Latest results and discussions on B7 & B1 activities

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With support of EURAC, CSIRO, ISE, AEE INTEC, ASIC

Content

- Notation / system representation
- Performance & Cost figures
- Examples

Notation / system representation

- In style of IEA SHC Task44

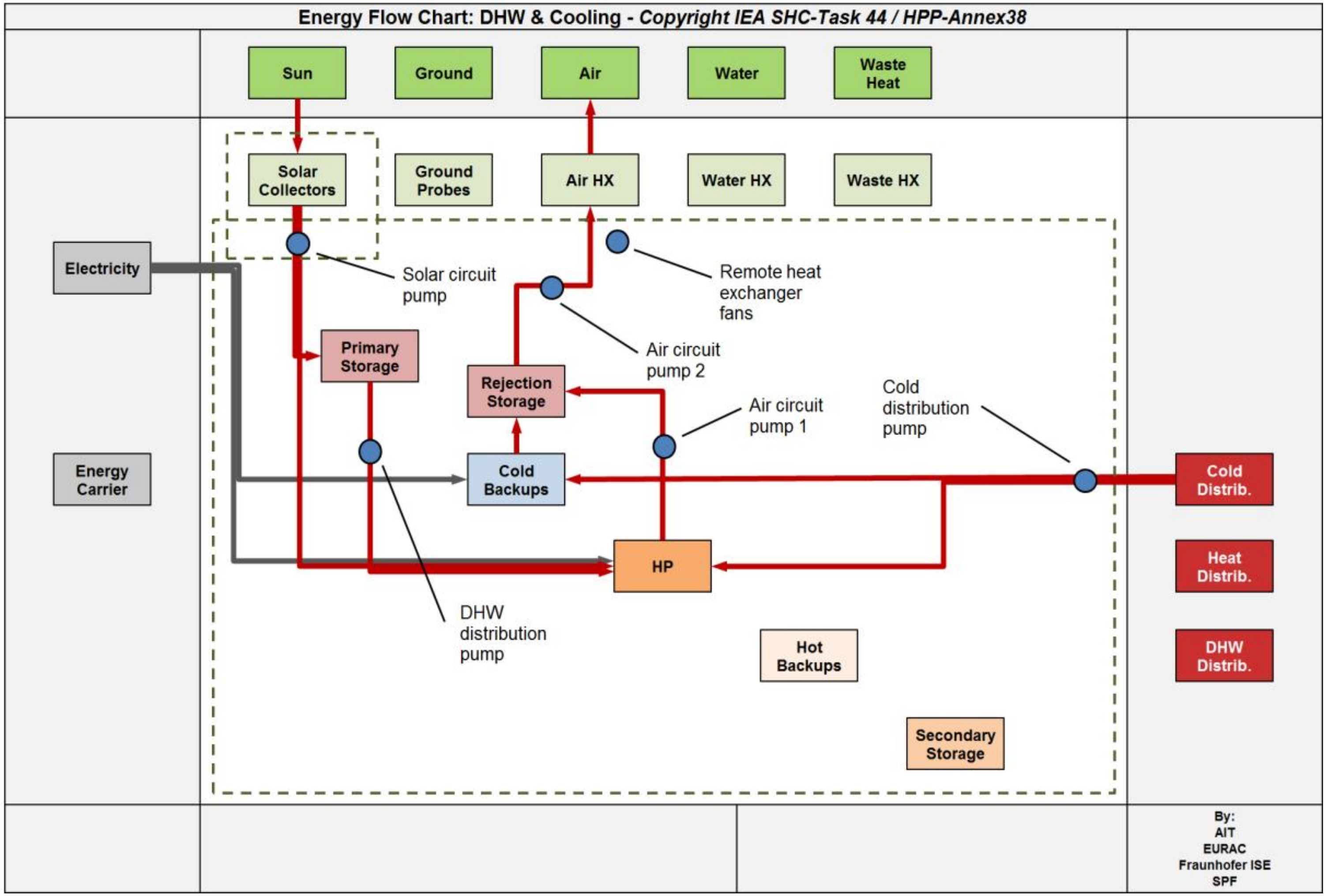
- Qsource.sink e.g. $Q_{CD.HP}$, $Q_{el.HP}$
- Square View
- Excel Tool adapted to T48
  - System boundaries
  - Key Figures (performance & costs)
  - Standard & individual/specific

