Calculation methods for SPF for heat pump systems for comparison, system choice and dimensioning

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Energy Technology

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Abstract

In this project, results from field measurements of heat pumps have been collected and summarised. Also existing calculation methods have been compared and summarised. Analyses have been made on how the field measurements compare to existing calculation models for heat pumps Seasonal Performance Factor (SPF), and what deviations may depend on. Recommendations for new calculation models are proposed, which include combined systems (e.g. solar – HP), capacity controlled heat pumps and combined DHW and heating operation.

Key words: Heat pump, SPF, calculation model, field measurements

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Preface

This report summarize the findings from SP Technical Research Institute of Sweden in the joint KTH-SP project “Calculation methods for SPF for heat pump systems for comparison, system choice and dimensioning”, project P9 in the Effsys-2 research programme, financed by the Swedish Energy Administration and participating companies and organizations.
The project was set up so that SP and KTH performed separate parts of the projects, but with discussions and meetings in between.
The project parts are reported according to the parts stipulated in the application.

Sammanfattning

I denna rapport redovisas de delar av projektet ”Beräkningsmetoder för årsvärmefaktor för värmepumpsystem för jämförelse, systemval och dimensionering” som SP Sveriges tekniska forskningsinstitut svarat för. Projektet har genomförts av SP och KTH. KTH:s del av projektet redovisas i en separat rapportdel.

I en inledande del av projektet har förberedelser för ett IEA samarbete, samt gemensam övergripande projektplanering tillsammans med industriparterna utförts. IEA-projektet har godkänts att starta av styrelsen för IEA Heat Pump Programme, och ett första inledande möte har hållits.

SP har koordinerat samt sammanställt resultat av fältmätningar. Väl genomförda fältmätningar är en förutsättning för validering av olika beräkningsalgoritmer. Sammanställningen visar att det finns ett flertal utförda fältmätningar i Sverige under de senaste 20 åren, men få har gjorts med SPF som fokus, utan ofta har mätningarna gjorts med syfte att studera en viss teknikförändring, eller andra faktorer. Det har inte under de senaste 10 åren utförts någon stor mätning på värmepumpar liknande de välkända Fraunhofermätningarna eller FAVA-studien i Schweiz. Den enda studie som syftat till att mäta SPF är den som SP utfört. Detta kan ses som en brist i ett land där värmepumpar har ett så stort genomslag för uppvärmningen av bostäder.

En kravspecifikation för mätdata som behövs för att användas för validering har tagits fram.

En sammanställning av befintliga standardliknande beräkningsmetoder (existerande algoritmer) för SPF har gjorts. Syftet med analysen har varit att beskriva existerande algoritmer (modeller) samt kartlägga om nuvarande program (Annex 28, SP´s beräkningsprogram mm) innefattar alla typer av värmepumpsystem som finns på marknaden idag. En viktig del är att undersöka hur kombinerad drift dvs. tappvarmvatten och värme behandlas i modellerna. En annan fråga är huruvida olika typer av kapacitetsreglering behandlas. Sammanställningen har visat att det finns en stor brist bland förekommande program och metoder vad gäller att ta hänsyn till :

- Kombisystem, såsom sol-vp
- Kapacitetsreglerade system
- System med kombinerad varmvattentillverkning och uppvärmning

Existerande algoritmer har jämförts med resultat från fältmätningar. Från existerande fältmätningar har data tagits för att jämföra resultaten med befintliga metoder för att beräkna SPF. En analys av hur väl dessa metoder förmådde beräkna SPF för de studerade systemen har gjorts. Denna analys visar att resultaten från fältmätningarna ofta visar på högre SPF än vad som beräkningsmodellerna ger. Det finns flera orsaker till detta, bland annat att modellerna använder sig av konstant marktemperatur (som i förekommande fall är lägre än verklig marktemperatur), att modellerna använder en bivalent punkt som aldrig uppträtt i de verkliga mätningarna mm. Den gjorda jämförelsen visar på ett antal viktiga faktorer att studera vidare.

För att utveckla ett enkelt program för jämförelse av värmepumpsystem är det viktigt att begränsa beräkningarna till ett antal klimatzoner och ett antal typhus. Målet är att beräkningsmetoden skall kunna användas både nationellt och internationellt. I ett dimensioneringsprogram skall däremot stor frihet ges att definiera det specifika huset för att utförligt kunna studera de behov som finns för de specifika installationerna.

En ny beräkningsmetodik för SPF och årsenergibesparing baserad på, eller som ersättning för existerande algoritmer som input för nytt Annex inom IEA HPP och Europastandard (CEN) har diskuterats. Det gemensamma beräkningsprogrammet skall baseras på indata från gällande

Europeiska standarder (EN 14511) för kombinerad drift med värme och tappvarmvatten. Det skall även till fullo implementera rutiner för drift med kapacitetsreglerade värmepumpar (kompressorer och pumpar/fläktar).

Förslag till vad som bör ingå i ett nytt transparent gemensamt beräkningsprogram som kan användas för jämförelse och certifiering har getts. Industrigruppen menade tidigt att det viktiga i denna del är att ta fram de samband som bör implementeras i ett beräkningsprogram, men att de själva oftast skriver in-house kod som de kan implementera dessa samband i. Detta gör att förutsättningarna blir likartade, men att tillverkarna fortfarande kan ha sina specifika (ofta hemliga) indata själva.

1 Introduction

The existing calculation tools for 1) design and 2) comparison need to be further developed to show the potential with new technology such as capacity controlled systems and more efficient system for combined operation with space heating and domestic hot water production. The overall aim is to develop existing tools for future needs. The outcome from the calculation tools should be useable for calculation of environmental impact. The purpose is to compare existing tools for calculation of seasonal performance factor and annual energy savings in order to propose needs for further development. For validation of the calculation tools existing data from laboratory and field measurements will be used.

Seasonal Performance Factor, SPF, is a term used mainly for real installations, compared to the Coefficient of performance, COP, which is evaluated in controlled lab environment. How SPF is estimated depends on the situation under which it is evaluated, see Figure 1 below.

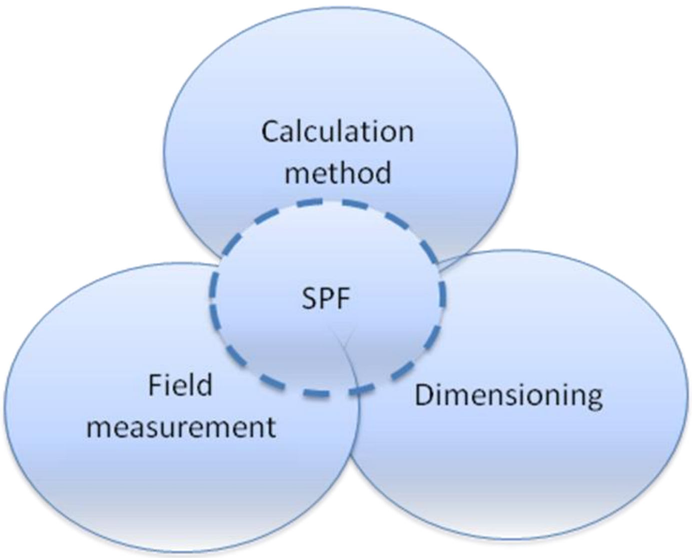


Figure 1. SPF can be determined in various ways, including field measurement, calculation methods and dimensioning software.

Based on lab measured performance data, SPF can be calculated according to calculation methods, that normally relates performance data in specific operating modes to annual climatic conditions, expressed as “bin models” where the number of hours in a year the temperature is between certain values are binned together. Model buildings are normally used to give annual heat demands and overall heat transfer resistances of the building.
For the installer of heat pumps, more specific details of the building must be prompted, as well as detailed data about the ground properties in the case of GSHP’s. Local climatic data is also used for estimating the heat demand. The climatic data contains a cold shock in order to dimension the heat pump capacity to extreme conditions that may occur during the lifetime of the installation. Other data such as the number of occupants, Domestic Hot Water (DHW) energy consumption is also normally entered in the software models for dimensioning.
To evaluate the real performance of the installed heat pump, field measurements are carried out to relate the useful heat produced to the energy input, often electrical power (but it could also be heat driven processes). The SPF of the heat pump is then often expressed as the ratio of the heat delivered to the heat distribution system (including DHW when relevant) to the electricity to operate the heat pump (including electricity to operate pumps and fans to bring the heat source to the heat pump).
The different level of detail given as input in the different stages of SPF calculation will lead to different SPF values. The main objective of this project is to identify what needs to be included in a new calculation method in order to better represent the real SPF of the heat pump in the building system.

2 Preparing an IEA HPP Annex on SPF

Preparations for an IEA annex on SPF have included preparatory meetings, and communication with research communities involved in the IEA HPP sphere. Meetings include a meeting during the ASHRAE winter Conference 2009 [1.1.1.1.11], NT meeting in Borås, September 2009 , and a Meeting in Paris march 5th, 2010 [2].
A draft legal text was prepared and circulated among interested parties and the executive committee in HPP. The draft legal text was discussed in the ExCo meetings in Rome, November 2009 and in Helsinki June 2010. In the Helsinki meeting it was suggested that the annex proposal for "Dynamic testing of heat pumps" should be integrated with the SPF annex. The kick-off meeting for the SPF Annex in June 30th- July 1st 2010 will discuss the possibility for this integration. The legal was just recently approved by the ExCo [3].
The preparation and starting up of the international Annex has taken much more time than expected, mainly due to constraints in timing and funding. However, on June 30 –July 1st, the kick-off meeting for the new annex is held in Albuquerque, New Mexico.

3 Summary of already performed field measurements.

In order to evaluate already made field measurements in Sweden, or made by Swedish manufacturers, meetings in the project discussed earlier made field measurements. The result is that there has been a large number of field measurements made during the last decades, see Appendix 1 and references [4-6], but few studies have had the specific goal to examine the SPF.
In order to make detailed analyses of the performance, also detailed data from the measurements are needed, and this was only available in two studies, the SP study ”Erfarenheter från fältutvärdering av fem bergvärmepumpar i Sjuhärad” and the Fraunhofer study “Heat Pump Efficiency” where a number of Swedish heat pump manufacturers participated with heat pump units. For Air-air heat pumps, only one study has been found [7]. These three studies are describes more in detail below.

3.1 Description of evaluated field measurements

3.1.1 Fraunhofer

The Fraunhofer-Institute for Solar Energy Systems ISE is running two large field monitoring project including approximately 200 heat pumps in total. The heat pump efficiency project includes approximately 110 installed heat pumps with a heating capacity of 5-10 kW. In the Replacement of Central Oil boilers with Heat Pumps in Existing Building Project 75 heat pumps are included. The heat pump types included are air to water, ground source and water to water heat pumps. In this study two heat pump producers, IVT and Nibe, have provided the project with data based on the field measurements in the Fraunhofer study.

3.1.1.1 Measured parameters

Table 1 gives an overview of the parameters normally measured in the Fraunhofer field measurements. Exactly what parameters tested might differ from test site to test site. For some test sites additional equipment are measured as well. Examples of such equipment are circulation pumps or control equipment.

Table 1. Measured parameters for brine to water heat pumps in the Fraunhofer study.

	Running time	Energy content	Energy consumption	Inlet temp.	Outlet temp.	Volume flow	Delivered heat during operation	Average power during operation
	(min)	(kWh)	(kWh)	(˚C)	(˚C)	(l/h)	(kW)	(W)
	Sum	Sum	Sum	Average	Average	Average		Average
Heat Pump, total	X		X				X	X
Compressor	X		X					X
Warm heat transfer medium circuit		X		X	X	X	X	
Cold heat transfer medium circuit (brine)		X		X	X	X	X	
Space heating circuit		X		X	X	X	X	
Domestic hot water circuit		X		X	X	X	X	
Supplementary heater			X					X
Measurement equipment			X					X
Pump, space heating circuit			X					X
Pump, warm heat transfer medium circuit			X					X
Pump, cold heat transfer medium circuit (brine)			X					X

For air to water heat pumps included in the study many of the measured parameters are the same. The data related to the cold heat transfer medium are replaced with data regarding fans in the outdoor unit. Additional the outdoor temperature and the humidity are measured for air to water heat pumps whereas it is not for the brine to water heat pumps.

Table 2. Measured parameters for air to water heat pumps in the Fraunhofer study.

	Running time	Energy content	Energy consumption	Inlet temp.	Outlet temp.	Volume flow	Delivered heat during operation	Average power during operation
	(min)	(kWh)	(kWh)	(˚C)	(˚C)	(l/h)	(kW)	(W)
	Sum	Sum	Sum	Average	Average	Average		Average
Heat Pump, total	X		X				X	X
Compressor	X		X					X
Warm heat transfer medium circuit		X		X	X	X	X	
Space heating circuit		X		X	X	X	X	
Domestic hot water circuit		X		X	X	X	X	
Supplementary heater			X					X
Measurement equipment			X					X
Pump, space heating circuit			X					X
Pump, warm heat transfer medium circuit			X					X
Fan			X					X

3.1.1.2 System boundaries

The system overview below shows the placement of the measurement equipment. The figure shows a general system, the real systems are many times more complicated and will not fit into the general description. In these cases additional meters are installed in order to be able to monitoring the system in a good way.

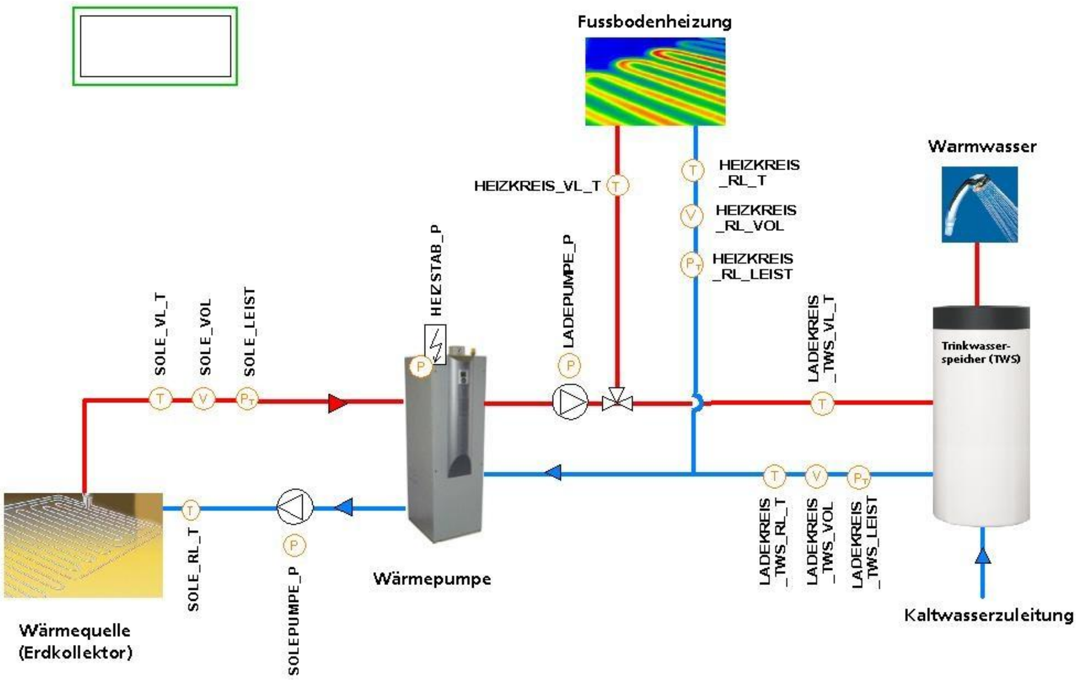


Figure 2. System overview, placement of measurement equipment.

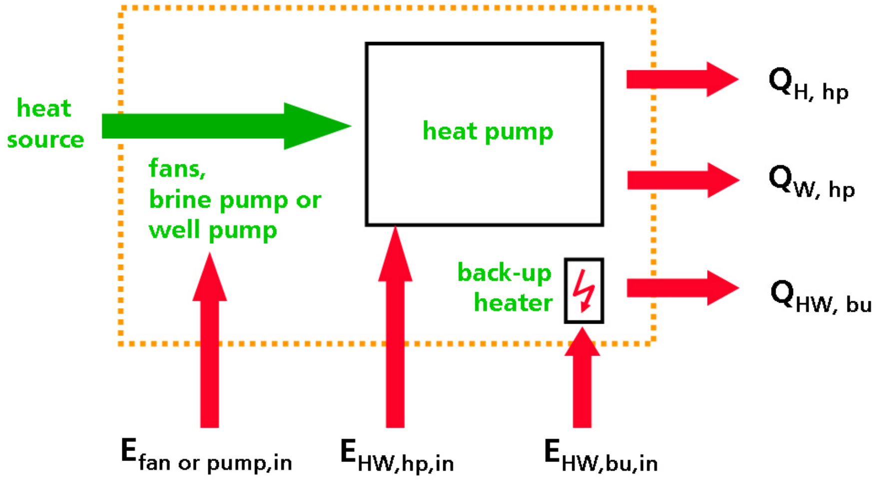


Figure 3. Schematic overview of used and delivered energy**.**

3.1.1.3 Sampling interval

The data are collected automatically and stored every minute. The stored data are remotely accessible by a GSM modem and transferred to the Fraunhofer Institute, followed by an automatic saving and sorting of the data. An automatic test of plausibility is also done, using specially made software.

The data used in this SPF project are presented as daily averages.

3.1.1.4 Measurement equipment

The meters are generally located at both the source and the heat side. For systems equipped with buffer tanks, the meters are installed before the tanks if possible. The meters are installed as close to the heat pump as possible but after the split of warm hot water transfer hot water into space heating and domestic water circuits. This in order to be able to measure energy amounts used for both space heating and domestic water separately.

Ultrasonic heat measuring device combined with data loggers are used to measure the produced heat. Temperatures, volume flows, amount of accumulated heat, electricity consumption of pumps and other equipment are measured by means data loggers.

3.1.1.5 Measurement uncertainty

No information about measurement uncertainty was provided in the Fraunhofer studies.

3.2 Measurement of ground source heat pumps

In 2003-2004 SP made a field measurements including five ground source heat pumps located in the Boras area. The study named “Årsmätningar av fem bergvärmeanläggningar i Sjuhärad” [6]. The measurements were performed from November 2003 to November 2004.

3.2.1 Measured parameters

The following parameters are measured:

- Thermal heat content, space heating
- Thermal heat content, tapped sanitary hot water
- Electricity consumption, total heat pump
- Electricity consumption, supplementary heater

- Indoor temperature
- Outdoor temperature
- Brine temperature, inlet (3 of 5 units)
- Brine temperature, outlet (3 of 5 units)
- Compressor, running time

Heat meters were installed between the space heating system and the heat pump, the same was done for the tapped sanitary hot water. Thereby internal heat losses were not measured. The meters was installed as close to the heat pump as possible in order to minimize the influence of these losses.

