Solar Thermal or Photovoltaic Cooling?

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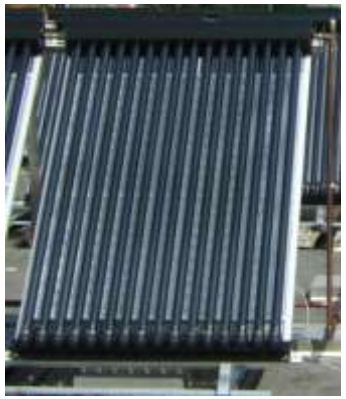
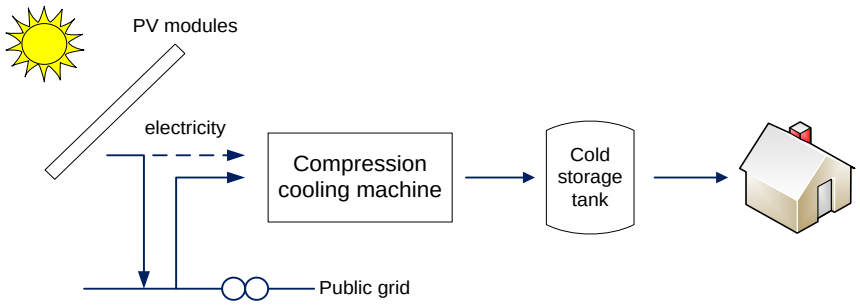
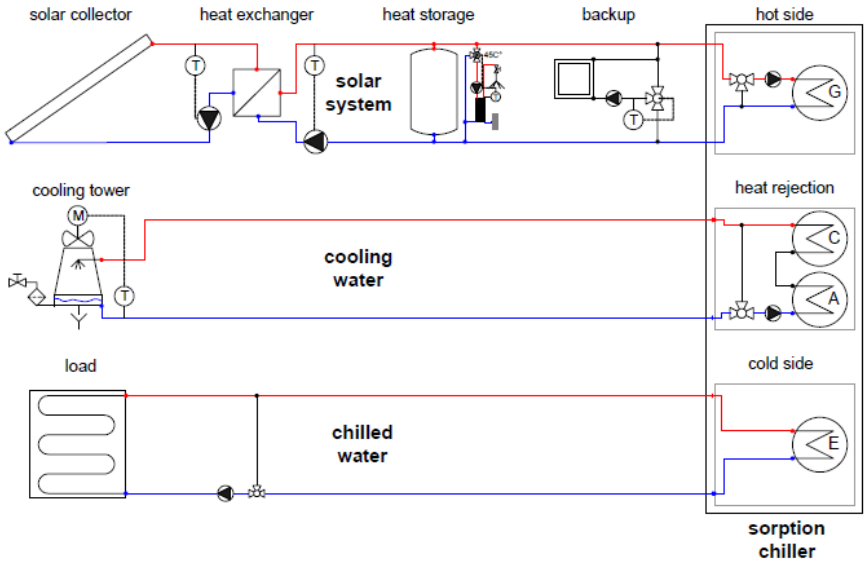
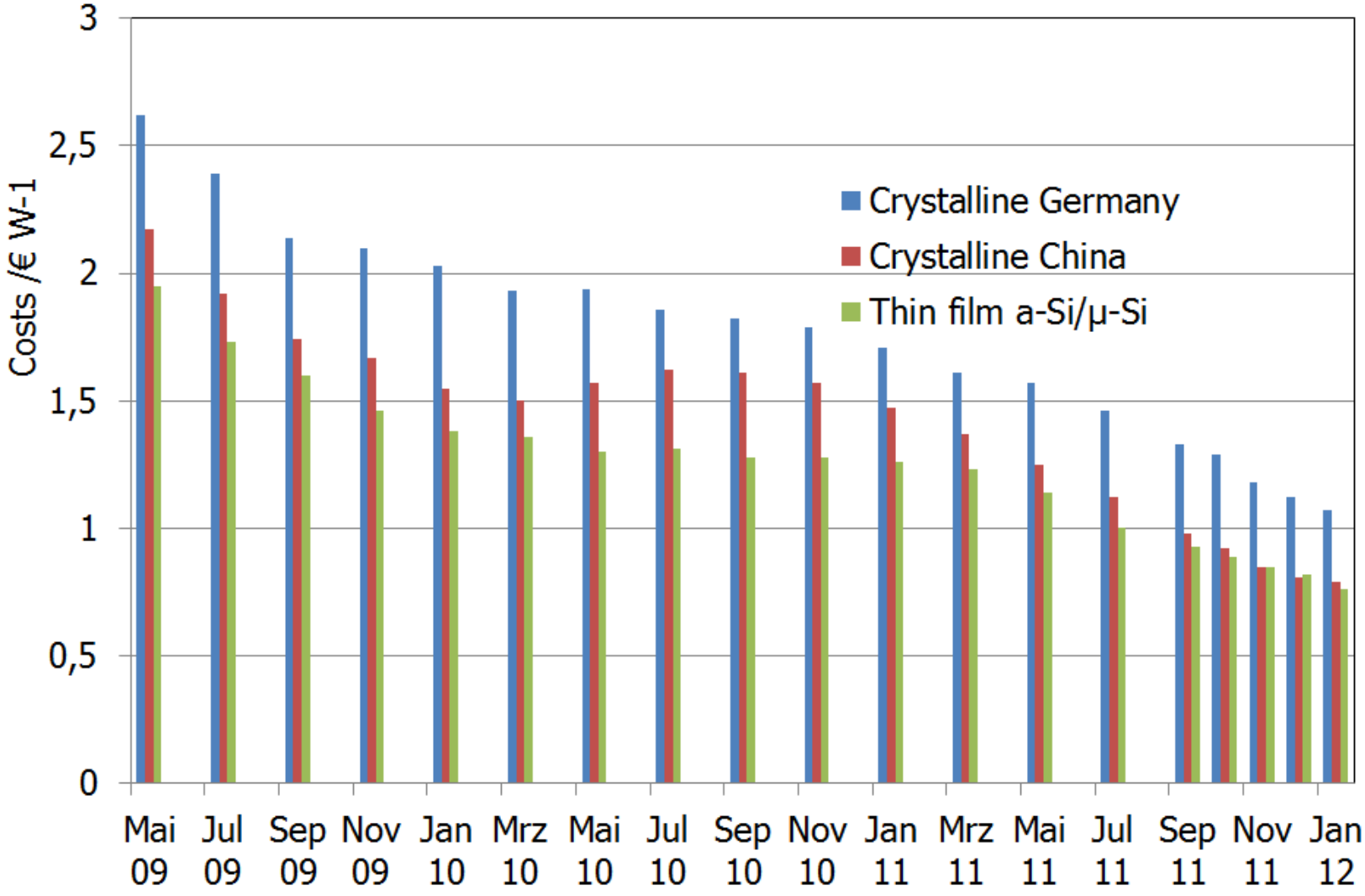
Solar cooling systems





