Heat pump system performance measurement in Annex 52

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- Long-term performance monitoring of any larger GSHP systems
- Four years: January 2018 – December 2021
- Seven participating countries, led by Sweden

- Three Subtasks:
  - (1) Bibliography + case study reports
  - (2) Guideline document on instrumentation & measurement
  - (3) Guideline document on analyzing and reporting of GSHP system performance

Achievements in the Annex Subtasks

Subtask 1 – Bibliography and case studies:

- Annotated bibliography - 82 publications describing GSHP systems in 17 countries
- 32 monitored GSHP case study projects in 7 countries - 29 completed case study reports.
- 2-pager case study summary

Subtask 2 – Guidelines on instrumentation and measurement:

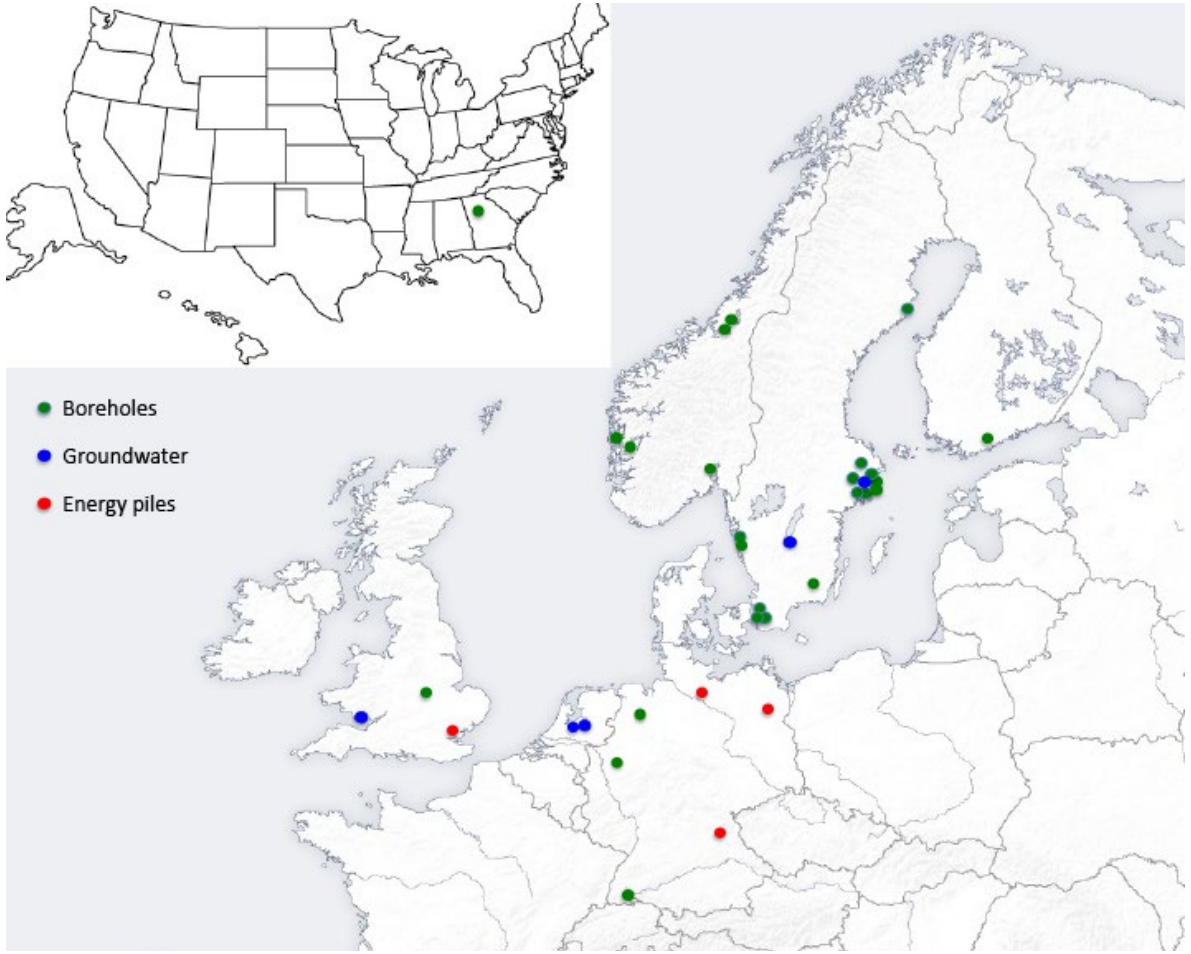
- Published instrumentation guideline
- Published uncertainty calculation guideline

