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Project

Seasonal performance calculation for residential heat pumps with combined space heating and domestic hot water production

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SUMMARY

Based on a literature survey to characterise the state of the art in international standardisation, a calculation method for the seasonal performance factor of heat pump systems has been developed. The method can deal with only heating or domestic hot water heat pumps as well as heat pumps yielding an alternative or combined production of space heating and domestic hot water production. For the combined production, however, results from component testing have to be available. As a first step, the method is restricted to hydronic distribution and monoenergetic operation (heat pump + electrical back-up heating). Special attention has been paid to a transparent procedure.

The method evaluates the annual cumulative frequency of the dry bulb ambient temperature to weighten the energy amount to be produced at certain meteorological and system dependent boundary conditions that have an impact on heat pump performance. Heat pump performance is given by standard testing, which is corrected for the operation conditions. Further correction is applied for part-load effects, auxiliary electrical energy input and storage losses.

For both heating and domestic hot water production, single Seasonal Performance Factors (SPF) are calculated, which are combined by weighting with the energy amounts supplied to heating and domestic hot water production respectively. SPF heating for the monoenergetic mode is derived by the energy amounts delivered by the heat pump and back-up system respectively.

After presentation of the method in standardisation committees, an intense testing and thereby further development is planned for 2003. Combined systems and a reduction of input data are in focus for 2003, too.

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Objectives

The objective of the project is the development of a transparent and easy-to-use calculation method for the seasonal performance factor of heat pump systems on the basis of publicly available data. The scope of the method are systems for both alternative and simultaneous hot water production. As a first step, the method is restricted to hydronic distribution and monoenergetic operation. The method aims to judge the potential of efficiency gains and thereby energy savings of simultaneous domestic hot water production with the same heat pump by means of e.g. desuperheating or condensate subcooling. As different degrees of sophistication revealed during the development, two versions of the method shall be created:

An easy-to-use hand calculation method and a more comprehensive version to be implemented in an Excel-sheet.

The goals for the year 2002 have been a literature survey of existing methods and a proposal for the calculation method. A literature survey was to be carried out to characterise the state of the art especially in international standardisation. On this basis, a calculation method was to be developed and presented in standardisation Committees.

The method shall be implemented in a national standard. Therefore cooperation with the standardisation committee SIA 384 on the national level by commitment to the CEN TC 228 Working Group 4 of the European Standardisation Committees is in progress.

Moreover the project is the first Swiss contribution to the upcoming IEA HPP Annex 28.

Work carried out and results

Literature survey

As basis for the development of the calculation method, a survey of existing directives and standards has been carried out. The found calculation methods can be classified in three groups:

1. methods, that directly give an SPF (seasonal performance factor) dependent on the operation conditions and/or system configuration [1]
2. methods, that evaluate data of the rated COP (coefficient of performance) and apply correction factors with regard to the operation conditions [2]
3. methods, that evaluate the annual cumulative frequency of the ambient temperature as basis to weighten corrected COP values at various operation points

As a transparent method is meant to be developed in this project, only methods of the third category are considered.

The survey has shown the following methods to be relevant for the development:

- VDI 2067-6: [3]
  "Economy calculation of heat consuming installations: Heat pumps"

- Handrechenmethode HTA Luzern: [4]
  "Handrechenmethode zur Bestimmung der Jahresarbeitszahl von Wärmepumpenanlagen für Heiz- und Warmwasserbetrieb"

- CEN/TC 228/WG 4 N 259 [5]
  "Methods for calculation of system energy requirement and system efficiency"

- ASHRAE standard 116 [6]
  "Methods of testing for rating seasonal efficiency of unitary air conditioners and heat pumps"

Proposed calculation method

A flow-chart of the approach for the calculation method is shown in the appendix. The system borders are the same as shown in figure 3 in the Annex overview in the Appendix.

Principle of the calculation method

The method evaluates the frequency of the ambient dry-bulb temperature. As first step, the ambient temperature is divided into classes, characterised by operation points, which are set in the centre of the considered temperature class. The number of operation points is free to choose and depends on the required exactness of the result. The resolution is also dependent on the quality and of available values of the heating capacity and the COP.