The electricity consumption of the supplementary heater was measured indirectly by measuring the running time and the instantaneous power for each efficiency step.

The indoor and outdoor temperatures were logged continuously. The indoor meter was placed centrally in the building with no influence of sunshine or other sources of interference. The outdoor meter was placed on the north or northeast façade.

3.2.1.1 Sampling interval

Table 3. Measured parameters and sampling interval

Thermal heat content, space heating	Once per week
Thermal heat content, tapped sanitary hot water	Once per week
Electricity consumption, total heat pump	Once per week
Electricity consumption, supplementary heater	Once per week
Indoor temperature	Every 20 minutes
Outdoor temperature	Every 20 minutes
Brine temperature, inlet (3 of 5 units)	Every 10 minutes
Brine temperature, outlet (3 of 5 units)	Every 10 minutes
Compressor, running time	Once per week

3.2.1.2 Measurement equipment

The measurement equipment used is listed in **Fel! Hittar inte referenskälla.**. The equipment used for measuring the brine temperature is not specified.

Table 4. Measurement equipment

Electrical energy	ABB Deltameter CBB 211700
Running time	Paladin
Electrical power	Siemens B4301
Heat meter	Siemens Ultraheat 2WR5151
Indoor temperature	Easy Log 24 RFT
Outdoor temperature	Easy Log 40 KH
Brine temperature	Not specified

3.2.1.3 Measurement uncertainty

No information about measurement uncertainty in the report.

3.3 Field measurement of air-to-air heat pumps

From March 2008 to February 2009 SP Technical Research Institute of Sweden made a field measurement of five air-to-air heat pumps in the Borås area. The results from the measurements are presented in SP report 2009:26 “Fältmätning av Luft/Luft värmepumpar I svenska småhus”. [7]

Electricity consumption and temperatures was logged continually and five performance tests were made during the year. The performance tests were planned to be made at different outdoor temperatures. Two test during spring and autumn and one during the winter. But due to the mild winter and divergence between the weather forecast and the actual weather conditions at the test site the planed dissemination was not reached. The performance test follows SP method no. 1721 [11].

3.3.1.1 Measured parameters

The following parameters are measured and logged continually:

- Electricity consumption, total to the building
- Electricity consumption, heat pump
- Electricity consumption, supplementary heat
- Indoor temperatures in tree rooms
- Outdoor temperatures
- Outdoor humidity

The following parameters are measured during the performance test due to SP method no. 1721:

- Airflow from indoor unit
- Air temperature before the indoor unit
- Air temperature after the indoor unit
- Electrical power, heat pump
- Air pressure

Figure 4. Measurement equipment due to SP Method no. 1721

3.3.1.2 Sampling interval

Table 5. Measured parameters and sampling interval

Electricity consumption, total to the building	
Electricity consumption, heat pump	Every 5 minutes
Electricity consumption, supplementary heat	Every 5 minutes
Indoor temperature	Every 20 minutes
Outdoor temperature	Every 20 minutes
Thermal heat content, space heating	5 measurements
Electricity consumption, heat pump	5 measurements

3.3.1.3 Measurement equipment

Table 6. Measurement equipment

Electricity consumption	ABB Deltameter CBB 211700
Logger pulse	Easy Log 40 IMP
Logger air temperature and humidity	Easy Log 24 RTF
Logger outdoor temperature	Easy Log 40 KH
Flow meter, air	VEAB
Air pressure meter	Testo 511
Temperature meters	PT100
Pressure meter	
Data logger	
Meter electrical power	

3.3.1.4 Measurement uncertainty

If the demands stated in SP method no. 1721 is fulfilled the Coefficient of performance (COP) can be calculated with an uncertainty lower than ±10%. The yearly delivered heat from the heat pump can be calculated with an uncertainty of ±20%.

The results presented follow the standard SP 1721. The capacity of the heat pump is measured during stable conditions and is not including any defrost cycle. Thereby the results for the SPF are based on data from the heat pump running at stable conditions, which will lead to an overestimation of the SPF. For COP calculations uncertainty will be smaller, since the output of heat is more or less proportional to the electricity consumption.

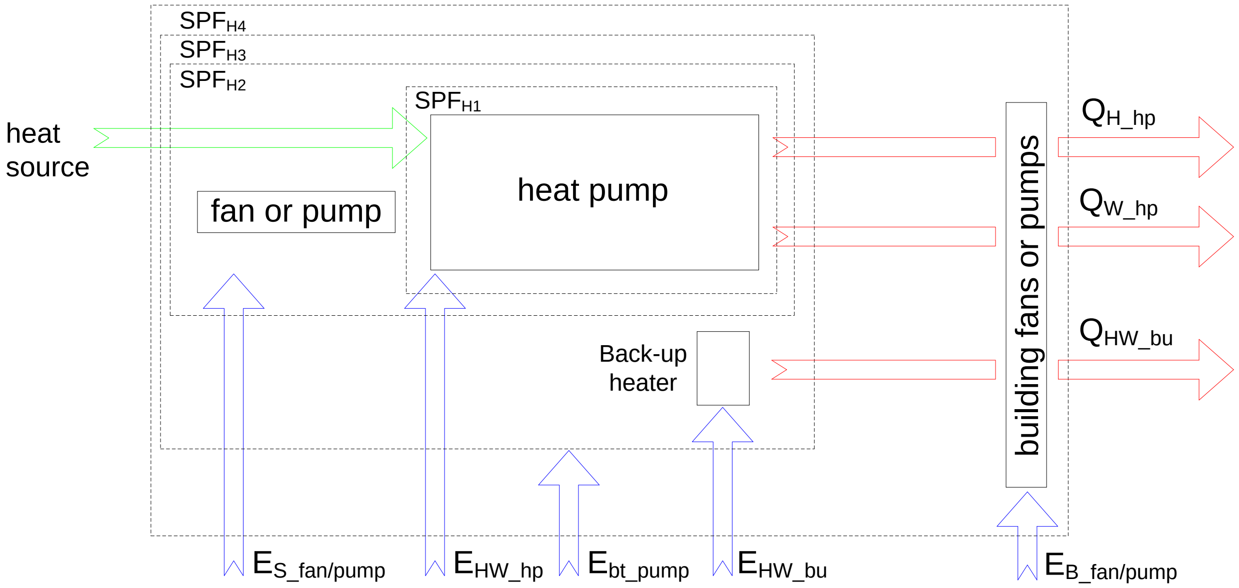
During the field measurements the conditions under a whole cycle was measured for internal use. But due to problems to have equivalent measurement conditions at all test sites it was decided to not include this information in the report.

4 Minimum required measured parameters in field measurements

The SPF-value can be calculated for different levels of the heating system. The level is described by defined system boundaries. This project relates to four different system boundaries developed in the SEPEMO EU project. The system boundaries are more detailed described in section 8.4.

The system boundaries are named SPF_1-SPF_4, each number describing its own system boundary. Different system boundaries mean different requirements of data to be measured. Before performing field measurements it must be clear what SPF level that is to be measured.

The figure below shows the different system boundaries developed in SEPEMO. SPF_1 includes SPF for the heat pump itself *only*. SPF_2 also includes heat source pumps and fans, the equipment to make the heat source available for the heat pump. SPF_3 also includes auxiliary heating, back up heating. SPF_4 includes heat sink equipment like fans or liquid pumps, to make the heat available in the house.



The required measurements differ between different types of heat pumps. The required measurements related to each type of heat pump is shown in Table 7.

Table 7. Minimum results for different heat pump types.

		A/W	DX/W	B/W	W/W	A/A
Electric energy input - total	kWh	x	x	x	x	x
Electric energy input backup heater	kWh	x	x	x	x	x
Electric energy input pumps/fans heat source side	kWh	x	x	x	x	
Electric energy input pumps/fans heat sink side	kWh	x	x	x	x	
Energy output heating / cooling	kWh	x	x	x	x	x
Energy output DHW	kWh	x	x	x	x	optional
SPF according the system boundaries	-	x	x	x	x	x
Average supply temperature heat sink*	°C	x	x	x	x	x
Average return temperature heat sink*	°C	x	x	x	x	x
Average supply temperature DHW*	°C	x	x	x	x	Optional
Average return temperature DHW*	°C	x	x	x	x	Optional
Average supply temperature heat source*, 1	°C			x	x	
Average return temperature heat source* , 1	°C			x	x	
Average outdoor temperature*	°C	x	x	x	x	x
Average indoor temperature*	°C	x	x	x	x	x
Outdoor humidity	%	x				x

*During heating season (operating season). 1Ground temperature should me measured in direct expansion systems

The performance of air to air heat pumps is measured according to SP method 1721. This method is more detailed explained in section 5.2. The boundary condition that is used in this method differs from the boundaries stated in the figure above. This method includes separate measurements of the auxiliary heater and the total electrical input to the heat pump, the fans in the indoor and outdoor unit included. For an air to air heat pump the auxiliary heating is not a part of the heat pump system, but a part of the building that is to be heated. The energy used for auxiliary heating should be measured in order to be able to calculate the energy cover ratio from the heat pump. The DHW production is also outside the heat pump system regarding air to air heat pumps. These parameters are optional to measure, but are interesting for information purposes.

4.1 Minimum results for the different SPF levels

The minimum result from the measurements according to each SPF level is stated in Table 8 below. Some parameters are necessary to measure in order to get data for the SPF equations, while some parameters are necessary to measure in order to understand the operating conditions for the heat pump and to be able to read and compare the results from different systems. The energy output can be measured either by using an energy meter or by measuring the supply and return temperatures together with the liquid flow.

Table 8. Required measurements for meeting the SPF levels according to SEPEMO.

		SPF_{H1}	SPF_{H2}	SPF_{H3}	SPF_{H4}
electric energy input heat sink auxiliary	kWh	-	-	-	x
electric energy input backup heater	kWh	-	-	x	x
electric energy input heat source auxiliary	kWh	-	x	x	x
electric energy input - total	kWh	x	x	x	x
energy output heat	kWh	x	x	x	x
energy output DHW	kWh	x	x	x	x
supply temperature (heat sink)	°C	x	x	x	x
return temperature (heat sink)	°C	x	x	x	x
supply temperature (heat source)	°C	x	x	x	x
return temperature (heat source)	°C	x	x	x	x
outdoor temperature	°C	x	x	x	x
outdoor humidity	%	x	x	x	x
indoor temperature	°C	x	x	x	x

4.2 Additional measurements

There are also parameters that can be measured that are not necessary for the calculation of SPF, but can be usable for other purposes, for example in an energy balance over the heat pump system or for information purposes. The storage losses of the storage tank can also be calculated by using extra measurements. Examples of extra measuring points are displayed in Table 9 below.

Table 9. Optional measurements

		SPF_{H1}	SPF_{H2}	SPF_{H3}	SPF_{H4}
energy output heat source	kWh	x	x	x	x
energy output into DHW storage	kWh	x	x	x	x
pressure difference, heat source	Pa	x	x	x	x
pressure difference, heat sink	Pa	x	x	x	x

4.3 Data acquisition system

The data must be recorded with a system that interfaces the sensors to a data acquisition system that can handle the necessary number of inputs from the entire sensor set.

5 Studied methods for field measurement

The relevant methods for field measurements that are studied in this project are three Nordtest methods (NT VVS) and one SP method:

- Large heat pumps - Field testing and presentation of performance (NT-VVS076)
- Refrigeration and heat pump equipment - General conditions regarding field testing and presentation of performance (NT-VVS115)
- Refrigeration and heat pump equipment - Check-ups and performance data inferred from measurements in the refrigerant system (NT-VVS116)
- Prestandaprovning av luft/luft värmepumpar i fält (SP metod nr 1721)

5.1 NT VVS methods

The NT VVS methods intend to cover the need of capacity- and functional controls and measurements for heat pumps in field applications in four different levels.
The methods states recommendations of how the measurements of temperature, flowrates, pressures and pressures differences shall be performed. In appendix estimations of measured uncertainties are given for all measured quantities with examples. The stated uncertainties for measurement given are:

- Level 1 < 5% capacity measurement
- Level 2 < 10% capacity measurement
- Level 3 < 15% capacity control

Table 10. Example of maximum permissible deviation from the mean value. Taken from the NT VVS 115-method.

Temperature, flowrate	maximum permissible deviation from the mean value (±)	
	Level 1	Level 2 and 3
Temperature of heat transfer medium, cold side	0.5 K	1 K
Flowrate of heat transfer medium, cold side	5%	10%
Temperature of heat transfer medium, hot side	1 K	2 K
Flowrate of heat transfer medium, hot side	5%	10%

The system boundaries are specified in each method. The measurements can either be carried out for the single heat pump or for the larger system, the plant.

Method NT-VVS 076 recommends that operating conditions are those for which the heat pump performance data has been guaranteed. NT-VVS 115 and NT-VVS 116 do not have recommendations. The thermal power output is decided by measuring the flow rate and temperature rise of the hot side heat transfer medium. Thermal power input is determined by measuring the flow rate and the temperature drop of the cold side heat transfer medium. Heat meters can be used. In method 116 also refrigeration condensing and evaporating pressures and temperatures are measured.

If possible the plant/ heat pump must have operated under stable conditions, within the limits of stated maximum deviations, for at least 30 minutes before the measurements starts. The measurement period is at least 30 minutes and readings are taken at a maximum interval of 3 minutes.

If the heat pump operates during defrost conditions the measurements shall be carried out with defrosted heat exchanger surfaces, during the most stable 30 minute period possible. The performance test in NT-VVS 115 and NT-VVS 116 is carried out when the heat pump has attained regular frosting-defrosting sequence starting at least 10 minutes after a terminated defrost cycle. In method NT-VVS 076, the defrosting function is checked concerning its influence on heat pump performance during one complete frosting- and defrosting cycle.

Measuring instruments must have a certificate of calibration traceable to a national or international primary standard that is not older than 1 year at the moment of testing.

Equations for calculating COP and SPF are given. The SPF equations include also any supplementary heating and states that standby losses must be concerned.

5.2 SP method nr 1721

SP method nr 1721 is a field measurement method for field testing of electrically driven air to air heat pumps in heating or cooling mode. The method includes heating capacity, electric power input and coefficient of performance. Instructions of how the measurements shall be performed are stated. If the test is conducted in accordance with the measuring requirements of the method, the coefficient of performance can be determined with an uncertainty of measurement lower than 10%. The method is validated in a combination of laboratory and field measurements.

The system boundaries are specified in the method. The measurements can either be carried out for the single heat pump, the heat pump system or for the entire heat system, see Figure 5.

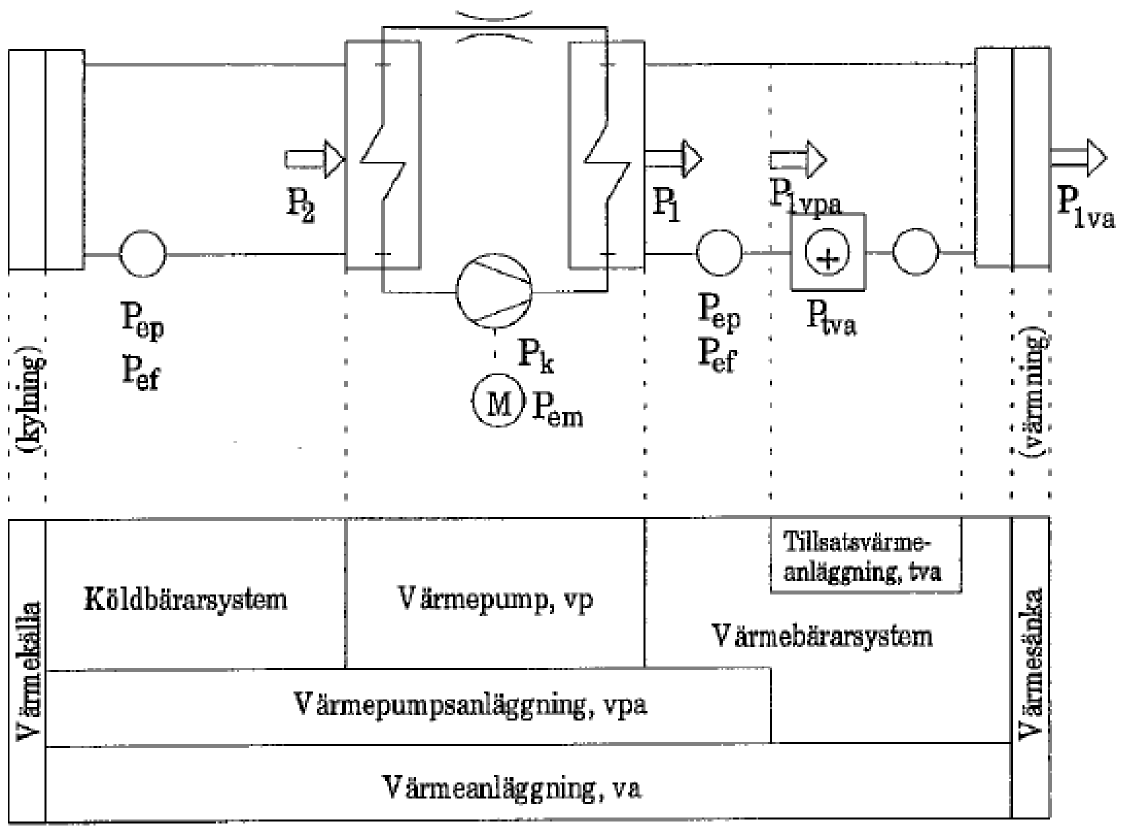


Figure 5. The figure shows the boundaries of the system for measuring the heat factors.

No examples or recommendations of operating points for the tests are stated in this method.

The total electricity consumption during the test is measured by attaching an electrical power meter or an integrated electrical energy meter to the supply cable of the heat pump.

The emitted heat effect is decided by measurements in the circulation flow. A volume- or a mass flow meter (installed according to the manufacturer's instructions) is used to measure the air flows in the heat transfer medium circuit. To minimize effects at the air flow, the meter is not allowed to affect the static pressure at the outflow of the heat pump more than ±3Pa. Therefore it is often necessary to include an extra fan.

The temperatures that shall be measured are: incoming cooling medium temperature, incoming heating medium and leaving heat transfer medium temperature. The temperature of the incoming cooling medium is measured by one sensor placed in the centre of the air intake. The temperature of the incoming heating medium is measured by at least four temperature sensors evenly spread over the air intake. The variation between the highest and lowest temperature indication shall be lower than 1 K. The temperature of the leaving heat transfer medium circuit is measured by at least four sensors evenly spread out at a point where the air is mixed. The mixing device is not allowed to affect the static pressure of the outflow of the heat pump more than ±3Pa, whereupon it is often necessary to include an extra fan. Heat exchange between the mixing device and the surroundings shall be taken into account. The variation between the highest and lowest temperature indication shall be lower than 1 K.

