WPSOURCE – Comparison of heat sources for heat pumps

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ABSTRACT

With the increasing use of heat pumps to supply thermal energy in buildings, a variety of low-temperature heat sources and heat exchangers are being found on the market as potential solutions. However, planners often lack an overview of the requirements and boundary conditions with regard to use heat pumps in a building design. Examples are land requirements for the heat exchanger, investment costs of the system, and different technologies or components that are available on the market. To facilitate the evaluation of heat pump systems, low-temperature heat sources, and heat exchangers, a compilation of different technical design approaches is desirable to help make decisions during preliminary planning.

The goal of the research project is to provide an energetic and economic evaluation of low-temperature heat sources for heat pumps. The pre-sizing program WPSOURCE is being developed in coordination with this project. WPSOURCE is an excel-based tool to assist with the basic assessment, selection, and dimensioning of different heat sources and heat exchangers for heat pump applications. With a given set of system parameters and market data, WPSOURCE assembles possible system configurations for specified operating conditions and identifies thermal and economical low-temperature heat sources and heat exchangers for the proposed heat pump system. The program offers a comparison between different systems, such as heat extraction rates of different heat exchanger/heat source combinations and estimated costs for a system.

1. INTRODUCTION

Heat pumps are gaining market acceptance for supplying heating in buildings, and for cooling as well. Using heat pumps for heating is now established as a viable option for builders and planners. Reversible heat pumps are used in non-residential buildings for heating and cooling with the same facility. Despite the slow adoption of the technology and non-optimal use of equipment, there is interest by consumers and designers in using the technology.

The common reasons for heat pumps operating at inefficient conditions result from an inadequate connection to low-temperature heat sources and/or incorrect dimensioning of the heat exchanger. Other conditions for poor operation come from choosing the wrong user mode of a heat pump and from overall optimistic assumptions during planning. This often results in heat pumps that do not in practice meet their primary energy, ecological, and economical potential.

The increase of installed heat pump systems has led to an increase of potentially useful low-temperature heat sources and heat exchangers to supply thermal energy. There are various optimization potentials which must be analyzed for different applications. However sufficient information and criteria for making decisions is not always available when making planning choices. There are innovative products which planners often aren’t aware of or are poorly informed of their performance or benefits. Some of these technologies are ice storages, energy fences, or high-performance energy piles.

The same questions are always raised while planning an energy concept for a building. Given the large number of options for heat exchangers and heat sources available, what are the main differences between heat exchangers? As well, what combination of heat exchanger and/or heat source can be used for a given case?

To summarize, the typical questions are:

- Which is the right heat source for my heat pump?
- Are there significant differences between similar heat exchangers (e.g. regarding efficiency or costs)?
- What boundary conditions and basic parameters need consideration?
- Where can I obtain a brand-neutral and clear comparison between possible heat pump systems and components?

One aim of the research project “future:heatpump” is to systematically analyze the performance of different heat pumps in combination with different heat exchanger systems and low-temperature heat sources and to identify suitable variations for energetic and economic opportunity to supply heating to a building. With the questions that are being posed for planning these heating systems, planners and clients are given a clear overview of the important information for a specific project and possible economical variations of the equipment.

2. PRE-CHECK-TOOL WPsource

To facilitate the preliminary planning of a heat pump system, it is helpful to provide a clear overview of different low-temperature heat sources and associated heat exchangers for a specific project. Therefore, the idea is to compile a list of relevant low-temperature heat sources and heat exchangers to estimate the performance, efficiency, and profitability of a heat pump system anywhere in Germany. Such an overview of these systems should allow a direct comparison between various heat sources, exchanger systems, and parameters. Some of these parameters are the extraction rates of heat exchangers in conjunction with heat sources and performance factors. The operating conditions and efficiency of the individual systems are determined by project-accompanying investigations on existing plants and extensive system simulations.

For this reason, the program WPsource helps to pre-design a system by evaluating heat sources and heat exchanger systems and providing approximate sizing of equipment for cases defined by the user. This program is used for the basic evaluation in the preliminary planning of energy concepts which use heat pumps as the primary heat generator in a building.

