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Task 48

IEA SHC Task 48 / B7

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Task 48

Short description:

Technical and economic evaluation and assessment tool (V4.0)

Developer of the Excel Tool

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Content

- General notes
- Calculation base
- Key figures and interpretation

General Notes

Important disclaimer

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More details regarding the calculation methods and base values can be found in the final report of **Activity B7: Collection of criteria to quantify the quality and cost competitiveness for solar cooling systems**

→ http://task48.iea-shc.org/publications

Abbreviation

ACM	Ab/Adsorption chiller	CT	Cooling Tower
NRE	Non-renewable	FC	Fan Coils
DHW	Domestic hot water	FE	Final Energy
SH	Space heating	HOM	Heating operation mode
C	Cooling	HP	Heat pump
BU	Backup unit	HR	Heat rejection
COM	Cooling operating mode	UE	Useful energy
LT	Low temperature	SC	Solar collector
MT	Medium temperature	HS	Heat source
HT	High temperature	HX	Heat exchanger
CU	Control Unit	PE	Primary energy
VCC	Vapour compression chiller	SHC	Solar heating and cooling

Abbreviation

SHP	Solar heat pump	COP	Coefficient of Performance(-)
SHP+	Solar heat pump plus energy distribution system	SCOP	Seasonal COP (-)
LHV	Lower heating value	EER	Energy Efficiency Rate (-)
DEC	Desiccant and evaporative cooling	SEER	Seasonal EER (-)
Ref	Reference system (VCC)	PER	Primary Energy Ratio (-)
		SPF	Seasonal Performance Factor (-)
el	electrical	Q	Energy flow (kWh)
coll	collector	$\dot{Q}$	Thermal Power (W)
sys	system	CAP	Capacity (W)
th	thermal	P	Power (W)

System Boundaries / Subsystems

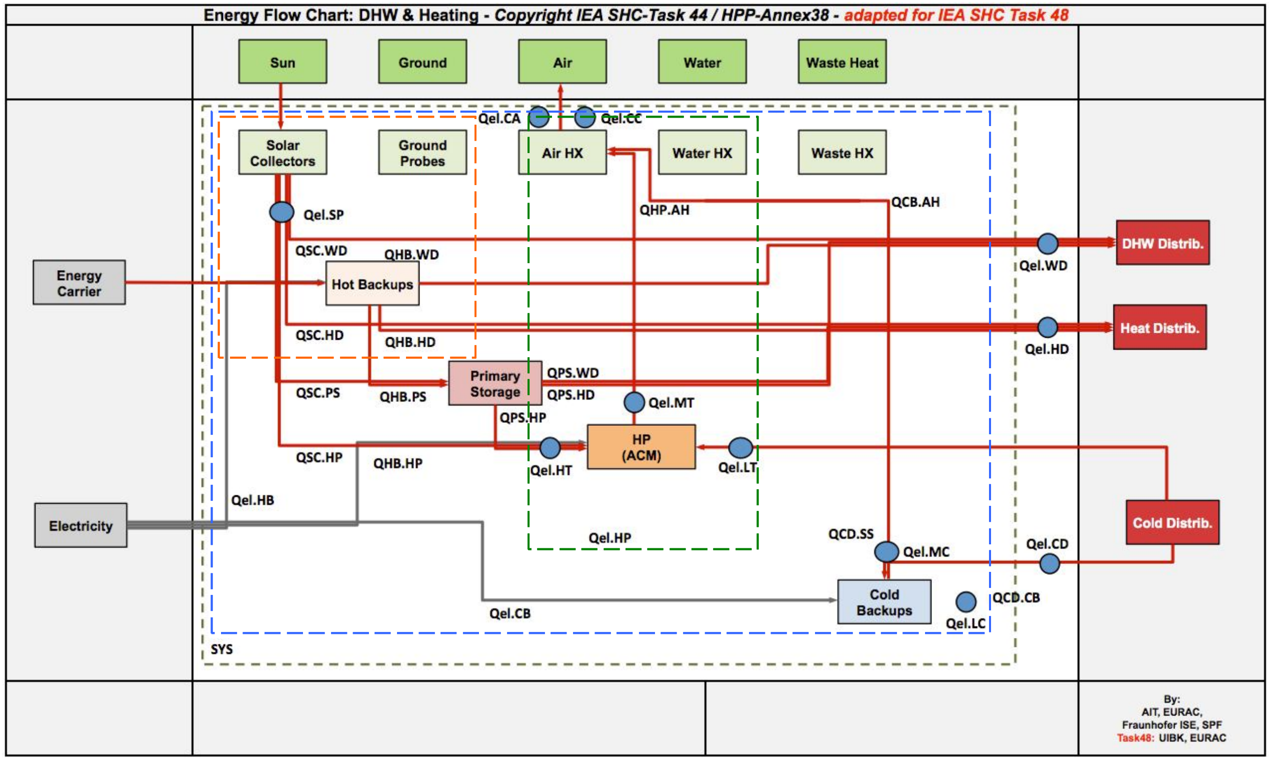
▪ sys	Overall system – including cooling (C), domestic hot water (DHW) and space heating (SH)
▪ C	Cooling – overall performance of the cooling system, including cold backup
▪ thC	Thermal cooling – performance of the ab-/adsorption chiller (a part of cooling)
▪ SH	Space heating – including backup
▪ DHW	Domestic hot water – including backup