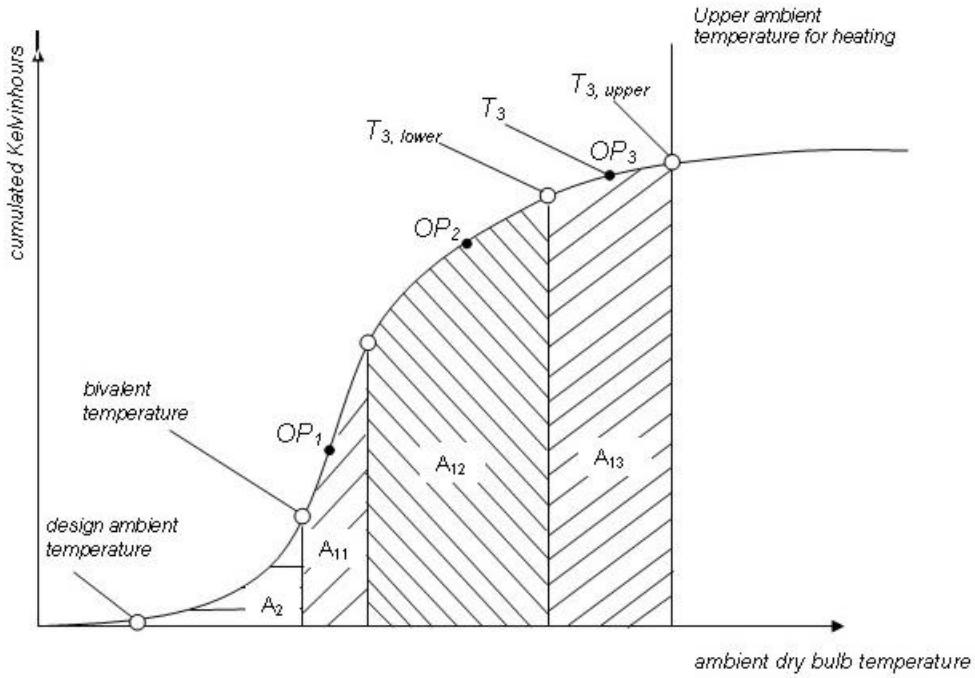


Figure 1: example of distribution of operation points in annual cumulative frequency

To take into account the dependency on the actual operation condition (source/sink temperature), a correction of the heating capacity and the COP is required. The results are the steady-state heating capacity and COP-values which are normally given by the manufacturer or test centres at standard rating points, e.g. according to EN 255-2 [15]. If only few data is available, an interpolation method shall be applied.

Further correction of these steady state values is applied to take into account losses by part load operation, electrical input by auxiliaries and defrost losses. The recent ones unless they are not included in the standard rating points according to EN 255-2.

These corrected values are weighted with the relation of heat production at the respective temperature class and the total heat production. This procedure is carried out for all operation points.

For monoenergetic systems, another correction has to be applied. The relation between the amount of energy delivered by the heat pump and the electrical back-up heater is used as weighting factor for the monoenergetic operation mode. As only electrical back-up is considered in this phase, the efficiency of the back-up system is 1.

The result is the seasonal performance factor SPF_h of the heat pump for heating only.

For the domestic hot water generation the procedure is performed in the same way as in the heating mode. Further correction has to be applied for storage and distribution losses during storage charging, if these losses are not included in the rated COP values.

The result is the seasonal performance factor SPF_w for the domestic hot water mode.

The two SPF numbers are combined by weighting them with the respective amount of energy.

In case of the combined generation of domestic hot water, further information of the process has to be provided. In an adequate test procedure, that is actually developed at the national heat pump test centre in Winterthur-Töss [6], standard COP-values have to be provided for the combined operation. In a further step, the amount of energy generated in the combined mode has to be determined. With these data, a weighting can be performed between the three operation modes only space heating, only hot water production and combined heating and hot water production.

The result of the weighting is the over-all seasonal performance factor SPF_{hw} of the system.

Steps to perform the calculation method

Step 1: Input data

The following data is needed as input information for the calculation method:

- Meteorological data of the site
    - hourly frequency of the ambient dry bulb temperature,
    - design air temperature
- Design values of the heating system
    - heating energy (calculated according to SIA 380/1:2001 [8])
    - space heating demand (calculated according to SIA 384/2 [9])
    - upper ambient temperature for heating, balance point (lower ambient temperature where back-up heater is required)
- heat pump parameters: heating capacity, COP-values according to EN 255
- design values of the domestic hot water system
    - hot water load, supply temperature hot water, inlet temperature cold water
- parameter of the storage system (heat-loss)
- annual frequency of the source temperature

If not all required input data is available, an appendix to the calculation method will provide default values, which are oriented at the lower end of efficiency available on the market. By this concept the method can be carried out in every case, but it is worth providing the real data, because they will probably deliver better results. This procedure is well established in European standardisation.

