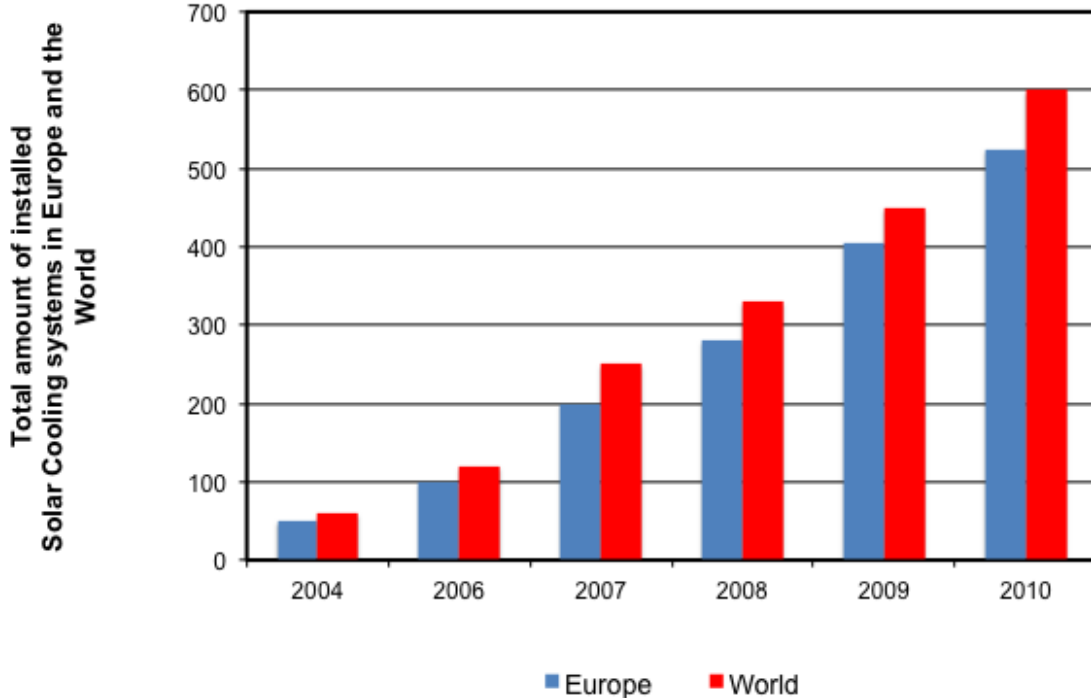




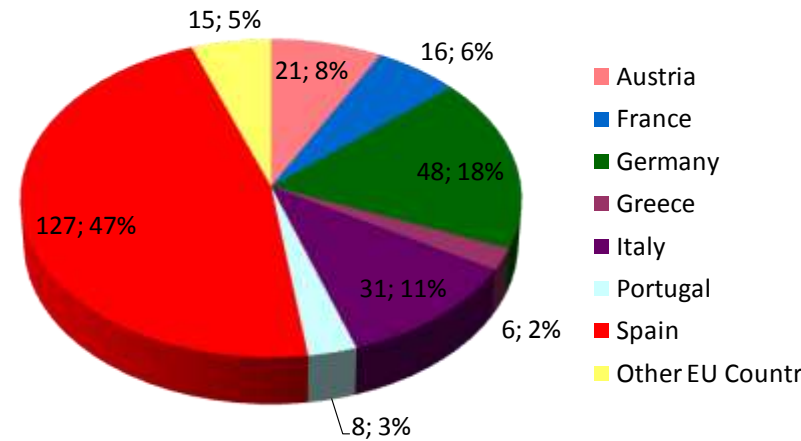
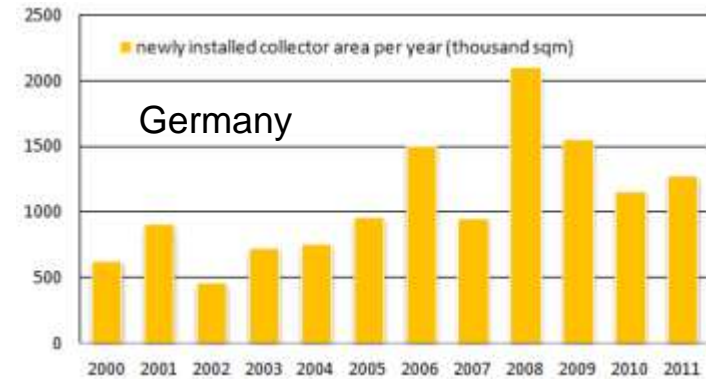
Technological developments and market perspectives for renewable energy cooling systems

Prof.Dr.habil. Ursula Eicker
Centre of Applied Research
Sustainable Energy Technology – zafh.net
University of Applied Sciences Stuttgart

Solar cooling market



Source: Green Chiller

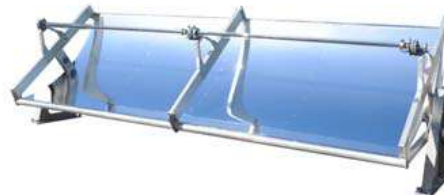


Yazaki largest with 13%, then Broad, Thermax, LG, Ebara
 2011 in France: 15 installations with 630 kW

Source: Tecsol

News and trends

- Modified German renewable heat law (1.5.2011) includes 15% solar or 50% biomass heating and cooling for new buildings and for rehabilitation of public buildings
- Combined heat-power-cold largest market segment: CHP for smart grid applications
- A high efficiency 50 kW LiBr/H₂O chiller was developed by ZAE Bayern/TU Berlin and Vattenfall with a COP of 0.8 from 25%-150% of nominal load, electric EER about 20
- Liquid desiccant work ongoing in many places including the use of non-corrosive ionic liquids



New large solar thermal systems deployed

- 3900 m² Flat plate collectors with 1575 kW single effect absorption (SOLID) in Singapore, 5000 m² 1750 kW Arizona
- 2052 m² parabolic trough collectors (Solitem) in Cyprus with 360 kW double effect chiller, 6 years amortisation
- 230 kW double effect chiller with PTC (NEP) in Cinema Complex, Newcastle, Australia

Packaged medium/large power absorption chiller systems with concentrated collectors

Thermax (India)
Hitachi (Japan)
Vicot Air Con (China)

News Release

HITACHI
Inspire the Next

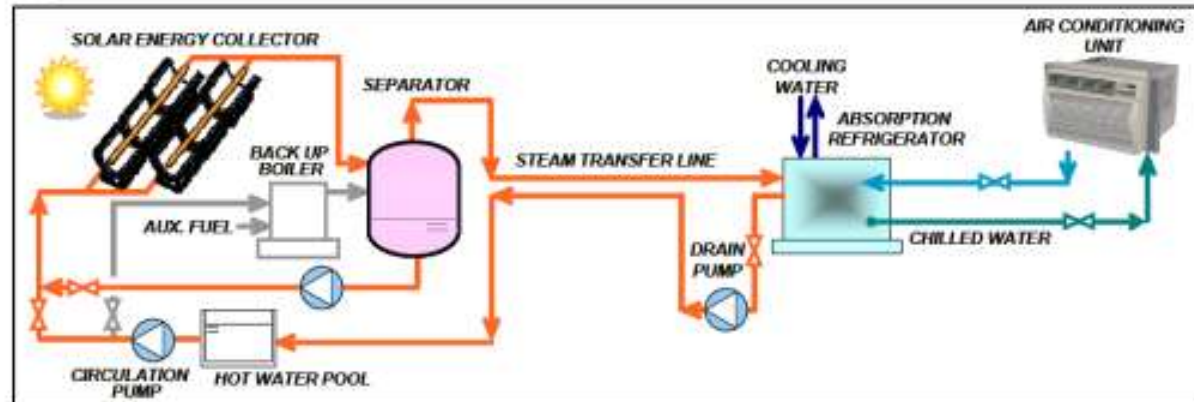
System flow

FOR IM

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Hitachi Plant Technologies Develops a Solar Activated Air C
Use of a high-efficiency solar energy collector developed by Hitachi Plan
consumption of fossil fuels and carbon dioxide emissi