The data collection starts when "the plant" has operated at least five minutes at steady state conditions, within the required permissible deviations, see Table 11. The stability is controlled by continuous measuring at intervals shorter than 1/5 of the stability period, maximum one minute interval.

Table 11. Required permissible deviations for data collection in SP Method 1721.

Temperature, flow	Maximum permissible deviations from mean value
t_{vbin}	± 1K
t_{vbut}	± 1 K
q_{vvb}, q_{mvb}	± 5%

The sampling period shall be at least 10 minutes and the collection of data shall be either continuous register or measuring by intervals more frequent than 1/5 of the measuring period (<2min). The operation shall be stable also during the measurement period.

When the heat pump operates during conditions where frosting occurs, the capacity test is performed after a defrost period at the most stable 10-minutes period possible (at least five minutes after the defrost period).

6 Studied methods for calculation of SPF

The matrix below (Table 12) is a summary of the most important standards studied in the project. It is divided into different categories trying to sort out the content of the different standards. All AHRI standards mentioned above refers to ASHRAE standard 37 for the description the test method and requirements for testing. The purpose of the AHRI standards is to provide test and rating requirements, requirements for operating and the like for different kinds of heat pumps. The standards EN 255-3, prEN 255-3, TS14825 and prEN14825 all refers to the standard EN 14511 for requirements to fulfil the test method. For data input to the calculations of the calculation method EuP Lot 10 and to some extent EuP Lot 1 and EN15316-4-2, one is referred to the test results from standard EN 14511.

The first category "type of standard" shows whether the standard describes a test method for laboratory tests, for field tests and if it includes a calculation model for the calculation of seasonal performance factor.

The second category "type of heat pump" describes what kind of heat pumps that is included in the standard or test method.
The third category "Operation" describes the type of operation that is treated by the standard. The different types of operation can be heating mode, cooling mode or production of domestic hot water. The column called "combined operating" refers to the simultaneous production of heating and/or cooling and the production of domestic hot water. The last column within this category "part load conditions" shows if the standard includes the operation of the heat pump in part load.

The intention of the fourth category "requirements" is to show whether the standard has any requirements of testing to reach accurate test results. Typical requirements could be that steady state has to be reached before the measurements are performed, requirements of maximum deviations from the stated measurements and a largest permissible uncertainty of measurements of the tests. The last column within this category shows whether the standard gives any recommendations of how the measurements shall be performed, such as the placement of sensors.

Table 12. Matrix of existing methods for testing and measurement and evaluation of SPF for heat pumps.

	Type of standard			Type of heat pump			Operation					Requirements				Aspects in capacity calculations					Calculations of	
	Laboratory tests	Field tests	Calculation model for SPF	ASHP	GSHP/WSHP*	AIR/AIR	Heating	Cooling	Domestic hot water	Combined operating	Part load conditions	Steady state	Permissible deviations	Uncertainty of measurements	Test set up/ performance of measurement	Pumps and fans included	Defrost period	Standby losses	On/off cycles capacity regulation	Other	COP/EER	SPF/SEER
NT VVS 076				x	x	x	x	x			x	x	x	x	x						x	x
NT VVS 115				x	x	x	x	x			x	x	x	x	x						x	x
NT VVS 116				x	x	x	x	x				Δ	Δ	x	x						x	
SP 1721						x	x	x				x	x	x	x						x	
ASHRAE standard 37	x			x	x	x	x	x				x	x	x	x		x			x		
AHRI 210/240	x					x	x	x			x	x	x	Δ	x				x		x	x
AHRI 870-2005	x				x		x	x			x	Δ	Δ	Δ	Δ						x	
AHRI 390-2003	x					x	x	x			x	Δ	Δ	Δ	Δ		x				x	
AHRI 320-1998	x				x*		x	x			x	Δ	Δ	Δ	Δ						x	
AHRI 325-1998	x				x		x	x			x	Δ	Δ	Δ	Δ	x					x	
AHRI 330-1998	x				x		x	x			x	Δ	Δ	Δ	Δ	x					x	
EN14511	x			x	x	x	x	x				x	x	x	x	x	x					
prEN14511	x			x	x	x	x	x				x	x	x	x	x	x					
EN 255-3	x			x	x				x			x	x	x	x	x	x	x			x	
prEN 255-3	x			x	x				x			Δ	Δ	Δ	Δ	x	x	x			x	
TS14825	x			x	x	x	x	x			x	Δ	Δ	Δ	Δ	x	x		x		x	
prEN14825	x		x	x	x	x	x	x			x	Δ	Δ	Δ	Δ	x	x		x		x	x
EN15316-4-2			x	x	x	x	x		x	x	x	α	α	α	α	α	α	α	x	α		x
EuP Lot 1	x		x	x	x		x				x	x	x	x	x	x	?		x		x	x
EuP Lot 10	x		x			x	x	x		x	x	Δ	Δ	Δ	Δ	x	x		x		x	x

The sign "Δ" means that the standard refers to another standard where the requirements are fulfilled.

The sign "α" means that the method is a calculation method that does not include requirements from a specified test method.

The fifth category "Aspects in capacity calculations" describes aspects that are taken into account in the capacity calculations. It describes whether liquid pumps and fans are included in the effective power absorbed by the unit. The "Defrost period" column describes whether the defrost periods are taken into account when measuring and calculating the capacity of the heat pump. The "standby losses" column means that standby losses are measured and taken into account when calculating the capacity of the heat pump. The NT-VVS 076 and NT-VVS 115 both mention that it is necessary to take standby losses into account when calculating the SPF, but there is no method of how to measure the losses. Both the standards for measuring the production of domestic hot water EN 255-3 and prEN 255-3 states methods of how to measure the standby losses, but the way of taking the standby losses into account when calculating the COP differs a lot between the standards. "On/off cycles and capacity regulation" shows whether the standard treats what kind of capacity regulation that is used by the heat pump. The last column "other" shows whether there are other important aspects apart from the earlier mentioned ones, which are taken into account in the capacity calculations. It shows that for some of the methods mentioned in the standard ASHRAE 37 adjustments of the line loss capacity and duct losses are made.

The last category "calculations of" describes the calculated outcome of the standard. The NT VVS standards provide simple equations of how to calculate SPF without a calculation model.

6.1 Other methods including calculation models

Besides the models mentioned above there are several other standards and models that can be used in order to find an appropriate model to calculate a seasonal performance factor. The ones studied in this project are shortly summarized in this chapter.

EN 15316-2-3 Heating systems in buildings – Method for calculation of system energy requirement and system efficiencies – Part 2-3: Space heating distribution systems
This method calculates the system thermal losses and the auxiliary energy demand of water based distribution system for heating circuits (primary and secondary), as well as the recoverable system thermal losses and the recoverable auxiliary energy. The calculations are related to a design effect and design heat load of the accounted zone (EN 12831). Correction factors are provided for a number of different conditions, these conditions can for example be corrections for the size of the building, for systems without outdoor temperature compensation, efficiency and part load. The method can be applied for any time step (hour, day, month or year).

EN 13790:2008, Energy performance of buildings – Calculation of energy use for space heating and cooling (ISO 13790:2008)
This standard provides a calculation method for the assessment of the annual energy use of buildings. Factors that are taken into account are for example the heat transfer by transmission and ventilation of the building when heated or cooled to constant internal temperature, contribution of internal and solar heat gains to the building energy balance and the annual energy use for heating and cooling.
There are two different main methods that are used by the standard, one where the heat balance is calculated during a sufficiently long time (one month or a season) and dynamic effects of the building are taken into account by an empirically determined gain and/or

loss utilization factor and one method where the heat balance is calculated over small time steps (typically one hour) and the heat stored in, and released from, the mass of the building is taken into account.

EN 12831 Heating systems in buildings – Method for calculation of the design heat load
This standard is used to calculate the design heat losses of a heated space; the result is then used to determine the design heat load at standard design conditions. The temperature distribution (air and design temperature) is assumed to be uniform. The climatic data that is used for the calculations are the external design temperature and the annual mean external temperature.

Factors taken into account are for example size of the building, type of building, activities inside the building, type of room, interior, building envelope and ventilation.

A number of standards/methods for the calculation of seasonal performance factor are investigated. Some of the methods only contain a calculation model while some of them also contain instructions of how to test the heat pumps. The calculation models that are studied in this project are prEN14825:2009 draft Nov 09, EN 15316-4-2:2008, EUP LOT 1 and EUP Lot 10.

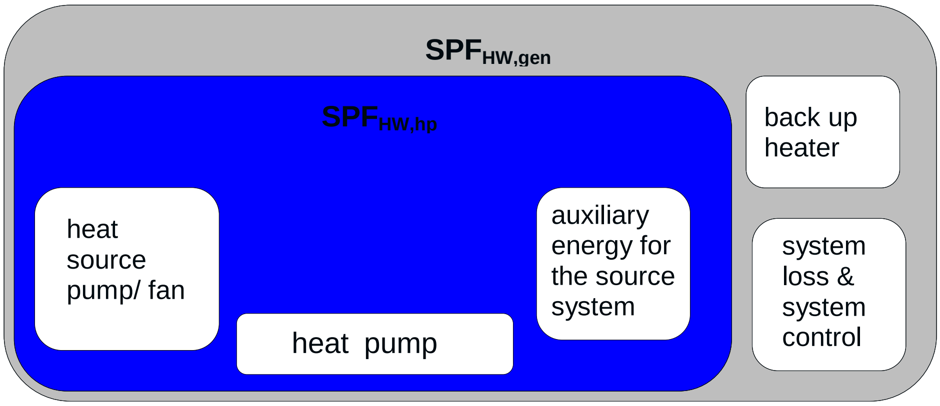
6.2 EN 15316-4-2:2008

Heating systems in buildings – method for calculation of system energy requirements and system efficiencies – Part 4-2: space heating generation systems, heat pump systems

15316-4-2 is a calculation model for the calculation of system energy requirements and system efficiencies. Input product data for the calculations, like heating capacity and COP are determined according to European or national test standards. The method treats calculations for space heating, production of sanitary hot water and combined operation of space heating and sanitary hot water production in either simultaneous or alternating operation. Presently there is no European standard for testing DHW production and space heating simultaneously; therefore a national standard shall be used instead. As an example in this standard calculations based on testing of a DHW cycle performed according to EN 255-3 during heating operation are done, see Annex D in EN 15316-4-2:2008.

System boundaries
The method takes into account different physical factors that can have impact on the SPF and required energy input. For example type of generator, type of heat pump, variation of heat source and sink temperature, effects of compressor working in part load (on-off, stepwise, variable speed units), and system thermal losses.

Losses due to ON/OFF cycling are considered small and negligible unless part load testing data or national values are available. If part load data is not available the stand-by auxiliary energy is considered enough for the degradation of COP in part load operation.



Input to the calculations
Two performance calculation methods for the generation subsystem are described corresponding to different applications (simplified or detailed estimation). The differences between the two methods are the required input data; the operating conditions taken into account and the calculation periods.

The simplified method
The considered calculation period is the heating season and the performance data is taken from tabulated values for fixed performance classes of the heat pump. Operating conditions are taken from typology of implementation characteristics, which means that they are not case specific. This method is in particular suitable when limited information of the generation subsystem exists.

The detailed method
This method is a temperature bin method where the specific operating conditions of each individual heat pump can be considered. The bins describe frequency of the outdoor temperature and the calculations are carried out with operating conditions for the heat pump that corresponds to the heat energy requirement of the space at each bin. The operating conditions of the bins are characterized by an operating point in the centre of each bin and in the calculations it is assumed that this point represents the operating conditions of the whole bin. The standard contains one example of climate; it represents the climate of Gelterkinden in Switzerland and span from -11°C-35°C with a resolution of one bin per K. Appendix A in EN 15316-4-2:2008 shows how to calculate bins using meteorological data for the actual spot. There are examples in the standard that uses only four bins, but with lower resolution, see figure 4 in EN 15316-4-2:2008. There are some criteria when choosing the bin resolution. The bins has to be evenly spread out over the operating range, operating points should be chosen at, or close to test points and the number of bins shall reflect the changes in heat source and sink temperatures. COP values and heat capacity can be interpolated from tested values to fit the bins.

The heat energy requirement of the distribution subsystem can be evaluated if the heat load for space heating and domestic hot water is known. The heat load for space heating is calculated based on cumulated heating degree hours which are defined by the difference between the outdoor air temperature and the indoor design temperature at the different bins. Analogously the DHW load depicted as constant daily profile can be cumulated.

Back up heaters can be accounted for, both for space heating and for sanitary hot water production. If no information about electrical back up heaters is given, an efficiency of 95% is used.

Input data for calculation with the bin method according to chapter 5.3.2 requires indoor design temperature, heat energy requirement of the space heating distribution subsystem according to EN 15316-2-3, type and controller setting of the heat emission system heat pump characteristics for heating capacity and COP according to test standards, results for part load operation according to prEN 14825, system configuration like back up heater calculated according to 15316-4-1 and installed heating buffer storage, power of auxiliary components (pumps etc.). It also requires input data for the DHW-production for example heat energy requirement of the distribution subsystem according to EN 15316-3-2 etc.

Output from the model
Two different seasonal performance factors can be calculated by using this model.

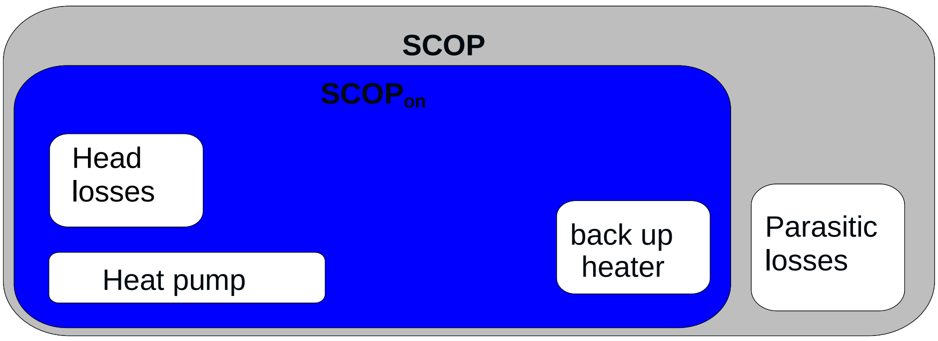
$SPF_{HW, gen}$ is the total seasonal performance factor of the generation subsystem. It includes the heat pump in space heating mode and production of sanitary hot water, the backup heater, the space heating distribution system and auxiliary energy.

$SPF_{HW, hp}$ is the seasonal performance factor of the heat pump with regard to the heat produced by the heat pump. It includes the heat pump in space heating mode and production of sanitary hot water, the auxiliary energy input for the source system and the auxiliary energy for the heat pump in standby mode.

6.3 Ecodesign LOT 10

LOT 10 applies to “residential room conditioning” appliances (air conditioners and ventilation) with cooling power ≤12kW. It describes a calculation model for calculating the seasonal energy efficiency for operating in heating or cooling mode. This model will probably be replaced by prEN14825 within shortly.

System limits
The model can be used to calculate the seasonal performance factor for an air/air heat pump. The model does not include any losses from the house. To complete the heat demand of the building a backup heater with COP that equals to 1 is accounted for.



Input to the calculations
To use the calculation model provided by the excel sheet the load profile of the building, P*designh* has to be selected. There are nine different sizes to chose between from size 3XS to XXL that spans from 1.1 kW to 19.2 kW. The function of the heat pump is set to either “heat only” or “heat and cool” and the type of heat pump is set to “split” or “multi-split”.

The model is a bin method with three different climates for the heating season and one for the cooling season. A table declares the number of bin hours occurring at each bin temperature, T_j, for each specific climate. The lowest temperature for each climate respectively is declared the design temperature, T_{design}. The part load ratio (of the building), pl_j, is calculated from the equation below:

$$Pl_j = \frac{(T_j - 16)}{(T_{design} - 16)}$$

The reference annual heating demand, Q_{HE} is decided in kWh for each climate as a product of P*designh* and the number of full load heating hours that corresponds to each climate.
Load fractions fracA, fracC and fracW indicate the fraction of the total heating demand (load) occurring in a specific bin at a specific climate. The fractions are given by:

$$frac_j = \frac{n_j * pl_j}{\sum_{j=1}^{40} n_j * pl_j}$$

Input to the calculations is the COP and capacity of the heat pump at four-five different temperature levels +12°C, +7°C, +2°C, -7°C and -15°C(-15°C is only required for the colder climate). The heat pump should be tested at part load to deliver the required heat load of the building at each temperature level. At this point the paper version is not consistent. In one way it says that the capacity of the heat pump at each bin shall complete the energy demand of the building at the part load declared by the product of the annual reference heating demand, Q_{He}, and $frac_j$, but in one way it says that the energy demand is declared by the product of the part load ratio, Pl_j, and P*design.* However the excel sheet uses the first alternative and therefore care should be taken when deciding the operating points (the required effect at each temperature bin) for testing the heat pump. This alternative does not provide any effect balances. Since one house is chosen for the calculations the required effect at each outdoor temperature should be the same among the climates, but this is not the case.

In cases where the heating power supplied by the heat pump is not enough to cover the energy demand of the building in a specific bin, the difference is filled up by a backup heater with a declared capacity of COP=1. Deciding the part load from the product of Q_{He}, and $frac_j$, might result in an underestimated effect demand and therefore underestimate the required backup heating.

Instructions of how the heat pump shall be tested are given in the method for each type of operation respectively; fixed capacity units, staged capacity units and variable speed capacity units.

A degradation factor Cd, which is the efficiency loss per kW of output power when cycling the heat pump, is decided from a specific cycling test.

The energy consumption for the heat pump when operating in thermostat off mode, off mode and crankcase heater mode is decided in tests, but is only required for the calculation of SCOP.

The turndown ratio for heating, which is the lowest steady state over the maximum power and the binlimit, which is the lowest operating temperature of the heat pump, is used as input to both of the SCOP calculations.

<u>Output from the model</u>
This model is used to calculate two different seasonal performance factors:

COP_{ON} is a seasonal performance factor for the heat pump that includes electricity of the backup heater. COP_{ON} is calculated by the total electricity used by the heat pump and the backup heater over the total heat demand of the building.
(LhpC_tp*COPC_tp+resC_tp)/LhsysC_tp

SCOP is a seasonal performance factor which unlike COP_{ON}, also includes the electricity consumption of auxiliary energy for the heat pump operating in thermostat off mode, off mode and crankcase heater mode.

The energy of the backup heater is included in all seasonal performance factors that results from the excel-calculation sheet.

