COMMISSION OF THE EUROPEAN COMMUNITIES

energy

Study day on the development of heat pumps in the Community for heating and air-conditioning

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SUMMARY

Study Day on the
DEVELOPMENT OF HEAT PUMPS
IN THE COMMUNITY FOR
HEATING AND AIR-CONDITIONING

organised by the Directorate-general for Energy
of the Commission of the European Communities
in Brussels, 8 December 1977 at 9.30 a.m.

PROGRAMME

9.30 Hrs	(1)	Design concepts and system applications of different types of heating and air-conditioning using heat pumps, currently commercially available. Discussion.
10.30 Hrs	(2)	The use of heat pumps in the different climatic zones of the Community: a) maritime zone; b) continental zone; c) mediterranean zone. Discussion.
12.30 Hrs		End of the morning session.
14.30 Hrs	(3)	Obstacles to the development of the various types of heat pumps for heating and air-conditioning in the different climatic zones of the Community. Discussion.
15.30 Hrs	(4)	Round table on future action necessary for the development of heat pumps. Conclusions and proposals.

The Study Day was held under the Presidency of Dr Michael DAVIS, Director of the Directorate "Nuclear energy, other primary sources, electricity of the Directorate-general for Energy".

Point (1) was the subject of a written communication from:

Mr Bernard GEERAERT, Chief Engineer at the Belgian National Laboratory of Electrothermics and Electrochemistry (LABORELEC).

Point (2) was the subject of oral presentations by:

a) Dr Geoffrey BRUNDETT, Section Leader: Applied Environmental Research, The Electricity Council;

b) Mr Jean Pierre MOREAU, Head of Division Electricity, Application Techniques, Electricité de France (EdF);

c) Mr Daniele FARINA, responsible for Thermodynamic Research at Industries Delchi.

Point (3) was the subject of a written communication from:

Mr Peter KALISCHER, responsible for electricity utilisation/technical applications at Rheinisch Westfälisches Elektrizitätswerk Ag (RWE).

The Round Table (4) was chaired by Mr Helmut SCHAEFER, Professor at the Technical University of Munich and Director of the Institute for Energy Economics,

with the participation of the authors of the communications and of:

Mr Trevor CHURCHMAN, Director of the Electricity Council Research Centre;
Mr Jean DUBOIS, Controller general adjoint at Electricité de France;
Mr Michel VILLAUME, President of the French Chambre of Consulting Engineers, representing the Union Internationale d'Electrothermie (UIE).

PRESENTATION AND DISCUSSION OF COMMUNICATIONS

Chairman

Good morning, ladies and gentlemen.

First of all, I should like to welcome you all to this Study Day on Heat Pumps. We are particularly pleased that so many of you have been able to come today; this is indeed an excellent turn-out.

The Commission has a considerable interest in the future of the heat pump. We recognize it is an important element in helping to achieve a greater penetration of electricity into the energy market and thus to contribute to the Community's energy policy of reducing our dependence on imported oil. We recognize that the heat pump, if properly designed and installed, also has an important contribution to make in achieving more rational use of energy. There are a number of difficulties still to be overcome before heat pumps find wide application. The objective of our Study Day is to review the state of progress of the heat pump in the Community and to identify the difficulties, whether these be technical, economic, commercial or of acceptance. I should like to mention that the Commission has a research and development programme, an important one in the energy area, and that the heat pump forms a part of this work.

The Commission has also sent to the Council of Ministers a proposal for a Regulation which would enable the Commission financially to aid demonstration projects in the energy-saving area, one of the areas given as an example is indeed that of heat pumps. We do not yet possess this financial instrument but we are striving to get it, and it is already under consideration by the Council of Ministers.

Finally, in my introduction I should like to express my appreciation to those who have helped us in the preparation of this Study Da : to the authors and the members of the round table for this afternoon, several of whom are grouped around me at this table. As for our procedure today, we shall have a series of oral presentations. They will be shorter than the papers, which are to be published, and then there will be an opportunity for discussion after each paper or set of papers. If you wish to take part in the discussion, I would suggest that you raise your hand; I will try and distribute the opportunities by picking out one speaker at a time, and when you are chosen, please leave your hand up and do not start to speak until the lamp on the microphone in front of you lights up; you will then be able to be heard by the interpreters.

We intend to publish the papers and the summary record of today's discussion.

Well, ladies and gentlemen, that is all I have to say by way of introduction, except that I do intend to terminate our morning session promptly at 12.30 and also to start our afternoon session promptly at the appointed time.

It now gives me much pleasure to introduce Mr Bernard Geeraert, who is Chief Engineer at the Belgian National Laboratory of Electrothermics and Electrochemistry (LABORELEC), who will give an oral presentation of his paper on the subject of the first part of our agenda, namely design concepts and applications of different types of heating and air conditioning using heat pumps which are currently commercially available.

(218) Mr Geeraert

Thank you, Mr Chairman, ladies and gentlemen.

The heat pump

The term "heat pump" is a generic name. The heat pump simultaneously produces refrigerative energy and calorific energy. There are applications in which the sole aim is utilization of refrigerative energy, as with air conditioning; there are other applications in which the aim is both calorific and refrigerative energy, as with integrated heating and air conditioning, and also with air dehumidification by cooling; and then there is a third set of applications, in which the heat pump is used solely for heating. The text you have in front of you relates only to this third appplication, and the organizers have explicitly asked me to speak also of the application in which refrigerative and calorific energy are used simultaneously or at least together.

I shall begin with integrated heating and air conditioning. There are two main methods: in the former, heating and air conditioning are integrated by a central heat pump, while in the latter a local heat pump is used. The central heat pump produces the refrigerative and calorific energy required for air conditioning of the building. The refrigerative energy is distributed in the form of a chilled water loop which feeds the central air preparation units and the terminal units (see Fig. 1). Calorific energy is distributed by a second loop, which feeds the heat exchanger for the preparation of sanitary hot water, primary air preparation, and the terminal units. If the heat balance is in deficit, a boiler provides the additional heating required. If the heat balance is in surplus, the excess heat is taken off to a cooling tower. This calls for a condenser with two tube nests or two separate condensers. The compressors used for these applications are of the centrifugal type - normally axial compressors, but in some cases also radial ones. Lately, screw compressors have come to be used increasingly for this application. The second means of integrating heating and air conditioning makes use of small local heat pumps connected to a water loop (see Fig. 2). Some of these heat pumps operate in the heating mode, drawing heat from the loop. Others operate in the cooling mode, for example, in rooms in which the free heat is substantial, and transfer heat to the loop. In this case, driving energy is consumed both to draw heat from the loop and to transfer heat to the loop.

This system is therefore more extravagant in its energy demand. If there is an overall excess of heat, this excess is taken off to a cooling tower, which must, in this case, be of the enclosed type so as not to pollute the loop. If there is a heat deficit, a boiler is required to make up the shortfall.

Considered purely from the energy point of view, central heat pumps are manifestly less greedy in their energy needs than small local heat pumps. To take a concrete case, for the Brussels climate, Figures 3a and 3b show energy consumption, represented in additional form, plotted against an additional scale which roughly represents the equilibrium temperature between heat and refrigerative energy requirements and the heat pump output. Curve a shows the sonsumption of a conventional air conditioning system with separate heating and air conditioning. Curve d represents the consumption of an integrated system with a central heat pump, while curve b represents the consumption of an integrated system using small local heat pumps. We find that small heat pumps do indeed consume more energy, but this is no reason to condemn them, because small, local heat pumps have certain advantages which are not shared by central heat pumps.

Firstly, small, local heat pumps can be installed in old buildings with hot water central heating. The loop need not be lagged, and is kept at about 20°C. A third advantage is that small, local heat pumps can be individually controlled. This is very important for small shops, and avoids the difficult problem of measuring the refrigerative and calorific energy supplied. Capital costs are appreciably lower than with a central system - in some cases by as much as 50%. Another advantage is that small heat pumps can be repaired at the factory, and standard exchanges are often carried out. In systems with, for example, 200 small pumps, you buy 205 and, in the event of a fault, there are only two pipes and one wire to remove in order to replace the heat pump. Another advantage is that no machine room is required, with its expensive foundations, and no space is wasted (for the technical facilities floor).

The central heat pump, on the other hand, has a lower primary energy consumption and can be used for preparation of sanitary hot water.

I shall now go on to a second application in which refrigerative and calorific energy are used at the same time. This is air dehumidification applied particularly in swimming pools. Instead of using ventilation to maintain a favourable climate in a swimming pool, the air can be cooled in the cold battery, the water can be condensed and taken off in liquid form, and the same air can then be heated on the hot battery of the heat pump so as to increase its humidity absorption capacity; this air can then be returned to the swimming pool building. How is this done? The air (with excessive humidity) is drawn in from the building (see Fig. 4) and is cooled in the cold battery to below dew point. The humidity is condensed and the same air is reheated and returned to the building. Unfortunately, an exclusively closed loop system as regards energy. But we have to blow in about 30 m^3 of air per hour and per swimmer for hygiene reasons, and so we have to extract a quantity of air after cooling and return the same quantity of fresh air, which is heated in the condenser.

Where the outside temperature is high, the heat can always be used to heat the swimming pool water and sanitary water. There are units available on the market designed specially for this application. But it cannot be said that all units have the same performance. I am now showing a slide (Figure 5) in which energy consumption per kg of water condensed is plotted against the relative humidity to be maintained. The full curves are valid for a temperature of 30°C and the conditions prevailing in a swimming pool. The lower curve represents a virtually theoretical limit. We find that some units are a very long way from this limit. So there are good units and less good units on the market. Air dehumidification by heat pump is in competition with the conventional system of ventiliation.

In a swimming pool, the temperature is 30°C. In Figure 6, primary energy consumption per kg of water condensed is shown along the X-axis. Curves a represent the primary energy consumption of a conventional ventilation system (a swimming pool is normally kept at around 60% humidity). This consumption can be reduced by installing a static or rotary recovery unit, which cuts primary energy consumption by about 40% (curves b). With the best heat pumps, primary energy consumption can be reduced by a further 20 to 25% (curves c). The dehumidification heat pump is an approach whereby primary energy can be saved, and is one of the most advantageous applications of the heat pump.

Mr Lebrun, Liège

How can substantial savings of fossil fuels be achieved in the case of the heat pump combined with a conventional heating system? You did not mention the COP which can in practice be attained in this way, and I still cannot see how, with fossil fuels, allowing for power plant efficiency and all losses, a mixed system can lead to substantial energy savings. Can you give some figures?

Mr Geeraert

I used the term fossil fuel, but I meant to say "fuel oil". What is important is not so much energy consumption but the fact that this energy has to be paid for, and it is a matter of foreign exchange leaving the country. This is the problem. So it has to be reduced. Because why should countries which have internal sources of fossil energy change over to more sophisticated systems, as this energy is at their disposal anyway? So it is essentially a problem of importing energy. As for your question about the COP, we have very little experience in Belgium with dual-mode heat pumps. But according to information gathered in Germany, it must be in the region of 3. Obviously, more information should be requested from the German representative, who knows the facts and will be able to answer, because there are something like a hundred systems in use in Germany.

Mr Lebrun

May I add another small comment. So the conclusion is not at all valid for Belgium, although it is so for a country which has another source of fossil energy, which, for example, need not be imported. The other question I should like to ask is as follows: does the electricity distribution authority therefore itself decide when you use the heat pump system, i.e., when it has surplus electricity whatever the price? ... is it the electricity company which automatically switches on the system?

(608) Mr Kalischer

There were two questions. One of them related to the possibility of saving primary energy in an alternately operated dual-mode heat pump system. In this case, in the climatic conditions prevailing in the Federal Republic of Germany, the oil heating system provides about one third of the annual heat requirement for heating, whereas the heat pump - i.e., at temperatures above freezing - covers the other two-thirds of the heating requirement at all outside temperatures. The heat pump operates with an annual average performance coefficient of about 3. Even if the efficiency of the power plant is taken into account, the heat pump will supply more heat than the amount of primary energy that must be expended at the power plant. This contrasts with oil heating systems which, if they are to provide this two-thirds of the heating requirement, consume about 70% more primary energy than the heat they furnish. That is the extent of the saving achieved.

That was the first question. Now the second: who switches the heat pump on and off? The way we have arranged things, it is switched automatically according to the weather. This means that when the outside temperature falls below a certain value - at present + 3°C - the heat pump is switched off and the oil-fired boiler on. In addition, we have allowed ourselves the possibility of intervening via the power-line carrier control system so that we can also switch at temperatures above +3°C in special cases. But these are, and will remain, special cases.

A question for Mr Geeraert about old housing, old housing only, and old housing built before the installation of a pump and heated by conventional radiators and not by underfloor heating. You have not mentioned the effect of improving the thermal insulation of buildings, as could be done when dual-mode heat pumps are installed in these buildings. With thermal insulation, the radiator installation could be retained but operated at a lower temperature level, thus improving pump efficiency and COP and hence the average annual COP. My question is therefore as follows:

Among the million houses - if I have correctly understood your report from my rapid reading - the million houses in Belgium and the 4.5. million in Germany, among this total number of houses, has the thermal insulation of an appreciable number of these houses been improved on this occasion or have they remained as they were before?

(A) Mr Geeraert

I think you must put that question to the representatives of the Centre Scientifique et Technique du Bâtiment (Building Research Centre). They compile statistics on the thermal insulation of buildings, but I agree with you entirely and would even add that it is not even necessary to have better insulation in order to use lower radiator temperatures. Most existing insulations - and the older they are, the more oversized they are - can be operated at appreciably lower temperatures, and I am in complete agreement with you that if older buildings are better insulated we can certainly operate at temperatures in the range 50 to 60°C.

Mr Meloni

The speaker mentioned at the end the possibility of using heat drawn from well water or the ground. Another way of using heat might be to make use of solar collectors operating at low temperature. What does the speaker think about this? Low-temperature solar collectors would have a good level of efficiency and could be built very economically. I should like to know if it is advantageous from the point of view of energy balances to operate the collectors at low temperature and then expend electrical energy to raise this temperature.

(A) Mr Geeraert

If I have correctly understood the question, we are talking about a combination of heat pumps and solar collectors. I have been asked to talk about systems which are currently available on the market, and I must confess that there are in fact a limited number of heat pumps on the market which can be used in combination with solar collectors, but I would not say that it is a system already in common use - as it is still at the pilot plant stage. But there are in fact heat pumps in the Community specially designed for combination with solar collectors. Here, in the Belgian climate, a single-glazed solar collector has an efficiency of about 33%; a double-glazed collector has about 50% efficiency. It is true that these efficiancies can be increased by drawing off the water at lower temperature, but the heat pump is already at the limit of economic viability, and solar energy is even further below the economic viability limit, but I am afraid that we shall be combining the two most expensive systems, solar energy and the heat pump. From the point of view of economic viability, I think there is no hope, certainly not in the present state of the art, and particularly because the prices of solar collectors are still prohibitive. Mr Villaume points out that there is still the major problem of storage. Solar energy use will really take off once the problem of interseasonal storage is solved, but at the present time no progress has been made to my knowledge, and storage is only possible for a few days. This kind of storage is expensive and subject to big losses.

Mr Cobut

I should like to make some remarks and comments on Mr Geeraert's presentation. First of all, in the first part, the comparison between the centralized heat pump and small, local heat pumps in a loop.

The advantage mentioned by Mr Geeraert of room-by-room control applies just as much to a centralized heat pump if terminals with thermostats are used. Again, terminal units used with a central heat pump are appreciably less noisy than local heat pumps situated in offices, whose NR noise level reaches as much as 40.

My second comment is as follows: in Mr Geeraert's curves on dehumidification by heat pump, I should like to know if the high rate of agitation occurring in ventilation by heat pump has been allowed for, and hence the power consumed by fans which are larger than in a conventional system.

Thirdly, Mr Geeraert mentioned the installed power in a residential plant with a dual-flow heat pump or one operating with extracted air. This power was 2 kW, whereas it is 4 kW for a heat pump operating on outside air. But what is the total installed power allowing for the fact that the extracted-air heat pump can only provide a third of the heat required?

My final comment is this: I believe that the debate must be widened to cover not only the heat pump itself but also integration of the heat pump and thermal insulation. At this stage, some countries, such as those in Scandinavia and the United States, are now attaining wall coefficients in the region of 0.3 kcal per hour per square metre . This is possible only if there is ventilation in the rooms and possibly air conditioning for seven to eight days per year. It is obviously preferable to save energy during a seven-month heating season even if it means refrigerating for seven to eight days per year as is the case in Belgium. At this point, the comparison from the energy balance point of view must no longer be considered exclusively in connection with the heat pump itself but on the basis of its possible integration with reinforced thermal insulation.

(A) Mr Geeraert

Concerning the first question on control, I was not talking about control but about measuring refrigerative and calorific energy. I am thinking mainly of small, individual shops. It is very expensive to install a measuring system for the calorific and refrigerative energy supplied, and people have no incentive to make savings if there is a central chilled water and hot water distribution system, whereas if they have their own air conditioner they are automatically induced to make savings.

Regarding noise, I am not competent to discuss this problem.

As for dehumidification, the curves that I showed are measured values allowing for the energy consumption of the fans and the entire system. They are values measured on equipment existing on the market and equipped with blowers and everything else. They are really the number of kWh per kg of water condensed, and not only the kWh of the compressor. The total installed power with recovery from extracted air and where outside air is used as the heat source is substantially the same. The actual heat pump power is less, but the total power is of the same order.

With regard to integration of the heat pump and the insulation, you touch here upon the very wide-ranging problem of superinsulation, as the transmission loss coefficients which you mentioned - 0.3 kcal/m^2 per hour in the 10 kcal case, i.e., a little more than 10 W/m^2 - are excessively low, so that we are in the field of superinsulation, and I think we can go on talking about this subject for a very long time.

Mr Salimbeni

I wanted to point out the advantages of using the heat pump with water as the source. It seemed to me that only the use of groundwater had been emphasized. This groundwater would be available only for short times, whereas it seems to me that much more general use could be made, for example, of town sewage, which would have even higher temperatures than the groundwater, giving some form of energy reclamation on domestic, industrial, and other uses. I should also like to emhpasize another point on the use of natural, lake, or sea waters. That is all I wanted to point out. With these systems, the COPs would be in the region of 3 to 3.5, or even 4 (seasonal COPs) - precisely comparable with, if not better than, values using groundwater. I should like to have some information on this point.

Prof. Schaefer

We have in Germany an experimental system which uses a heat pump to remove heat from the sewage of a private apartment block and provides hot water from this heat. This system is financed by the Federal Ministry of Research and Technology. The system operates satisfactorily as regards heat recovery - the performance coefficient is a little higher than 3 - but we are already having serious problems with our water treatment engineers, who complain that we are cooling the sewage and thus influencing the quality and quantity of the treatment plants, which in fact work best at temperatures in the 25 to 35°C range.

Mr Plantikow

I should just like to make a correction. The dual-mode system has repeatedly been described as the German system. Perhaps it is not legitimate to say this. Most of the heat pumps existing in Germany operate not in two modes but only in a single mode. This dual-mode system may perhaps be the one used by all the German electricity utilities, but it cannot simply be referred to as the German system. I would say that more than 60 or 70% of the heat pumps in Germany operate in a single mode. So there are also possibilities of building single-mode systems as well; the technical possibilities already exist and have been put into practice without operating on a dual-mode basis. For example, heat exchange evaporators can be split up, being laid partly in the ground and used partly as air heat exchangers. This possibility is just now being checked out and the idea is that when the outside temperature is at its lowest, heat will be drawn, for example, only from the ground heat exchanger, so that dual-mode systems, for instance, are no longer necessary. I just wanted to make this correction.

Chairman

Thank you for your contribution. Well, ladies and gentlemen, I am afraid we must now go on to the next part of the programme, but I wish to assure you that there will be an opportunity to consider many of these very relevant questions - not all of which can yet be answered - particularly at the round table this afternoon, where we hope to have not only a strong interaction between the members of the round table, but also with all of you.

Now as regards the second part of our programme, the use of heat pumps in different climatic zones, we had arranged for three speakers. I have an announcement to make, namely that unfortunately Signor Giuffrida is ill and unable to present his contribution under item 2 c) on the Mediterranean zone. I should like to ask if there is anybody, for example from Italy, who feels able to step in and say at least a few words when we come to that point on the programme; if so, would he please make himself known to Mr Gerini.

Mr Moreau

Of the different systems proposed in France for the use of heat pumps, as Mr Geeraert said in his introduction, one of the most popular systems, at least in the construction of collective housing, makes use of heat pumps operating with the air extracted from rooms. As you know, we have in France regulations which stipulate that a volume of air approximately equal to the volume of the main rooms must be renewed every hour. By "main rooms", I mean living rooms and bedrooms. Here, for example, is an apartment building; we have a heat pump at the top, two air distribution systems, an air blowing system, which is the one shown in green on the screen, and an extraction system, shown in orange-yellow on the screen. The extraction system is for the "technical rooms", i.e., the kitchen, bathroom and WC. So heat is exchanged by recovering the heat contained in the spent air and transferring it to the fresh air. This system recovers 30 to 40%, in terms of power, of the losses, depending on the position of the apartment - whether it is on an intermediate floor or in a more exposed position, at the gable end of the building or below a terrace. Recovering 30 to 40% of losses means, if the heat pump is used appropriately, that 60 to 70% of the heat requirements of the building can be supplied. The air is discharged at a temperature of 1 to 4°C. Allowing for supplementary electric resistance heaters providing the basic heating, the blown air temperature is between 15 and 40-45°C. Of course, supplementary heating is always necessary; it is decentralized, taking the form of supplementary convectors, as you see here in red, in the rooms. These can be totally decentralized (separated?) from the air distribution, as shown in the diagram, or they may be integrated in the air distribution system in the form of resistance heaters placed in the terminal outlets. The characteristics of a heat pump using blown air, from the data, are about 10 W/m^3 circulating through the condenser. I shall now show some slides.

I shall not return to the general layout showing the arrangement of the different components of the heat pump. Imagine that the inside of the rooms is on the right-hand side of your screen, and the outside on the left. So you see that the heat pump takes in air from outside - fresh air - and heats it on a battery which is the heat pump condenser. The supplementary heating resistance is in series. Then follows humidification if required, after which the air is blown into the rooms. On the recovery side, there is the air extracted from the rooms, at a temperature between 18 and 20°C, which at the same time includes the heat - the internal contributions - of the different rooms; this air is cooled on the heat pump evaporator.

Here is a set of buildings heated by heat pumps operating on extracted air, in the Rouen region. They are blocks of about 200 dwellings. About a thousand dwellings in this region are currently heated by extracted-air heat pumps. Some of these heat pumps are located in the roofs of the buildings. Here you will see an enlargement of the heat pump layout with extraction and blowing outlets - a system of ducts for air distribution or return to the various rooms. Now, very briefly: the extraction vent in the kitchen - it is a one-roomed flat - the extraction vent on the vertical part here, and the blowing vent at the end of the room here, simply for practical utilization. The vents in the rooms, with the supplementary convector, are thus sited low down.

Now let us consider the transposition of the extracted-air system to the case of individual houses. Here you have a fresh-air intake; this air enters the heat pump, is heated, leaves the pump and is blown into the rooms. This air is recovered from the "technical rooms", cooled, and then ejected after cooling to about 15°C. To return to the blowing facilities, here is a diagram of the duct blowing system. Other systems have also been investigated. This is one of the problems, and it is always very difficult in a multidwelling building to position the dual-flow blowing system; attempts are being made to use insulators positioned inside a floating cover, which would allow transfer of the hot air blown into the apartment without having to put in a duct visible on the walls of the residential rooms.

These are not shown here. They will be insulators with a sort of square grid pattern inside a floating cover, allowing the heat to be conveyed. Other arrangements have also been considered - such as placing ducts inside the floating cover. So different systems are being studied. The main problem encountered in multiple dwellings with the extracted-air system is to secure appropriate distribution of the air flows, which thus provide the basic heating - appropriate distribution to the different apartments, also taking account of the losses of these apartments. This means the introduction of variable flows ranging between, say, 0.8-0.9 of the total living volume and 1.2-1.3 times this volume, as indicated in the slide just shown.

Regarding fresh air, here is a pump used in an individual house in an extracted-air system. The air intake is at the bottom, with a filter. Heat is recovered in the compressor, the air passes through the first exchanger, which heats it, and is then blown to the apartments. The spent air is recovered, fed through the cold exchanger - the evaporator - and discharged outside the building. These pumps are installed in the roof space or basement. Ducting in individual houses must obviously be very thoroughly insulated or fed through the heated space - i.e., the air can be distributed through false ceilings in a corridor where this corridor provides the possible distribution to the various rooms.

Here is a heat pump working on the same principle as the type already described in sufficient detail. I merely wish to point out that these pumps can be reversible; of course, where they treat only a single volume, this is normally not enough for correct refrigeration. Where cooling is required in summer, air flows between two and three volumes must be introduced. Hence the possibility of reversing - exchange between the condenser and evaporator sections - giving cooling in summer and providing additional comfort from one's own heat.

Here is a horizontal heat pump configuration. Extracted air is on the left. Here is the extracted air inlet. It is fed through the battery and ejected here. Fresh air arrives on the right; it is fed through the compressor, through the condenser battery, and discharged to the various main rooms in the apartment. These are units for individual houses ranging between 3/4 hp and 1.5 hp.

As an alternative, fresh air - i.e., outside air - can be mixed with the extracted air. In other words, the system is a cross between heat pumps operating solely on outside air and those using solely extracted air.

This alternative has been applied in practice in a number of individual houses. Extracted air supplements the spent air and is then discharged to the outside. In other words, heat is recovered from both these fluid flows. Apart from this, fresh air provides the normal air renewal together with the recycled air to give the correct flow through the exchangers, and an air flow which is afterwards blown into the main rooms. So this is a variant of the previous system, which uses rather more powerful heat pumps - in the region of 2 to 3 hp - in which heat is recovered both from the extracted air and from the outside air.