System Boundaries / Subsystems

The Energy-Flow chart display all possible connections (energy flows) between components

Boundaries:

- sys
- SH/DHW
- C
- thC



Worksheets - How to handle the Task 48 Tool

Colours used in the Tool

drop downs menu	Please select an option, some option are just for information, others influence the result significantly!
value to be filled in	Please fill in the certain value, ALL values are needed!
T48 Standard	Input Values to the T48 Standard calculation can not be changed. They were defined and agreed during the work on Task 48
specific value	Input values can be adopted at different highlighted position in this Tool. This allows a country or project specific calculation of both technical and economic key figures
editing specific values	Cell to edit the specific value (x1, x2)

INPUTS prior calculation

1. **“INPUT”:** define all types of source, capacities and dimensions
2. **“Conversion”:** the necessary primary factor and efficiencies can be defined
3. **“Data”:** Enter monthly energy balances in the worksheet
   → press the “Run Calculation” button

Worksheets - How to handle the Task 48 Tool

Technical Assessment

4. **“Calc_T48”:** all detailed yearly and monthly results with standard values of T48 can be found there
5. **“Calc_spec”:** all results with specific values
6. **“Labelling”:** the energy labels for all 5 boundaries

Economic Assessment

7. **“eco_base”:** add specific values for relevant economic bases
8. **“cost_calc”** detailed calculation of the investment, replacement and maintenance and operation costs

Summary

9. **“Summary”** standardized overview of the plant and its technical and economic performance

Calculation base

T48 Standard values – Energy Carrier

	T48 Standard	Unit
Primary energy factor for electricity ε_{el}	0,4	kWh_{el}/kWh_{pr}
CO_2 factor for electricity	0,55	kg/kWh_{el}
Efficiency of the natural gas boiler η_{HB}	0,9	-
Primary energy factor for natural gas ε_{EC}	0,9	kWh_{el}/kWh_{pr}
CO_2 factor for natural gas	0,26	kg/kWh_{el}
Efficiency of the pellets boiler η_{HB}	0,85	-
Primary energy factor for pellets ε_{EC}	10	kWh_{el}/kWh_{pr}
CO_2 factor for pellets	0,045	kg/kWh_{el}