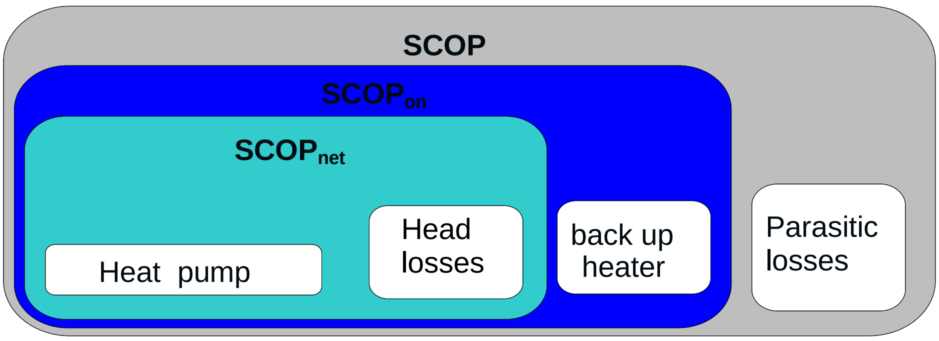
The annual electricity consumption split up in supplementary heating, heat pump operation and auxiliary heating is given from the calculations.

The annual carbon emission and label energy class is also result of the calculations.

6.4 PrEN14825

This is a standard under development that aims to cover the laboratory testing and a calculation model for SPF calculations for electric driven heat pumps. The heat pumps are tested at a number of different part load conditions (4-6) designed for heating or cooling the house to a set temperature of 16°C at different outdoor temperatures. Different test conditions are given for each type of heat pump.
This standard serves as an input for the calculation of the system energy efficiency in heating mode of specific heat pump systems in buildings, as stipulated in the standard EN15316-4-2:2008.

<u>System limits</u>
The model can be used to calculate the seasonal performance factor for air/air- ground source- and air source- heat pumps. The model does not include any losses from the house. To complete the heat demand of the building a backup heater with COP that equals to 1 is accounted for. The system boundary in SPF 4 applies. (Data is treated according to EN14511 where the effect of heat sink pumps and ventilation fans is corrected to overcome the pressure differences of the heat pump.)



<u>Input to the calculations</u>
The calculation of the seasonal performance (SPF or SEER) is performed using a temperature bin method where each bin represents one degree Celsius and the number of bin hours occurring at the corresponding temperature is given. The cooling season is represented by one climate that span from 17°C-40°C while the heating season is represented by three different climates: one colder, one average and one warmer, that

span from -30°C-15°C, see Table 29 and 30 in prEN 14825:2009 draft Nov 09. Each climate corresponds to one design temperature and one design heat load of the building.

The heating/cooling demand and the number of bin hours for the different climates are determined as templates, taking different aspects into account; the climate, type of building and building characteristics, set point and set back settings and internal gains. Those aspects also decide the number of hours in which the heat pump works in active mode, thermostat off mode, standby mode, crankcase heater mode or off mode. The electricity consumptions at the different modes are determined from tests. These effects are called the parasitic losses.

Input to the calculations is the COP and capacity of the heat pump tested at four-five different temperature levels +12°C, +7°C, +2°C, -7°C and -15°C (-15°C is only required for the colder climate). The heat pump shall be tested in equivalence with standard EN 14511:2007, with the same test methods, test set up, uncertainty of measurements and the way of evaluating data. The heat pump shall be tested at part load to deliver the required heat load of the building at each temperature level. Instructions of how the heat pump shall be tested by means of part load and type of operation; fixed capacity units, staged capacity units and variable speed capacity units, are given in this method.
The required part load for the building at the test points are given by:

$$Part\ load\ ratio = \frac{(T_j - 16)}{(T_{design} - 16)}$$

Where T_j is the outdoor (bin) temperature and T_{design} is the lower temperature limit of the selected climate.

If the declared capacities of a unit matching with the required heating/ cooling demand the corresponding COP/EER value is to be used. This may occur with staged capacity or variable speed capacity units. If the declared capacity is higher than the heating/cooling loads, the unit has to cycle on/off. Then a degradation factor (Cd (air/air or Water/air) or Cc (others)) has to be used to calculate the corresponding COP/EER values. Cd and Cc can be determined by testing; else a default value of 0.25 and 0.9 respectively is used.

The bivalent temperature, which is the lowest temperature when the heat pump can deliver 100% of the heat demand of the building, is necessary to use the excel sheet. The design heat demand of the building is a consequence of the stated bivalent temperature. The reference annual heating demand, kWh/a, is given by the product of the full load in heating P_{design} and the equivalent number of heating hours.

The operation limit of the heat pump is set to the lower temperature limit for which the heat pump can operate.

<u>Output from the model</u>
With above input the excel sheet gives two different SCOP: $SCOP_{NET}$ and $SCOP_{ON}$. $SCOP_{NET}$ is the seasonal performance factor for the heat pump, while $SCOP_{ON}$ also includes the electricity and heat delivered to the building from a backup heater.
The paper version of the standard also calculates a seasonal performance factor, SCOP that includes the parasitic losses of the heat pump. The effect from each operational mode is tested according to the standard while the corresponding operational hours for each mode respectively are found in a reference table.

6.5 EuP LOT 1 - Boiler testing and calculation method

This model is used to calculate the specific seasonal energy efficiency *etas* of a space heating boiler. The model contains possibilities to include several different types of space heating appliances in the efficiency calculations, such as boilers, heat pumps, electricity or solar systems. The types of heat pumps included in the model is air source and ground source heat pumps tested in either floor heating- or in radiator heating mode. The model only applies for space heating.

<u>System limits</u>

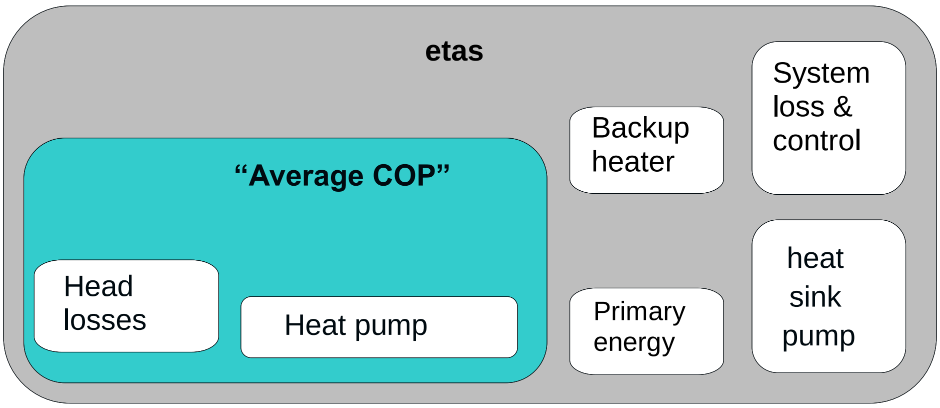
Heat pump data is taken from tests according to EN14511, therefore the head losses from heat source fans or liquid pumps are taken into account in the heat capacity and COP data. This model also includes the heat sink liquid pump.

The model takes into account the net space heating demand, Lh, of the house. The heat demand of the house is a consequence of the choice of the load profile and the so-called system losses Lsys. The size of Lsys depends on the characteristics of the boiler and the installation characteristics. The system losses include fluctuation losses, stratification losses, distribution losses, buffer losses and timer losses, which are set as a percentage that is depending on the heat demand.

The model also includes losses from control, auxiliary equipment and system buffer standing losses.

A back up heater is used to cover up the energy demand that the heat pump cannot deliver.

The electricity use in the model is accounted with the primary energy factor 2.5.



<u>Input to the calculations</u>

The test method for testing the heat pump refers to best testing practice e.g. EN 14511 (see document 7) except for some deviations. The test points are similar to the test points in EN14511:2007, but the temperatures of the return/feed temperature differs, se table IV.2 in the standard. In LOT 1 the temperature difference between T_{return} and T_{feed} gets larger the higher temperature of the T_{feed}. Only three test points are necessary to calculate the seasonal energy efficiency by using this model.

The calculation uses a temperature bin method to evaluate the seasonal energy efficiency, etas. There are three different climates to chose among, warmer (+2°C), average (-10°C) and colder (-22°C), see table I.1, LOT 10. Each bin describes the equivalent number of hours corresponding to the bin temperature with a resolution of one bin/K. Input data to the calculations can be either the test points given in this method or test points given in EN 14511.

The maximum heating capacity, Pmax, at the different climates is calculated from the heating capacity data obtained in the test. It is not possible to choose the size of the required heat load for the building, but is given by the model for each bin level based on the capacity of the heat pump. To meet the lower heat load requirements at the different bin levels, the heat pump is assumed to work in part load condition. The heat pump does not have to be tested in part load operation; instead the model uses a degradation factor, Cd, to calculate the COP when working in part load condition. Cd can either be obtained from tests or a default value, Cd=0.15, can be used.

For fixed capacity units the default is COPmin= 0.89*COP at power output Phpmin=0.5*Php.
For staged capacity units the default is COPmin= 0.975*COP at power output Phpmin=0.5*Php.
For variable capacity units the default is COPmin= COP at power output Phpmin=0.4*Php.

It is optional to choose whether the heat pump operates with night set back or not. The bin assumes constant night temperatures during night set back to +1°C, +6°C and 0°C for each climate respectively.

Other inputs to the calculations is type of heat pump, type of operation of the heat pump, type of control of the heat pump, type of heating (floor heating or radiator heating), minimum source operating temperature, the effect of auxiliary equipment and backup electricity heater.

Other possible energy sources can also be chosen, but this chapter only treats the heat pumps.

<u>Output from the calculations</u>
The model calculates the energy use and losses based upon constant fractions. The fraction of the energy use and the different losses is displayed by the model. A diagram shows the energy supply per temperature bin and how it is covered from different energy sources. The seasonal energy efficiency, etas, is calculated.

$Etas = Lh/Q_{tot}+cctrl$ *where* $Q_{tot}=Lh + L_{sys} + Q_{gen} + Q_{el}$

etas is the net space heating demand of the house over the sum of the generated heat of the system. Q_{tot} is the sum of the space heating demand (Lh), the losses from the heating system (L_{sys}), the primary energy losses of the energy input to the system (Q_{gen}) and the energy needed by the auxiliary equipment such as control and heat sink pumps (Q_{el}).

All electricity used by the heat pump and the backup heater is multiplied by a primary energy factor of 2.5. The model is not transparent. It is tricky to follow the outputs of the model since it consists from several excel-sheets and the information turns up all over. It is also difficult to understand all steps of the calculations. To be able to compare the results with field measurements and prEN14825 a value of SPF, the so called “average COP” (see the system boundaries) is calculated without the system losses. Average COP corresponds to $SCOP_{net}$ in prEN14825.

6.6 SP-method A3 528

SPA3 528 is a calculation program that is used to calculate the seasonal performance factor and energy saving over the year for houses having a defined heating requirement. It can be used for air/air heat pumps, air source heat pumps and ground source heat pumps. The heat loss from the house is defined in the program and given as the total loss factor, k-value, of the house [W/K]. The method can be used to calculate the energy requirement of a building with a k-value of either 109 W/K or 199W/K. A duration diagram of the outdoor temperature can be calculated from the mean annual temperature and together with the loss factor, the area under the duration curve gives the actual power requirement.

The heat pump is tested in accordance to EN 14511 at outdoor temperatures of -15°C, -7°C, +2°C and +7°C with an indoor temperature of +20°C. The heat pump is also tested in part load conditions according to CEN/TS 14825 at +7°C (75% and 50%) and at +2°C (50%). The lowest ambient temperature is assumed to be -15 °C and no heating is assumed to be required for ambient temperatures above +17 °C. The output data from the tests, thermal heat capacity and electrical input power, is used as input to the calculations.

7 Strengths and weaknesses with current methods

7.1 prEN14825

Strenghts

A strength of standard prEN14825 is that it includes all kinds of heat pumps (except exhaust air heat pumps). The model treats heat pumps both in heating and cooling operation. The fact that the heat pump is tested in exactly part load should result in more sufficient results compared to degradation coefficient etc. The model is foreseeable and quite easy to follow.

Weakness

The model is not completely clear with its definitions of part loads. The part load ratio for which the heat pump is to be tested is the part load energy demand of the building at the corresponding temperature bin. To perform the SPF calculations according to prEN14825 the heat pump is tested at a certain climate (A,W or C) and a certain heat load profile for the building. This means that the test data might not be suitable for another climate or another heat load.

It is also not completely transparent since it describes (ANNEX C) the reference heating/cooling demand and the number of hours in each operational mode (active mode, thermostat off mode, standby and crankcase heater mode) is decided from weighted climate, type of building, internal gains, set back setting and so on, but there is no reference that describes the calculations. Therefore it is not possible to recalculate the hours to fit specific needs. The climate hours that describes the temperature bins does not seem to be adjusted in any ways since it is the same hours that is used in Ecodesign LOT 1.

Another weakness is that the model does not include domestic hot water.

Possibility

The model could be developed so that it would be possible to decide the energy demand of the house. It could also be a possibility to fit the model to your own climate. Maybe the ground water temperature and thereby the bore hole temperature could be climate depending.
It should be obvious how interpolations or extrapolations of capacity and/or COP should be performed to avoid differences between users.

Risk

The performance of water/water heat pumps can be overestimated, especially at the cold climate, since they are only tested at +10°C at the cold side (in reality the ground water temperature can be lower than this). This can also be the case for other ground source heat pumps.

The degradation coefficient Cc might be a disadvantage for a ground source heat pump when default values are used. Cc =0.9 is a larger degradation of GSHP’s than what is shown in reality. There is a risk that the requirement of having heat pumps tested in part load might lead to extensive laboratory tests, which is costly. It is also difficult to get sufficient data from existing laboratory tests, since few heat pumps are tested in part loads.

7.2 EN 15316-4-2

Strength

This model is very wide and thorough in its content. It treats both room heating and tap water production. The model is adaptable to different climates and the resolution of the temperature bins can be chosen.

The model specifies the requirements and losses of the certain house and defines recoverable respectively unrecoverable energy.

It is not necessary to test the heat pump at the part loads, since there are default values that can be used.

The model can be used to calculate the SPF for the entire system with the building included or only for the heat pump.

Weakness

The strengths of this model could also turn out to be its weaknesses. The wideness of the model makes it complicated and twisty. There are too many aspects that are taken into account in the calculations. The standard refers to several other standards for calculations of losses and needs. The model requires large knowledge of the house.

The fact that default values can be used to calculate the operation in part load for the heat pumps can result in lower accurateness of the model.

The model does not treat operation in cooling mode.

Possibility

The model can be studied and give input to a new easier model.

Risk

There is a present danger of doing mistakes when using the model. The large amount of data that is taken into account will probably result in much estimation that will differ from case to case and will therefore result in incomparable outcome of the model. Also the same heat pump installation can probably give different results depending on the way it is calculated, (choosing method, input, accuracy and test points).

7.3 EuP LOT 1

In general, the Energy Using Products (E**u**P) Directive have broadened to include also Energy Related Products (E**r**P), but for the treatment in this report, we choose to use the term EuP, since heat pumps are energy using.

Strength

Test data from EN 14511 can be used in the calculations. The model provides default values to recalculate the test points to fit the part load of the heat pump for the different kinds of heat pumps (fixed capacity, staged capacity och variable capacity). The capacity and corresponding COP values are then interpolated between the temperature bins. However, the accurateness of the recalculation is unknown.

The model itself has suggested test points with a radiator curve (supply temperature) that is adjusted to the outdoor temperature. At colder outdoor temperatures the supply temperature is higher and at warmer outdoor temperatures the supply temperatures are lower.

The model can be used to calculate how to cover the energy need of the house by using different techniques, for example solar cells, heat pumps and fossil fuel. This is a good thought, but might not be interesting in this project (?).

Weakness
Unfortunately the model still contains bugs and technical mistakes in the equations and the way of thinking. It seems to be adjusted to boilers and bio boilers instead of heat pumps.

The model does not include a power balance, but is doing a temperature balance instead. This makes the distribution of the energy need and the required amounts of backup heat differ from the theoretical needed.

The model includes a decided fraction of heat loss that cannot be escaped from. For example if the heat pump does not use night set back a default penalty loss of 12% from the total delivered energy is subtracted. The losses from the apparatus and system operation are also decided in percentages.

At part load operation there is no change in the system flows. This does not seem right with controlled radiators. (Should the radiators be controlled or is it enough with a displacement/adjustment of the radiator curve?)

The night set back function uses the same night temperature all year around, which is not the case in reality.

It is not possible to choose the energy requirement of the house; instead the energy demand is an outcome of the capacity of the heat pump. If the heat pump is not monovalent also the fraction of backup heat is needed to decide the energy demand of the house.

GSHP's are treated unfairly when recalculating the operation data to part load operation. The ground source heat pumps are degraded by a factor 0.89 at 50 % of the delivered capacity. (The Cd factor, i.e. the on/off control, is overestimated for water borne systems)

Even though the program is transparent in the sense that all equations are reported in the model, it is very hard to understand and follow the calculations, and the program cannot be said to be transparent in the general sense. The interface of the program is not very friendly and can easily confuse the user. The model does not include tap water.

Possibility
Making the ground water and borehole temperature climate dependent might lead to results more sufficient to its actual installation spot.

Risk
The model is not adjusted to fit heat pumps and is disadvantaging heat pumps. Despite this the COP and capacity of water to water heat pumps can be overestimated since they are tested at +10°C at the cold side (this can also happen to ground source heat pumps, but probably not to the same extent).

7.4 EuP LOT 10

Strength
This model can be used both in heating and cooling mode and it has three different climates both for the cooling season and the heating season. The model has reference heating/cooling demands to choose between.

Weakness
The model takes only air to air heat pumps into account. In accordance to prEN14825 the test points for the heat pump has to be chosen specifically to fit the chosen climate and heat profile of the house.
In accordance to LOT 1 the model does not include an effect balance at each temperature bin. This results in that the heat demand of a house at a specific temperature bin is different at different climates and that the heat requirement of a backup heater is misleading.
The model does not seem to be entirely consistent, partly it is contradicting itself.

Possibility
To make the model usable at other spots it would be better to make it possible to use other climates. Now the model only provides a number of specified heat loads of the house. It would be useful to be able to freely choose the heat demand of the house. There is a risk though, that since the heat pump has to be tested in part load, it has to be tested at each specific heat requirement.

Other types of heat pumps could be included in the model. The model only provides the SPF (SCOP) with the backup heater included. For comparable reasons, it would be useful to include a SPF with backup heater excluded.

Risk
It is not obvious whether the excel model is compatible with the standard. There are also some calculations in the standard that seems to be incorrect.