Many low power systems available

InvenSor
LTC9 & HTC11
Water / Zeolith

SorTech
ASC08 & ASC15
Water / Silica Gel

Sakura
SHL003 & SHL005
Water / Lithium Bromide

Pink
PC14 & PC19
Ammonia / Water



Source: InvenSor



Source: SorTech



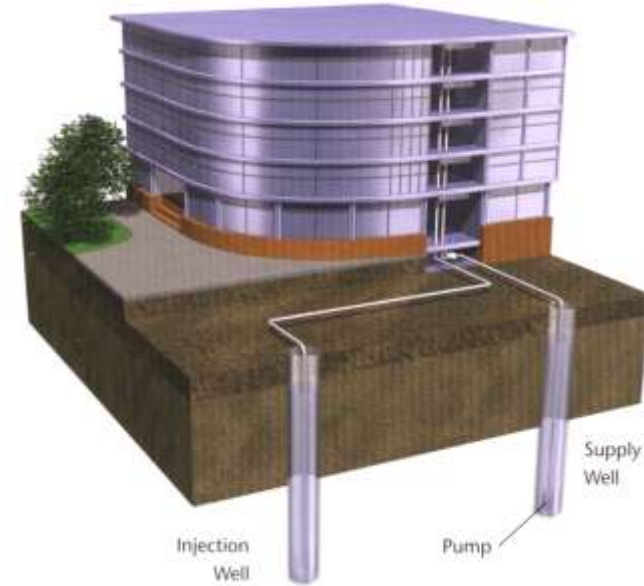
Source: Sakura



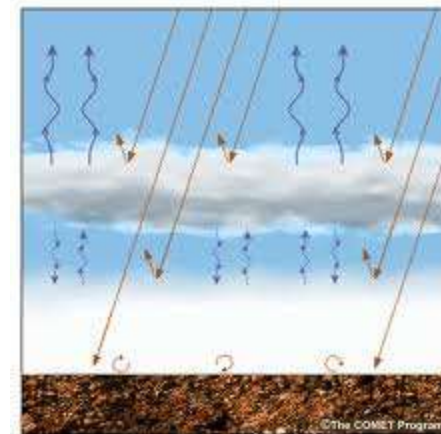
Source: Pink

Trends: packaged low power absorption chiller systems

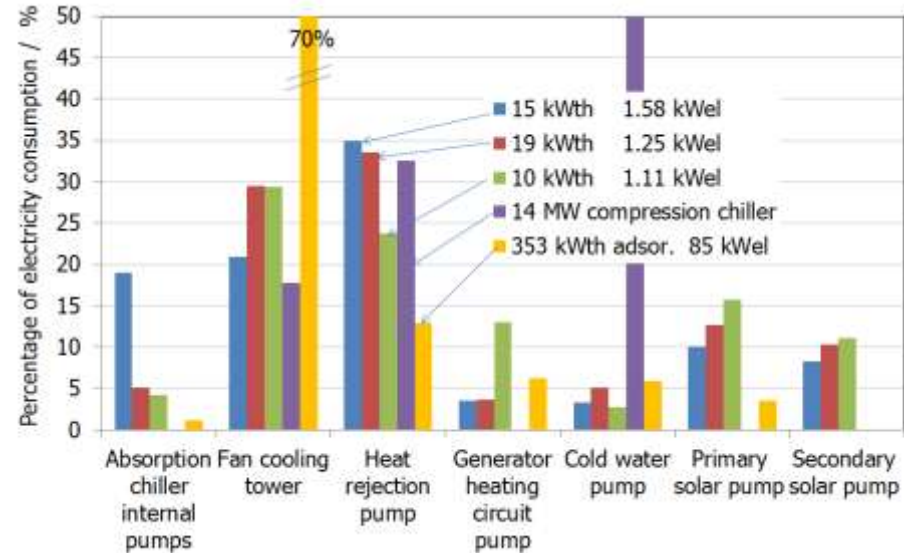
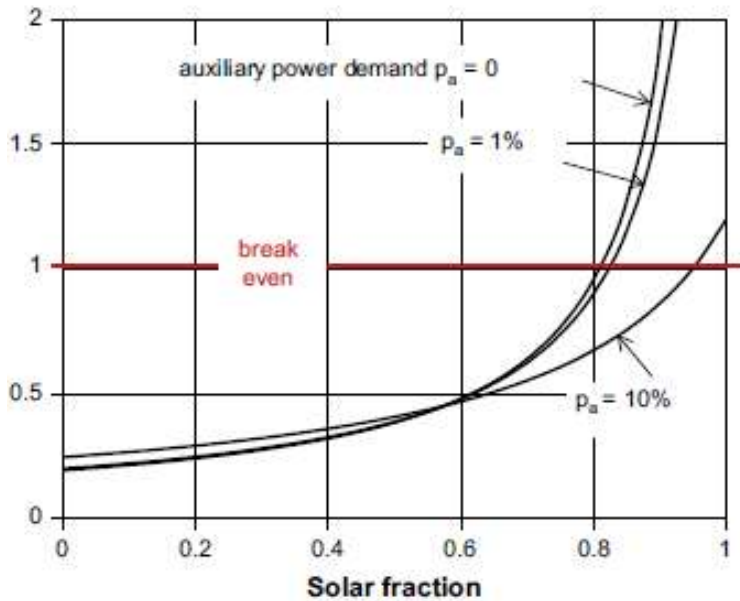
Heat rejection important issue for primary energy efficiency



Source: Jiangsu Huineng



Primary energy savings?

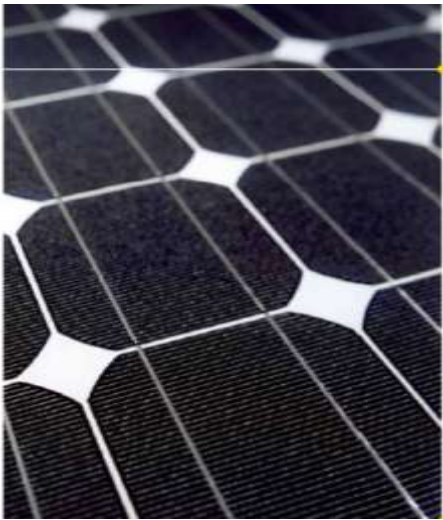
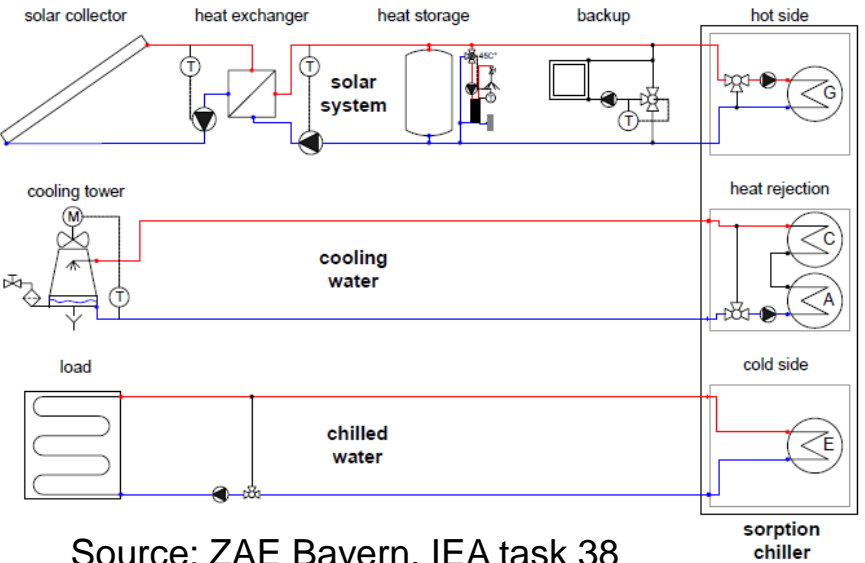


Comparison:

compression system COP 5.0

absorption system COP 0.6

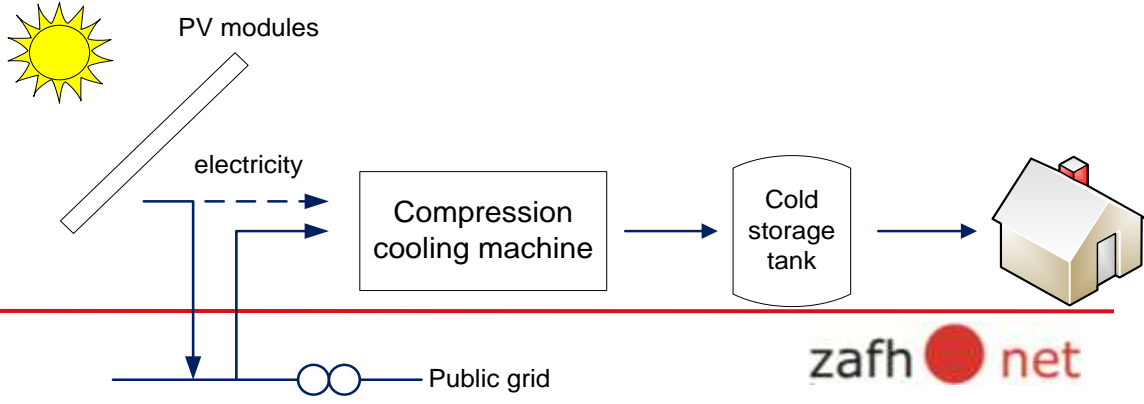
Photovoltaic electricity generation and compression cooling



