A4: Pump Efficiency and Adaptability

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- State of the art
  - pump efficiency
  - chiller hydraulic design
- Electricity Consumption of pumps in a SHC system
- Efficient thermal energy transfer between components (AECR)
- Costs
- Adaptability & Control strategies
- Guidelines & Best practice

PUMP EFFICIENCY
- state of the art -

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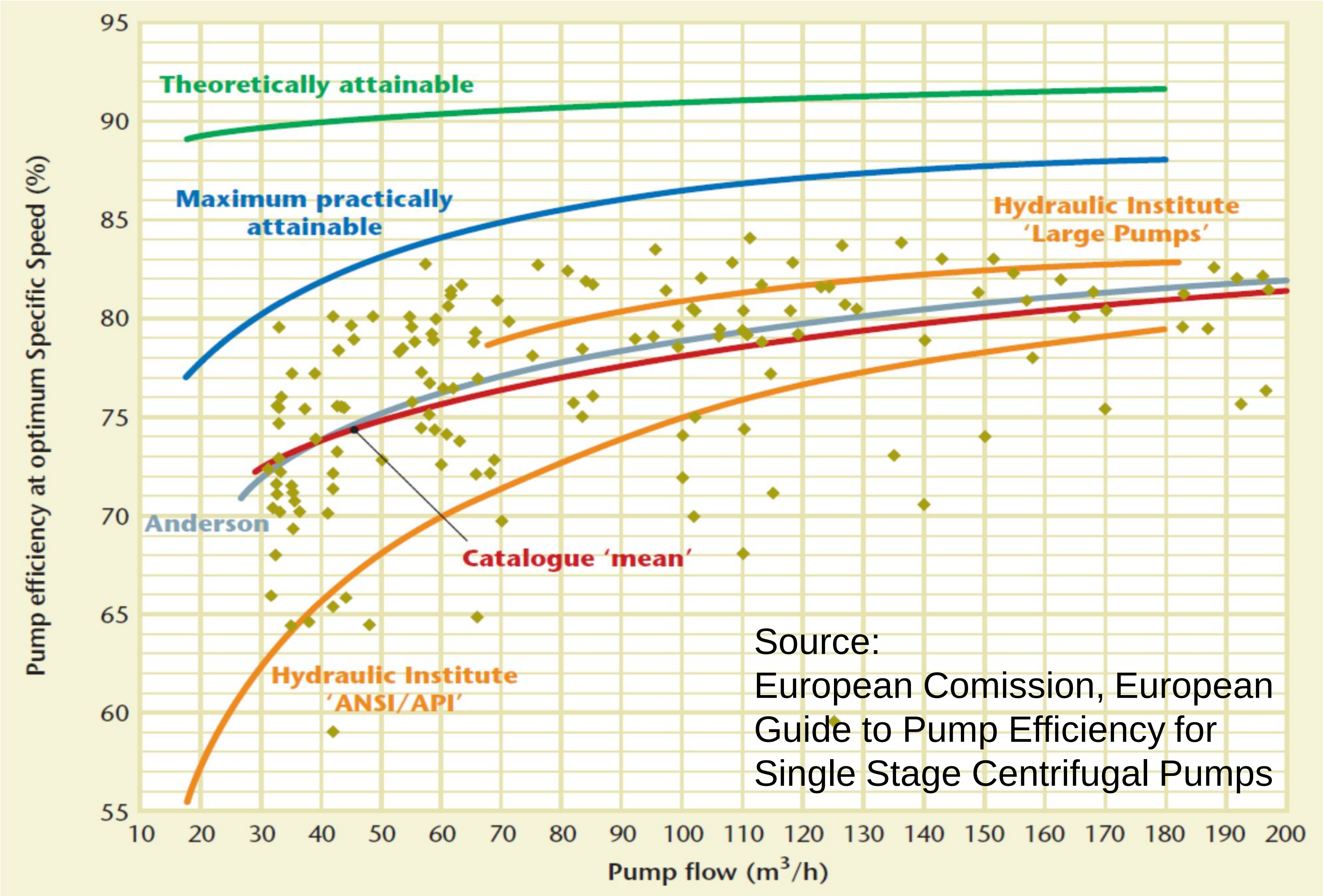

Source:
European Comission, European Guide to Pump Efficiency for Single Stage Centrifugal Pumps