Subtask 3 – Guideline on analyzing and reporting of GSHP system performance:

- Extended system boundary schema - 6 system levels - used on the 32 case studies.
- Published key performance indicator guideline

Monitoring projects

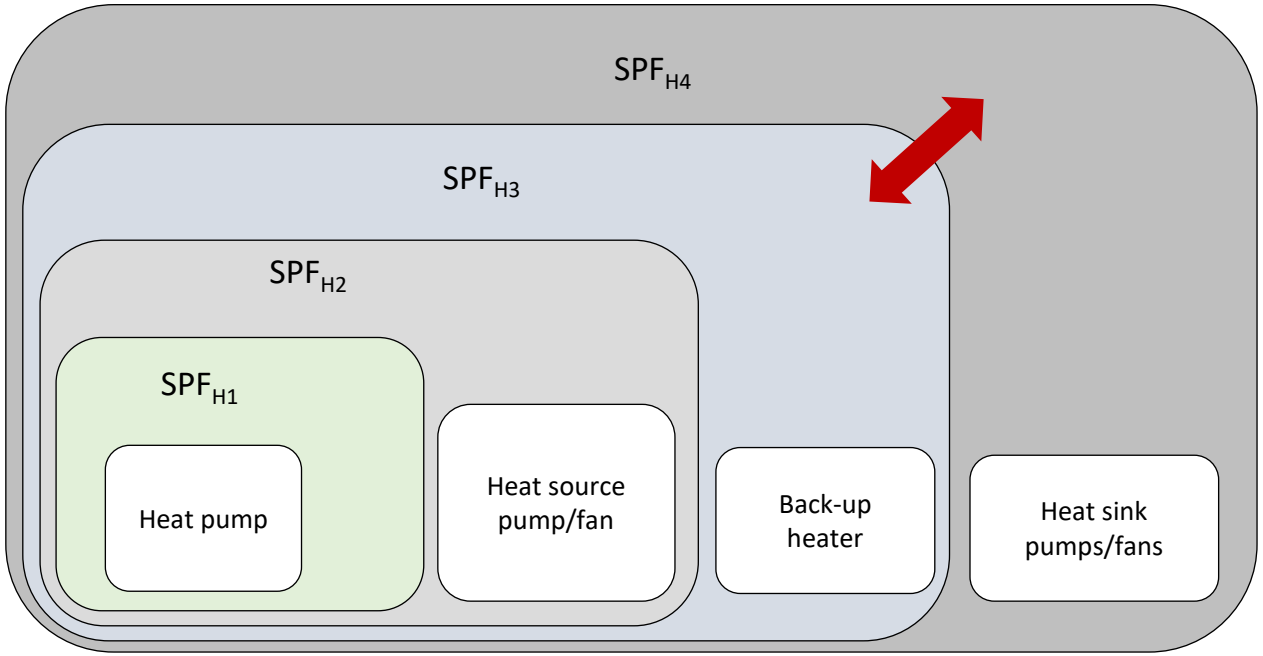
32 monitored case studies in 7 countries – 29 completed reports

