working as heat pipe combined with a compact heat pump with reduced heating capacity and additional electrical heating is the best solution. The brine pump is not needed and the heating pump takes over the heat transport from the heat pump which is installed nearby the earth probe to the heating system.

Key Words: *low cost heat pump, residential building, emission, CO₂, earth probe, heat pipe.*

1 INTRODUCTION

In 1999 the ILK Dresden took part at the Berlin Heat Pump Conference with a poster presentation on a low cost heat pump /1/. Meanwhile the development results were transferred for use into a SME. Furthermore the ILK has continued the development of similar concepts together with a well known enterprise. The optimization of components and the refrigerant charge were the most important tasks. The heat pump application in Germany makes only smaller steps compared to other countries. This paper tries to analyze the causes for this problem and the chances for a further improvement of the acceptance of the heat pump.

2 MOTIVATION FOR INVESTMENT COST REDUCTION

The share of primary power demand for heating amounts to more than 30 %, in private households even about 78 %. The reduction of this primary power demand and the reduction of CO₂ emissions is a global task. The development of the customary heating engineering has been reached a high level and therefore the development potential for efficiency and environmental control is exhausted. A further reduction is only possible by alternative solutions.

Figure 1 shows the primary power demand of several heating systems (electrical driven heat pump = 100%). It becomes quite obviously by graph: The heat pump is such an alternative /2/.

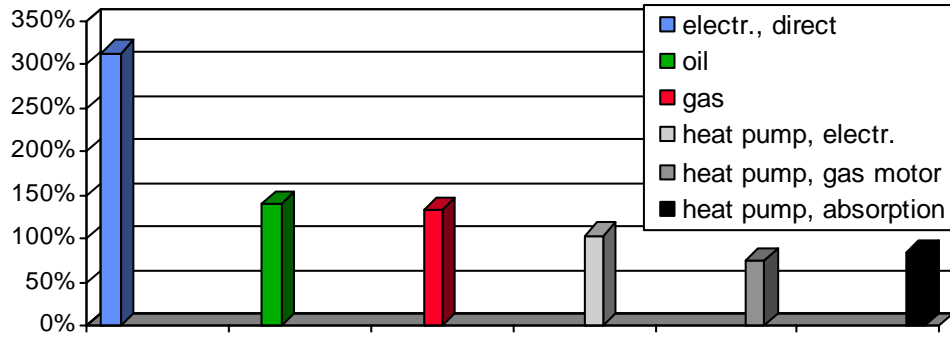


Fig. 1. Primary power demand for several heating systems

In Germany it is only made the start how the number of sold heat pumps for heating and service water (Figure 2) shows. Manufacturers, IZW (Information Centre of Heat Pumps) and BWP (German Association of Heat Pumps) are promoting a wider application of the heat pump. In this time the German Government shows inactivity. The use of heat pumps has reached a higher level in Sweden, Austria or Switzerland (Figure 3) /3/.

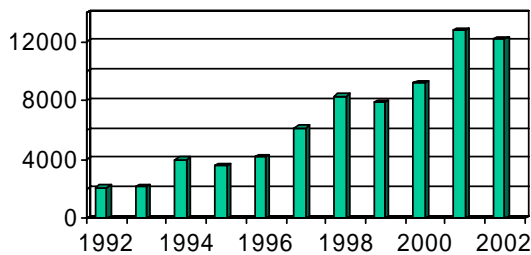


Fig. 2. Heat pump market, Germany

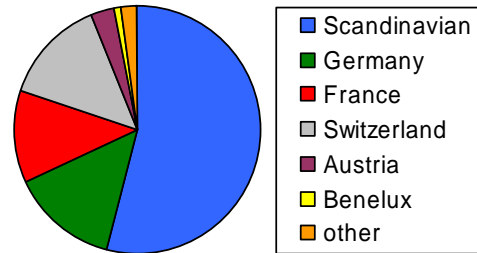


Fig. 3. Heat pump market, Europe

One of the causes for the slowly development in Germany are the costs because the investment costs for the heat pump are higher than for customary heating systems. These higher costs are to compensate by lower operational costs during an acceptable running period (Figure 4). There are a lot of serious total cost calculation schemes which can show the economy of a heat pump.

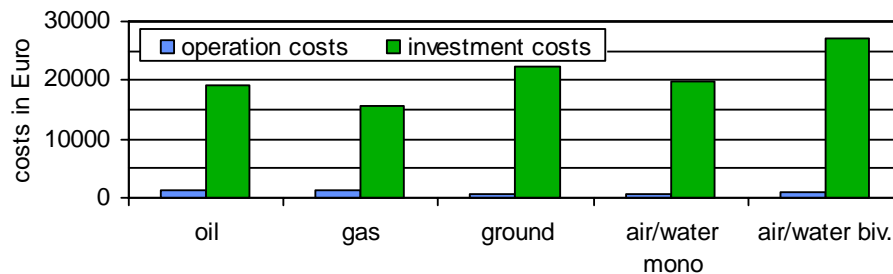


Fig. 4. Investment and operational costs for oil and gas heating systems vs. heat pump systems (building: 140 m², heat demand: 6.7 kW)

Especially in the field of residential buildings the investment costs possess a higher importance because the client must have these funds or must use a credit. The conditions offered by banks make the financing of „special wishes“ like a heat pump in Germany very difficult. So you can conclude: a reduction of the hardware costs should result in a wider application of the heat pump. Furthermore the

clients hesitate at the use of the heat pump because it is a relatively new technique. Therefore heat pumps should be designed user-friendly.