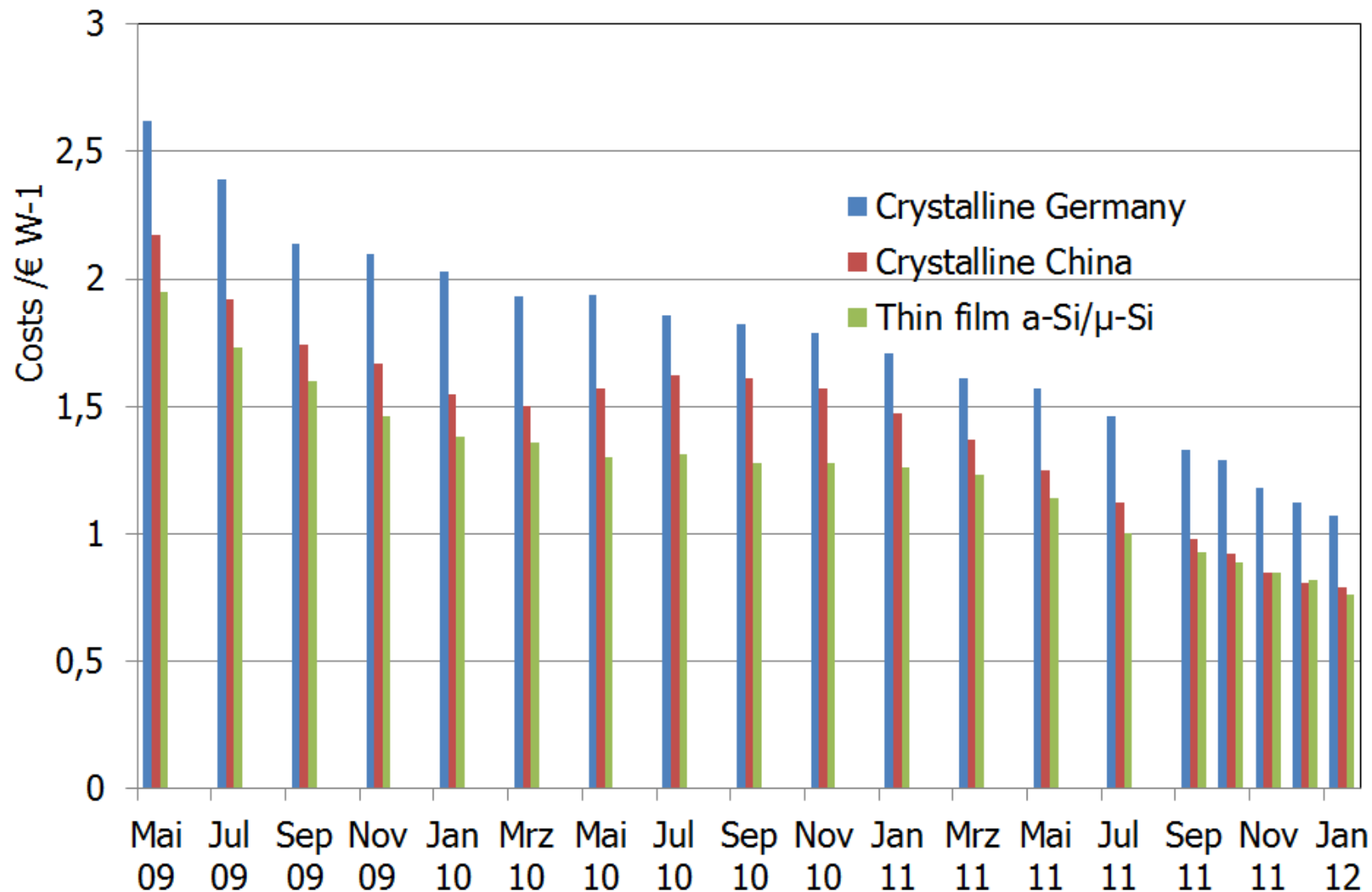
Source: ZAE Bayern, IEA task 38



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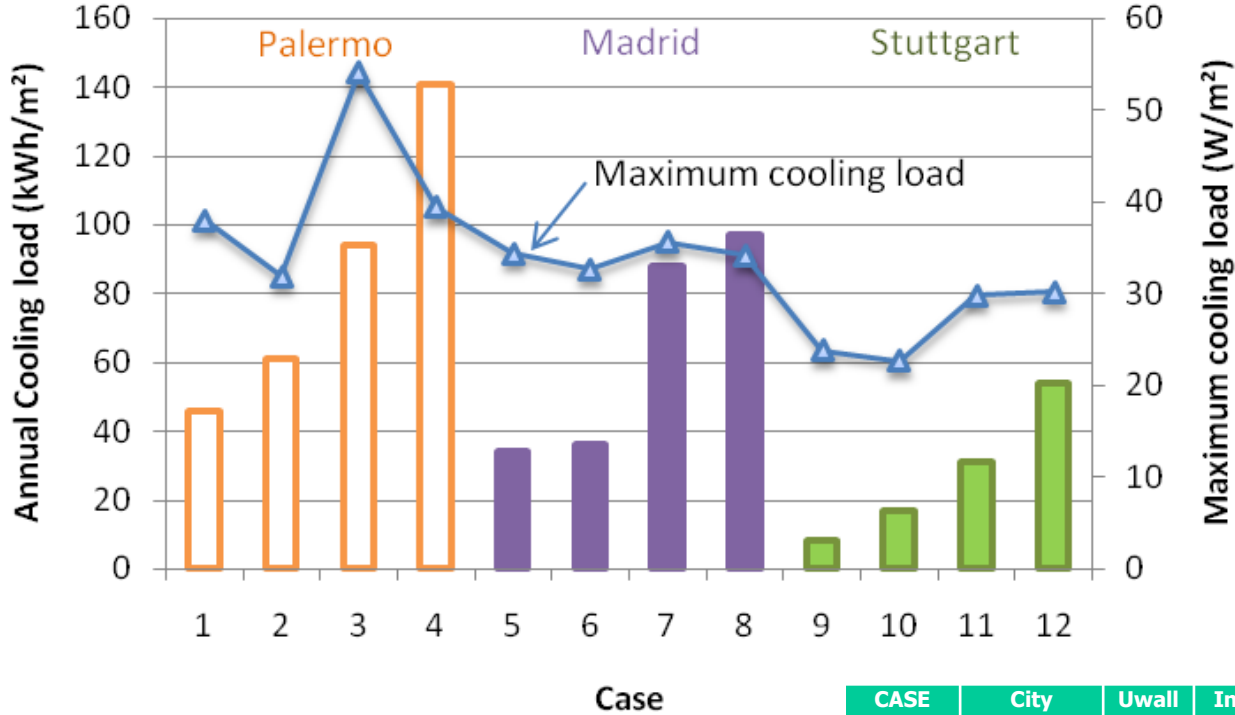