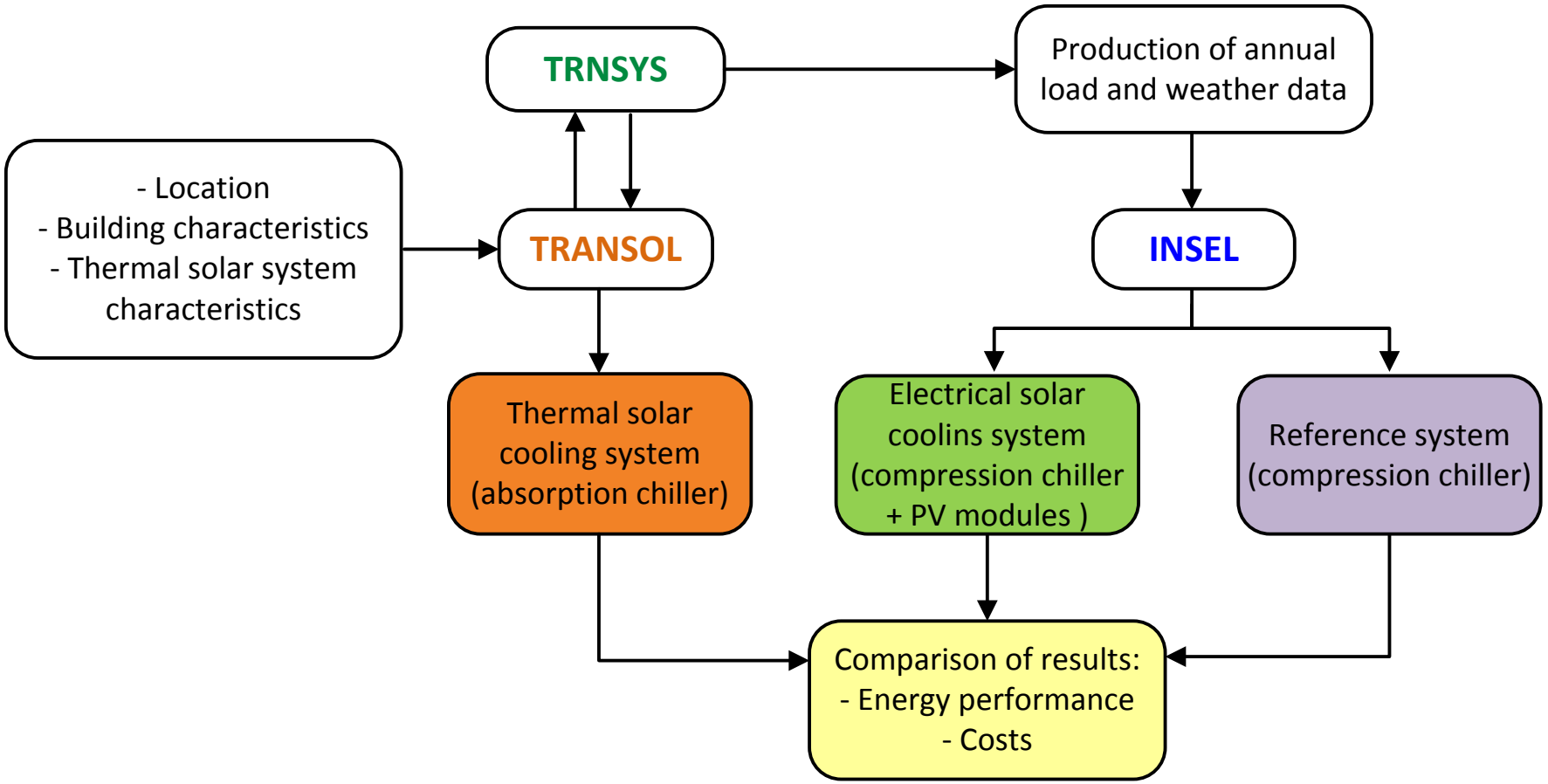


PV Module Prices Development 2009 - 2011



Source: www.solarserver.de

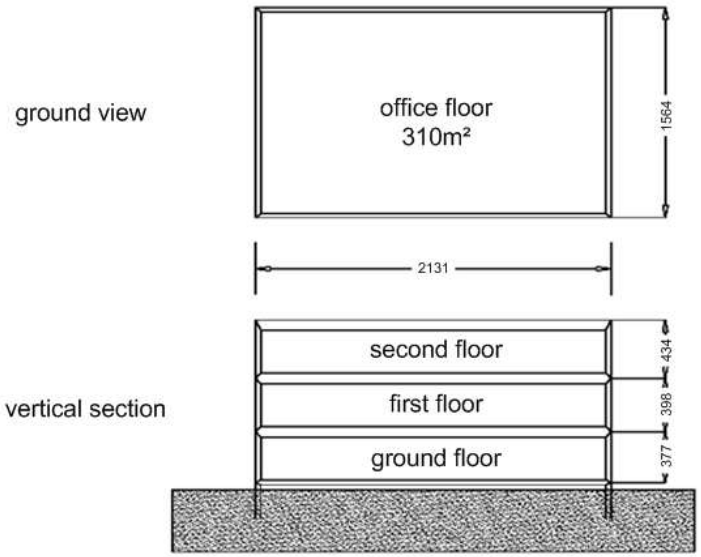
Methodology: Simulation studies in planning phase

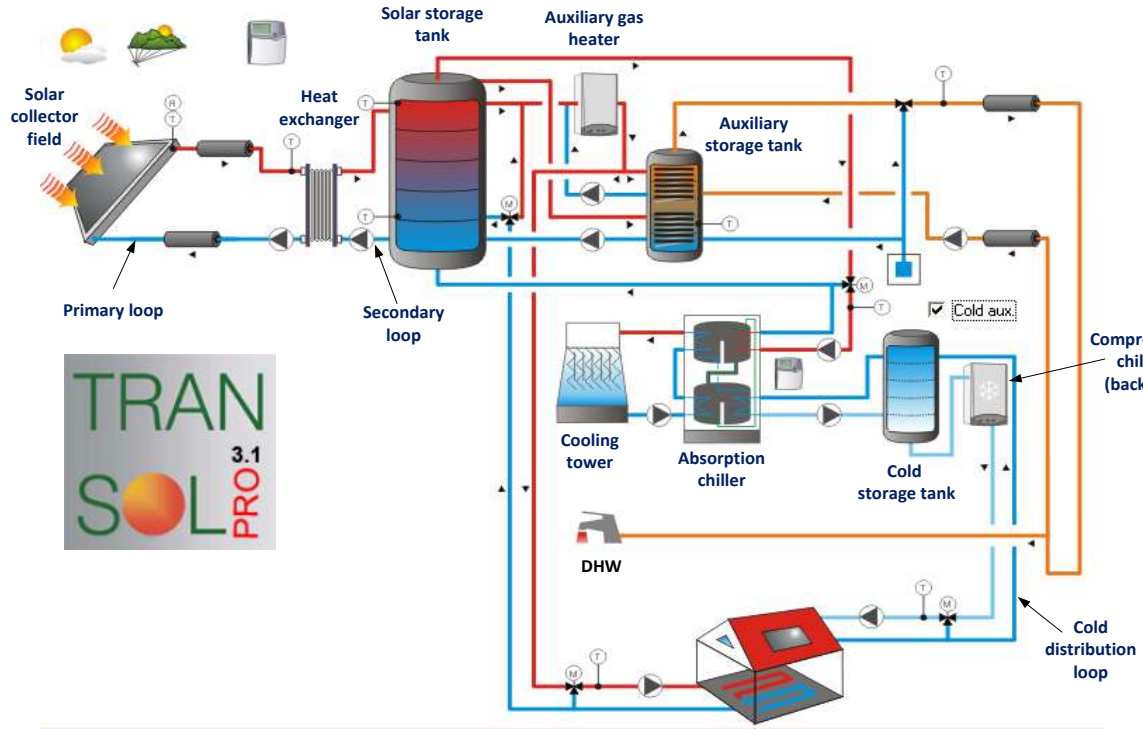


Small office building European conditions

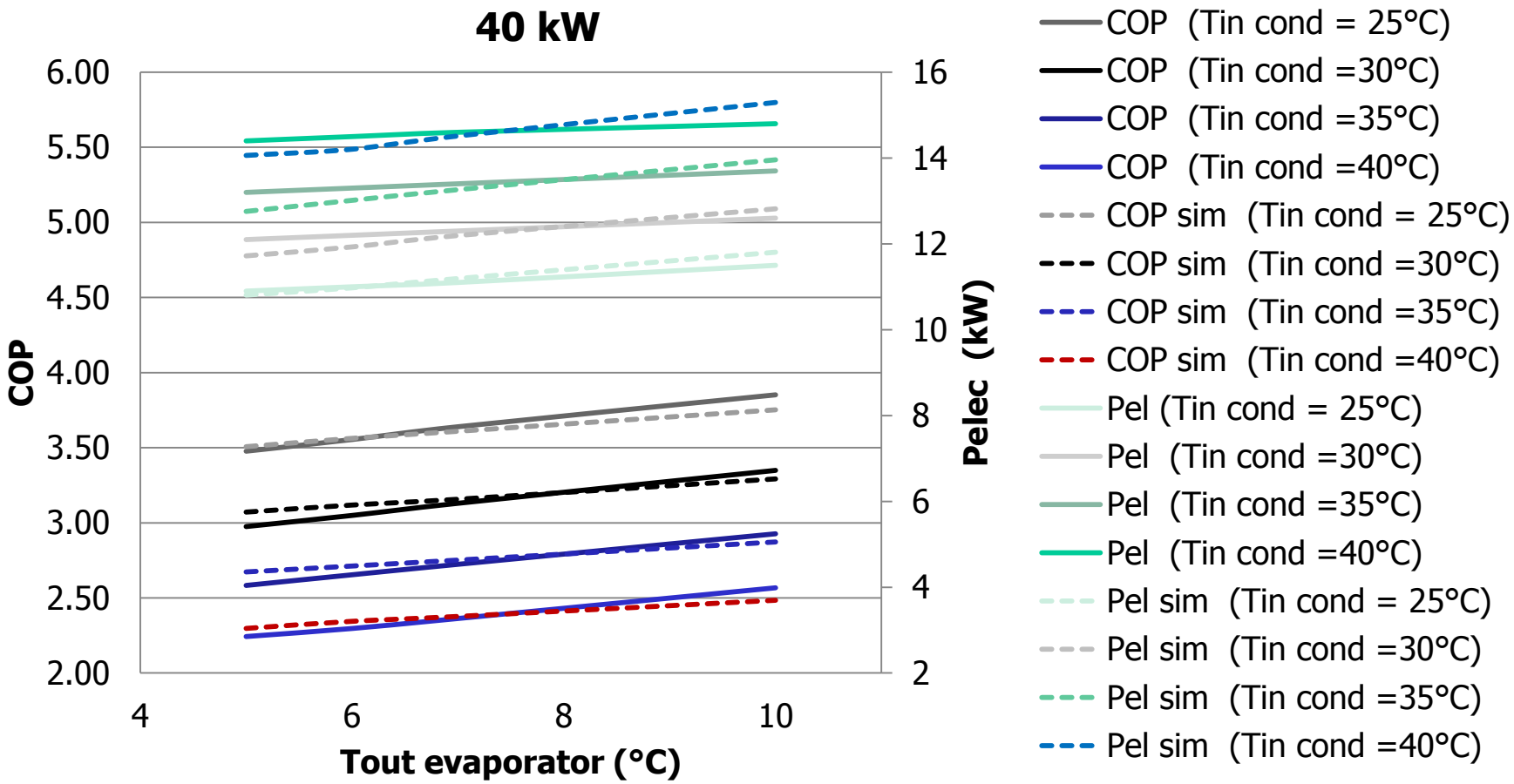
Task 25 Office building in three climates (Palermo, Madrid, Stuttgart)

- Absorption 35 kW (COP = 0.7) versus Compression 30 to 50 kW
- Backup CCM 10kW (COP= 3.5)
- Flat plate/vacuum tube collectors – Monocrystalline Silicon
- Heat storage (5m³)
- Cold storage (1m³)
- Wet cooling tower