Here is another possible application: the possibility was mentioned just now of using either air or water as the heat transfer medium; the tendancy now is increasingly to use a system with hot water as the heat transfer medium to convey the heat to the apartments. This is due to certain problems encountered in dual-flow systems - mainly distribution problems, and also balancing problems - water distribution techniques are much more within the range of installers, as these have always been the cornerstone of heating installations. So hot water can be prepared by an extracted-air/water pump.

You will now see an example of an individual house with a system of this type. Here it is. This pump is installed in the roof space. The extracted air enters - you cannot see the inlet as it is hidden by the equipment - at the rear, is fed through the evaporator battery, and is then extracted to the roof. Then there is a hot water circuit (here you see its balancing circuit) which goes to a battery that uses this hot water, whose temperature is 40 to 45°C and which is a blower-convector.

Here is the blower-convector which can make use of this low-temperature water. Different types of emitters for low-temperature water can obviously be used. The blower-convector is one possible method. Another possibility is underfloor heating. Different systems are currently on trial in France.

Another possibility might be to use mixed radiators with a hot water battery and a supplementary electric battery. Of course, as I said at the beginning, all systems using extracted air require supplementary heating. In multidwelling buildings, this is always decentralized. In individual houses, it may be centralized, and in this case it is controlled by a thermostat in the living room - the largest room - or else it may be completely decentralized, in which case the living room still controls the heat pump but the bedrooms have some degree of individual control.

Here is an example of the use of the extracted-air heat pump which you have just seen. As you see, an individual house with direct heating, with a living room temperature kept at 18 to 20°C, consumes about 14 000 to 15 000 kWh. The heat pump gives a saving of about 4 000 kWh, so that a ratio between direct heating and a heat pump of about 1.4 is possible. This is already a very good coefficient - not a performance coeficient but what we call an operating coefficient.

Now another possibility. We talked about this at the beginning too: I mean pumps using outside air only. That is the conventional technique, which may or may not be reversible.

Here is an example of an individual house with the heat pump having an external exchanger, which is therefore exposed on the outside wall. Inside are the condenser and ducts for feeding the various rooms.

Here is another system, where the heat pump still operates on outside air. These systems will obviously seem crude to you, but the main requirement is to save a certain amount of energy. You know that the heat pump is an expensive piece of apparatus, and I believe we must try to install it as satisfactorily as possible, but we must not put in unnecessary trimmings.

There are two possible approaches: either a compact unit, or a so-called separate system linked by a freon umbilical cord to the condenser part of the machine outside.

A system was referred to just now whereby the heat pump is used to take over from oil-fired boilers. This technique is now on trial in France. A number of installations are in operation. Mr Geeraert gave some figures, with which I fully agree.

Here is an individual house of traditional construction, which can be equippped with a heat pump which can take over from the oil-fired boiler.

Here are some examples of outside evaporator configurations used. Here is the freon umbilical cord linking the evaporator to the machine which is in the basement beside the boiler.

Here is the entire installation on the boiler. You can see a boiler of the old, traditional type with return water lines, in which the heat pump is placed in series-parallel. With this system, therefore, alternate heat pump or boiler operation is possible, but series operation can also be used - i.e., at certain outside temperatures the heat pump can provide preheating, with the boiler giving the final heating.

Here is a possible application of this system using an external air/water pump. The building can be heated during winter and either a swimming pool or the sanitary hot water heated for the rest of the year.

The same system can be used in multidwelling blocks. We are at present working on a project which will probably be implemented next year in a building with underfloor heating with a boiler and heat pump.

Now for some tertiary applications which are eminently suitable for the heat pump: swimming pools, where the heat pump can be used for dehumidification, thus reducing the amount of fresh air required for air renewal; hotels, where heat can ge recovered from always substantial air flows - two to three times the total volume of the rooms. The heat pump then becomes very important, and can also provide cooling in summer. Also clinics. Clinics have very similar characteristics to hotels - i.e., the need for air distribution to the rooms, and comfort cooling in summer. The air renewal rate is also two to three volumes. Large, tertiary buildings are another case in point. Here, either decentalized loop-type configurations may be used, or centralized machines as just described by Mr Geeraert.

A final application relates to shopping centres, where unit heat pumps treating 400 to 500 m^2 can be installed. This approach is also applicable in the industrial field for the same purposes.

Thank you, Mr Chairman.

Chairman

Thank you very much, Mr Moreau. We will proceed straight away now with Dr Brundett.

Dr Brundett

I was going to describe the temperate climate; the actual house style does have some influence upon the equipment. User habits are very much influenced by the climate; the energy implications of that are rather important and we will summarize that to deal with the equipment. The kind of weather which we have is only a small amount of very cold weather, the bulk of it is around 7°C: long, gentle temperature climates but no extremes in that sense, which gives you a degree-day pattern rather like that for Britain: 2 000 to 2 500 degree-days a year. We have this because of the country's island nature and mild climate and the water all around the island. We tend to get a fairly wet period particularly in the winter, so the winters are not the time to take your holiday in Britain. A key feature, and I would like to dwell on this illustration for a few moments, is that the moisture level in the outdoor air varies with external temperature along the bottom line. The top yellow line is the saturation curve for water vapour and that is the band for ninety per cent of the time - the water vapour is almost saturated outdoors over the winter period. Only when we reach summer conditions does it become less than about 85-90% relative humidity. This means that damp climates such as Britain's are very near the fog condition during most of the heating season. If we look at extremes and compare them with America where the bulk of the heat pump development is being concentrated, this is the 90° band for the temperature on the left-hand side and moisture on the right-hand side, so we can see that the Americans do get very got in summer and very humid. We don't get anywhere near so hot and we certainly go nowhere near so cold, and in summer we are not so humid, so the American equipment is designed to cope with the yellow part of the graph. Their problems are quite different from those of the maritime climate on the right. The equipment is designed to cope with this extreme - the combination of high himidity and high temperature, which is a particularly distressing climatic condition. I think you would pay anything to get comfort under thos extremes, but Britain, or the maritime climate, is not so humid in summer, not so hot and not so cold in winter, and if we look at the extreme condition, this is the number of days below that temperature outdoors. We seldom go even for part of the day below about 7°C and the design condition which appears to have been reasonably successful for the last 40 years in Britain, is to take -1°C as the normal design condition, where the climate will be colder than that on average for about five or six days a year. This means that I can try to summarize the weather by saying the last maritime problem for the northern part of Europe is overheating, but it is a prolonged, moderate, cold, wet climate. If we now look at the housing stock into which the equipment has to fit, I don't think I can say that the housing stock is determined by the climate but it is very important in its equipment implication. 85% of Britain's houses are of that type - single dwellings as distinct from blocks of flats. These are detached houses, semidetached houses and that I suppose is the classic British house, two houses together, about 85 m^2 floor area, three bedrooms. How closely de we pack our houses? Well, very closely indeed, I think, in our country. It is something like 45-60 dwellings per hectare. The important implication in that is that you cannot bring noisy equipment without it interfering with your neighbours, because your neighbours are very close indeed. I use this to illustrate the variation in heat loss and the way - because of our mild climate and our, perhaps, neglect on insulation - a lot of our houses are very badly insulated by anyone's standards. Something like 40% of our houses are earlier than 1918 and they have solid brick construction, so that insulation is the important message, I think as we discussed early this morning, in conjunction with any heating scheme, insulation has a very big effect in such a climate - certainly if the insulation is bad now, as it is in our country.

So that I can try to summarize the housing stock by saying it tends to be rather small in size - 85 m^2 - badly insulated and closely spaced. If we are now going to heat such space, we need to know what are people going to do with the equipment. Again, perhaps because we are sheltered by such a temperature climate, we do not worry too much about heating bedrooms, so that if any of you have stayed in Britain you may be familiar with the bedroom problem of running the bedroom in rather cool conditions, but we do have one warm room in the house where popele live. However, we don't work at constant temperature and this is sometimes a misconception which engineers treasure because it makes their calculations easy. This is a trace of a thermohydrograph showing the kind of swings in temperature over the day, which means that we have to consider the sizing of equipment to give the kind of response which the user needs, and maybe this is where some consideration of a background continuous heater and some form of supplementary heating to provide that top-up when it is needed, is part of the design philosophy.

I would like you to reflect back on to the moisture graph, the fact that Britain is near fog conditions; that means that since moisture is generated within the house, then the amount of ventilation needed to remove it - if that is the way to remove the moisture - is by putting more and more ventilation into the house as the weather becomes warmer and the moisture level outdoors becomes higher, and that red line is the kind of ventilation requirement if we assume something like 7 kg a day of moisture generated by the habits of the people within the house. This is reflected in the habits of users in the way they control their ventilation in such a mild climate by opening their windows to match that kind of need. We also, and we are not quite sure if this is a climatic variation, have rather heavier clothing than the Americans, but I am not quite sure about the rest of Europe, which means that we have lower temperatures than certainly the Americans use. Now let me look at the energy considerations of all that you have learned so far. We have - if I look at the heat loss of a house versus the temperature - this kind of relation, and it is a current research problem to identify the relative magnitude of the cross-hatched area, because that apeears to be the energy due to the ventilation habits of the users controlling the moisture. It means that if we look at the energy spectrum with temperature - if you follow the conventional wisdom of the heating and ventilating engineer - you will have the theoretical line there, but in reality, particularly in mild weather, you will have an extra ventilation load. If we can control the ventilation and if we can utilize the free heat (this is the shaded area it the bottom) which is already available by people's equipment, the sunshine, their metabolic heat - this is already in the house. The top line gives the kind of heating need of such a building. If we insulate and control the ventilation we should be able to cut the energy down dramatically because in a mild climate the free heat becomes a very important part of your total energy need.

Now let me look at the implications for the equipment. First of all, I will consider the heat pump in the classic way it hss been discussed so far, using the outside air as the heat source and the air circulation on the inside to dissipate that energy. We have looked at the design of the American units and my colleague Mr Blundell has reoptimized the design; if the pump is not to do cooling - if you are to optimize the design of the heat pump for a heating duty, which is the main need of such a maritime climate, then the condenser size must be much bigger than that which is appropriate for the American equipment. The suggestions for improving the coefficient of performance are roughly to double the condenser area for such a heating duty, and this is the kind of reflection which we now know, we have tested this in a laboratory to see if it does work, and it does; we can now redesign the simple components of the heat pump, optimize it for heating only, and get quite a significant improvement over most of the American equipment available now.

However, there is one other big difference between the maritime climate and perhaps the American climate. I return to this moisture line of the outdoor air; being mild weather, saturated, the water vapour pressure is quite high. If - the second illustraiion down shows the time below 10°C for outdoor air - you go very cold, say - 10°C, the American condition, then the water vapour pressure is very low and the rate of ice buildup is also very low. If we are dealing with mild weather, say + 10°C, there is no ice to form because the heat exchanger surfaces are not below freezing point, but in between - which unfortunately coincides with the maritime climate - we peak in rate of ice buildup, and so the defrost mechanism, and its reliability and success, is much more important to this climate than to the American climate. We also need to consider the problems of the electricity supply, starting current surges, perhaps a British characteristic and not worth spending too much time on, but more than 1 kW of electrical load inductively applied needs special dispensation with the electricity industry in Britain. Noise is the other problem which we have already discussed, that the outdoor fan noise on the American unit is too high anyway and some sort of silencing is necessary there. Before I finish with this I would like to say that a small heat pump looks like having a promising future, in conjunction with insulation, with a good defrost mechanism and low noise and, of course, low cost and high reliability. I would like to finish with a few words on the moisture removal side because I see that is the immediate need for such a climate as ours. If we can remove the moisture from the ventilation air so that we no longer need to have very high ventilation rates, then that will save a lot of energy in mild weather, and the kind of unit we are now considering is a very small heat pump; I'm thinking of something like 60 W, 100 W possibly, operating in a dehumidifier role within the house, perhaps optimized for an upstairs condition of something like 13°C, which is a typical figure, and about 80 or 90% relative humidity. So those, gentlemen, are my two options or two choices for heat pump development for a maritme climate. Thank you!

<u>Chairman</u>

Thank you very much, Dr Brundett. That has shown very clearly some of the special characteristics of the British maritime climate, the kind of conditions that one has to match.

Now I would like to invite Mr Farina, of the Delchi Company, to say a few words, impromptu, and therefore I imagine a rather short contribution, about the conditions in the Mediterranean zone. He is stepping in at short notice to replace Mr Giuffrida, who is, as I said, unfortunately ill.

Mr Farina

I am sorry that Dr Giuffrida has not been able to come in person. I am happy to comply with Dr Davis's request for me to say a few words. It is true that I am absolutely unprepared, so I will say whatever occurs to me.

With regard to the Mediterranean area, I must say first of all that up to now the pure heating applications in the Mediterranean area are very few, and, in Italy in particular, utilization has not developed very far. It might perhaps be thought that since we have warmer and also fairly dry climates, the seasonal coefficient of performance could be increased. This is true: in practically the whole of Italy, and I think also in Spain, we can achieve a coefficient of performance in the region of 2.5, 2.8, or even 3, for small heat pumps, that is, from 5 to 30 kW (thermal). So it might at first sight be thought that the heat pump could be very attractive. But this is not so, because the use of heat pumps for heating alone, even with high COPs, does not always give a return on investment, because the heat pump today still costs quite a lot and the period of use, especially in southern Italy, is very short during the year - 90 days, or 80 days, or 60 days, and so its economic viability is highly problematical. The heat pumps which have so far been installed are all of the air-to-air or air-to-water type, because the outside temperature is high enough, as I have said, to give a relatively high coefficient.

A more attractive approach for our areas - in particular, also north Africa and the Middle East - is year-round all-electric air conditioning, i.e., when the heating system is replaced by a year-round air conditioning plant, when you compare even today's electricity costs with those of gas oil, fuel oil, and gas, the conventional boiler can be eliminated, with its need for oil, with all the possibilities of lack of fuel which can arise every so often during the year. This is also true for parts of northern Italy, and on days when the temperature is slightly lower we can cope with simple electirc resistance heaters; as my British colleague said, there are normally very few intensly cold days in Britain, which is much further north than Italy. In northern Italy, for example Milan, we have a design condition of, say, +6 to +7°C, so that here again, the boiler can be eliminated where it is possible to have year-round air conditioning. A typical application which we have already put into practice as an idea in the Near East is a complex of about 60 blocks each containing ten apartments. Each apartment has its own reversible heat pump; we have supplied about 700 of these heat pumps (10 to 30 kW (thermal)), which are of the air-to-water type, in which the heat or cold is drawn from the outside air and the prepared cold or hot water is circulated through the apartment by convectors. This system is extremely simple to install, and, as already stated, renders a central heating plant, boilers, storage tanks, etc., superfluous. Another advantage is that we consider that the heat pump generally has a much longer life than a boiler. Boilers for an apartment or a block of flats currently, I think, have a life of six, seven or eight years. A heat pump, on the other hand, even if it does not last for ever, has a virtually unlimited life - simply replace a few compressor parts and the machine is as good as new again.

Now a few words on running costs. As already stated, a heat pump heating system at present gives a net saving of 25-30% on non-running costs in Italy as comparedwith a gas oil system. Unfortunately, as I said at the beginning, we have problems of economic viability which limit utilization for heating alone. We have for the past two years or so already had an establishment for air-to-air, air-to-water, and even water-to-air heat pumps - my colleague already mentioned the latter in connection with closed-loop energy recovery systems. For the future we intend - in fact, we have already planned a study on the use of heat pumps, based on studies to be carried out within three years to increase the coefficient of performance, under our conditions at present in the region of 2.6 to 2.7, to 3-3.5. We consider that this is feasible given component improvements - especially with two-speed compressors, by increasing exchange surface areas,

We consider that at present and also within the next few years, a great deal of progress can be made with the coefficient of performance - I am referring to air-to-water or air-to-air machines - because we are approaching what might be a technological limit, i.e., at a certain point the machine will cost so much, and its construction will consume so much energy, that when you consider the cost of manufacturing the steel, manufacturing the components, and the energy consumed in making the components for the machine, these costs eventually become prohibitive, so that it is no longer worth while to go beyond certain coefficients of performance; at least, we feel that this is true in the present state of the art. That, I think, is all I have to say, and I do apologize for having improvised.

Chairman

Thank you very much, Mr Farina, for your impromtu talk about the Italian situation.

Well there, ladies and gentlemen, you have the contributions to part 2 of our agenda; there now remains half an hour for discussion.

Mr Hannay

First of all I should like to ask Mr Moreau a question. He said a great deal about heat pumps operating with extracted air. I consider that the principle of introducing approximately one volume per hour into the living rooms involves the use of a highly complicated technique to try to save energy. In round figures, this probably means something like 180 to 200 m^3 constantly in a medium-sized dwelling. If you now consider the air flows required in air-conditioned buildings, you find that a constant flow of 180 to 200 m^3 is sufficient for a constant population of six persons in a house. So I think that introducing one volume per hour into living rooms involves substantial overventilation, so that the way to save energy is probably simply to reduce this ventilation rate to reasonable proportions - say, 0.5 to 0.6 as recommended in other countries - in which case it would not be necessary to use heat pumps to achieve greater savings of energy.

I should like to ddd one comment to this question. In a dwelling into which one volume per hour is introduced by single-flow or dual-flow controlled mechanical ventialtion for hygiene purposes, how much air is also introduced by natural ventilation, especially in individual houses simply as a result of the occupation of the building? I know that it is not easy to answer this question because little is known about this natural ventilation, but according to the information that we do have at present, it is quite likely that these houses with mechanical ventilation giving one volume per hour air renewal are actually ventilated at a rate of 1.5 volumes per hour - in other words, they are very substantially overventilated.

Chairman

Mr Moreau and the other participants, I should like to try and limit each question and each answer to one minute if possible.

Mr Moreau

It is difficult to answer questions about ventilation rates. It is a matter of regulations, and I imagine that representatives of the Centre Scientifique et Technique du Bâtiment (Building Research Centre) in France, which drew up these regulations, could reply. I think that considerations of humidity levels and odour transmission were responsible for these rates. It is now a problem outside our jurisdiction.

With regard to the actual rates occurring, it is a fact that considerable parasitic infiltrations often occur, and this is one reason why I did not mention this just now, but we are working on extracted-air/water techniques, and then the blowing circuit ceases to be relevant, so that we only have to deal with a single circuit - the extraction circuit. This may not be ideal, but it halves our problems.

Mr Bertrand

The question I am going to ask is addressed virtually to you only, Mr Chairman. Basically, it is addressed to the European Commission.

As we know, the general characteristics of a climate depend on five parameters, namely, the minimum temperature assumed, the mean temperature assumed, the duration of the heating season, humidity and insoluation. A heat pump has two fundamental parameters: its installed price, and its COP curve.

Does the Commission of the European Communities not consider that an exhaustive study of the influence of these parameters for each type of pump would not be extremely useful and worth while? Admittedly it would take time, but would it not be extremely valuable, to give all European manufacturers a better knowledge of the European market which is theirs?

Chairman

Thank you very much, Mr Bertrand, that is indeed a good question, a good suggestion. I hope that what will come out of our discussion today is a better realization of the many problems which remain, so that heat pumps in their various forms may be applied in an optimal way to our rather big climatic regions with different climates. Obviously, some guidance is required and this is one point which I would like to take note of as a possible suggestion that the meeting might make to us later in the day that such a study would be of value. I expect to find that there are other directions as well where there are things that need to be done. If it is clear that it needs to be done at a Community level, I can assure you we shall be as responsive as we can.

Question from a Participant

I should like to return to the previous question; my question overlaps with Mr Bertrand's.

It seems to me that apart from the differences in approach between manufacturers, we must first look at the problems of housing and climate, which are inescapable. In particular, I consider that the matter of ventilation, which is subject to regulations in France, is not governed by regulations solely because the authorities are particularly powerful in France, but simply - as I think the British speaker really showed - because humidity is a reality.

I consider that humidity cannot be separated from thermal insulation. In terms of energy saving, we must insulate, and seal off our houses, and if these two conditions are satisfied, humidity, and hence also ventilation, must be very carefully considered. In my opinion the heat pump is precisely a system whereby all climate, temperature, comfort, ventilation, and humidity conditions can be satisfied.

I should like to ask Mr Geeraert a question about swimming pool applications. Just now he talked about heat recovery using, in particular, a rotary recovery unit to reclaim heat from the extracted air and transfer it to the fresh air needed by those using the pool, and he also mentioned the use of the heat pump for dehumidification.

The question is about the following: rotary heat recovery systems all extract more or less moisture, so that they transfer water vapour to the fresh air, which is inconsistent with the purpose of the heat pump and gives it more work to do, whereas there are other possibilities in which this transfer of moisture can be avoided - in particular, plate type heat exchangers and heat pipes.

Mr Geeraert

I don't understand why a heat pump should transfer moisture in dehumidification. On the contrary, it is static and rotary heat recovery systems which transfer moisture.

Intervention by a Participant

I think we have a misunderstanding here. You spoke of the use of rotary recovery units to recover energy from the extraction of the hygienic air required by the users in swimming pools, so that this energy can be returned to the fresh air. At the same time, the swimming pool air was dehumidified by a heat pump, that is, with evaporators and condensers. After all, you pinpointed both problems.

Mr Geeraert

Your problem is about energy recovery from the extracted air - that is, ventilation and recovery from the extracted air, or the problem of closed-loop dehumidification.

From the energy standpoint, closed-loop dehumidification is more advantageous, but this is unfortunately not permissible in a swimming pool. The volume of fresh air required is 30 m^3 per swmmmer per hour. So we have to use a combined system with partial recovery from the extracted air but mainly for dehumidification, and while the pool is closed there is every advantage to be gained from closed-loop operation. It is more economical.

Chairman

Are you still not satisfied?

A Participant

I think we have misunderstood each other because I in fact agree with Mr Geeraert that it is inappropriate to renew the air in swimming pools for dehumidification. Given that air has to be introduced, moisture must not be transferred to this air, particularly with a rotary system. That is what

I mean. The air extracted from a swimming pool contains something like 16 to 17 grams of water per kg of air, whereas the fresh air introduced has a water content varying in winter between 1.5 and 7-8 grams. So a rotary system increases the water content of the air blown into the building, thus adding somewhat to the work of the dehumidification heat pump, whereas this moisture transfer does not occur in other, static systems.

Mr Geeraert

If I have correctly understood the question, you are saying: why use a rotary recovery unit, but my example did not relate to a rotary recovery system but to a plate type unit, or a recovery unit in an intermediate water circuit, but at any rate not a rotary unit. So it was a comparison between a ventilation system without energy recovery, a ventilation system in which energy is recovered by a static recovery unit from the extracted air - a plate type unit or a system using an intermediate water circuit - and a heat pump used as far as possible for dehumidification.

Prof. Schaefer

Perhaps the simplest answer is that there are also rotary heat exchange systems which do not transfer moisture, or transfer it only to a very limited extent.

Mr Robin

I should like to ask a much more general question. Comparisons in terms of primary energy between different heating systems are easy where only a single primary energy source is concerned - for instance, comparison between fuel oil heating and electric heating, where the electricity is itself generated from fuel oil.

But what procedure be adopted in the case of different primary energy sources? This applies to sources which cannot in practice be used direct for heating locally, such as industrial coal, water energy, and particularly - now and in the future - nuclear energy. An availability factor should therefore be introduced. Furthermore, the real problem facing the Member States and the Community is primary energy importation, so an important factor ought to be introduced. In other words, to evaluate the relative advantages of electric heating and heat pumps, they need to be distinguished by the origin of the kilowatt-hours used. Has such an alalysis already been contemplated either by the Member States or by the Community?

Chairman

What I propose to do about that question is to ask the panel to take it up this afternoon, because I think questions of comparison of primary energy are important. However, as far as the Community is concerned, the policy is indeed very clear, and that is, in energy policy the first objective is indeed to limit and reduce our dependence on imported oil, for obvious reasons; to diversify our sources of other energy so that coal, hydraulic, natural gas, nuclear, all have a significant place in our energy economy. They have different characteristics of supply and by a judicious combination of these, it should be possible to get both the assurance of security as well as economy, but I propose to leave the question until the panel this afternoon.

Question from a Participant

I should like to return briefly to the matter of moisture within buildings.

With heating systems using static exchangers or even ventilation by heat pump or other means, it is found that the humidity in winter never exceeds 35 to 40%. Overventilation merely makes matters worse. I still cannot understand these regulations which insist on a particular renewal rate per hour, while most users require humidification in the air introduction system.

Mr Brundett

I think the question is really directed at the French scheme. Ventilation does dilute body odours, moisture and things like this, and the real question is, for the long-term solution, is dilution a satisfactory technique anyway, and is it right that the minimum criterion for ventilation is body odours? There are very simple electrical techniques that may remove body odours - ozone or ultraviolet destruction - very low-energy methods of doing it. For moisture removal in a domestic situation I still favour the heat pump dehumidifier within the house, rather than a heat pump allied to a forced ventilation system. But I think the French climatic conditions are quite different, and I think if they can get some summer cooling on the air side, that probably is the real advantage for the heat pump in the French climate, as I understand it.

Intervention by a Participant

I think we can go on and on arguing about the French regulations. Part of the intention of these regulations was to keep the dwellings in good condition, but on this count they are probably excessive, and 0.6 or 0.7 volumes would be enough. May I first of all draw attention to the fact that when you say one volume, that means one volume of the main rooms, and that represents on average 0.8 in terms of the dwelling.

The second point about the French regulations in fact concerned multidwelling buildings, and was essentially a **problem** of odour transmission - kitchen semlls, bathroom smells, etc.

What I think is that these regulations exist, and they are the way they are. A question asked recently was whether the ventilation could be modulated - i.e., delivering one volume per hour but shutting it down at certain times, especially at night. The public health authorities and those concerned with the quality of life, etc., gave a negative answer: no, we do not want this. So all that they can tell you is that regulations exist. In my opinion, if the required value were reduced to 0.7, there would be no fundamental change, except that the extracted-air heat pump would have a lower output capacity, it is true, or else I would say that there would be some slight changes in technique, but that would not prevent us from using the heat pump for all that.