→ Input needed and will be used in Subtask C

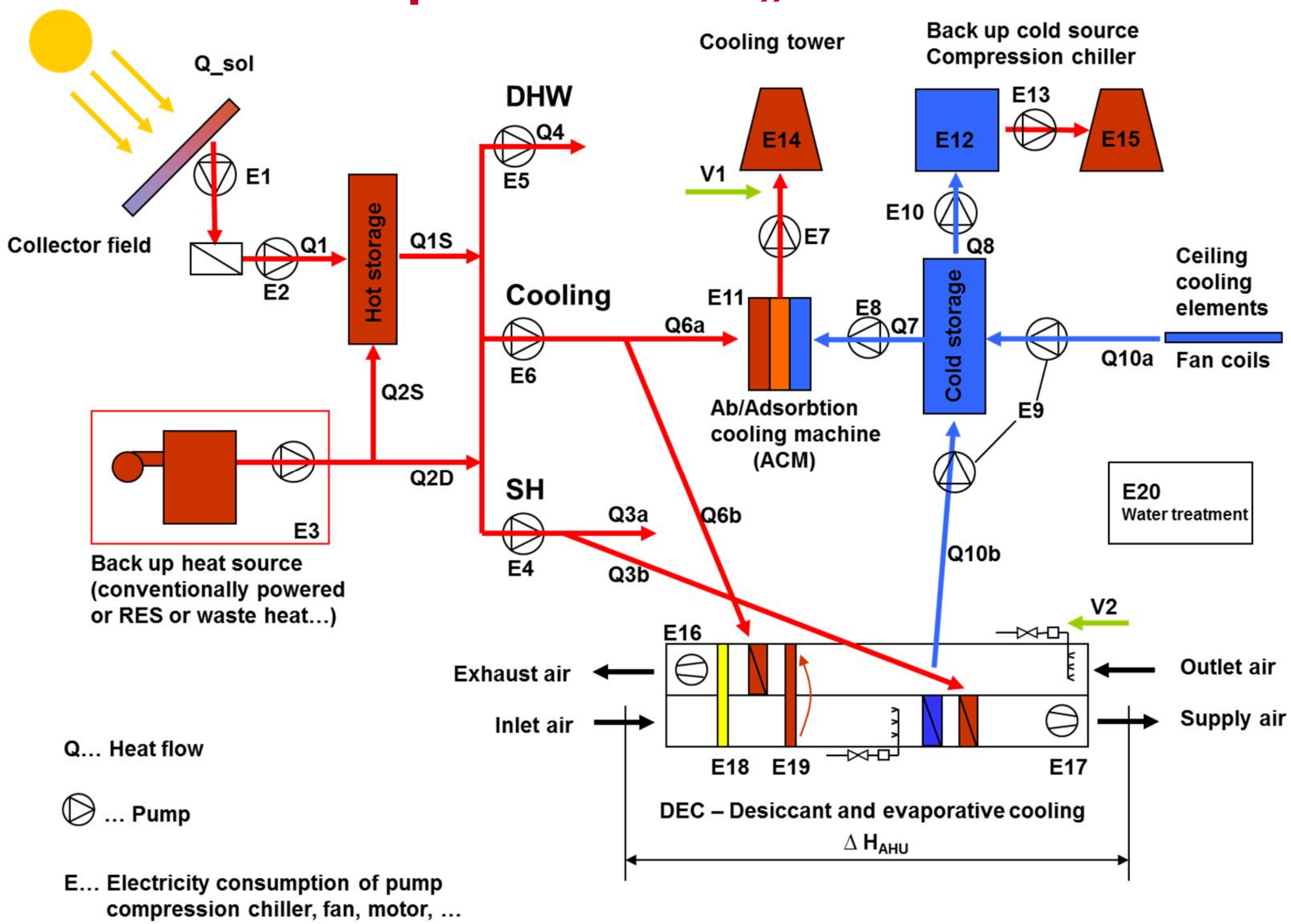
Notation / system representation

Energy Carrier to Hot Backups	EC.HB
Sun to Solar Collectors	SU.SC
Solar Collectors to Primary Storage	SC.PS
Solar Collectors to HP	SC.HP
Solar Collectors to Heat Distribution	SC.HD
Solar Collectors to DHW Distribution	SC.WD
Air Heat Exchanger to Air	AH.Ar
Primary Storage to HP	PS.HP
Primary Storage to Heat Distribution	PS.HD
Primary Storage to DHW Distribution	PS.WD
Cold Backups to Air Heat Exchanger	CB.AH
HP to Air Heat Exchanger	HP.AH
Hot Backups to Primary Storage	HB.PS
Hot Backups to HP	HB.HP
…	xx.xx

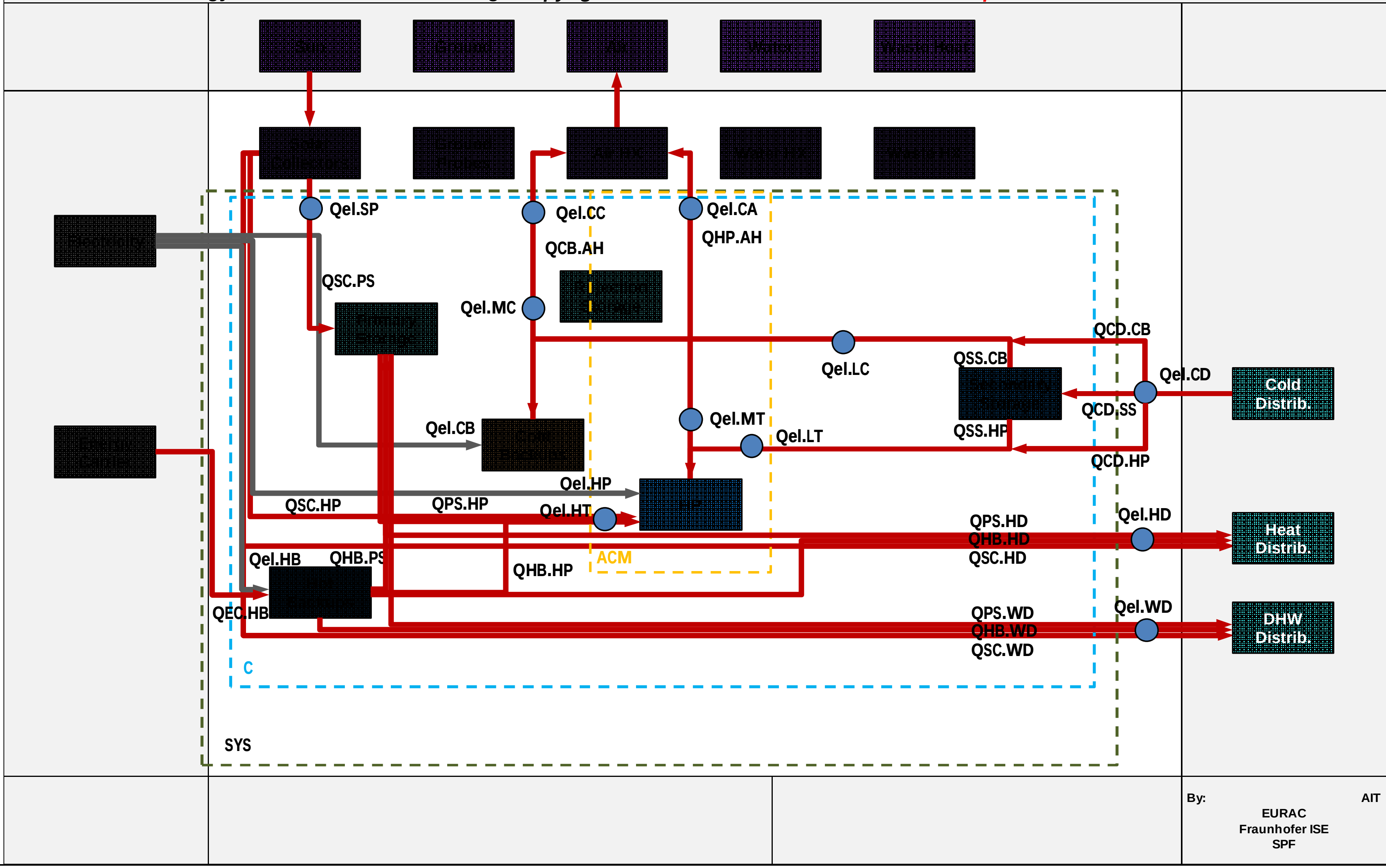
Square view – simple example



Square view – „max“



Energy Flow Chart: DHW & Cooling - *Copyright IEA SHC-Task 44 / HPP-Annex38* - *adapted for IEA SHC Task 48*



