D4.2. / D 3.4. Concept for evaluation of SPF
Version 2.0

A defined methodology for calculation of the seasonal performance factor and a definition which devices of the system have to be included in this calculation:

*Air to air heat pumps*

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**Foreword**

The aim of this document is to define the system boundaries for calculating the SPF for heating and cooling of air to air heat pump systems, with non ducted external units, and internal units that can be ducted or non-ducted. Defining the system boundaries has direct impact on the necessary measurement equipment to measure the needed parameters for the calculation of the different SPF. For this reason the document should be revised after the first measurement period to see if the defined system boundaries can be measured in the field or should be adapted.

**Nomenclature**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHA</td>
<td>space heating</td>
<td>[-]</td>
</tr>
<tr>
<td>HP</td>
<td>heat pump</td>
<td>[-]</td>
</tr>
<tr>
<td>CU</td>
<td>Cooling unit</td>
<td>[-]</td>
</tr>
<tr>
<td>SPF  (i)</td>
<td>Seasonal performance factor (Index: (H) for heating, (C) for cooling)</td>
<td>[-]</td>
</tr>
<tr>
<td>COP</td>
<td>Coefficient of performance</td>
<td>[-]</td>
</tr>
<tr>
<td>EER</td>
<td>Energy efficiency ratio</td>
<td>[-]</td>
</tr>
<tr>
<td>SEER</td>
<td>Seasonal energy efficiency ratio</td>
<td>[-]</td>
</tr>
<tr>
<td>SCOP</td>
<td>Seasonal coefficient of performance</td>
<td>[-]</td>
</tr>
</tbody>
</table>

**For heating mode:**

- \(Q_{H_{hp}}\): quantity of heat of the HP in SH operation \([\text{kWh}]\)
- \(Q_{H_{bu}}\): quantity of heat of the back-up heater for SH \([\text{kWh}]\)
- \(E_{S_{fan}}\): electrical energy use of the HP source fans \([\text{kWh}]\)
- \(E_{B_{fan}}\): electrical energy use of the heat sink (building) fans \([\text{kWh}]\)
- \(E_{H_{hp}}\): electrical energy use of the HP for SH \([\text{kWh}]\)
- \(E_{H_{bu}}\): energy use* of the back-up heater for SH \([\text{kWh}]\)

*For additional heating other than electrical back up heater the energy content of the fuel demand has to be taken into account

**For cooling mode:**

- \(Q_{C}\): produced cooling energy of the CU for cooling \([\text{kWh}]\)
- \(E_{S_{fan}}\): electrical energy use of the CU heat sink fans \([\text{kWh}]\)
- \(E_{B_{fan}}\): electrical energy use of the building fans \([\text{kWh}]\)
- \(E_{CU}\): electrical energy use of the CU \([\text{kWh}]\)
**Seasonal Performance Factor (SPF) evaluation**

D4.2.-“Concept for evaluation of SPF” describes a standard evaluation method for monitoring results to get data for quality characteristics for heat pump systems and technologies. This SPF calculation method also provides the possibility to include the impact of fans on the performance of the heat pump system, which will be taken into account by the definition of different system boundaries.

The methodology of calculating the SPF makes it possible to compare the heat pump system with common heating systems like oil or gas. By this comparison it is also possible to calculate the CO$_2$eq and primary energy reduction potential from different heat pump systems compared to other heating systems.

This evaluation method is based on a harmonised monitoring methodology, also developed in the “SEPEMO” project, which allows disposing all necessary measurement data for applying the evaluation method presented in this document.

**System boundary description**

The definition of the system boundaries influences the results of the SPF depending on the impact of the auxiliary drives. Therefore the SPF should be calculated according to different system boundaries. This will reflect the impact of the different devices on the performance of the system.

Due to the fact that the units can operate in heating or in cooling mode the system boundaries and the SPF calculation methodology is separated for heating and cooling mode. According to the described system boundaries the SPF can be calculated for cooling and space heating. There is no hot water domestic production considered for air to air heat pumps.

For systems with an additional heating system other than an electrical back up heater (e.g. oil, gas or biomass) the quantity of heat and the energy content of the fuel demand have to be determined for calculating SPF$_{H3}$ and SPF$_{H4}$. The energy content can be determined by measuring the fuel demand and multiplying with the calorific value of the fuel. For additional solar thermal systems the electric auxiliary energy to run the system has to be measured. With the heat energy delivered to the heating system by the additional heating the energy supply ratio of the heat pump system is calculated.

Because air to air systems have different architectures than water based systems, a specific nomenclature has been developed.

