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THE POSSIBILITIES OF USING HEAT PUMPS IN HISTORICAL CITIES

Heat pumps are alternative appliances for production and processing of energy. Because of variety of these devices and wide potential for using them, only main aspects of that use were discussed. Main types of heat pumps are presented. Each case was analyzed taking account of their usability in historical cities. Ecological and economical aspects as well as the possibilities of cooperating heat pumps with other common heating systems were discussed.

1. INTRODUCTION

The heat pump is a device for heating buildings, in the form of a heat engine driven in reverse. The internal energy of some part of the environment is used as an energy source, giving heat Q_1 to the working substance. An electric motor does work W in taking the substance round the cycle in which the temperature is raised to slightly above that of the building.

Due to the ability of the pumps to absorb heat from the sources of low temperature they have many applications. They are used not only as the devices which improve the efficiency of heating systems, but also as self-sufficient heating units. Some of the heat pumps can both absorb and give out heat, depending on the need.

The principle of the operation of heat pumps is based on the second law of thermodynamics, according to which it is possible to increase the energy level of a system, simply, by making the system work. In most cases, use is made of reversible liquid–steam change phase, which is accompanied by heat radiation. The main advantage of heat pumps is their high efficiency. They can give out twice as such energy (or even more) as they consume.

Due to these devices it is possible to reduce the demand for energy (electrical and heat), which is an important environmental issue.

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2. SUGGESTIONS FOR USING HEAT PUMPS IN KRAKÓW

• **Central heating systems in private houses.** Heat pumps, used as central heating systems for small buildings and houses, use as the source of heat: the heat of water, ground or air. They can give out even four times as much energy as they need to work. The real efficiency factor (taking into account waste of energy) is always more than 100%.

In Kraków, the use of small heat pumps is limited. They are used for detached houses only. In this case, geothermal energy is too expensive, air has too little amount of energy which is not coherent (the lowest temperatures of this source fall on the period of the highest demand for heat). Areas near the houses in most cases are too small for horizontal heat exchangers, whereas vertical heat exchangers are more expensive – in order to install them, deep holes have to be bored in the ground. The price of the heat pump whose work is based on ground source is about € 5000–6000 for a house.

The air source-based heat pump, which uses the latent heat of the moisture in the air, does not need boring holes. The heat exchanger is small, however, it costs € 9000. Heat pumps designed to recuperate heat in waste air or to cooperate with glaze collectors are also expensive and not as efficient as small units.

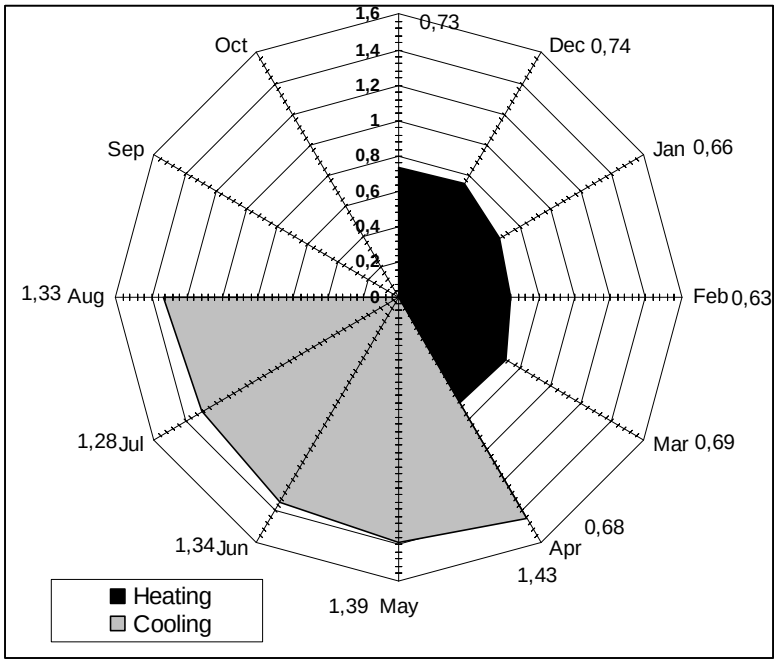
Mass replacement of standard central heating systems with heat pumps in houses in Kraków will not be possible, mainly for the reason of its cost.

• **Using geothermal energy.** Application of large geothermal heat-pump systems with the power of 4 MW and more can reduce the use of coal and other fuels from 20 to 35%, as well as the emission of carbon dioxide and other dangerous substances, e.g., sulfur dioxide or nitrogen oxides, to the atmosphere. There are some systems of this kind in Poland, but not of great power. Geothermal system for Kraków would have to be able to generate at least 100 MW to make the changes of emission visible.

