Solar Heating and Air-Conditioning of Buildings

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Outline

1. Introduction
2. Solar heating and air-conditioning solutions
3. Solar thermally driven cooling systems
4. Case study
5. Summary and conclusion

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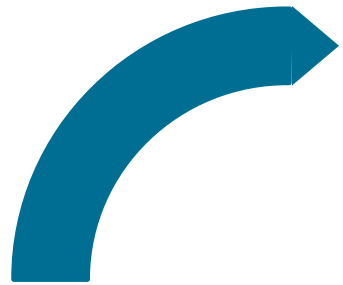
Holistic approach to energy efficient buildings

Reduction of energy demand
- Building envelope
- Shading
- Ventilation



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- Air (T, x)
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- PV
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Towards zero energy buildings

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- Europe: new buildings have to be NZEB (net zero energy buildings) from 2020 on (public buildings 2018)

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- Europe: new buildings have to be NZEB (~~net~~ nearly zero energy buildings) from 2020 on (public buildings 2018)
- "A 'nearly zero energy building' is a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby."
- Solar energy is the main on-site renewable energy source to cover the remaining energy demand

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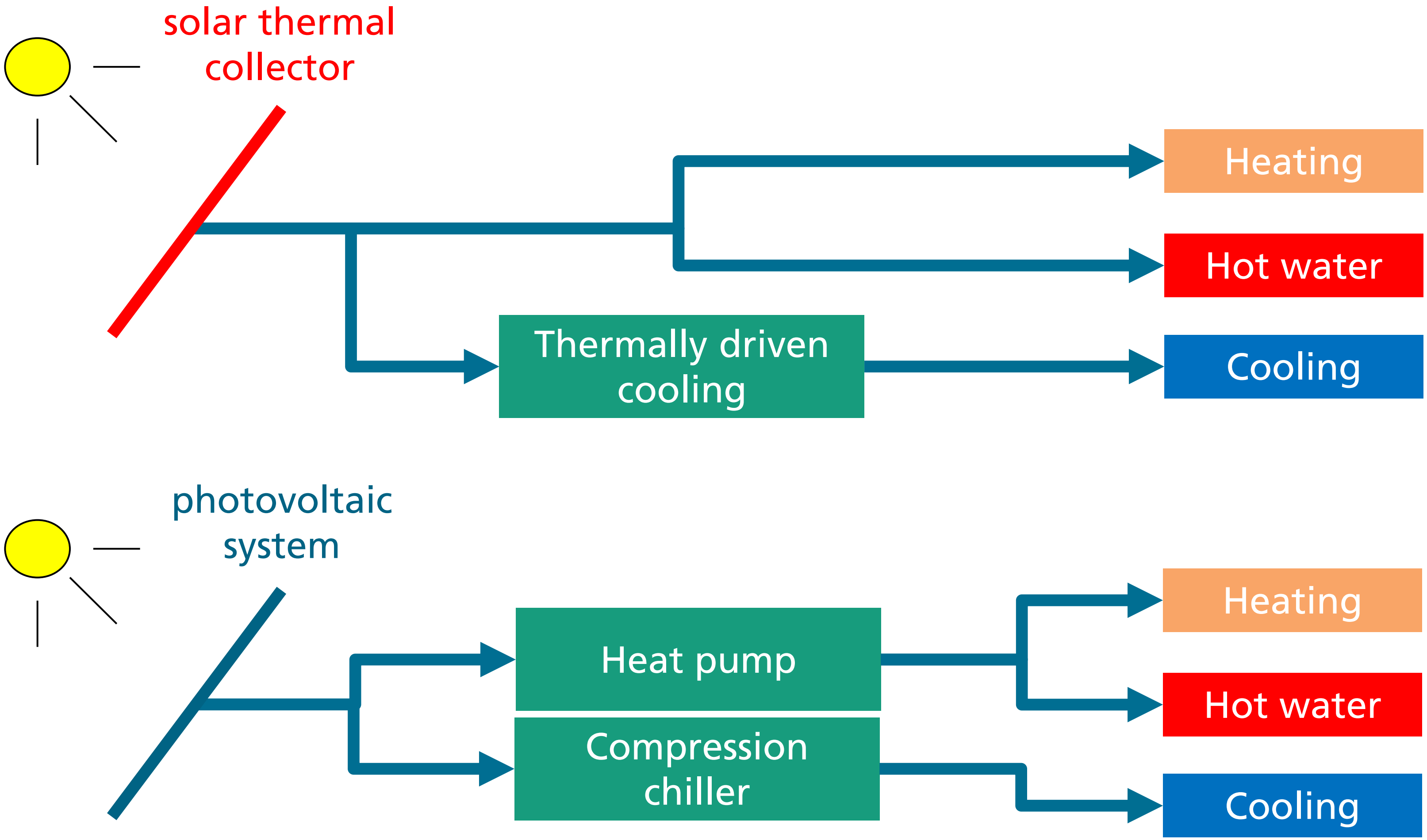
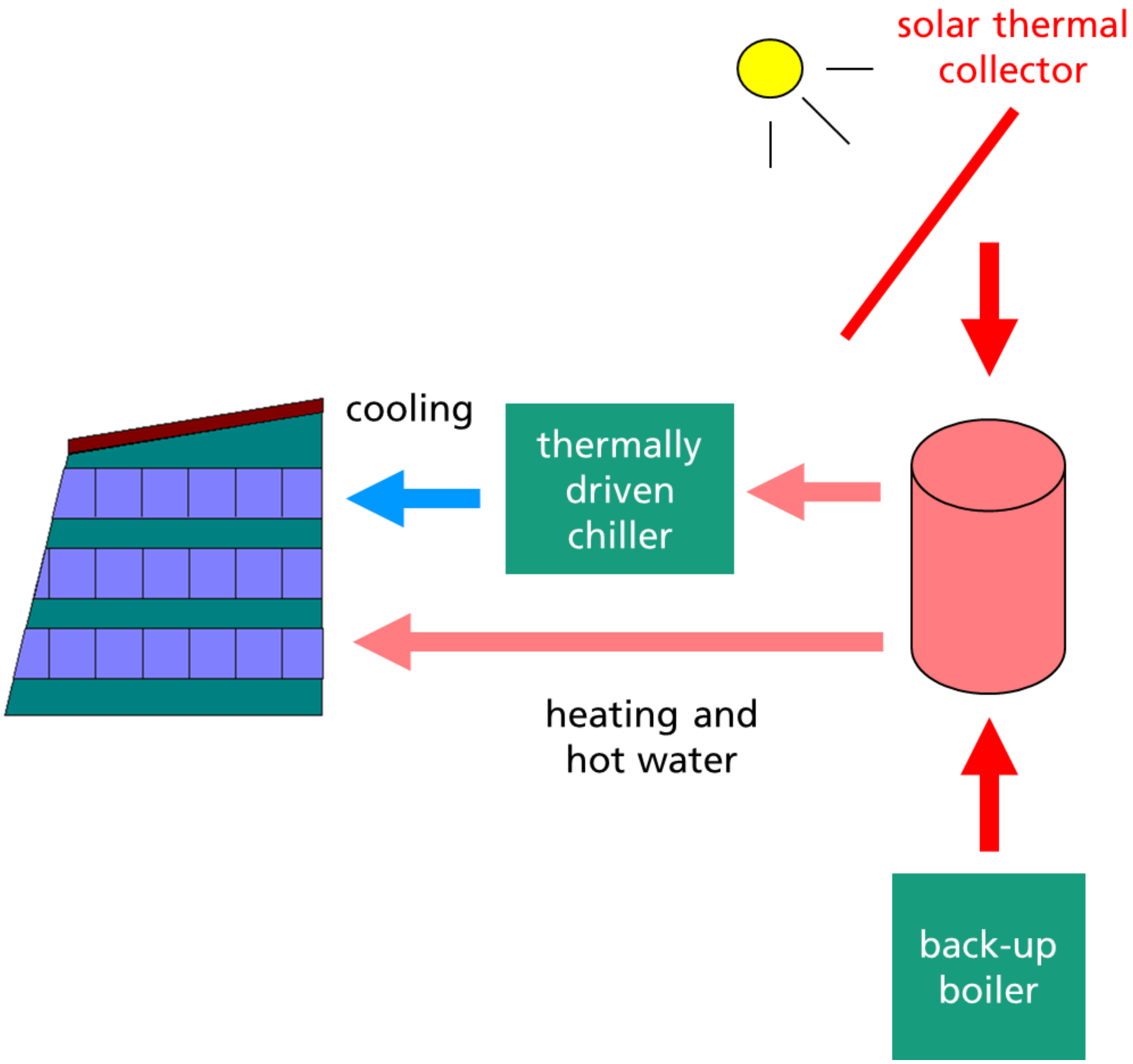
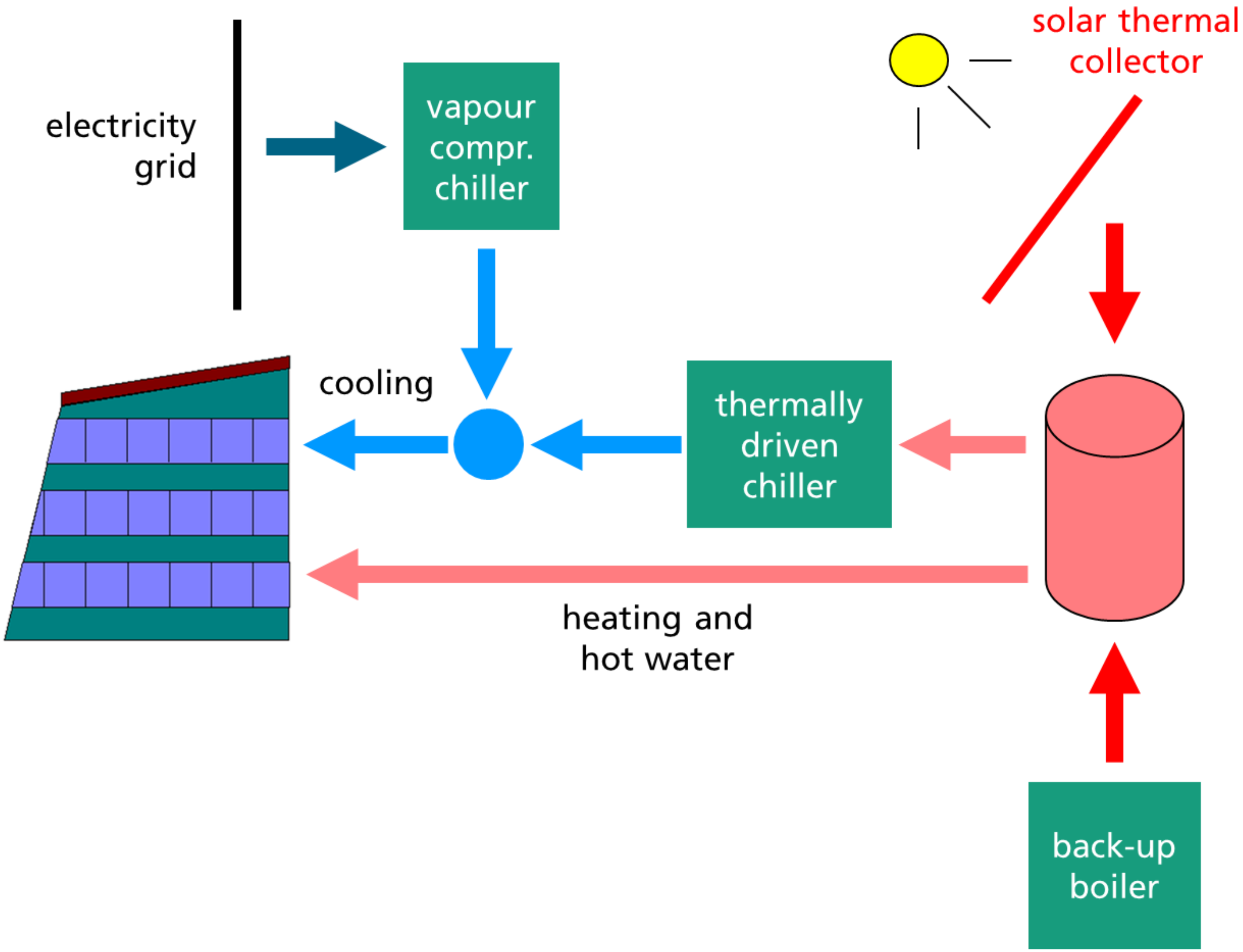
Solar heating and air-conditioning – general solutions