**System boundaries – heating mode:**

SPF$_{H1}$:
This system contains only the heat pump unit. SPF$_{H1}$ evaluates the performance of the refrigeration cycle i.e. it is computed based on the electric energy delivered to the heat pump minus its fans’ consumption. The system boundaries differ from the COP defined in EN 14511 [1], since the standard takes, in addition, a part of (for ducted units) or the totality (non ducted units) of the sink fan consumption to overcome head losses, and the source fan consumption.
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**SPF\(_{H2}\):**
This system contains the heat pump unit and the equipment to make the source energy available for the heat pump. SPF\(_{H2}\) takes into account, in addition to SPF\(_{H1}\), total source fan consumption, and the sink fan consumption only for non ducted internal units.

*Note: COP in EN 14511 and SCOP\(_{NET}\) in prEN 14825 are similar to SPF\(_{H2}\) for ducted unit (except only a part of the source fan is included in the standard definition for ducted units) and almost exactly the same as SPF\(_{H2}\) for non ducted units, except that in SCOP\(_{NET}\) the crankcase and standby consumption during compressor stop are not included (see table 1 at the end of the document).*

**SPF\(_{H3}\):**
This system contains the heat pump unit, including its fans (as for SPF\(_{H2}\)) plus the back up heater. SPF\(_{H3}\) represents the heat pump system and thereby it can be used for comparison to conventional heating systems (e.g. oil, gas,…). This system boundary is similar to the SPF in VDI 4650-1 [4], EN 15316-4-2 [5]. For non ducted air to air heat pumps, SPF\(_{H3}\) is comparable to the SCOP in prEN 14825. For ducted air to air units, the sink fan consumption to circulate the air in the duct network is excluded. *(see table 1 at the end of the document)*

**SPF\(_{H4}\):**
This system contains the heat pump unit, the equipment to make the source energy available, the back up heater and all auxiliary drives including the auxiliary of the heat sink system. SPF\(_{H4}\) represents the heat pump heating system including all auxiliary drives which are installed in the heating system. SPF\(_{H4}\) is equal to SPF\(_{H3}\) for non ducted unit *(see table 1 at the end of the document)*

![Figure 1: Example scheme for a heating system](image)

**SPF-calculation – heating mode:**
In this chapter the formulas for calculating the SPF for heating mode together with the energy flowcharts for the different system boundaries are described.
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Figure 2: energy flow chart for the heating mode

\[ SPF_{H1} = \frac{Q_{H_{hp}}}{E_{H_{hp}}} \]

\[ SPF_{H2} = \frac{Q_{H_{hp}}}{E_{S_{fan}} + E_{H_{hp}}} \]

\[ SPF_{H3} = \frac{Q_{H_{hp}} + Q_{H_{bu}}}{E_{S_{fan}} + E_{H_{hp}} + E_{H_{bu}}} \]
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\[
SPF_{H} = \frac{Q_{R_{hp}} + Q_{H_{bu}}}{E_{S_{fan}} + E_{H_{hp}} + E_{H_{bu}} + E_{B_{fan}}}
\]

**System boundaries – cooling mode:**

SPFC\(_1\): 
This system contains only the cooling unit. SPF\(_C_1\) evaluate the performance of the refrigeration cycle i.e. it is computed based on the electric energy delivered to the cooling unit minus its fans’ consumption. The system boundaries are similar to EER defined in EN 14511 [1], except that the standard takes, in addition, a part of (for ducted units) or the totality (non ducted units) of the sink fan consumption to overcome head losses, and the source fan consumption (see table 1 at the end of the document).

SPFC\(_2\): 
This system contains the cooling unit and the equipment to dissipate the heat energy. SPF\(_C_2\) takes into account, in addition to SPF\(_C_1\), total source fan consumption, and the sink fan consumption only for non ducted internal units The system boundaries SEER\(_{ON}\) in prEN 14825 [2].

*Note: EER in EN 14511 and SEER\(_{NET}\) in prEN 14825 are similar to SPF\(_C_2\) for ducted unit (except only a part of the source fan is included for ducted units) and almost exactly the same as SPF\(_C_2\) for non ducted units, except that in SEER\(_{NET}\) the crankcase and standby consumption during compressor stop are not included (see table 1 at the end of the document).*

SPFC\(_3\): 
This system contains the cooling unit, the equipment to dissipate the heat energy and all auxiliary drives of the cooling system. SPF\(_C_3\) represents the cooling system including all auxiliary drives which are installed in the cooling system. For non ducted air/air units, SPF\(_C_3\) is exactly the same as SPF\(_C_2\) (see table 1 at the end of the document)
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Figure 3: Example scheme for a cooling system

**SPF calculation – cooling mode:**
In this chapter the formulas for calculating the SPF for cooling mode together with the energy flowcharts for the different system boundaries are described.