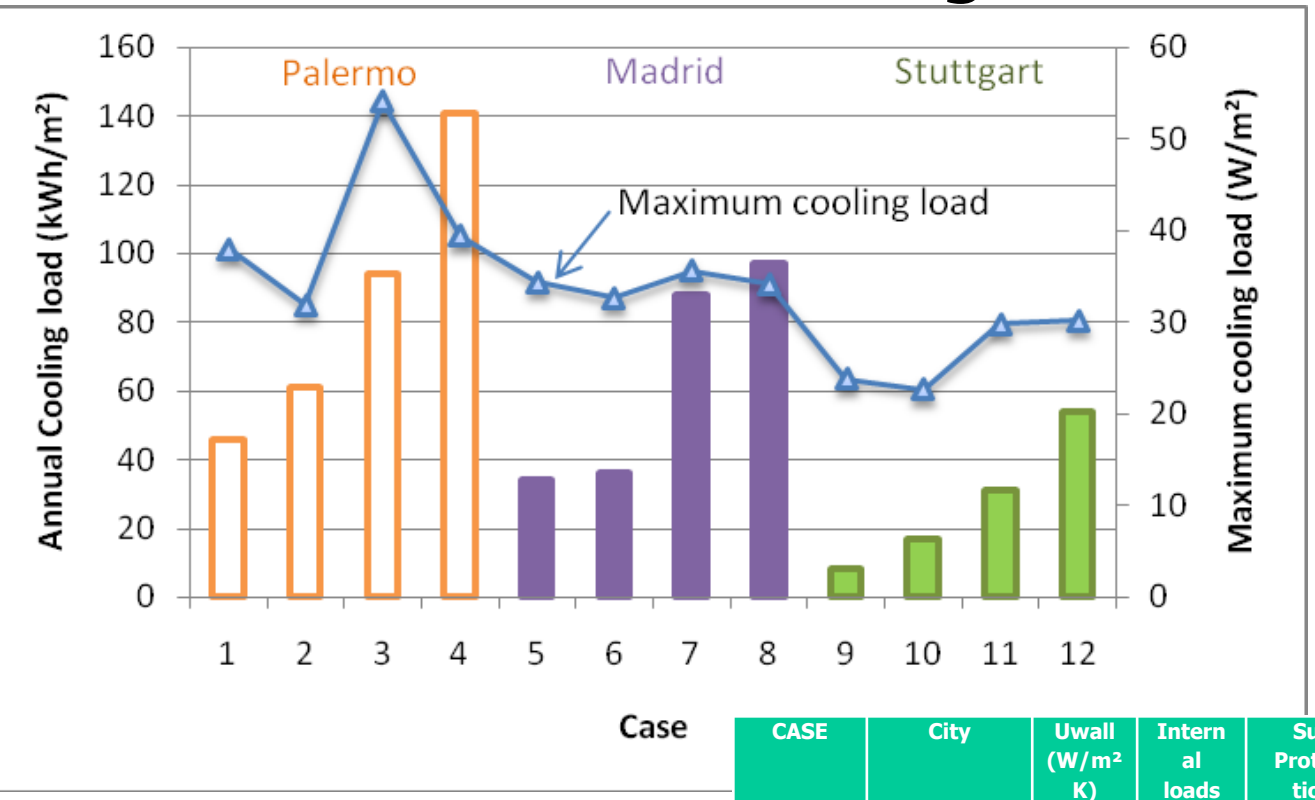




Compressor performance model

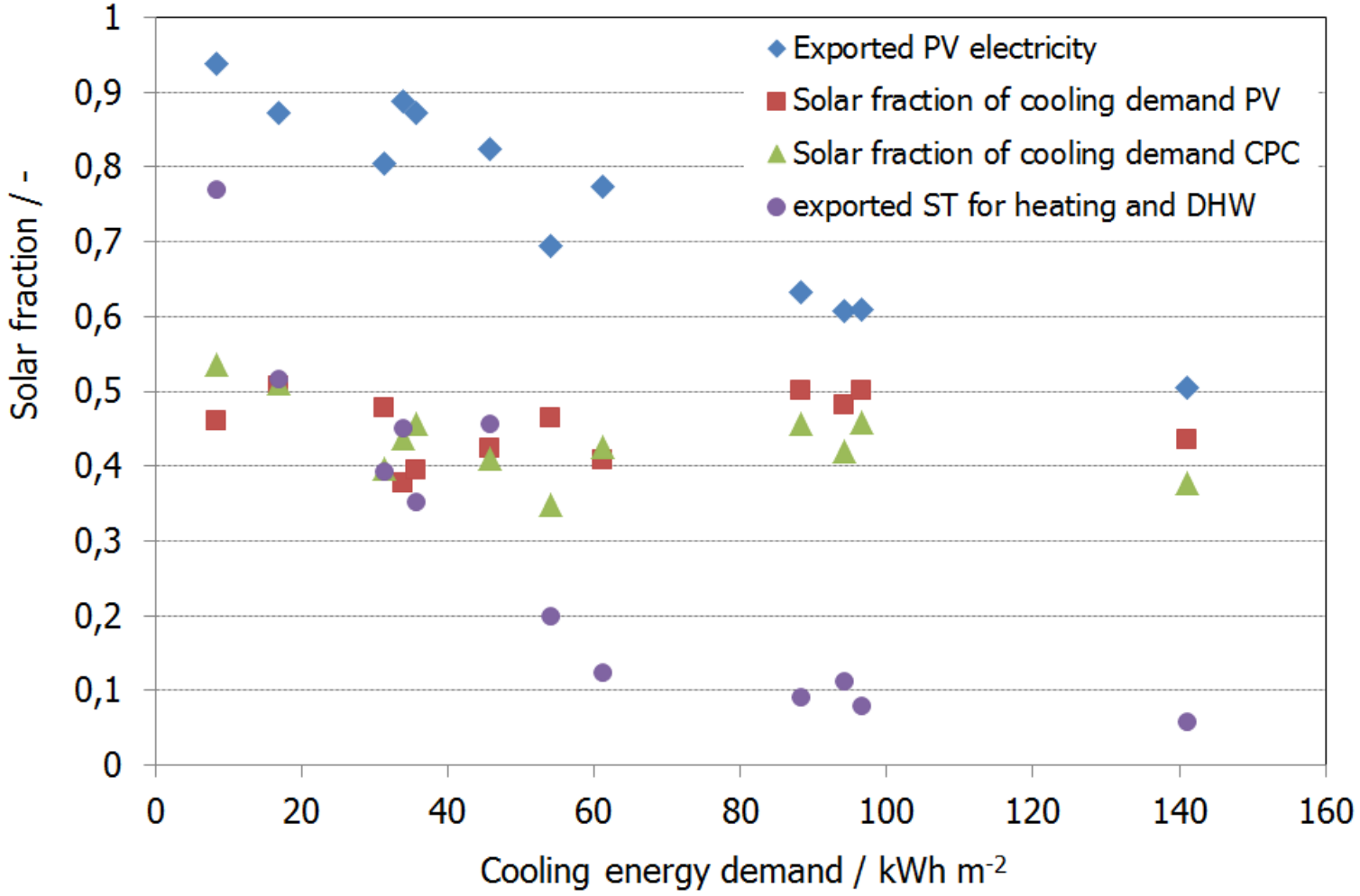


Cooling loads



CASE	City	Uwall (W/m² K)	Internal loads	Sun Protec-tion	Annual cooling load (kWh/m²)	Annual heating load (kWh/m²)	Maximum cooling load (W/m²)
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