• **Cooling and air conditioning.** The development of each city is connected with greater demand for heating and cooling. Not only public institutions but also blocks of flats, in more and more cases, have air conditioning. A drop in temperature needs huge amounts of energy, especially, when cooling system is based on numerous small air conditioning units that consume electrical energy, which is very common in Kraków (for example, the Cracovia hotel).

Every summer we may observe an increased consumption of energy. This is the result of using small devices called air-split heat pumps and the operation of air conditioning systems in every new building. Popular air-split systems which are on the market are not appropriate for historical cities because of many reasons. First of all, they are small, and therefore not very efficient. Secondly, they do not prove themselves to be good heaters, for they give out only 60–80% of the energy absorbed (electrical heater gives out at least 95%), and unaware heater users exploit them in that mode very often. In the figure, the results of tests made on air-split heat pump, at the laboratory of Kraków University of Technology (Nov 2004–Aug 2005) are presented.

This picture shows the differences between the efficiency of heating and cooling mode of air-split heat pump.



The efficiency of air-split heat pump: heating and cooling [1], [2]

The third reason for rare use of heat pumps is that they are based on the worst heat source, namely atmospheric air [1]. So far, the only way to reduce an unfavourable effect of these pumps is to combine small air conditioning systems and recuperation of some of the heat.

• **Regeneration of energy.** Recuperative heat pumps are able to use again the energy produced which normally is considered to be the waste energy. The air in ventilation systems (both warm and cold) and wastewater have this kind of energy. Recuperative heat pumps have been applied in large building structures (railway stations, hospitals, student hostels). In Kraków, for example, there are about 18000 student lodgings, where over 19300 students live, which is 2.7% of the whole population of Kraków. One student uses on average 0.9 m^3 of hot water per month. Heat pump, with the coefficient of performance equal to 2, can recover energy, by cooling that water used by all students from 30 to 20 ^oC, up to 700 GJ, which means the demand for coal lower by 15 tons per month and the reduction of CO_2 emission by 50 tons. Emission of other oxides is reduced as well.

Large amount of waste energy can be recovered in other institutions and public buildings. In the existing blocks of flats, the costs of installation of such pumps are enormous, and very often it is not possible to recover heat because of the architectural design of those buildings. However, in the plans of new housing estates, the recuperative systems should be taken into account.

Recuperative heat pumps are expensive, but those costs can be recovered soon because of the reduction in the costs of heating. These systems can influence the climate and the air quality in historical cities.

• **Combined heat and power.** The construction of combined heat and power systems aims at using energy in the best possible way. Parallel production of heat and electrical energy provides a lot of economical and ecological benefits. Additional heat-pump systems allow us to use again the energy produced earlier which is, however, of low potential. Absorption heat pumps, which use heat energy instead of electrical one, are particularly efficient.

Combined heat and power system has one more advantage: it can reduce temperature in an economical way, and, at the same time, can satisfy the needs for still growing demands for cold in Kraków. These systems proved their quality in many installations in the world [3].

Cooling of the air can be carried out in two ways. The first one is to place heat pumps near the power plants. This allows the use of large absorption units with greater efficiency and the transport of the cold to customers, for example, in the form of cold water. The second method is based on the transport of hot medium (hot water or steam) to customers, who use that energy for their own heat pumps. In both cases, the efficiency of combined heat and power systems is greater, the demand for electrical energy falls, because (so far) waste heat generated in power plants is used instead of electrical energy, and the market for heat in the summer time develops. In this way we may reduce the extensive use of small and inefficient air-split systems.

This kind of energy policy called *trigeneration* (heat, cold and electrical power) seems to be most effective in energy systems and is successfully applied in many European cities [4].

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POMPY CIEPŁA – MOŻLIWOŚCI ZASTOSOWANIA W MIASTACH ZABYTKOWYCH

Przedstawiono pompy ciepła jako alternatywne urządzenia do wytwarzania i przetwarzania energii. Z uwagi na dużą różnorodność tych pomp oraz wiele możliwości ich wykorzystania omówiono tylko główne zagadnienia związane z ich użyciem. Zaprezentowano główne typy pomp ciepła i przeanalizowano je pod względem przydatności i funkcjonalności w miastach zabytkowych. Uwzględniono aspekty ekonomiczne i ekologiczne korzystania z pomp ciepła, a także tendencje w zapotrzebowaniu na różne rodzaje energii w miastach. Omówiono możliwości współpracy pomp ciepła z innymi źródłami energii.