PV Module Prices Development 2009 - 2011

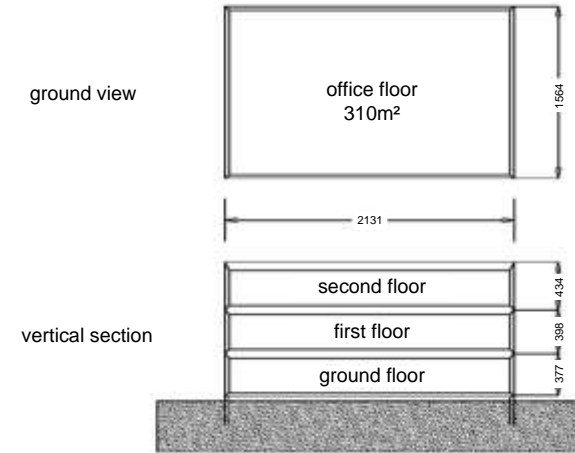


Source: www.solarserver.de

Cooling loads of buildings

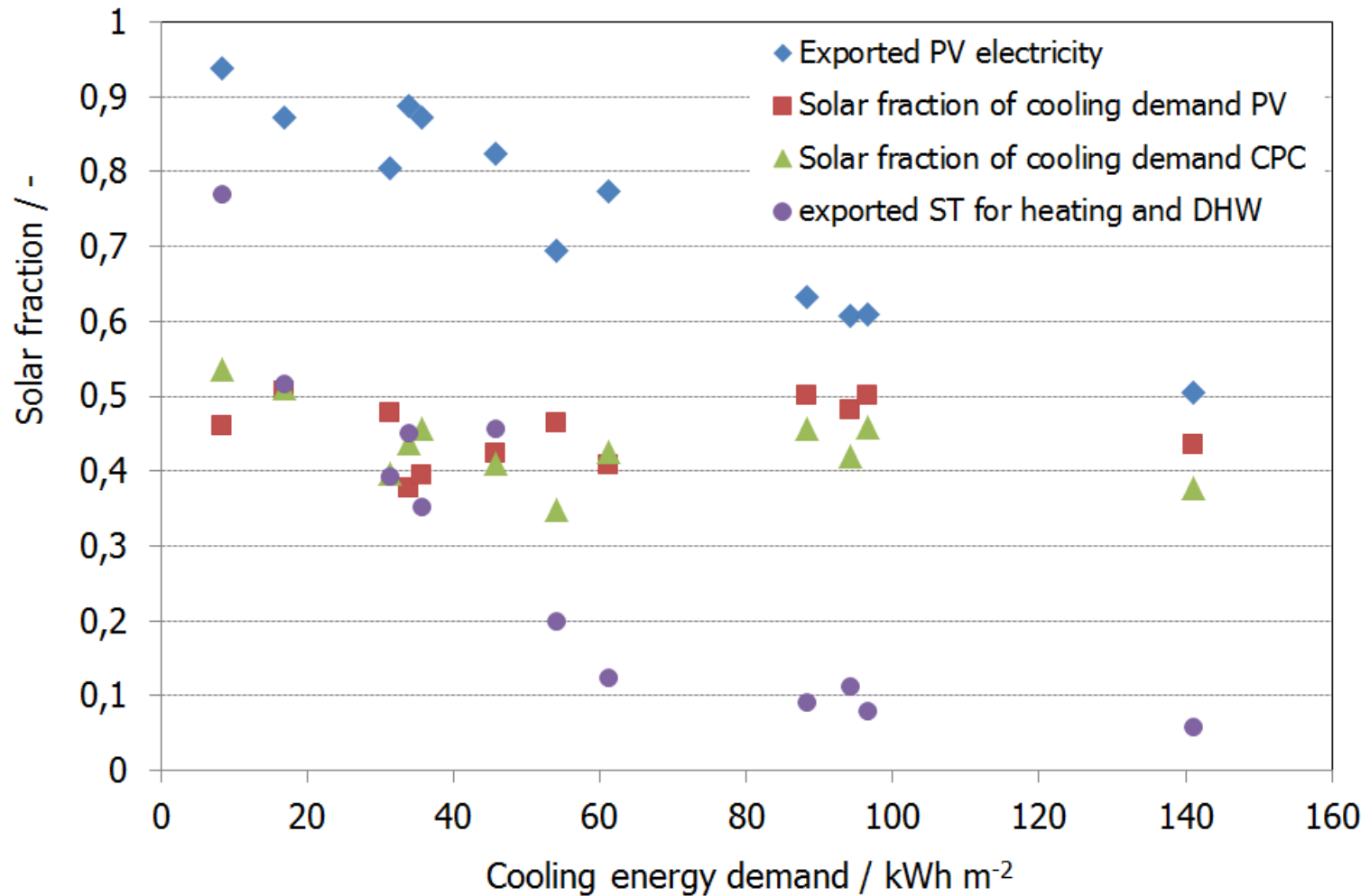


3 storey office building
927 m² surface

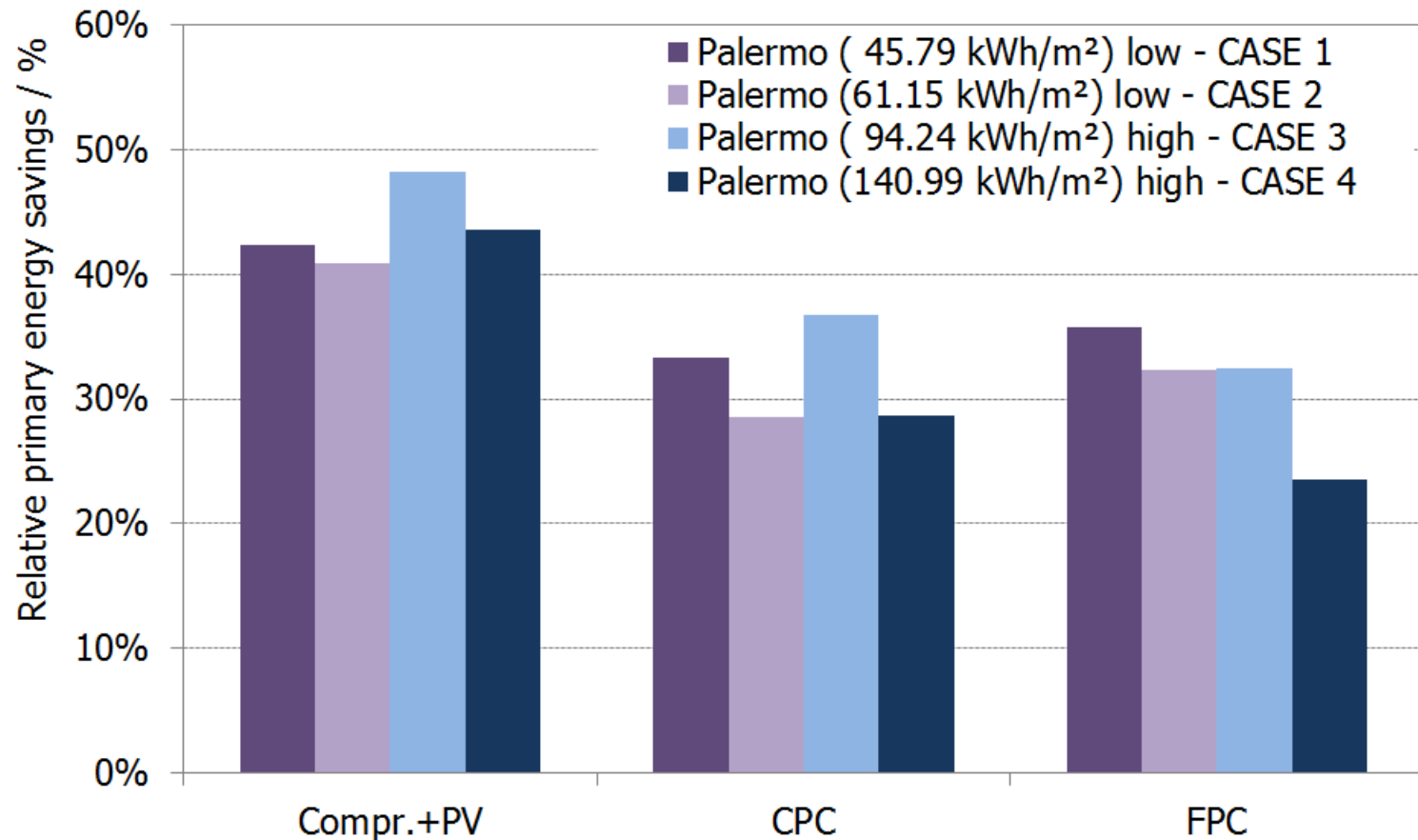


CASE	City	Uwall (W/m ² K)	Internal loads	Sun Protection	Annual cooling load (kWh/m ²)	Annual heating load (kWh/m ²)	Maximum cooling load (W/m ²)
Case 1	Palermo	1.1	low	yes	46	18	38.0
Case 2	Palermo	0.41	low	yes	61	0	31.9
Case 3	Palermo	1.1	high	no	94	2	54.1
Case 4	Palermo	0.41	high	no	141	0	39.4
Case 5	Madrid	0.66	low	yes	34	11	34.4
Case 6	Madrid	0.41	low	yes	36	5	32.6
Case 7	Madrid	0.66	high	no	88	0	35.6
Case 8	Madrid	0.41	high	no	97	0	34.2
Case 9	Stuttgart	1.1	low	yes	8	56	23.8
Case 10	Stuttgart	0.41	low	yes	17	20	22.6
Case 11	Stuttgart	1.1	high	no	31	25	29.8
Case 12	Stuttgart	0.41	high	no	54	2	30.2