HYDRAULIC DESIGN
- pressure losses in heat carrier circuits -

						Driving heat circuit				Reject heat circuit				chilled water circuit					eta 40%		
Manufacture	Type	Process	Capacity	Heat	COP thermal	INLET	OUTLET	FLOW	Pressure drop	INLET	OUTLET	FLOW	Pressure drop	INLET	OUTLET	FLOW	Pressure drop	Hydraulic work	min. Electricity for pumps	Electricity internal	EER chiller
			kW	kW	-	°C	°C	m³/h	mbar	°C	°C	m³/h	mbar	°C	°C	m³/h	mbar	Watt	Watt	Watt	-
INVENSOR	HTC18vario	Adsorption Zeolite/H2O	18	34.6	0.52	85	76.5	3.6	310	27	34.5	6	290	18	14	3.9	300	111.8	279.6	20.0	60.1
	HTC18plus	Adsorption Zeolite/H2O	18	34.6	0.52				pump incl.				pump incl.				pump incl.				36.4
	LTC10vario	Adsorption Zeolite/H2O	10	16.7	0.60	72	66	2.5	220	27	31.5	5.1	260	18	15	2.9	170	65.8	164.5	20.0	54.2
	LTC10plus	Adsorption Zeolite/H2O	10	16.7	0.60	72	66	2.5	pump incl.	27	31.5	5.1	pump incl.	18	15	2.9	pump incl.			395.0	25.3
SORTECH	ACS15	Adsorption silicagel/H2O	15	26	0.58	7 K		3.2	260	5 K		7	440	3 K		4	500	164.2	410.6	14	35.3
	ACS08	Adsorption silicagel/H2O	8		#DIV/0!	7 K		1.6	230	5 K		3.7	350	3 K		2	300	62.9	157.2	7	48.7
MITSUBISHI F	AQSOA		9.8	21.8	0.45	70	65.1	3.84	275	32	37.2	7.62	698	16	11	1.69	423	196.9	492.3	36	18.5
AGO	100	Absorption H2O/NH3	100	217	0.46	105	82			25	30			1	-5					5570	18.0
	50	Absorption H2O/NH3	50	109	0.46	105	82			25	30			1	-5					4190	11.9
EAW	Wegracal SE 80	Absorption LiBr/H2O	83	111	0.75	86	71	6.4	70	27	32	33.4	400	15	9	12	70	406.9	1017.2	3400	18.8
	Wegracal SE 50	Absorption LiBr/H2O	54	72	0.75	86	71	4.1	50	27	32	22	450	15	9	7.7	65	294.6	736.5	3400	15.9
	Wegracal SE 30	Absorption LiBr/H2O	30	40	0.75	90	80	3.5	400	30	35	12	500	17	11	4.3	400	253.3	633.3	500	26.5
	Wegracal SE 15	Absorption LiBr/H2O	15	21	0.71	90	80	1.8	400	30	35	5	900	17	11	1.9	400	166.1	415.3	300	21.0
PINK	PC19 Minus	Absorption H2O/NH3	12.3	26	0.47	95	88	3.2	640	24	30	5.5	270	0	-3	3.5	120	109.8	274.5	450	17.0
	PC19 Fan-coils	Absorption H2O/NH3	18.6	30	0.62	85	78	3.6	680	24	30	6.9	440	12	6	2.7	65	157.2	393.0	450	5.5
	PC19 act.ceilings	Absorption H2O/NH3	19.5	27	0.72	75	68	3.3	650	24	30	6.7	410	18	15	5.6	280	179.4	448.6	450	21.7
HUIN	RXZ-58	Absorption LiBr/H2O	58	82	0.71	90	85	14.3	500	30		25	500	15	10	10	400	656.9	1642.4	300	29.9
	RXZ-35	Absorption LiBr/H2O	35	49	0.71	90	85	8.6	400	30		15	400	15	10	6	300	312.2	780.6	300	32.4
	RXZ-23	Absorption LiBr/H2O	23	33	0.70	90	85	5.8	400	30		10	400	15	10	4	300	208.9	522.2	300	28.0
	RXZ-11	Absorption LiBr/H2O	11	16.5	0.67	90	85	2.9	800	30		5	500	15	10	2	600	167.2	418.1	150	19.4
THERMAX	LT-2	Absorption LiBr/H2O	70	100	0.70	90.6	85	15.7	200	29.4	36.7	20	300	12.2	6.7	11	590	434.2	1085.4	600	41.5
	LT-1	Absorption LiBr/H2O	35	50	0.70	90.6	85	7.8	120	29.4	36.8	10	120	12.2	6.7	5.5	680	163.2	408.1	600	34.7
SAKURA	SHL010	Absorption LiBr/H2O	35.2	49.3	0.714	88	83	8.4	60	31	36.5	13.13	300	13	8	6	270	168.4	421.0	180	58.6
	SHL008	Absorption LiBr/H2O	26.1	36.45	0.716	88	83	6.7	60	31	36.5	10.51	320	13	8	4.8	250	137.9	344.8	180	49.7
	SHL005	Absorption LiBr/H2O	17.6	24.65	0.714	88	83	4.2	30	31	36.5	6.57	140	13	8	3	260	50.7	126.8	100	77.6
	SHL003	Absorption LiBr/H2O	10.5	14.58	0.72	88	83	2.5	30	31	36.5	3.94	130	13	8	1.8	210	26.8	67.0	100	62.9
Dummy	Test11	not defined	10	16.67	0.6	90	85	2.871	1060	37	42	4.593	1050	13	10	2.871	550	262.4	655.9	100	13.2
Dummy	Test22	not defined	10	16.67	0.6	90	85	2.871	1060	37	45	2.871	420	13	10	2.871	550	161.9	404.7	100	19.8
Dummy	Test33	not defined	10	16.67	0.6	90	85	2.871	1060	37	45	2.871	420	15	10	1.722	200	127.6	319.0	100	23.9
Dummy	Test44	not defined	10	16.67	0.6	90	80	1.435	260	37	45	2.871	420	15	10	1.722	200	53.4	133.6	100	42.8
Dummy	Test55	not defined	10	12.5	0.8	90	80	1.077	150	37	45	2.422	300	15	10	1.722	200	34.2	85.6	100	53.9
YAZAKI	WFC-SC30	Absorption LiBr/H2O	105	151.2	0.69	88	83	35.9	604	31	35	55.1	464	12.5	7	16.5	701	1633.8	4084.5	310	23.9
	WFC-SC20	Absorption LiBr/H2O	70	100.8	0.69	88	83	17.28	464	31	35	36.7	453	12.5	7	11	658	885.6	2214.0	260	28.3
	WFC-SC10	Absorption LiBr/H2O	35	50.2	0.70	88	83	8.64	904	31	35	18.4	853	12.5	7	5.5	561	738.6	1846.6	210	17.0
	WFC-SC05	Absorption LiBr/H2O	17.5	25.1	0.70	88	83	4.32	770	31	35	8.2	383	12.5	7	2.77	526	220.1	550.3	48	29.3

HYDRAULIC DESIGN
- pressure losses in heat carrier circuits -

The hydraulic design of some chillers impede good seasonal performance

Mind:

⇒ **Low pressure drops**

⇒ **High thermal COP**

⇒ **High temperature difference in the heat carrier medium circuits**

Electrical COP of the chiller solely

	Power kW	Temp °C	Flow m^3/h	P-Drop mbar	Hydraulic P1 - kW
Hot water	21	90/80	1,8	400	0,020
Reject heat	35	30/36	5,0	900	0,125
Chilled water	15	17/11	1,9	400	0,021
	71	25 / 44 K Lift/Thrust		P1 (Eff.~35 %) P2	0,166 0,475
	COP	Weight	Dimensions (LxWxH)		Chiller auxiliary
	0,71	500 kg 660 kg	1,8x0,8x1,8 m		0,300
				Maximum electrical COP	**19**
				Maximum electrical COP (50% cooling capacity)	**9.5**