Key Figures

- SPF, Seasonal Performance Factor

$$SPF_{i,th} = \frac{\sum Q_{i,out}}{\sum Q_{i,in}} \qquad SPF_{i,el} = \frac{\sum Q_{i,out}}{\sum W_{el,i,in}}$$

  - Thermal, electrical
  - Different boundaries (system, time,…)!

- PER, Primary Energy Ratio

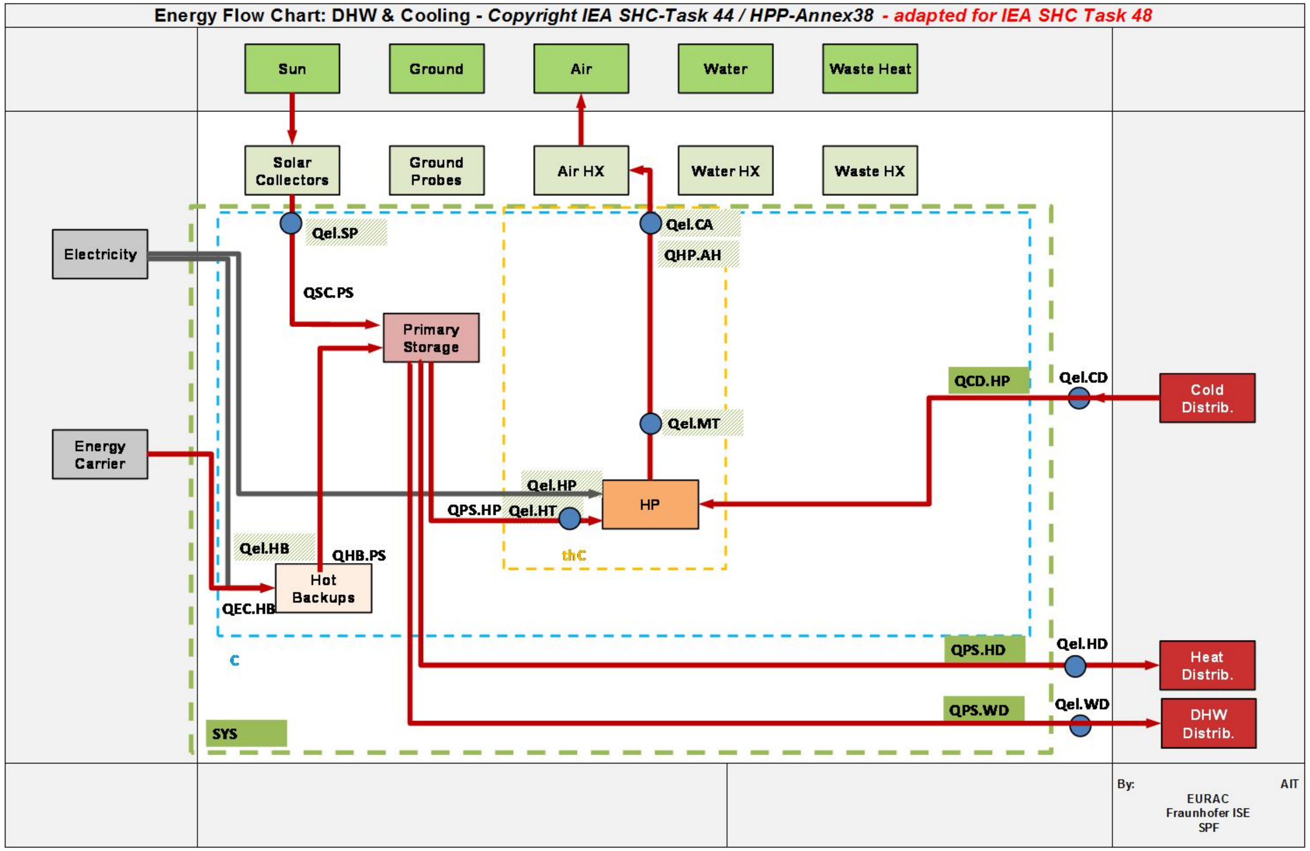
$$PER_i = \frac{\sum Q_{i,out}}{\sum \left(\frac{Q_{el,i,in}}{\varepsilon_{el}} + \frac{Q_{i,in}}{\varepsilon_{in}} \right)}$$

  - Different boundaries!

System boundaries – Complete system (C+H+DHW)