WPsource currently includes single and multi-family houses, as well as office buildings. The residential buildings assume that the heat pump will provide heat for both space heating and domestic hot water (DHW) consumption. For office buildings, only the space heating is applied to the heat pump. It is common in office buildings to provide DHW by another heat source. Subsequent planning of cooling requirements through the use of a heat pump is a part of the project "future:heatpump_II". Cooling needs in residential buildings will not be integrated into the program. Cooling in most residential buildings is attributed to architectural conditions or higher comfort requirements.

When the user inputs the building typology and its respective thermal standard, WPsource determines possible and suitable heat source and heat exchanger combinations for the individual application in the pre-selection process. Recommendations are also made for dimensioning the heat exchangers as well.

Further, ecological (CO_2 emissions, primary energy consumption) and economic (investment and operating costs) factors are determined in parallel to the technical equipment comparison. Information on secondary conditions which are important for a respective equipment approach are provided by the program as well. An example is the requirement for sound attenuation for air-water heat pumps or pumping tests that are required when using groundwater as a heat source and/or sink.

Figure 1 shows an example of the user interface of WPsource. During the development, attention was paid to clarity and user-friendly operation.

Figure 1: User interface for WPsource (only in German available)

2.1 From basic research to evaluation and interpretation

The program was developed on the spreadsheet program MS Excel®. Following the structured design of the program, general content and data from literature and standards were inserted into the program. Numerical simulations were performed for various combinations of reference buildings, heat pumps, and heat source/exchanger combinations at locations throughout Germany. Boundary conditions for these simulations were partially varied (e.g., soil parameters) and the results of these simulations, with derived functions and contexts, were implemented into the program. (Fig. 2)

In the context of system variations, measurements, and simulation results, technical information and recommendations that were vendor or manufacturer-specific were documented for the equipment. The recommendations for efficiency and standards were implemented as well with corresponding building typologies, heat sources, and heat pumps.

Simulation results were the essential basis for assessment, pre-selection, and dimensioning in WP_{SOURCE}. Simulations allowed for the expansion of program options and selection of more low-temperature heat sources and heat exchangers, along with their dimensioning.