ELECTRICITY CONSUMPTION
- sub systems -

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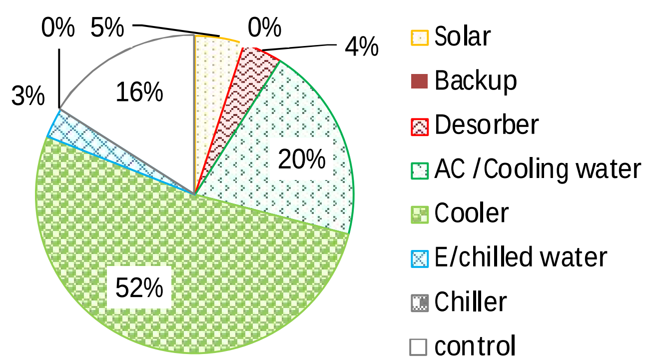
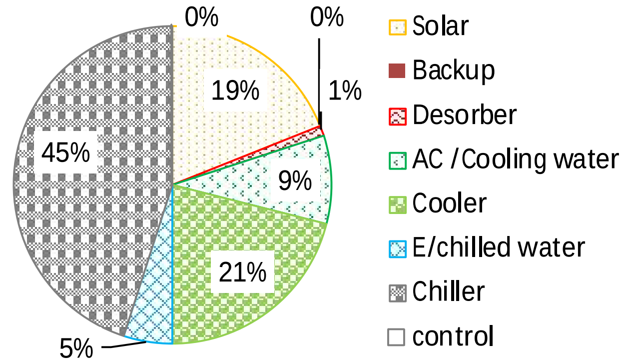
Measuring results from several national Research projects
(SolarCoolingMonitor / SolarCoolingOpt / Roccoco / SolarRück and Annex34 etc.)

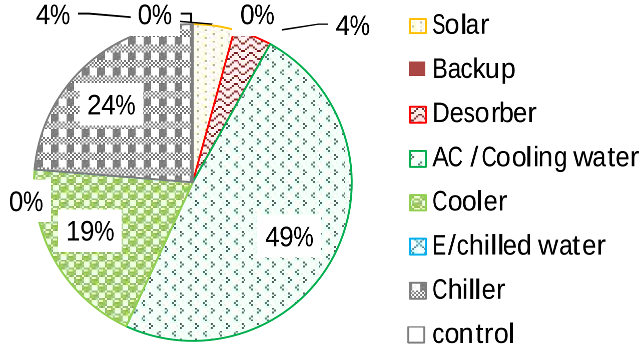
Project: **MA34**
Location: Vienna, Austria
Type: 7.5 kW Silicagel/Water Adsorption chiller
Brand: Sortech
SEER: ~ 6



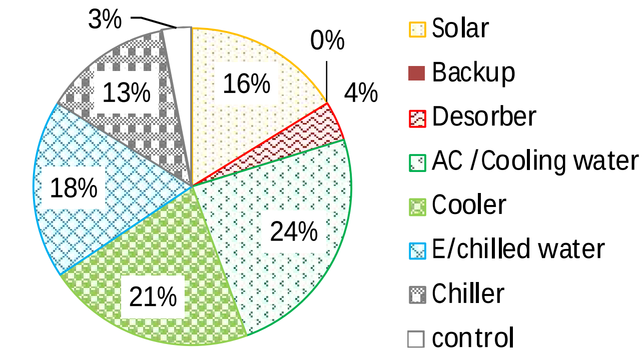
Project: **Sun Master / Xolar**
Location: Rohrbach, Austria
Type: 80 kW LiBr/Water Absorption chiller
Brand: EAW
SEER: ~ 6,7



Project:	**Feistritzwerke**
Location:	Gleisdorf, Austria
Type:	19 kW NH3/Water Absorption chiller
Brand:	PINK
SEER:	~ 5



Project:	**SolarHeatCool+PCM**
Location:	Garching, Germany
Type:	10 kW LiBr/Water Absorption chiller
Brand:	SK Sonnenklima
SEER:	~ 11



⇒ Heat rejection system dominates electricity consumption
⇒ Direct comparison of different SHC-systems is not possible