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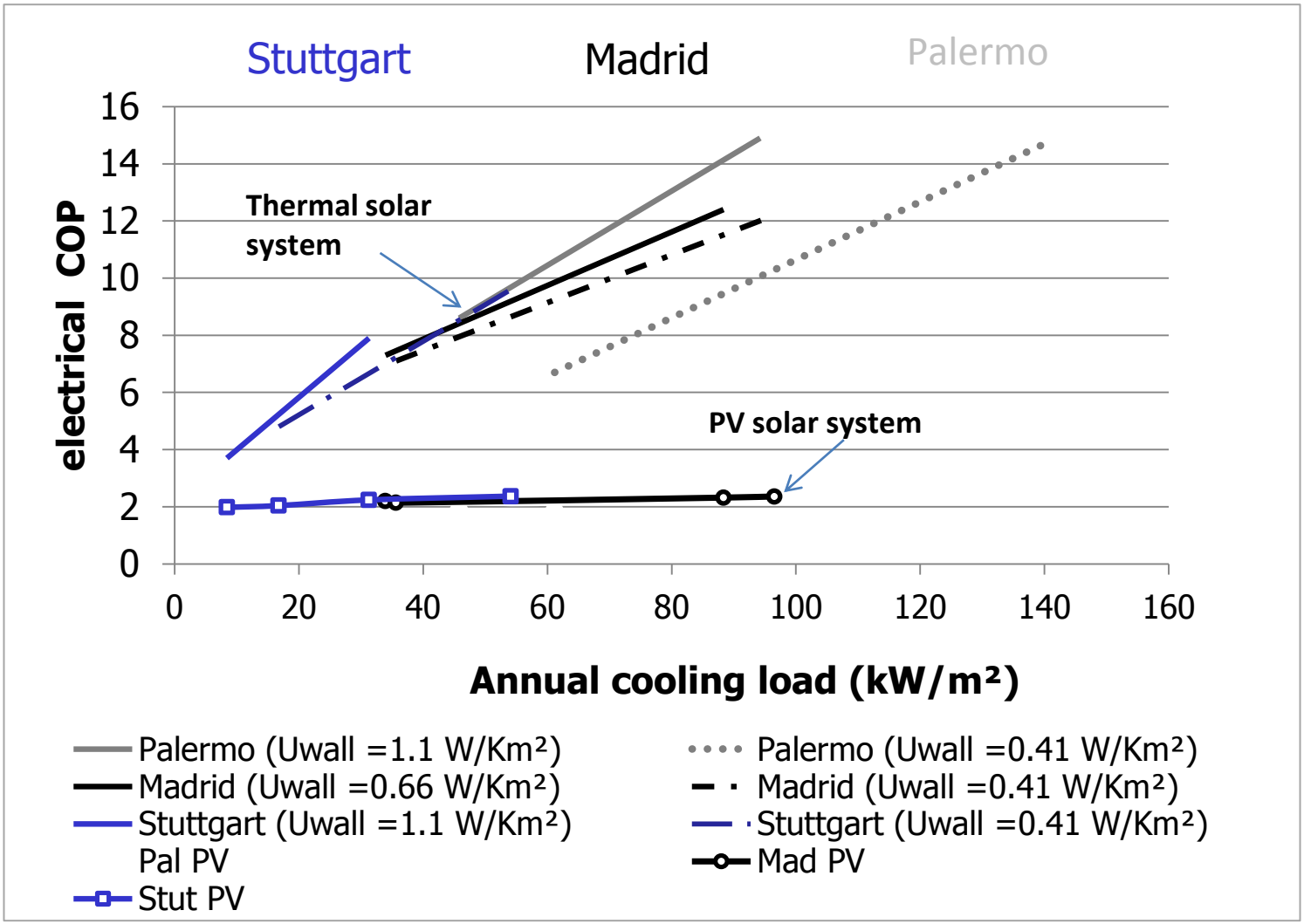
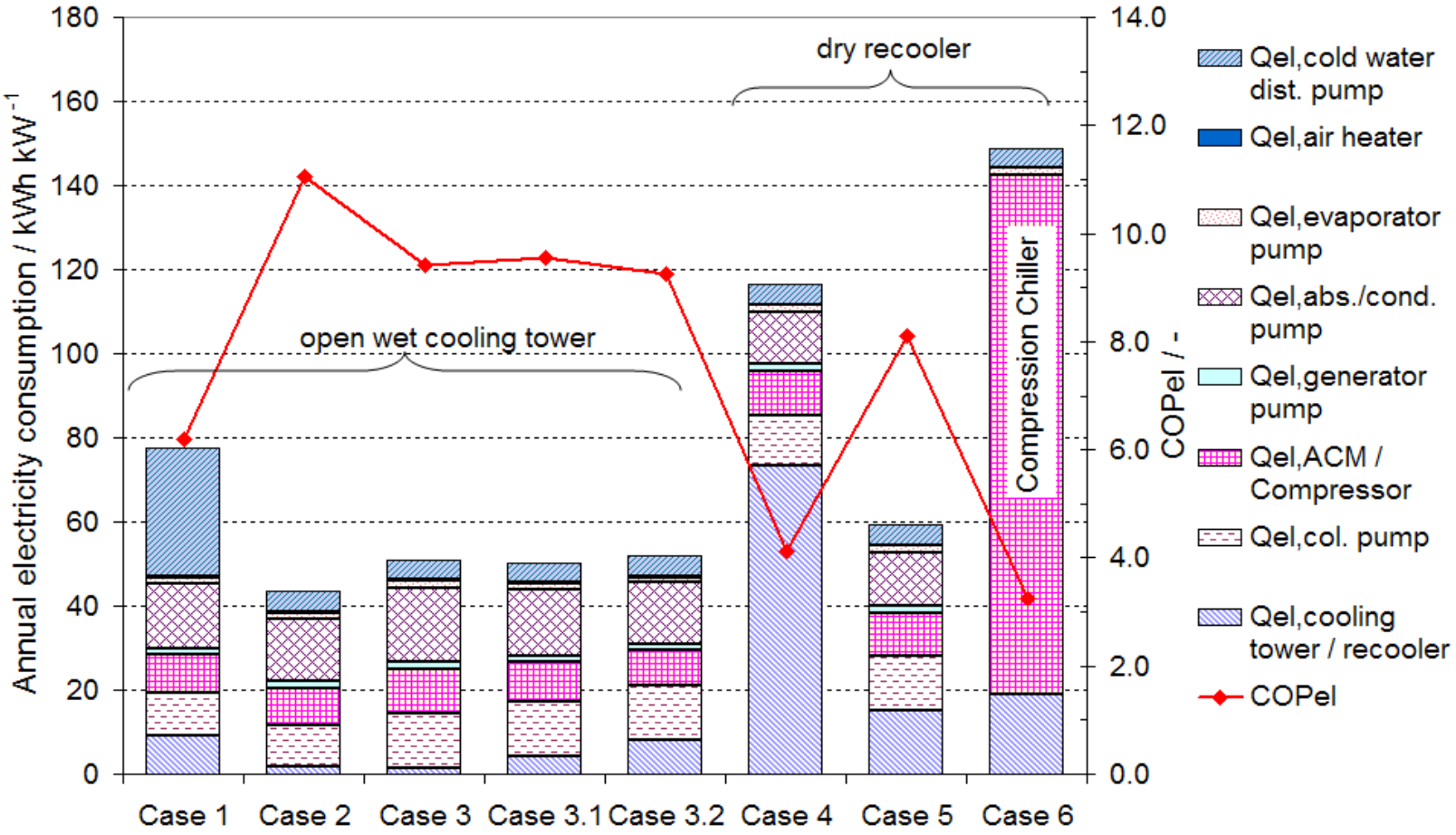
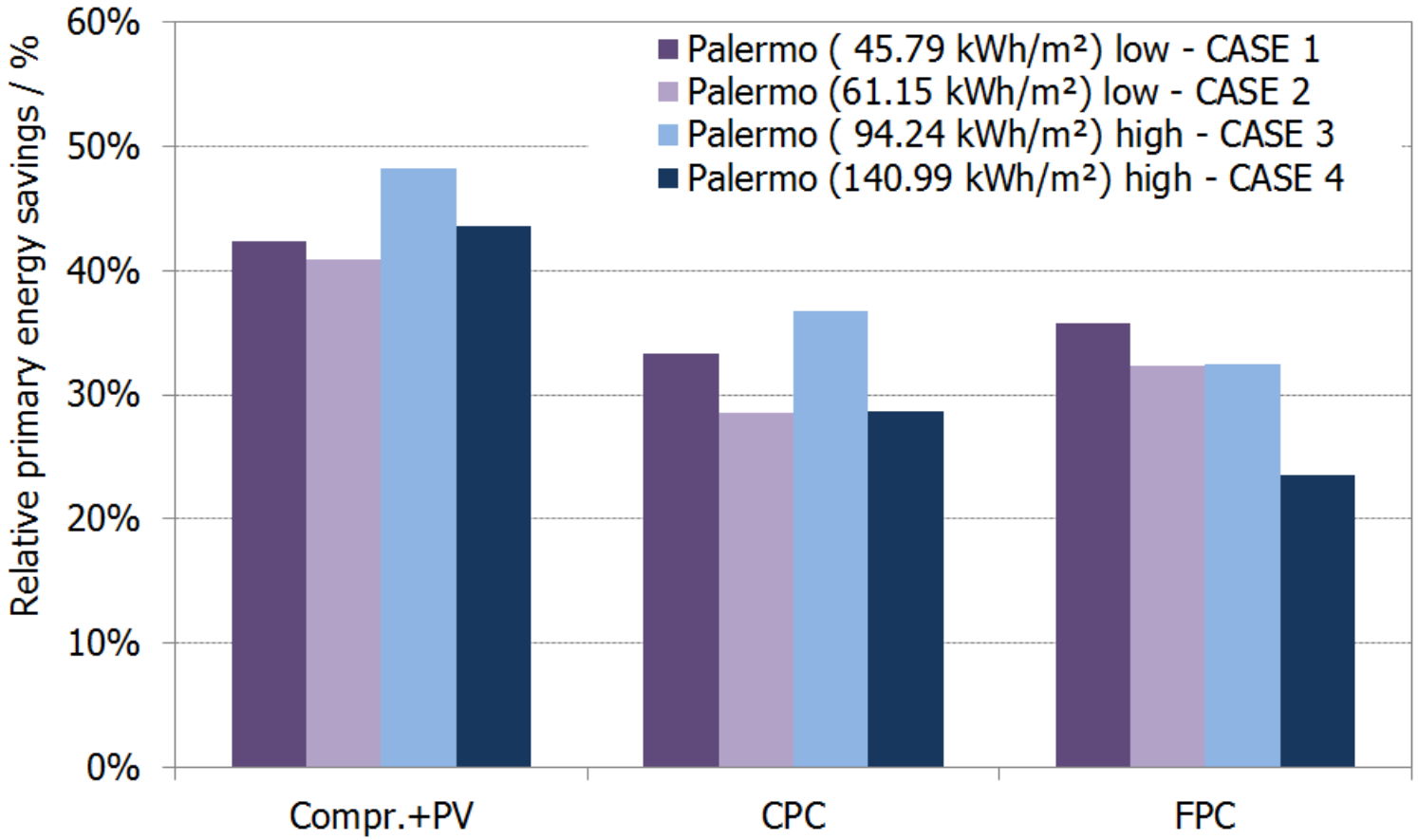
Electrical energy requirement



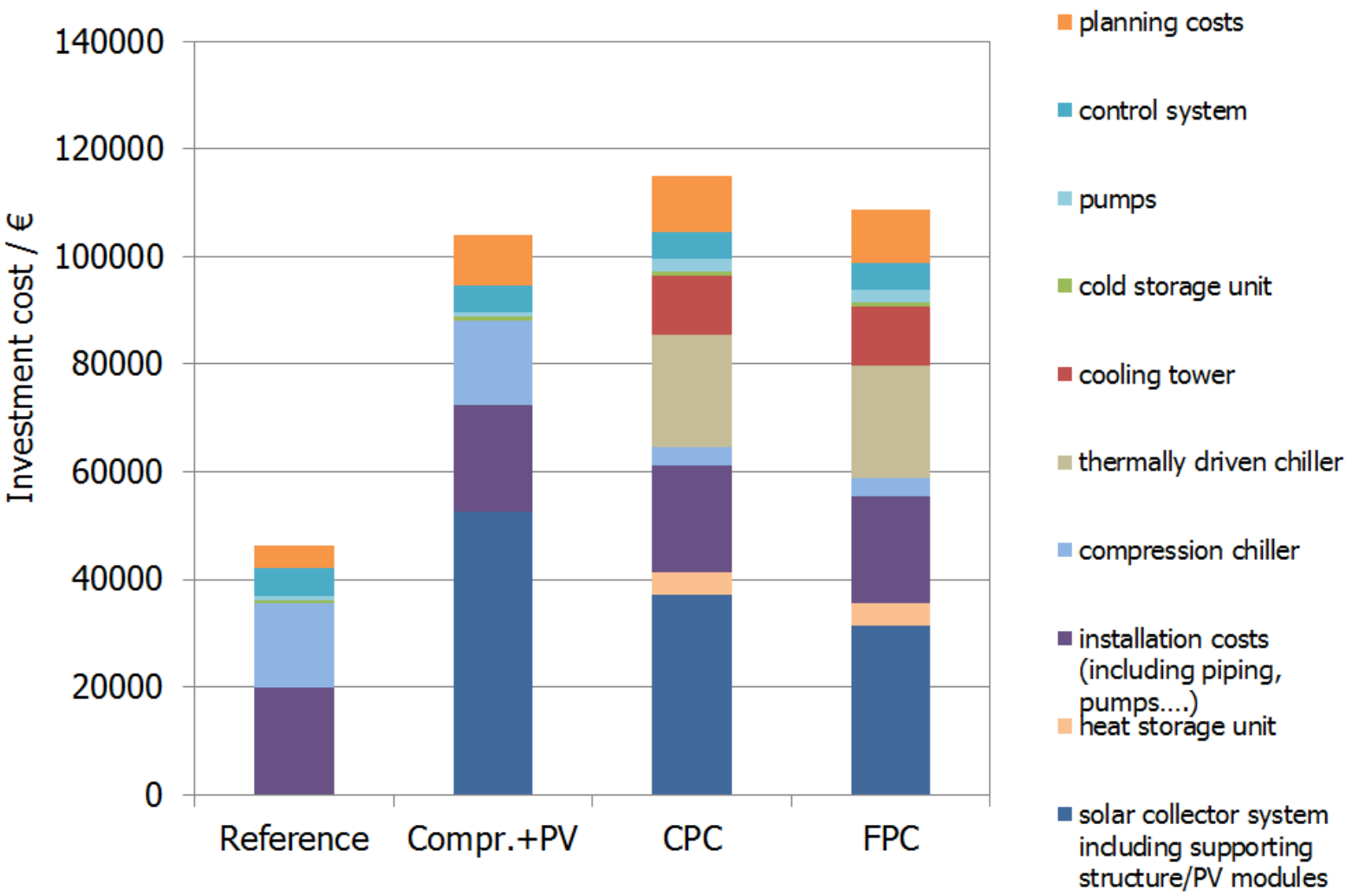
Reduction of auxiliary energy by optimised control