8 Comparison of existing calculation methods and results from field measurements

8.1 Heat (and cooling-) demand of the house

This study is focused on heat pumps for indoor heating. The study is made in houses with different heat demand. The ground source heat pumps in this study are considered monovalent, but it is difficult to determine the actual energy demand of the house. When using the calculation models the required heat load of the house is decided by the capacity of the heat pump.

The studied air to air heat pump is not monovalent. The energy demand of the house with the heat pump installation was estimated in the field study. When using the calculation models the energy demand of the house were tried to be the same as in the field study.

8.2 Indoor climate

The indoor climate is expected to reach 20°C for all models. In the calculation models the heat pump is used to reach a temperature of 16°C. Internal gains are expected to contribute to the last temperature increase.

The actual indoor temperature has not been measured in the Fraunhofer field measurements. Thereby it is not possible to compare the real indoor temperatures with the temperatures estimated in the calculation models.

8.3 Outdoor climate

The outdoor climate follows the climate of the year. The calculation models use the same temperature climate when calculating SPF for the ground source heat pumps. The climate corresponds to a European average climate, Strasbourg, with the coldest temperature of -10°C.

The field measurements of the ground source heat pumps are carried out in Germany. The heat pumps installations used for the SPF calculations are spread over the country, from the Hamburg area in the north to Stuttgart in the south. In the calculation models the average climate is chosen as the climate mostly corresponding to the German.

The air to air heat pump installation is made in a climate that is similar to the “colder” climate. Therefore the colder climate is used in the calculation models when calculating SPF for the air to air heat pump.

8.4 Definition of SPF field measurement system boundaries

In the ongoing EU project “SEPEMO-Build (SEPEMO short)” four SPF’s with different system boundaries are defined. The definitions from the SEPEMO project have been used for calculating the SPF for the field measurements. The four defined SPF’s are:

SPF_1 includes only the heat pump unit itself. Thereby SPF_1 is identical to the average COP for the measured period.

$$SPF_{H1} = \frac{Q_{H\_hp} + Q_{W\_hp}}{E_{HW\_hp}}$$

SPF_2 consist of the heat pump unit and the equipment needed to make the heat source available the heat pump.

$$SPF_{H2} = \frac{Q_{H\_hp} + Q_{W\_hp}}{E_{S\_fan/pump} + E_{HW\_hp}}$$

SPF_3 represents the heat pump system SPF. SPF_3 includes the heat pump and the heat source pump as in SPF_2, but also the back up heater.

$$SPF_{H3} = \frac{Q_{H\_hp} + Q_{W\_hp} + Q_{HW\_bu}}{E_{S\_fan/pump} + E_{HW\_hp} + E_{HW\_bu}}$$

SPF_4 includes all parts relates to SPF_3, additionally SPF_4 also includes the distribution of the heat.

$$SPF_{H4} = \frac{Q_{H\_hp} + Q_{W\_hp} + Q_{HW\_bu} + Q_{DHW\_bu}}{E_{S\_fan/pump} + E_{HW\_hp} + E_{bt\_pump} + E_{HW\_bu} + E_{B\_fan/pump}}$$

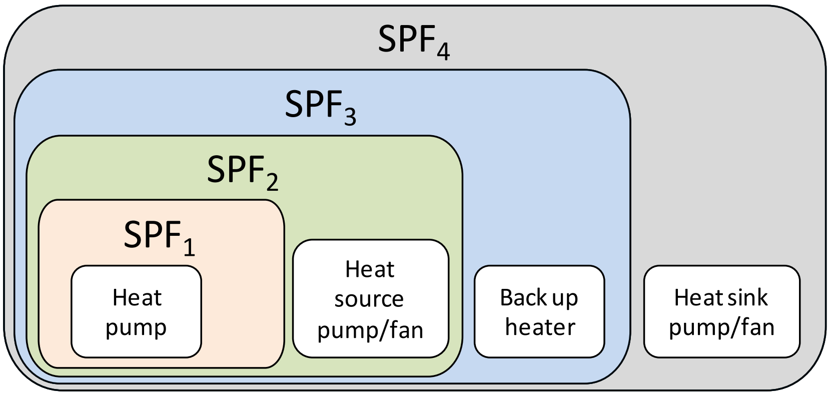


Figure 6 System boundaries for calculations of SPF

SPF_1 is normally measured on the brine/water sides of the evaporator/condenser, but it could also be measured directly in the refrigeration loop with e.g. the Climacheck equipment [10]. This requires measurement of the pressure and temperature of the refrigerant. This methodology is very efficient if the status/condition or diagnosis of the heat pump is to be evaluated, but generally in domestic heat pumps, the measurement is not easy to carry out since measurement sockets are not generally installed.

8.5 Calculation of SPF

In this study SPF is calculated for three of the four different system boundaries and categories by using data from the field measurements. The system boundaries used are SPF_2, SPF_3 and SPF_4 and are described in section 8.4. The categories are “heating only”, “heating and domestic hot water production” and “domestic hot water production”.

For facilities where the installed heat pump also is tested in a laboratory, the laboratory test results are used to calculate SPF by using the calculation models. This is the case for seven different ground source heat pumps and one air to air heat pump.

This chapter will explain how the calculations are performed and what assumptions are made for the different models.

Field measurements

Ground source heat pumps
All analyzed heat pump systems are installed in German single family houses with floor heating. The heat pump is more or less monovalent, only a very small amount of backup heat has been used during the year of measurements. The heat pumps in the study were all installed in new built houses during the years 2004-2008. The data used for the SPF calculations are based on field measurements carried out during one year, with one exception the SPF for site no. 1 is based on data measured from January to August.

The calculations of SPF's are based on the field measurements data from the Fraunhofer study. In the data we have received from the Fraunhofer study the total energy consumption for the heat pump system and its components is presented as well as the energy consumption divided into energy used for space heating and energy used for production of domestic hot water.

In this project we have not been able to evaluate exactly how these allocations have been made. For some of the studied installation sites a part (up to 20%) of the total electricity consumption has been allocated neither to space heating nor to the domestic hot water production. This is mainly the case for the electricity consumption. For the heat produced no energy gap is seen between the total energy production and the energy divided into space heating and domestic hot water.

The calculated SPF's in the study are based on the energy allocated to the space heating only, this in order to make the results comparable to the results from the calculation models in prEN14825 and Lot 1, which not include the production of domestic hot water.

Air to air heat pumps
The field measurement of the air to air heat pumps is carried out in single family houses located in the Borås area of Sweden. All houses in the study have electricity driven radiators for back up heating. The field measurements are based on SP method 1721. From the field measurements SPF_2 and SPF_3 has been calculated as described below.

The electricity consumed by the heat pump, W_{HP}, is measured continually while the produced space heating is measured at five "performance tests" done at different outdoor temperatures. During the performance tests the heating capacity of the heat pump is measured during stable conditions and is thereby not including any defrost period. Therefore the calculated COP for each test point is based on data from only a part of the operating cycle.

The total amount of heat produced during the total measuring period needs to be calculated based on the five performance tests. The calculations are made as follows:

$$Q_{HP\_year} = \sum W_{HP\_month} * COP_{average\_month}$$

COP is calculated from the performance tests at made at different outdoor temperatures. During the performance test both the electricity consumed (W_{HP}) and the produced heat (Q_{HP}) is measured and COP can be calculated as:

$$COP = \frac{Q_{HP\_test}}{W_{HP\_test}}$$

From the five performance tests the COP for the heat pump can be expressed as a function of the outdoor temperature. From this function an average COP for each month is calculated based on the average temperature for the month. Knowing the electricity produced each month by the heat pump the SPF_2 can be calculated:

$$SPF_2 = \frac{Q_{HP\_year}}{W_{HP\_year}} = \frac{\sum W_{HP\_month} * COP_{average\_month}}{W_{HP\_year}}$$

The electricity consumed by the backup heaters is also measured, thereby SPF_3 is calculated as:

$$SPF_3 = \frac{Q_{HP\_year}}{W_{HP\_year} + W_{backup\_year}} = \frac{\sum W_{HP\_month} * COP_{average\_month}}{W_{HP\_year} + W_{backup\_year}}$$

Due to lack of data from laboratory testing of the heat pump models included in the field measurement, this study has only been able to compare the SPF values from the field measurements with the SPF calculated with the calculation models prEN14825 and Lot 10 for one of the tested heat pumps.

prEN14825

Ground source heat pumps

When using prEN14825, data according to Table 13 has to be filled in. The chosen climate, “average” gives that Tdesign is -10°C. Tbivalent is the outdoor temperature where the capacity of heat pump covers the heat demand of the house. It is set to -10°C, to make the heat pump monovalent, like in the field study. TOL, the operation limit temperature, is set to -25°C. This temperature declares where the heat pump no longer can operate. The model calculates Pdesign as a result of Tbivalent and is the heat demand of the house at Tdesign.

Table 13. Input data for the prEN14825 calculation model.

T design	-10	°C
T bivalent	-10	°C
T OL	-25,00	°C
P design	8,81	kW

The test conditions for the heat pumps were taken from Table 20 in the standard, brine to water heat pump, average climate and low temperature application. The unit is assumed to be a fixed capacity unit with fixed outlet temperature. The heat pumps in the study where all tested in full load according to EN 14511. For the part load conditions the COP was calculated by using equation 12 in the standard. The test point used for the calculations was the 30°C/35°C point from EN 14511 laboratory data. The capacity and COP at Tbivalent and TOL is set to the maximum, while the COP for the delivered capacity at the different outdoor temperatures is calculated by using equations from the standard prEN14825. The default degradation factor where Cc=0.9 is used.

Air to air heat pumps
The data for SPF calculations regarding air to air heat pumps are taken from the field measurements. There are no laboratory data available for the heat pumps tested in the field study.

The colder climate is chosen for the calculations, since this climate is similar to the climate where the field installation is. The bivalent operation point of the heat pump is calculated by using SPA3528, which is another model for the calculation of SPF. The bivalent point is 0°C. The operation limit point is set to -20°C.

At -7°C the heat pump operates in full load to deliver heat to the house. At +2°C and at +7°C the heat pump operates in part load. COP for part load operation is interpolated by using linear interpolation between existing test points. At +2°C the interpolation is made between full load operation and operation at 47% part load, at +7°C the interpolation is made between part load operation at 50% and 57% of the heat pump capacity. At +12°C the required heat load is so small that the heat pump is assumed to cycle on/off. The capacity of this point is calculated by using equation 11 in the standard. The COP for the bivalent point is interpolated from test points in full load operation at +2°C and -7°C.

<u>Lot 1</u>
In Lot 1 there are some general inputs that has to be filled in into the excel sheet. The following inputs are used:

- Reduced setback: Yes
- Radiator (with setback): No
- Floor heat (24h): Yes
- Control: 4 – Weather ctrl BT
- Pump: 3 fixed speed
- Pump timer: 24h
- Buffer: No
- Tmino: -25°C

The only heat generator in use is heat pump. No back up heater is included in the calculations.

The default degradation factor, Cd= 0.15, is used. Default is also used for hpaux (=30W) and hpsb (=10W). The test conditions are taken from the reference test conditions in table V.3. in the standard. The test point used for the calculations was the 30°C/35°C point from EN 14511 laboratory data. The model recalculates the test data to fit with the test conditions of Lot 1 (table V.2.).

Data for part load operation is calculated from equations of “option B” at page 27 in the standard, where COP_{min}= 0.89*COP at power output Phpmin=0.5*Php for a fixed capacity unit.

From Lot 1 two different results are obtained, “etas” and “average COP”. Etas are calculated by involving the primary energy factor of 2.5 which makes it difficult to compare with other calculated SPF. However, “average COP” corresponds to SPF 1.

<u>Lot 10</u>

Air to air heat pumps
The design load of the house is chosen to 8,5kW, which is the design load that best corresponds to the size of the house in the field measurement. The house in the field is installed in a climate, similar to “colder” climate, therefore “colder” is chosen. The test

points for the calculation are given in a table at page 24 in LOT 10 Annex II. The heat pump is tested according to EN 14511 and CEN/TS 14825 for part load conditions.

The heat pump is a variable capacity heat pump, but since the heat pump is not tested at exactly the required heat effect (within ±3%), the calculations of COP has to be performed in accordance with a staged capacity unit.

At -15°C and -7°C the delivered capacity from the heat pump is lower than the house requires; capacity and COP data are taken from operation in full load at these outdoor temperatures. An exception from the standard is made, since the standard proposes a recalculation of the COP at those points. The recalculation does not seem to make sense and is therefore ignored.

At +2°C and +7°C the heat delivered from the heat pump exceeds the required heat from the house and is therefore operated in part load. COP for part load operation is interpolated by using the equation for staged capacity units at page 26 in the standard. At +2°C the interpolation is made between full load operation and operation at 47% part load, at +7°C the interpolation is made between part load operation at 57% and 44% of the heat pump capacity.

The heat pump is not tested at +12°C. Full load operation at +12°C is extrapolated from test data at +7°C and +2°C. 50% part load is extrapolated from 50% part load operation at +7°C and +2°C. COP for the required effect is extrapolated by using this data. Each extrapolated COP value is corrected with a degradation factor of 0.975.

Default values are used for the degradation factor (Cd=0.1), turndown ratio heating (=25%), thermostat off mode (50W), crankcase heater mode (=10W) and off mode (=10W). The bin limit is set to -20°C.

8.6 Analysis of the results

The results from the SPF calculations of the different heat pump installations in field is compared with the results obtained from the laboratory data used in calculation models.

Ground source heat pumps
Most of the heat pumps installed in field operates both in floor heating mode and produces domestic hot water. The measurements include both kind of operations and the results are presented in Table 14and Figure 7 below. SPF for domestic hot water production is always lower compared to operation in heating mode. The energy balances is not 100% complete for the field measurement, which is quite common in field measurements, since heat losses are present, but cannot be measured directly as they can be in the laboratory.

Table 14 The table shows two different SPF from the field measurements in two different levels. SPF for heating and DHW (domestic hot water) is lower than SPF for heating only. This is because COP for domestic hot water production is lower than COP for heating

Results field measurements				
	Heating and DHW	Heating and DHW	Heating only	Heating only
	SPF 1	**SPF 3**	**SPF 1**	**SPF 3**
site 3	3,70	3,46	4,66	
site 6			3,86	3,43
site 8	4,13	3,02	4,71	
site 9	3,97	3,64	4,53	
site 11	3,62	3,32	4,71	4,56
site 13	2,71	2,55	3,99	3,83
site 14	4,14	3,55	5,43	5,16

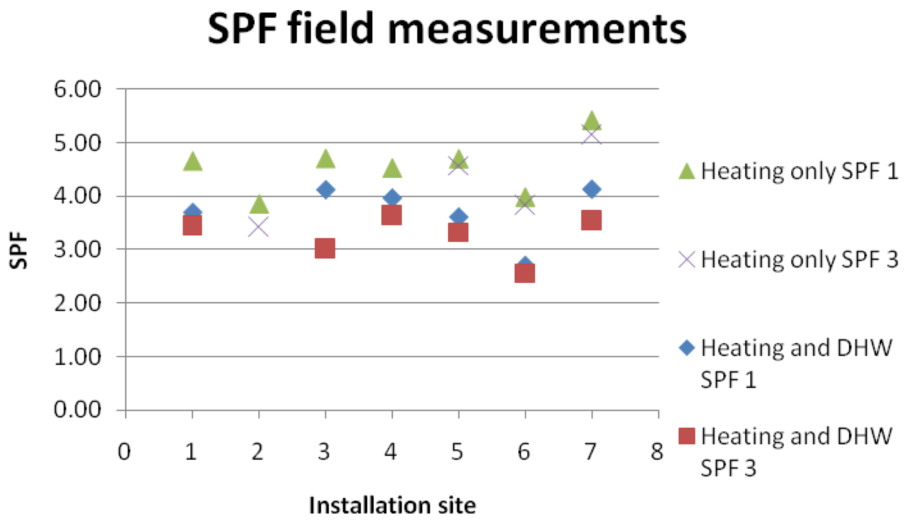


Figure 7 The figure show SPF results from two different SPF, "heat only" and "heat and DHW" (domestic hot water heating) at two different levels, "SPF 1" and "SPF3", from field testing.

The conditions for measurements in a laboratory and in field differ with respect to various factors e.g. the boundary conditions. SPF_1 in field measurements includes the electrical energy from the heat source brine pump, while "average COP" and "$SCOP_{net}$" only includes the head losses. This could make the electrical energy use a little larger for the field measurements, but on the other hand "average COP" and "$SCOP_{net}$" also contain head losses for the heat sink side which SPF_1 does not. The electrical energy from the heat sink pump for SPF_1 is included in SPF_3.

Table 15. The table shows the results from using Lot 1. Average COP is comparable with SPF 1 from the field measurements. Pdesign shows the maximum capacity needed for the house

Results Lot 1			
	avg COP	etas	Pdesign
site 3	3,57	1,05	7,7
site 6	3,49	1,03	7,6
site 8	3,49	1,02	5,9
site 9	3,49	1,03	7,6
site 11	3,83	1,12	7,2
site 13	3,88	1,12	5,8
site 14	3,88	1,12	5,8

Table 16. The table shows results from using prEN14825. SCOPnet is comparable with SPF 1 from the field measurements. Pdesign shows the maximum capacity needed for the house.

Results prEN14825			
	SCOPon	SCOPnet	Pdesign
site 3	3,66	3,66	8,81
site 6	3,58	3,58	8,7
site 8	3,6	3,6	7,17
site 9	3,58	3,58	8,7
site 11	3,96	3,96	9,64
site 13	4,02	4,02	8,01
site 14	4,02	4,02	8,01

Since the ground source heat pumps in this study is considered monovalent, the comparison of the results are mainly done for SPF_1 from the field measurements and SPF that corresponds to SPF_1 from the calculation models, “average COP” from Lot 1 and “SCOPnet” from prEN14825. The results are presented in Figure 8 below.

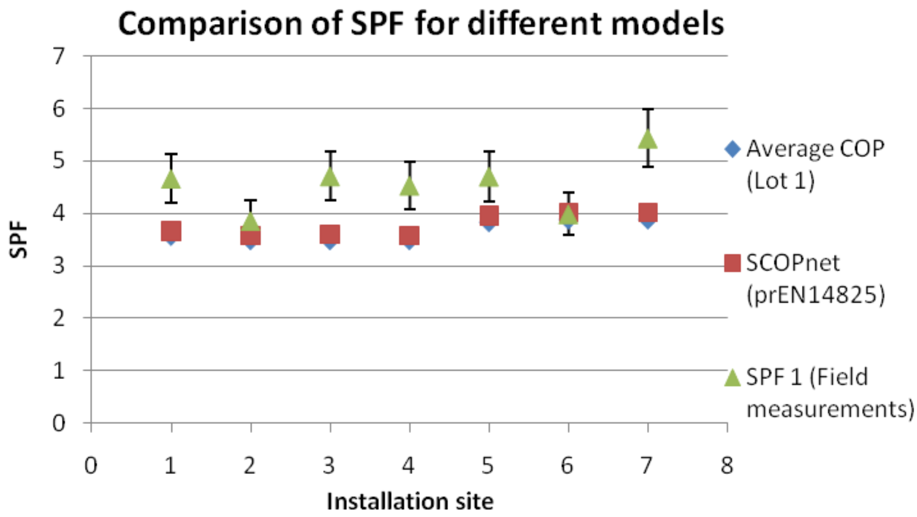


Figure 8 The figure shows a trend that SPF_1 is higher compared to “average COP” and “SCOPnet”. Field measurements imply a higher uncertainty compared to measurements in a laboratory. The bars of error show an error of ±10% to cover the margins of error.