Mr Lerin

You say that reducing the requirement to about 0.7 volume per hour would not change very much. I should like to return to this point, because I believe that the measurements we have show that in dwellings without special precautions we already have something like 0.4 volume per hour of natural infiltration. This means that only another 0.3 volume per hour would need to be provided by controlled ventilation. You might as well admit that this is hardly worth while. You have just answered that you can do something by extraction, but it is by no means certain that your extraction will cover all the infiltrations. In spite of this extraction, you can still have transverse ventilation of the dwellings. But I think another very important point to which we could return is the problem of human behaviour and actual human needs, and we must also resolve the current ambiguity about whether a system is economic for the user. I believe that it practically never is, any more than practically any other precaution currently suggested to users to reduce energy consumption. It is hardly worth the user's while to reduce his energy consumption - firstly, because this accounts for only, say, 5% of the family budget here in Belgium, and secondly because energy is still much too cheap. So we must resolve this first ambiguity and decide whether we are arguing on the level of the user or of the community. It is therefore vital for us to correctly evaluate needs and take full account of the effects of human behaviour. The importance of open windows was just emphasized. We need to know whether people do or do not heat their bedrooms, whether they open the window at night, etc. These are all little things that are liable to upset our theoretical calculations.

Another contributor

I am sorry that we are concentrating solely on this problem. Be that as it may, it is paradoxical and ventilation rates are relatively high in France but that very demanding requirements are imposed at the same time, at least as regards window quality in new buildings. Windows are required to be substantially airtight. This is so as to control ventilation when the idea is to control ventilation and to endeavour to reduce infiltrations. Another point is that in France people are constantly saying how absurd it is to have the heating on with the windows open. So when we are told .... In England, when people want ventilation, they open the window; I say that this practice is not allowed in France. When you see an open window you imagine that it is for reasons of ventilation since the rooms are ventilated, but it is probably because of excessive and badly controlled heating. So this is what we are really concerned about. I also mentioned another problem: whether we are talking about the advantage of the user or of society. This is a very difficult problem because most authorities which advocate energy saving and energy recovery or saving systems in general are, of course, concerned with society. The problem is to move on to the level of individual advantage. One of the problems with the heat pump is that the individual is asked to make a high capital outlay while it is not obvious to him that he will get an economic return on his expenditure. So if heat pump use does not develop further this is because of its cost and the cash savings that can be achieved. Obviously, if energy prices were to be considerably increased across the board, the capital cost of a heat pump would not increase in the same proportion, and the economic viability situation would look completely different. Before 1973 only a madman would have gone in for a heat pump. I did, but I was regarded as a madman. Since 1973 it is seen as a little less crazy to concern oneself with heat pumps, but perhaps in a few years it will not be thought mad at all.

Mr Churchman

Mr Farina stepped in and gave us a very interesting talk on the Mediterranean climate. Mr Farina, I wonder if he or any of his Italian colleagues or other people who live in the glorious Mediterranean climate can say what it is about the existing American heat pump, which after all was designed principally for cooling, that stops its application in the Mediterranean zone of the Community. The American style of heat pump is optimized for cooling with a limited amount of heating, so it should, on what we know of the Mediterranean climate, satisfy the need three. What is wrong with it?

Another Contributor

The American heat pumps from the Westinghouse licensees are very suitable for our applications; in my opinion they need to be improved from the point of view of defrosting, because in northern Italy in particular we have similar weather to that of England, i.e., high humidity and fog, and this is the rather critical problem that we must solve - ice formation and defrosting - and this is connected with the reliability of the machine itself.

Mr Bonari

We have talked about many systems and methods for tackling and solving this problem of rational energy use, or alternative energy, but in all this morning's technical considerations we may have forgotten the problem of rational energy use in single-family dwellings; that is, we have rather neglected this aspect, while I feel that energy consumption in these small houses is much greater in unitary terms than in buildings with many apartments. May I therefore urge the technicians, the experts, if I may say so, not to ignore this aspect of the problem. Thank you.

Another Contributor

I can only add what I said this morning that I feel that we must intensify our efforts to increase coefficients of performance by improving the heat exchangers and, in particular, components, compressors, etc.

However, it would be good if some of these components - for example, compressors, reversing valves, and defrosting systems - could be developed in Europe, because up to now 90% of the heat pumps built in Europe make use of American components for these items, whereas in fact there are in Europe excellent manufacturers of, for example, compressors, but these compressors are not normally suitable for heat pump applications. As everyone knows, at the end of the 1950s the Americans experienced a huge growth of heat pumps, as has already been pointed out, but this development came to an end in the 1960s owing to the disasters which occurred with these heat pumps. This was due mainly to components, and I would say that the (American) components currently available are good, but the corresponding European ones, such as compressors, are not at all suitable, whether Italian, French, British or German, because the operating conditions of heat pumps differ very greatly from those of ordinary air conditioners used for cooling only. So I would ask the Italian and European manufacturers to become more aware of the need to make components suitable for heat pumps, so that we are less dependent on American technology. That is all I have to say.

Prof. Schaefer

Yes, I agree entirely with my Italian colleague that where water at temperatures of 12 or 13°C or even higher is constantly available throughout the year, that is an excellent heat source for heat pumps. And there are also cases - for example, in the Federal Republic there is a river called the Erft - in which effluents come from the lignite mines, so that the river has a virtually constant temperature. A very large-scale study has shown that it is perfectly possible to extract substantial quantities of heat from this by means of heat pumps, and we have even coined a term for this: "cold district heating", that is to say, we use natural watercourses as a free heat transfer medium, sometimes also for waste heat from power plants, and only extract the heat at the location where it is required using a heat pump.

Mr Kalischer

If we have spoken mainly of air as the heat source, this is because it is universally available. In the Federal Republic, the number of houses which we could provide with heat pumps using groundwater or other waters is perhaps not even 10% of the number which we could provide with heat pumps if we also use air. Air calls for more sophisticated technology. If we can master the technique of the heat pump using air as the heat source, then we shall always be able to cope with situations where better heat sources - water and earth - are available.

Chairman

I now invite Mr Kalischer to present point (3) of our programme.

Mr Kalischer

Ladies and gentlemen, may I first of all say how pleased I am to see that we have a lady in our audience. I regard this as a good sign, a good omen, for the growing interest of ladies in the heat pump. I can assure you from my own practical experience that ladies have a very important influence on whether heat pumps are installed or - unfortunately the more frequent case - not installed. So I think that this is a good sign.

I have been asked to report on the difficulties which can arise in the development of different types of heat pumps, confining myself to the field of heating and air conditioning. It is not surprising that the heat pump has now been remembered and that it is expected to contribute to solving our energy problems. After all, it promises indirect utilization of the free solar energy contained in our environment without at the same time bringing with it the problems which we unfortunately still face with direct solar energy utilization - e.g., collection of solar radiation. However, obeying the second law of thermodynamics, the heat pump requires a certain amount of driving energy, which we must supply to it - in practice usually electricity. Mr Geeraert has already stated that about 99% of the heat pumps currently in operation use electricity as their motive power source. Depending on the heat source and the application, this proportion ranges between 15 and 40% of the heat output. Precicsely for this reason, the electrically driven heat pump is often accused of wasting primary energy owing to the low efficiency of of electricity generation. To ensure a uniform basis for discussion, I should first of all like to compare the energy balances of different heating systems. This can be done most clearly with energy diagrams. I have therefore brought four diagrams which attempt to do this for four systems. We can, of course, argue about the data on which these four diagrams, which I will show you in a moment, are based - about the efficiencies, etc. - but the margin about which we will be arguing is not big enough to make any substantial difference to the basic conclusion.

The first diagram shows the primary energy requirement of a conventional oil-fired central heating system; the heating heat requirement - i.e., the useful heat output - is called 100. (I am sorry that the catpions to this diagram are given only in German. They are translated in the text which you have received.) If we follow the path back, we find that because of the losses arising in energy conversion on combustion and those involved in producing fuel oil and other products from the crude oil and in transport, etc., a total of 173 parts of primary energy must be used - 173 parts of crude oil - to produce these 100 parts of useful energy. So much for conventional oil-fired central heating. If we now compare this with a groundwater or earth source heat pump and follow the path back in the same way, we arrive at a primary energy component of 90 needed as the input, including power plant losses, which are allowed for at the bottom here as the main loss component. This means that, allowing for power plant losses, the primary energy requirement of a heat pump having groudwater or earth as favourable heat sources is still only about half as much as that of an oil-fired system.

The third diagram applies to a dual-mode (bivalent) heating system as already present, i.e., a system which uses not only a heat pump but also an oil-fired installation on very cold days. You will see that in this case about 64 + 47 = 111 parts of primary energy are needed - if air is used as the heat source, as in the dual-mode heating systems hitherto used in Germany - in order to satisfy the 100% heat requirement. This is still only 65% of the primary energy requirement of an oil-fired system. So this system - this question already arose before - also saves primary energy. One of the crucial factors in this favourable result is that in particular the lower surface area efficiencies of oil heating on part load, i.e., in spring, summer and autumn, are ineffective because the heat requirement is met in full at these times of the year by the heat pump.

Optimum primary energy utilization is attained with a heat pump driven by a gas engine or also by a diesel engine. The engine then not only drives the compressor for the refrigerant circuit, but the energy content of the exhaust gases is also utilized, giving a very low primary energy content over the conversion chain as a whole - less than 50% of that of the oil-fired central heating system. Unfortunately, this system is still at a very early stage in its development, and series production of small units in particular, for the large number of one and two-family houses, is not to be expected in the short term. For larger installations, however - multidwelling blocks and other large buildings - this system is ready for practical application now. It is particularly economical of primary energy. Overall, the heat pump in fact has three principal advantages: firstly, all in all, only about half the primary energy needed by a conventional oil-fired heating system is used; secondly, the primary energy source employed is not so dependent on imports as crude oil, at least in most European countries; and, thirdly, pollution at the point of use is negligible. This is a very important point at the present time, now that we are becoming more and more aware of the quality of our environment and of the requirements that this imposes on technology. I have started with these primary energy balances because of the repeatedly adduced argument that the "low efficiency" of electricity generation makes the heat pump a pretty useless instrument because it cannot really save primary energy. I wanted to make it quite clear that this is untrue. For this is one of the main obstacles to the further diffusion of the heat pump - a certain climate of opinion working indirectly against heat pumps, at least in Germany.

Now I should like to consider in detail the other obstacles to the rapid diffusion of the heat pump. As you know, present-day heat pump technology limits the available temperature level to a figure permitting applications only in a very small sector of industry and commerce. For space heating purposes, however, this temperature level is as a rule sufficient, so that from the technical point of view, the heat pump can today perfectly well be used in this very large, self-contained energy consumption sector, which accounts for over 40% of final energy consumption in the Federal Republic. Nevertheless, as we know the heat pump is making only very hesitant progress on the market.

The obstacles to its progress can in fact be subdivided into the following groups: obstacles due to heat pump technology; obstacles resulting from other peripheral conditions applicable to heat pump utilization; obstacles due to administrative measures; psychological obstacles; and, finally, problems of economic viability. I wish to try and examine these obstacles individually in detail.

First of all the obstacles associated with the technology of heat pump installations. The physical principle of the heat pump has already been used in refrigeration for many years, and the machines used in that field have attained a very high level of reliability. Precisely for that reason refrigeration engineers keep on saying that the heat pump is nothing other than a refrigeration machine and does not therefore pose any special technical problems. This may be true from the physical point of view, but practical experience has shown that heat pumps designed on this basis have seriously damaged the image of the heat pump. This is due to the particular operating conditions applicable to heat pumps used for space heating. The heat requirement fluctuates between 0 and 100%; the heat is predominantly required in the part load region; machines are switched on and off frequently; evaporation and condensation temperatures vary substantially - these are some of the special features which demand a technology specifically designed to cope with them. The serious damage done to the image of the heat pump due to unreliable equipment in the 1960s in the USA is largely attributable to failure to take account of these facts.

Even though sufficient reliable heat pumps are now available on the market in Europe, improved heat pump technology could nevertheless substantially enhance market prospects. In my opinion, we should concentrate for this purpose primarily on the following points: Firstly, in increasing the annual coefficient of performance, i.e., the ratio of heat output to driving energy input. Secondly, on reducing the noise level, especially when air is used as the heat source. We must not forget that the heat pump is in competition with other, noiseless heating systems. Noise is a point that can be appraised by anyone. Then we have to consider equipment design from the point of view of low-cost production of large series, because the heat pump only has prospects of further dessemination if it can be produced in long runs and this reduces the price. The final requirement is in the same area: the equipment must be so designed as to minimize the work of installation on-site - i.e., it must be as far as possible prefabricated and designed for ease of installation.

All the heat pumps currently available in Europe are still far removed from the optimum in one or more of the points mentioned. However, heat pump technology can be seen to be in rapid development. But it is also evident that the large firms with substantial financial resources still have little interest in specifically directed development work. This will remain the case as long as big sales are not to be expected. For this reason, the most serious endeavours are on the part of small to medium-sized firms, whose development capacity is correspondingly limited.

Next, I would mention the obstacles presented by general peripheral conditions. These conditions are very important for the use of the heat pump, and are largely dependent on location. This is most obvious when we consider heat sources. We have already talked about the desirability of groundwater and earth as heat sources for the heat pump, as their temperature is almost equally suitable throughout Europe. However, they are unfortunately not everywhere available in sufficient quantity. Over large areas, especially densely populated regions, they are totally unavailable as a heat source. The temperature of the outside air, the only heat source which is truly available everywhere without restriction, is, however, subject to substantial climatic variations. In Sweden, for example, this has led to a concentration of development work primarily on groundwater and earth as heat sources in spite of all difficulties. The same applies, for instance, in Denmark. In that country, outside air is probably attractive as a heat source only for dual-mode (bivalent) heat pump heating systems - i.e., perhaps I should limit this last statement to Sweden with its somewhat less favourable climate. It is not quite so extreme in Denmark. The heat required on very cold days must, as stated, then be obtained from a conventional heat generator. The latest Swedish conclusions also point in this direction. In the UK, on the other hand - as also clearly pointed out earlier - the outside air is regarded as the most suitable heat source, and because Britain is an island in which no marked cold peaks occur, heating exclusively by heat pump also appears to be a reasonable possibility. But, as also stated, the high atmospheric humidity presents fresh technical obstacles due to icing of the evaporator and defrosting problems, and these must also be seen as hindering the diffusion of the heat pump.

Finally, in southern Europe, the annual heat requirement for heating is so low that the relatively high capital cost of a heat pump installation is not justified for heating alone. In summer, however, cooling is often necessary in these areas, so that a switchable unit capable of operating in both modes would have good prospects, at least theoretically, as in large areas of the USA. But in practice, as I think we must clearly see, the comparatively low standard of living in many parts of southern Europe stands in the way of the installation of an air conditioner, which could constitute an economic basis for a heat pump heating system. When we look at the countries stretching from Sweden to the southern tip of Europe, we can in fact see that there is no uniform market for heat pumps in Europe at present, and this is a serious handicap for the heat pump. Specific products are required for individual areas. But this further reduces the prospects of achieving long production runs and thus producing inexpensive units.

A further point is that the prevailing heating and air conditioning customs differ from country to country. The use of heat pumps is facilitated by heating systems which centrally produce the heat required for all rooms in the house and then feed it to the individual rooms as required via a distribution system. Central heating installations of this kind, as commonly used, for example, in Switzerland or the Federal Republic, in large areas of France, or in Scandinavia, involve a heavy capital investment, which the houseowner makes on grounds of comfort irrespective of the form of heating chosen. If a heat pump is installed, the existing system can be utilized without thereby occasioning additional costs attributable to the heat pump. But where such a central heating system does not exist, as in parts of Britain and Ireland, the houseowner must be induced, when a heat pump is fitted, to install a central hot water or hot air distribution system at the same time, or to confine himself to decentralized individual units in the individual rooms. This results in additional costs for the central system in both cases, simply because a large number of small units are more expensive than one large unit. A further problem with the central system is that the fabric of the existing building has to be tampered with and that modifications are necessary inside the building.

Another important difficulty at present still impeding the installation of heat pumps is the lack of specialized knowledge on the part of both building planners and contractors. The heat pump will only be adopted on a wide scale when architects and heating engineers have sufficiently familiarized themselves with heat pump technology, because these two professions - architects and heating engineers - are very important sources of information for building project sponsors, hardly any of whom would be prepared to make a decision against their advice.

I now come to adminstrative obstacles. It has always been the case that all innovations having any significance at all from the administrative point of view are subject to difficulties in this field. In the last analysis, the reason for this is that every administration must work in accordance with specific rules and regulations, orders, standards and specifications, which of their nature cannot allow for innovations. In fact, it will never be possible to eliminate this problem. It is only essential to see that once these difficulties are recognized, they be disposed of as quickly as possible and as unbureaucratically as possible.

In the Federal Republic of Germany, for example, the Building Trades Regulations (Handewerksordnung) specify what work may be done by workers in each trade. If a tradesman transgresses these limits, this is sanctioned as a breach of the regulations. But if these regulations were to be consistently observed, this would mean that the installation of a heat pump would required workers in up to four different trades: a refrigeration engineer, a heating engineer, an electrician, and often also a bricklayer. This would of course be impossible from the point of view of the houseowner or building project sponsor. This problem may be even worse in other European countries. Apart from the organizational difficulties and additional costs which thereby arise, this gives the heat pump the reputation of being a complicated heating system which can only be installed at great expense. Administrative difficulties are in general as many-sided as administration itself. Taken individually, none of them is very significant, but together they constitute an appreciable impediment. If, as, for example, in the Federal Republic, the law stipulates that the chimney sweep must act as adviser to the population on all matters pertaining to space heating, it becomes evident what latent problems this causes for a heating system which has no chimney and therefore also has no need of a chimney sweep.

However, it must be emphasized that impediments and obstacles are not the only things that may originate from administration; if properly conceived, an administration has vast possibilities of promoting the development of heat pumps in a goal-directed manner. These possibilities extend from financial support by tax concessions, loans and similar facilities, via simplified approval procedures, to education in general and vocational schools. Here, too, certain initial approaches are already evident, but much more could still be done in this field.

The next group of obstacles are the psychological ones. Most building project sponsors or houseowners, architects, and heating engineers, while they are probably familiar with the heat pump in theory, know hardly anything about its practical application. For hhis reason the heat pump is tarred with the brush of scepticism which at first attaches to all innovations. This situation is exacerbated by the fact that this method of heat generation as a rule appears pretty incomprehensible to the nontechnical person and m y often even smack of a perpetual motion machine.

The basic problem of these psychological obstacles is in fact lack of information. Other, much more spectacular energy media are again and again displacing the heat pump from the place to which it is entitled in this field even if their prospects are much more limited. For example, direct utilization of solar energy and wind power are presented in detail much more frequently than the heat pump. Even responsible politicians frequently prefer to nourish unrealistic hopes in these fields instead of facilitating the development of the realistic possibility of heat pump utilization. Here again, the complicated thermodynamic relationships of the heat pump process may be a reason. The heat pump is unfortunately a stepchild of the information media. But the psychological obstacles can only be eliminated by intensive information and education. This must not be merely theoretical but must also show on the basis of practical examples that a proven technique is available. It is only in this way that important decisionmakers, such as architects and heating engineers, can be won over to the idea of recommending their clients to install a heat pump. This is also the only way of disposing of the prejudices which have their roots in technical problems of the past. Removal of the psychological obstacles is one of the fundamental prerequisites for the widespread application of the heat pump.

This problem has been generally recognized, and initial attempts to solve it are already evident in some European countries. In Denmark, for example, the assumption of some guarantee as to the operation and energy consumption of the heat pump by the electricity utilities is a present being discussed.

This discussion may in the meantime have even been concluded - I do not know.

In the Federal Republic of Germany, one electricity utility has installed 50 speciment plants, and the same utility is also granting the first 1 000 heat pump customers a special discount of 25% on electricity costs.

At the same time, both countries are taking great care to ensure that only thoroughly reliable heat pump systems are installed. These initial systems are intended to present the heat pump as a robust and reliable technology and thus to take it out of the sphere of the futuristic. Another bridge that could be built to overcome the psychological obstacles would be to combine the heat pump, which, as stated, is still regarded as having some uncertainty attaching to it, with a well known and proven heating technology. This is the case with the bivalent or dual-mode form of heating described. By virtue of the presence of the oil-fired boiler, this combined system gives the customer the necessary feeling of security, actual security of supply. I believe that this would constitute an important means of support facilitating the diffusion of the heat pump, and constituting one of the best ways of improving the prospects of the bivalent (dual-mode) heat pump heating system.

Finally, I should like to discuss the economic viability of the heat pump and the obstacles arising out of the fact that, it must be admitted, it is not yet entirely economic. As you know, a heat pump system is more expensive to install in terms of capital than a comparable fuel-fired heating system. If the heat pump is to stand up to comparison with, for example, an oil-fired heating system as regards overall heating costs, then this extra capital outlay must be offset by lower energy costs. This is most likely to be possible with large heat pump units, which can use favourable energy sources. I believe that this realization was in the last analysis also the reason why a great deal of work is being done in France on installations in large buildings using geothermal heat sources. In Sweden, too, multidwelling blocks are also regarded as affording better prospects.

Considerable problems have, however, emerged in the Federal Republic of Germany. These have arisen wherever the owner himself does not live in the building - as is usually the case in multidwelling blocks. In such cases the owner was mainly interested in low capital costs, to enable him to keep rents low, so that the heat pump, with its higher capital cost, had no prospects - regardless of the fact that the tenant, once he had rented the flat, then naturally had to pay more for heating. For this reason efforts in Germany too have been concentrated more on the specifically more expensive, smaller heat pump for heating one and two-family houses.

Compared with a conventional oil-fired heating system, a system using a heat pump works out at something like 25 to 30% more expensive as regards overall costs - i.e., captial servicing and energy costs, under current peripheral conditions, equipment costs, heating oil prices, and electricity prices. I emphasize that this applies at current prices and given the current cost situation. Although a cumulative consideration covering, say, the next ten years - i.e., the approximate lifetime of the heat pump - would result in a more favourable picture, the fact that the heat pump is more expensive in terms of overall cost at present understandably constitutes a serious problem as regards mass introduction. However, this problem could be solved by specifically directed promotion by the State, as is often already done in other fields, such as district heating. If smaller heat pump units could then be produced in long runs, the equipment would become substantially cheaper, so that this subsidization system would not have to continue indefinitely, particularly as increasing savings on energy costs would accrue from the operation of the heat pump as energy becomes more and more expensive.

The economic situation of the heat pump is very complex, as a large number of parameters are relevant and all of them may be subject to more or less substantial variations. These parameters include capital costs, the coefficient of performance of the heat pump, the price of electricity, the price of comparable fossil heat generation, in the case of dual-mode systems the relative proportions of the heat supplied by heat pumps or fossil-fired heat generators, and any financial subsidization of the heat pump.

It is virtually impossible to make a general statement about these parameters for European conditions as a whole, but I would nevertheless like to give an example of a single-family house with dual-mode (bivalent) heating. This diagram shows the relationship between capital costs and energy costs - on the left-hand side for a bivalent heat pump/oil-fired heating system and on the right-hand side, for comparison, for an oil-fired heating system alone. You will see that three parameters basically determine the cost: firstly the price of fuel oil, secondly the price of electricity, shown by those lines over there, and thirdly the fixed costs, which are represented by the diagonal lines up here. Two examples are shown here: first of all, for the oil-fired system on the right, an oil price of 30 pfennigs per litre, which is the current price in the Federal Republic, which leads to a total energy cost for the oil-fired system of about 1 600 DM; the fixed costs of the oil-fired system, servicing of capital, operating and maintenance costs, amount to about 2 100 DM, so that the total annual cost is 3 600 DM.

For comparison, consider the example of the heat pump on the left, operated on a dual-mode basis. With fuel oil again at 30 pfennigs per litre, and assuming electricity to cost 12 pfennigs per kWh, the energy cost is the same, 1 600 DM. This example is chosen so that the capital cost, which is about 50% higher, leads to a total additional cost for the heat pump in the region of 25%. This diagram thus shows what variations would make the relative proportions more favourable, and the prospects of this actually happening can now be estimated. I should like to begin with the price of electricity. The overall costs would be the same if, other conditions remaining unchanged, the price of electricity were to fall to, say, 0 pfennigs per kWh. As you will realize, this is not possible. The costs would also be the same if the capital cost of the heat pump were to fall to the same level as for an oil-fired heating system - i.e., to be more precise, if the capital cost of the dual-mode heat pump system were to fall by 50%. The overall cost would once again be the same if the price of oil were eventually to rise to rather more than 50 pfennigs per litre, i.e., by about 65%. Probably all three parameters will vary in these directions. Our electricity utility is now offering an electricity price of about 7.5 pfennigs for heat pump operation, and this already brings us much closer to the equal cost level. If the heat pump goes into series production, the equipment costs are bound to fall, and the same will happen as installation techniques become more developed, so that the difference in the fixed costs of the equipment will also be reduced. Finally, I believe we can be certain that oil prices will increase, so that the overall costs of an oil-fired heating system will increase in the future - and they will increase faster than those of a heat pump heating system. In other words, all three factors are moving in directions tending to make the heat pump economically viable. So this is where the heat pump has its chance for the future - and, in my opinion, the relatively near future. We must simply endeavour to modify the factors which we can control as soon as possible. Reducing the energy consumption of the heat pump by improved techniques, for example, also comes under this heading, as I stated earlier.

I should now like to summarize briefly. I believe that the European heat pump manufacturers at present adequately cover the European heat pump market as regards both quantity and quality, and are therefore able to actually go into the market with the heat pump. Improved heat pump technology - in particular, reduction of energy consumption and bringing down the price of heat pump manufacture and installation - however, would be highly conducive to the wider adoption of heat pumps, as stated. But the system that is then actually chosen depends greatly on the climatic peripheral conditions and on the general standard of heating technology in the country concerned. However, one of the most serious obstacles to the rapid diffusion of heat pump technology lies in the lack of information to the population, and it is precisely in this field that the authorities could give us support; this is just as important as financial support for a certain number of pilot plants which could remove the taint of the futuristic from the heat pump concept. Attempts to solve the problems are already evident in all the fields mentioned, but our energy problems now appear to be approaching crisis point so fast that an intensification of our efforts nevertheless appears indicated. Thank you very much.