→ Specific values country wise

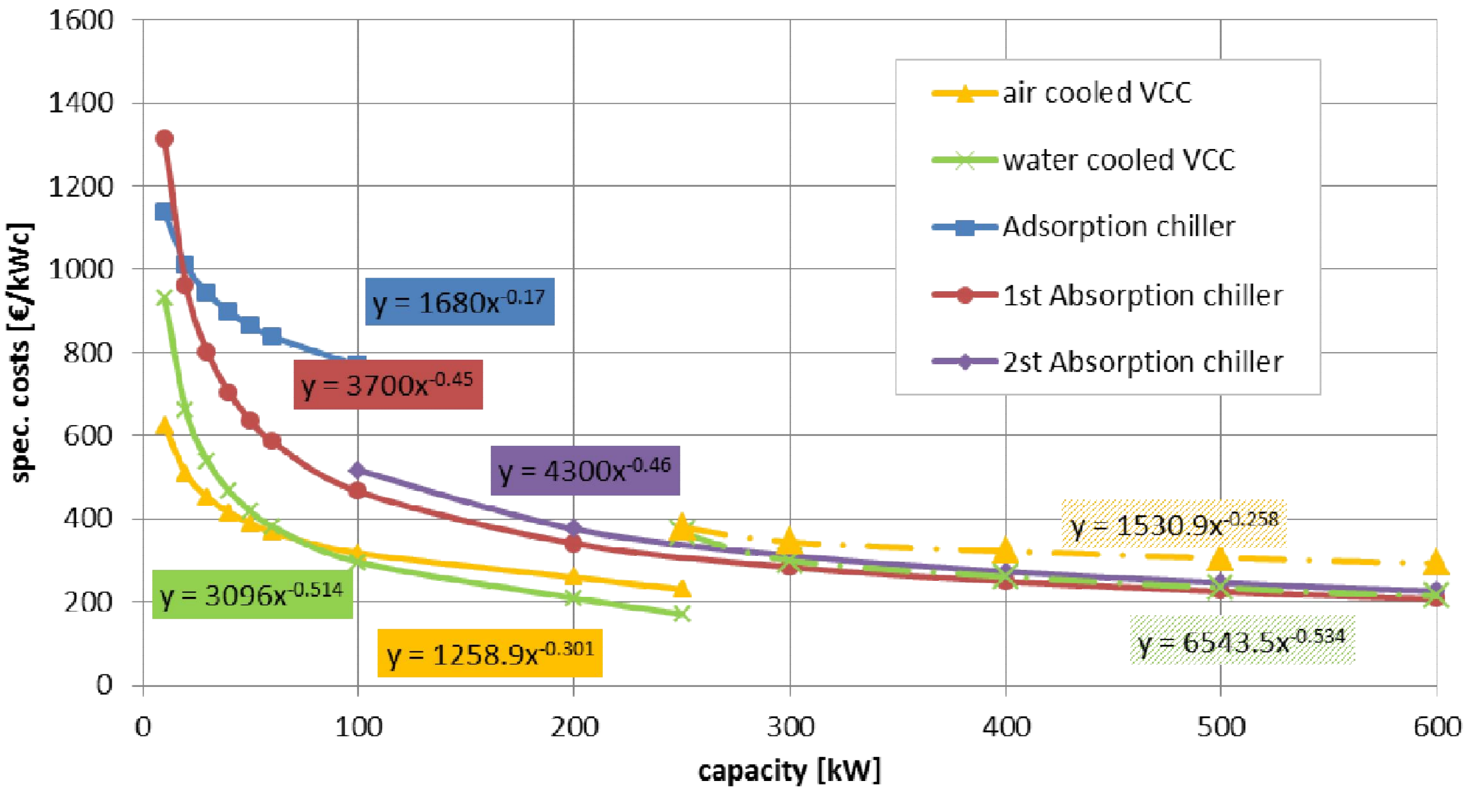
T48 Standard VCC – $ESEER_{ref}$

Capacity (kW)	Water cooled VCC (> 20 kW)	Air cooled VCC (50 – 600 kW)
5	0	2,5
10	0	2,5
20	3,05	2,92
50	4,06	4,2
100	4,25	4,19
250	4,19 5,84	3,95 3,95
500	5,81	3,78
1000	5,99	3,94

→ SPF_{ref}: Multiplication of ESEER by 0,75

T48 Standard Investment costs

- For all main components, size dependent, reconstruction, e.g. VCC/ACM



T48 standard economic base

Economics	
Period under consideration	25 a
Credit period	10 a
Inflation rate	3 %

Energy costs	
Electricity (energy)	10 ct/kWh
Electricity (power)	80 €/kW.a
Natural gas	5 ct/kWh
Water	2.5 €/m³

Key Figures and Interpretation

Seasonal Performance Factor – SPF

= ratio of useful energy flows (output)
to consumed energy flows (input)