There are two main differences between “average COP” and “$SCOP_{net}$“:

- There are differences in degradation for part load operation
- Lot 1 does not make an capacity balance of the heating demand of the house at each outdoor temperature.

The last factor results in that the design capacity, P_{design}, turns out to be larger for the house when using $SCOP_{net}$ compared to “average COP”. The result show that P_{design} for “average COP” is approximately 13-28% lower compared to “average COP” and SPF is approximately 3-4% lower. The degradation of COP is a little bit tougher when using Lot 1 compared to using prEN14825. The comparison is illustrated in Figure 9 below.

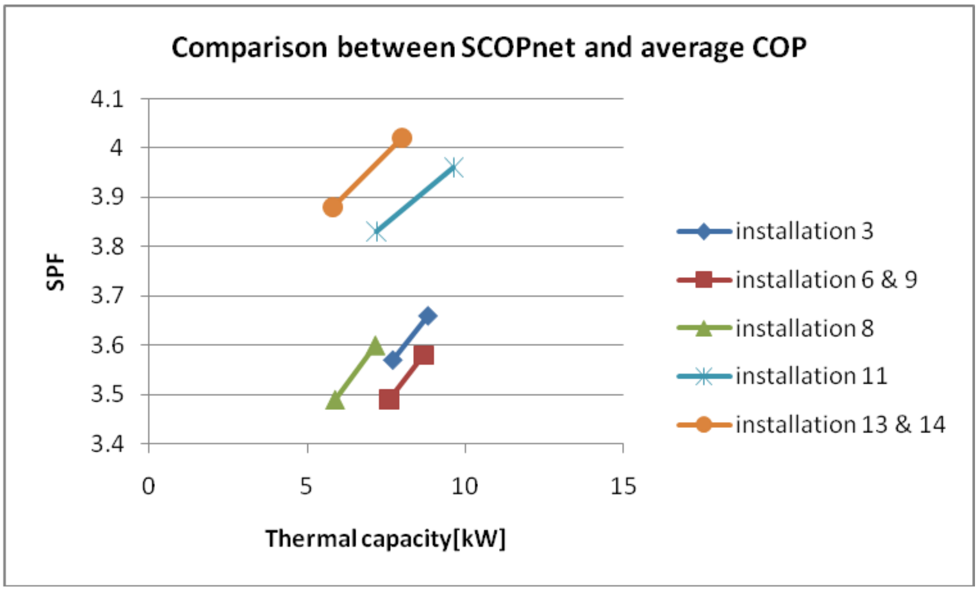


Figure 9. The figure illustrates the differences in design capacity when using EuP Lot 1 and prEN14825. The lower value corresponds to Lot 1 and the higher value corresponds to prEN14825.

Air to air heat pump
Laboratory test data was available for one of the air to air heat pumps that were studied in field. SPF from the field study and SPF from the calculation models are presented in Table 10 below. SCOPnet is the SPF for the heat pump that corresponds to SPF_1. SCOPon is SPF for the heat pump with the backup heater included and corresponds to SPF_2. SCOP is SPF for the heat pump with both backup heater and parasitic losses included. There are some problems by comparing the laboratory test data and the data from field testing, since the field tests do not include the defrosting periods. Therefore SPF from field testing might turn out a little higher than in reality.

Table 17. The table shows a comparison of result for the air to air heat pump.

Results field measurements			
	SCOPnet	**SCOPon**	**SCOP**
prEN 14825	2,52	1,96	
Field measurement	2,4	2,1	
Lot 10		2,15	2,12

8.7 Conclusions from comparisons

Some of the field installations show different SPF_1 despite that the same heat pump model is installed. This can be an indication of how important the sizing of the heat pump is. An oversized heat pump results in for example more part load operation and causes standby losses.

The calculation models show that there can be benefits when installing a heat pump where the bivalent temperature is higher than the lowest operation temperature of the year, even though backup heating is necessary.

9 Requirements for a new calculation model to evaluate SPF from lab measurements

The requirements on a new calculation model differs defpending on the aim of the model. In general, three different uses can be identified:
Based on lab data understand the consequences of technology choice in comparison with competing heating technologies
To understand the consequences of correct sizing of the heat pump
To make a correct dimensioning of the heat pump in a specific house

It should also be possible to study three modes of operation, DHW production, heating or combined DHW production and heating.

Based on the models, it should be possible to make comparisons of e.g. LCC and environmental performance of different systems

What should be included/ not included in the model?

- It should be possible to decide the energy demand of the house in the model, either by given reference loads, or by choosing a specific energy demand of the house. This should be separated into space heating and domestic hot water. When the model itself calculates the losses of the house it can be misleading and not sufficient for the actual house. This can be one boundary of the project. Alternatively, typical houses are used in typical climates, both preset in the model.

- To take into account for the climate at the installation, generally accepted spot climate data, for example Meteonorm data [9], Should be a part of the model.

- The dynamics of the house can be a part of the model. The perceived temperature of the house is not fully consistent with the actual outdoor temperature. At colder temperature dips of for example -15°C, the house will not experience the real outdoor temperature, but experiences a temperature of -12°C instead (due to internal heat gains). Even the irradiance of the sun differs between the seasons (and different spots). The energy demand of the house is affected from those variances over the year, why it might be an idea to calculate the SPF over monthly periods. Also the use of a fictive outdoor temperature would be an alternative. The climate data can be adjusted (flattened out) depending on a number of inputs, but a temperature dip is still needed in order to make a proper effect dimensioning (this is dimensioning the entire system such as deep wells etc.).
  In a serious effort to evaluate dynamics, other factors have to e incorporated in a model, such as form factor, impact of building weight, window area compared to wall area, placement of windows, etc., which make such a model very complex.

- For ground source heat pumps, the temperature of the ground is varying during the year. The model should include a correction for this. This could be expressed as a function where the ground source temperature is a function of the outdoor temperature over the year.

- The model should contain a radiator heat curve where requisite supply temperature is calculated, an example of this can be found in the thesis of Fredrik

Karlsson [8]. At a colder outdoor temperature, the supply temperature should peak; this makes the test scheme tables in EN 14511 deficient. Also other heat distribution systems, such as under floor heating, and mixed systems should be included in the model.

- Part load performance of the heat pump must be properly taken into account, and be based on relevant testing standards.

Night set back is a choice in some calculation models; this is not relevant for heat pumps and should not be a part in a new calculation model.

- Back up heaters is sometimes necessary to complete the energy demand of the house. Back up heaters should be included in the calculation model. Supplementary heating should be possible to choose between different sources of supplementary heat, e.g. electricity, solar or biomass heating.

- The possibility to include the production of domestic hot water to the SPF calculations is also a necessity in future calculation models. It should also be described how this shall be measured in tests alternatively, how the amount of produced domestic hot water shall be estimated. Today there are two main ways how to do the measurements, including the losses or not (one can measure the amount of energy that is obtained by tappings or the amount of tap water the heat pump is producing). A lot of work has already been done in this respect in the IEA HPP Annex 28 [13]. Also, there is a CEN standard on the way on how to treat DHW production. This standard however does not take into consideration combined heating and DHW production.

- Accumulators should be possible to include in the model.

- A model must contain clear system boundaries for what is to be included in the calculations and how measurements are performed. As a basis, the system boundaries presented in the SEPEMO project [12] is recommended.

- The model must be transparent so it is possible to follow and understand the calculations. The studied models all contain parts that are more or less transparent. For example how the estimation of the number of equivalent heating hours is performed is not shown in any method.

An outcome of the results should be to see that a properly sized heat pump is the best alternative to install. An oversized heat pump will result in unnecessary on/off cycling losses and an undersized heat pump will result in unnecessary high back-up heating.

For the calculation, either BIN methods or hour by hour calculations could be used. The existing calculation models based on heat pump performance testing according to standards are all using BIN models. Therefore, to keep a clear connection to existing test standards, it is the easiest to base a new model on BIN models. A hybrid model using chronological BIN’s could also be an interesting option to look into.

The drawback with this approach might be that dynamic effects, especially in cases with large or well stratified accumulators are not treated in a way that the full potential of these units are revealed.
In the proposed IEA Annex, a thorough investigation of the positive and negative effects of these approaches should be performed.

10 Conclusions

For a new calculation method to better represent real SPF values there is a need to rely on consistent sets of performance data acquired from lab testing. These lab testings guarantee consistency, repeatability and reliability.

If the objective is to give better values for individual houses, more details on the building envelope, climate data etc. must be provided for the specific setup.

If the objective is to give reliable values for typical conditions, type houses in type climates should be used, but with better details than currently used in existing models.

A new model should include combined DHW and heating to the full extent.

Other key numbers, such as energy performance, energy savings, environmental performance and life cycle cost should be developed in a harmonized way. These key numbers act as a complement to SPF values.

System boundaries should be transparent and comparable with other heating technologies. The use of more than one system boundary allows analyzing parasitic losses from pumps, fans and piping work. The use of different system boundaries also allows to communicate what parts of a heat pump system that working properly or not satisfying in the final installation.

It is important to not only act as a national project in the case of SPF, since much of the activities are on an European or even global level, so the results from this project will be very valuable input to the international work within IEA.

11 Further work

The results from this project will be fed into the IEA Annex on SPF, and further development of a calculation method can be proposed to relevant stakeholders from that Annex.

12 Publications from this project

Within this project, SP have presented results in the form of an article to the Swdish magazine KYLA., "Jämförelse av metoder och fältmätningar för utvärdering av årsvärmefaktor (SPF) ". The article was planned to be published in issue 3, 2010.
An abstract has been submitted to the forthcoming IEA heat pump conference in 2011.

13 References

1. Meeting notes SPF Annex Chicago 2009-01-27
2. Meeting notes Paris: HPP SPF Annex 2010-03-05
3. A common method for testing and rating of residential HP and AC seasonal performance, draft legal text IEA HPP Annex
4. Ekonomisk och driftserfarenhetsmässig utvärdering av bergvärmepumpar, Utarbetad av Per Levin, Projektengagemang Energi och klimatanalys Danderyd, februari, 2008
5. Two large field-teste of new heat pumps in Germany, Miara, M. 9th IEA heat pump conference, Zyrich, 2008
6. Årsmätning på fem bergvärmeanläggningar i Sjuhärad, Energimyndigheten, 2005
7. Fältmätning på Luft/Luft värmepumpar i svenska enfamiljshus, SP, 2009, to be published
8. Capacity Control of Residential Heat Pump Heating Systems, Fredrik Karlsson, Building Services Engineering, Department of Energy and Environment, Chalmers University of Technology, Göteborg, Sweden 2007
9. Meteonorm, Global Meteorological Database for Engineers, Planners and Education, http://www.meteonorm.com/pages/en/meteonorm.php
10. Climacheck website, accessed 2010-04-21, http://www.climacheck.com/
11. Prestandaprovning av luft/luft Värmepumpar i fält, SP metod nr 1721, Fahlén, P., Kjellgren, C., SP AP 1994:51, Energiteknik, Borås 1994
12. Seasonal Performance factor and Monitoring for heat pump systems in the building sector (SEPEMO-Build), IEE/08/776/SI2.529222, http://www.sepemo.eu/
13. Final Report IEA HPP Annex 28, Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating, HPP-AN28-1, ISBN: 91-85533-30-0

Appendix 1. References for field measurements, presented in RIS-format.

TY - BOOK
A1 - Abrahamsson, Thore
T1 - Skövdebadet - solenergiuppvärmning? : alternativstudie avseende uppvärmning genom värmepump, solfångare och värmelager i utebassäng
AU - Jonson, Sten
AU - Norin, Fredrik
Y1 - 1979
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningen, 0346-5616 ; 1979:71
SN - 91-540-3035-8
ER -

TY - BOOK
A1 - Andersson, Per-Åke
T1 - SIMSYS : simuleringsprogram för värmecentraler med ny energiteknik
AU - Askling, Åke
AU - Dalenbäck, Jan-Olof
Y1 - 1986
CY - Göteborg
T3 - Intern skrift / Chalmers tekniska högskola, Avdelningen för installationsteknik, 99-0354505-3 ; 24
T3 - Rapport / Chalmers tekniska högskola, Avdelningen för installationsteknik, 0280-2899 ; 1986:2
ER -

TY - BOOK
A1 - Backman, Anders
T1 - Värmeåtervinning ur avloppsvatten med värmepump för 400 lägenheter i Falun : projektering
Y1 - 1983
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1983:103
SN - 91-540-3991-6
ER -

TY - BOOK
A1 - Björk, Erik
T1 - Praktisk provning av vattenburet värmesystem med värmepump och konvektorer/radiatorer
AU - Wiklund, Sören
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:131
SN - 91-540-3356-X
ER -

TY - BOOK
A1 - Bokalders, Varis

T1 - Energisnåla hus : [30 hus med energisnåla lösningar: solfångare, värmeåtervinning, växthus, braskamin, värmepump, passiva solhus, värmelager]
Y1 - 1981
KW - Uppvärmning (byggnader)
KW - Energieffektiva byggnader
CY - Västerås
PB - Ica bokförl.
SN - 91-534-0568-4
ER -

TY - BOOK
A1 - Boklund, Tord
T1 - Värmepump för luft-vattensystem med mekanisk vinds- och krypgrundsventilation som värmekälla : enplansbyggnad
Y1 - 1983
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1983:53
SN - 91-540-3940-1
ER -

TY - BOOK
A1 - Buresten, Rune
T1 - Solvärme med värmepump som komplement till en oljeeldad värmecentral i Göteborg
AU - Gunnarsson, Ingemar
Y1 - 1983
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1983:26
SN - 91-540-3891-X
ER -

TY - BOOK
A1 - Claesson, Staffan
T1 - Lågenergihus i Högås : hydrologiska förutsättningar för värmepump med en mindre tjärn som värmemagasin
AU - Sandén, Kent
Y1 - 1976
N1 - Examensarbete
T3 - Examensarbete / Institutionen för vattenbyggnad, Chalmers tekniska högskola, 99-0211330-3 ; 1976:4
ER -

TY - BOOK
T1 - Energi ur grundvatten : inventering av stora grundvattenmagasin för energiutvinning med värmepump : slutrapport mars 1980
Y1 - 1980
ER -

TY - BOOK
A1 - Eriksson, Sven-Olof
T1 - Stockholmsprojektet : energibehov i flerbostadshus med solvägg, tung stomme och värmepump : kv Konsolen
Y1 - 1993
KW - Flerbostadshus

KW - Energieffektiva byggnader
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - R / Byggforskningsrådet, 1103-6346 ; 1993:44
SN - 91-540-5590-3
ER -

TY - BOOK
A1 - Eriksson, Sven-Olof
T1 - Stockholmsprojektet, kv Konsolen : energiteknisk utvärdering av flerbostadshus med solvägg, tung stomme och värmepump
Y1 - 1993
N1 - Lic.-avh. Stockholm : Tekn. högsk.
CY - [Stockholm]
T3 - Arbetsrapport / Institutionen för byggnadsteknik, Kungliga Tekniska högskolan, 0349-6562 ; 1993:1
ER -

TY - BOOK
A1 - Faarinen, Jukka
T1 - PoD anläggning av öppet absorptionssystem.
Y1 - 1993
N1 - Examensarbete
CY - Luleå
T3 - Examensarbete / Tekniska högskolan i Luleå, Ingenjörslinjen 80 poäng, 1102-4070 ; 1993:22I
ER -

TY - BOOK
A1 - Hammarsten, Patrik
T1 - Experimentell studie av R22/R142b som arbetsmedium i en värmepump.
Y1 - 1992
N1 - Examensarbete
CY - Göteborg
ER -

TY - BOOK
A1 - Hill, Anders
T1 - Återvinning av värme med värmepump från lokaler där spillvärme alstras
AU - Matsson, Lars Olof
AU - Ryberg, Anders
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:145
SN - 91-540-3628-3
ER -

TY - BOOK
A1 - Holmgren, Mats
T1 - Användning av värmepump för återvinning av värme vid godssvalning
AU - Stigmarker, Håkan
Y1 - 1984
CY - Jönköping

PB - Svenska gjuteriföreningen
ER -

TY - BOOK
A1 - Hult, Johan
T1 - Jämförelse mellan konventionell gaspanna och värmepump med inbyggd gaspanna
AU - Jonasson, Jens
Y1 - 2000
CY - Malmö
PB - SGC
T3 - Rapport SGC, 1102-7371 ; 113
ER -

TY - BOOK
A1 - Jeal, David
T1 - Erfarenheter av luft-vatten värmepump med djurvärme som energikälla : uppvärmning av personalutrymme vid Ökna lantbruksskola
AU - Norrfors, Mats
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:137
SN - 91-540-3612-7
ER -

TY - BOOK
A1 - Jelbring, Hans
T1 - Prov med värmepump och sjöförlagd värmeväxlare vid Kungliga slottet
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:43
SN - 91-540-3498-1
ER -

TY - BOOK
A1 - Jensen, Lars
T1 - Uteluft och mark som värmekälla för värmepump i kv Bobinen i Malmö : utvärdering
AU - Wetterstad, Lennart
Y1 - 1985
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1985:89
SN - 91-540-4430-8
ER -

TY - BOOK
A1 - Johansson, Lars
T1 - Energibehov vid torkning : jämförelse mellan mekanisk värmepump och öppet absorptionssystem för torkskåp inom hushåll : CFD-analys avabsorbator
Y1 - 1998
CY - Luleå

T3 - Examensarbete / Luleå tekniska universitet,
Civilingenjörsprogrammet, 1402-1617 ; 1998:020
ER -

TY - BOOK
A1 - Johansson, Mats
T1 - Datorprogram för studium av temperatur- och
frysningsförlopp i mark kring kylrör till värmepump
AU - Westman, Kristina
Y1 - 1979
CY - Lund
T3 - Rapport BKL, 0281-6318 ; 1979:9
ER -