$$SPF_{el,sys} = \frac{Q_{CD.sys} + Q_{HD.sys} + Q_{WD.sys}}{\sum Q_{el,sys}}$$

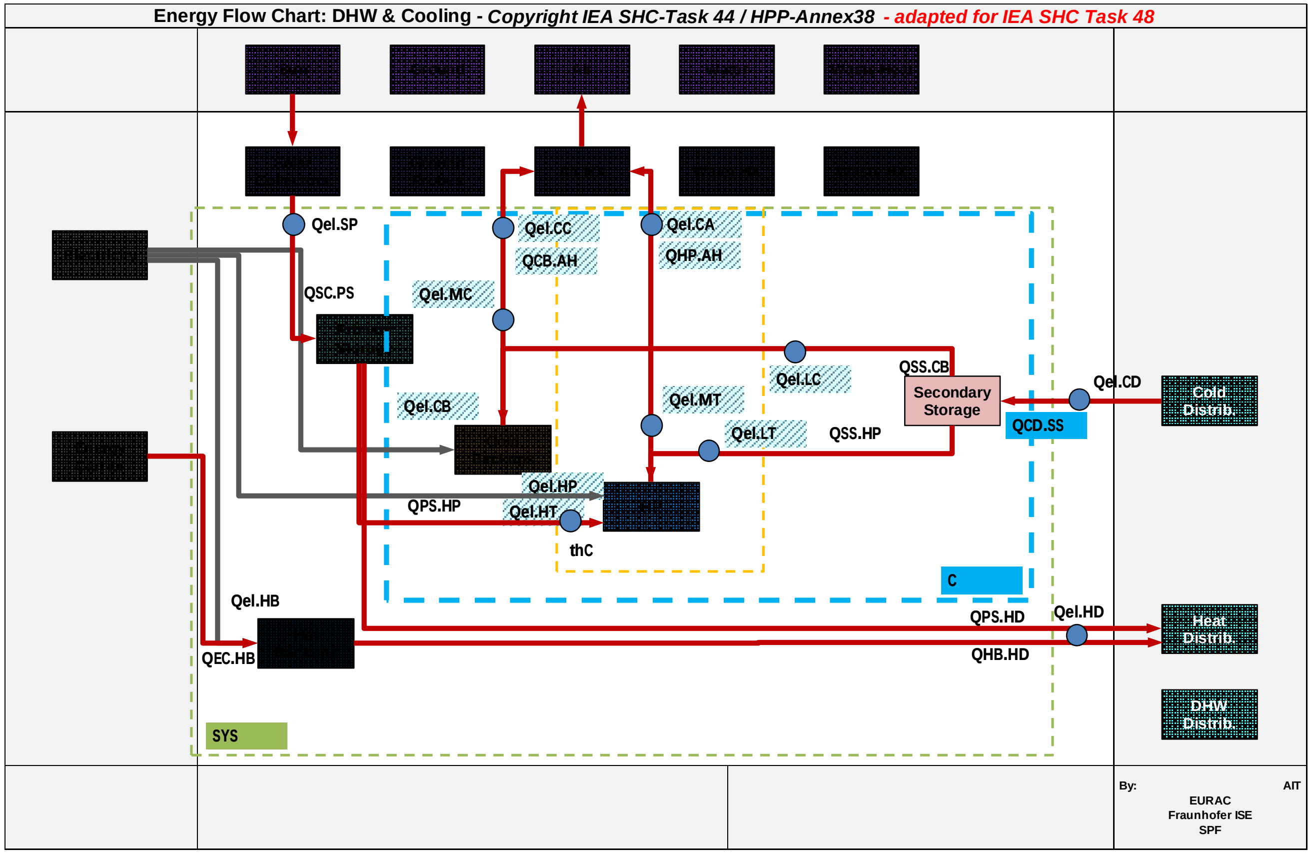
$$PER_{NRE,sys} = \frac{Q_{CD.sys} + Q_{HD.sys} + Q_{WD.sys}}{\frac{\sum Q_{el,sys}}{\varepsilon_{el}} + \frac{Q_{EC}}{\varepsilon_{EC}}}$$



System boundaries – Cooling & Backup (th, el)

$$SPF_{el,C} = \frac{Q_{CD.SS} + Q_{CD.HP} + Q_{CD.CB}}{\sum Q_{el,C}}$$

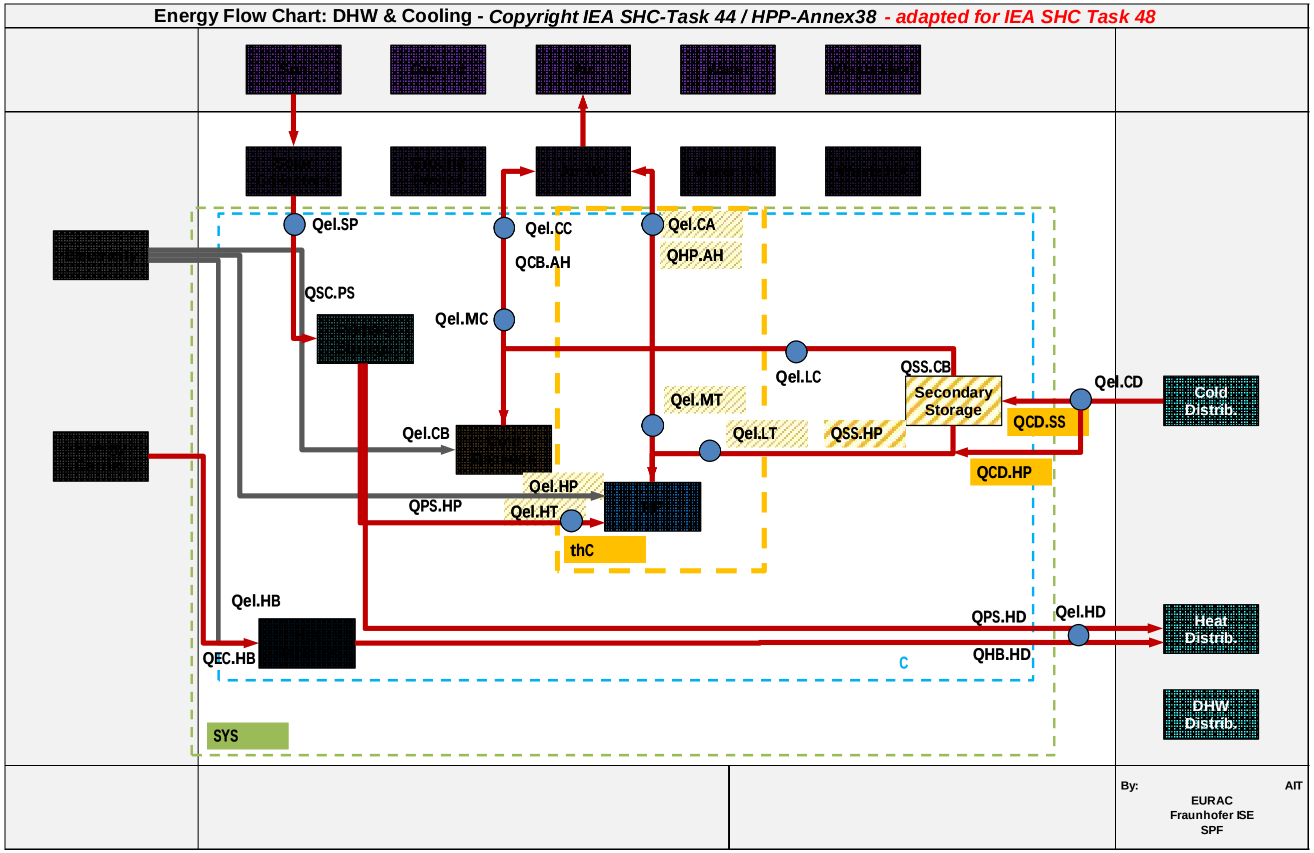
$$PER_{NRE,C} = \frac{Q_{CD.SS} + Q_{CD.HP} + Q_{CD.CB}}{\frac{\sum Q_{el,C}}{\varepsilon_{el}} + \frac{Q_{EC.HB} * \%_{C,HB.HP} + Q_{EC.HB} * \%_{C,HB.PS} * \%_{C,PS.HP}}{\varepsilon_{EC}}}$$