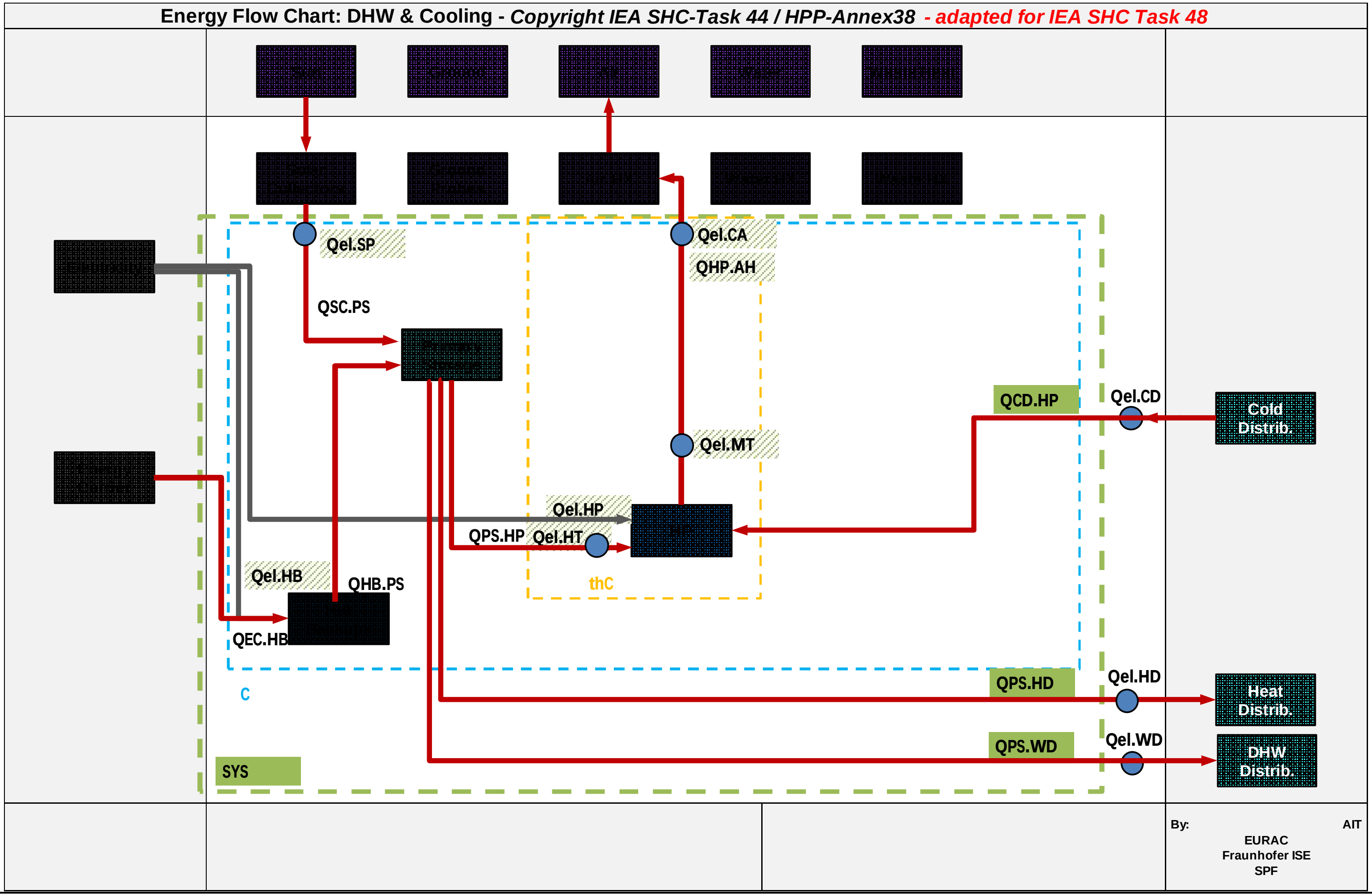
$$SPF_i = \frac{\sum Q_{i,out}}{\sum E_{i,in}}$$

- Electrical SPF_{el}: only electrical inputs
- Thermal SPF_{th}: only thermal inputs