TY - BOOK
A1 - Kahsay, Samson
T1 - Processintegration av en kompressions-/absorptions-
värmepump (KAVP) vid Värö bruk
AU - Wikensten, Bo
Y1 - 1999
N1 - Examensarbete
T3 - Examensarbete / Chalmers tekniska högskola,
Institutionen för värmeteknik och maskinlära, 99-1473418-9 ;
99:4
ER -

TY - BOOK
A1 - Karlsson, Hanna
T1 - Utredning om ökade fjärrleveranser från Shell
Raffinaderi AB genom installation av värmepump
Y1 - 2002
CY - Göteborg
PB - Chalmers tekniska högsk.
T3 - Examensarbete (Institutionen för kemiteknik och
miljövetenskap/Värmeteknik och maskinlära, Chalmers tekniska
högskola); 02:12
ER -

TY - BOOK
A1 - Lagerkvist, Knut-Olof
T1 - Mätning och utvärdering av värmepump med avloppsvatten
som värmekälla i Falun
Y1 - 1987
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1987:42
SN - 91-540-4726-9
ER -

TY - BOOK
A1 - Landé, Johan
T1 - Praktiska prov med olika köldmedier [i] brine-vatten
värmepump
Y1 - 1992
CY - Stockholm
PB - Institutionen för mekanisk värmeteori och kylteknik, KTH
T3 - Trita-REFR, 1102-0245 ; 92:8
ER -

TY - BOOK
A1 - Ljungqvist, Jarl
T1 - Värmepump med frånluft som värmekälla för tappvatten i befintligt flerbostadshus i Göteborg
AU - Ohlsson, Kjell
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:126
SN - 91-540-3818-9
ER -

TY - BOOK
A1 - Mogensen, Palne
T1 - Fullskaleförsök med berg som värmekälla för värmepump i Järfälla : mätning och utvärdering
Y1 - 1985
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1985:123
SN - 91-540-4470-7
ER -

TY - BOOK
A1 - Mårtensson, Alf-Göran Mårtensson
T1 - Redovisning av försök beträffande värmeåtervinning från djurstall med värmepump placerad i bostadshuset samt nedsmutsningens inverkan på lamellbatteriers funktion.
Y1 - 1983
CY - Lund
T3 - Intern stencil / Sveriges lantbruksuniversitet, Institutionen för lantbrukets byggnadsteknik (LBT) och konsulentavdelningen/teknik, 99-0412863-4 ; 6
ER -

TY - BOOK
A1 - Nilsson, Christer
T1 - Torkning av spannmål med hjälp av värmepump och balktork
Y1 - 1990
CY - Lund
PB - LBT
T3 - Sammanställt / Sveriges lantbruksuniversitet, Institutionen för lantbrukets byggnadsteknik (LBT), 1101-5845 ; 3
ER -

TY - BOOK
A1 - Nordström, Hans
T1 - Mätning, modellbygge, simulering och reglering tillämpat på en anläggning med värmepump
AU - Svensson, Lennart
Y1 - 1977
CY - Lund
ER -

TY - BOOK
A1 - Nordström, Hans

T1 - Mätning, modellbygge, simulering och reglering tillämpat på en anläggning med värmepump
AU - Svensson, Lennart
Y1 - 1977
CY - Lund
T3 - Rapport BKL, 0281-6318 ; 1977:9
ER -

TY - BOOK
A1 - Norén, Bjarne
T1 - Studie av kombinationen gasturbin med värmeväxlare och värmepump
Y1 - 1981
CY - Lund
T3 - Technical report from the Division of Heat and Power Engineering, 0280-9931 ; 5106
ER -

TY - CHAP
A1 - Norgren, Mårten
T1 - Värmepump i Bodens reningsverk betalar sig på tre år
Y1 - 1982
JF - Kommun-aktuellt
VL - 1982: nr 8, s. 15
PB - Kommun-aktuellt
SN - 0347-5484
KW - Uppvärmning (byggnader)-- Sverige -- Norrbotten
KW - Värmepumpar-- Sverige -- Norrbotten
KW - Boden
ER -

TY - BOOK
A1 - Nyman, Bertil
T1 - Värmebalans i småhus med kombinerat uppvärmningssystem - solfångare, värmepump, värmeväxlare samt tidsstyrd värme och ventilation : [licentiatavhandling]
Y1 - 1982
CY - Stockholm
PB - KTH
ER -

TY - BOOK
T1 - Oskadliggörande av läckande CFC-köldmedier från värmepump- och kylanläggningar : förstudie
AU - Jacobson, Sten Olle
AU - Keck, Karl-Erik
AU - Jacobson, Lars
Y1 - 1988
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1988:71
SN - 91-540-4932-6
ER -

TY - BOOK
A1 - Persson, Sven-Erik
T1 - Värmepump med ismaskin för 43 lägenheter i Sälen : förstudie

Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:49
SN - 91-540-3479-5
ER -

TY - BOOK
A1 - Sjöbris, Karin
T1 - Värmeåtervinnings- och rökgasreningsanläggning : kondensation av rökgaser i kombination med värmepump : förstudie
Y1 - 1987
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1987:118
SN - 91-540-4836-2
ER -

TY - BOOK
A1 - Stock, Christina
T1 - Kriterier för dimensionering av bergborrande brunnar för energiuttag med värmepump.
Y1 - 1984
T3 - Examensarbete / Institutionen för vattenbyggnad, Kungl. Tekniska högskolan, 99-0535463-8 ; 291
ER -

TY - BOOK
T1 - Stora värmepumpsboken : nyttig kunskap, vägledning och inspiration när du funderar på att köpa värmepump
Y1 - 2009
CY - Arvika
PB - Thermia Värme AB
SN - 91-631-7643-2
ER -

TY - BOOK
A1 - Svensson, Torbjörn
T1 - Värmeåtervinning ur avloppsvatten med värmepump för fjärrvärmeanslutning i Enköping : förstudie
AU - Wahlberg, Herje
AU - Wahlberg, Olof
Y1 - 1983
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1983:58
SN - 91-540-3913-4
ER -

TY - BOOK
A1 - Svärd, Ann-Christine
T1 - Bestämning av värmefaktorn för en värmepump vid Östra Sjukhuset, Göteborg
Y1 - 1979
N1 - Examensarbete
CY - Göteborg

T3 - Examensarbete / Chalmers tekniska högskola, Avdelningen för installationsteknik, 99-0354504-5 ; 4
ER -

TY - BOOK
A1 - Tengblad, Niklas
T1 - Resultat från prov med liten luft-luft värmepump med propan/gasol som köldmedium
Y1 - 1993
CY - Stockholm
PB - Avdelningen för tillämpad termodynamik och kylteknik, Institutionen för energiteknik, Kungliga Tekniska högskolan
T3 - Trita-REFR, 1102-0245 ; 93:12
ER -

TY - BOOK
A1 - Jagenäs, Arne
T1 - Mätning av ljudnivå från värmepump.
Y1 - 1981
T3 - Rapport / Chalmers tekniska högskola, Avdelningen för byggnadsakustik. S, 0282-3446 ; 81:03
ER -

TY - BOOK
A1 - Jansson, Lennart
T1 - Värmepump med uteluft som värmekälla : projektering av värmepumpsystem för befintligt flerbostadshus i Söderköping
AU - Strindehag, Ove
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:124
SN - 91-540-3814-6
ER -

TY - BOOK
A1 - Jilar, Torbjörn
T1 - Fjärås centrum - solvärmesystem med värmepump : utvärderingsresultat
Y1 - 1987
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1987:11
SN - 91-540-4692-0
ER -

TY - BOOK
A1 - Jilar, Torbjörn
T1 - Solvärmeteknik i stor skala : Ingelstad - en värmecentral utan värmepump
Y1 - 1984
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1984:103
SN - 91-540-4171-6
ER -

TY - BOOK

A1 - Johansson, Jan
T1 - Naturvärmesystem för biltestningsanläggning i Slagnäs : ground heat storage sytem for the car test plant at Slagnäs
AU - Josephsson, Börje
Y1 - 1995
N1 - Examensarbete
CY - Luleå
T3 - Examensarbete / Tekniska högskolan i Luleå, 0349-6023 ; 1995:139E
ER -

TY - BOOK
A1 - Jonsson, Eric
T1 - Fullskaleprov med solfångare i kombination med ytjordvärmesystem för uppvärmning av småhus : [ett energisnålt alternativ för uppvärmning av småhus] : [beskrivning av ett kombinationssystem] : [utvärdering och rapport]
Y1 - 1983
CY - [Eskilstuna]
PB - [Eskilstuna kommun]
ER -

TY - BOOK
A1 - Jönsson, Sven-Erik
T1 - Värmepump för spillvärme till fjärrvärmenät : teknisk och ekonomisk utredning gällande spillvärme från Domsjö sulfitfabrik till Örnsköldsviks fjärrvärmenät : förstudie
AU - Sandberg, Edvard
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:72
SN - 91-540-3278-4
ER -

TY - BOOK
A1 - Kangro, Andrus
T1 - Värmeåtervinning med värmepump i djurstallar : mätning och utvärdering av anläggning i Klovarp
Y1 - 1982
CY - Lund
T3 - Specialmeddelande / Sveriges lantbruksuniversitet, Institutionen för lantbrukets byggnadsteknik (LBT), 0348-0593 ; 115
SN - 91-576-1167-X
ER -

TY - BOOK
A1 - Larsen, Johan
T1 - Uppvärmningsalternativ med värmepump för industri
AU - Usinovski, Dime
Y1 - 2003
CY - Göteborg
PB - Chalmers Lindholmen högsk.
ER -

TY - BOOK
A1 - Lemmeke, Leif

T1 - Renvatten som värmekälla till värmepump : en studie i Åkarp
AU - Persson, Ulf
AU - Luterkort, Staffan
Y1 - 1984
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1984:75
SN - 91-540-4125-2
ER -

TY - BOOK
A1 - Lindahl, Anders
T1 - Värmepump för utvinning av havsvattenvärme : förstudie beträffande havsvattenvärmeväxlare
AU - Stenström, Börje
AU - Öst, Staffan
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:123
SN - 91-540-3337-3
ER -

TY - BOOK
A1 - Nilsson, Emma
T1 - Småhus med solceller och värmepump : utvärdering av Ekosolkonceptet
Y1 - 2008
CY - Göteborg
PB - Chalmers tekniska högskola
ER -

TY - BOOK
A1 - Stråhlin, Fredrik
T1 - Optimering av värmeoproduktion : en studie vid Birka Energi AB
Y1 - 1999
N1 - Examensarbete
CY - Luleå
T3 - Examensarbete / Luleå tekniska universitet, Civilingenjörsprogrammet, 1402-1617 ; 1999:281
UR - http://epubl.luth.se/1402-1617/1999/281
ER -

TY - BOOK
A1 - Westerlund, Lars
T1 - Öppna absorptionssystem : absorbatorers egenskaper
Y1 - 1989
N1 - Examensarbete
CY - Luleå
T3 - Teknisk rapport / Tekniska högskolan i Luleå, 0349-3571 ; 1989:17T
ER -

TY - BOOK
T1 - Årsmötet 1975. D. 2, Krångede och Gammelänge kraftstationer - ökning av turbineffekten

Y1 - 1975
CY - Stockholm
PB - Svenska kraftverksfören.
ER -

TY - BOOK
A1 - Collin, Mats
T1 - Ångmotordriven värmepumpsprocess för bostadsbebyggelse : förstudie och jämförelse med dieselmotordriven värmepump
AU - Palmgren, Mikael
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:133
SN - 91-540-3604-6
ER -

TY - BOOK
A1 - Dahlberg, Marcus
T1 - Marknadspotential för en kemisk kyl/värmepump
Y1 - 2002
CY - Stockholm
T3 - Trita-IEO. EX, 1403-7777 ; 2002:26
ER -

TY - BOOK
A1 - Franck, Per-Åke
T1 - Värmepump med vertikalt jordvärmesystem och vindkonvektorer
AU - Modin, Björn
Y1 - 1981
CY - Göteborg
T3 - Rapport / Jordvärmegruppen, Chalmers tekniska högskola, 0349-9723 ; 2
ER -

TY - BOOK
A1 - Luterkort, Staffan
T1 - Gasmotordriven värmepump för fjärrvärmenätet i Oxie : förstudie
AU - Lemmeke, Leif
AU - Torisson, Tord
Y1 - 1984
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1984:128
SN - 91-540-4237-2
ER -

TY - BOOK
A1 - Mårtensson, Alf-Göran
T1 - Energibesparing med värmepump - stalluft som värmekälla
Y1 - 1978
KW - Värmepumpar
KW - Stallbyggnader
KW - Energisparande
CY - Uppsala
PB - Sveriges lantbruksuniv.

SN - 91-7088-931-7
ER -

TY - BOOK
A1 - Saue, Olav Jarle S.
T1 - Solinfångande bassäng, pulserande värmelager och värmepump : diskussion av driftstrategier
Y1 - 1982
CY - Lund
T3 - Technical report from the Division of Heat and Power Engineering, 0280-9931 ; 5118
ER -

TY - BOOK
T1 - Skarpnäcks trädgårdsstadsförening 80 år : från kakelugn till värmepump : 1927-2007
AU - Barkman, Clas
KW - Skarpnäcks trädgårdsstadsförening
KW - Stockholm-- historia -- Skarpnäck -- 1900-talet -- sekelskiftet 2000
CY - Johannneshov
PB - Skarpnäcks trädgårdsstadsförening
ER -

TY - BOOK
A1 - Sönsteröd, Gunnar
T1 - Värmepump och oljepanna i bivalent drift : fältmätningar på typfall
Y1 - 1988
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1988:3
SN - 91-540-4846-X
ER -

TY - BOOK
A1 - Agerstrand, Torgny
T1 - Projekt Bergvärme : energiuttag med värmepump ur bergborrade hål : förstudie
AU - Ericsson, Lars O.
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:172
SN - 91-540-3418-3
ER -

TY - BOOK
A1 - Backman, Lennart
T1 - Spillvärme från mejeri till fjärrvärmenät via värmepump : alternativprojektering i Östersund
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:46
SN - 91-540-3228-8
ER -

TY - BOOK
A1 - Berntsson, John
T1 - Konstruktion av slavenhet för styrning av värmepump
AU - Bäckhage, Eric
Y1 - 2006
N1 - Examensarbete
CY - Göteborg
PB - Chalmers tekniska högskola
ER -

TY - BOOK
A1 - Bärring, Mats
T1 - Återvinning av värmeförluster i fjärrvärmekulvertar med värmepump : kulverttyper och systemoptimering
AU - Rosenberg, Mats
Y1 - 1986
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1986:53
SN - 91-540-4571-1
ER -

TY - BOOK
A1 - Cedheim, Lars
T1 - Nedbrytning av glykoler i värmepump och solvärmesystem : förstudie
Y1 - 1986
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1986:4
SN - 91-540-4506-1
ER -

TY - BOOK
A1 - Cedheim, Lars
T1 - Nedbrytning av glykoler i värmepump och solvärmesystem : laboratorieundersökning
AU - Blume, Ulla
AU - Lundgren, Björn
Y1 - 1988
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1988:107
SN - 91-540-4980-6
ER -

TY - BOOK
A1 - Elmroth, Arne
T1 - SPARSAM : fem energisnåla småhus med glasveranda och värmepump
AU - Granberg, Gunnar
Y1 - 1987
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1987:47
SN - 91-540-4736-6
ER -

TY - BOOK
A1 - Grafström, Hans
T1 - Värmepump vid friluftsbad med havsvatten som värmekälla : projektering, uppföljning och utvärdering
AU - Lagergren, Staffan
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:45
SN - 91-540-3692-5
ER -

TY - BOOK
A1 - Hammerbo, Erik
T1 - En femte värmepump vid Rya värmepumpverk, Göteborg
AU - Johansson, Björn
Y1 - 1994
N1 - Examensarbete
T3 - Examensarbete / Chalmers tekniska högskola, Institutionen för installationsteknik, 1400-9552 ; 104
ER -

TY - BOOK
A1 - Hultmark, Göran
T1 - Grundvattenvärme med värmepump vid strandbadet i Karlskoga : utvärdering
Y1 - 1985
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1985:141
SN - 91-540-4479-0
ER -

TY - BOOK
A1 - Jacobsson, Carl
T1 - Värmeutvinning ur havsvik med värmepump för villauppvärmning
AU - Jönsson, Sven
Y1 - 1981
N1 - Examensarbete
CY - Göteborg
T3 - Examensarbete / Institutionen för vattenbyggnad, Chalmers tekniska högskola, 99-0211330-3 ; 1981:2
ER -

TY - BOOK
A1 - Johansson, Anders
T1 - Förvärmning av uteluft till värmepump med markkollektor : datormodell
Y1 - 1990
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1990:68
SN - 91-540-5246-7
ER -

TY - BOOK
A1 - Lindvall, Anna

T1 - Strategier vid val av värmepump till småhus : en energijämförelse mellan varvtalsreglerade och on-/offreglerade värmepumpar
Y1 - 2007
CY - Helsingborg
PB - LTH Ingenjörshögskolan vid Campus Helsingborg, Lunds universitet
T3 - Examensarbete (LTH Ingenjörshögskolan vid Campus Helsingborg), 1651-2197 ; THID-07/5069
ER -

TY - BOOK
A1 - Margen, Peter H.
T1 - Optimering av solvärmecentraler med respektive utan värmepump : VVS 78
Y1 - 1978
CY - Nyköping
PB - Studsvik energiteknik
ER -

TY - BOOK
A1 - Olsson, Ulf
T1 - Dieselmotordriven värmepump för gruppbebyggelse och större fastigheter : förstudie i Fisksätra
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:45
SN - 91-540-3226-1
ER -

TY - BOOK
A1 - Rosengren, Bengt
T1 - Förvärmning med värmepump av dricksvatten till mjölkkor : Preheating of drinking water to dairy cows by means of heat pump
Y1 - 1991
CY - Lund
T3 - Specialmeddelande / Sveriges lantbruksuniversitet, Institutionen för lantbrukets byggnadsteknik (LBT), 0348-0593 ; 179
ER -

TY - BOOK
A1 - Schroeder, Kjell
T1 - Sjövärmeprojekt Motala Väster : utvärdering och analys av värmekälla och värmepump
AU - Svensson, Torbjörn
Y1 - 1989
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1989:58
SN - 91-540-5019-7
ER -

TY - BOOK
T1 - Solenergi och värmepump värmer kontor och industrilokaler.