AUXILLIARY ENERGY CONSUMPTION RATIO
- AECR Comparision of different systems -

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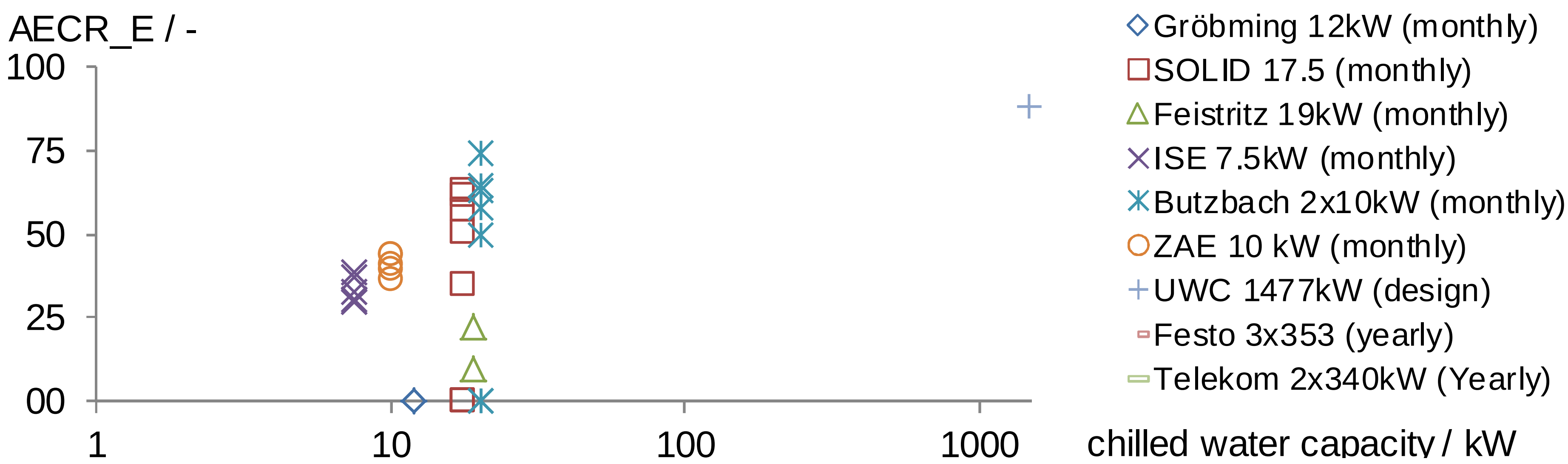
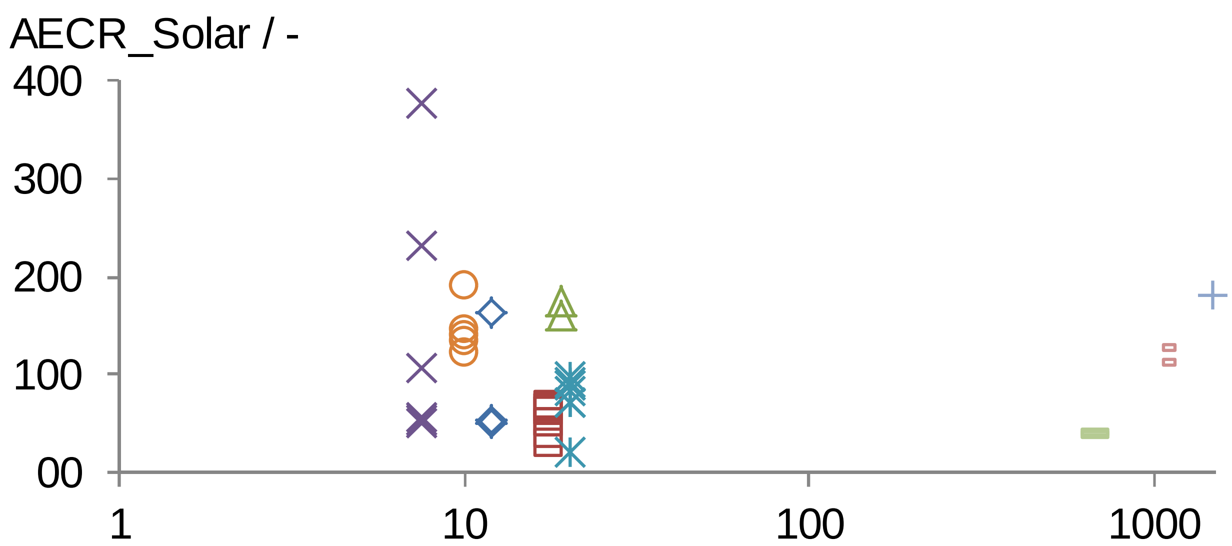
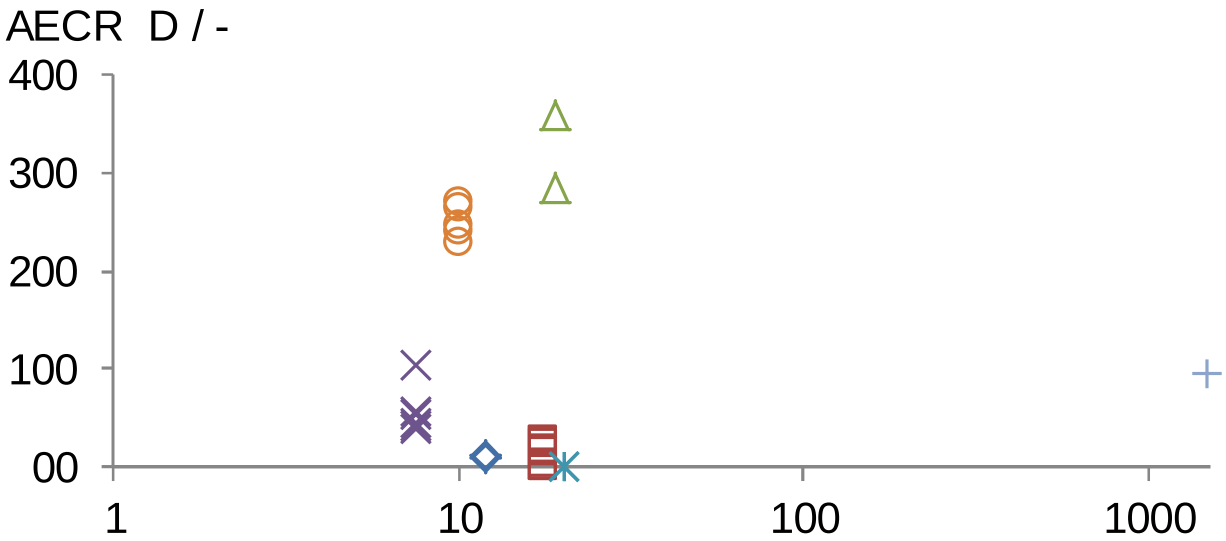