3 CONCEPT OF THE LOW COST HEAT PUMP SYSTEM

3.1 Demands upon the Low Cost Heat Pump

The following basic demands result from the above called problems: high lifetime, high reliability and low noise level (see Table 1). The application chances of heat pumps are improved essentially if the heat pump can be used for cooling during the summer months too.

The concept of the heat pump system is to select carefully and all the components of the system are to design exactly to fulfill the demands upon a low cost heat pump. The possible reserves of all heat pump components including heat distribution are lower than for customary heating plants. The application is limited but especially suited for new-construction of one-family-houses and flats with low heating demand, low temperature heating, bivalently/monoenergetic. An upgrading of a building by such a low cost heat pump is not possible generally.

Table 1. General demands upon a low cost heat pump

reduced investment costs
cooling during the summer
free of maintenance
high liability
long lifetime
low noise level
attractive design
exact dimensioning

3.2 System Example

A heat pump system for a one-family-house with an effective area of 140 m² acc. to /2/ was selected as an example for this paper. According to the constructional design of residential buildings the heat demand for a one-family-house was reduced considerably in Germany. A heating capacity of the heat pump of 6.7 kW is required and results in a yearly power demand of about 14,100 kWh. The hot-water demand amounts to 160 l/d at a supply temperature of 45 °C. For this aim a heating energy of about 6 kWh/d is required.

3.3 Heat Source

At first it is to decide the question of heat source. Table 2 shows the evaluation of several heat sources according to the suitability for the low cost heat pump. The best solution is the vertical earth probe with brine or the design as heat pipe. If there is no demand for cooling during the summer months the probe as heat pipe should be selected or otherwise the vertical earth probe with brine. It possesses the advantage of the operation as heat sink. This circumstance is not given for a heat pipe probe. A disadvantage is the needed brine pump which is not required for heat pipe if the heat pump is installed at the head of the heat pipe directly. In this case the condenser part of heat pipe can be designed as evaporator of the heat pump. It is recommended to consider the horizontal earth probes which have high investment costs. But it depends strongly on the location what can result in another evaluation in special cases.

Table 2. Evaluation of heat sources for low cost heat pumps

	a	b	c	d	e	f	total
Air	3	2	1	1	2	2	11
earth collector	0	2	3	3	3	3	14
vertical earth probe, brine	3	2	3	3	3	3	17
vertical earth probe, heat pipe	3	3	3	3	3	0	15
surface water	2	3	2	2	2	2	13
ground water	2	2	1	3	2	3	13
solar collectors/absorbers	2	3	0	2	2	0	9

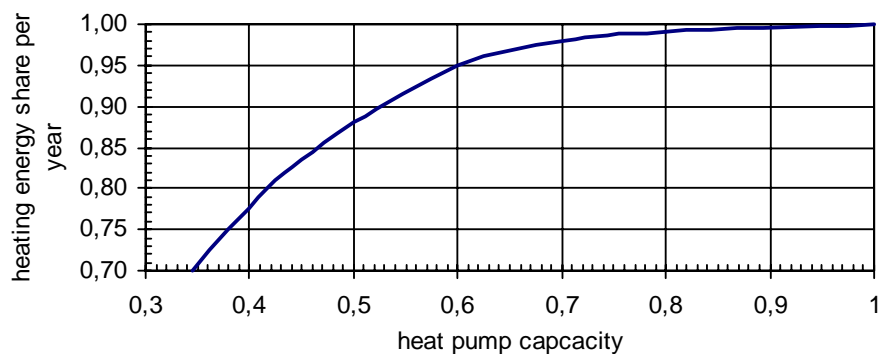
(a – investment costs, b – power demand for additional components, c – suitable for monovalent heat pump, d – temperature stability of heat source, e – maintenance/lifetime, f – suitable as heat sink if cooling; 3 – very well suited, 2 – well, 1 – bad, 0 – bad / not suited)

3.4 Splitting of Heating and Hot Water Generation

If the condensing temperature of the heat pump is adjusted in such a way that heating and hot-water are produced in parallel the power input of the heat pump is increased by 37 % for R410A, by 33 % for R134a and by 42 % for R404A. Therefore the above called parallel operation is not possible. There are two alternatives – the priority switching of the heat pump for hot water (and loading of the hot water accumulator during the night hours with switched-off heating respectively) or an additional hot water device. The second alternative is to prefer according to target of simple concepts (low cost). Separate hot water heat pumps for hot water generation with accumulator and ambient air as heat source are offered on the market.