Y1 - 1983
T3 - SV-rapport, 99-0308735-7 ; 1983:1
ER -

TY - BOOK
A1 - Stillesjö, Staffan
T1 - Värmepump eller direktel för lågenergihus i grupp : förstudie
Y1 - 1984
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1984:187
SN - 91-540-4281-X
ER -

TY - BOOK
T1 - Termokemisk lagring i kombination med dieseldriven värmepump : fullskaleprov i Televerkets arbetslokal i Jakobsberg
AU - Bakken, Kjell
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:102
SN - 91-540-3782-4
ER -

TY - BOOK
T1 - Värmeåtervinning med värmepump från Scaniarinken i Södertälje
AU - Hagstedt, Bertil
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:123
SN - 91-540-3812-X
ER -

TY - BOOK
A1 - Wilén, Peter
T1 - Grundvatten som värmekälla för husuppvärmning med värmepump : litteraturstudie, system och ekonomi
Y1 - 1981
CY - Göteborg
T3 - Rapport / Jordvärmegruppen, Chalmers tekniska högskola, 0349-9723 ; 1
ER -

TY - BOOK
T1 - Energi ur grundvatten : inventering av stora grundvattenmagasin för energiutvinning med värmepump. Kartbilaga till slutrapport : länsvis redovisning av tätorternas och tätortsregionernas energiresurser i stora grundvattenmagasin
Y1 - 1980
ER -

TY - BOOK

A1 - Jacobson, Lars
T1 - Jordvärmesystem med värmepump i befintlig och ny bebyggelse : förprojektering av sju objekt i Västsverige
Y1 - 1982
KW - Geotermisk energi
KW - Värmepumpar
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:112
SN - 91-540-3793-X
ER -

TY - BOOK
A1 - Larsson, Lars I.
T1 - Kraftvärmeverk och värmepump för utnyttjning av rökgasens kondensationsvärme
Y1 - 1980
CY - Lund
T3 - Technical report from the Division of Heat and Power Engineering, 0280-9931 ; 5101
ER -

TY - BOOK
A1 - Löving, Ronald
T1 - Elmotordriven värmepump för luft/vatten i Backatorp, Göteborg
AU - Bäckström, Bernt
Y1 - 1983
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1983:87
SN - 91-540-3988-6
ER -

TY - BOOK
A1 - Möller, Kjell
T1 - Gastät lagring och torkning av spannmål med värmepump : Airtight storage and drying of grain using a heat pump
AU - Nilsson, Christer
Y1 - 1988
CY - Lund
PB - LBT
SN - 91-576-3577-3
ER -

TY - BOOK
A1 - Andersson, Frank
T1 - Fjärås centrum : projektering av solvärmesystem med värmepump
AU - Länsberg, Mats
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:8
SN - 91-540-3170-2
ER -

TY - BOOK

A1 - Areskoug, Mats
T1 - Miljöfysik
Y1 - 1997
N1 - Prel.uppl.
KW - Miljöfysik
CY - Malmö
PB - Lärarhögskolan
ER -

TY - BOOK
A1 - Areskoug, Mats
T1 - Miljöfysik
Y1 - 1998
CY - Malmö
PB - Malmö högskola, Lärarutbildningen
ER -

TY - BOOK
A1 - Axby, Fredrik
T1 - Rökgaskondensering med värmepump = Flue gas condensing with heat pump
AU - Pettersson, Camilla
Y1 - 2004
KW - Fjärrvärme
KW - Värmeteknik
CY - Stockholm
PB - Värmeforsk
T3 - Värmeforsk, 0282-3772 ; 891
ER -

TY - BOOK
A1 - Backman, Anders
T1 - Värmeåtervinning ur avloppsvatten via värmepump : förstudie i Gävle
AU - Hallenberg, Jonas
AU - Bustad, Tohmmy
Y1 - 1983
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1983:44
SN - 91-540-3922-3
ER -

TY - BOOK
A1 - Berendson, Jaak
T1 - Värmepump Motala Väster : korrosionsuppföljning
Y1 - 1991
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1991:50
SN - 91-540-5374-9
ER -

TY - BOOK
A1 - Bergström, Ulf
T1 - Direktverkande värmepump för småhus : utvärdering av funktion och energibesparing genom fältmätningar
AU - Fehrm, Mats

AU - Mattsson, Per Olof
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:18
SN - 91-540-3641-0
ER -

TY - BOOK
A1 - Bovin, Jan
T1 - Stirlingmotordriven värmepump : förstudie avseende planerat experimentbygge i Kågeröd
Y1 - 1990
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1990:25
SN - 91-540-5180-0
ER -

TY - BOOK
A1 - Bäckström, Bernt
T1 - Värmepump med energistapel : förprojektering av befintligt mindre flerbostadshus i Göteborg
AU - Hallén, Tomas
AU - Samuelsson, Torbjörn
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:140
SN - 91-540-3618-6
ER -

TY - BOOK
A1 - Carlsson, Jan
T1 - Värmepump typ Stirling : examensarbete
AU - Åkersten, Lars-Erik
Y1 - 1981
CY - Göteborg
T3 - Rapport / Institutionen för energiteknik, Ångteknik med reaktorteknologi, Chalmers tekniska högskola. T, 0280-9249 ; 93
ER -

TY - BOOK
A1 - Edman, Jan
T1 - Isbana som värmekälla för värmepump : förstudie i Hörby
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:157
SN - 91-540-3389-6
ER -

TY - BOOK
T1 - Energiutvinning ur ytvatten via värmepump : förprojektering i Borlänge
AU - Backman, Anders
Y1 - 1980

CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:109
SN - 91-540-3326-8
ER -

TY - BOOK
A1 - Enström, Henrik
T1 - Louddens värmepump : utvärdering av avloppsvatten/fjärrvärme-värmepump
AU - Solin, Lars
Y1 - 1987
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1987:16
SN - 91-540-4679-3
ER -

TY - BOOK
A1 - Enström, Henrik
T1 - Uppsala värmepump : utvärdering av avloppsvatten/fjärrvärme, värmepump
AU - Solin, Lars
Y1 - 1988
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1988:97
SN - 91-540-4960-1
ER -

TY - BOOK
A1 - Enström, Henrik
T1 - Visby värmepump : utvärdering
AU - Nilsson, Madelaine
Y1 - 1989
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1989:29
SN - 91-540-5020-0
ER -

TY - BOOK
A1 - Fransson, Kenneth
T1 - Energiåtervinning i animalieproduktionen med värmepump : värmekälla mjölk och stalluft
Y1 - 1982
N1 - Examensarbete
CY - Uppsala
T3 - Rapport / Sveriges lantbruksuniversitet, Institutionen för arbetsmetodik och teknik, 0347-9773 ; 77
SN - 91-576-1314-1
ER -

TY - BOOK
T1 - Från kakelugn till värmepump : en presentation av värmepumpinstallationerna i Forsmarks bruk
Y1 - 1987
CY - Vällingby

PB - Vattenfall
ER -

TY - BOOK
T1 - Från S- till F-system med värmepump : ombyggnad av självdragssystem till mekanisk frånluftsventilation med värmepump : ett praktikfall
AU - Erikson, Bengt E.
Y1 - 1985
CY - Gävle
PB - Statens inst. för byggnadsforskning
T3 - Meddelande / Statens institut för byggnadsforskning, 0347-4348 ; 85:1
SN - 91-540-9219-1
ER -

TY - BOOK
A1 - Grafström, Hans
T1 - Värmepump för uppvärmning av friluftsbad : förstudie i Sölvesborg
AU - Lagergren, Staffan
Y1 - 1980
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1980:44
SN - 91-540-3224-5
ER -

TY - BOOK
A1 - Gustafsson, Gösta
T1 - Avfuktning med värmepump i växthus : Dehumidification with heat pump in greenhouses
AU - Nimmermark, Sven
Y1 - 1991
CY - Lund
T3 - Rapport / Sveriges lantbruksuniversitet, Institutionen för lantbrukets byggnadsteknik (LBT), 0348-0259 ; 74
ER -

TY - BOOK
T1 - Gårdsvärme : ved, halm, torv, värmepump
AU - Liedholm, Hans
AU - Leuchovius, Torbjörn
Y1 - 1983
CY - Stockholm
PB - LT
SN - 91-36-02108-3
ER -

TY - BOOK
A1 - Hallén, Tomas
T1 - Västra klinikerna i Jönköping : grundvatten som värmekälla för värmepump
AU - Edberg, Bo
Y1 - 1985
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1985:88

SN - 91-540-4428-6
ER -

TY - BOOK
A1 - Hallenberg, Jonas
T1 - Avloppsvatten som värmekälla till värmepump : utvärdering av installation i Boden
AU - Wahlberg, Herje
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:125
SN - 91-540-3816-2
ER -

TY - BOOK
A1 - Hallenberg, Jonas
T1 - Sjövatten som värmekälla till värmepump : erfarenheter från uppvärmning av två småhus i Falun
AU - Norbäck, Kjell
Y1 - 1982
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1982:46
SN - 91-540-3694-1
ER -

TY - BOOK
A1 - Henningsson, Lars
T1 - Värmepump : installationsförslag och marknadsundersökning
Y1 - 1982
CY - Luleå
T3 - Examensarbete / Tekniska högskolan i Luleå, 0349-6023 ; 1982:067E
ER -

TY - BOOK
A1 - Henriksson, Jan
T1 - Bygg din egen värmepump
AU - Nilsson, Hans
Y1 - 1983
CY - Ljungby
PB - Colego
ER -

TY - BOOK
A1 - Hill, Anders
T1 - Ammoniak som köldmedie i värmepump
Y1 - 1989
CY - Stockholm :
PB - Statens råd för byggnadsforskning ;
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1989:103
SN - 91-540-5120-7
ER -

TY - BOOK
A1 - Hirschfeldt, Claes-Henrik

T1 - Utvärdering av en öppen kemisk värmepump
AU - Olofsson, Richard
Y1 - 1995
CY - Luleå
T3 - Examensarbete / Tekniska högskolan i Luleå, Ingenjörslinjen 80 poäng, 1102-4070 ; 1995:44I
ER -

TY - BOOK
A1 - Härröd, Peter
T1 - Energibesparing med värmepump i banddiskmaskin
AU - Jorlöv, Andreas
Y1 - 2000
N1 - Examensarbete
CY - Göteborg
PB - Chalmers Lindholmen högsk., Chalmers tekniska högsk.
ER -

TY - BOOK
A1 - Högström, Carina
T1 - Värmepump med propan som köldmedium
Y1 - 1999
N1 - Lic.-avh. Stockholm : Tekn. högsk.
CY - Stockholm
T3 - Trita-REFR, 1102-0245 ; 99:26
ER -

TY - BOOK
A1 - Karlsson, Erik
T1 - Värmepump 1, Findus i Bjuv
AU - Taberman, Marie
Y1 - 2003
CY - Göteborg
PB - Chalmers Lindholmen högsk., Chalmers tekniska högsk.
ER -

TY - BOOK
A1 - Lemmeke, Leif
T1 - Storskalig värmeförsörjning med värmepump : principförslag med kombinerat utnyttjande av yt- och grundvatten som värmekälla
Y1 - 1981
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1981:126
SN - 91-540-3597-X
ER -

TY - BOOK
A1 - Lindelöf, Jan
T1 - Effektiv effektivare värmepump : idéhandbok om värmepumpar
AU - Sandström, Bengt
AU - Sandquist, Hans
Y1 - 1995
CY - Stockholm
PB - Stockholm energi
SN - 91-630-3394-1

ER -

TY - BOOK
A1 - Lundén, Roger
T1 - Värmepump med effektutjämningssystem : en studie av ett system där värmepump kombineras med värmeackumulering i jord
Y1 - 1977
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningen, 0346-5616 ; 1977:85
SN - 91-540-2784-5
ER -

TY - BOOK
A1 - Lundqvist, Per G.
T1 - Stirling värmepump : konstruktion, byggande och prestandaprovning : slutrapport
Y1 - 1996
CY - Stockholm
PB - KTH, Inst för energiteknik
T3 - Trita-REFR, 1102-0245 ; 96:20
ER -

TY - BOOK
A1 - Mårtensson, Hans
T1 - Värmepump i villan
Y1 - 2007
KW - Värmepumpar
CY - Västerås
PB - Ica
SN - 978-91-534-2873-2 (inb.)
ER -

TY - BOOK
T1 - Oljebrännare vs värmepump
AU - Andersson, Ola
Y1 - 1997
N1 - Examensarbete
CY - Göteborg
PB - Ingenjörs- och sjöbefälsskolan vid Chalmers tekniska högsk.
ER -

TY - BOOK
A1 - Persson, Lars
T1 - Pelletseldning eller värmepump? : historik, nutid, framtid
Y1 - 2005
CY - Delsbo
PB - GDE-Net
ER -

TY - BOOK
T1 - Processmodell för värmepump
AU - Abrahamsson, Lars
Y1 - 1986
CY - Luleå

T3 - Teknisk rapport / Tekniska högskolan i Luleå, 0349-3571 ; 1986:012T
ER -

TY - BOOK
A1 - Ransmark, Sven-Erik
T1 - Värmepump med Lorenzprocess
Y1 - 1985
T3 - Institutionen för värme- och kraftteknik, Tekniska högskolan i Lund, 0282-1990 ; 3128
ER -

TY - BOOK
A1 - Renntun, Mats
T1 - Värmepump och värmelagring
Y1 - 1978
CY - Lund
T3 - Technical report from the Division of Heat and Power Engineering, 0280-9931 ; 5078
ER -

TY - BOOK
A1 - Rönnelid, Mats
T1 - Solfångare och värmepump : utvärdering av ett värmesystem i Uppsala
AU - Tepe, Rainer
Y1 - 2004
KW - Solfångare
KW - Solenergi
KW - Geotermisk energi
KW - Uppvärmning (byggnader)
CY - Borlänge
PB - EKOS, Högskolan i Dalarna
ER -

TY - BOOK
A1 - Saros, Georg
T1 - Att välja värmepump : handledning för att välja värmepump och att räkna på ekonomin
AU - Pettersson, Anders
Y1 - 1998
CY - Stockholm
PB - Konsumentverket :
SN - 91-7398-636-4
ER -

TY - BOOK
A1 - Tepe, Rainer
T1 - Solfångare och värmepump : marknadsöversikt och resultat av en preliminär simuleringsstudie av värmesystem med solfångare och bergvärmepump
AU - Rönnelid, Mats
Y1 - 2002
KW - Solfångare
KW - Solenergi
KW - Solenergi
CY - Borlänge
PB - SERC, Högskolan i Dalarna

T3 - Centrum för solenergiforskning, Högskolan Dalarna, 1401-7555 ; 75
ER -

TY - BOOK
A1 - Tepe, Rainer
T1 - Solfångare och värmepump : marknadsöversikt och resultat av en preliminär simuleringsstudie av värmesystem med solfångare och bergvärmepump
AU - Rönnelid, Mats
Y1 - 2002
KW - Solfångare
KW - Solenergi
KW - Geotermisk energi
KW - Uppvärmning (byggnader)
CY - Borlänge
PB - EKOS, Högskolan i Dalarna
T3 - EKOS publikation, 1650-1497 ; 2002:2
ER -

TY - BOOK
T1 - Värmepump : ett tekniskt system i utveckling
Y1 - 1988
CY - Stockholm
PB - Styr. för teknisk utveckling
T3 - STU-information, 0347-8645 ; 671
SN - 91-7850-243-8
ER -

TY - BOOK
T1 - Värmepump för avloppsvatten i Sala.
Y1 - 1982
CY - Vällingby
T3 - SV-rapport, 99-0308735-7 ; 1982:3
ER -

TY - BOOK
T1 - Värmepump för avloppsvatten i Sundsvall.
Y1 - 1982
CY - Vällingby
T3 - SV-rapport, 99-0308735-7 ; 1982:4
ER -

TY - CHAP
A1 - Waldenstad, Bengt
T1 - Testas i Härnösand : Stirlingmotor driver värmepump
AU - Österberg, Roine
Y1 - 1985
JF - VVS & energi
VL - 1985:5, s. 35-36
PB - VVS & energi
SN - 0280-9524
KW - Stirlingmotorer-- Sverige -- Ångermanland
KW - Värmepumpar-- Sverige -- Ångermanland
KW - Härnösand
ER -

TY - BOOK

A1 - Wirén, Mikael
T1 - Avancerad värmepump för enbostadshus :
marknadsförutsättningar i Sverige, Norge, USA och Kanada
Y1 - 1988
CY - Stockholm
PB - Statens råd för byggnadsforskning :
T3 - Rapport / Byggforskningsrådet, 0349-3296 ; 1988:48
SN - 91-540-4891-5
ER -

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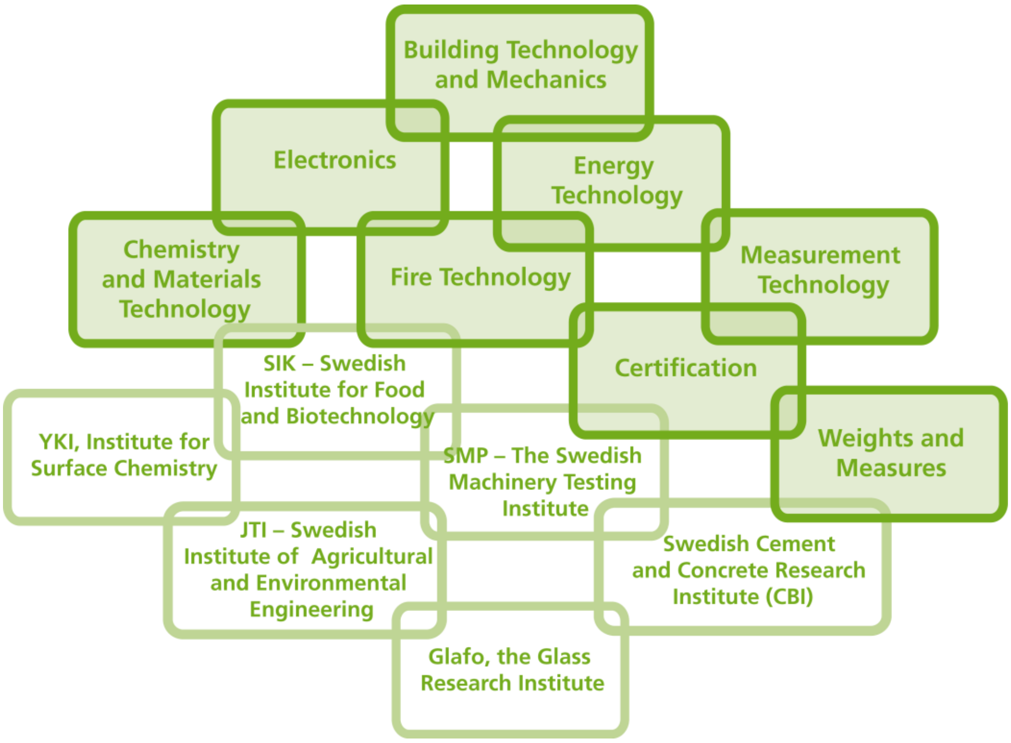

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