Weighting Factor

➢ **1.4**

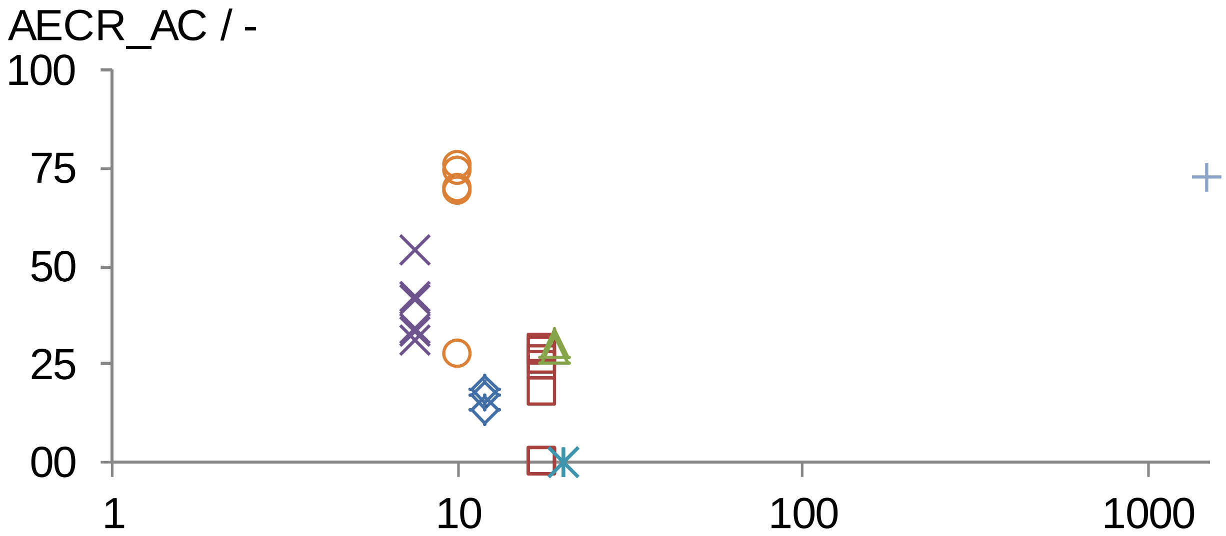
Q_E / $COP_{therm.}$ / $\eta_{Storage}$



Weighting Factor

~ 1.4

Q_E / $COP_{therm.}$



Weighting Factor

~ 2.4

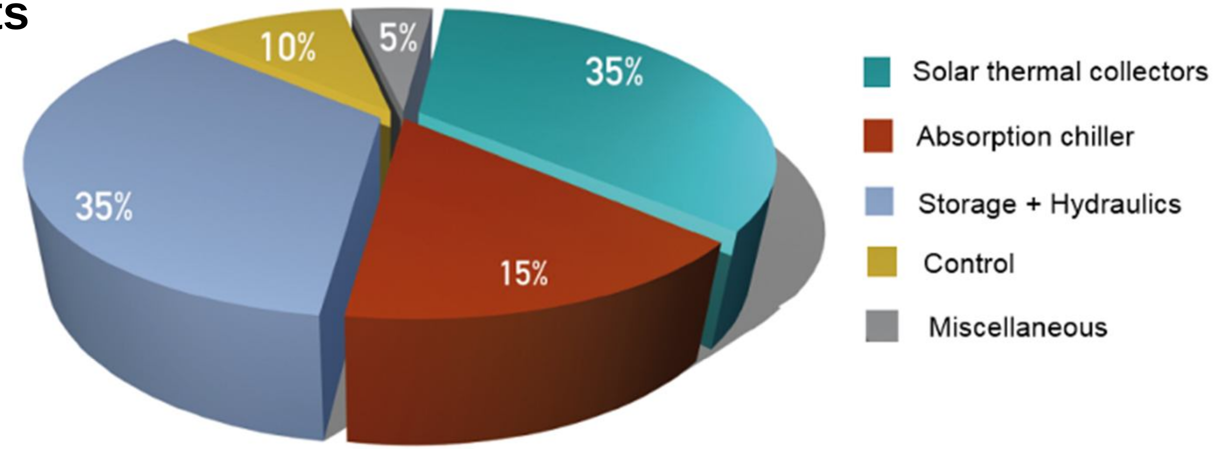
Q_E / $COP_{therm.}$ + 1

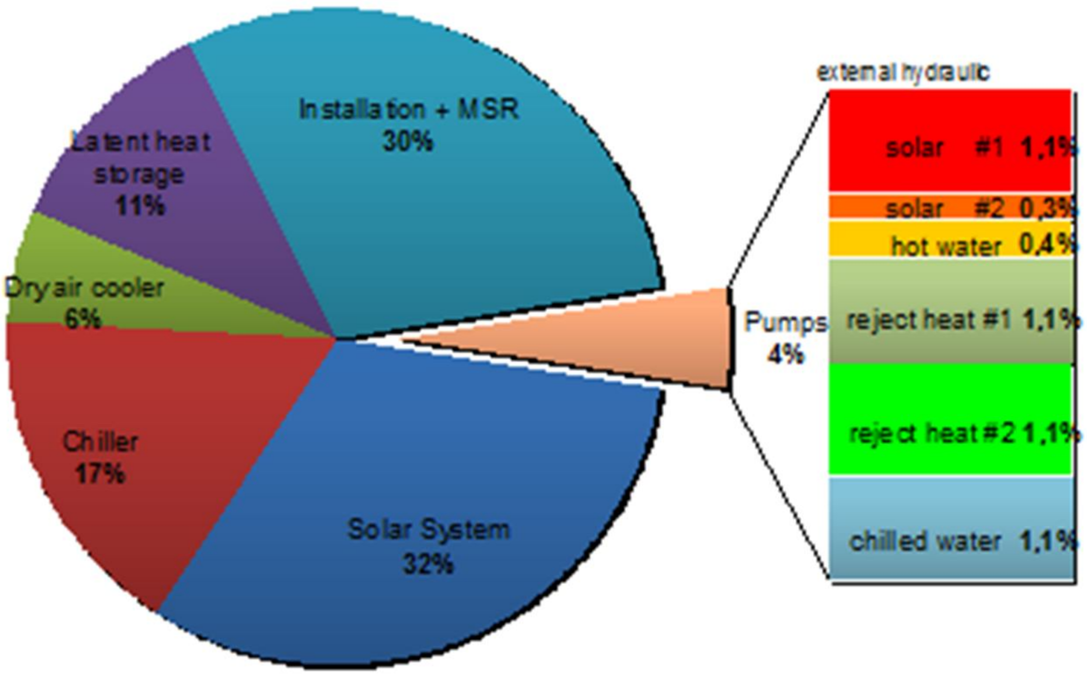
⇒ **Worse AECR**

⇒ **High factor**

Percentage on overall costs

33% Collector field
33% Piping & installation
20 % chiller
< 5% pumps





⇒ **Investment costs not completely negligible BUT… have minor effect on overall system costs**