Step 2: Meteorological calculation

Meteorological data sets of the ambient temperature in hourly distribution can be obtained by standard software, e.g. Meteonorm [10], for many sites of the world. For the transformation to the annual cumulative frequency, which is needed as input, a computational routine has been written to provide the necessary data. It will be implemented in the Excel-sheet. For the hand calculation the needed data can be given as look-up tables for specific climatic region of Switzerland as appendix to the method.

From the given meteorological data, the following values can be derived:

- Generation load weighting factors for different resolution of operation points
- Source temperature for air-to-water heat pumps

Step 3: Heating capacity and COP-values

Usually information about the heating capacity and COP dependent on source temperature and supply temperature of the heating system is provided by test centres. If data of standard rating points (e.g. according to EN 255-2) are not available, information of the manufacturer can be used.

As a first step for Switzerland, the standard rating points of WPZ-Töss [11], which are shown in fig. 2 for different types of heat pumps, have been taken as basis for the calculation method. These cover all points of EN 255 and include some additional points. A linear interpolation of these standard rating points is a good compromise between exactness and effort for the processing and can be performed by hand, too.

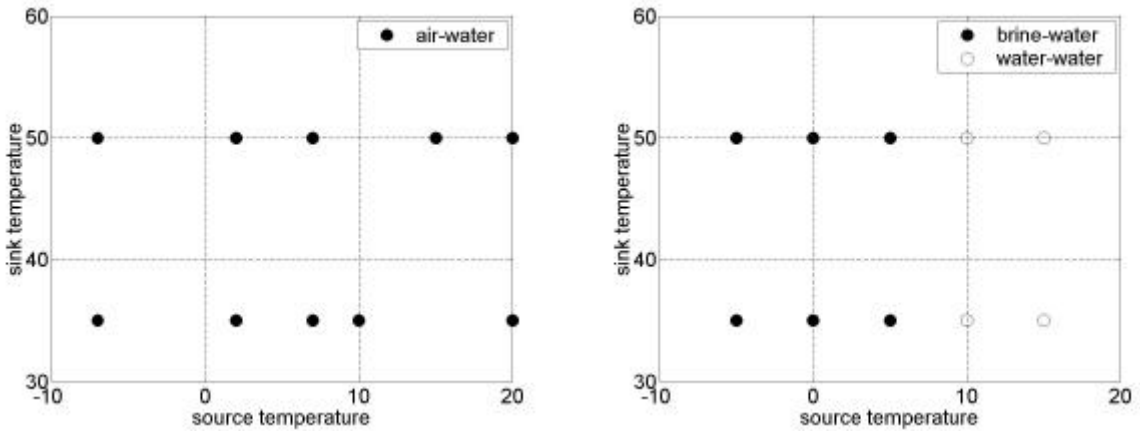


Figure 2: standard rating points of WPZ for air-water, brine water and water-water heat pumps

As a second step, methods to handle reduced input information shall be developed and implemented in the Excel sheet. A spline interpolation seems to be a well-suited possibility to deal with reduced data availability.

Step 4: correction of the rated COP-values

Correction for part load operation

For the correction of part-load operation effects, additional information about the heat pump has to be provided. In the project “dynamic heat pump testing" [12] methods for the calculation of the heat generation degradation of the heat pumps due to cycling have been developed. The necessary component characteristics can be derived from a developed test procedure [13]. The problem is that up to now, this is no standard testing, so data might not be available.

Correction for auxiliaries

The electrical input by auxiliaries can be derived from rated power of the auxiliaries and their runtime. The runtime strongly depends on control strategy and dimensions of the components. Circulation pumps run through the whole heating period or the runtime of the pumps is coupled to the operation of the heat pump. A mean value of the runtime can be obtained by the design heating capacity of the heat pump and the yearly energy demand.

Correction for defrosting

Usually available data of the rated heating capacity and the COP take into account the energy input to defrosting cycle, so an explicit correction of defrosting is not necessary. Therefore the priority of models for defrosting correction is not so high. Results of a project [14] shall be considered to provide correction terms if needed.