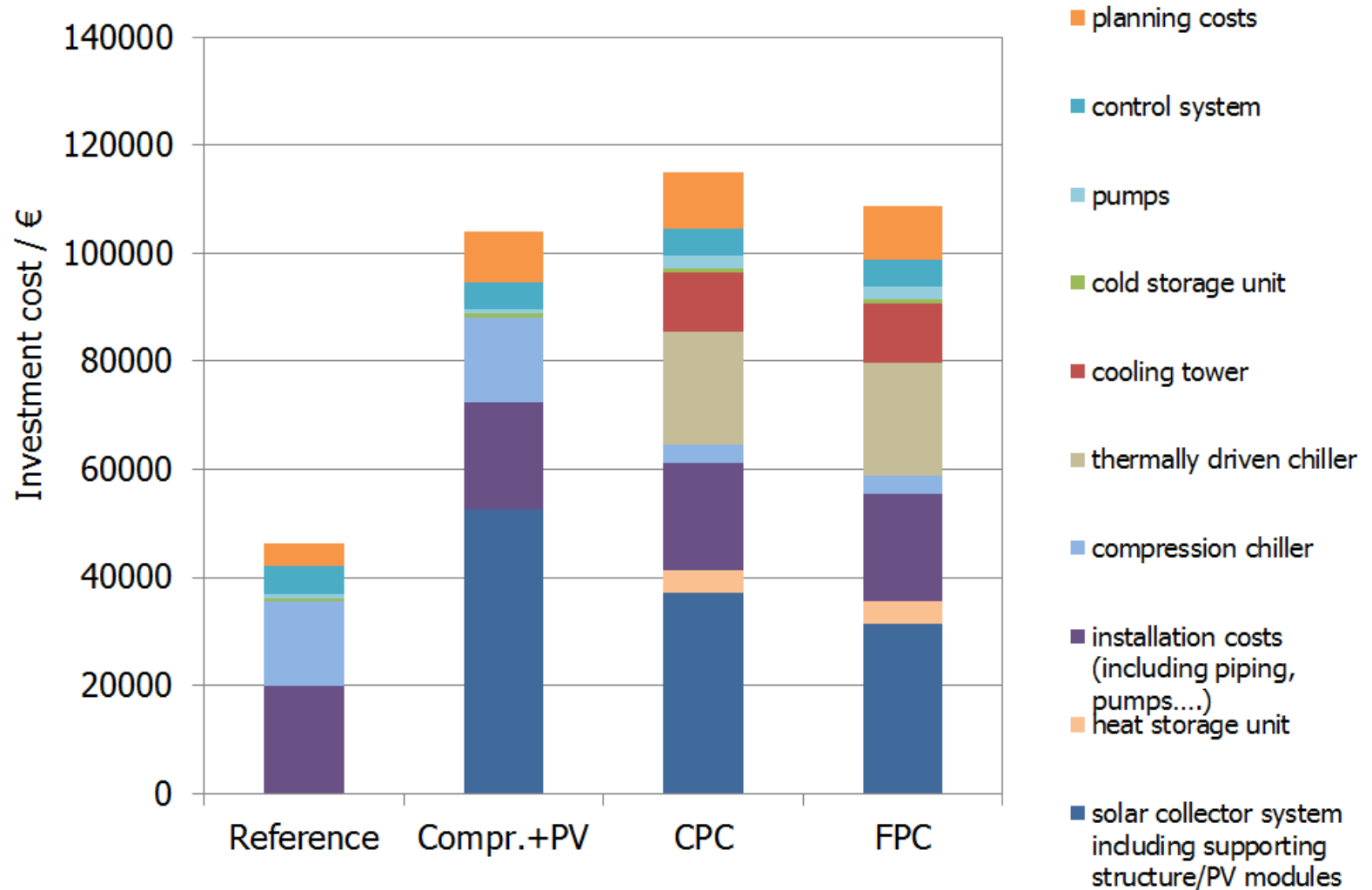
Solar fraction for PV and ST cooling



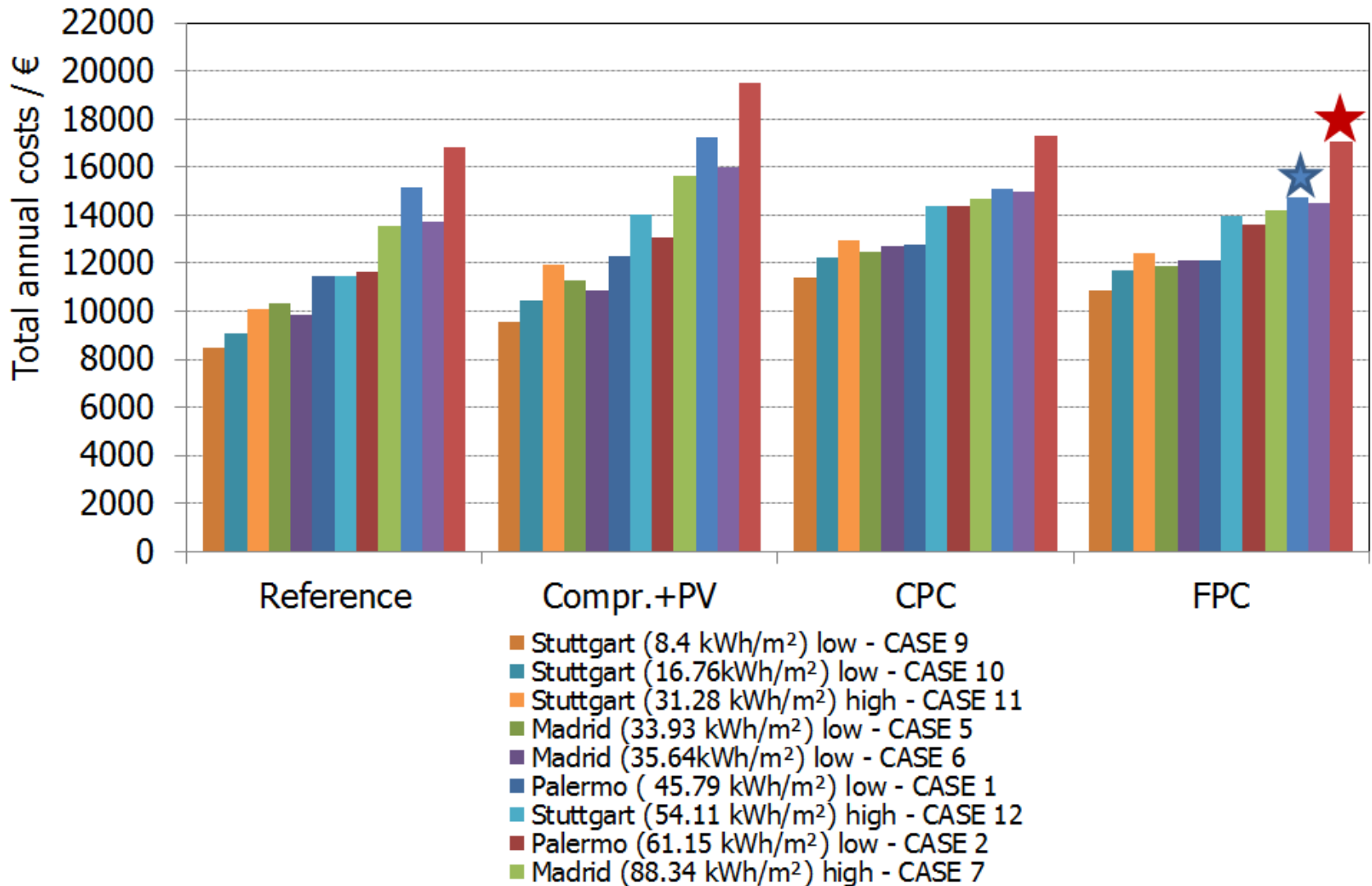
Primary energy savings for cooling



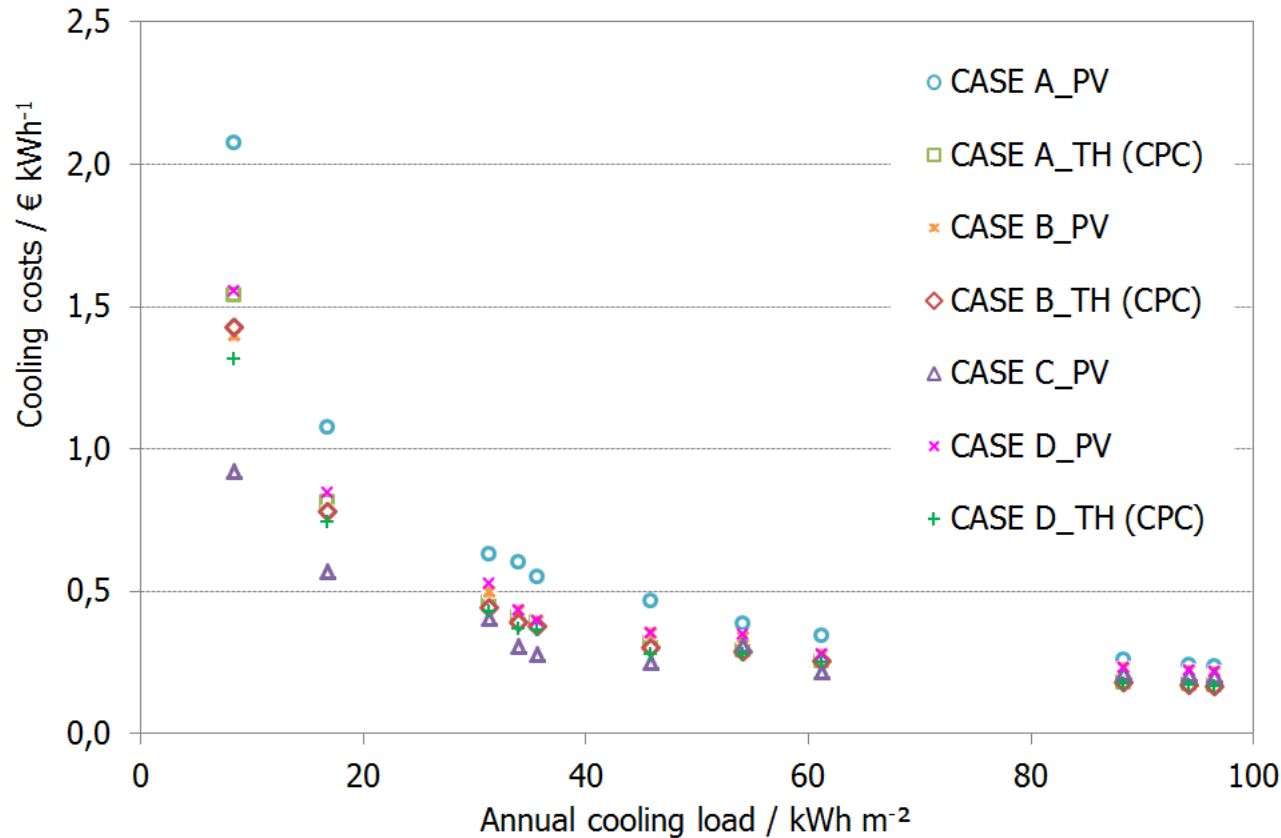
Cost comparison



Total annual costs



Cost of cooling production



$$\text{cost of cooling production} = \frac{\text{annual total costs of solar system}}{\text{total cooling energy produced}}$$