System boundaries – Thermal cooling

$$SPF_{el,thC}=\frac{Q_{CD.SS} * \%_{C,SS.HP} + Q_{CD.HP}}{\sum Q_{el,\text{th.}C}}$$

$$PER_{NRE,thC} = \frac{Q_{SS.HP} + Q_{CD.HP}}{\frac{\sum Q_{el.thC}}{\varepsilon_{el}} + \frac{Q_{EC.HB} * \%_{C,HB.HP} + Q_{EC.HB} * \%_{C,HB.PS} * \%_{C,PS.HP}}{\varepsilon_{EC}}}$$



Definition of Key Figures (1)

- **PER$_{ref}$** – according to T38

$$PER_{ref\_NRE} = \frac{Q_{HD.sys} + Q_{WD.sys} + Q_{CD.sys}}{\frac{Q_{HD.sys} + Q_{WD.sys} + Q_{loss\_ref}}{\varepsilon_{boiler} * \eta_{boiler}} + \frac{Q_{CD.sys}}{SPF_{ref} * \varepsilon_{el}} + \frac{Q_{el.ref}}{\varepsilon_{el}}}$$

- **fsav**, non renewable primary energy savings

  (different system boundaries possible!)

$$f_{sav\_PER-NRE} = 1 - \frac{PER_{ref\_NRE}}{PER_{i\_NRE}}$$

Definition of Key Figures (2)

- **SPFequ**
  for same primary energy demand
  this SPF has to be matched
  by other systems (ref or other renewable,…)

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

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

$$\left[\frac{kWh_{th}}{kWh_{el}} = \frac{\frac{kWh_{th}}{kWh_{prim}}}{\frac{kWh_{el}}{kWh_{prim}}}\right]$$

Definition of Key Figures (3)

- **CAP**$_{\textbf{solar}}$ - Incremental Solar Cooling Capacity

"Incremental" is "performance with – performance without" non conventional energy

- Avoided peak demand in electrical equivalent units
- Based on 10 days with highest cold demands

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

$$\widehat{CAP}_{solar} = \frac{CAP_{solar}}{A}$$

Reduces the calculated capacity/size if non RE use leads to lower performance than use of conventional backup (prevents oversizing)

- Could be used for subsidies based on size of system

Definition of Key Figures (4)

- **E_{total}**, Incremental Energy Saved
  - Quantities are converted into equivalent electrical energy
  - using an appropriate primary energy factors
  - utilizing appropriate reference efficiencies for the business as usual alternative heating or cooling appliance

$$E_{total} = \frac{\left(Q_{WD.sys} + Q_{HD.sys} + Q_{hloss} - Q_{HB.PS} * (1 - \%_{PS.HP}) - Q_{HB.HD} - Q_{HB.WD}\right)\varepsilon_{el}}{\varepsilon_{EC}\eta_b} + \frac{Q_{CD.sys} + Q_{closs} - Q_{CB.sys} - (QHB.sys * \%HB.C) * SPFth}{SPF_{ref}} - \Delta E_{aux.SHC}$$

E_{total} = *Heat from solar to hot distribution/DHW* + *Cold from TDC* − *"New" gas Consumed by TDC* − *Parasitic electricity consumed*

All in units converted from heat to electricity by relevant primary energy conversion factors

Definition of Key Figures (5)

- **ΔSPF$_{shc}$**, Incremental Seasonal Performance
  - incremental change
  - solar air-conditioning systems ↔ vapour compression air-conditioners.
  - on a seasonal basis
  - in electrical equivalent

$$\Delta SPF_{SHC} = \frac{\left(Q_{WD.sys} + Q_{SH.sys} + Q_{hloss} - Q_{HB.HD} - Q_{HB.WB} - Q_{HB.PS} * \%_{PS.HD+WD}\right) + \left(Q_{CD.sys} + Q_{closs} - Q_{CB.sys} - (QHB.sys * \%HB.C) * SPFth\right)}{\left(Q_{EC.HB} * \%_{HB.C}\right) * \varepsilon_{el} + E_{aux.SHC}}$$

$$\Delta SPF_{SHC} = \frac{\text{Heat from solar to hot distribution/DHW} + \text{Cold from TDC}}{\text{“New” gas Consumed by TDC} + \text{Parasitic electricity consumed}} \qquad \frac{\text{(Heat units)}}{\text{(Electrical equiv units)}}$$

Cost figures (1)

- Total annualized costs [€/kWh]
- kWh_{prim} / CO_2 avoidance costs

$$CO_{2\_avoidance\ cost} = \frac{cost_i - cost_{ref}}{CO_{2\_ref} - CO_{2\_i}} \left[\frac{EUR_{avoidance}}{kgCO_2} \right]$$

- According to VDI 2067
- Standard / specific values

Cost figures (2)

- Done in collaboration with Hilbert Focke, ASiC

- Cost for system parts (cooling, heating, DHW) separately
- Cost for reference plant included
- At the moment only AB/Adsorption cooling, no DEC
- Change between different boundary conditions (economic factors, energy prices, specific costs….) easily possible
- Cost function (€/quantity are highly wanted)
- Reviewed with data from Austrian installations
- …..