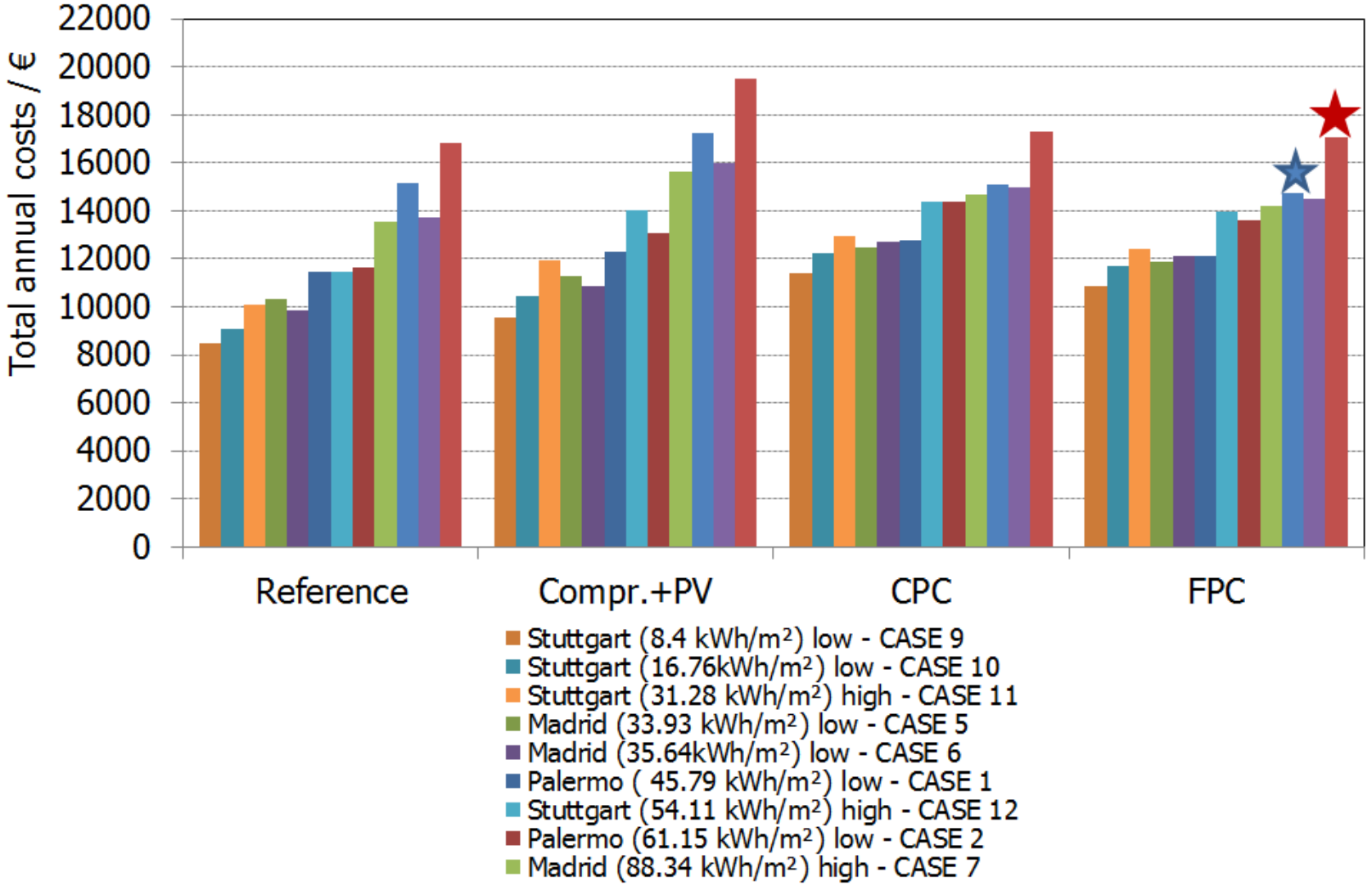
Primary energy savings for cooling



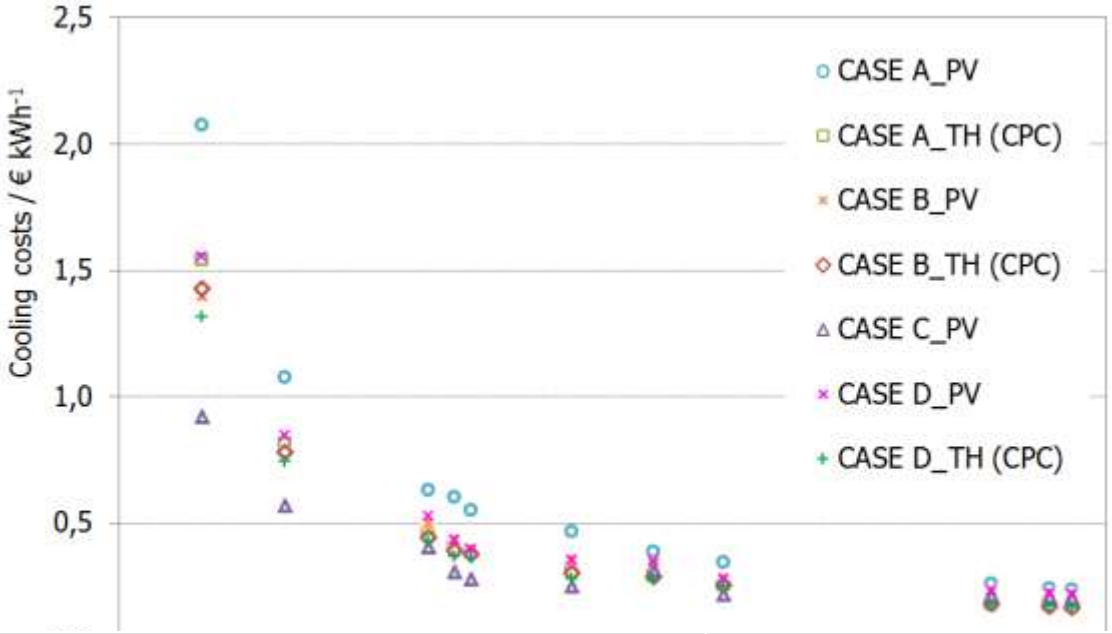
Cost comparison



Total annual costs



Cost of cooling production

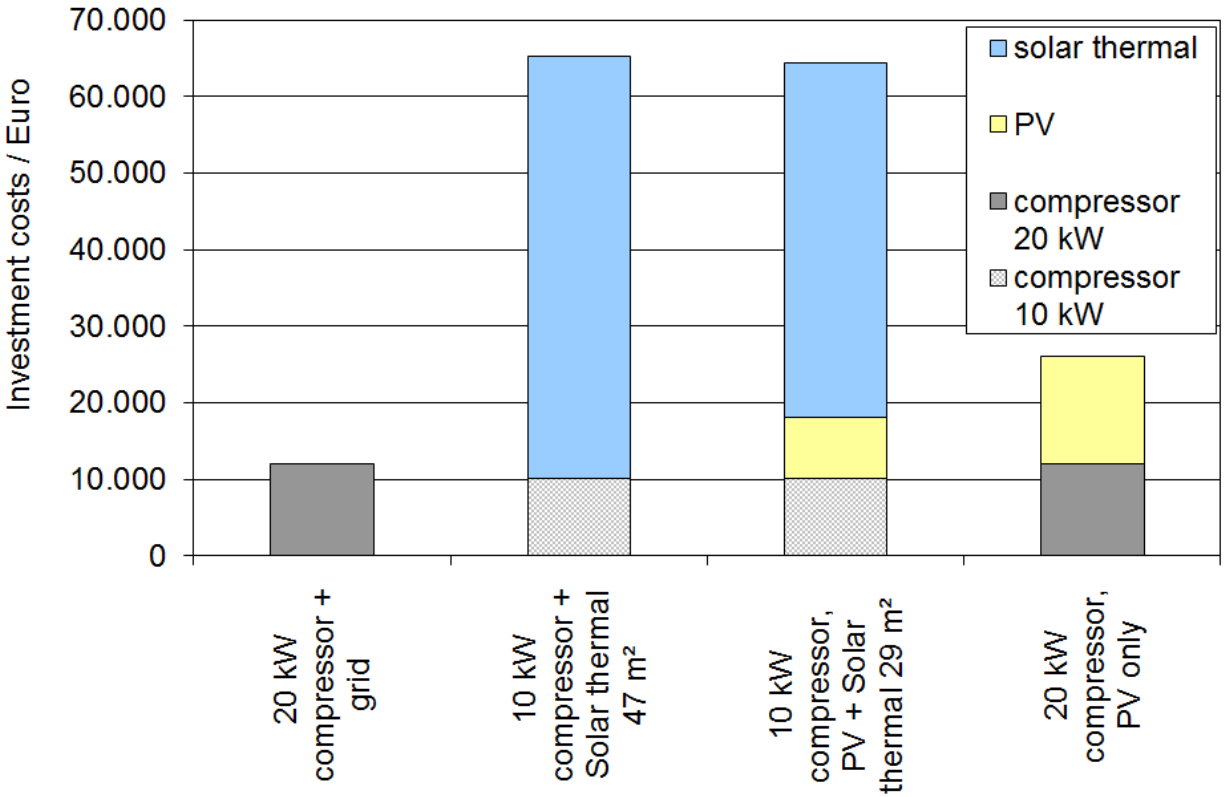


CASE	Photovoltaic cooling system		Thermal solar cooling system	
	PV Export Grid	Feed in tariff	Heat use	Heat price
A	No	-	No	-
B	yes	Germany 0.2455 €/kWh Italy 0.2085 €/kWh Spain 0.1855 €/kWh	Yes	Germany 0.0572 €/kWh Italy 0.0542 €/kWh Spain 0.0506 €/kWh
C	yes	Germany 0.42 €/kWh Italy 0.33 €/kWh Spain 0.4 €/kWh	-	
D	yes	Germany 0.19 €/kWh Italy 0.2085 €/kWh Spain 0.1855 €/kWh	Yes	Germany 0.114 €/kWh Italy 0.108 €/kWh Spain 0.101 €/kWh