R O U N D   T A B L E

Chairman

I am going to ask Professor Schaefer of the Technical University in Munich to animate this round table. I shall remain here at his side and hopefully the two of us will be able to make what we can of it. Would you like to make your introduction, Professor Schaefer.

Prof. Schaefer

Mr Chairman, ladies and gentlemen, I should now like to open the round table - or long table, as it in fact is - but before I do so, I should first like to introduce you to three gentlemen who have not yet presented papers but who are participating in this round table. May I introduce Mr Churchman, of the Central Electricity Board. He is responsible for the Board's research centres. I should also like to introduce Mr Dubois, who is also participating, and Mr Villaume, whom we now also cordially welcome as a participant in this round table.

Before I throw the discussion open, I have two more comments to make, and then I should like perhaps to try and sum up.

My first comment is as follows. Having regard to our timetable, would you please keep your contributions limited to not more than two minutes. Secondly, to help our interpreters and all participants who rely on the translation of the proceedings, will you please see that you artificially slow down your rate of delivery. Everyone who knows me knows how much I must control myself to speak so slowly here now. May I ask everyone else to try and do likewise.

Now perhaps one more note on the discussion that we are now about to have, which is to concentrate on the problems and difficulties of the wider introduction of the heat pump concept. All aspects have already been referred to in this morning's papers and Mr Kalischer's paper this afternoon. In the last analysis, they all boil down to the problem of economic viability and hence that of cost. Four groups of costs can be distinguished: equipment costs, relating to the actual heat pump hardware; equipment installation costs; maintenance and repair costs; and finally, the energy costs arising out of the operation of the system. All these groups of costs can basically be modified and reduced only if we make progress in the technical development of these matters as well. I should simply like to mention one or two basic points, on which we can perhaps afterwards hear the opinions of the experts.

One of these points, regarding the euqipment costs, is certainly important. We need to achieve series production of equipment or at least of individual components of the equipment, and this also means that we should reach at least a broad agreement on performance parameters. Secondly, we need to prolong equipment life. I don't mean generally, but for certain specific points and system components which are still liable to failure. The next important point, it seems to me, is to achieve the kind of design that will facilitate installation and thus reduce installation costs. If we do not succeed in designing the equipment so as to minimize installation costs in houses, then, as Mr Kalischer already implied, we shall founder on the matter of installation costs alone. This also means making further attempts to arrive at a modular form of construction. As regards maintenance and repair costs, what I said just now about the technical side naturally applies, but also - and I have heard too little about this so far - I consider that we should try to simplify the whole field of equipment regulation and control and to restrict the necessary facilities to the absolute minimum, to increase equipment availablity and reduce the frequency of servicing and repairs. Incidentally, this also involves scaling the control facilities so as at all costs to avoid short equipment duty cycles of only a few minutes, as are sometimes encountered in practice. On the one hand these shorten equipment life and on the other they substantially impair the coefficient of performance.

Another point - as anyone who has anything to do with the details of these matters knows - is the problem of uniform distribution of the flow of refrigerant to the individual registers of the evaporator. This problem has not yet been solved, and nor has the problem of improved defrosting techniques. The fourth point is in fact connected with defrosting: I refer to all measures aimed at improving efficiency, as these have not yet been exhausted; defrosting and the resulting complication and expense is an important factor in impairing rates of utilization for air heat pumps is the creation of variable-speed electric drives which are nevertheless inexpensive. If we had these, we could control the output of our heat pumps better. Another point - which we should also address ourselves to - is the achievement of better control arrangements for the heating systems served by maximizing the temperature differential between the forward and return exchange temperatures while, of course, at the same time reducing the overall level to a lower temperature range. I should like to conclude by mentioning one point about which I have heard nothing at all today: the consumption of auxiliary energy for control and regulation, and for the pumps and blowers which inevitably belong to a heat pump system.

Ladies and gentlemen, do not forget that in present-day equipment this total consumption amounts to 10 to 15% of the electricity consumption of the compressor drive; control and regulation systems alone - i.e., relays and all the associated components - consume 1 to 1½% of the electrical energy required by the drive itself in most current equipment. These, then, are the points to which we must address ourselves on the technical side. I hope I have not spoken for too long, and would now like to invite any of our experts to contribute if they have any brief comments to make on what I have said or on individual points.

Would speakers if possible please keep to the two-minute limit in the first round. Perhaps we can proceed in alphabetical order; may I first call upon Mr Brundett if he has any comment to make.

Mr Brundett

I would see heat pump development following the modular approach of mass-producing a small reliable unit and I think that the biggest problem that we have to discuss is which market will come first, so that each country's needs are very different and we have to find out which is the first commercial need in the different market areas to start the successful promotion.

I think perhaps the most important thing we have to address ourselves to is that when you remember the housing stock of the Community has a recycling time of at least a hundred years, we are wasting our time because we don't have that amount of time if we only consider new properties. So when we are looking at which part of the market will come first, we have really got to say how one can apply a heat pump to existing buildings, if we are to have any influence at all on meeting the energy gap, which is normally recognized as coming, if you are an optimist, depending on which industry you belong to, in the '80s, if you are a pessimist in the '90s. So we must see how we can attack the existing housing properties, and if we are to make sure that we are going to reduce this capital cost, I must give a plug, you must do the sort of very careful system design which is represented by the sort of studies that Chris Blundel over there has done on the design of your heat exchangers, and for the benefit of the industrialists here, we are going to have to break the heat pump down into modules where some of the components at least are common so we can allow long-run production, and one of the things we should address are what are those modules if we want our manufacturing colleagues to go into production.

Mr Dubois

I should like to mention a contribution by an American called Mr Grainer, of the Edison Institute, at a Unipede colloquium just held in Bordeaux, which appears to state the problem but not to solve it; but it does seem to me to state very clearly the problem with which we are faced. As you know, the heat pump took a very long time to penetrate the market in the United States, mainly for reasons of reliability but also on grounds of cost. Up to 1975 an already respectable figure of 100 000 heat pumps per year for domestic applications had been reached, and this figure remained relatively stable from year to year. This figure of 100 000 rose to 360 000 in 1976, and it is estimated that 500 000 heat pumps will have been commissioned in 1977. That gives an idea of the order of magnitude, and means that about half of all new dwellings - I am not talking about old dwellings, Mr Churchman, but about new ones - about half of all new dwellings are equipped with electric heating, and half of these with a heat pump - that is, a third of the total. This is an impressive figure, and Mr Churchman said that this was because we opted for a technique which suits our needs and which is repetetive, and because we have 20 years of development of a specific technique behind us. Turning now to the meeting, which was mainly European, he told us: "I am horrified to see that what you people are thinking of are techniques, and if it is true that a market of 500 000 pumps per year, even at European level, is about the limit of what we can hope for not in the short term but in the medium term ..."
If we add together everything that has been said since this morning, if we put together the external sources, internal media, partial or total use, bivalent or monovalent operation (to use the German terminology), if we put together the different types of heat pumps and the different means of providing supplementary heat, we arrive at a total of about a hundred models or systems, nearly all of which have been mentioned this morning. So I believe that the problem is in fact tragic, and is in the centre of what

we are looking at today: will the Europeans manage to find - not the solutions, because local circumsctances vary from country to country in Europe - but the two solutions which would enable us to proceed. We were told several times this morning that the climatic situation varies from country to country in Europe, but if anything the climates differ less than as between different parts of the United States, and I do not believe that this is the principal obstacle. The main obstacle is that we are a group of intelligent thinkers and that we have all invented a system of our own.

Prof. Schaefer

Thank you, Mr Dubois. We could certainly say a few things about this last comment, but I think we should first proceed further in our round, and I should like to call upon Mr Geeraert.

Mr Geeraert

The first comment I should like to make is as follows: we must not allow ourselves to be paralysed by the coefficient of performance and by efforts to increase it, but we must above all increase reliability; it is much less disasterous to have equipment which is not reliable. So I should like to support the other speakers; I believe it is essential for us to achieve standardization like that of our competitors - for example, in boilers. Both boiler protection and control facilities are more or less standardized, and I believe, as Professor Schaefer said just now, that we must try to standardize, and to standardize not only the heat pumps themselves but also, and in particular - as heat pumps now have reasonable performance - to standardize their installation, i.e., the system coupled to the heat pump, because in Belgium at least this is where the biggest mistakes are made - on installation. A third point, also about standardization, is that we need a standard form of representing performance. There are, of course, the American standards for air-to-air heat pumps, and in Germany a committee is in the process of drafting standards, but it is essential for us all to speak the same language and to express the results in the same form.

Prof. Schaefer

Thank you very much, Mr Geeraert. Precisely this last point is, I believe another extremely important part of the matters which we still wish to discuss here.

(1574) Mr Kalischer

Many of the general points which I could make I have, of course, already mentioned in my paper, which was based on them. But I should like to return to the suggestion that European manufacturers should concern themselves more with component manufacture. In my opinion the fundamental problem that the market simply does not yet exist, so that potential manufacturers are not yet prepared to invest money for development, cannot be avoided. I believe that it is very important for the Member States to intervene and support us here, because this is something which will not come about spontaneously, because the necessary economic background is simply lacking for economic success, and no firm will go into this without the prospect of economic success, which will certainly not be possible in the short term. Now I should like to take up a point made earlier by a member of the audience, and this is the suggestion that we examine which heat pump systems would have prospects of succeeding under which peripheral conditions; three main groups of applications can be distinguished here. These are the groups for continental climates, for maritime climates, and for the Mediterranean climate. In my opinion, completely different requirements are applicable to each of these groups. A little more clarity in this area would certainly be highly desirable, although, Mr Geeraert, I consider that standardization at this point would be very dangerous, because if we already begin now to try and force a system which hardly yet exists properly into a certain framework, we run the risk of suffocating valuable alternative possibilities before they even have a chance to germinate. In my view, it must be possible to use the heat pump in old buildings in all fields of application. I also consider that further development of components is very important, but I should like to make it perfectly clear that when we move on from components to actual equipment some nasty surprises may be in store if we do not already prepare ourselves and gain experience and work in this field now. We will not necessarily be able to catch up later without problems. It is not just a matter of soldering together familiar and well-proven components and you then have a reliable heat pump. The nasty surprises which we have experienced come about when you have put together a piece of equipment which unexpectedly does not work, and the same kinds of surprises are likely to occur when this equipment is to be integrated in a heating system. Here again difficulties occur which no one had expected. For this reason we must begin today on a broad front, extending as far as installation in buildings, in order to gather experience.

Prof. Schaefer

Thank you,Mr Kalischer. I hoped from your introductory sentence that you would break the record for brevity of a contribution, but thank you all the same. May I call on Mr Moreau.

Mr Moreau

It is hard to be original when you come right at the end. What could be said is that it is not necessarily catastrophic that there has been such a mushrooming of research on, and practical systems using, heat pumps in the last few years, because different approaches have to be tried, and I think the first thing to do is to get to know the results that are obtainable with these different approaches, so that more and more careful followup on the ground will be necessary in the years to come and not merely individual operations which cannot be generalized or which are not very valuable on the specific level; instead, we should be able to build or install sets of at least 10, 15 or 20 machines or houses or buildings, to give us a statistical basis, from which we can choose some promising directions and establish objectives; from then on, series production, and also installation techniques, can go into top gear. Certainly, substantial gains could be obtained from series production of equipment - maybe 20 or 30% - but these are liable to be limited because - do not forget - the equipment concerned already includes components which are well known and therefore the subassemblies are relatively well covered as regards prices and manufacturing techniques. Gains are certainly possible as regards productivity, and as regards simplification of the machines, but perhaps miracles should not be expected in these fields. On the other hand, there are some points on which gains should be possible, such as distribution of the heat. Do not forget that there is a ratio of 2, 2.5, or sometimes 3 between the cost of the heat pump and that of the installed system, so that a lot of work must be done here to obtain favourable results. Old buildings certainly do represent an attractive application for heat pumps, promising dividends both for the user and for the distributor, and since the installation already exists in most cases, a reduction in the manufacturing cost of the generator would have a much greater effect. That is what I think can be added to what has already been said, with which I am, of course, in overall agreement.

Prof. Schaefer

Thank you, Mr Moreau. May I now ask Mr Villaume to speak.

Mr. Villaume

May I say first of all that I am in an even worse position than Mr Moreau, because I really am last. Having said this, I believe that nevertheless Mr Dubois's fears should be allayed, because he is worried about there being 100 systems compared with only one in the United States. Personally, I don't think that this is a bad way of going about things unless one merely wishes to repeat what others have already done, and, all in all, I don't think this is the European spirit. So I am more inclined to agree with Mr Moreau, and should like to say first that we should perhaps remember that in order to learn how to do things we first have to do them. Since we have not yet achieved a sufficiently large market in Europe for substantial standardization, I believe that it is desirable to allow the different techniques to develop. This said, if you consider that the heat pump is essentially a generator and that, Mr Dubois, as regards emission of the heat there are people whose job it is, and if the people concerned with the heat pump concentrate on heat pumps and those concerned with emission concentrate on emission, you will already have a much smaller number of systems than you state. Having said this, I think there are three fundamentals: water-source heat pumps, air-source heat pumps, with a small difference between extracted air and outside air. Personally, I am therefore much more optimistic, and I feel that by attacking the market perhaps a little later than the United States, we may have a chance of diversifying our market, and we should not hesitate to use whatever source may be available, particularly for the heat pump. In France, in particular, the aim of standardization should not make us give up the idea of connecting a heat pump to geothermal heat sources for example. France has many coasts, so that sea water is attractive, and there are already a number of systems in France which use it. So I should like to take up a much more general position, which concerns the reasons for a much more technological development. If our current concern is solely to save oil, we should not forget that we are thinking mainly of saving foreign exchange. For many countries without energy resources of their own, the only way of saving foreign exchange is to replace the energy resources which are lacking by technological development, and I consider that Europe must not fail in this field and imagine that only technological development can present an alternative to energy resources. Now this technological development can take place on a number of levels: some people think that the development of nuclear energy will solve all our energy problems. I personally believe that there are limits to this kind of development, that the multiplication of power plants will constitute another, so that we are not entitled to misuse energy even if nuclear energy develops. Now the heat pump, especially if electrically powered, makes good use of energy, and is also a good means of technological development. I therfore consider that we should commit ourselves totally to this development and accept the risks. Accepting the risks is what was meant when Mr Brundett said: "We regard the heat pump as unreliable at present". Well, it may be unreliable when a technology of this kind first begins; there are bound to be imperfections; it is true that reliability raises certain problems, but in general the industry is aware of its responsibility and knows how to solve the problems - the immediate problem of giving the customer some security by making up for any lack of reliability with today's means; others will, I believe, take over later, and as reliability increases, there will be people whose job it is to maintain heat pumps and see that they operate smoothly. That is more or less what I wanted to say, and I personally have every confidence in the development of the heat pump.

Prof. Schaefer

Thank you for your remarks. You have also mentioned the problem of saving oil and foreign exchange, and that reminds me of a question we had this morning from the audience, about evaluation of substituting heat pumps for different fossil energy sources. At the Chairman's suggestion, this was postponed, but perhaps we can now return to it, and I should like to give Mr Colling an opportunity to reply, but may I first say that Mr Bonarini also wishes to make a contribution, and I will call on him later. I imagine that we shall also hear something about the matter of these different forms of construction for different air conditioning systems, perhaps also on the part of the manufacturers of such systems, as many of them are present among us today, and it would be nice to hear their opinions as well, and also on the problem which Mr Dubois clearly stated, that we are now cleverly developing 100 or 102 different types; no doubt he means that we must reduce this multiplicity.

Now, Mr Colling, if you would be so kind.

Mr Colling

The question which Mr Robba asked this morning was as follows: Energy comparison in terms of primary energy between different heating systems is easy where a single form of primary energy is concerned, for example, direct use of fuel oil and the use of electricity, which is in turn generated from oil. What procedure should be adopted in the case of different primary energy sources, when electricity, for example, is generated from coal, water energy, or nuclear energy? Should a primary energy availability factor then be introduced? Again, the real problem as far as the Member States of the Community is concerned is the importing of primary energy. Should an import factor or a balance of payments factor be introduced? Has this type of analysis already been contemplated by the Memeber States and by the Commission?

French contribution

This does indeed seem to me to be a central problem, not only for heat pumps but, in general, for all forms of utilization of the only kind of secondary energy which currently exists - that is, electricity - which may make use of different primary energy sources depending on circumstances. To reply to Mr Robba, the first point is that in our opinion it should be remembered that when we talk about a kilowatt from an oil-fired thermal power plant, the fuel oil used in thermal power plants is not the same as that used in domestic systems. Now, as Mr Robba says in his question, the problem arising is that of the dependence of our countries on foreign sources; in other words, the only basis for us to calculate what we might call the impoverishment of our countries as our energy consumption increases is our foreign exchange expenditure which goes to foreign countries, in particular, in the Middle East. So the basic, central problem is the foreign exchange cost. We at Electricité de France have carried out internal studies on this question of the foreign exchange costs; their principle is not disputed, but the methods - figures and assumptions - are now under discussion with the Government. The French Government does not currently have a position on this point, but Electricité de France does. We say that the foreign exchange cost of heavy fuel oil cannot be the same as that of domestic fuel oil, of only because heavy fuel oil is cheaper than crude oil itself, and the oil industry is not suspected of selling its products at a loss. Some estimates have been made on the basis of calculation, and these show that the foreign exchange cost in a country such as France is lower in the case of heavy fuel oil than where domestic fuel oil is concerned. This applies to all applications of electricity and not specifically to heat pump applications. It should be added that when we think today, in 1978, we are thinking about systems which will be commisssioned in 1980, and when we consider the development of the European electricity utilities' generating facilities, if only in these two years, we shall no longer be able to claim in 1980 that the supply required by the development of electricity applications, including the heat pump, comes solely from oil. In France, oil is being progressively and quickly replaced by coal prior to the commencement two or three years later of the nuclear era. This brings us to a comparison between electric heating and heat pumps. What we have been talking about so far is the calculations carried out in France on ordinary resistance heating. We now consider that a heat pump, of course, must be more favourable for the country, and here I agree with Mr Guillaume that whatever the form of energy used a direct electric heating system

or else it is certainly not worth while. In our internal calculations, we now consider that a heat pump is no dearer than a fuel-fired heating system provided that an overall average annual COP of 1.4 can be achieved, and this is a basis which we have laid down for ourselves to facilitate the development of the heat pump in France.

Mr Kalischer

We have tried to quantify the various data for the primary energy consumption of heat pump systems and the possibility of substituting these systems for imported primary energy sources. This was done by a very heterogeneous group in the Federal Republic, including manufacturers, authorities, energy utilities, etc. We in fact find that primary energy consumption and substitution of imported energy are two completely different things; the figures we have arrived at, which are also set out in a brochure, naturally refer specifically to the situation in the Federal Republic, but the system could also be extended to other peripheral conditions as, of course, to other heat pump systems, which are not dealt with in this brochure. I personally believe that the free market economy is strong enough to control on the basis of price, so that we need not introduce a weighting factor for the heat pump. This will be done automatically via the price of imported energy sources, which will probably increase faster than those of our indigenous sources. I therefore believe that we can simply rely on the evolution which will come about by itself. We need not intervene here.

Prof. Schaefer

Thank you, Mr Kalischer. You have largely covered what Mr Churchman wanted to say, and now I can finally call upon Mr Bonarini to speak.

Mr Bonarini

Mr Chairman, first of all I am speaking because this round table is a comb-shaped square table, and so this is one reason why I am speaking. Secondly, it seems to me that we have asked ourselves, as we say in Italy, whether the chicken or the egg comes first. Following the increase in the cost of energy due to factors extraneous to the Community economy, I believe that we must increase the imagination factor of both the technicians and the economists. It is clear that the position of the Community is not comparable with that of the United States because, as we all know, the USA is virtually self-sufficient in energy, which we in the European Community are not, if it is true that the 1985 programme is still valid for the European Community, according to which large quantities of energy are to be saved. Regarding the heat pump, obviously it must save more energy than must be expended on saving energy. I therefore agree with Mr Farina that the limits to the use of the heat pump are set by the cost of producing more sophisticated heat pumps and by greater consumption for these pumps. Having said this, I feel that in addition to the action being taken in the various member countries of the Community, the Commission should at an early date coordinate the various activities of the member countries in the field of promotion and of taxation, as well as by subsidizing new designs. Finally, we need to go ahead with what the Chairman, Mr Davis, said this morning about the possibilities of financing finalized projects. So I feel that we want - at least I want - to hear a word of comfort from Mr Davis about the possibilities of the Community's financing new industrial initiatives in this direction. Thank you.

Chairman

I would just like to take up that last point of Mr Bonarini. In their wisdom, our Council of Ministers believe that the Commission is kept most efficient on a small budget, and so we have to be very clever. First of all we have to argue very hard in order to get any money at all, but having got it, what we have got to do is to try and use it very wisely in such a sense that it has a multiplying effect. I can assure you that if we can get the money we shall attempt to do that.

Prof. Schaefer

Thank you, Mr Chairman. I think I can see that Mr Bonarini has bee comforted to some extent, and has taken these words of encouragement to heart.

MacMillan, UK

I would like to try to get back to the big problem, very briefly, of the standards. There is this obvious problem of how do you reach an agreement on what a given heat pump is actually doing. I can elaborate on that theme if wanted. But there is another problem, which is very important for people who are trying to design the machines, and this is the specification of components. There is a tendency to specify, for example, compressors either under refrigeration conditions, that is very low in evaporating temperatures and reasonable condensing temperatures, in the air conditioning mode with very high suction temperatures. Now, unfortunately, heat pump applications lie right in between and it is quite difficult to find what the rated value of a compressor is under the sort of conditions that we want to actually design. Now, I would appreciate comments from the industry, or anyone else, on how best we can improve this position.

French contribution

We have here today a number of representatives of electricity utilities. We are talking about saving energy at the stage of the final consumer. What can be expected in the short term in the field of raising efficiency at the power plant or recovering energy wasted at these plants?

Prof. Schaefer

With regard to the matter of increasing efficiency levels in .... power plants, I would say that we should not nurture excessively high hopes. We have at present virtually reached the technological limits when you think of the efficiencies of conventional fossil-fuelled plants (about 43%) and of gas-turbine/steam-turbine combined plants (46 to 47%). In light water reactors, the limit is, of course, lower owing to the technology of the fuel elements (in the region of 32 to 34%). One way of increasing these efficiencies is the combined generation of heat and power; the limits here are set by the considerable seasonal variations in the demand for electricity on the one hand and the demand for heat on the other.

Chairman

I would rather like to put to the round table this question: I formed the impression today that most people here believe that there is a future for the heat pump and an important future. In many cases it is not yet economic, but from the point of view of manufacturers, it must be a rather baffling kind of market for them. We have seen from the speeches toaday that there are all kinds of variants; there are at least three distinguishable climatic areas. Now if we try and solve all the problems at the same time I predict we will not succeed. Therefore there has to be a concentration: some of the key words that I have heard the panel say today: modules, standardization, go for old buildings early, tackle the costs, what about the free market; is it possible for the round table to identify for us what they think would be some of the initial limited targets to go for, because otherwise I fear that the manufacturers will not know what to do. Perhaps also, Professor Schaefer, we could hear not only from the panel on this, but also from some of the manufacturers who have been giving thought to this.

Mr Bonnet

I should like to ask what is perhaps a heretical question: are we absolutely certain that there is a big market for the heat pump in Europe in the housing field?

It seems to me that the main field for growth in heat pumps is in existing oil-fired heating systems, in which the heat pump can allow substantial energy savings, but this approach will be in competition with insulation of the relevant premises. Would it not be interesting to know what would be the most economical approach in the long term, having regard to the possible and foreseeable trend of costs in each of the two techniques? The answer to this question would provide the industrialists concerned with some information about the potential market.

Prof. Schaefer

I think I can answer this question at least in part and in general terms. Of course, better insulation of buildings as a whole and such things as rational heating are to some extent in conflict, and this conflict could make it difficult for district heating to gain widespread acceptance because better thermal insulation would mean that these facilities would be used for too short a time. In the case of the heat pump, however, I should like to say that I feel, considering at least our projects so far, that optimum heat insulation in the building plus the heat pump is a fundamental condition for the heat pump's having any prospects at all of economic viability. For these projects, I do not consider there to be any conflict.

J.M. Maskens

My question is similar in some respects to Mr Bonnet's; I understand your opinion that thermal insulation must not conflict with heat pumps but that every effort must be made for the two to be combined. We may nevertheless wonder whether it would not be useful to follow very closely what is being achieved in the field of heat pumps, so that we can be sure that the energy savings we are aiming at, and which are theoretically attainable, are actually achieved in reality; in this connection it would be helpful to put together all the documentation that already exists, as well as possible new information on new systems, so the the heat pump really is used and boosted if it achieves the savings expected from it. For example, last week at the symposium of the Comité français d'Electro-thermie in Versailles, actual consumption figures on a kWh/m^2 per year basis were cited to show that the heat pump installations covered by this survey consumed more electricity over an appreciable sample of dwellings than the average consumption with direct electric heating. We therefore feel it would be desirable for the projects which are still possible in this field to be followed up very closely and monitored in actual practice. So I would like to see actual measurement and confirmation that the savings we assume can be obtained are actually obtained in reality.

Prof. Schaefer

This is certainly an important task, and one with which the Community could certainly assist in the form mentioned earlier by Mr Bonarini. Surely it would be possible for such things also to be financed; on the other hand, I would say that this should also be extended to manufacturers' products, because it is often found when such equipment is installed that the data and character is specified quantitatively by the manufacturer for his products are not attained in practice, so that the heat pump system becomes less favourable. In other words, we really ought to take account of this too, Mr Maskens, as you also belong to the manufacturing side. How can the manufacturers also ensure that the data relevant to heat pump operation can be specified correctly?