Application of Key Figures

- Seems to get complex!?
- Measurement requirements?
  - 3 + 2 +? Heat Meter
  - 3 +? Electricity Meter

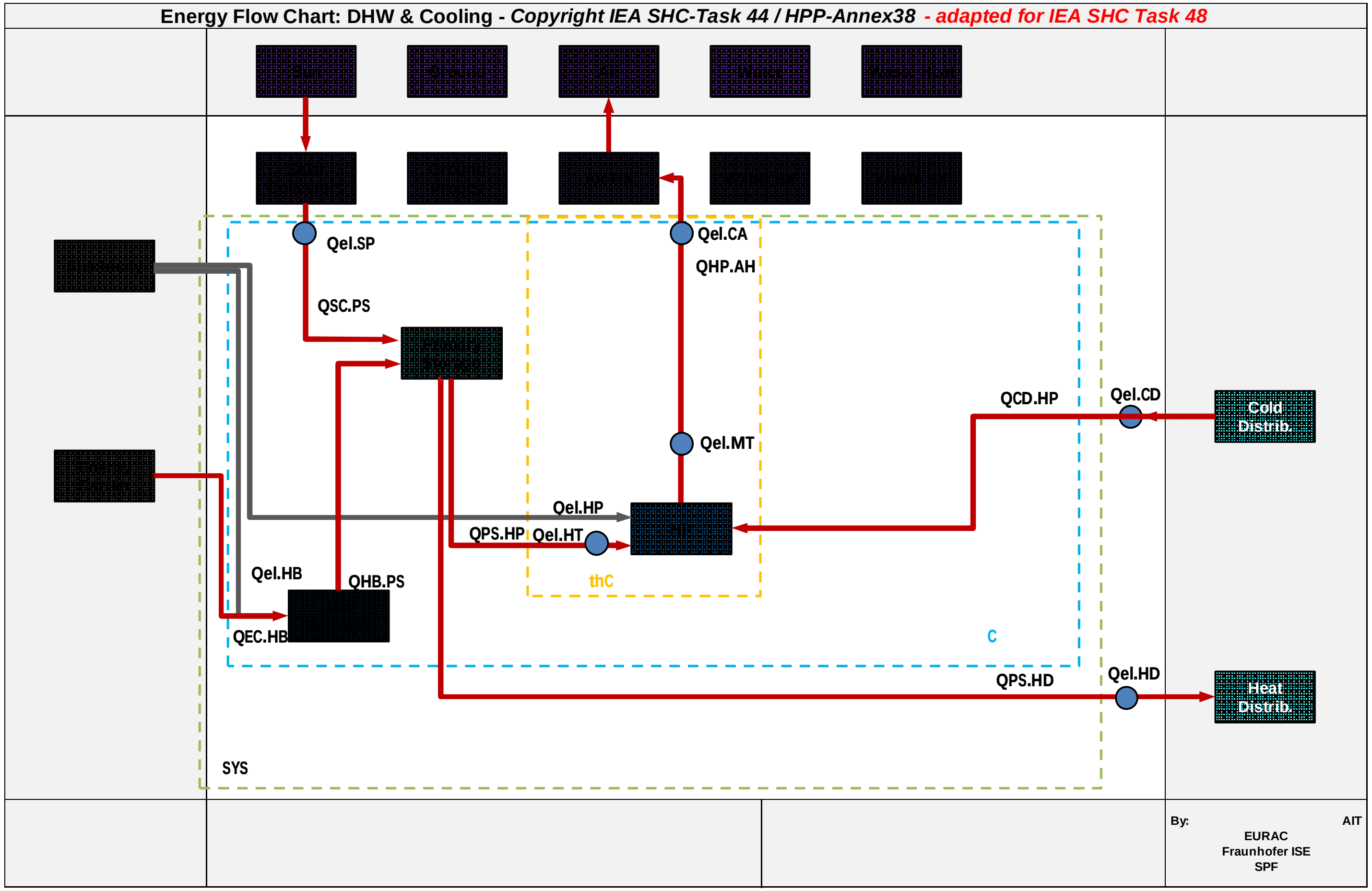
→ Best practice should be simple

→ Good comparison to “known” quantities (SPF, EER,…) used by Heat pumps systems

→ Different fields (subsidies, labeling,..) need different key figures!

Example 1

- Feistritzwerke Gleisdorf (AEE INTEC)



Example 1

In kWh/a (from Oct.-Nov.)

		2011	2012	2013
Total cold distribution to system	**QCD.system**	13.354 (12%)	16.097 (8%)	14.360 (11%)
Total space heating from system	**QHD.system**	100.568 (88%)	181.390 (92%)	116.338 (89%)
Total domestic hot water consumption from system	**QWD.system**	0	0	0
Total hot back up to primary storage	**QHB.system**	98.2 (77.0%)	175.8 (83.3%)	118.9 (81.6%)
Total solar collector to primary storage	**QSC.system**	29.4 (23.0%)	35.2 (16.7%)	26.7 (18.4%)
Total primary storage to space heating	**QPS.HD**	100.6	181.4	116.3
Total primary storage to heat pump	**QPS.HP**	22.2	26.4	24.6
Losses	**Qhloss**	4.8	3.2	4.7
Total secondary storage to system	**QSS.system**	0	0	0
Total electricity for thermal cooling	**ΔEaux.C**	2.758	2.762	2.636

Example 1

- Thermal backup - Renewable

  ε_{el} =10 kWh_{el}/kWh_{prim}
- SPF_{ref} = 2,8
- Reference system

  Natural gas boiler & vapour compression chiller

- thC and C are the same
- CAP not calculable
- Savings just because of biomass

	unit	2011	2012	2013
SPF_{th}	-	0,60	0,61	0,58
$SPF_{el.sys}$	-	39,35	67,16	46,84
$SPF_{el.thC}$	-	4,84	5,83	5,45
$SPF_{el.C}$	-	4,84	5,83	5,45
$PER_{NRE,ref.SYS}$	-	0,85	0,84	0,84
$PER_{NRE,refC}$	-	1,12	1,12	1,12
$PER_{NRE,sys}$	-	6,28	7,35	6,48
$PER_{NRE,thC}$	-	1,6	1,8	1,7
$f_{sav.NRE.PER.sys}$	-	0,87	0,89	0,87
$f_{sav.NRE.PER.C}$	-	0,30	0,38	0,34
$SPF_{equ\ C}$	-	3,99	4,50	4,27
$SPF_{equ\ thC}$	-	3,99	4,50	4,27
$SPF_{equ\ SYS}$	-	15,69	18,37	16,19
CAP_{solar}	kW	124	156	137
$\hat{CAP}_{solar}$	kW/m²	1,9	2,5	2,1

Example 1

- Sensitivity of Thermal backup
- No effect on SPF
- PER high impact
- fsav & SPFequ!