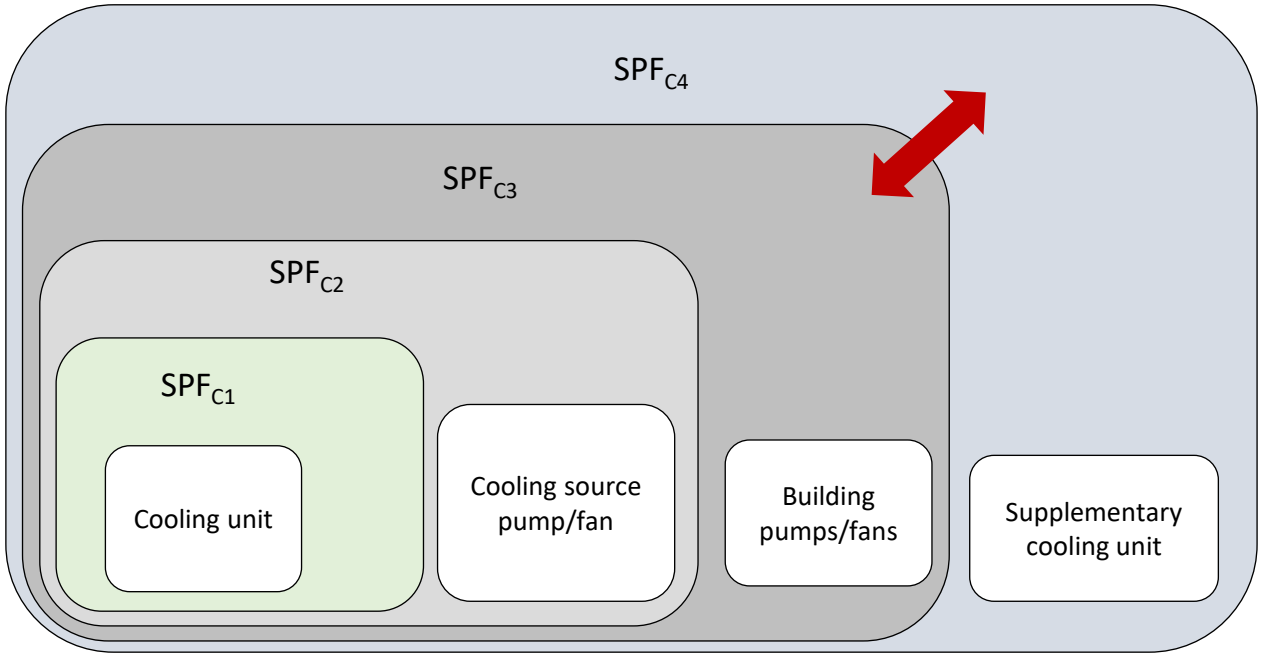


RESIDENTIAL BUILDING	4	1	1	-	-	-	-
COMMERCIAL BUILDING	9	5	4	3	1	1	2
INDUSTRIAL BUILDING	1	-	-	-	-	-	-
BOREHOLES	12	3	5	1	1	1	-
GROUNDWATER	2	-	-	1	-	-	2
ENERGY PILES	-	3	-	1	-	-	-