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

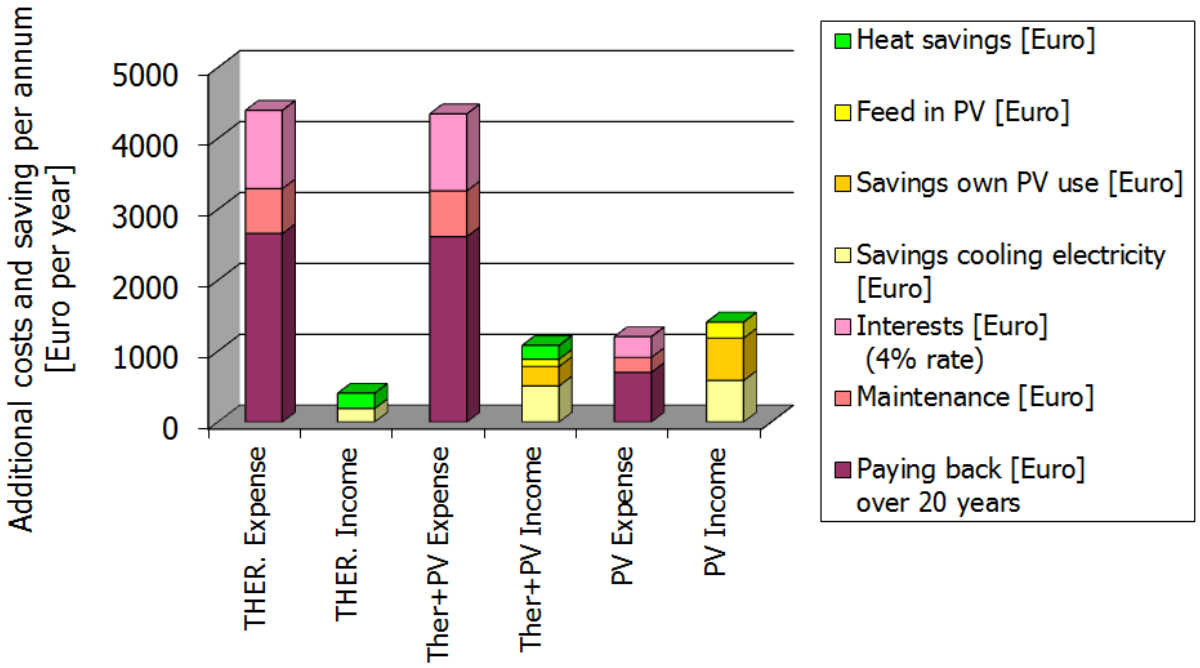
Design project Baden Württemberg State Ministry

Motivation:
strong summer overheating, no night ventilation
Renewable heat law: 15 % solar thermal for heating and cooling (of public buildings)



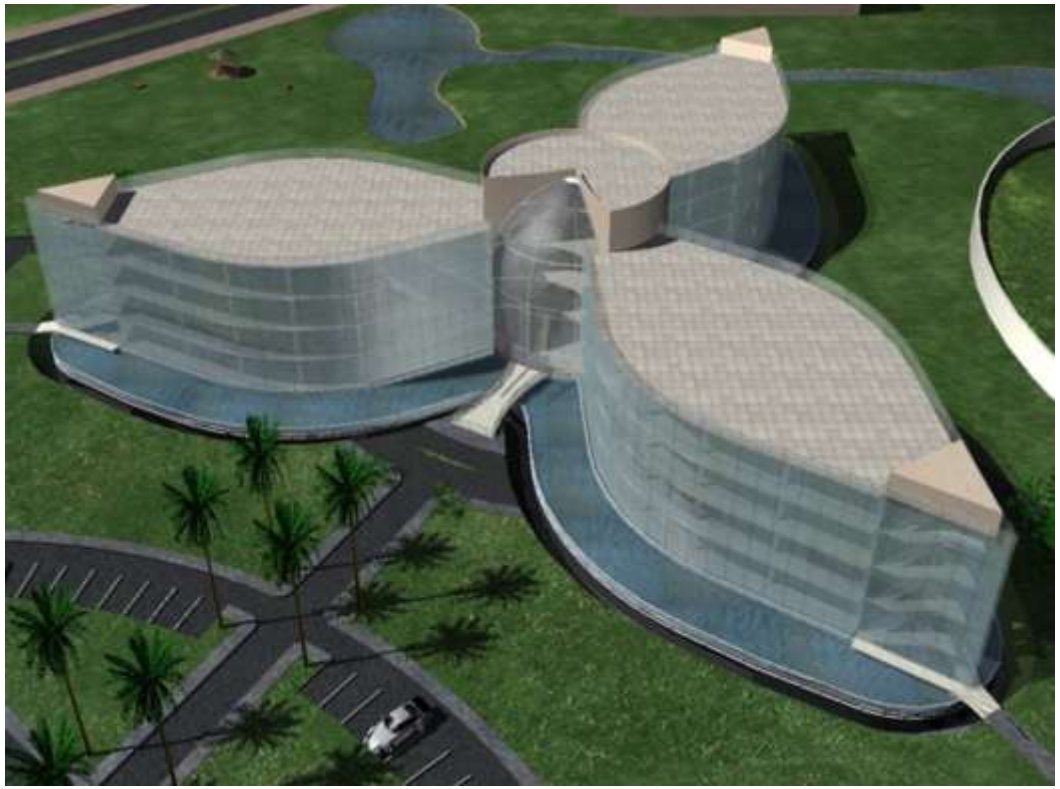
Result:
25-50% solar fraction with thermal cooling system

Recommendation for small systems



PV most cost effective – but low solar fractions of 20-30%
Solar thermal cooling for base load to reduce costs
Peak loads with electric compression + PV with grid feed in

Large solar cooling systems for mediterranean climates

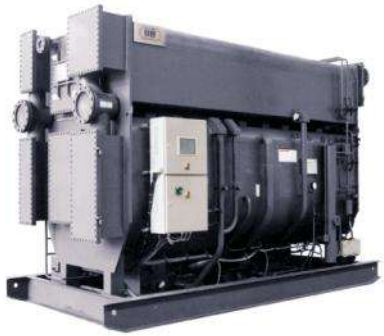


Cairo office building
15100 m² surface
52 W/m² cooling load
130 kWh/m² cooling energy demand

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 m²	1350 m²	20 m³	10 m³
Case 2	**Double** Effect	**500 kW**	Linear Fresnel	2050 m²	1320 m²	20 m³	10 m³
Case 3	**Triple** Effect	563 kW	Linear Fresnel	**1280 m²**	**800 m²**	-- m³	10 m³