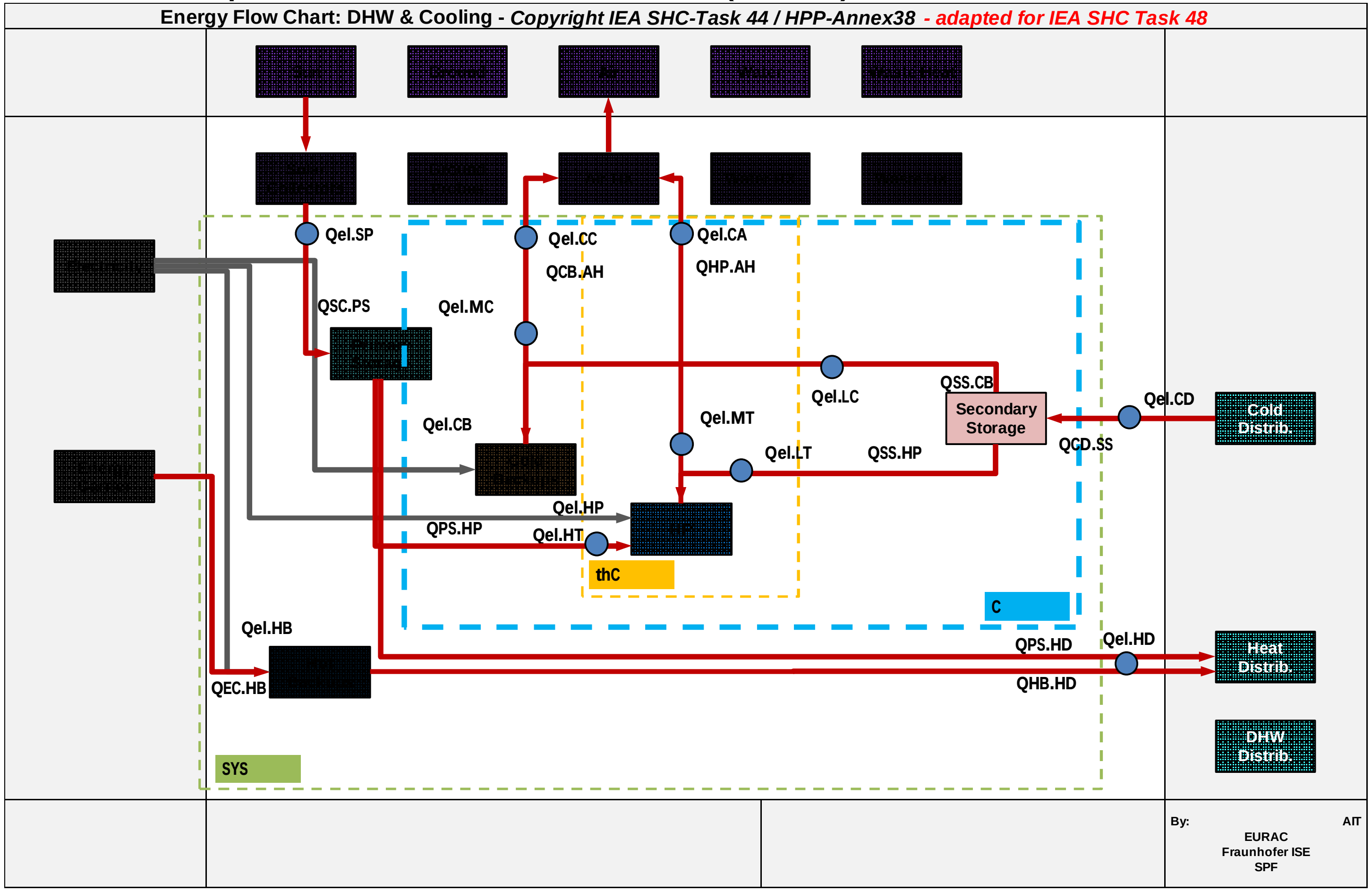
	units	ε_{EC} 0,9 / GAS	10 / BIO
SPF_{th}	-	0,58	0,58
$SPF_{el.sys}$	-	46,84	46,84
$SPF_{el.thC}$	-	5,45	5,45
$SPF_{el.C}$	-	5,45	5,45
$PER_{NRE,ref.SYS}$	-	0,84	0,84
$PER_{NRE,refC}$	-	1,12	1,12
$PER_{NRE,sys}$	-	**0,85**	**6,48**
$PER_{NRE,thC}$	-	**0,54**	**1,71**
$f_{sav.NRE.PER.sys}$	-	**0,01**	**0,87**
$f_{sav.NRE.PER.C}$	-	**-1,09**	**0,34**
$SPF_{equ\ thC}$	-	**1,34**	**4,27**
$SPF_{equ\ SYS}$	-	**2,13**	**16,19**
CAP_{solar}	kW	**92,38**	**137,40**
^CAP^solar	kW/m²	**1,44**	**2,15**