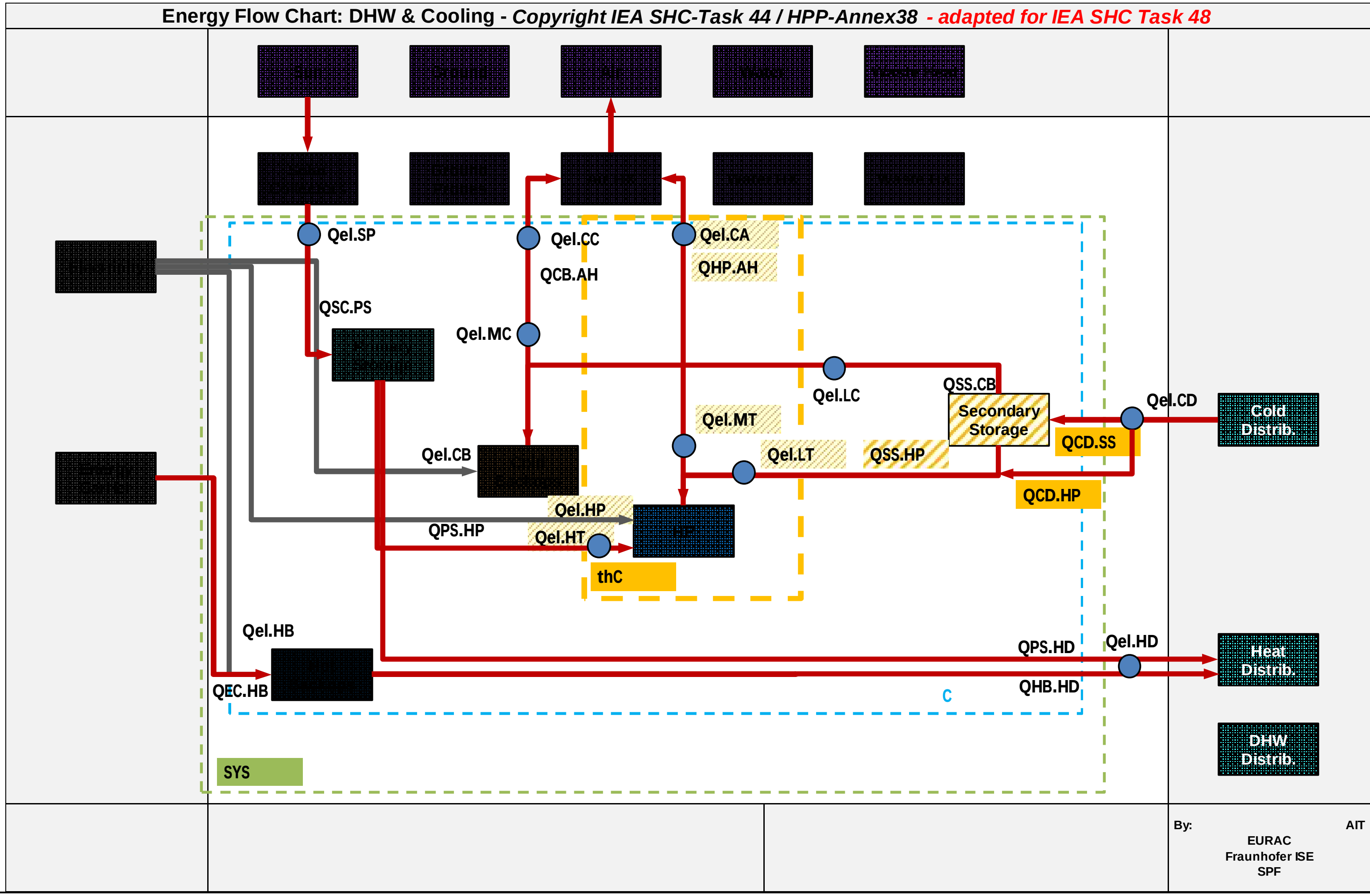
Seasonal Performance Factor – SPF

SPFel,sys	$SPF_{el,sys} = \frac{Q_{CD.system}+Q_{HD.system}+Q_{WD.system}}{Q_{el.sys}}$
SPFel,C	$SPF_{el,C} = \frac{Q_{CD.SS}+Q_{CD.HP}+Q_{CD.CB}}{Q_{el.C}}$
SPFel,thC	$SPF_{el,thC} = \frac{Q_{CD.SS}+Q_{SS.HP}+Q_{CD.HP}}{Q_{el.thC}}$
SPFel,DHW	$SPF_{el,DHW} = \frac{Q_{PS.WD}+Q_{SC.WD}+Q_{HB.WD}}{Q_{el.DHW}}$
SPFel,SH	$SPF_{el,SH} = \frac{Q_{PS.HD}+Q_{SC.HD}+Q_{HB.HD}}{Q_{el.SH}}$
SPFth,sys	$SPF_{th,sys} = \frac{Q_{SS.HP}+Q_{CD.HP}}{Q_{SC.system}*\%_{SC.C}+Q_{HB.system}*\%_{HB.C}}$
SPFth,C	$SPF_{th,C} = \frac{Q_{SS.HP}+Q_{CD.HP}}{Q_{SC.HP}+Q_{PS.HP}+Q_{HB.HP}}$