The SEPEMO (2012) project system boundary schema

Developed primarily for small residential heat pump systems





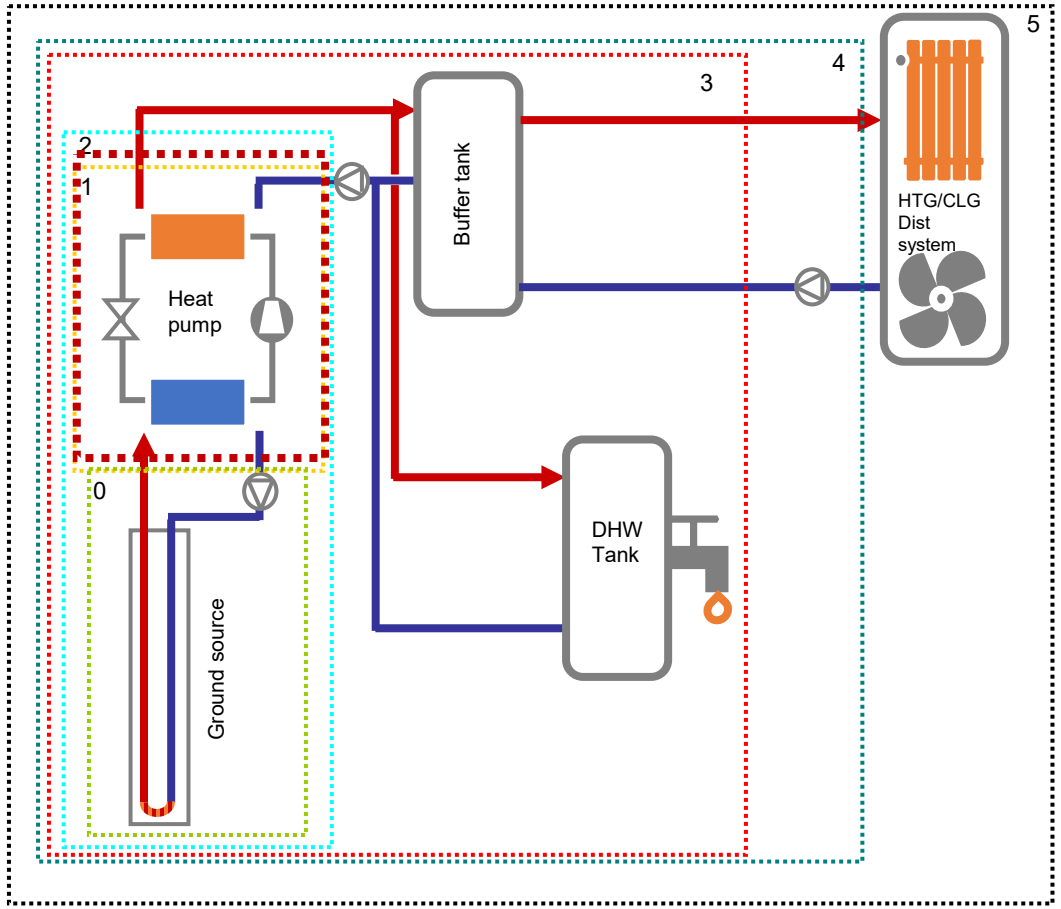
Figures based on: Nordman, R., et al. 2012. Seasonal performance factor and monitoring for heat pump systems in the building sector. SEPEMO-Build Final Report.

The Annex 52 System Boundary schema

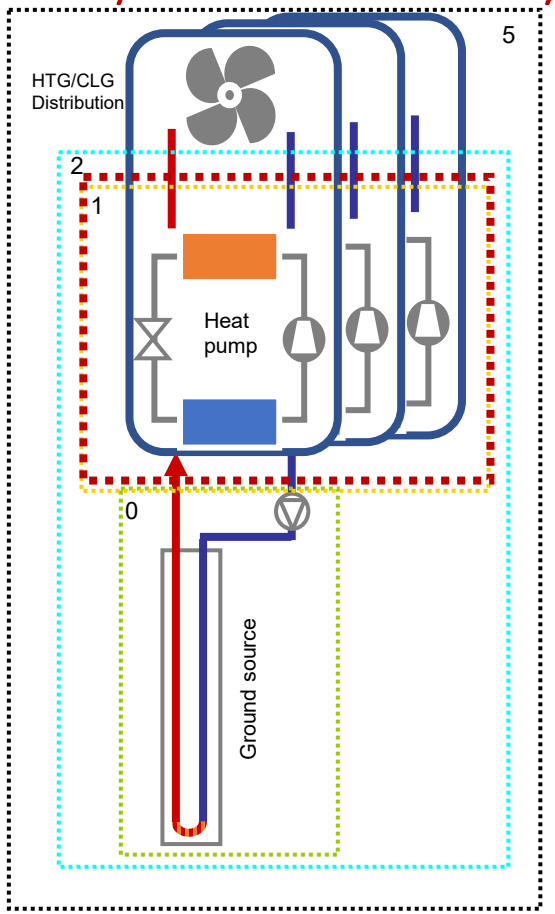
- Consistent boundaries for heating and cooling => SPFHC possible
- One level for evaluation of the ground source itself
- Flexibility to handle multiple supplementary H/C sources
- One level for buffer tank
- Flexibility to handle HT-BTES, DHC, direct cooling etc
- …and yet some consistency with the SEPEMO boundary schema used within the EU

System boundary 0 gives the ratio of heating and/or cooling delivered to pumping energy for the GHEX, including effects of pressure loss in HP and piping between GHEX and HP.