Incremental Performance in Example Calcs

			2011	2012	2013
Incremental heat saved by solar collectors for heating	ΔQSC,HD	kWh thermal	24252.13	30802.38	22217.82
Incremental electrical PE equiv saved by solar collectors for heating (1)	**ΔEheat total**	kWh electrical PE equiv	**11976.36**	**15211.05**	**10971.76**
Cooling provided by heat pump	QCD.HP	kWh thermal	13354.00	16097.06	14360.31
Incremental HP saved electricity compared with a reference VC chiller (2)	**ΔEcold total**	kWh electrical PE equiv	**4769.29**	**5748.95**	**5128.68**
Backup heat used in heat pump	**QHB.HP**	kWh thermal	**17098.99**	**21972.43**	**20046.85**
Parasitic electrical PE equiv from back up thermal energy to heat pump (3)	**ΔEHB.HP**	kWh electrical PE equiv	**8443.94**	**10850.58**	**9899.68**
Parasitic electricity (4)	**ΔEaux.C**	kWh electrical	**2758.09**	**2762.12**	**2635.80**
Incremental Energy Saved		**ΔETotal**	**5543.61**	**7347.30**	**3564.96**
Incremental Seasonal Performance Factor		**ΔSPF SHCe**	**3.36**	**3.45**	**2.92**
		SPF HPth	**0.60**	**0.61**	**0.58**
		SPF HPel	**4.84**	**5.83**	**5.45**

Example 2

- Bezirkshauptmannschaft Rohrbach (ASIC)



Example 2

		kWh / Period: 1 summer
Total cold distribution to system	**QCD.system**	18.700 (41%)
Total space heating from system	**QHD.system**	27.010 (59%)
Total domestic hot water consumption from system	**QWD.system**	0
Total hot back up to system	**QHB.system**	18.300
Total primary storage to system	**QPS.system**	19.030
Total solar collector to system	**QSC.system**	19.940
Total secondary storage to system	**QSS.system**	18.700
Total electricity to system (excl. Distribution pumps)	**Qel.system**	6.452
Total electricity for thermal cooling	**Qel.thC**	1.241
Total electricty for cooling	**Qel.C**	6.402
Total electricty of chiller incl. alle pumps and reccoling	**Qel.ACM**	1.182
Total electricty of vapour compression chiller	**Qel.VCC**	5.162
Total electricty of reference SH+DHW production	**Qel.ref**	540
	ΔEaux.C	1.241

Example 2

- SPFref = 2,8
- SPFel.thC = SPFequ.thC

SPF_{th}	-	0,61
$SPF_{el.sys}$	-	7,09
$SPF_{el.thC}$	-	5,35
$SPF_{el.C}$	-	2,92
$PER_{NRE,ref}$	-	0,92
$PER_{NRErefC}$	-	1,12
$PER_{NRE,sys}$	-	1,18
$PER_{NRE,C}$	-	1,17
$PER_{NRE,thC}$	-	2,1
$f_{sav.NRE.PER.sys}$	-	0,22
$f_{sav.NRE.PER.C}$	-	0,04
$SPF_{equ\ C}$	-	2,92
$SPF_{equ\ thC}$	-	5,35
$SPF_{equ\ SYS}$	-	2,95
CAP_{solar}	kW	164
$\hat{}CAP\hat{}_{solar}$	kW/m²	2,6
Etotal	kWh	17543
ΔSPF_{SHC}	-	12,61

Example 2

Sensitivity on electrical Backup

$SPF_{ref} = SPF_{CB}$

Effect on SPF, PER,…

	SPFref & SPF_{CB}			
	2,3	**4,6**	**6,8**	**8,9**
SPF_{th}	0,61	0,61	0,61	0,61
$SPF_{el.sys}$	**7,09**	**11,69**	**14,92**	**17,32**
$SPF_{el.thC}$	5,35	5,35	5,35	5,35
$SPF_{el.C}$	**2,92**	**4,84**	**6,20**	**7,22**
$PER_{NRE,ref}$	**0,86**	**1,06**	**1,15**	**1,20**
$PER_{NRErefC}$	**0,93**	**1,84**	**2,72**	**3,57**
$PER_{NRE,sys}$	**1,18**	**1,41**	**1,51**	**1,57**
$PER_{NRE,C}$	**1,17**	**1,94**	**2,48**	**2,89**
$PER_{NRE,thC}$	2,14	2,14	2,14	2,14
$f_{sav.NRE.PER.sys}$	**0,27**	**0,25**	**0,24**	**0,24**
$f_{sav.NRE.PER.C}$	**0,20**	**0,05**	**-0,10**	**-0,24**
$SPF_{equ\ C}$	**2,92**	**4,84**	**6,20**	**7,22**
$SPF_{equ\ thC}$	5,35	5,35	5,35	5,35
$SPF_{equ\ SYS}$	**2,95**	**3,53**	**3,78**	**3,91**
CAP_{solar}	**153**	**185**	**196**	**201**
^CAP^_{solar}	**2,4**	**2,9**	**3,0**	**3,2**
Etotal	**18013**	**19155**	**19536**	**19726**
ΔSPF_{SHC}	12,61	12,61	12,61	12,61

Incremental Performance in Example Calcs

Incremental heat saved by solar collectors for heating	ΔQSC,HD	kWh thermal	9620.00
Incremental electrical PE equiv saved by solar coll	**ΔEheat total**	kWh electrical PE equiv	**4750.62**
Cooling provided by heat pump	QCD.HP	kWh thermal	6640.00
Incremental HP saved electricity compared with a	**ΔEcold total**	kWh electrical PE equiv	**2371.43**
Backup heat used in heat pump	**QHB.HP**	kWh thermal	**0.00**
Parasitic electrical PE equiv from back up thermal	**ΔEHB.HP**	kWh electrical PE equiv	**0.00**
Parasitic electricity (4)	**ΔEaux.C**	kWh electrical	**1229.30**
Incremental Energy Saved		**ΔETotal**	**5892.75**
Incremental Seasonal Performance Factor		**ΔSPF SHCe**	**13.23**
		SPF HPth	**0.64**
		SPF HPel	**5.40**

Summary

- From numbers to letters
- Possible representation / square view
  - automatically generated when using the excel tool
- Two results specific / individual
- Different possible technical key figures
  - Depending on the application
- SPFequ
  - good comparable with heat pumps
  - Influence of different backup
- System boundary are important to go for subsystem efficiency
- Cost calculation nearly finished

Next Steps

- Complete Tool & Documentation (June/July)
- Testing with real cases (summer) → your Inputs is needed!
- Using results in Subtask C,…
- …

Thank you for your attention!

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