French contribution

We are talking about heat pumps, but I should like to recall some points that have already been emphasized during the day - the fact that the heat pump cannot be considered in isolation. The heat pump forms part of a system, and the building is an extremely important link in this system. After all, the European Community is an old community with old housing stock, and even the new housing is old, because we still build in the traditional manner. The United States is apparently a new continent with new housing, already mass-produced, so that it lends itself much more readily to these applications in many cases. The second point is this: Mr Dubois mentioned the 500 000 American pumps built in 1977, but I consider that probably 80% of these are used mainly for refrigeration, whereas if we were to build 500 000 pumps in Europe, they would be used 90% for heating alone. Another point, in reply to the American comment: I think the European manufacturers lack imagination, because in fact if the situation in Europe is similar to that of the United States, where there are a very small number of manufacturers of powerful components and a large number of manufacturers of much less powerful pumps .... In Europe the situation is much the same, but we in Europe want to produce heating facilities. I think that we lack imagination because we take the American compressor as the basis, and all manufacutrers, whether they are French, Japanese, Italian or German, generally build compressors under American licence, and this is where efforts should be made at Community level.

Chairman

May I just come in on the last point that was made because I believe that we have a rather difficult situation in Europe. There are different needs of the market, the manufacturers are not certain as to how big the market is, there is a diversity of systems to be considered. Is there, perhaps, in the fairly near future a need for a kind of trade association, can one envisage that perhaps with the help of a trade association it might be possible for the manufacturers, who are at the same time trying to identify the market, to develop their products, to hope for a certain standardization, to better express what it is they have in common, and also to sue such a trade association as a means of reaching and persuading the public of the lines that look most promising? This is, I think, quite an important question. I don't know whether we are in a position to answer it today, but it is an important question.

Mr Graziano

I should like to apologize to our French friends, but I am going to speak in English because I should like to address the Chairman, Mr Davis.

I represent LCF Le Compresseur Frigorifié, France, and I am a manufacturer. Mr Chairman, you have very rightly expressed your opinion and your concern about the attitude of the manufacturers towards the problem. Being one of them, first of all I would like to thank you for having organized this Study Day because I think that it brought out a lot of interesting things all over Europe and it shows that everybody is aware of the problem and that there is apparently a common desire to solve it. To come back to the objective of this meeting, which is to save energy - unless I am wrong - by importing less oil, and save hard currency. Now, as far as I could judge today, everbody, including the panel , was talking about some wonderful new thing called the heat pump - I dearly like the expression of the speaker who said "We would like to have in England a little something nice and clean and extremely cheap, that would take care of our problems." Mr Kalischer of Germany said, as I understood it, that what we need in Germany is something more sophisticated which would even give a much better ratio and higher savings than ever anticipated so far, but it should be, of course, very cheap. Now, on the other hand, he and some other gentlemen were mentioning that the heat pump, yes, it is needed, we want it, but for 1 200 reasons, it will not work because of this, because of that, psychology, administration, etc. We have got all these problems. So, my first suggestion would be, Mr Chairman, could we bring all these desires and problems and whatever you have to a sort of common European denominator and then come to the manufacturers, because after all, in every area of the industry, they are always the ones who finally come up with the hardware with the collaboration of the utiliy companies, with the consulting engineers, and the installers, etc., but finally they brought out the product which was needed and desired by the market. Now, being in Europe, I can sense that here, at least not only do I not care about the climatic conditions; I don't think that this is an obstacle, but rather about the systems we have heard about here with all the possible.... ...... I am already over the two minutes but I have nearly finished. It is up to us - to the manufacturers - to solve the problem and come out with the product. Mr Dubois said that the Americans just went about the problem and they have solved it. Now, Mr Villaume said that we in Europe are as intelligent as the American, so we can do as well or even better. I think that, let's take what exists, the knowhow, and after all they have got something like 30 years of experience, and try to adapt it to the different European market needs. We will do it, the manufacturers, and I might speak on behalf of all my colleagues, but please help us instead of hindering us and tell us what you want. My question to you, Mr Chairman, and that is the end of it: where do we go from here? Thank you.

Chairman

Mr Churchman wants to make an intervention at the moment, but first of all I would just make a response to your very interesting intervention.

Yes, the Commission will be very glad to do what it can, but remember we are not constituted to make what you might call a proper market survey, so I would like to turn your question and another question to the manufacturers, potential manufacturers of the Community, and that is: are you prepared to engage in a dialogue with us with the objective of trying to identify what really are the objectives? We can't do it on our own but we will certainly work with the industry.

Mr Churchman, I think you should come in now.

Mr Churchman

I think the Chairman is absolutely correct there. The attitude which came there from the manufacturers is one which we recognize as part of what was the English desease, which I think is actually spreading to Europe; that no longer do we have manufacturers who have sufficient cash - I think is the right word - to be able to do these developments on their own. It would appear that we have to intervene because the sort of things that we are worried about when we talk about reliability of the pumps, we talk about reducing the cost by mass runs. Most of the experts are not experts in production techniques, so we must have this iteration between the manufacturing industry and the experts. I mean, unfortunately the EEC Commissioners in their wisdom have created a legal liability law for performance and safety, and this is one of the things that, of course, helps our manufacturers to be a little more backward in coming forward and introducing new things, so it would appear that we need to do something of the form that our Director here has called for. Forming an association to create this iteration, and one could say that one could close down the options and take a heat pump that does not attempt to provide all the energy in a house. One could, say, go for a maximum lift of 15°C, a minimum temeperature for the energy source of, say, 3°C, and a maximum power into the compressor of 1 kW, a lifetime of 20 years involving a fairly high on/off frequency to account for the defrost cycles, because I suspect our original concept that we wanted three different heat pumps for the three different climatic zones in Europe is in actual fact not correct. I would hope that everybody here will agree to some proposals from the Commisssion that will create a small group between the manufacturers and the experts that could come up with an initial design criterion.

Thank you very much, Mr Chairman

Mr Schaarschmidt

Ladies and gentlemen, I am not a technical man and can therefore not contribute anything to the technical matters on which we have been concentrating. But I have clearly understood - and we are all agreed on this - that it is a matter of saving primary energy, in particular oil, and foreign exchange, and consequently of creating a market for heat pumps. We have heard a few times that there are also psychological obstacles on the part of customers, lack of knowledge on the part of the authorities, who are making diffculties for us. I consider that psychological obstacles must be eliminated primarily by information, and I should like to ask what possibilities we have of providing more information about the heat pump and its potential, both current and future. May I ask the Commission whether it will be issuing a press release on today's meeting and whatever else is happening in the member states generally; for the most peculiar opinions about the heat pump and air conditioning are being spread abroad in the individual countries up to the highest levels of our governments. What can be done to dispose of this poor image of the heat pump compared, for example, with solar energy? Thank you very much.

Mr Macharen

I very carefully checked through your list to count the number of manufacturing organizations that were represented by their technical experts here today, and I don't find very many. I wonder if this reflects the strength of the American domination of the European industry. I would like to also go on to say that we at Prestcold are very aware of the need to look into heat pump development and we are in discussion with a number of agencies in the United Kingdom with regard to the development of specific systems, and we have one or two interesting programmes that are currently in hand. I would take a little bit of exception to Mr Churchman's statement that the European industry is totally lacking in funds to go forward into the industry; as far as heat pumps are concerned, I feel that we will make our efforts available when we see the markets developed, and we are beginning to see those markets develop now. With regard to a dialogue with the EEC, I think we as manufacturers will be very interested in having a dialogue with you and seeing how our common pool of market experience might come together.

Mr Villaume

I apologize for returning rather late to certain matters, but I believe that there are perhaps some things which should not be allowed to pass. We have heard about heat pumps having a coefficient of performance in the region of 1, or even less than 1. I say that this belongs to the "imperfections" that were mentioned. Yet I believe that we must be frank just the same. The problem is to decide whether we are to develop the heat pump or not, and I said earlier that if we are to develop it this means technological development. This technological development involves risks, and these risks include such imperfections and systems which do not prove satisfactory. We have to take note of this and be capable of remedying these situations and making improvements, but, I repeat, if we do nothing, we will not learn how. So this is one point. Next, I should like to say something about a question which was not fully discussed, which this gentleman asked, and which in fact concerned the problem of energy recovery from power plants. It may indeed be thought that you could have combined generation in an electricity generating plant, giving both electricity and heat, so that nothing more need be said about the heat pump. Firstly, it is not as simple as that. You need to know at what level the heat is generated and what the effect of this is on the efficiency of the thermal power plant. But the second and basic problem is whether it is or is not possible to transport the heat.

This is nevertheless important. Some countries have power plants which are very close to towns and have town distribution systems. These therefore lend themselves to combined generation. But this is the exception rather than the rule. Most power plants are a relatively long way from towns. Transporting heat is extremely expensive. I should like to set you a little problem, sir. Imagine you are building a power plant to supply heat pump systems; what do you do? The power plant indeed has low efficiency. The waste heat is disposed of in the river. You place heat pumps in the river to recover the heat, so that you perform a Carnot cycle in reverse. You will see that efficiency is then considerably increased, by combining the power plant with the heat pump, and you do this without piping or transmission lines. Because you have used the river for this purpose. This at least bears thinking about, and I personally feel that it opens up a potential for the heat pump to develop, especially if you consider that in the case of a town you would need to lay pipelines in built-up areas. And that is extremely complicated.

Finally, the Contributor spoke about the development of machines of European construction. The reason why I emphasize the need for development, for creating this development in Europe and encouraging European manufacturers to commit themselves to the market for the heat pump, is because our intention in using the heat pump is to save foreign exchange, so it appears absurd to spend foreign exchange in order to save foreign exchange. If we have any means of defending ourselves, it is technology, but only if this technology is European technology. So let us be reasonable.

That is what I wanted to say in a nutshell.

Mr Dicker

Speaking as a manufacturer coming from the theoretical world to the real world, unless we can see large volumes, I believe we will be restricted to using derivatives of the American heat pump components. To look at the volume market I think we must look at the domestic market. The problem is that if we succeed in the domestic market, there will be a move towards electricity, I believe, from oil and gas. In view of the past performance of many electrical supply authorities in Europe regarding the changing stop/go attitude towards the direct on-peak heating and the indirect off-peak heating, I believe that these authorities must now assure the public and the manufacturers and the heating trade that there will be a long-term promise regarding tariffs that will make heat pumps economically viable for the long term. Only with this assurance will the general public be persuaded to make this necessary investment to give us the volume market to do the development work.

Mr Döhling

I am one of the unimaginative manufacturers who have been making heat pumps for four years and bringing them on to the market in small quantities. The dilemma with which we are confronted has also shown itself here again. Very many people are active in this field, and they see the situation from completely different viewpoints, which makes things very difficult. The heat pump is a refrigeration machine which is now being used for heating, and this causes problems of its own. Unfortunately, many heating specialists are occupying themselves with the machine, with which they are in fact unfamiliar; nor are they familiar with the tradition which the machine has. So if heat pumps are presented too optimistically in response to questions about compressor performance data, that is because these questions are answered by outsiders who do not understand compressors. That is one point. We have also heard that another problem of the heat pump is that it is in fact uneconomic to purchase one if it is to be used only for heating. So we need sponsors or people who are nevertheless interested in purchasing a heat pump. This means that resources must somehow be provided. If there is an oil crisis or a political situation which jeopardizes the availability of fuels, demand in our country is strong and we also sell more heat pumps. Another point is that certain systems approaches are being sponsored by electricity utilities, so that aid is also forthcoming for the practical implementation of such projects. These are the few small initial steps that have hitherto been taken in promoting the serious development of heat pumps. When you look at the number of systems that are being worked on, the number of different machine ratings from 1/2 kW to 3 - 4 kW as well as large-scale plants for swimming pools......... we are building all of these, and that is not to mention many other things, such as industrial water heating, as well as energy consumption in houses. So we need sponsors and collaborators and also a source of finance, to ensure that these things can also be used economically as of now, and they must be built.

Prof. Schaefer

Thank you very much. I don't think anyone would dispute that in principle. The only question is, if we have such sponsors, what is it that is to be sponsored? And one thing rather alarms me, if I may say a few words as chairman. Although we have heard a number of engineers, they all act as if it were disastrous that we have not only built one type of heat pumps in Europe but that we are building and testing many very different types. I can only say that I consider it very dangerous to argue in this way. I consider that we in Europe in particular must see that we develop an optimal system which will afterwards have different types, and in order to arrive at this we must first investigate a wide spectrum of possibilities and test them, and only then decide on a small number of types which we can then develop further. The fact that some of the components even in today's equipment could be more standardized is another problem, and I feel that discussions like those initiated here and which will hopefully be pursued could be very useful.

Yes, Mr Villaume misunderstood me; in my contribution about the efficiency of power plants, I meant precisely that there are possible applications of the heat pump already at power plant level. I am not only thinking of district heating but also of the possible establishment of industrial zones close to power plants, where heat transfer would be relatively cheap and where low-priced heat energy would therefore be available for certain industries. I am also thinking of what has been done in France in connection with low-temperature crop growing near power plants. These are all possibilities that could be studied to improve the overall efficiency of power plants.

Prof. Schaefer

That is a very interesting suggestion. As stated, we in the Federal Republic even have a term for this - we call it "cold district heating" - and may I also say that the idea of evacuating power plant waste heat into rivers and retrieving it later in a suitable place would also contribute to reducing thermal pollution of rivers, if the distances involved were not too long.

Mr Dubois

The matter of utilization of power plant heat would involve us in at least a whole day's debate, and there has in any case already been one, Mr Davis. A question was asked about the problem of the trend of electricity prices. However, I should like everyone who is not involved in electricity generation or distribution to remember that very little of the cost of a kilowatt-hour is accounted for by generation and a great deal by transport and distribution varies with the consumption density, i.e., it declines continuously with time. In general, in most western countries, at a time of stable kWh generation costs, the reduction in electricity prices was in the region of 2% per annum. This has not been evident anywhere owing to inflation. But, to put a figure on it, it took ..... 10 minutes of operation to produce the most expensive kWh sold in France immediately before the war; this requires 4 minutes today.

The second aspect is obviously generation. At the final stage, i.e. that of the heat pump user, generation accounted for only about 10% of the total price before the Yom Kippur war. Of course, this portion of the price per kWh increased sharply after that war, and is now somewhere in the region of 20-25%. But as oil is progressively replaced, in all the countries which we represent, by uranium, which has an extremely low marginal price, the proportion accounted for by generation will also increase. Studies carried out in France show that in 1986 prices per kWh - of course, at constant prices - will be back to the level at which they stood in 1973, before the massive increases due to the energy crisis. I believe this applies to most of the countries of Europe. The same cannot be said for other energy sources.

Chairman

I would like to invite a colleague of ours in the Community who is concerned with research and development in the heat pump area. I mentioned at the outset that the Commission is sponsoring a certain amount of work: I would like him very briefly to tell us a little about this work, but more particularly I would like to ask him whether he can confirm that we are indeed going in the right direction: that heat pumps are giving us the kind of possibility of more rational use of energy of which so far we are making an act of faith. Mr Ehringer.

Mr Ehringer

Well, Mr Chairman, it is not difficult for me to give the exact answer you are requesting. Perhaps it is better if I first start in general terms. In this round table discussion this afternoon we learned that many problems are connected - technical problems are connected with the application of heat pumps for heating purposes in dwellings. We have also learned that this requires a lot of research and development, and certainly also demonstrations. Much research and development work has been performed in our member countries of the European Communities and I think the details of this work are known to all of you, but the European Community is also performing the research programme with the objective of energy conservation, and part of this programme is connected with the development of heat pumps for heating purposes, of dwellings, and also for industrial applications. The Council of Ministers in 1975 decided on a research and development programme costing 11 million u.a., and these funds will be paid to contractors in the framework of cost-sharing contracts with the aim of research and development with the objective of energy conservation and also heat pumps. We have already committed more than 2 million u.a., or between

2 and 3 million u.a., only for the objective of heat pump development, and nearly all of the money available is already committed. The research work under contracts with industries in the Community countries includes, for instance, development and improvement of the components of heat pumps and their integration in optimized combinations. We have also tried in this way to improve the coefficient of performance and the reliability of the heat pumps. We tried to develop a control system with microprocessors, and further, we favour the development of modular type heat pumps. We are also looking to the primary heat source, that means the ground, the groundwater and the air, and we also examine the effects on the environment because we have a sort of cold wind in the heat exchanger and this cold wind may disturb the other people living around this heat exchanger.

Another point of concern is the defrosting system; this has to be improved and the control system has to be properly related to it. Then we have a special development of advanced type heat pumps, in particular of the absorption type heat pump, which has the advantage that it does not include - with one exception - moving parts, so it is less noisy and less liable to need repair. We are now preparing a new research and development programme which will be presented next year, we hope, to the Council of Ministers, which starts in 1979, and for this preparation work we would very much appreciate a priority list of research problems from this meeting here perhaps, in order to be able to present a reasonable and balanced programme to our Council of Ministers. Thank you, Mr Chairman.

Mr Müller

It is true that this point about lack of information has already been mentioned. But I believe that it is really one of the crucial points in this matter. What is needed is not the kind of information involved in making the number of heat pumps smaller than the number of symposia on heat pumps, but the information which automatically accrues from a system which has been constructed. In my opinion we need completed demonstration plants which incorporate the fully developed technology available in the design of this equipment, and we must not be content with performance figures or coefficients of less than 2, but must take account of the fact that in as many as 600 systems in the area we serve we already have a technique which, for example, gives a coefficient for a heating season, including all auxiliaries and peripheral equipment, of in the region of 3.6 for groundwater-source heat pumps; with earth as the heat source, the average coefficient is always above 3, and with single-mode (monovalent) air heat pumps the average coefficient of performance is always above 2.5. If we have built such plants and can demonstrate them, then I believe this is the information required in order to open up a wider market for this technique as a whole.

We have heard a great deal about lack of information and the need to have better information about heat pumps, with the obvious aim of obtaining a better knowledge of the performance of our product and improving it. But I believe that whatever our level of information about heat pump performance, when we are required to demonstrate the economic viability of the system we are compelled to make comparisons with other systems – in particular, and certainly for a long time to come, with traditional systems, and here I believe we have sometimes been a little too unthinking about the performance, or the possibilities of improving performance, of traditional systems. Many voices have been clamouring and urging the Community to improve and promote information on heat pumps, but I believe that if we are to be rational and logical and avoid the stumbling blocks or imperfections mentioned by Mr Villaume we must at the same time and in parallel promote information on other systems, and also avoid the often encountered error of comparing heat pumps with maximum, optimum coefficients of performance with traditional systems which are normally judged much more severely.

Mr Bernier

Much has been said about the problem of reliability of heat pumps systems; but in spite of everything, it has to be said that some types of equipment have now been fully developed. Manufacturers have made considerable efforts in this direction, and I think that it was absolutely necessary. From another viewpoint, one problem today is that there is a total lack of information about the installation proper, and this is extremely important as regards satisfactory construction of a complete system. It is not the hardware but the installation that must be considered. A bad installation with a good heat pump remains a bad installation. I consider that this point is really fundamental and that it is absolutely necessary to develop information at European level for the Community in this direction, so as to avoid all the problems which currently arise in connection with bad installations. Thank you.

Prof. Schaefer

Ladies and gentlemen. May I thank everyone who has taken part in this discussion, but time now compels me to bring this discussion to an end. In conclusion, I can in fact only attempt to summarize briefly; this will inevitably be somewhat subjective, as I had to do it during the discussions themselves. But I believe that you will agree with me if I conclude that the differing climatic conditions and also the differences in the housing stock and in the customs of our populations in the individual countries compel us to adopt different solutions with the heat pump, but that, secondly, in spite of these differences, there are, of course, manv technical problems which are the same everywhere, some of which, it seems to me, are at present being tackled in parallel in the countries of the European Community without there being sufficient contact between the bodies concerned, whereas such contacts would allow the objective to be attained more quickly. And that brings me to the third point: I have the feeling, precisely from this meeting, that considering the work of the manufacturers and of the elctricity utilities, while fully recognizing the interests of the firms concerned, there is nevertheless a relatively wide spectrum of matters of heat pump technology which we could talk about, and discussions in such a group would make it possible to achieve the goal of more efficient production and wider introduction more quickly. So I would like to ask the Chairman to try to organize more meetings like the present one. Because I feel that precisely this kind of meeting can be exceptionally useful; one possibility might be for us to meet here again in a year's time, and perhaps we should also again give serious thought to the idea of discussing the suggestions made here - in particular, of whether there are any possibilities of those concerned with heat pump technology getting together. That means the manufacturers and the electricity utilities, but surely also the scientists working in this field. We could then arrive at some common criteria, perhaps beginning with the attempts that have already been made to arrive at common definitions of concepts - this is already progressing well now, but could perhaps be pursued to the stage where the first steps towards drafting standards could be made. Perhaps you have some specific ideas on these points, and it might be a good idea if you would set these down in writing before the next meeting and send them to our Chairman's Directorate. Now I have one last question or request, if you like, to our Chairman: It seems to me very important for us to build demonstration prototype plants on a larger scale than hitherto by individual firms and utilities, involving a relatively large number of heat pumps systems, if possible close to a town, with full measuring and monitoring facilities, so that we can obtain more general information on a European basis, susceptible of quantitative proof. What we really need here is to have a group of systems of this kind for each of the three climates mentioned here this morning - the maritime climate, the continental climate and the Mediterranean climate.

I should also like to thank you all for your active participation and for being so patient at having to wait so long; I am afraid many people's arms will have become stiff during the last two hours. I will now hand over again to the Chairman.

Chairman

Thank you very much, Professor Schaefer, for moderating the round table of experts and also the discussion with our participants in this round table.

First of all I would like to reply to your question: could we have another Study Day? Do I take it that the general feeling here today is that this sort of day is rather useful, do you agree? Right, we will endeavour to arrange another such Study Day. You have a short intervention?

Mr Kol

My remark is the following: The next meeting on this subject could be perhaps more useful in tackling the market aspect by inviting, also, people who represent the market. I mean, architects, investors in property, and representatives of the people who live and work in the buildings. Thank you.

Chairman

Thank you, although I hear a little scepticism on my left here! Well, certainly we will attempt to organize another Study Day. The other question which Professor Schaefer asked is, can we look forward to the idea of some proving of prototype systems, and my answer to that is that if the Commission secures the funding for the demonstration projects which I mentioned at the outset and which is presently before Council, the answer is 'yes' and the Commission will be glad to do this. Of course, there will be limited funds available but I believe with your help we can be selective and choose some of the important systems which are proving. That is post-R D, of course.

Now, in summing up, I would like to say that we from the Commission have very much appreciated this opportunity of having you here today, and particularly the members of the round table and the speakers, whose contributions have made this possible. We have found it very interesting from the side of the Commission. We are, as you know, locked in very largely to our offices and to paperwork, and to have the opportunity of meeting people from the real world and interacting with them is most valuable.

Now what have we got out of it? I have felt that it is clear that there is a big diversity of need throughout the Community. However, the rough classification of three broad types of climate seems to be about right. I fear that unless we limit our fields of activity somewhat we may find ourselves designing twenty or a hundred systems and missing the market altogether and missing the opportunity of what we are striving for, which is to let the heat pump make its due and proper contribution to our energy economy. Therefore, I believe that the identification of a few avenues of approach, a definition of what it is we really want, three or four types of prime interest, is necessary, and therefore I am extremely pleased at the very favourable reaction that we had to the suggestion that we might have a dialogue between the Commission and particularly manufacturers, or potential manufacturers, in this area, with a view to trying to localize and define what it is that we want. Now, what I want to ask you is: those of you who are interested in participating or contributing to such a dialogue, would you be good enough to write us a little letter or even a postcard expressing your interest, and we will try and pick out a manageable number of people with whom to have a dialogue.

I have said that we intend to publish today's proceedings. It must be of course merely a summary of the discussion but with the papers fully published. I have some doubt whether it is the right moment to respond to one suggestion which we had from one speaker and that is that he would like immediately to publish something popular to improve the image of the heat pump. I fear that this is a little premature in my view because I don't think we can quite yet promise to deliver to the great public as it were reliable systems, and nothing would do us more harm than if they suddenly got very enthusiastic and went out at great expense and bought systems which they didn't know how to buy and which perhaps we can't yet give an adequate degree of assurance about. So I am inclined to think that is a little too soon.

Then we have raised the question of some kind of trade association. On this I am inclined to think that it probably is a little premature to try and use the good offices of the Commission to help with the foundation. However, the dialogue of which we have spoken, I believe, is the kind of avenue which could very well lead in the course of time to the founding of such an association, which might have a key role to play, not only in helping to define the standards, the kinds of modules that are required, etc., but also which might well be able to help with the problem of how the public and how the customer should be informed.

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ANNEX 1

COMMISSION OF THE EUROPEAN COMMUNITIES

DIRECTORATE-GENERAL FOR ENERGY

Seminar on the

DEVELOPMENT OF HEAT PUMPS IN THE COMMUNITY

Brussels, 8 December 1977

DESIGN OF DIFFERENT TYPES OF COMMERCIALLY-AVAILABLE HEATING AND AIR-CONDITIONING SYSTEMS WITH HEAT PUMPS AND ASSOCIATED SYSTEMS

Communication from Mr Bernard Geeraert,
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Brussels, 10 October 1977

The heat pump is a machine which can raise the temperature of a quantity of heat by consuming exergy. This input exergy may take the form of mechanical energy for a compression heat pump, electrical energy for a Peltier-effect heat pump and thermal energy for an absorption, re-absorption, tuyère-type and other types of heat pump.

In the present state of the art, the compression heat pump is the only type to have found widespread use. Most heat pumps are driven by an electric motor.

Since the heat pump is a machine which transfers energy from one medium to another it is a simultaneous producer of cold and warmth. Machines used for cooling are classed as refrigerators; those which are used for heating or for both cooling and heating are called heat pumps.