Correction for storage losses

Unless no COP-values according to EN 255-3 are available, the COP values for the domestic hot water production have to be corrected for the storage losses. If the system configuration includes a storage for heating, correction for these losses have to be applied for the heating mode, as well. Storage losses could be given directly as energy values [kWh/24h] or as heat loss coefficient [W/m^2/K], where a medium temperature difference over the storage envelope must be evaluated. The heat loss values are usually included in the manufacturer data of the storage.

Step 5: Calculation of SPF

The corrected COP-values are weighted with the amount of energy of the respective operation point according to fig. 1. The resulting SPF_h for the heating and the SPF_w for domestic hot water are combined by weighting the amount of energy as well according to the equation

$$SPF_{hw} = \frac{Q_h + Q_w}{Q_h / SPF_h + Q_w / SPF_w} \qquad \text{(eq. 1)}$$

where Q is the delivered energy for space heating and domestic hot water respectively and SPF is the respective Seasonal Performance Factor. For combined production of heating and domestic hot water production, further information has to be provided by test results, because heating capacity decreases for the times of combined production.

National Cooperation

Close cooperation is ongoing with a parallel project at the Swiss national heat pump test centre at Winterthur-Töss [7]. The project has the objective to develop a test procedure for alternative and simultaneous working heat pump systems on the basis of existing standards, in particular the EN 255-2 [15] and EN 255-3 [16]. The test procedure provides additional information of the heat pump for the combined heating and hot water generation. The existing test procedures are not sufficient for the combined operation mode.

International Cooperation

The calculation method has been presented in the CEN TC 228 Working group (Document N 273), which is committed to energy system calculation methods. An ad-hoc working group for the heat pump calculation method for prEN 14335 has been formed with the members of France, the UK and Switzerland. Up to the next meeting in March, the ad-hoc group will present a version of the calculation method to be sent for public enquiry.

As mentioned above, the project is the first Swiss contribution of the upcoming Annex 28 of the IEA HPP implementing agreement with the title "Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating." The annex is to start at the 1st January 2003. Besides Switzerland, participating countries are AT, CA, FR, NO, US, UK. Interested are GE, JP, NL and SE, too. In February 2003 a kick-off meeting is planned in Switzerland at FHBB to coordinate the activities of the participating countries. A short description of the Annex 28 is attached in the Appendix.

Evaluation of 2002 and Perspectives for 2003

The objective for 2002 was the proposal of the calculation method and the presentation in standardisation committees. With the comments of the committees, a revision and further development of the method will be carried out in 2003.

However, some difficulties revealed during the development process, e.g. no test result are usually available for the part load operation. Therefore a focus in 2003 is on refinement of the single steps with regard to reduced data input. Simulation can help to derive default values, which can be provided as look-up tables or diagrams. In this context simulation results of the project STASCH [17] can be evaluated for this project.

Another focus in 2003 is on evaluation of the combined operation, as testing proceeds in the project at WPZ [7]. In particular, the combination of the SPF of the three operation modes has to be investigated.

References

[1] *VDI Richtlinie 2067,* ***Kostenberechnung für Heizanlagen, Blatt 6, Wärmepumpen, Kurzverfahren,*** VDI-Verlag, Düsseldorf, 1986

[2] *VDI Richtlinie 4650, Blatt 1,* ***Berechung von Wärmepumpen, Kurzverfahren zur Berechnung der Jahresaufwandszahlen von Wärmepumpenanlagen****, Elektro-Wärmepumpen zur Raumheizung*, VDI Verlag, Düsseldorf, November 2000

[3] *VDI Richtlinie 2067,* ***Kostenberechnung für Heizanlagen, Blatt 6, Wärmepumpen, Langverfahren,*** VDI-Verlag, Düsseldorf, 1986

[4] G. Zweifel, M. Wetter: ***Handrechenmethode zur Bestimmung der Jahresarbeitszahl von Wärmepumpenanlagen für Heiz- und Warmwasserbetrieb****,* 1997, aus Kostengünstige Niedertemperaturheizung mit Wärmepumpe, Technisches Handbuch, download from the website of the research programme www.waermepumpe.ch/fe/nth category "Berichte"

[5] C. Feldmann: ***Methods for calculation of system energy requirement and system efficiency*****,** Working Paper N 259 of CEN TC 228 Working Group 4, 2002