Solar cooling for Kairo office building



15100 m² surface
52 W/m² cooling load
130 kWh/m² cooling
energy demand

Comparison of large multi-effect systems

Case	Chiller Type	Cooling Capacity	Collector Type	Collector Area		Storage Tank	
				brut	aperture	hot	cold
Case 1	Single Effect	422 kW	Vacuum Tube	2025 m ²	1350 m ²	20 m ³	10 m ³
Case 2	Double Effect	500 kW	Linear Fresnel	2050 m ²	1320 m ²	20 m ³	10 m ³
Case 3	Triple Effect	563 kW	Linear Fresnel	1280 m²	800 m²	-- m ³	10 m ³



THERMAX, single effect
ProChill LT12C



Shuangliang, double effect
500 kW



Kawasaki Sigma, triple effect
Ace CF01-10-0001

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Solar Collectors and back-up



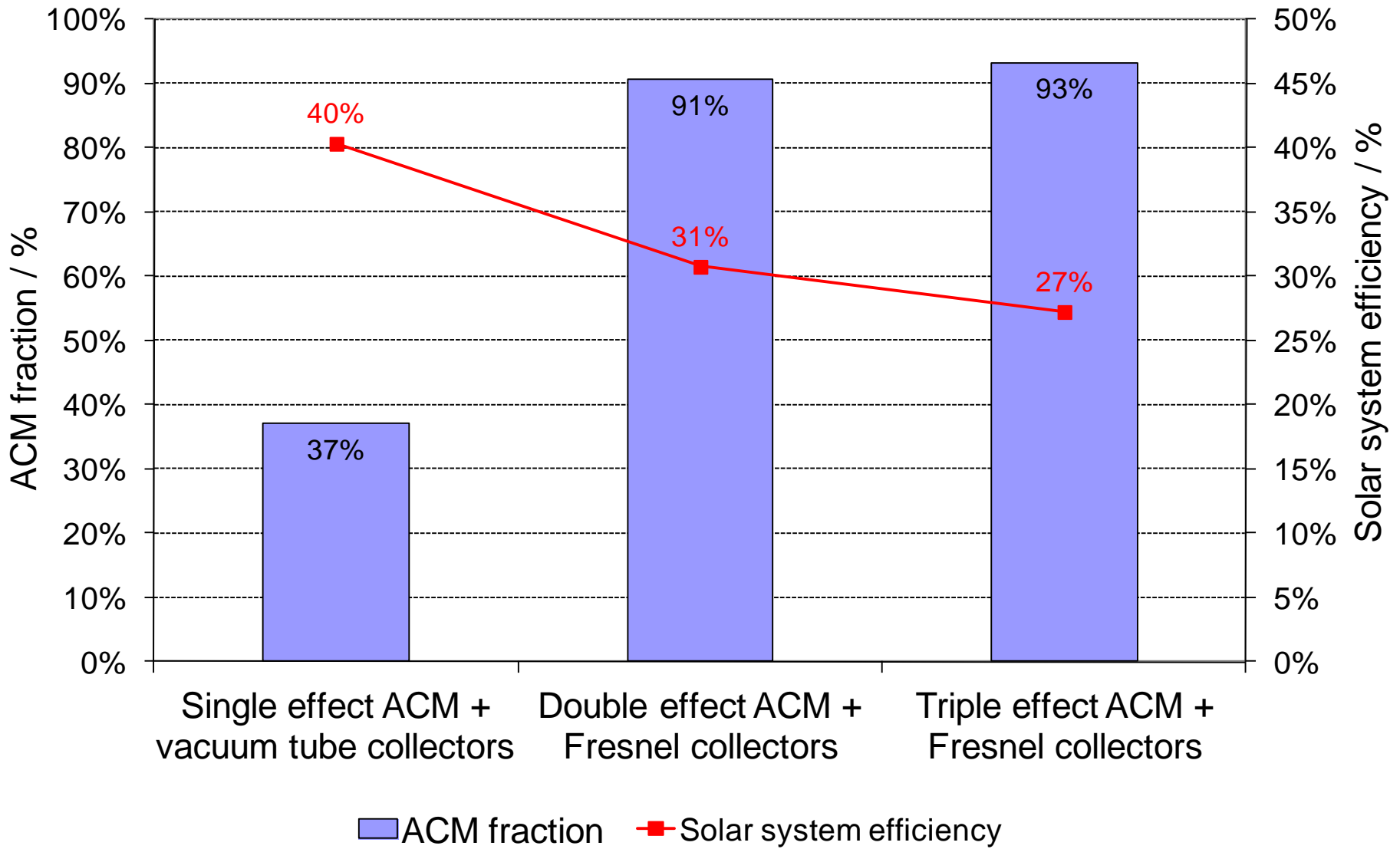
Vacuum tubes
 Jiangsu Sunrain
 TZ47/1500-10U
 $\eta_0 = 0.65$
 $a_1 = 1.585 \text{ W/m}^2\text{K}$
 $a_2 = 0.002 \text{ W/m}^2\text{K}^2$



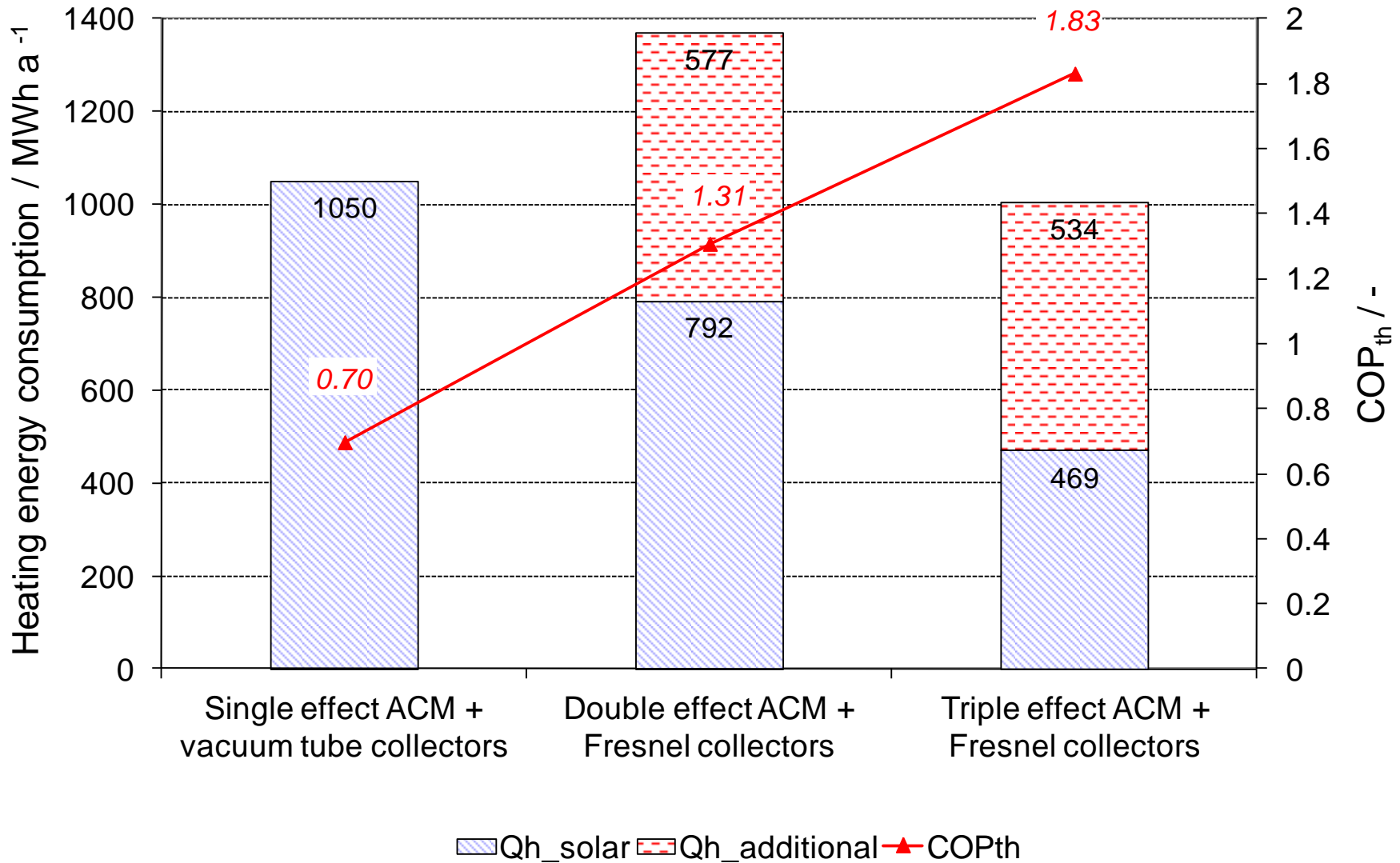
Linear Fresnel
 Industrial Solar GmbH
 $\eta_0 = 0.62$
 $a_1 = 1.585 \text{ W/m}^2\text{K}$
 $a_2 = 0.002 \text{ W/m}^2\text{K}^2$