⇒ **Go for high efficiency pumps**

Main advantages:

+ **Reduced Wiring** (Only BUS cable and Power Cable needed)
+ **Free communication protocol** (RS485)
+ **Integrated measuring equipment** provides additional data (Flow, head, speed, electricity consumption, temperature…) for part load adaption and performance evaluation
+ "Intelligent pumps" might replace most of the measuring equipment needed

Main problems:

- Possible but **complex** and not recommended for plumbers on-site
- Some measuring values are calculated and therefore not precise under extreme part load conditions
- Standby electricity consumption is increased

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Pump speed proportional related to flow (Q)

Pump speed has a cubical effect on electrical power consumption

$$Q = V \cdot \rho \cdot c_p \cdot \Delta T$$

Heat transfer between component

$$\left(\frac{V_2}{V_1}\right)^3 = \left(\frac{P_2}{P_1}\right)$$

Affinity laws

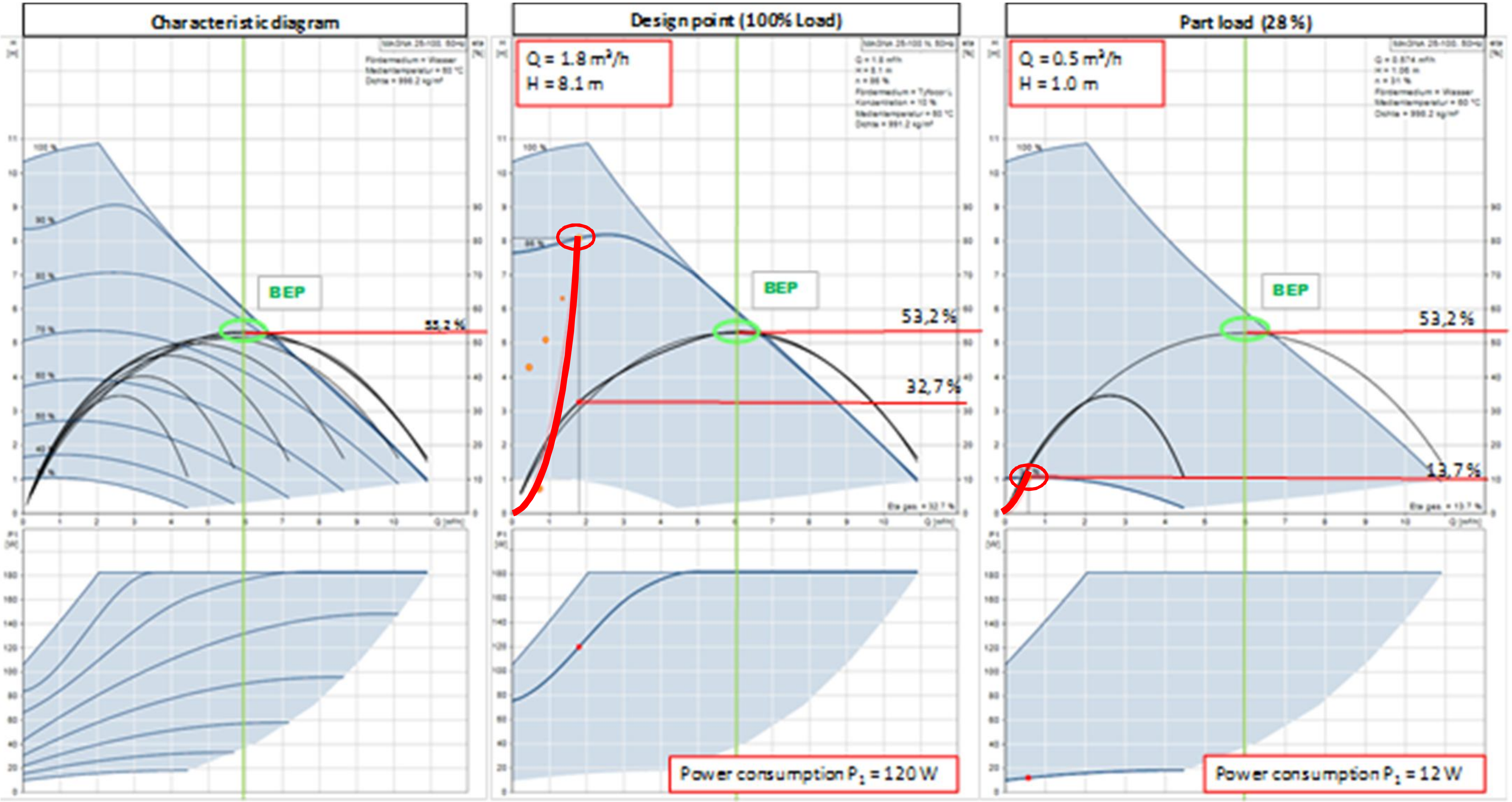
$$P_1 = \frac{V \cdot p}{36 \cdot \eta}$$

Electricity to hydraulic work (water)

⇒ **Reducing heat carrier medium flow in part load conditions allows for cubical electricity savings (theoretically)**