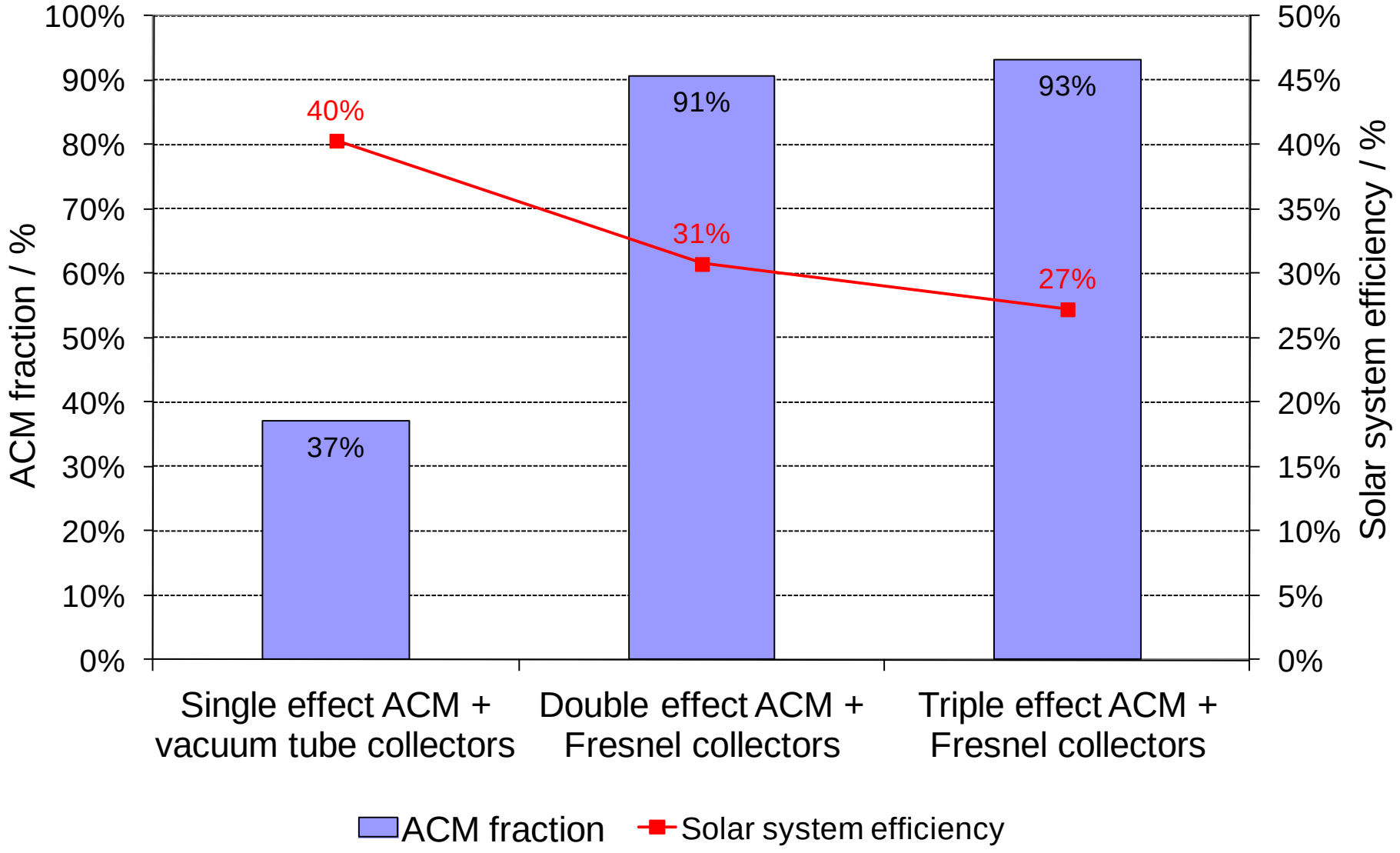
THERMAX, single effect
ProChill LT12C



Shuangliang, double effect
500 kW

Kawasaki Sigma, triple effect
Ace CF01-10-0001

Absorption Cooling Fraction and Solar System Efficiency



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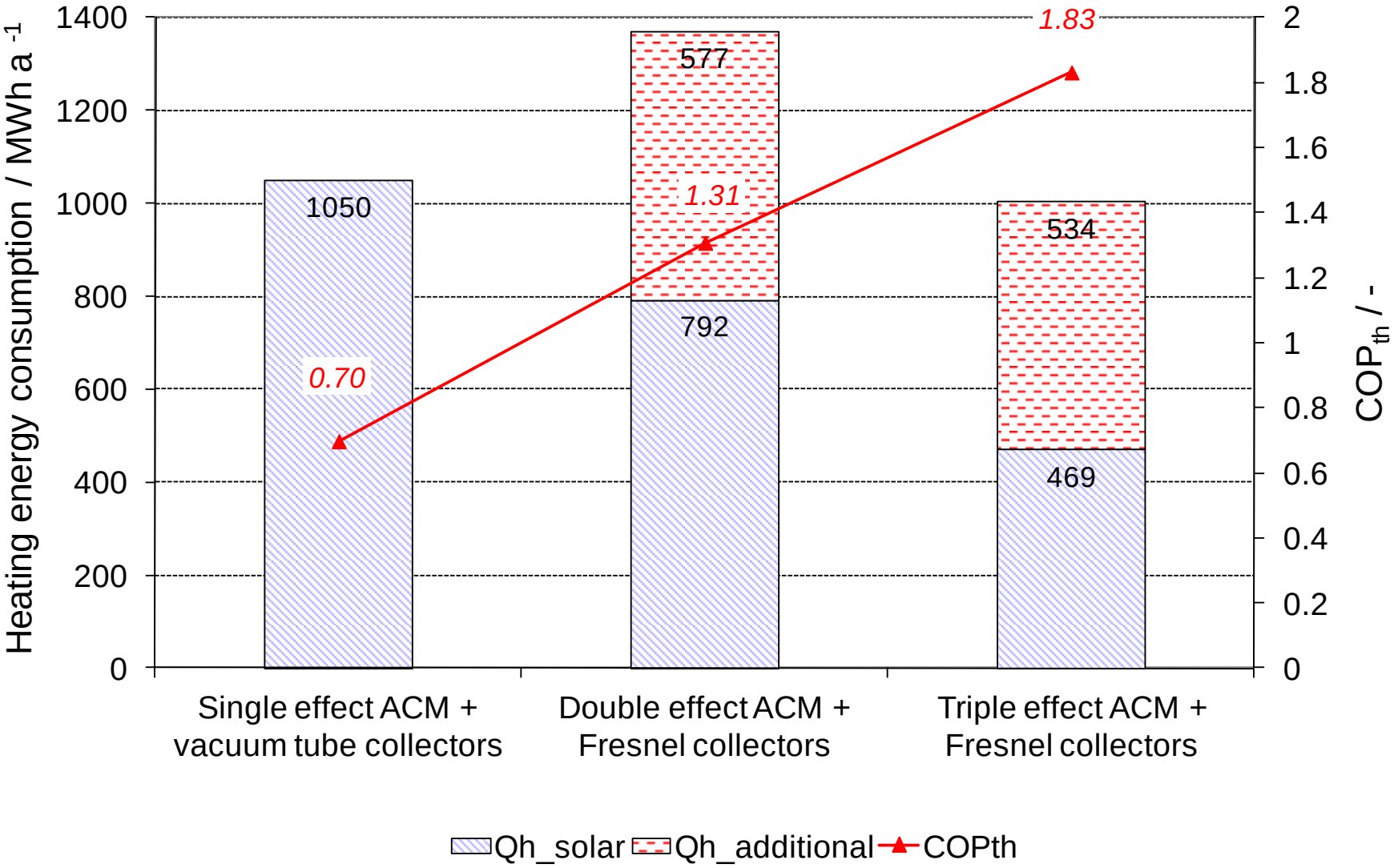
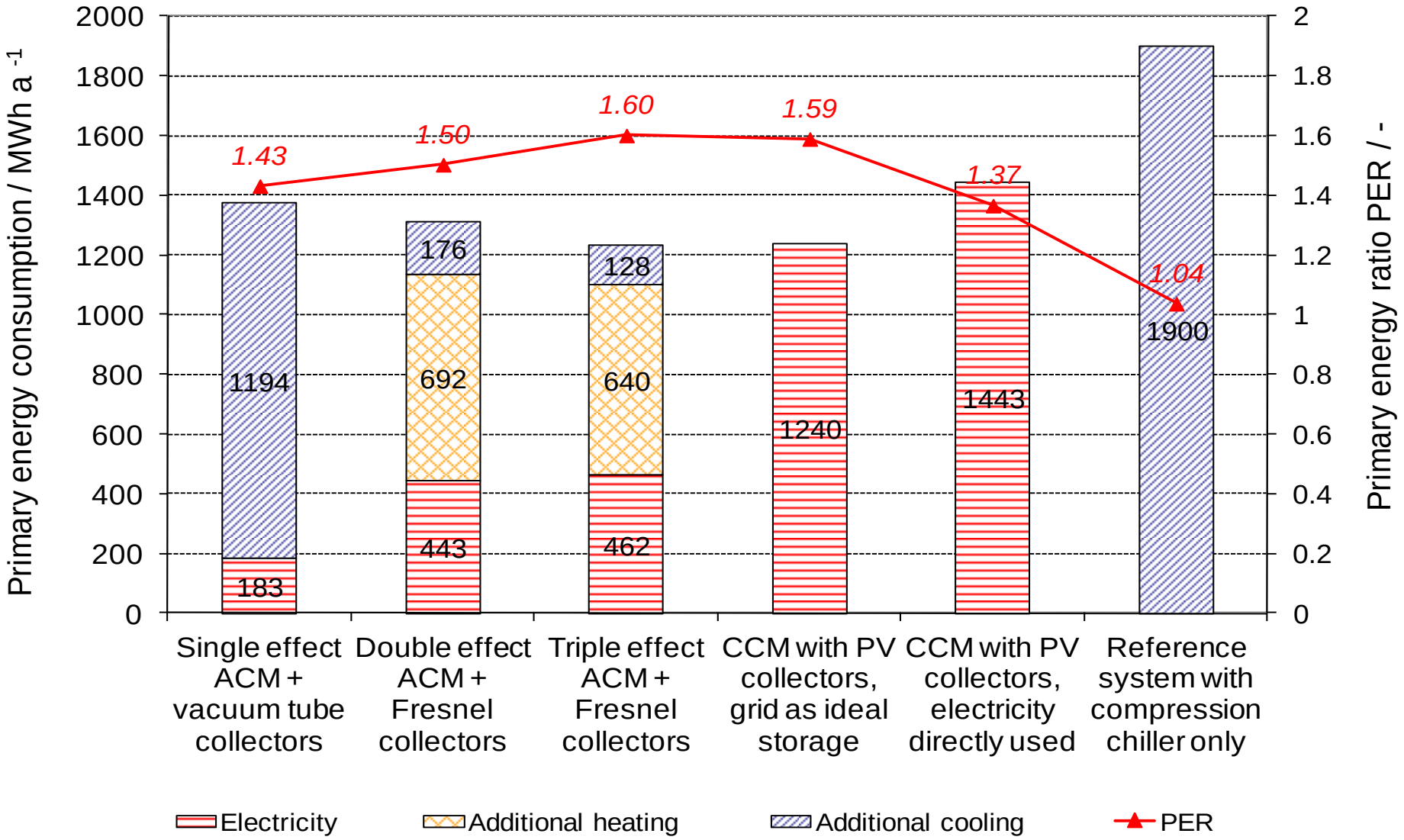
Heating Energy Consumption and Average COP_{th}