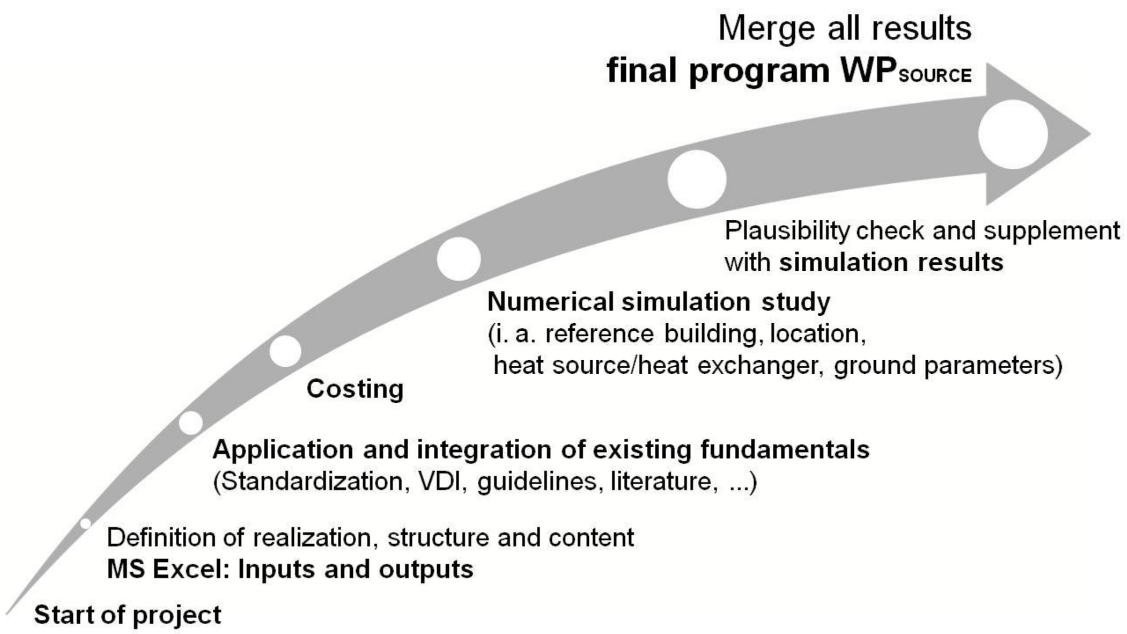

Figure 2: Workflow - Process of development of WP_{SOURCE}

2.2 Construction and methodology of WP_{SOURCE}

Figure 3 shows the simplified structure of the program as well as the structure of the information flow. In order to enable the use of the program by a wide group of people and to take account of different levels of detail and aspects in the planning of heat pump systems, flexibility and versatility in the settings and inputs is an essential feature of WP_{SOURCE}.

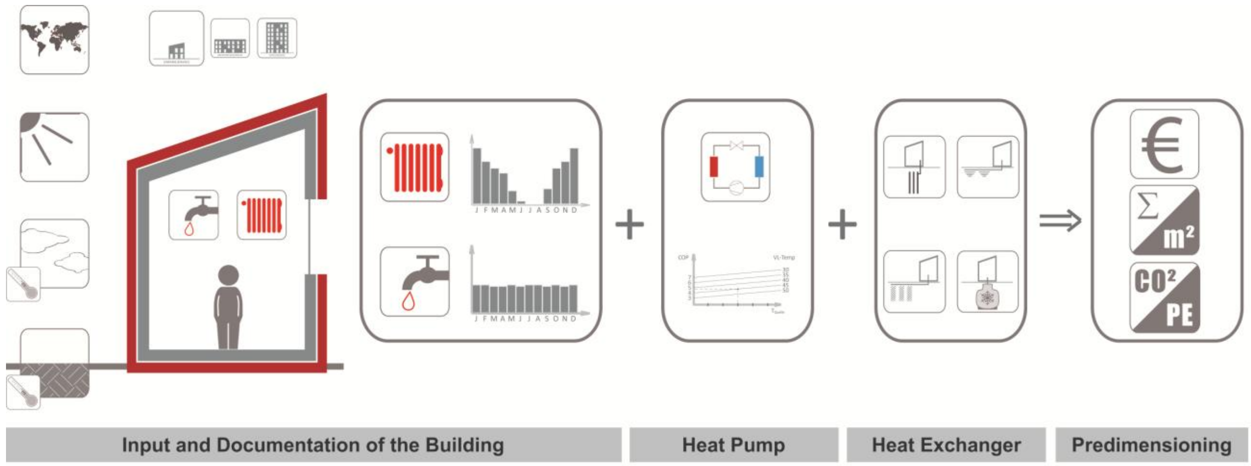

Figure 3: Scheme of the structure and flow of information in WPSOURCE

A key feature of WPSOURCE is the flexibility of settings and inputs which enable users to accommodate a wide range of options and different levels of detail. With a user-friendly interface and operation, comments and help texts also facilitate the use of the program and help prevent errors in using the program and information input.

By using option buttons, the user can change settings and basic parameters for each project. When information is not provided by the user when prompted, default values in the program are assigned to assist in completing the selection process.

Step 1: Input and documentation of the building heat demand

The operation of the program begins with documenting and specifying the general conditions of the project. After entering the data (name and location), characteristics of the building are added next. These would be the property size, building net floor area, thermal building standard, energy demand, and other items as well. The user will also make first assumptions of the design of the heating and/or cooling system. From this information provided by the user, the program determines the heating and cooling energy demand (including heating and cooling load).

A user, who has either a detailed understanding of a heat pump system or only a general idea, can receive useful information from the program. A knowledgeable user could define a building class and energy demand for a building, or use information from the calculations according to the EnEV standard. Different options will be available in the future version where the user will also be able to define DHW demand for residential buildings and a cooling demand for office buildings.