Case	Chiller Type	Cooling Capacity	Backup heating	Additional cooling (compression chiller)		
				power	heat rejection	Average COP _{el}
Case 1	Single Effect	422 kW	---	380 kW	direct dry	2.8
Case 2	Double Effect	500 kW	Gas boiler	300 kW	direct dry	2.8
Case 3	Triple Effect	563 kW	Direct gas burner	240 kW	direct dry	2.8

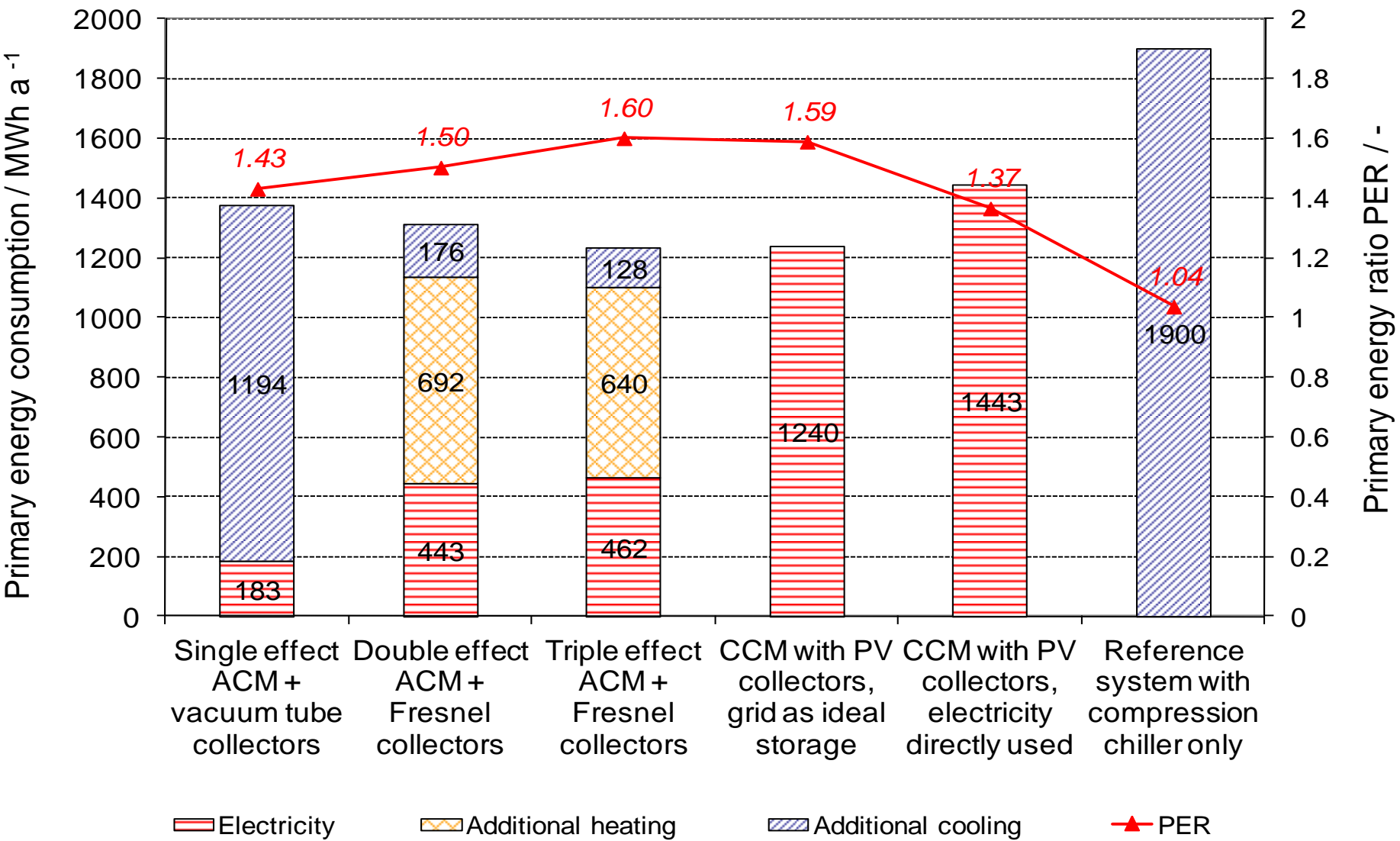
Absorption Cooling Fraction and Solar System Efficiency



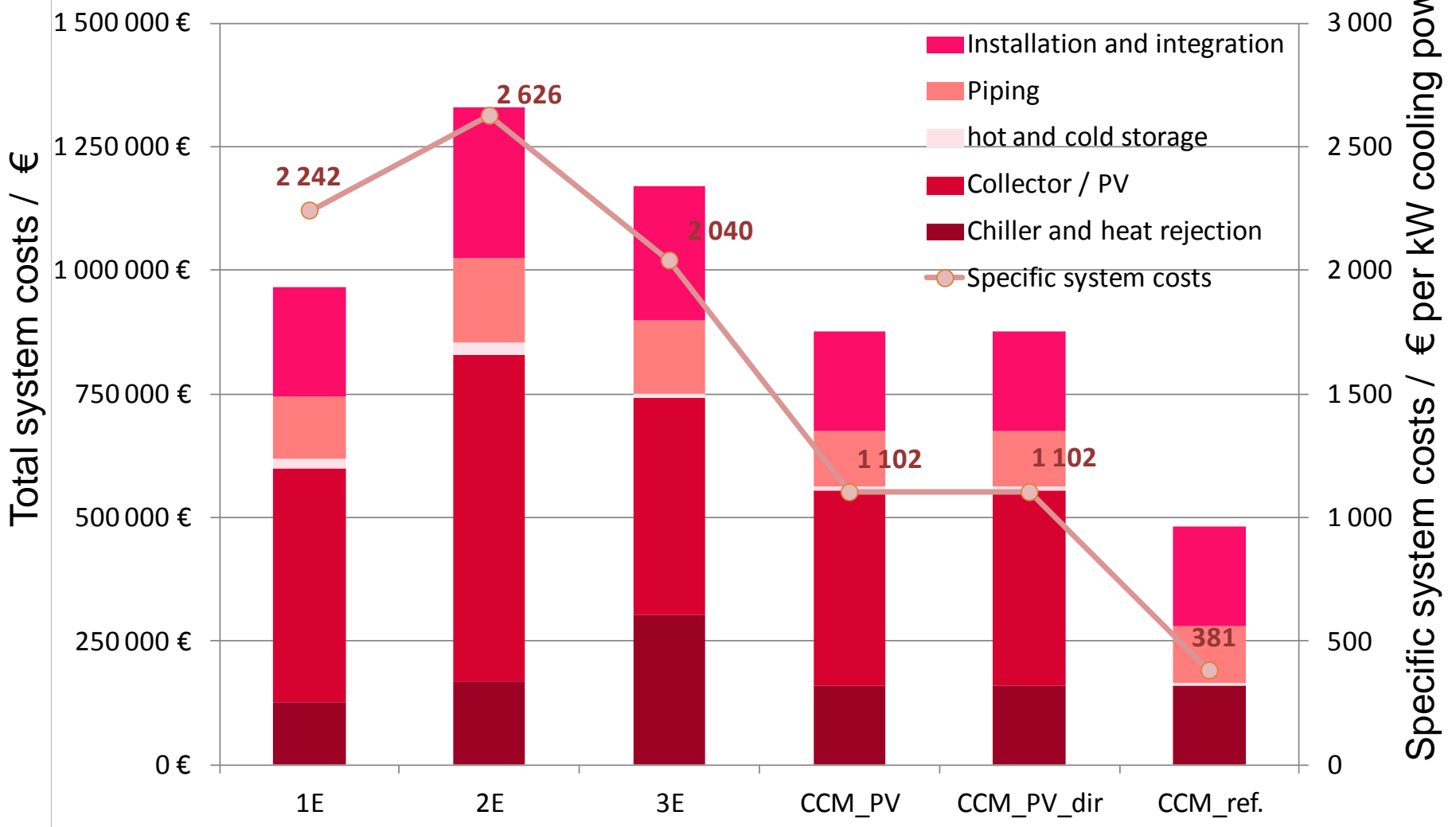
Heating Energy Consumption and Average COP_{th}