European style centralized GSHP system



American style distributed GSHP system



Supplementary heating/cooling at a level is indicated with +

System boundary 5 gives the ratio of heating and/or cooling delivered to all energy used by the source side and load side to deliver it

Boundary AND time frame must be clearly stated for PF: Seasonal (SPF), Monthly (MPF), Daily (DPF), Binned (BPF)

Internal and External approach to heat pump performance

Internal Approach

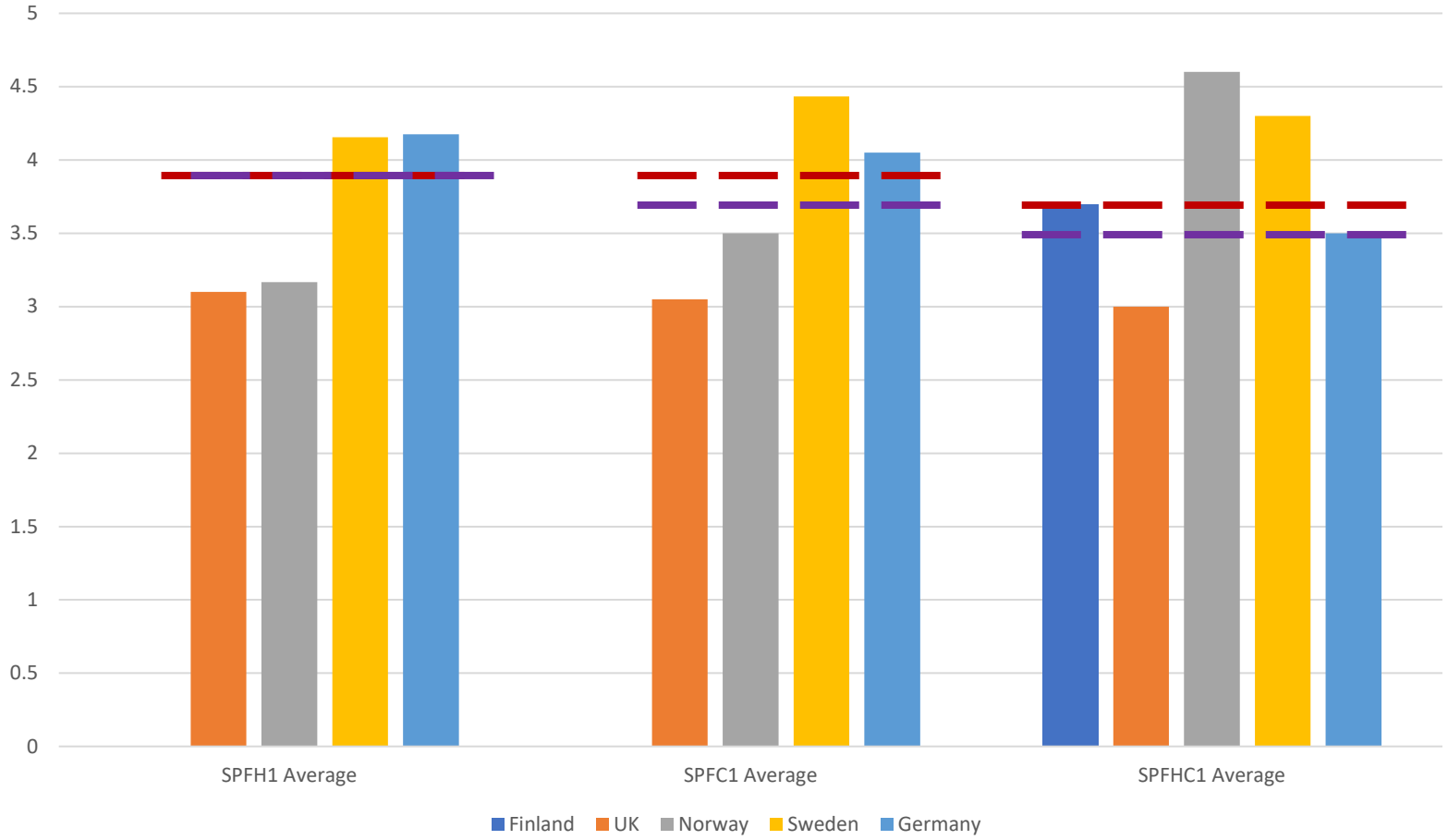
- Uses measurement of:
  - Pressure & temperature of the refrigerant.
  - Compressor power + …
  - An estimate of the compressor heat loss.
  - Thermodynamic properties for the refrigerant.
  - Temperature on the secondary refrigerant or air side.
- More sensors
- Provides useful additional information about individual HP components