Step 2: Heat Pump

WPSOURCE defines the size of a heat pump that will meet the requirements of covering heating requirements of the building. The characteristics of the heat pump are generated from a large number of pumps on the market. The hypothetical heat pump generated numerically in the program represents a medium-quality heat pump, respective to power consumption. This allows the program to generate a Coefficient of Performance (COP) for the pump. Characteristic values of reference heat pumps were implemented in the program so that the required power could be simulated with the numerically simulated heat pump.

Step 3: Low-temperature heat source

After the average monthly heating load and demand has been calculated, the extraction rate of energy from the low-temperature heat source is determined. This forms an essential basis for the selection and meaningful dimensioning of the low-temperature heat source.

Step 4: Predimensioning

On the basis of the program results (system simulations, analyzed system behaviour, and correlation of system variants), WPSOURCE generates the sizes of the equipment for pre-selection While the data underlying the program comes in hourly or higher time-step resolution, the dimensioning is based on monthly values. The environmental (CO_2-emissions, primary energy) and economic factors (investment and operating costs) are documented as monthly values as well. The comparison is simplified with an annual value aggregated from the monthly values.

Step 5: Further information

Appropriate warnings and/or instructions are given for the suggested systems and equipment as required. These could be operating conditions for the equipment, sound attenuation requirements, pumping tests for groundwater use, or other factors. Notices for multi-functionality of equipment are given as well, such as the ability to use a heat pump for cooling in certain situations as well.

2.3 Low-temperature heat sources and heat exchanger

Most heat pumps and low-temperature heat sources are often underutilized. At locations that have favourable geological conditions heat pumps and low-temperature sources can provide a substantial part or all of the heating and/or cooling requirements. A variety of other heat sources which do not have a suitable temperature level for heating can be made useful through a combination of a heat pump and a suitable low-temperature heat exchanger.

Through all of the information merged in the project “future:heatpump”, 13 categories of heat exchanger and heat pump systems were identified as common available options. As a separate category, a typical air-to-water heat pump is included in the overview as a comparison. In addition, special hybrid forms, such as e-Tank® are shown as well (Fig. 4).

Sample systems have been defined for the implementation of the technologies examined in WPSOURCE. Different buildings (single and multi-family houses, office buildings) and various low-temperature heat sources were taken into account as well. System selection looks at current equipment available on the market as well as selected heat sources and heat exchangers that reflect growing market trends for commercial use. As a part of the simulations, six different heat exchanger systems were connected to a heat pump for generating data and comparing these to a common air-water heat pump system.

Detailed investigation of low-temperature heat exchangers:

- Borehole heat exchanger
- Spiral-shaped borehole heat exchanger
- Geothermal basket
- Horizontal ground heat exchanger
- Waste water heat exchanger
- Ice storage with air-solar-thermal absorber
- Air-water heat pump