Primary Energy Efficiency



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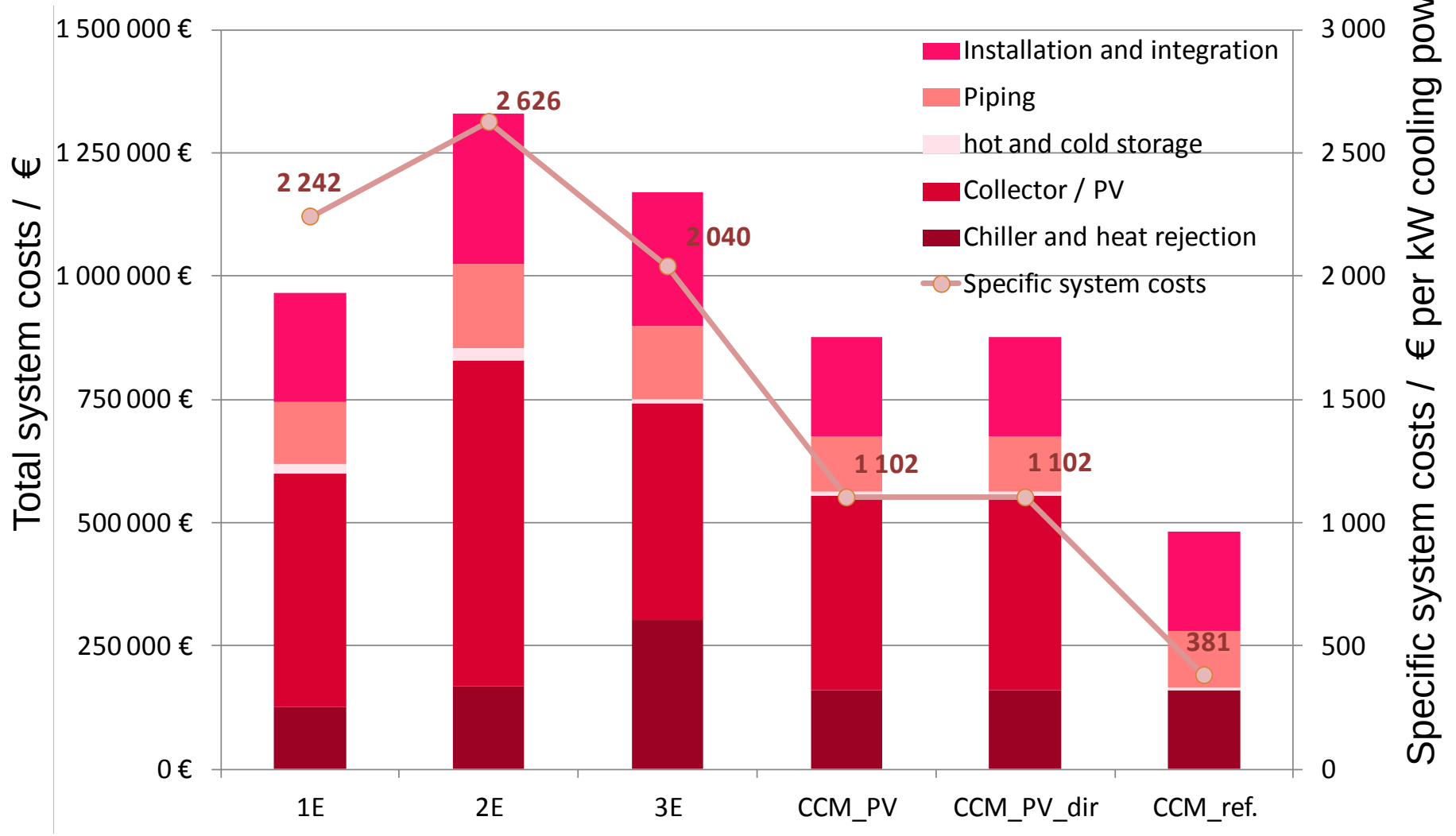
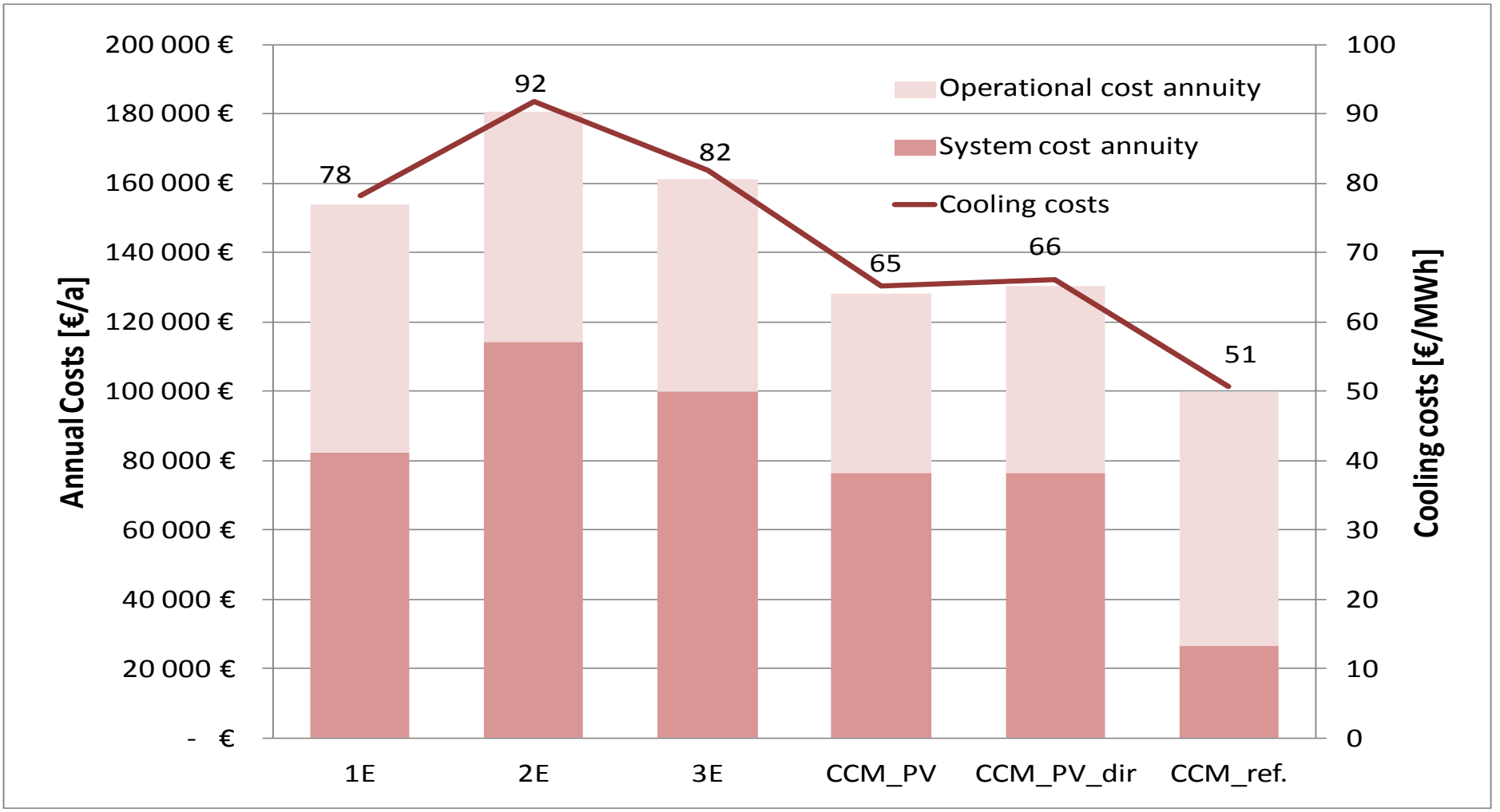
System Costs Including Installation and Integration

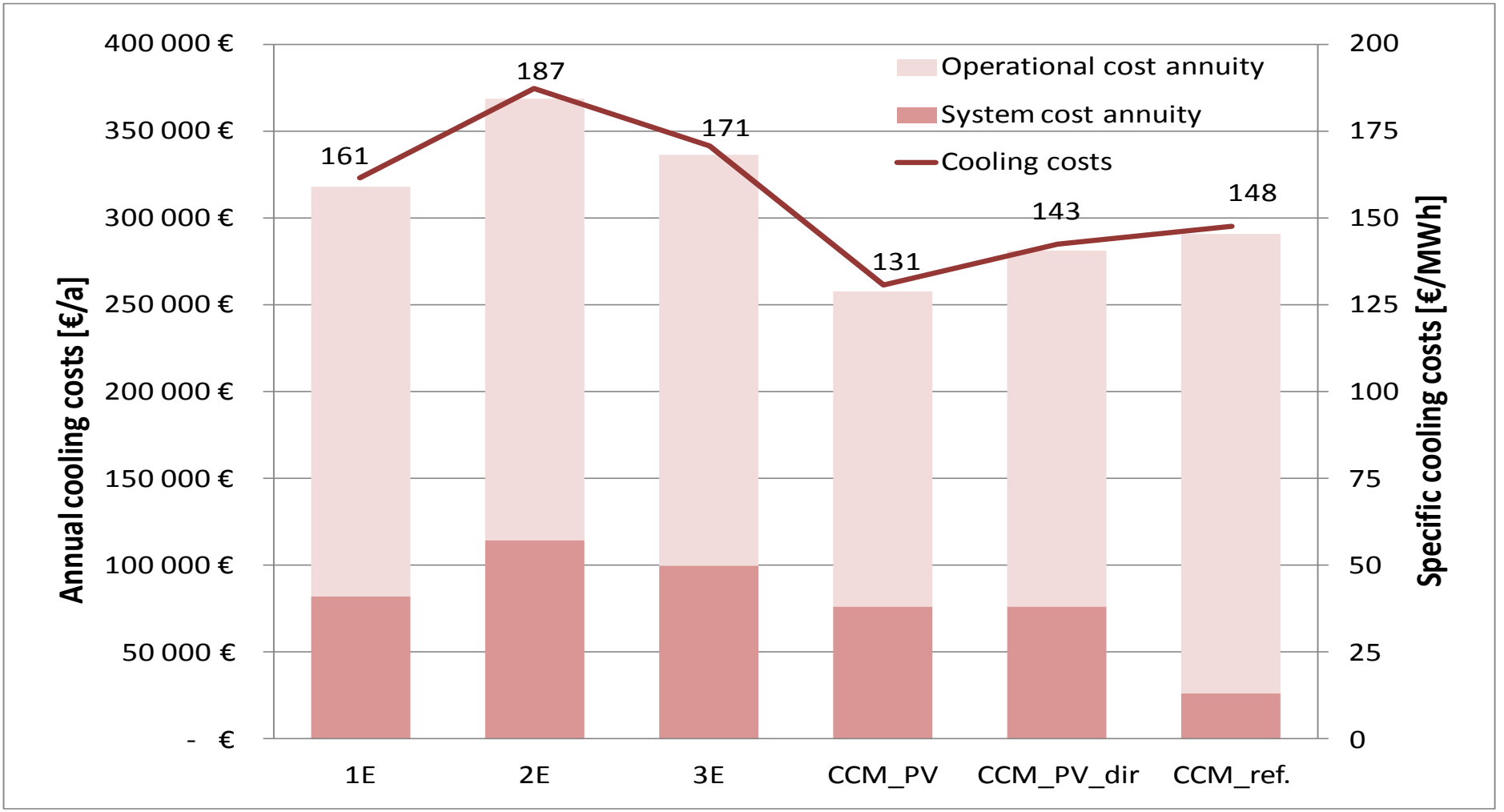


Overall Cooling Costs / Office Building in Cairo, Egypt



Prices: Gas = 0.0174 €/kWh Electricity = 0.062 €/kWh Water = 1.6 € / m³
Source: www.worldtribune.com Inflation rate = 5.6%/a 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

Conclusion

- Solar thermal and photovoltaic cooling allows for primary energy savings of 30 to 50% in typical office building projects
- Good partial load control is important for primary energy savings
- For reduced feed in tariffs and increasing heat costs the total costs of PV and solar thermal cooling are comparable
- For long operating hours solar cooling is competitive with conventional cooling
- The primary energy efficiency of solar thermal cooling is comparable or higher than photovoltaic cooling, especially when double or triple effect chillers are used