External Approach

- Uses measurements made external to the vapor compression cycle:
  - Calorimetric measurement of the load side heat transfer
  - Compressor power + …
  - Possibly – humidity
  - Thermodynamic properties on the secondary refrigerant or air side.
- Less invasive
- May have low accuracy in “over pumped” systems

All but 3 used external approach

Annex 52 case studies SPF1 results



Annex 52 Case Studies:

SPF1 from 20 case studies, 78 years

Simple Average (12): SPFH1 3.9
Simple Average (8): SPFC1 3.9
Simple Average (6): SPFHC1 3.7

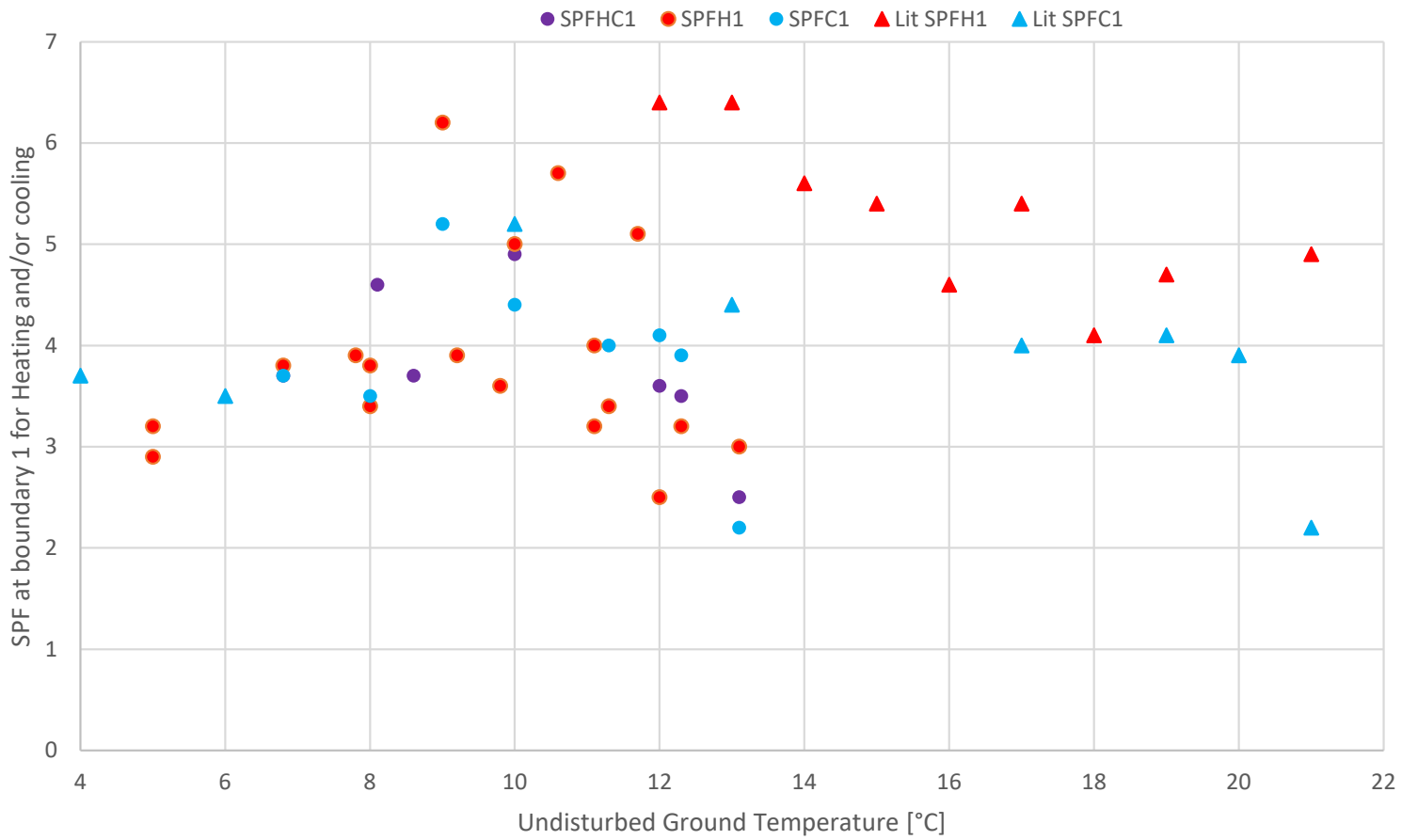
Average (all years): SPFH1 3.9
Average (all years): SPFC1 3.7
Average (all years): SPFHC1 3.5