PUMP EFFICIENCY on-site
- missmatch between pump and system curve -

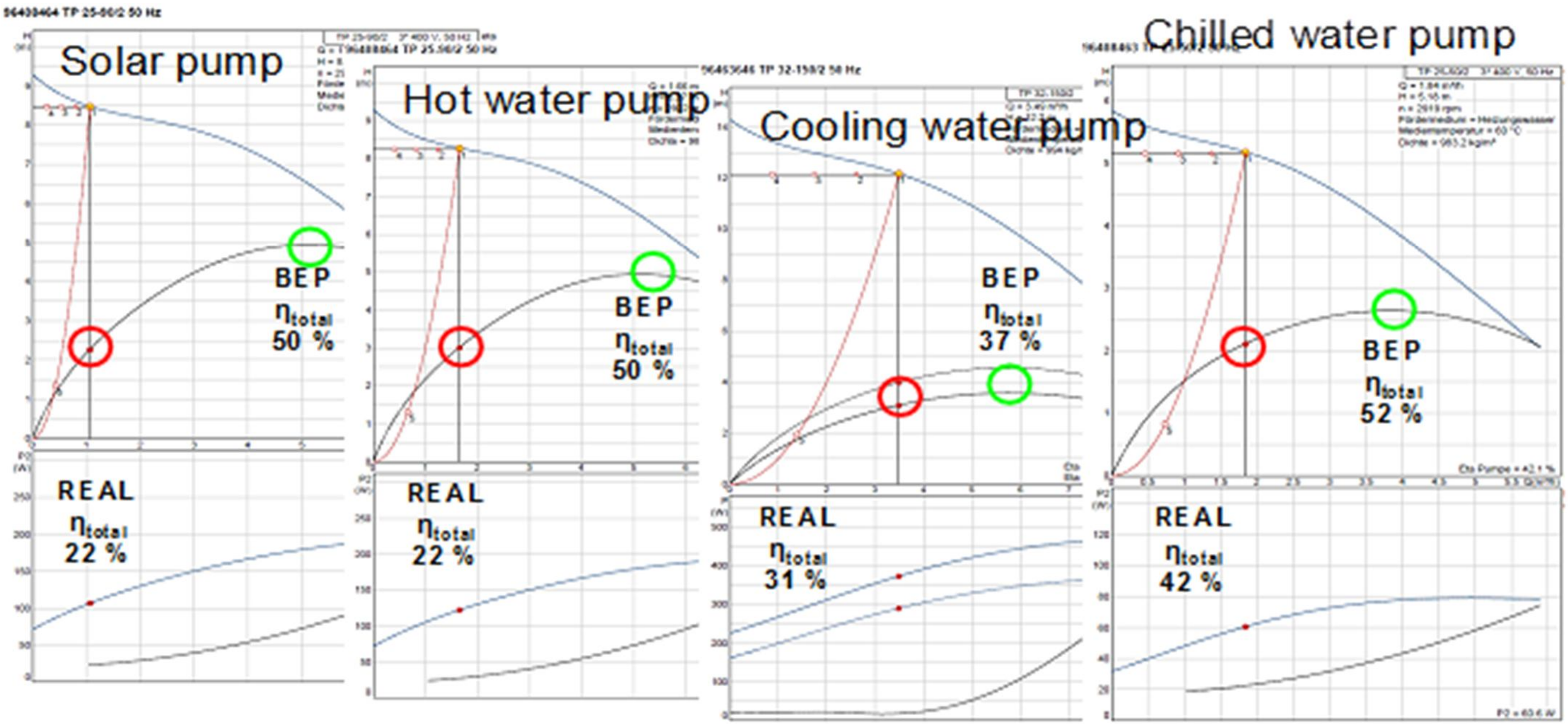
Task 48



⇒ Worse pump efficiency despite high efficiency pumps

PUMP EFFICIENCY on-site

- missmatch between pump and system curve -



⇒ Nominal operation point has to be designed slightly right the BEP in order to achieve good system performance in part load

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- Reduce heat carrier flow through the main components
- Prefer high temperature differences (especially in the cooling water loop)
- Prefer chiller design with low pressure losses through internal heat exchangers,
- Reduce pipe length of water/glycol circuits to a minimum
- High thermal COP (reduces driving and rejected heat quantity simultaneously)
- Reduce pressure losses in the pipework (sharp edges, Valves, filters, etc.)
- Optimize pipe diameter (flow speed ~0.8…1.5 m/s for medium sized SHC-System
- Select the operating point of pumps lightly right from **B**est **E**fficiency **P**oint in the Sweet or Happy zone to achieve best pump efficiency at part load conditions
- Use high-efficiency pumps (at least for chilled water and cooling water loop)
- Pump speed related to heat flow (high performance in a wide operating range)
- Continuous review of AECRs during system operation exposes malfunctions

⇒ **Recommended standard values of AECR in order to achieve a good seasonal system performance.**