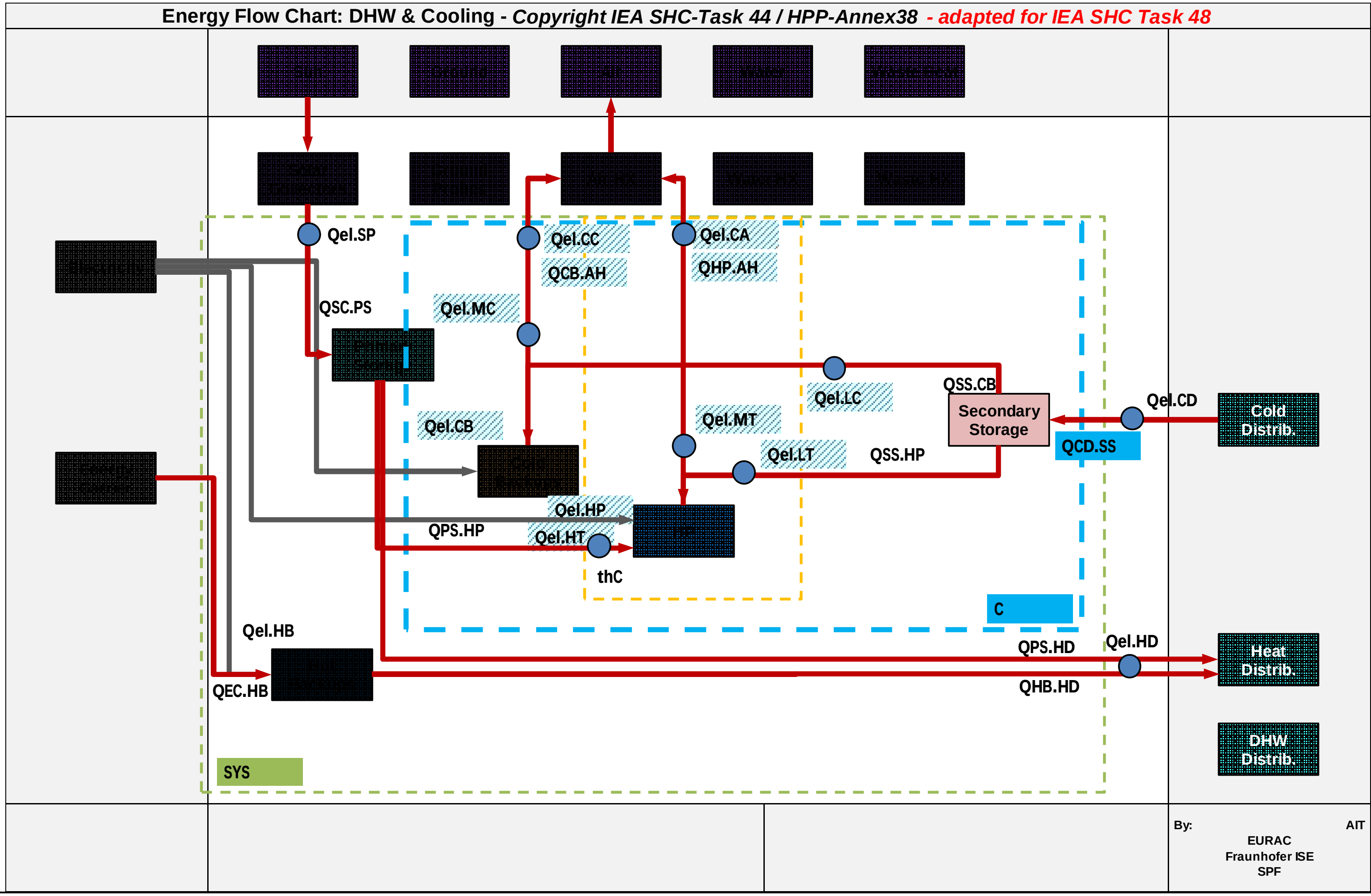
Seasonal Performance Factor – $SPF_{el.sys}$



Seasonal Performance Factor – $SPF_{el.thC}$



Seasonal Performance Factor – $SPF_{el.C}$



Primary Energy Ration – PER

= ratio of useful energy output
to non renewable primary energy input

$$PER_i = \frac{\sum Q_{i,out}}{\sum\left(\frac{Q_{el,i,in}}{\varepsilon_{el}} + \frac{Q_{i,in}}{\varepsilon_{in}}\right)}$$

Compared to SPF, PER takes the quality of rating (primary energy factor) for cooling, heating and hot water into account (more in depth of the economic or environmental point of view)

Primary Energy Ration – PER

	Non Renewable Energy	Non Renewable Energy – Reference
PERnre,sys	$PER_{NRE,sys} = \frac{Q_{CD.system} + Q_{HD.system} + Q_{WD.system}}{\frac{Q_{el.sys}}{\varepsilon_{el}} + \frac{Q_{EC}}{\varepsilon_{EC}}}$	$PER_{NRE,ref,sys} = \frac{Q_{CD.system} + Q_{HD.system} + Q_{WD.system}}{\frac{Q_{el.ref}}{\varepsilon_{el}} + \frac{Q_{CD.sys}}{SPF_{ref} * \varepsilon_{el}} + \frac{Q_{HD.sys} + Q_{WD.sys} + Q_{loss.ref}}{\varepsilon_{boiler} * \eta_{boiler}}}$
PERnre,C	$PER_{NRE,C} = \frac{Q_{CD.SS} + Q_{CD.HP} + Q_{CD.CB}}{\frac{Q_{el.C}}{\varepsilon_{el}} + \frac{Q_{EC.HB} * \%_{HB.C}}{\varepsilon_{EC}}}$	$PER_{NRE,ref,C} = SPF_{ref} * \varepsilon_{el}$
PERnre,thC	$PER_{NRE,thC} = \frac{Q_{SS.HP} + Q_{CD.HP}}{\frac{Q_{el.thC}}{\varepsilon_{el}} + \frac{Q_{EC.HB} * \%_{HB.C}}{\varepsilon_{EC}}}$	$PER_{NRE,ref,thC} = SPF_{CB.th} * \varepsilon_{el}$
PERnre,DHW	$PER_{NRE,DHW} = \frac{Q_{WD.system}}{\frac{Q_{el.DHW}}{\varepsilon_{el}} + \frac{Q_{EC.HB} * \%_{HB.DHW}}{\varepsilon_{EC}}}$	$PER_{NRE,ref,DHW} = \frac{Q_{WD.system}}{\frac{Q_{el.ref.DHW}}{\varepsilon_{el}} + \frac{Q_{WD.system} + Q_{loss.ref}}{\varepsilon_{boiler} * \eta_{boiler}}}$
PERnre,SH	$PER_{NRE,SH} = \frac{Q_{HD.system}}{\frac{Q_{el.SH}}{\varepsilon_{el}} + \frac{Q_{EC.HB} * \%_{HB.SH}}{\varepsilon_{EC}}}$	$PER_{NRE,ref,SH} = \frac{Q_{HD.system}}{\frac{Q_{el.ref.SH}}{\varepsilon_{el}} + \frac{Q_{HD.system}}{\varepsilon_{boiler} * \eta_{boiler}}}$