[6] *ASHRAE standard 116:* ***Methods of testing for rating seasonal efficiency of unitary air conditioners and heat pumps*****,** American society of Heating, Refrigerating and Air conditioning Engineers, inc., Atlanta 1995

[7] A. Montani: ***Wärmepumpentest für die kombinierte Raumheizung und Warmwasseraufbereitung*****,** annual report, download from the website of the research programme www.waermepumpe.ch/fe category "Berichte"

[8] SIA 380/1:2001, ***Thermische Energie im Hochbau***, 2001, Schweizerischer Ingenieur und Architektenverein

[9] SIA 384/2, ***Wärmeleistungsbedarf von Gebäuden***, 2001, Schweizerischer Ingenieur und Architektenverein

[10] ***Software Meteonorm***, Version 4.0, Meteotest, 2002

[11] ***WPZ Bulletin***, November 2002, download from http://www.wpz.ch

[12] E. Shafai, D. Zogg, M. Ehrbar, L. Wirth*:* ***Dynamischer Wärmepumpentest, Phase 1-3, Etappe 3, Modellansatz für die prüftechnische Charakterisierung der Minderwärmeproduktion***, final report, download from the website of the research programme www.waermepumpe.ch/fe category "Berichte"

[13] M. Ehrbar, B. Hubacher: ***Dynamischer Wärmepumpentest, Phase 2 Validierung des Modellansatzes und Entwicklung einer Prüfprozedur***, final report 2002, download from the website of the research programme www.waermepumpe.ch/fe category "Berichte"

[14] M. Ehrbar, B. Hubacher: ***Verbesserung des Abtauens bei luftbeaufschlagten Verdampfern***, final report, 2000, download from the website of the research programme www.waermepumpe.ch/fe category "Berichte"

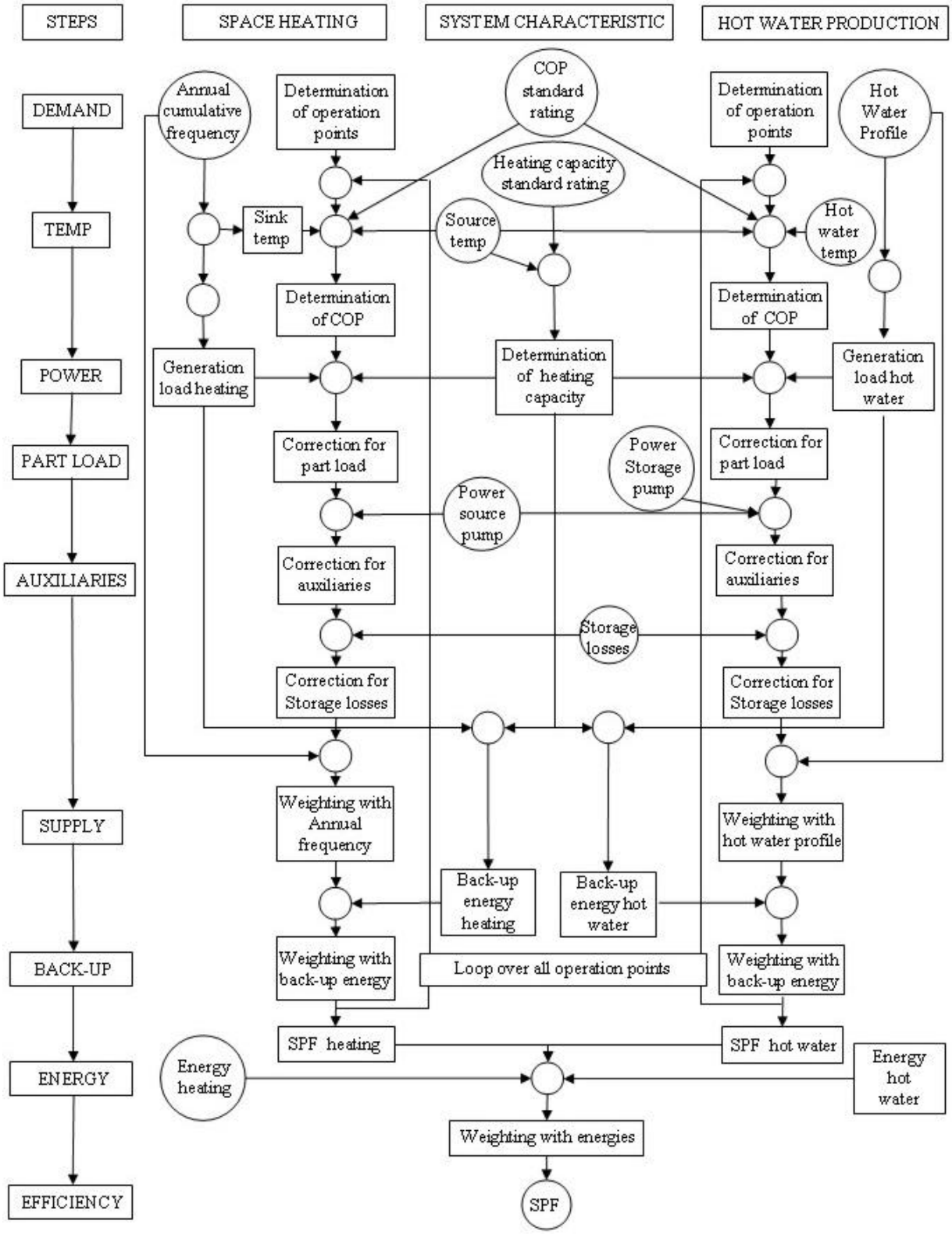
[15] EN 255-2: ***Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors – Heating mode – Part 2: Testing and requirements for marking for space heating units,*** SN EN 255-2:1997