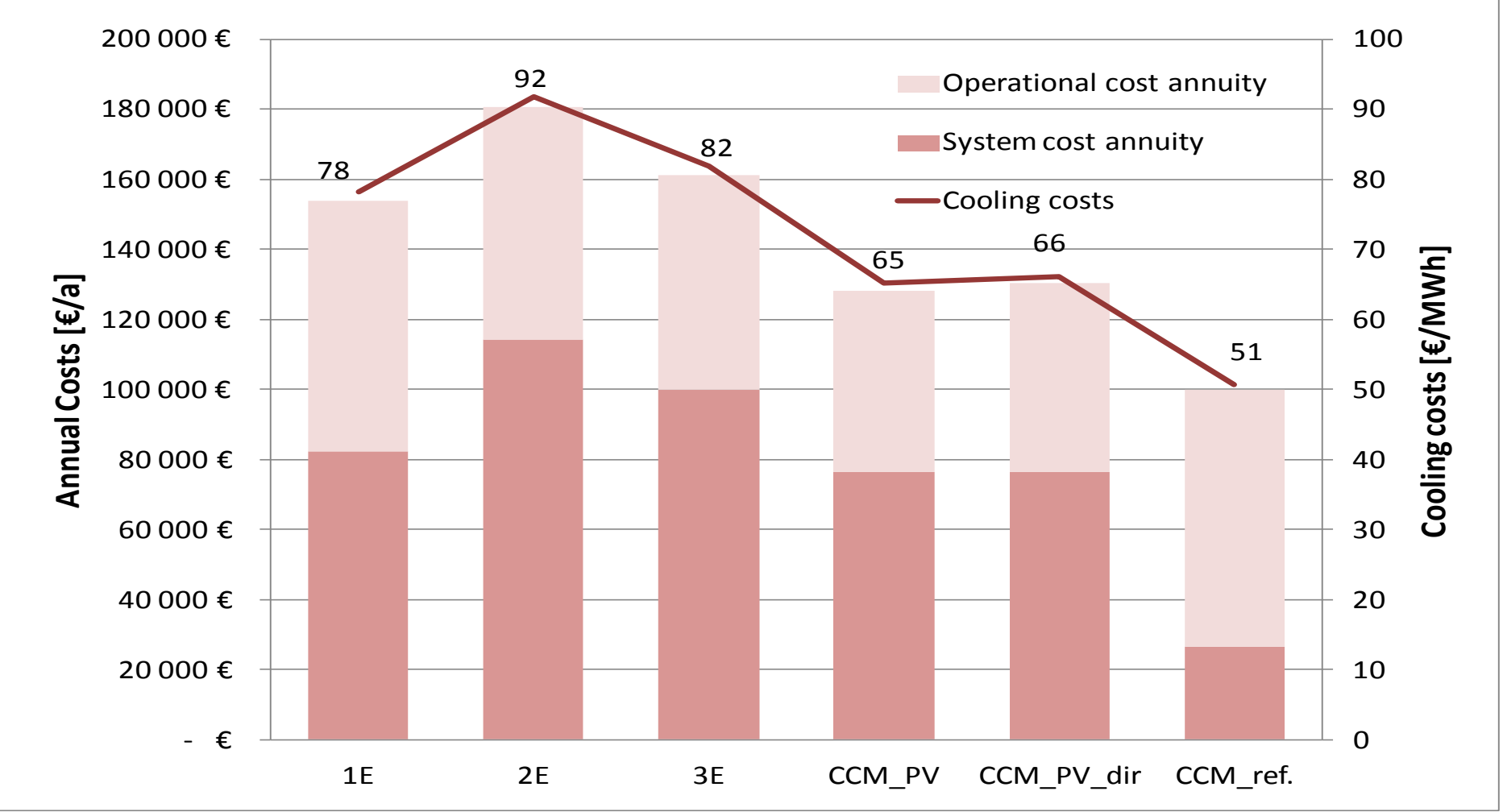
Primary Energy Efficiency



System Costs Including Installation and Integration



Overall Cooling Costs / Office Building in Cairo, Egypt

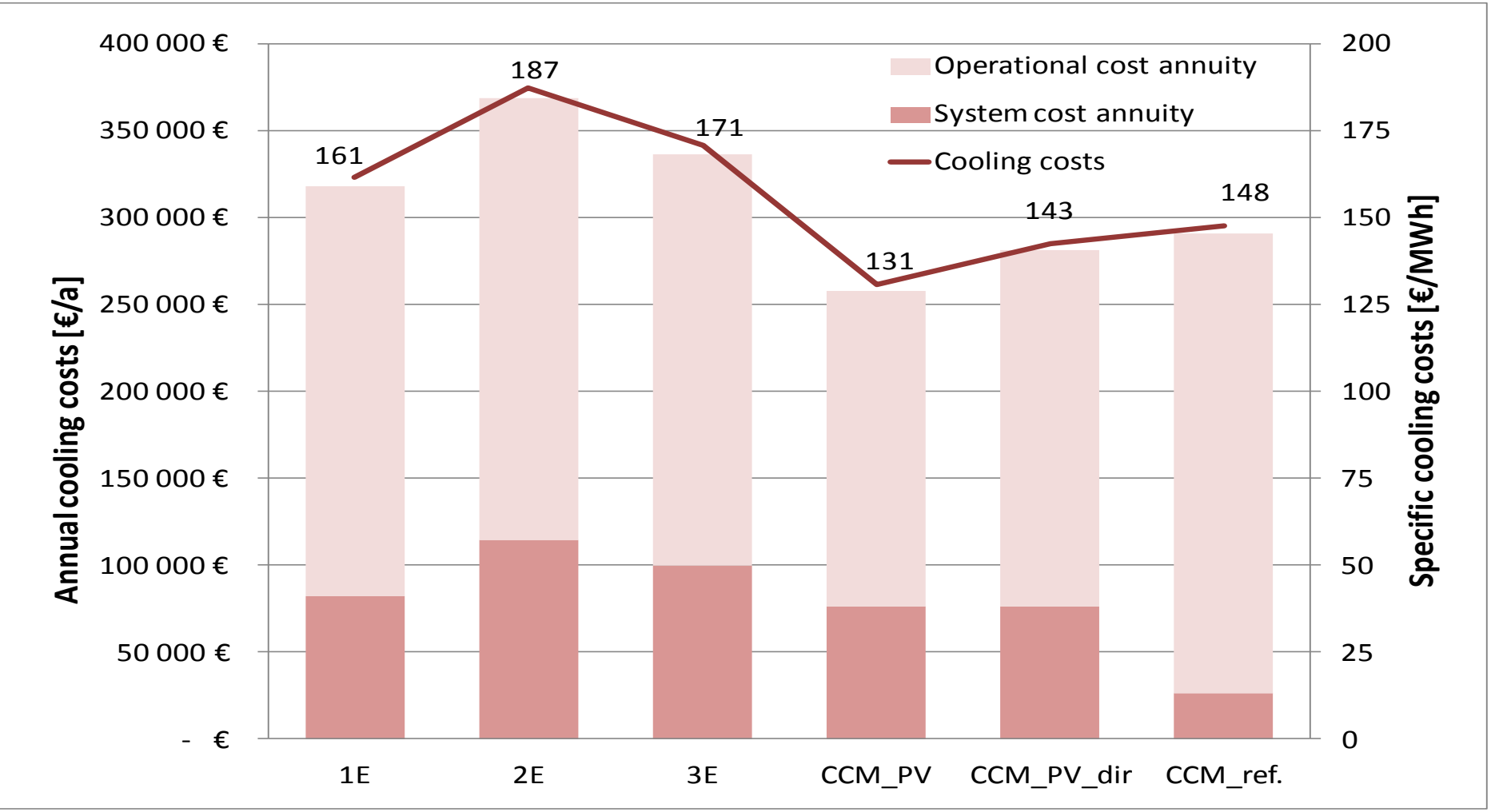


Prices: Gas = 0.0174 €/kWh
 Source: www.worldtribune.com

Electricity = 0.062 €/kWh
 Inflation rate = 5.6%/a

Water = 1.6 € / m³
 Discount rate = 6%/a

Overall Cooling Costs / Office Building in Cyprus



Prices: Gas = 0.101 €/kWh

Electricity = 0.230 €/kWh

Water = 4.0 € / m³

Inflation rate = 5.6%/a

Discount rate = 6%/a

Conclusions

- Cooled surface area and solar cooling market is growing
- New components and solar cooling kits are available in all power ranges
- Solar thermal cooling can be cost effective today with long chiller lifetimes and high cooling loads
- The primary energy efficiency of solar thermal cooling is comparable or higher than photovoltaic cooling, especially when double or triple effect chillers are used
- An efficient heat rejection system is essential
- Primary energy savings of 30 to 50% are reached at solar fractions around 50%