1. CHOICE OF HEAT SOURCE

Heat pumps are virtually always driven by electrical energy but their heat source may vary (outside air, extracted air, water, ground, etc.).

Outside air is a heat source which varies particularly in temperature from one place and one year to another. It is therefore impossible to give performances which are representative of the Community or of one country as a whole. The examples given are valid for the climatic conditions in Brussels (minimum temperature of - 10°C, 2 165 degree-days (15/15) equivalent to 3 000 degree-days (18/18). The heat source is extremely important in a heating system incorporating a heat pump. The most common sources used for domestic heating in some countries are listed in Table 1.

TABLE 1

Country	Main heat source
Belgium	Outside air (90%)
Denmark	Ground (100%)
Federal Republic of Germany	Water (~40%) and ground (~60%)
France	Extracted air (70%)
United Kingdom	Outside air (100%)
United States	Outside air (100%)

2. HEAT PUMPS ESPECIALLY DEVELOPED FOR DOMESTIC HEATING

Three types of heat pump have been especially developed for domestic heating:

(1) Air-to-air heat pump using outside air as a heat source, developed from American air conditioning systems;

(2) Air-to-air heat pump using extracted air (circulated air) as a heat source, developed in France in particular;

(3) Air-to-water heat pump using outside air as a heat source with auxiliary or alternative fossil fuel heating, developed in the Federal Republic of Germany in particular.

Diagrams showing how each of these three types of heat pump operates are given in Figures 1, 2 and 3.

Fig. 1: Air-to-air heat pump using outside air with auxiliary electrical resistance heating. The flow of outside air is two to three times greater than that of air inside the building, which is of the order of 3 to 6 complete hourly changes of the volume of air heated. The internal airflow for a building of 400 m^3 is between 1 200 and 1 600 m^3/h and the outside airflow 4 000 m^3/h.

Fig. 2a: Air-to-air heat pump using extracted air with auxiliary electrical resistance heating. Heat can only be recovered on the basis of the renewal of the air in the building (a maximum of 1 to 2 changes per hour). The airflow to be handled is much lower than in the preceding cases (300 to 600 m^3/h).

Fig. 2b: Air-to-water heat pump using extracted air with auxiliary electrical resistance heating.

Fig. 3: Air-to-water heat pump using outside air with fossil fuel auxiliary heating.

2.1 Air-to-air heat pumps using outside air

2.11 Background

The first American-made heat pumps appeared on the European market about ten years ago. These were reversible air-conditioning systems fitted with an inversion valve which enabled the hot gases from the compressor to be channelled into the external or internal heat exchanger. The drawback of such systems was that they were of optimal design for operation in the cooling mode only and not in the heating mode because:

(a) heat exchangers were not suitable;

(b) the inversion valve had to be boosted for the system to work in the heating mode;

(c) the defrosting system for the external exchanger was unreliable;

(d) the external ventilator was too noisy.

These disadvantages have been overcome by American manufacturers in the next generation of heat pumps. Air-to-air heat pumps have also since been developed in Europe; these have exchangers (1) and capacities which are more suited to the climate of European countries:

(a) Roof-mounted heat pumps (particularly designed for industrial buildings). Each pump is able to ventilate approximately 500 m^2 of factory space, provides free cooling and can recover a certain percentage of heat from the extracted air.

(b) Split heat pumps with separate external and internal exchangers.

(c) Compact heat pumps which can recover a certain percentage of heat from the extracted air in some appliances.

2.12 Characteristics of the air-to-air heat pump using outside air as its heat source

(a) The heating capacity decreases in a ratio of 2:1 when the outside temperature drops from +15 to -10°C (see Fig. 4).

(b) The coefficient of performance of the heat pump (COP) decreases as the outside temperature falls. The average COP for the heating season in the climatic conditions of Uccle is 2.75.

(c) The heat pump is four to five more times as expensive in terms of investment costs per kW than conventional resistance heating systems and will therefore be of a size enabling it to cover most heating requirements but not all heat losses. The optimum temperature for determining size under the climatic conditions in Uccle is between 0 and -2°C. Supplementary heating must therefore cover 60% of heat losses at - 10°C but only 10% of heating requirements (the other 90% being met by the heat pump). The power consumed by the resistance accounts for approximately 20% of the total energy consumption of the heating system. The average coefficient of performance for the overall heating season (including auxiliary resistance heating) can be as high as 2. It should, however, be remembered that direct resistance central heating consumes twice as much power. Resistance heating is usually decentralized and can be thermostatically regulated from one room or one radiator to another (a 20 to 30% saving over central heating). On this basis, the seasonal coefficient of performance for a heating system using a heat pump is no more than 1.6.

(d) When outside temperatures fall below around + 5°C the external exchanger ices up. It is usually defrosted by reversing the thermodynamic cycle (passing the hot gases leaving the compressor through the iced-up exchanger) and takes four minutes every two hours of operation. In the heating season an external exchanger has to be defrosted between 1 000 to 1 500 times in Uccle.

2.13 Characteristics of equipment in use

The majority (approximately 90%) of heat pumps installed in buildings in Belgium (around 1 000) are the air-to-air type and are American made. European heat pumps (primarily French) have recently appeared on the market.

At the present time there are many systems which do not attain the performances mentioned under point 2.12(c) (seasonal COP of 1.6 to 2); in some cases this is due to the system design but more often to the quality of the installation.

The performances of machines currently marketed are satisfactory but their reliability leaves much to be desired (the defrosting system and relays are unreliable, certain components are liable to rust (fins, cylinders, etc.) and the refrigeration system is not waterproof). The excessive noise caused by the ventilator in the external exchanger has given rise to complaints at night (outside air flows of between 3 000 and 5 000 m^3/h).

<u>The quality of the installation</u> of heating systems using air-to-air heat pumps leaves much room for improvement at the moment:

(1) Ducts have been badly installed (i.e. are not watertight, are not adequately insulated, unacceptable flow distribution and pressure losses, etc.). Conventional heating system fitters are more accustomed to installing hot water pipes and air conditioning fitters are not interested in private dwellings. Efforts have been made by manufacturers' and heating engineers' organizations to remedy this situation. Architects should incorporate ducts and heating systems in their plans at the drawing board stage. The mass air flow inside an average-sized dwelling is between 1 200 and 2 500 m^3/h. The maximum flow speed may not exceed 5 to 7 m/sec in the ducts and 3 m/sec at the injection orifices.

(2) The entire machinery (and, in some cases, the split units) of the internal exchanger is under-sized. If the heat pump is designed for an outside temperature of above 0°C, the seasonal COP decreases virtually linearly to the design temperature.

(3) Excessive energy consumption by direct auxiliary heating caused by the unsatisfactory interlocking with the heat pump

Maintenance is badly organized. It will be difficult to remedy this until there is a significant rise in the number of installations used. Some importers have concluded contracts with an insurance company to provide a five-year guarantee for parts and labour at a cost of Bfrs 3 000 a year.

The power rating of a heating system using a heat pump and supplementary resistance heating is as high as that of a direct electrical heating system. Although the resistance heating is not often used (200 hours a year) it is required at the electricity network's peak period (winter), particularly in the mornings when the temperature setting is raised, and this makes this type of heating system less attractive to electricity distributers. Research is being carried out to find a solution to this problem. One of the methods currently used is to not lower the temperature setting during the night.

2.14 Primary energy consumption and investments

The primary energy consumption of a heating system with an air-to-air heat pump is the same as that of a fossil fuel heating system (assuming the buildings they are used to heat are identically insulated). At the moment, buildings with electrical heating are always better insulated than other buildings. The investment costs of a heat pump system built according to sound engineering practice are 10 to 30% higher than those of a conventional heating system, but the heat pump system has an additional advantage in that it can be used to cool a building in summer. The primary energy consumed to cool a normal dwelling is between 2.5 and 5% of that consumed in heating and therefore hardly affects the primary energy balance.

The most suitable compressor in a heat pump used in the heating of private dwellings has a rated power of 3 to 5 kW.

The total costs (depreciation, consumption and maintenance) are about 30% higher than conventional fossil fuel heating systems; these are still more economical at current energy prices and assuming identical insulation of buildings.

2.15 General impression of the air-to-air heat pump

The machine's performances are satisfactory but its reliability leaves much to be desired. The greatest improvements called for are in installation which should be carried out according to sound engineering practice. Warm air heating systems are less popular in Belgium than individual conventional radiator heating systems. Faulty installation may give air-to-air heat pump heating systems a bad reputation.

2.2 Air-to-air heat pump heating system recovering heat from extracted air

2.21 Background

This system was developed in France. Instead of using outside air (possibly) mixed with air extracted from inside the building as a source of heat the system works solely on extracted air (see Figs. 2a and 2b). The relative importance of ventilation losses increases as the thermal insulation of buildings is improved. The first heat pumps using extracted air were designed as rivals to the static and rotory recuperators for the pre-heating of fresh air. There has been a trend recently to recirculate the heat recovered as hot water.

2.22 Characteristics of the air-to-air heat pump using extracted air as a heat source

(a) The heating capacity of the condenser and the COP are virtually independent of the outside temperature as can be seen in the two systems with different compressor shown in figure 5. The small units have a COP of 2.5 to 3 whilst the more powerful units have a COP of 4 and over.

(b) Capacity is limited by the extracted airflow. In a normal, well-insulated ($G_1 = 0.7$ W/m^{3}K) dwelling in which the air is renewed every hour, one-third of the total heat losses can be offset by heat recovered from ventilation.

(c) A twin-flow mechanical ventilation system is required to recover the heat for the pre-heating of fresh air. In France the CSTB has introduced mechanical ventilation to prevent mould forming on the woodwork and walls of unoccupied buildings. Mechanical ventilation is rarely used in Belgium in private dwellings although it is used in residential buildings and in the tertiary sector (offices, swimming pools, shops, etc.).

(d) The extracted air (at a temperature of between 20 and 18°C) is not usually cooled to below 5 to 4°C in order to prevent ice from breaking up on the evaporator. However, once buildings are reheated, evaporators are likely to ice up if the extracted air is colder than usual. In the past manufacturers have not always included a defrosting system and this has led to difficulties.

(e) If the recovered energy is used to reheat the fresh air, a twin-flow mechanical ventilation system must be installed. The duct cross-section is, however, smaller than in a warm air heating system with a heat pump working on outside air (the flow is usually 1 V/h for heat recovered from extracted air and 4 to 6 V/h in the case of low-temperature hot air heating systems).

(f) The compressor capacity of an extracted air heat pump for domestic heating is only 1 to 2 kW as against 3 to 5 kW in a heating system incorporating an outside air heat pump.

2.23 Characteristics of heating systems with extracted air recuperator heat pump

This type of heat pump provides base heating. Supplementary heating (fossil fuel or electrical resistance heating) is required for a full heating system. Fossil fuel heating uses less primary energy but necessitates heavier investment. Resistance heating may take the form of central electrical resistances installed in the heat pump itself for electric radiators installed in each room.

(a) The seasonal coefficient of performance of auxiliary resistance heating is shown in Figure 6 (2) for the climatic conditions in Brussels as a function of the losses through ventilation and the temperature of the extracted air after cooling on discharge into the atmosphere (the most representative temperature being + 5°C). Approximately 10% higher performances have been achieved in the climatic conditions of Paris.

(b) The rival of the extracted air recuperator heat pump is the heat exchanger (plate type, water/glycol intermediate circuit type, heat pipe type and rotary type for collective heating systems). In the present state of the art, greater primary energy savings can be achieved by heat recovery through the heat pump than through the exchanger provided that the heat pump's COP is above 2.5. This is illustrated in Figure 7 (2). Assuming that the seasonal efficiency of a fossil fuel-fired system is 60% and the efficiency of electricity production and distribution is 33%, primary energy consumption with a heat pump and with a recuperator heat pump is shown in the diagram as a function of the number of changes of air for a building with specific transmission losses of 0.7 W/m^3K. The recuperator has an efficiency (η) and a coefficient of merit (COM) (ratio of recovered energy to energy input required for recovery). The most representative curve with a static exchanger gives an efficiency η of 0.6 and a COM of 8. The most representative COP for the heat pumps is between 2.5 and 3 for private households and simple recuperators. Some manufacturers (French (3) and Danish (4) are building combined systems consisting of static heat pipe or plate exchangers and one or more heat pumps (to form a Lorentz cycle); higher COPs can be obtained even for these low capacity systems (in France SYREC (3) has combined a heat pipe with two heat pumps and in Denmark DANFOSS (4) has built a system consisting of a cross-current plate exchanger and a heat pump). More powerful heat pumps used in the tertiary sector can achieve COPS of 4 and over with no effort (5).

The mass of curves at (a) in Figure 7 represents consumption with heat recovery and peak fossil fuel heating, that at (b) heat recovery by the heat pump and auxiliary fossil fuel heating and (c) heat recovery by the heat pump with auxiliary resistance heating.

2.24 New trends

The extracted air recuperator heat pump has been developed on the largest scale in France where a thousand or so private or collective dwellings have been fitted with such recuperators.

There is a trend towards recirculating the heat recovered from the extracted air in the form of hot water for base heating via the floor, for feed to convectors and, in summer, as domestic hot water. This technique requires no more than a single-flow mechanical ventilation system. In its simplest form, heat is recovered solely from the waste pipes from the kitchen and bathroom by a small air-to-water heat pump similar to that used in office air-conditioning units. The heat recovered is used for a single convector in the living room.

2.3 Heating by means of a bivalent air-to-water heat pump

2.31 This heating system has been developed in the Federal Republic of Germany but it is only just beginning to make inroads on the market (a hundred or so installations are in use). The basic ideas behind this system are:

(a) It is impossible (and uneconomical) to use a single-stage compressor to provide hot water at a temperature of 90 to 70°C (the temperature for which conventional heating systems are designed) when the outside temperatures are at their lowest level.

(b) Auxiliary electrical heating systems draw off electricity during the peak period of the year, particularly if the winter is hard. For the electricity producers such a short load period is an extremely uneconomical use of production and transport facilities.

(c) If it is to be economic a heat pump heating system must be able to satisfy the needs of older dwellings fitted with central hot water heating. This market consists of 1 million dwellings in Belgium and 4.8 million in the Federal Republic of Germany. To do this the heating system would have to be manufactured on a large scale at competitive prices.

2.32 It is logical to use an auxiliary heating system based on an easily-storable energy source such as fossil fuel (e.g. fuel oil, liquid gas or coal). This kind of heating system using two forms of energy is called bivalent.

There are two types: the first is called a parallel bivalent heating system. The heat pump alone supplies hot water as long as the outside temperature does not fall below 4 to 3°C and the external exchanger does not ice up. When the outside temperature drops below this level a fossil fuel heating system of reduced thermal inertia is used to supply the heat required to defrost the exchanger and provide the additional heating. A heat pump could meet 80 to 95% of energy requirements (with typical yield of 90%). Electricity supply could be cut off by the electricity boards to relieve local grids at peak hours without affecting users' comfort.

The second type is called alternative bivalent heating. When the outside temperature falls below a certain level (e.g. when the external exchanger begins to ice up) the fossil fuel heating provides all the heat load required and the heat pump is switched off. The heat pump covers no more than 50 to 75% of heating requirements (depending on the year), with typical cycle of 67%. The system could automatically switch over from the heat pump to the boiler to relieve the electricity grid and power stations in peak consumption periods (i.e. in the coldest weeks of the winter). This system is of interest to both electricity distributors and producers. In the Federal Republic of Germany the RWE is offering a very low tariff of 7.25 pf/kWh (6) in a promotion campaign to the first thousand users of alternative bivalent heat pump systems.

2.33 Although the bivalent boilers and their regulation and switchover systems might be technically tried and tested we have had no experience in this field in Belgium; this type of heating system has not penetrated the market because the investment costs are prohibitive. The bivalent boiler costs approximately three times as much as a conventional boiler and its installation costs half as much again as the boiler.

In the Federal Republic of Germany, the additional investment required to install this type of heating system in a new dwelling would be DM 6 000 to 7 000 compared with a conventional fuel heating system (according to RINCK (6)). The energy savings would be DM 500 a year. At current energy prices, the overall energy balance would be against the heat pump by between DM 800 and 1 000. The power rating of the type of heat pump used in a bivalent system is 4 kW.

3. HEATING SYSTEMS USING WATER COOLING UNITS AS HEAT PUMPS - HEATING BY MEANS OF A MONOVALENT WATER-TO-WATER OR GROUND-TO-WATER HEAT PUMP

A monovalent heat pump is a heat pump which is of a size to cover all heating requirements, even at the lowest outside temperatures, without auxiliary heating. This type of heating system is only suitable for low-temperature heating of new well-insulated buildings. A conventional refrigerator can be used as a heat pump. The first generation of such systems, developed 25 years ago, use refrigerator-type units and are still satisfactory.

This system has been developed particularly in certain regions of the Federal Republic of Germany (approximately 1000 units) and in Denmark. There are fifty or so such systems in use in Belgium. These systems work at off-peak times (direct floor or convector heating) or on night rates (floor storage heating). These storage systems consume more energy because the storage efficiency of the floor is low (approximately 85%) and the load cannot be accurately adjusted to the outside temperature.

3.1 Using ground water as a heat source (Fig. 8)

For a normal dwelling the maximum water flow is 3 m^3/hr and consumption is 3 000 to 6 000 m^3/year. The quality of the water used must be almost the same as that of potable water and must in all events contain no ferrous salts ($<$1.5 mg/l) which act like flocculants in the exchangers. A seasonal COP of 4 can be achieved by this sytem if water can be drawn from shallow depths. For each 20 m of depth the COP drops by about 10%. Current systems have COPS of between 2.4 and 4. A dead well is necessary to replenish the ground water. In some countries drainage taxes have to be paid for cooled water discharged into the sewers. The cost of sinking a well is around Bfrs 7 per watt of power supplied by the source (7). This system is not widely used because of the limited availability of water of satisfactory quality at suitable depths.

3.2 Using the ground as a heat source (Fig. 9)

The ground is a less suitable heat source than ground water as its temperature varies within a heating session (at a depth of 1.5 m) from around +10°C to slightly below freezing point. The capacity is 30 W/m^2. The area of ground to be cooled is therefore about twice the surface to be heated. For an average dwelling, 250 m^2 of land is required for water/glycol pipes to be laid. It costs Bfrs 15 per watt of power supplied by the source (7) to provide the requisite land. Consequently this increases investment costs which are more than double those of a direct resistance heating system.

The seasonal COP obtained is 3.

4. SUMMARY OF THE CHARACTERISTICS OF SOME HEAT PUMP HEATING SYSTEMS USED FOR DOMESTIC HEATING

(see table 13, page 11)

5. EUROPEAN HEAT PUMP MANUFACTURERS

A survey of air-to-air heat pumps sold in France, their characteristics and a thermodynamic diagram has been published by Mr. Bernier in (8).

A list of manufacturers can be found in (9).

TABLE 13: Summary of the characteristics of some heat pump heating systems used for domestic heating

Type		Outside air-to-air heat pump	Extracted air-to-air or -water heat pump	Alternative bivalent air-to-water heat pump	Water-to-water heat pump	Ground-to-water heat pump
- Source		Outside air	Extracted air	Outside air	Ground or surface water	Ground
- Source temp.	°C	+15 ..... -10	+18..... +20	+15 .... -10	+10	+10.... -2
- Seasonal COP (including auxiliary heating system)		1.6 ... 2	Depending on rate of complete air change ~1.6	-	3 4	3
- Average heat pump COP		2.75	2.5 4	3	4 .... 4.5	 4
- Country		B, UK, US	F	D	D	D, DK
- Number of installations		USA: 1 m B,UK: 1 000	1 000	100	1 000	1 000
- Heat pump power rating	kW	3...... 5	...1..... 2	4	4	4 ... 5
- Auxiliary method of heating		Central resistance heating	Central resistance or individual electric radiator heating	Fuel oil or other fossil fuel heating	-	-
- Relative output of auxiliary heating	% of total output	60	75	100	0	0
- Relative energy output of heat pump	% of needs	90	60	...67...	100	100
- Private dwellings		New	New (air-to-air new and old (air-to-water)	new and old	new	
- Advantages		Can be used for cooling in summer	Can be used for cooling in summer Cross section of ducts small	Electricity company can cut off supply by remote control	High COP	Inexhaustable source
- Disadvantages		Short period of utilization for auxiliary heating Duct cross-section (4 to 6 V/h)	Twin-flow mechanical ventilation system necessary for air-to-air heat pump	Heavy investment costs	Source not generally available	Heavy investment costs

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P.C. AIR EXTERIEUR / AIR

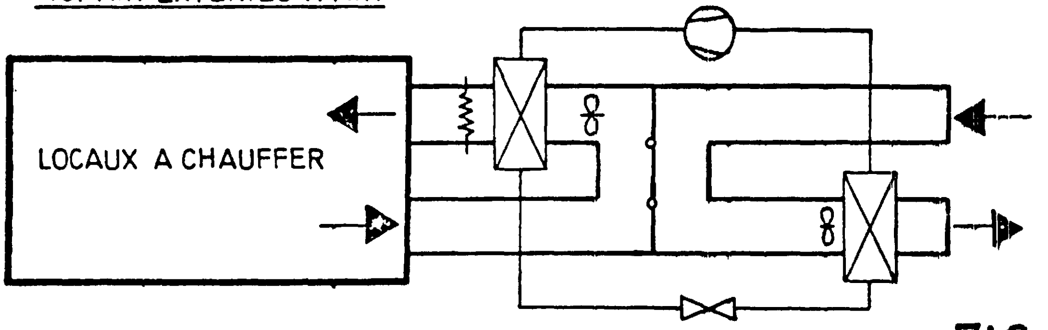


FIG. 1

P.C. AIR EXTRAIT / AIR

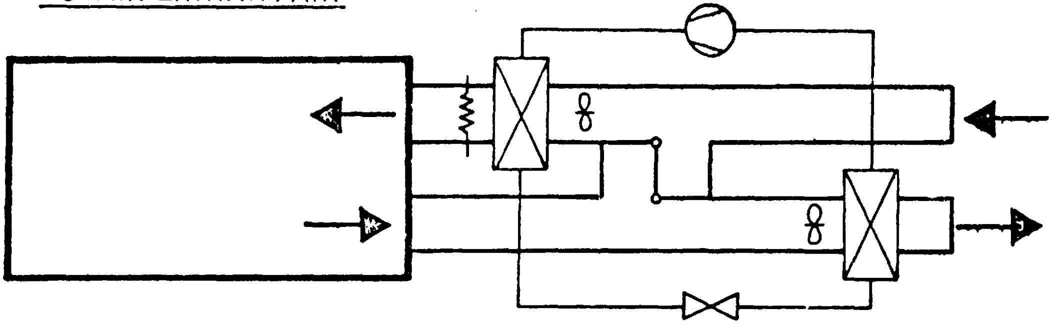


FIG. 2 a

P.C. AIR EXTRAIT / EAU

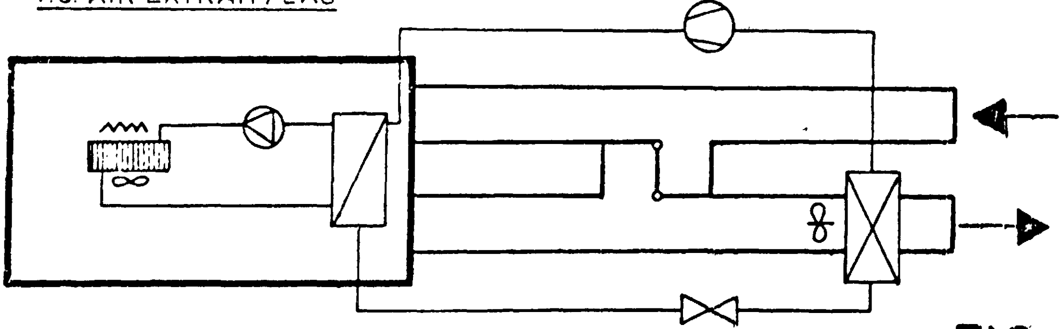


FIG. 2 b

P.C. AIR EXTRAIT / EAU - BIVALENT

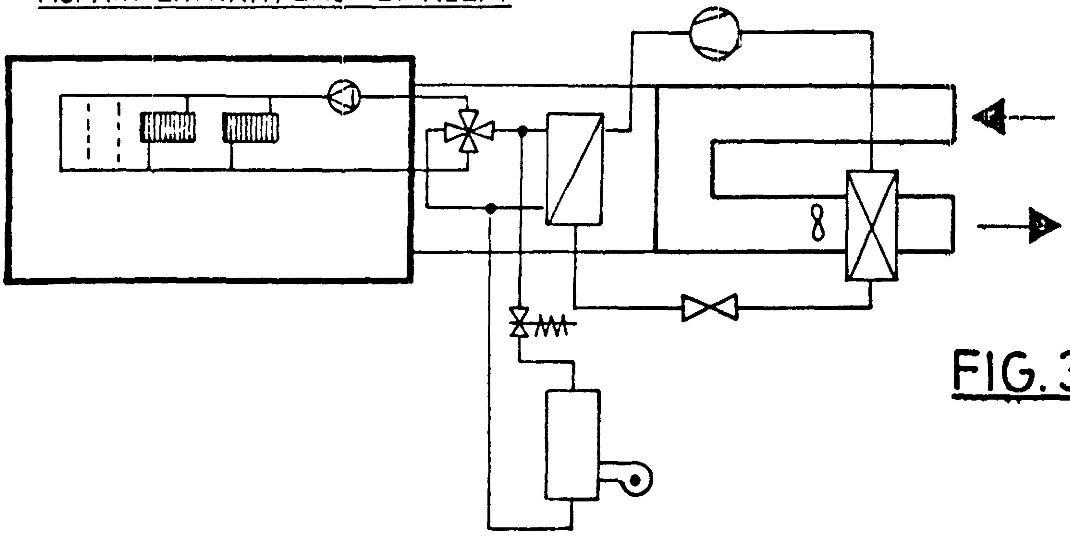


FIG. 3

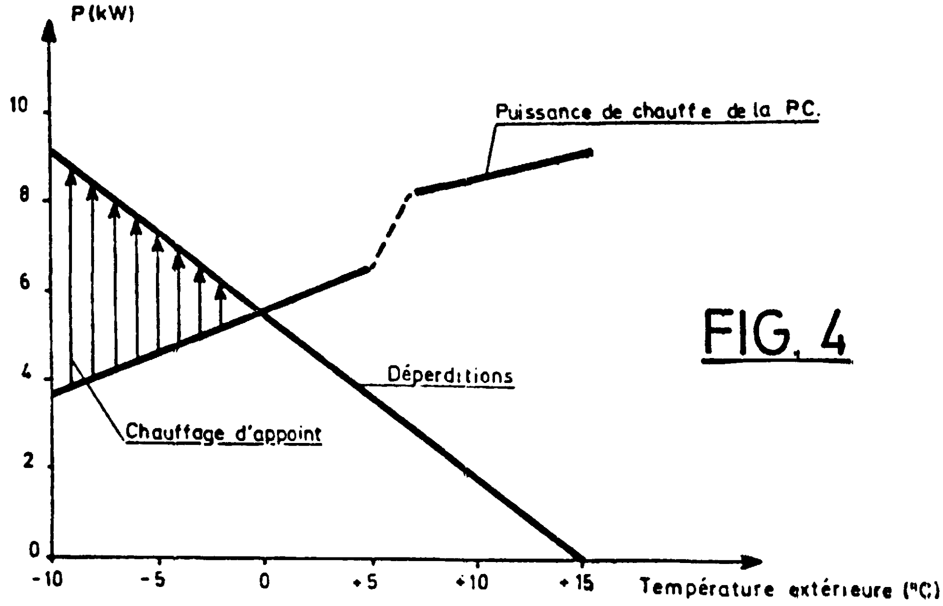

P (kW)
10
8
6
4
2
0
Puissance de chauffe de la PC.
Déperditions
Chauffage d'appoint
-10
-5
0
+5
+10
+15
Température extérieure (°C)