![Figure 4: energy flow chart for the cooling mode](image)

\[
SPF_{C1} = \frac{Q_c}{E_{CU}}
\]
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\[ SPF_{C^2} = \frac{Q_C}{E_{S	ext{-fan}} + E_{CU}} \]

\[ SPF_{C^3} = \frac{Q_C}{E_{S	ext{-fan}} + E_{CU} + E_{B	ext{-fan}}} \]
Comparison of the system- boundaries in standards and the system – boundaries of the SPF-calculation methodology

There are different existing standards and regulations for calculating the SPF. These calculation methodologies are mainly based on input from the testing standard EN 14511. The system boundaries of testing standards are however focused on the heating or cooling unit itself. For comparing test results of the units with other units, the system integration is not taken into account. Therefore these standards do not include the entire energy consumption of the auxiliary drives on the heat sink and heat source side. The following descriptions show the differences between the system boundaries for field measurements and testing standards. The aim is to point out the difference between field testing and testing on a test rig, which does not necessarily mean that there should be no differences as this is not possible for practicable measurement systems in the field. The main difference of the evaluation methodologies is that testing is focused on the unit and the field measurements are focused on the system. For field measurements measuring the proportional energy input on the heat sink and heat source side requires high efforts for the measurement equipment and cannot be realized within the common field measurement methodology.

Hence the system boundaries for testing and field measurements will be slightly different, this has to be taken into account when comparing calculated SPF and measured SPF.

**EN 14511**: This standard describes the testing procedure to calculate the COP or EER. The average electrical power input of the unit within the defined interval of time is obtained from:
- the power input for operation of the compressor and any power input for defrosting;
- the power input for all control and safety devices of the unit and;
- the proportional power input of the conveying devices (e.g. fans) for ensuring the transport of the heat transfer media inside the unit.

This equates to the system boundary of SPF$_{HI}$/SPF$_{C1}$, with the difference being, that SPF$_{HI}$/SPF$_{C1}$ does not include the proportional energy input of the auxiliary devices.

**EN 15316 4-2**: This standard describes a calculation Bin method for energy consumption, starting from, among other, heating load evolution, heating curve of the heat pump, climate conditions and standard heat pump testing points. This method standardizes boundary contains the heat pump unit, the equipment to make the source energy available, internal and external boilers and back-up heaters. This equates to boundary SPF$_{H4}$. The difference is that SPF$_{H4}$ in the standard EN 15316-4-2 the thermal losses of the heating system are calculated (although EN 15316-4-2 drawings are more adapted to hydronic space heating.)
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prEN 14825:
The calculation methodology and the measurement procedure of this standard are based on the standard EN 14511. Therefore the auxiliary drives are mentioned partly in the SCOP calculation. SCOP\textsubscript{NET} is more or less similar to SPF\textsubscript{H2} and SCOP/SEER to SPF\textsubscript{H3}/SPF\textsubscript{C2}. Unlikely EN 15316-4-2, different running conditions are set, according climate (3 zones: cold, average, warm) and space heating emitters, what gives SCOP/SEER for heat pump whose features are known at 6 tested conditions.

European Directive 2009/125/EC Lot 10:
Calculation of energy consumption in Lot 10 is similar to prEN 14825

The following table 1 gives an overview of the difference between the defined system boundaries for evaluating the measurement data and existing standards.

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**Key**

1. heat source system (here: vertical borehole heat exchanger)
2. Source pump
3. Heat pump
4. DHW storage loading pump
5. DHW storage
6. DHW back-up heater
7. Primary pump
8. DHW hot water outlet
9. Heating buffer storage
10. Space heating back-up heater
11. Circulation pump space heating distribution system
12. Heat emission system
13. DHW cold water inlet

Figure 5: system boundary EN 15316-4-2
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<table>
<thead>
<tr>
<th>Component</th>
<th>SPF_H1/C1</th>
<th>SPF_H2/C2</th>
<th>SPF_H3</th>
<th>SPF_H4</th>
<th>EN14511</th>
<th>EN15316-4:2</th>
<th>prEN14825*</th>
<th>Lot 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Source fan</td>
<td>---</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Back-up</td>
<td>---</td>
<td>---</td>
<td>x</td>
<td>x</td>
<td>---</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Sink fan</td>
<td>---</td>
<td>x **</td>
<td>x **</td>
<td>x</td>
<td>head losses</td>
<td>x</td>
<td>head losses</td>
<td>head losses</td>
</tr>
</tbody>
</table>

* refers to SCOP and SEER
** only for non-ducted internal unit system

Table 1: comparison of system boundaries
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**Literature**

[1] EN 14511, Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling, March 2008

[2] prEN 14825, Air conditioners, liquid chilling packages and heat pumps, with electrically compressors, for space heating and cooling- Testing and rating at part load conditions and calculation of seasonal performance, November 2009