Fractional Savings - fsav

= non renewable primary energy savings of the system
in comparison to a reference system

$$f_{sav.NRE.PER} = 1 - \frac{PER_{NRE.ref}}{PER_{NRE.i}}$$

fsav should be > 0

if fsav is < 0 no saving can be achieved, the entire systems consumes more than the reference system

Equivalent Seasonal Performance Factor – SPF_{equ}

= SPF in electrical equivalent units,

equals PER, but is converted into a comparable magnitude for VCCs

$$SPF_{equ.sys} = \frac{PER_{NRE,sys}}{\varepsilon_{el}}$$

The electrical equivalent Seasonal Performance Factor for cooling ($SPF_{equ,C}$) can be used to compare the overall building cooling system with a vapour compression system SEER value, even when hot backup is used.

Interpretation hints

- SPFel can be used only limited to compare environmental impact of the system
- SPFel can be misleading when backups are included
  - E.g. SPFel.DHW >150
- SPFel.thC equals SPFel.C when a hot backup is used
- SPFel.thC should only be used to compare with VCC SEERs without hot backup

- SPFequ can be used to compare environmental impact of system with different energy quality inputs (electricity, natural gas,…)
- SPFel equals SPFequ when no hot backup is used

Incremental Energy Saved – ΔE_{e_equ}

= energy saved in electrical equivalents

$$\Delta E_{e\_equ\_sys} = \frac{(Q_{WD.sys}+Q_{HD.sys}+Q_{hloss})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} + \frac{(Q_{HP.sys}+Q_{closs})}{SPF_{CB.th}} - \frac{(Q_{HB.sys})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - (\Delta E_{aux.sys} + Q_{el.VCC})$$

Primary energy savings are summed over the entire year and include all of winter heating, summer cooling and domestic hot water. All components are converted into equivalent electrical energy savings

Incremental Energy Saved – ΔEe_equ

ΔEe_equ_sys	$\Delta E_{e.equ.sys} = \frac{(Q_{WD.sys}+Q_{HD.sys}+Q_{hloss})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} + \frac{Q_{HP.sys}+Q_{closs}}{SPF_{CB.th}} - \frac{Q_{HB.sys}*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - (\Delta E_{aux.sys} + Q_{el.VCC})$
ΔEe_equ_C	$\Delta E_{e.equ.C} = \Delta Ee.equ.thC + \frac{(Q_{hloss}*\%_{SC.C})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - Q_{el.VCC}$
ΔEe_equ_thC	$\Delta E_{e.equ.thC} = \frac{Q_{HP.sys}+Q_{closs}}{SPF_{CB.th}} - \frac{(Q_{HB.sys}*\%_{HB.C})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - \Delta E_{aux.thC}$
ΔEe_equ_DHW	$\Delta E_{e.equ.DHW} = \frac{(Q_{WD.sys}+Q_{hloss}*\%_{SC.DHW})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - \frac{(Q_{HB.sys}*\%_{HB.DHW})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - \Delta E_{aux.DHW}$
ΔEe_equ_SH	$\Delta E_{e.equ.SH} = \frac{(Q_{HD.sys}+Q_{hloss}*\%_{SC.SH})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - \frac{(Q_{HB.sys}*\%_{HB.SH})*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}} - \Delta E_{aux.SH}$

Incremental Seasonal Performance Factor – ΔSPFsys

= the efficiency (in electrical equivalent units) of that part of the system, which distinguishes from a common heating and cooling system

$$\Delta SPF_{sys} = \left(\frac{\textit{heating and cooling provided by a non conventional source (solar)}}{\textit{Primary energy supplied by the conventional source (in Electricity equivalent units)}}\right)$$

In this way the incremental Seasonal Performance Factor treats the solar cooling system like a stand-alone product rather than a building heating and cooling system.