[16] EN 255-3: ***Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors – Heating mode – Part 3: Testing and requirements for marking for sanitary hot water units,*** SN EN 255-3:1997

[17] T. Afjei at al: ***Standardschaltungen für Kleinwärmepumpen***, final report, download from the website of the research programme www.waermepumpe.ch/fe category "Berichte"

Appendix

Flow Chart of the calculation method



Annex 28 of IEA HPP Implementing Agreement

Test procedure and seasonal performance calculation for residential heat pumps with combined space and domestic hot water heating

Date of the Annex: 01/01/2003 – 30/04/2005

Kick-off meeting probably in February at FH Beider Basel

Participating countries/institutions (alphabetical order):

Austria (Arsenal), Canada, France (CETIAT), Norway (SINTEF), Switzerland (FHBB), USA

Interested Countries:

Germany, Japan, Netherlands, Sweden

Systems to be investigated:

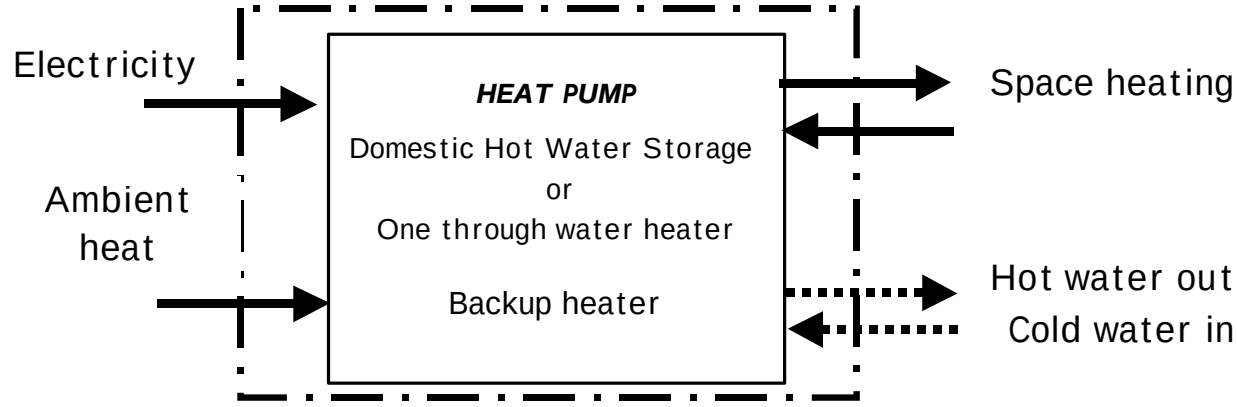


Figure 3: System borders of the systems investigated

Objectives:

The Annex will yield

- **Comprehensive test procedures** for heat pump systems with combined space and domestic hot water heating as IEA recommendations to the national and international standardization institutions.

- **Easy to use methods to calculate the over-all seasonal performance factor** of heat pump systems for the alternative and simultaneous space - and domestic hot water heating.