FIG. 4

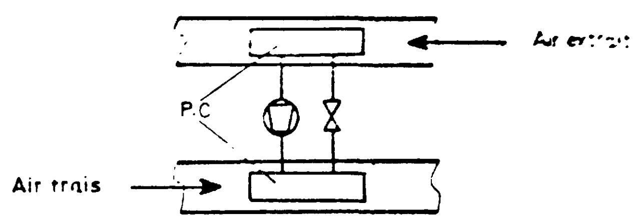
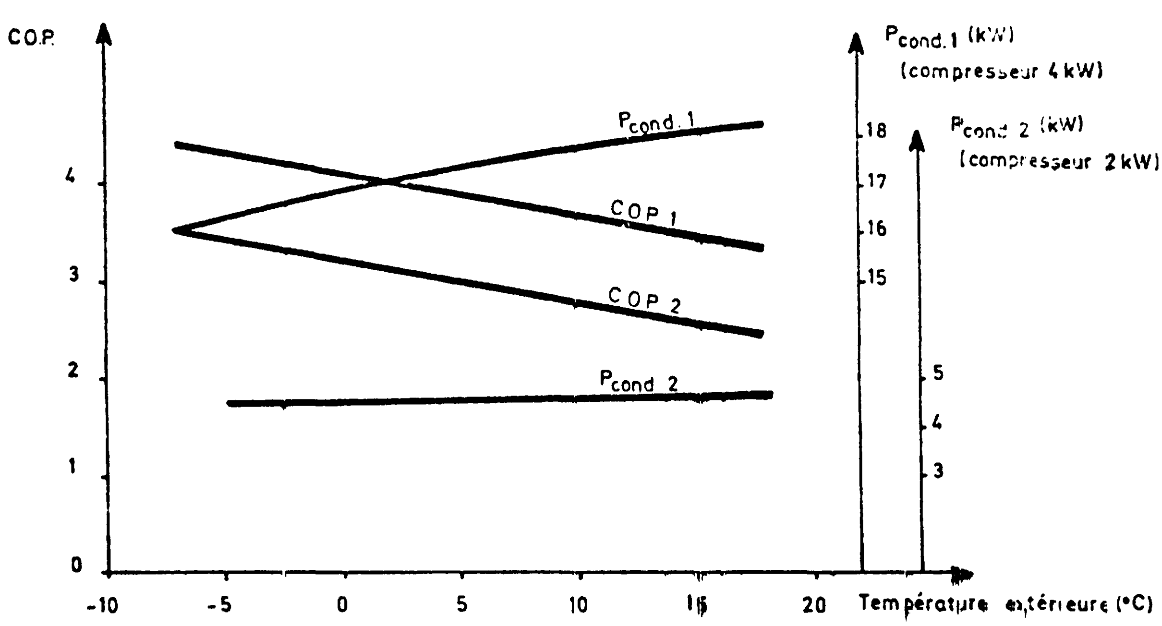

P.C
Air frais

FIG. 5


C.O.P.
4
3
2
1
0
$P_{cond.1}$
COP 1
COP 2
$P_{cond\ 2}$
18
17
16
15
5
4
3
(compresseur 4 kW)
(compresseur 2 kW)
-10
-5
0
5
10
20
Température extérieure (°C)

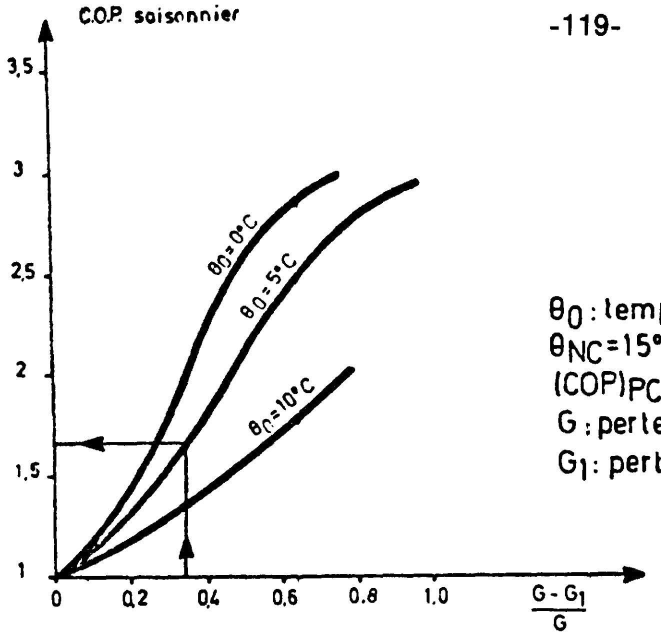


FIG. 6

θ_0 : température de l'air de rejet
θ_{NC}=15°C ; θ air extrait =18°C
$(COP)_{PC}$ = 3
G : pertes par transmission + ventilation
G_1 : pertes par transmission

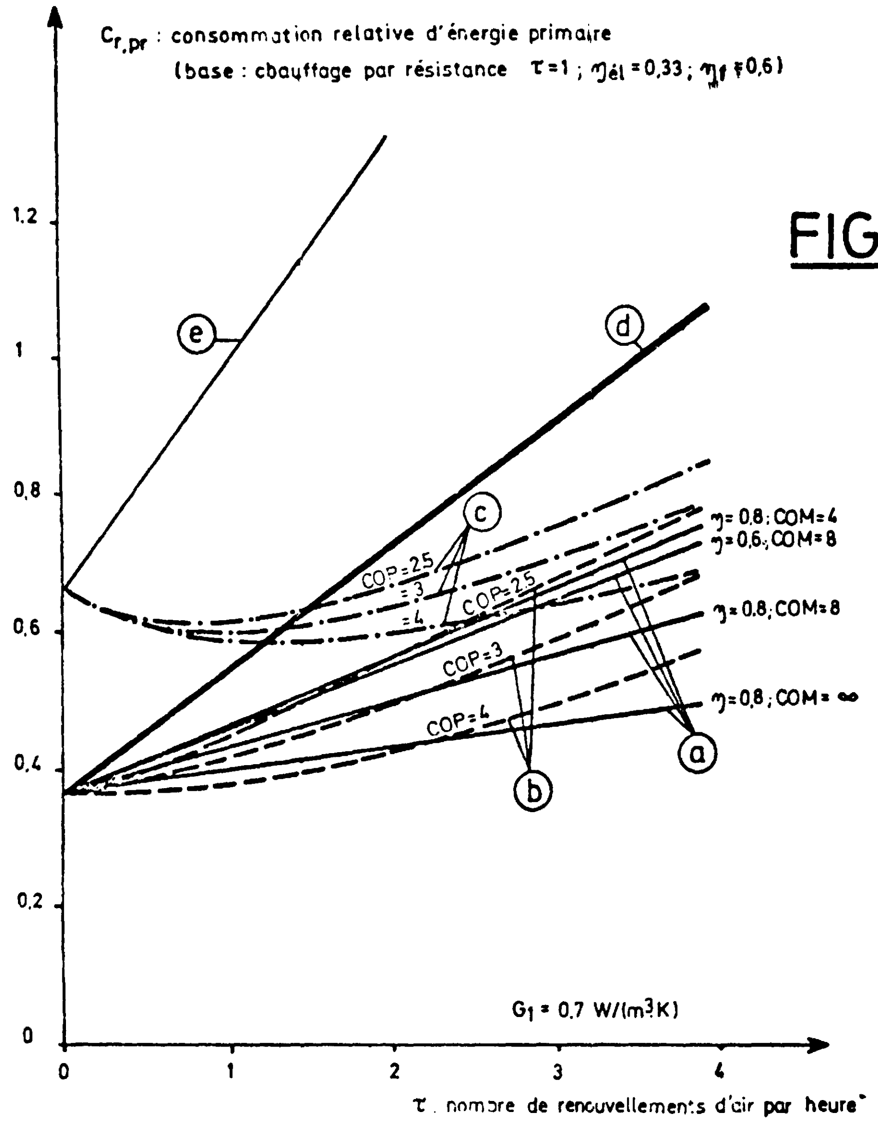


FIG. 7

(a) Echangeur statique + combustible fossile
(b) PC + combustible fossile
(c) PC + résistance
(d) Combustible fossile, sans récupération
(e) Chauffage par résistance, sans récupération

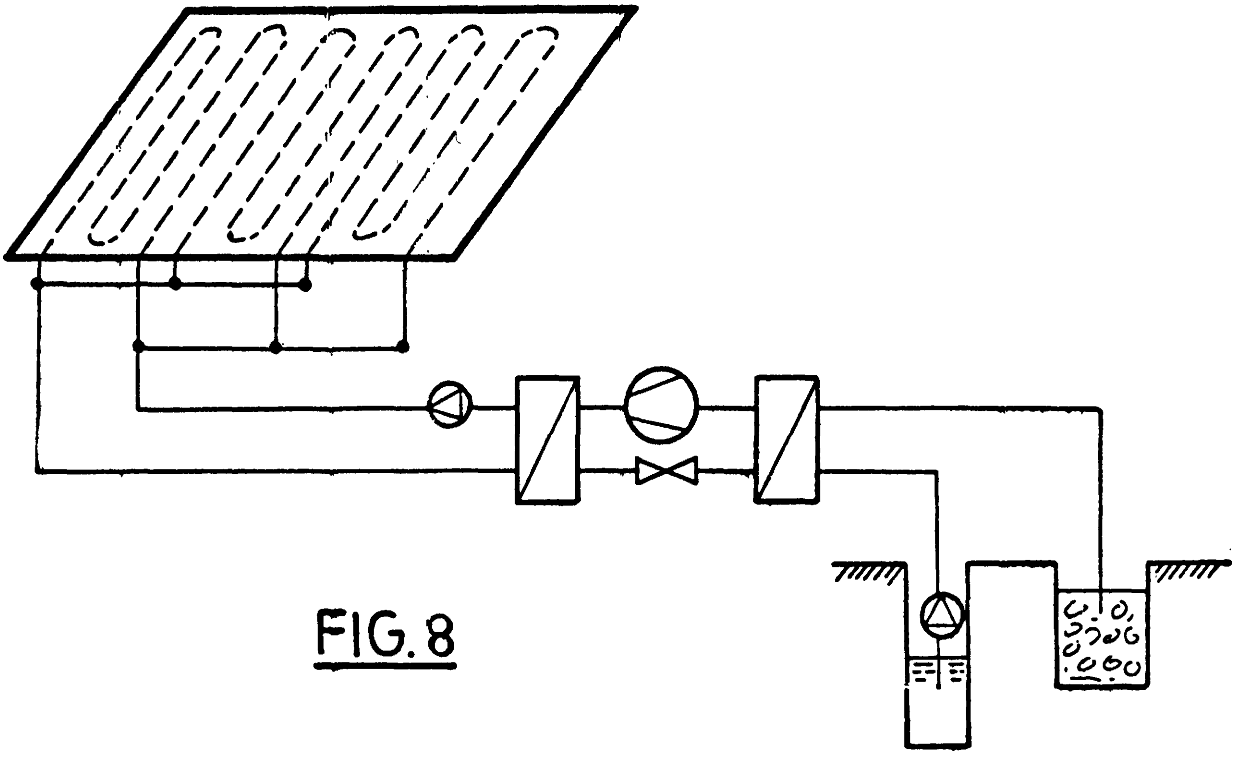


FIG. 8

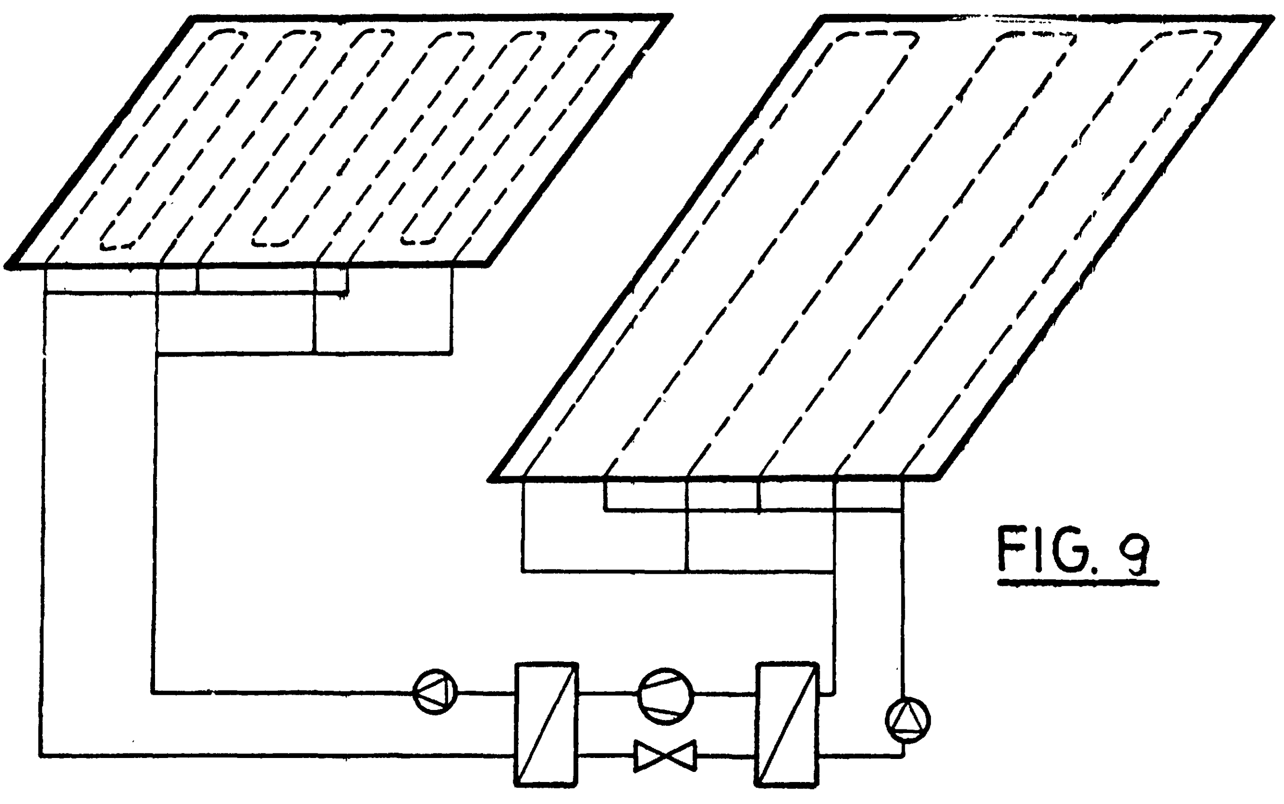


FIG. 9

COMMISSION OF THE EUROPEAN COMMUNITIES

DIRECTORATE-GENERAL FOR ENERGY

Seminar on the

DEVELOPMENT OF HEAT PUMPS IN THE COMMUNITY

Brussels, 8 December 1977

DIFFICULTIES IN THE DEVELOPMENT OF VARIOUS TYPES OF HEAT PUMP FOR SPACE-HEATING AND AIR-CONDITIONING APPLICATIONS IN THE INDIVIDUAL CLIMATIC ZONES OF THE EEC

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Essen, 2 December 1977

Difficulties in the development of various types of heat pump for space-heating and air-conditioning applications in the individual climatic zones of the EEC

By Dipl. -Ing. P. Kalischer

1. Introduction

The difficult, if not menacing, situation in the world energy supply has prompted efforts to tap virgin sources of energy to be stepped up everywhere. This led to the rediscovery of the heat pump, the basic physical principle of which has been known for more than 100 years and which has been used in actual practice for space-heating purposes for more than 40 years. The heat pump enables heat to be extracted from the ambient air, the ground or groundwater and utilized for space-heating or similar applications. It is thus no wonder that the heat pump has now been brought to the fore and that it is expected to help solve our energy problems as it paves the way towards making indirect use of the solar energy stored "free of charge" in our environment without this entailing the serious drawbacks involved in collecting solar radiation direct.

In line with the second law of thermodynamics, however, the heat pump requires a certain input of power, in most cases electricity, in an amount equal to between 15 and 40 % of the amount of heat released depending on heat source and use. Mainly because of this, the heat pump, particularly the electrically-driven one, has been criticized because, ultimately, it does not save any primary energy owing to the low efficiency in power generation. To create a uniform basis for discussion, the following shows the energy balance of some heating systems.

The question can best be answered by means of energy flowsheets. The following four flowsheets are an attempt to do this for four different systems. The data on which the energy flowsheets are based are of course open to discussion. However, differences in opinion are negligible and do not alter the relationship between the individual systems as regards the primary energy requirement.

Basic data:

Annual utilization of oil heating	62 %
Utilization of oil heating with dual-source operation	75 %
Mean power plant efficiency	36 %
Efficiency in the transmission of electrical energy (high, medium and low voltage)	93 %
Efficiency in the treatment of heating oil (= refinery conversion losses)	93 %
Efficiency of heat distribution in buildings (heat pump heating only, as otherwise contained in annual utilization figure of oil heating)	95 %
Coefficient of performance of ground or groundwater heat pump	3.5
Coefficient of performance of air-to-liquid heat pump	3.3
Liquid-to-liquid heat pump in internal systems, e.g. solar installations	3.5

In all four flowsheets the heat requirement for space-heating has been fixed at 100. This quantity of energy is equivalent to the useful energy required in the form of heat for maintaining the desired conditions in spaces during one year.

To permit the energy of heating oil to be converted into heat energy, about 1.6 times the amount of energy must be expended at the energy conversion site in the heating systems usually installed in residential buildings (Fig. 1).

In a comparison of the conversion chain obtaining when a ground or groundwater heat pump is used with that obtaining with oil heating, the relationships are as shown in Fig. 2.

As can be seen from the comparison of energy flowsheets 1 and 2, the ratio between the primary energy requirement of fuel-fired heating systems and that of groundwater or ground-to-water heat pumps is about 2 : 1 (173 : 90). In spite of the poor power station efficiency, oil heating therefore still requires almost twice as much primary energy which, in addition, has to be imported. The energy flowsheet for dual-source heating (Fig. 3) shows that, seen over the year, heating oil furnishes one third of the heat requirement and the heat pump two thirds. In line with the two previous explanations it can be seen that this system, too, requires much less primary energy (only about 65 %) than the usual oil-fired heating installation.

One of the decisive factors in this is the very poor efficiency of oil heating which does not make itself felt in summer and in the transitional periods because the heat pump is then used rather than oil heating.

The primary energy requirement is at a minimum when the heat pump is driven by a gas engine (Fig. 4).

The engine not only performs the work of compression for the refrigerant cycle; the energy content of the exhaust gas is partly used for space-heating. Over the whole conversion chain the primary energy requirement is even lower than that of the electrically-driven heat pump. Unfortunately this system is still in its teething stage and no series-produced equipment can be expected in the near future, particularly for small installations (single and double-family houses). In view of all this the heat pump offers three substantial advantages from the aspect of the national economy:

- o It only requires about half of the primary energy needed by the usual oil-fired systems.
- o The primary energy used is not affected by politics to the same extent as oil.
- o The emission of pollutants at the ultimate site is negligible.

2. Impediments to the Rapid Spread of the Heat Pump for Space-heating Purposes

The present heat pump technology restricts the available temperature level to a value where the pump has only limited application in commerce and industry. For space-heating, however, this temperature level is adequate so that, at least technically, the use of the heat pump in this major energy demand sector, which in the Federal Republic is responsible for more than 40 % of energy consumption, would be feasible. Nevertheless the heat pump is only making slow progress on the market owing to a number of impediments which can be classified as follows:

- o Heat pump technology
- o Conditions for the use of heat pumps
- o Administrative impediments
- o Psychological impediments
- o Economy of the heat pump

The following detailed considerations may provide a base for eliminating at least some of these impediments to the, in itself desirable, spread of the heat pump.

2.1 Impediments arising from heat pump technology

The physical principle underlying the heat pump has been used in refrigeration engineering for many years. The machines used here have reached a very high level of reliability and refrigeration engineers still maintain that the heat pump is nothing more than a refrigerating machine and therefore poses no particular problems.

In physical terms this is correct but actual practice has shown that heat pumps designed on this basis may be detrimental to the image of such apparatus. This is due to the special conditions to which heat pumps for space-heating applications are exposed. Load variations from zero to 100 %, partial-load service most of the time, frequent switching on and off and large variations of the condensing and evaporating temperatures are some of the special conditions which require an appropriate design. The serious damage which unreliable heat pumps did to the image of the system in the USA in the 'sixties was mainly due to the fact that this requirement had not been properly observed.

Although in Europe sufficiently reliable heat pumps are now available, improvements in design might nevertheless substantially increase the market potential. Attention should mainly be focussed on the following:

o an increase in the coefficient of performance, i. e. the ratio between heat released and power input,

o a reduction in the noise level, especially when air is used as source of heat, as the heat pumps have to compete with other noiseless heating systems,

o a design suitable for low-cost manufacture in large production runs

o a design permitting the unit to be installed with a minimum of cost at the ultimate site.

All the heat pumps currently available on the European market are far below the optimum in one or more of the above respects but there are signs that heat pump technology is undergoing a rapid development. It has been found, however, that as long as sales prospects are few, the big financially-strong companies are not showing much interest at present in purposeful development work. More serious efforts are therefore being made by small and medium-size firms whose capacity for development work is limited.

2.2 Impediments due to general conditions at the ultimate site

The general conditions governing the use of heat pumps are mainly dependent on the ultimate site. This becomes most obvious when the heat sources are considered.

Groundwater and ground which, throughout Europe, offer equally good temperature conditions for the use of heat pumps, are not adequately available everywhere. In many areas, particularly those densily populated, they must be totally disregarded as sources of heat.

The temperature of outside air, the only source of heat freely available everywhere, is, however, subject to considerable climatic fluctuations. In Sweden, for instance, this was the reason why development work was primarily concentrated on groundwater and ground as sources of heat in spite of the attendant difficulties. Outside air there can only offer advantages when a dual- source system is used which on very cold days supplies heat from a conventional fuel-fired heat generator. Recent Swedish thinking is aimed in this direction.

In the United Kingdom, however, with its mild maritime climate, the outside air is regarded as the most suitable source of heat. As extremely cold spells are rare, the use of the heat pump as the exclusive source of heat seems to be sensible. The high moistute content of the air, however, raises new problems owing to considerable icing of the evaporator and these must be regarded as a hindrance to the spread of the heat pump.

In the southern European regions the annual demand for heat for space-heating is so low that this alone would not justify the relatively high investment for a heat pump installation. During the summer it is frequently necessary there to use comfort cooling so that a double-duty unit capable of both heating and cooling would, at least in theory, have equally good conditions as in most parts of the USA. In actual practice, however, the comparatively low standard of living in large areas of southern Europe will be an obstacle to the installation of an air-conditioner that could form the basis of a heat-pump heating system.

This aspect indicates another important factor affecting the spread of heat pumps: the prevailing attitudes in respect of heating and air-conditioning.

The use of heat pumps is best suited for heating systems using a central source of heat which is then distributed to the individual rooms as required. These central heating systems, as used in Switzerland, West Germany, parts of France and in many parts of Scandinavia, for example, involve high capital expenditure on the part of the owner and are selected for reasons of comfort regardless of the heat supply. If a heat pump is used the heating system can be retained without any additional cost attributable to the pump. If such a central heating system, however, is not available as, for instance, in many parts of the UK and Ireland, the owner must not only be persuaded to instal the heat pump but also a central hot water or hot air distribution system. Apart from the extra cost thus incurred, this involves further problems arising mainly from the reconstruction of the building.

The lack of specialist knowledge on the part of planners and contractors is another major impediment to the installation of heat pumps. Only when architects and heating contractors have become sufficiently familiar with heat pump technology will the heat pump enjoy wider acceptance because these two professions are important sources of information for the owners who only rarely act against their advice.

2.3 Administrative Impediments

Experience shows that all innovations, as they are of importance administratively, are liable to suffer restraints from this area. The cause for this can hardly be eliminated as every administration has to abide by certain rules (ordinances, decrees, regulations, standards, etc.) which, by their very nature, cannot cater for such innovations. Steps should, however, be taken to remove such difficulties as quickly as possible once they have been recognized.