Incremental Seasonal Performance Factor – ΔSPFsys

ΔSPF.sys	$\Delta SPF_{sys} = \dfrac{Q_{WD.sys}+Q_{HD.sys}+Q_{hloss}-Q_{HB.sys}*(1-\%_{HB.C})+Q_{HP.sys}+Q_{closs}}{\dfrac{Q_{HB.sys}*\%_{HB.C}*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}}+E_{aux.sys}}$
ΔSPF.C	$\Delta SPF_{C} = \dfrac{Q_{HP.sys}+Q_{closs}}{\dfrac{Q_{HB.sys}*\%_{HB.C}*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}}+E_{aux.thC}}$
ΔSPF.thC	$\Delta SPF_{thC} = \dfrac{Q_{HP.sys}+Q_{closs}}{\dfrac{Q_{HB.sys}*\%_{HB.C}*\varepsilon_{el}}{\varepsilon_{EC}*\eta_{HB}}+E_{aux.thC}}$
ΔSPF.DHW	$\Delta SPF_{DHW} = \dfrac{Q_{WD.sys}+Q_{hloss}*\%_{SC.DHW}-Q_{HB.sys}*(1-\%_{HB.C}-\%_{HB.SH})}{E_{aux.DHW}}$
ΔSPF.SH	$\Delta SPF_{SH} = \dfrac{Q_{HD.sys}+Q_{hloss}*\%_{SC.SH}-Q_{HB.sys}*(1-\%_{HB.C}-\%_{HB.DHW})}{E_{aux.SH}}$

Incremental Solar Cooling Capacity – CAPthC

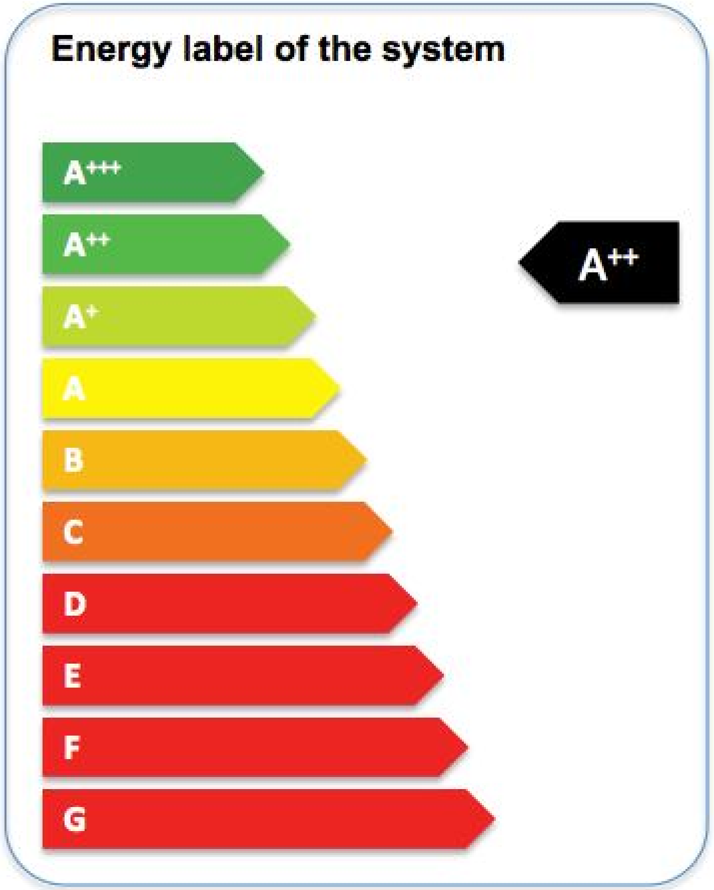
= the incremental peak electrical saving rate (capacity) from solar cooling in electrical equivalent units (over the performance time)

$$CAP_{solar} = \frac{\left(\frac{Q_{\text{CD.system}} + Q_{closs} - Q_{\text{CB.system}}}{EER_{ref}(f(kW))} - \frac{Q_{\text{HB.system}} * \%_{HB.C} * \epsilon_{el}}{\epsilon_{EC} * \eta_{HB}} - \Delta E_{aux.\text{thC}}\right)}{t}$$

Energy Labelling

Rating levels:

> 90 %
90 - 80 %
80 - 70 %
70 - 60 %
60 - 50 %
50 - 40 %
40 - 30 %
30 - 20 %
20 - 10 %
< 10 %



Rating of the entire System

fsav is used for labelling:

$$f_{sav.NRE.PER.i} = (1 - \frac{PER_{NRE.ref.i}}{PER_{NER.i}}) * 100$$

Levelized costs

- Levelized cost of energy (SH+DHW+C)

- Calculated on the bases of VDI 2067
- Annualized cost for
  - Investment
  - replacement & residual value
  - Maintenance & service
  - Operational costs (energy, water)

USE with care!

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