BEST PRACTICE
- high saving potentials -

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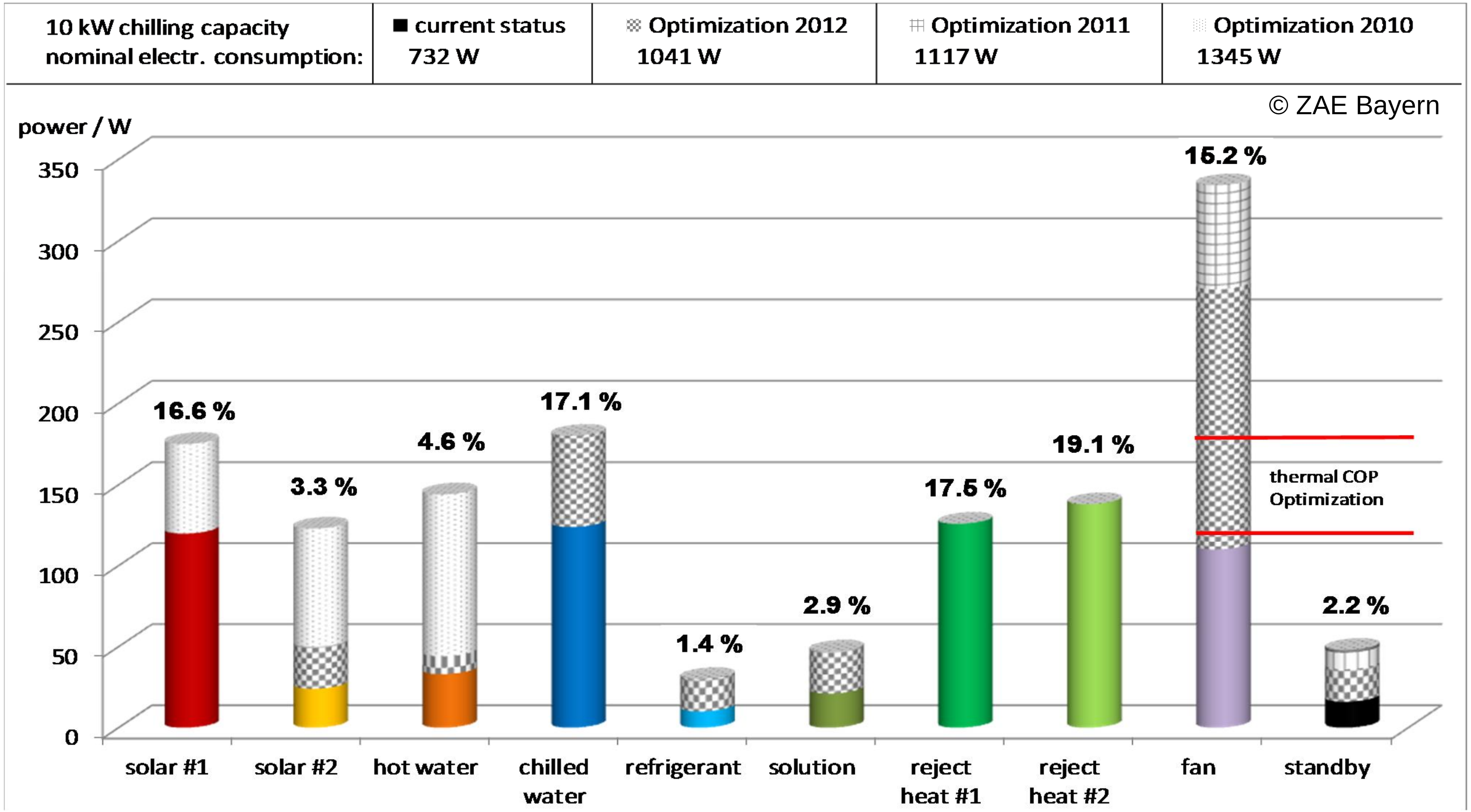
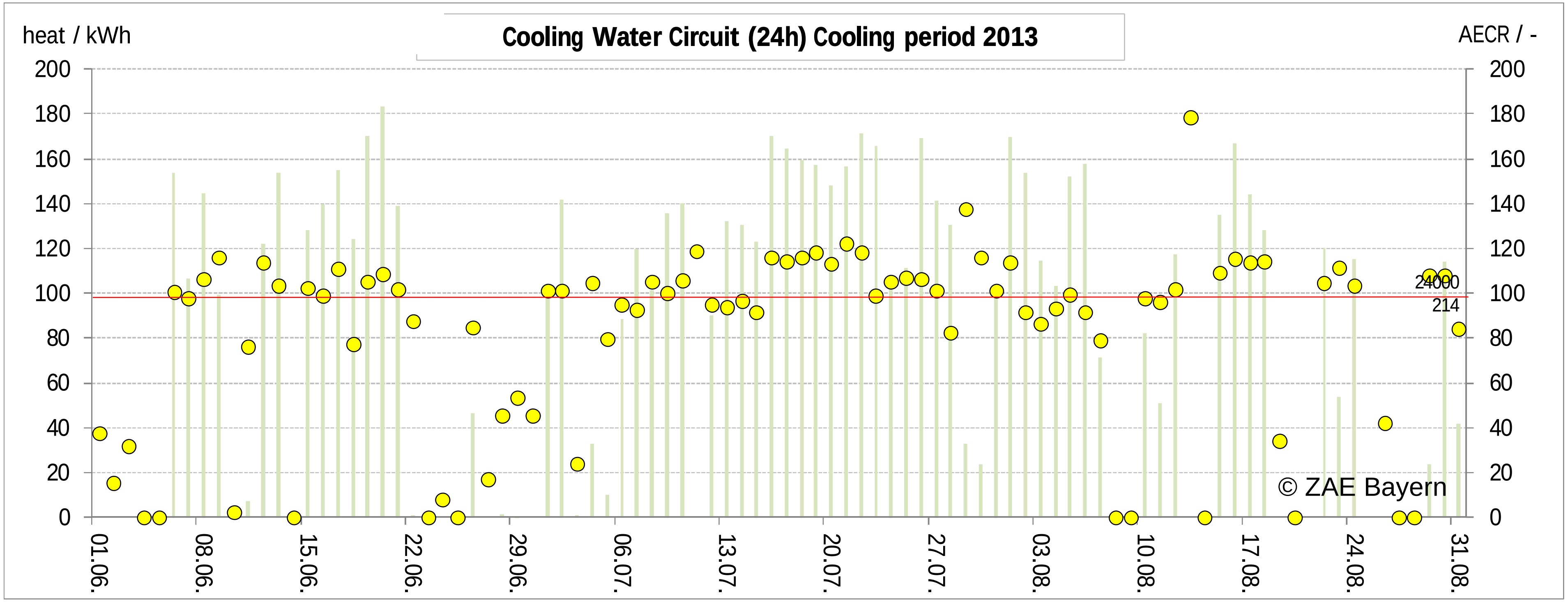


⇒ Accurate pressure drop calculation and pump selection essential



⇒ **High hydraulic and pump efficiency over a wide capacity range due to variable pump speed and improved control strategies**

Modern high efficiency pumps provide about 50 to 80 % overall efficiency

⇒ **A high overall SPF_{electr} (SEER) up to 20 seems to be feasable**

Hydraulic design of some chillers impede good seasonal performance

⇒ **Compromise between investment & operating costs**

High efficiency pumps does not implicate a high SPF automatically

⇒ **The strong relationship between pump and plant curve demands a proper system design and pump selection.**

Pump costs aggregate to less than 5% of overall installation costs

⇒ **Go for high efficiency and intelligent pumps**
(especially in the cooling and chilled water loop) **It's worth it !!!**