In the Federal Republic of Germany, for instance, the trade code specifies what work can be done by what craftsman. If craftsmen overstep these established limits, such a breach of the code is punished as an "infringement". Rigourous compliance with the trade code, however, would result in up to four different tradesmen being involved in the installation of a heat pump (refrigeration technician, heating system installer, electrician and mason). In other countries this problem is probably even more pronounced. Apart from organizational difficulties and the resultant extra cost such a procedure would give the heat pump the image of a complex heating system.

The administrative impediments are as many faceted as the administration itself. Taken singly they are not of great significance but in toto represent an appreciable hindrance to the spread of heat pumps. If, as in West Germany, the chimney-sweep, for instance, is made by law an advisor to the public in all questions relating to space-heating, it becomes clear what inherent problems this poses for a heating system that requires no chimney and thus no chimney-sweep.

It must be stressed, however, that not only restraints may emanate from an administration but that the latter, if properly run, has an enormous potential for promoting the spread of heat pumps. These possibilities extend from financial facilities (tax treatment, loans, etc.) through relaxed approval procedures right down to the dissemination of information in schools and vocational training institutes. Some progress has been made here but a lot more could be done.

2.4 Psychological Impediments

Most owners or principals, architects and contractors for heating installations are familiar with the heat pump in theory but rarely in practice. Like all innovations, the heat pump is thus confronted with a highly sceptical attitude. This is further aggravated by the fact that the heat generating process, as a rule, remains obscure to the layman and often arouses the impression of perpetual motion.

The basic problem underlying these psychological impediments is inadequate information. Other, far more spectacular although much less promising, energy sources repeatedly push the heat pump into the background as regards the dissemination of information. The direct use of both solar energy and wind, for instance, is far more frequently the topic of extensive articles than the heat pump and politicians also often prefer to nourish unrealistic hopes rather than to help promote the use of the heat pump as a realistic possibility. The heat pump is the step-child of the media.

Psychological impediments can only be removed by the intensive dissemination of information. This must not be restricted to the theoretical aspect but must be accompanied by demonstrations showing that the heat pump has proved its merits under actual operating conditions. It is only in this way that important decision-makers, such as architects and heating contractors can be persuaded to advise their customers to instal a heat pump and prejudices which stem from past technical problems eliminated.

Removing the psychological impediments is a must for the widespread use of the heat pump. This problem has generally been recognized and in some European countries there are already signs of a solution. In Denmark, for instance, the question of the power supply utilities granting a certain warranty for the function and energy consumption of heat pumps is currently being discussed. In West Germany a power supply utility has built 50 demonstration installations.

In addition, this utility grants a 25 % discount on the electricity rate to the first 1000 heat pump customers. At the same time great care is taken in both these countries to ensure that only fully operative heat pump systems are installed. These first installations are intended to demonstrate the reliability and soundness of the heat pump technology and thus free it from its futuristic image.

The psychological impediments can also be eliminated by combining the heat pump, about which people are still somewhat in the dark, with a well-known and time-tested heating system. This, for instance, is the case with dual-source heating where the additional presence of a fully reliable oil heating system gives the customer the necessary feeling of security.

2.5 Economic Impediments

Installing a heat pump system always involves higher initial cost than comparable fuel-fired heating systems. If the heat pump is to compete, for instance, with oil heating in terms of the total heating costs, the extra initial cost can be offset by a lower energy cost. This is particularly feasible with large heat pumps capable of using favourable sources of energy.

In the final analysis this will have been the reason why in France emphasis is placed on large installations using geothermal heat sources. In Sweden, too, multi-family houses are considered to offer better possibilities.

In West Germany major problems were, however, encountered whenever the owner did not live in the house. In such cases the owner was mainly interested in a low initial cost in order to be able to keep the rent at a low level. The heat pump with its high initial cost thus did not stand a chance. For this reason efforts in Germany centred on the small heat pump with a higher specific cost for heating single and double-family houses. In comparison with oil-fired heating, such a heat pump system involves 25 to 30 % more expense in terms of installation and energy costs under the present circumstances.

Although a cumulative analysis over the heat pump's full service life - about 10 years - presents a more favourable picture, this fact understandably poses a serious problem for the spread of the heat pump, which could, however, be solved if the government were to promote its use for specific applications in the same way as it frequently does with district heating. This would lead to small heat pumps being manufactured in large production runs and thus to a substantial price reduction so that such government subsidies would not have to be retained ad infinitum, particularly since increasing savings in energy cost would result from the operation of a heat pump in view of the anticipated rises in energy prices.

The heat pump is subject to the influence of a variety of important economic factors liable to undergo minor or major changes. These include:

- initial cost
- coefficient of performance of the heat pump
- electricity rate
- price paid for the comparable amount of heat generated from fossil fuels
- distribution of the heat load on the heat pump or fuel-fired heat generator with dual-source installations
- possible subsidies to promote the spread of the heat pump

It is hardly possible to present an outline of the above aspects for Europe. In Fig. 5, however, the relationship between initial cost and energy cost for a dual-source heat pump/oil heating installation in a single-family house is compared with the cost of a straight oil-fired heating system. The example given in the graph shows the total cost difference assuming equal energy costs. The overall cost would be roughly equal if the following were to happen:

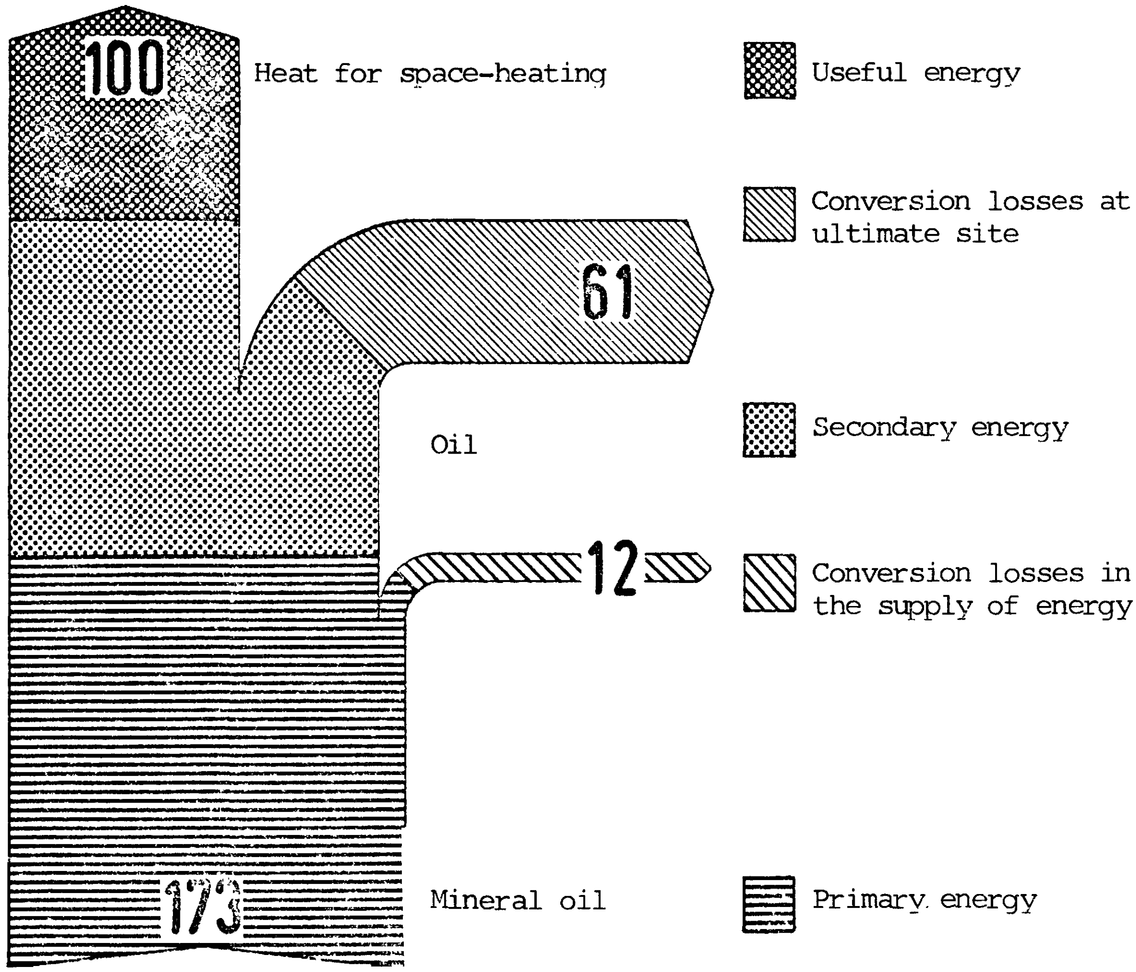
- Reduction in the heat pump's energy consumption by design improvements
- Reduction in the heat pump's price by mass production and simplified installation
- Rise in oil prices
- Relatively smaller rise in electricity rates

In all the above four points the tendency is towards a removal of the economic impediments.

3. Summary

European manufacturers of heat pumps fully meet present demand on the European heat pump market both in terms of quantity and quality. Improvements in heat pump technology, particularly a reduction in energy requirement and lower cost in the manufacture and installation of heat pumps, would greatly promote the spread of this system. The choice of heat pump largely depends on the climatic conditions and on the general standard reached in space-heating technology in the country concerned. One of the most serious impediments to the rapid spread of the heat pump is, however, the fact that the population is ill-informed. More support, especially in this area, could be forthcoming from the public authorities which would be just as important as financial grants for a number of pilot installations to free the heat pump from its futuristic stigma.

There are already signs of solutions to all these problems. The extraordinary rate at which our energy problems seem to get worse would, however, make it advisable for these efforts to be intensified.

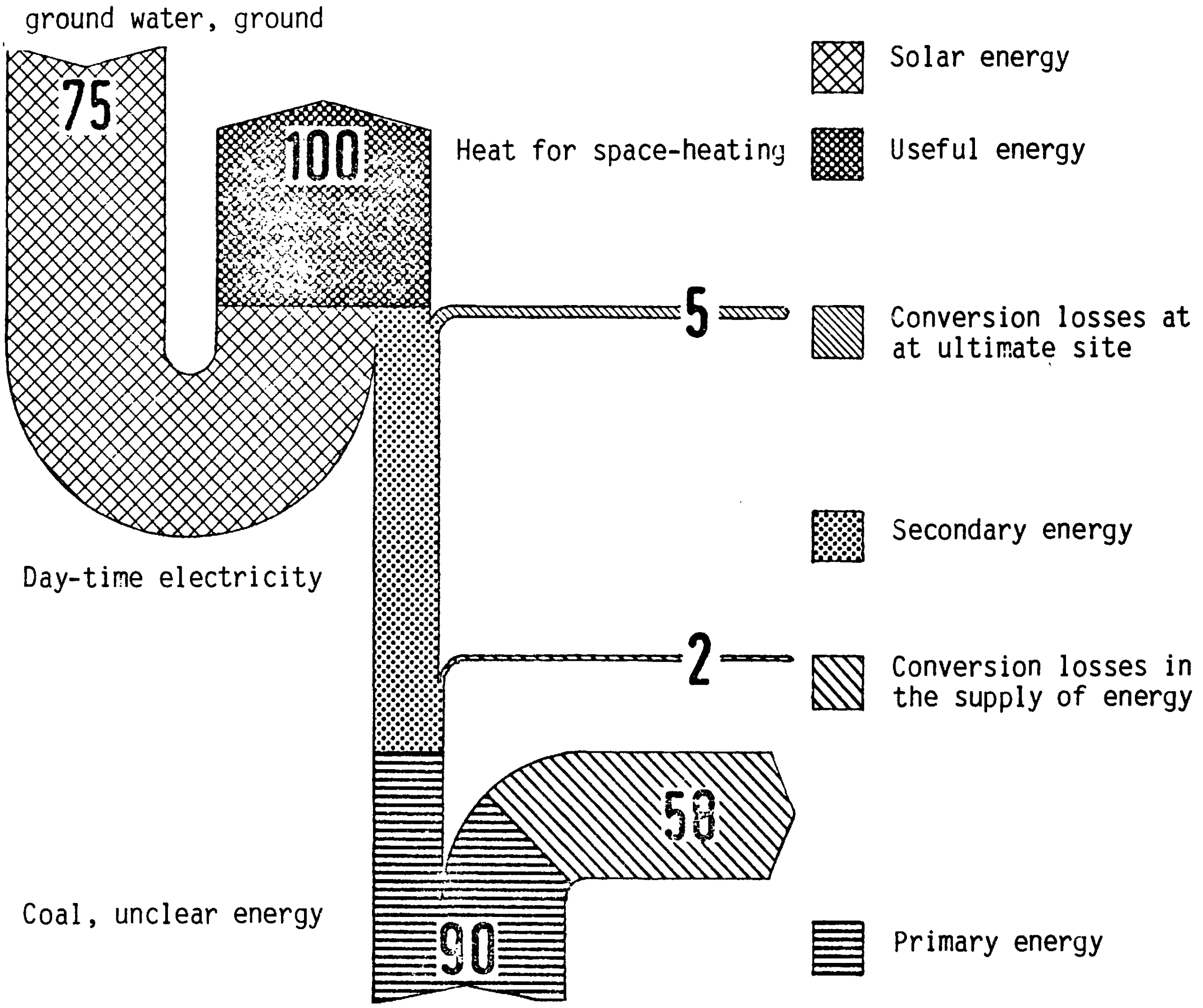


Central heating using light fuel oil,
natural gas or coal/coke

RWE

ENERGY FLOWSHEET
Fuel-fired heating

1



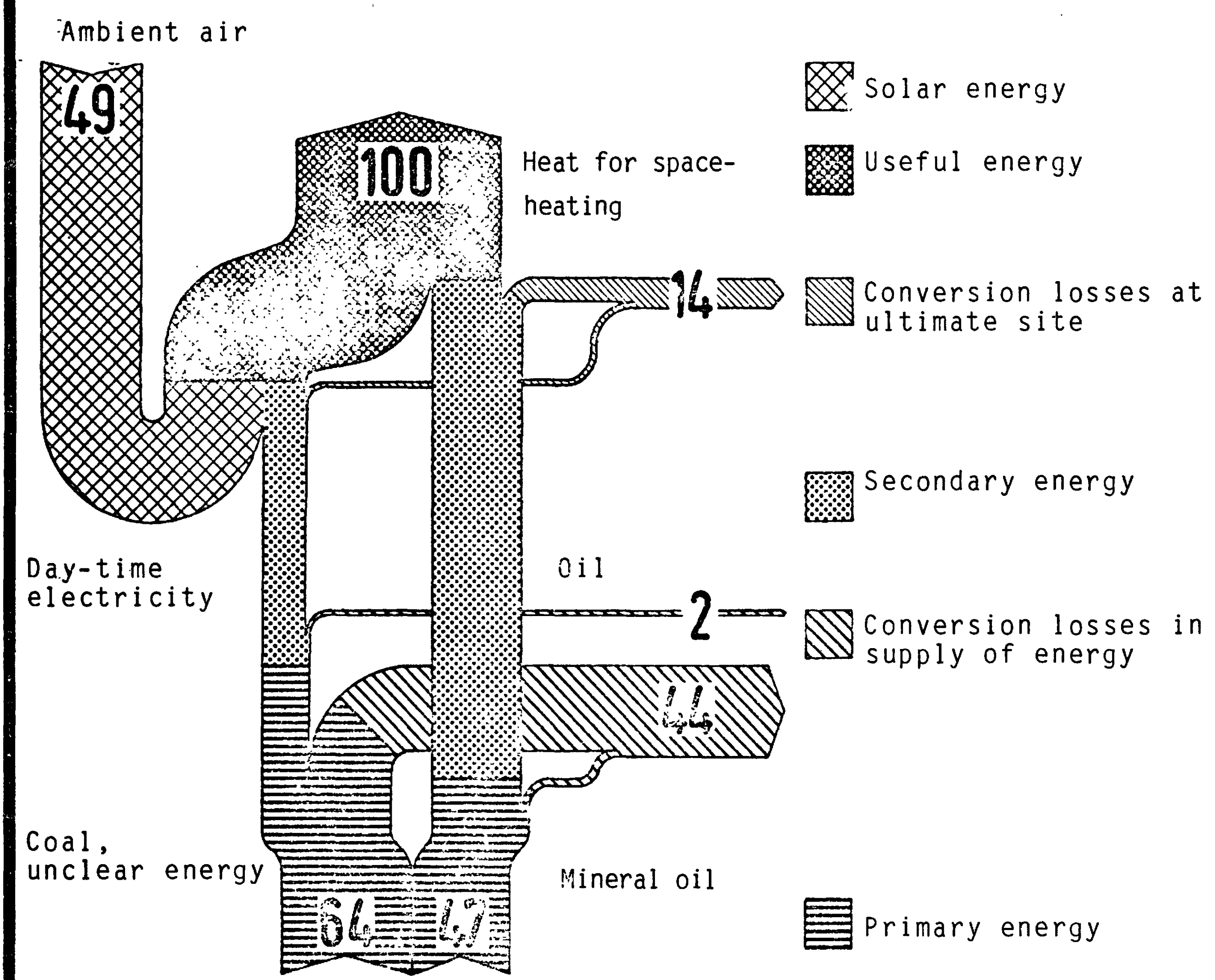
Central heating using electrically driven
ground water or ground-type heat pumps

RWE

ENERGY FLOWSHEET

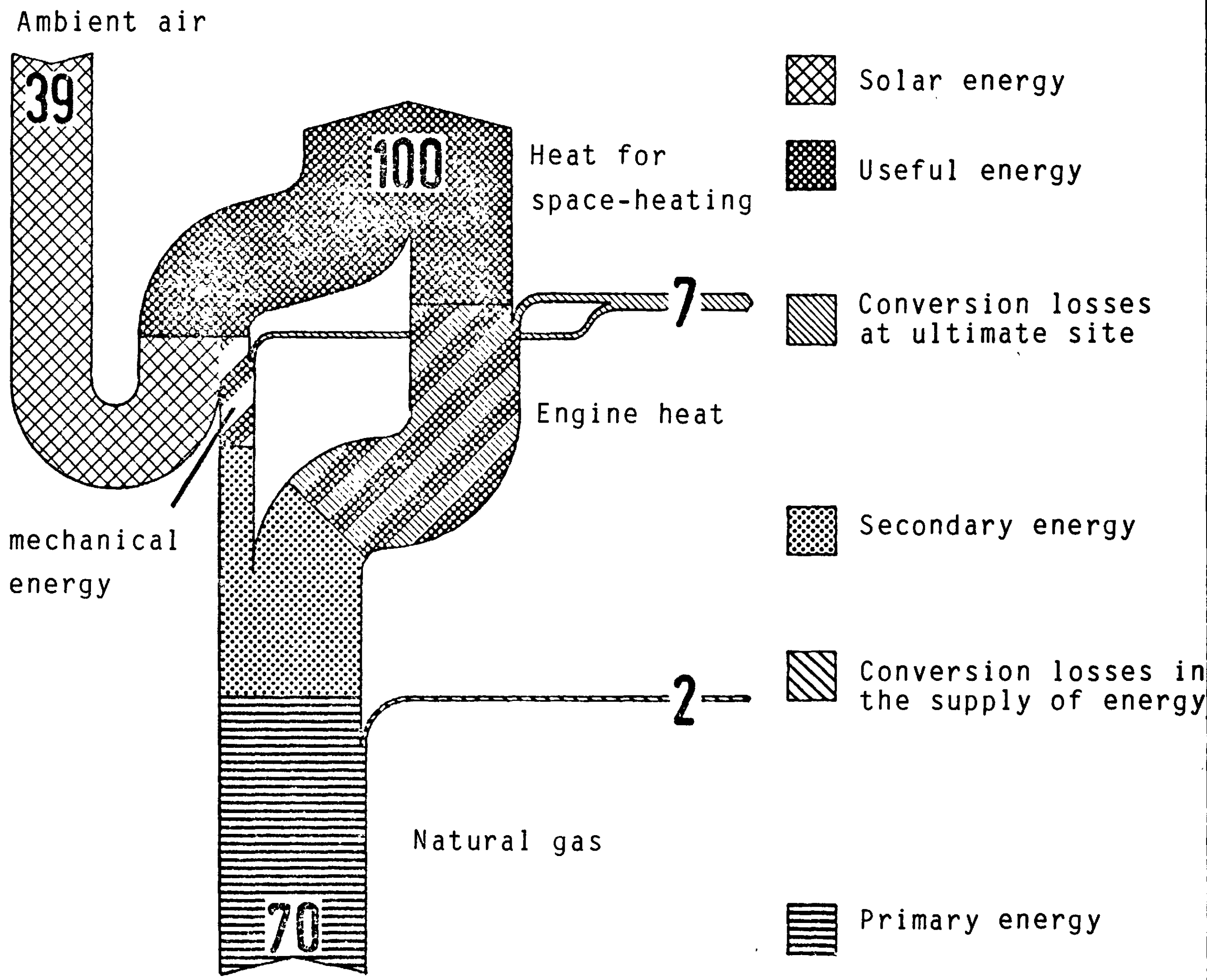
Ground water or ground-type heat pump

2



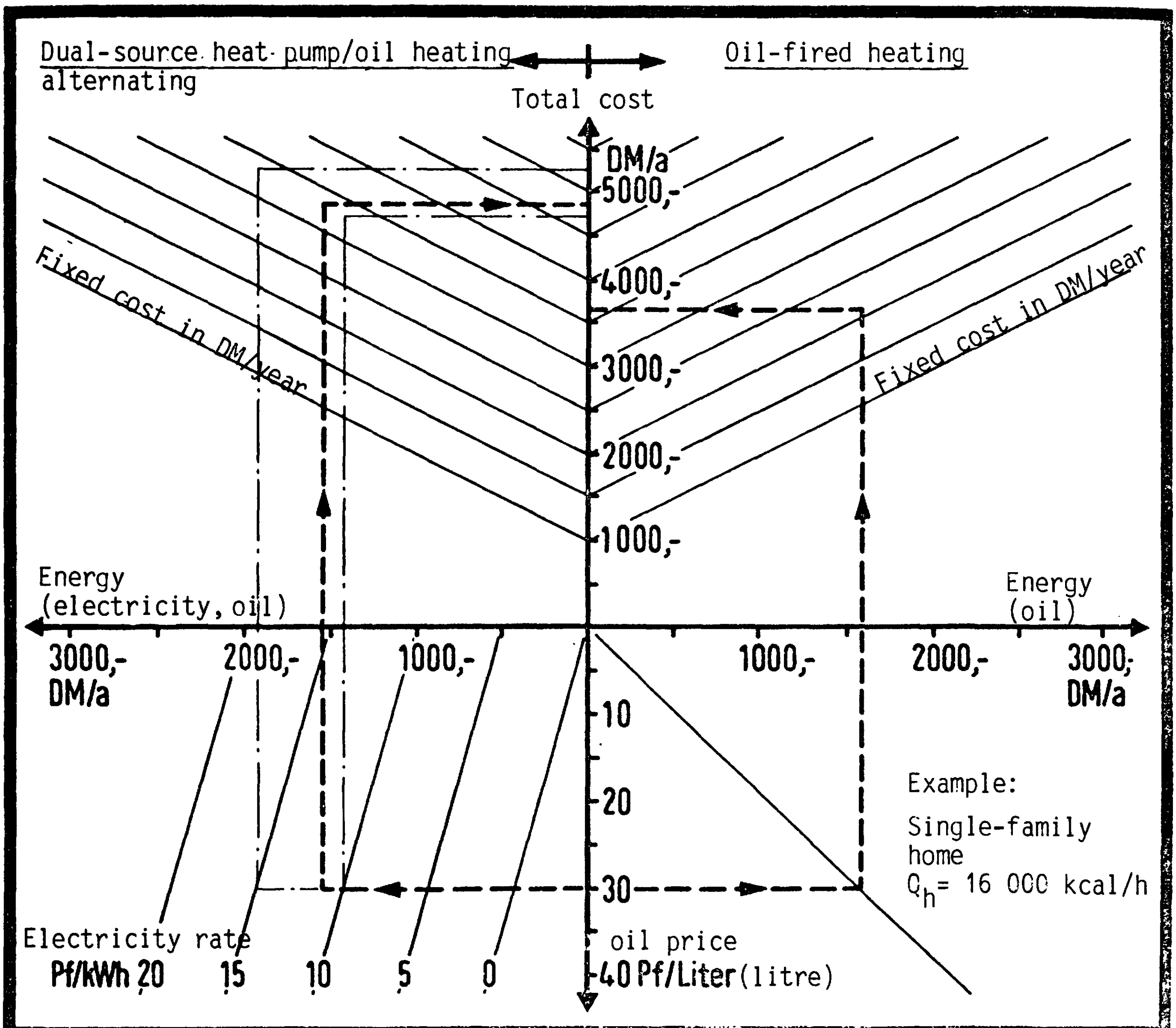
Central dual-source heating (oil or LPG-fired heating in cold winter spells, on other days electrically-driven heat pump using the air as heat source)

RWE	E N E R G Y F L O W S H E E T Dual-source heating with air heat pumps	3



Central heating using a heat pump driven by a gas engine (natural gas) with the air as heat source

RWE	ENERGY FLOWSHEET Air heat pump (natural gas)	4



RWE

COMPARATIVE OPERATING EXPENSE

Oil-fired heating - dual-source heating - heat pump/oil

5

European Communities — Commission

EUR 6161 — Study day on the development of heat pumps in the Community for heating and air-conditioning

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This publication is on the proceedings on the 'Study day on the development of heat pumps for heating and air-conditioning in the Community', organized by the Directorate-General for Energy of the Commission of the European Communities, on 8 December 1977 at Brussels.

A rapid development of the use of heat pumps can lead to appreciable results in the rational use of energy with clear economic repercussions. Certain problems relating to standardization, technical improvement, technologies, reliability, electrical tariffs and to commercial development and maintenance are however holding up the development of the use of heat pumps.

Examination at European level of common problems by manufacturers and all other interested circles can help the development of this system of heating and air-conditioning.

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