Literature review:

Simple Average (39): SPFH1 4.0
Simple Average (12): SPFC1 5.5

SPF for level 1 vs Undisturbed Ground Temperature (UGT)

Values from Annex 52 Case Studies and Literature Review



No clear relationship between SPF1 and Undisturbed ground temperature in case studies or literature

SPF1 Result summary

Measured case studies

Average SPFHC1: 2.2-4.9 Overall SPFHC1: 3.9	Average SPFH1: 2.5-6.2 Overall SPFH1: 3.9	Average SPFC1: 2.2-5.2 Overall SPFC1: 3.7

In line with results from literature

Two systems had particularly high SPFH1 (Average 6.2 and 5.7) due to:

- Significant supplementary heating
- Low distribution temperature

General conclusions from Annex 52

GSHP systems generally work satisfactorily

…but further optimization often possible

Good quality long-term performance monitoring of GSHP systems are valuable for

- Commissioning
- Fault detection
- System optimization

…but so far rare

Consistent and clearly stated:

- System boundaries
- Evaluation time frame

are paramount

General conclusions from Annex 52

Need for more frequent uncertainty analyses

Missing instrumentation & poor data quality occur frequently ⇒ Guidelines for instrumentation & uncertainty analysis most welcome

Minimizing parasitic losses and energy usage by

- Legionella protection
- DHW circulation
- Distribution system

will improve performance

Using the guidelines will help lower the costs for monitoring programs

General conclusions from Annex 52

System SPFs at all boundary levels are highly variable from system to system

No clear relationship between SPF and other factors

SPF generally decreases as the boundary is extended

This is not unique to GSHP systems or ASHP systems

Field measurements of other H & C systems would be most welcome

This would help increase over-all efficiency in H & C distribution systems

Annex 52 deliverables - Summary

Outcomes:

- 1 Final Report + 3 guideline documents + 3 task reports + 2-page summaries
- 27 case study reports from 29 buildings
- In total > 1000 pages
- 119 measurement years
- Three sets of open access measurement data series from two buildings

In addition (so far):

- 7 journal papers
- 14 published conference papers
- 18 magazine articles
- 10 other related reports and publications

All reports available here: https://heatpumpingtechnologies.org/annex52/documents/

Final comment

The focus of Annex 52 is GSHP systems

BUT

…much is also directly applicable to ASHP systems & AC systems!

Thank you for your attention!

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This work is part of the IEA HPT Annex 52, Long-term performance measurement of GSHP systems serving commercial, institutional and multi-family buildings.

https://heatpumpingtechnologies.org/annex52/documents/