3.5 Determination of Heat Pump Heating Capacity

In /1/ it was shown that a large share of the annual power demand can be realized by lower heat pump capacities which are different from the maximum heat demand of the building caused by the frequency of outdoor temperatures (Figure 5). By this way a heat pump (4 kW) with 60 % of calculated heating capacity delivers 95 % of the annual heating energy (13,400 kWh). The difference share (700 kWh) is to realize by an additional heat source. A cost effective possibility is an additional electrical heating with a capacity of about 2.7 kW which can be switched on when required e. g. in two standard capacity stages (1 kW and 2 kW) is a solution.

**Figure 5. Heat pump capacity vs. heating energy share per year**

3.6 Cost Structure of the Heat Pump System

The shown cost structure of Figure 6 results from the selected example of /2/. It is valid for a water/water heat pump with vertical earth probe. The most expensive components are the heat distribution system including ventilation (7,200 €) and the complete heat pump unit itself (9,100 €). The costs for the heating installation room are the same, excepted at oil heating (3,100 €) and air/water heat pump (3,100 €) and so they are not relevant for a cost saving comparison. The heat distributing

system which is very important for the energy efficiency should not be considered as possibility for cost saving. By this way the heat pump with 9,100 € is the only possibility for cost saving. A cost saving potential of the heat pump versus oil heating of 3,200 € and versus gas heating of 6,500 € could be used to make the investment costs attractively for heat pumps.

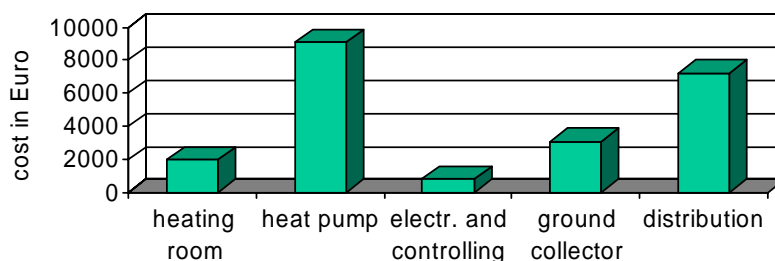


Fig. 6. Cost structure for the example of heat pump plant

4 CONCEPT FOR THE HEAT PUMP UNIT

The heat pump unit for this example has a reduced heating capacity of 4 kW (condensing temperature max. 45 °C, evaporation temperature min. 2 °C). A cost structure for the hardware of the heat pump introduced in /1/ with a nominal heating capacity of 4.5 kW acc. to Figure 7 was determined. The total hardware costs (buying) for this example amounts to 1,450 € without discount. You can not discuss here about absolute amounts because the buying conditions depend on a lot of factors. Each producer must do itself acc. to its conditions. The same problem is valid for the manufacturing costs. But cost shares can be derived.

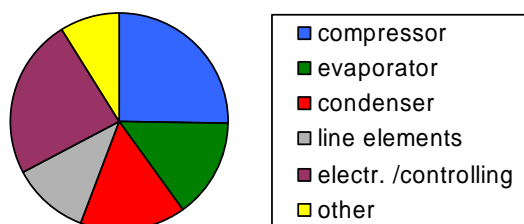


Fig. 7. Hardware cost structure of a compact heat pump with a small capacity

The heat pump unit is a compact and sealed system acc. to EN 378 (exception: measurement engineering for the experiments) and tested for several refrigerants (partly with required modifications) /1/. The refrigerant charge for HFCs is higher than 200 g. The 150 g (safety requirements) for propane were reached not yet but the needed reduction potential should exist. The main components are: hermetic reciprocating piston compressor, plate-type condenser, coaxial evaporator, thermostatic expansion valve, simple controlling (possibility: capacity controlling from 50 to 100 % with a twin compressor).

At first it is notable that in Figure 7 no position of cost factors are dominating. The most expensive component is the compressor. In this case the costs depend strongly on the taken number of pieces. The same fact is valid for the controlling system. Its costs take in the second place in the cost structure figure. Here is to remark: by integration of further wished functions exists the danger of cost rise. It should be checked which functions are needed really. This position shows too a strong dependence of the price on the number of pieces.

According to the selected design of components it is to remark too:
In the past there were hermetic reciprocating piston compressors with a pipe coil for heat uncoupling from the oil sump on market. The emitted heat of compressor housing can be reduced and the COP rises by use of this technology. This design is not available in this time. An improvement potential depends on the development of scroll compressors from 5 kW heating capacity /4/ adapted to the heat pump application. Prices are not yet.

Plate-type condensers are an optimum referring to efficiency and costs. It is to consider that a small refrigerant accumulator can be required depending on refrigerant charge and selected evaporator design. In this time the coaxial evaporator is to prefer to the plate evaporator because of the better refrigerant distribution. A special design is required for combination with the vertical earth probe as heat pipe.

Today there is no alternative for the thermostatic expansion valve because of costs. The paper should point out that the heat pump could more attractive if the hardware costs are reduced. Possibilities for this aim are shown.

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