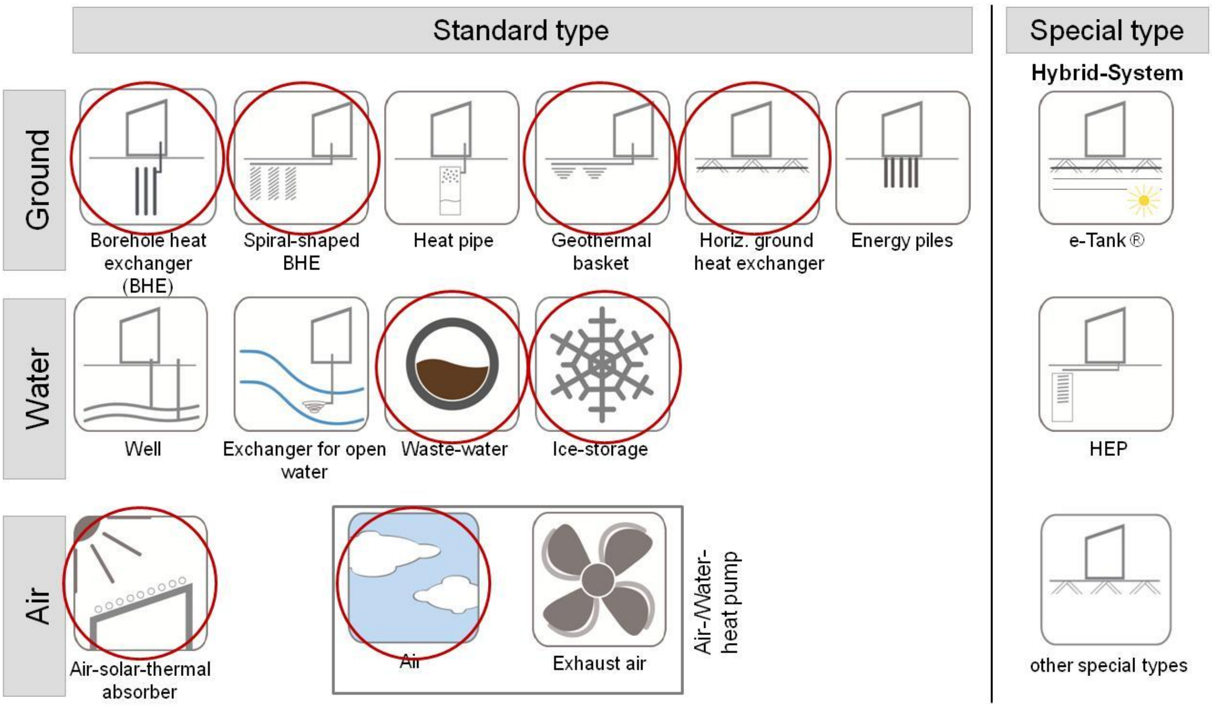

Figure 4: Heat exchanger systems for heat pumps (red circles = currently implemented in WPSOURCE)

3. CONCLUSION AND OUTLOOK

Heat pump technology will play an important role in the future of heating and cooling in buildings. To efficiently exploit this potential energy supply, an effective selection of low-temperature heat sources and heat exchangers must be chosen which are suitable for each application.

The program WPSOURCE provides a multi-functional tool which can be used in a wide range of areas for project-specific preselection adapted to the prevailing conditions as well as the approximate dimensioning of suitable low-temperature heat sources and heat exchangers for heat pumps.

The results of the research project "future:heatpump" show that very good results can be achieved almost independently of the heat exchanger system with regard to the operation of the heat exchangers and heat pumps. For the user, significant differences between the heat exchanger systems result from the different space requirements of the individual systems and the investment costs.

In addition to the costs, the conditions "building plots" and "space heating demand" play a decisive role in the planning, design, and selection of the system and its components. An important role is that building plots are comparatively small nowadays. Even with existing buildings, available free land cannot be expected to be of sufficient size. For this reason, it can be assumed that in the case of single and multi-family houses (large), systems that cover a wide area will be infrequently used. On the other hand, room heating demand is steadily decreasing as a result of increasingly well-insulated construction - and thus generally reducing the heating requirement. Due to the decreasing heat and coupled area requirements for a near-surface system, flat area heat exchangers, which are attractive due to lower installation costs, could again gain market share. Due to the significant reduction in the area of room heating, the domestic hot water increasingly represents the main part of the required thermal energy in a home. The required temperature level for DHW heating is generally above 50 ° C and thus above the flow temperature normally required in space heating systems (e.g. in-floor heating) of modern buildings. With a decreasing SPF, this circumstance has a negative effect on the efficiency of a heat pump system. This relationship should be taken into account in future energy concepts with heat pumps.

In the context of future planning, WP_{SOURCE} can assist planners and builders in the selection of suitable low-temperature heat sources and exchangers as well as system comparison and sizing. In addition, an overview is provided for key criteria such as space requirements, system efficiency, and investment costs.

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Our tool WP_{SOURCE} can be downloaded here:

https://siz-energie-plus.de/futurehp_wpsource_dl