Solar thermal: TDC + boiler



Solar thermal: TDC + boiler + vapour compr. chiller



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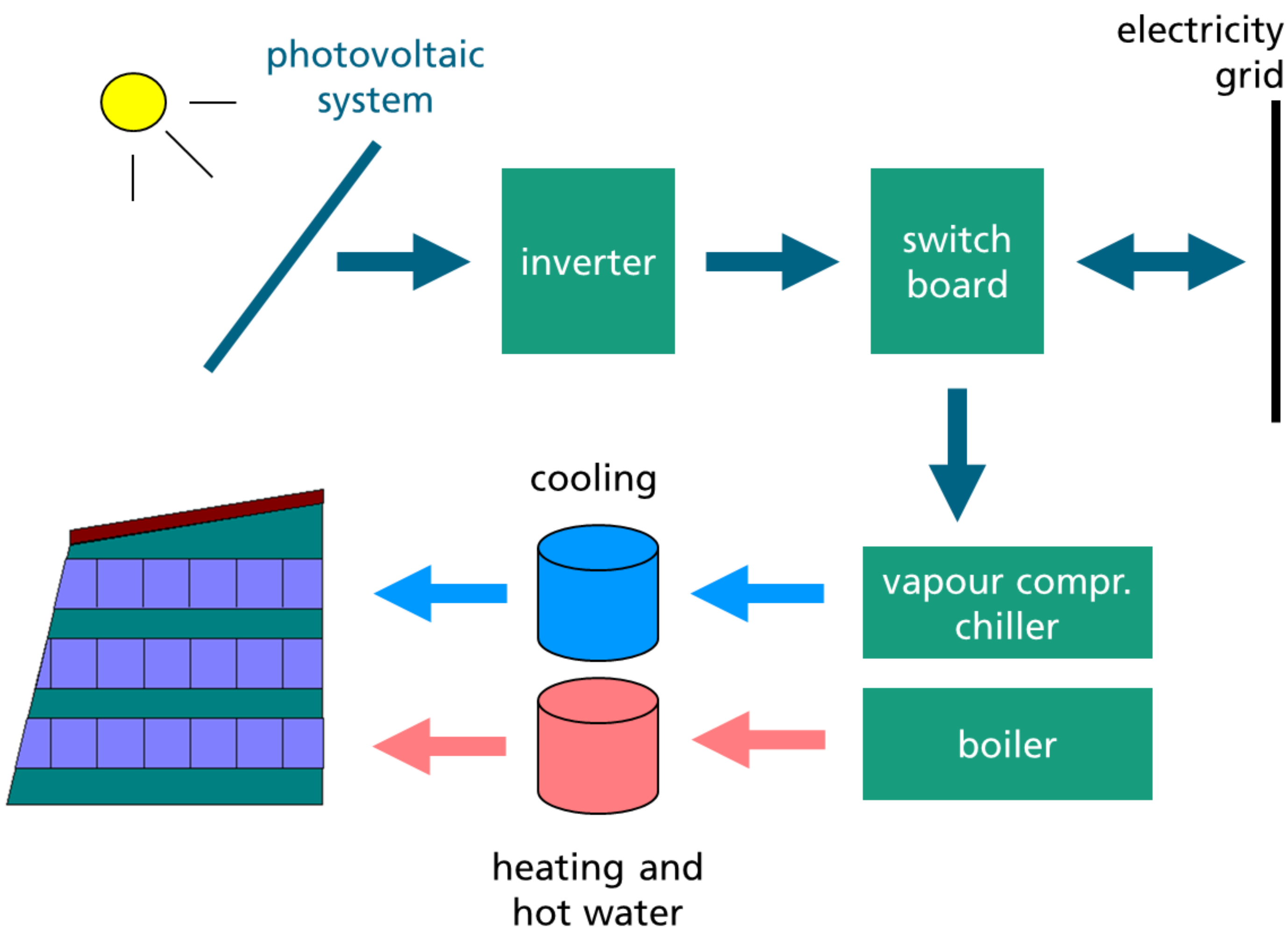
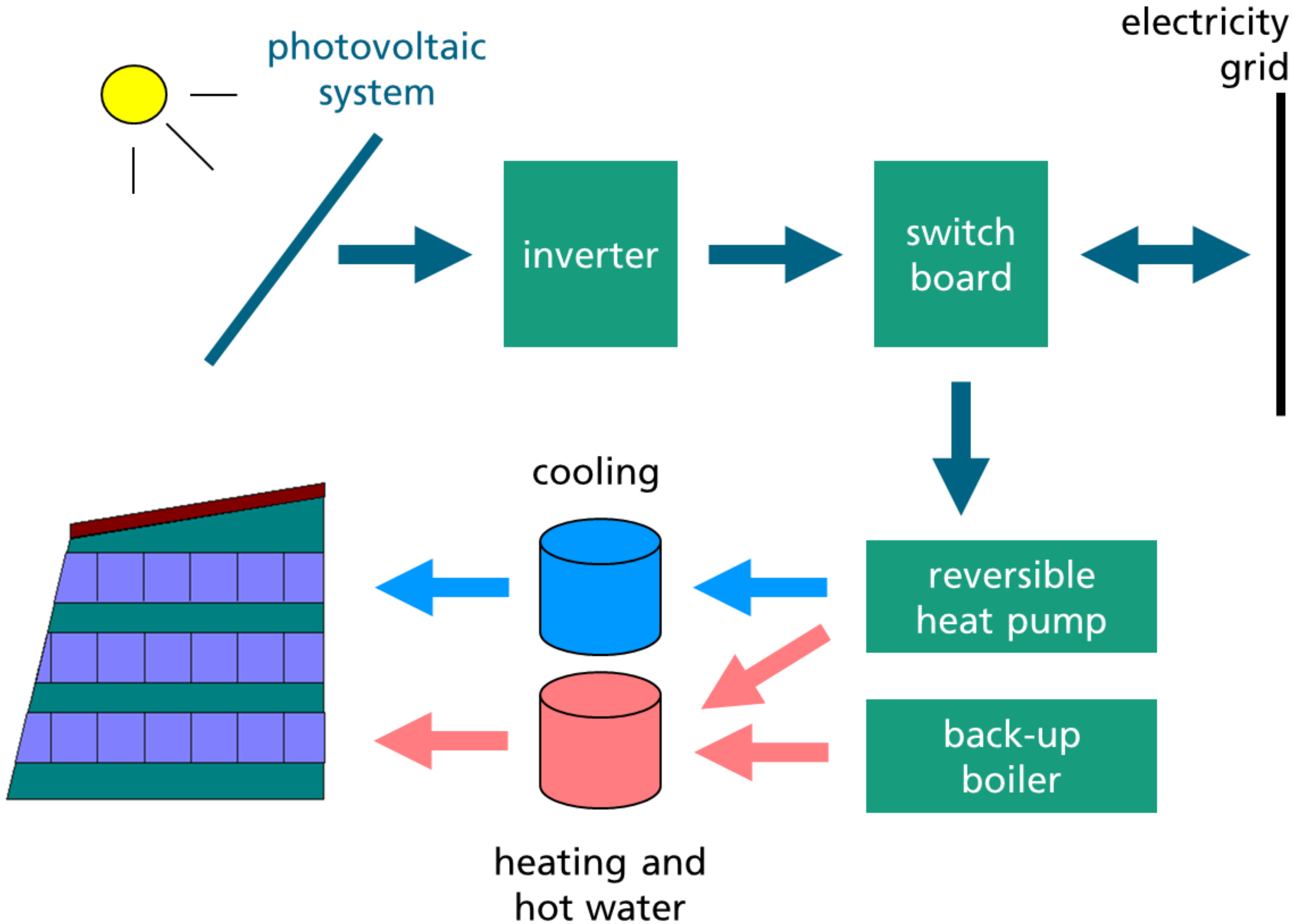
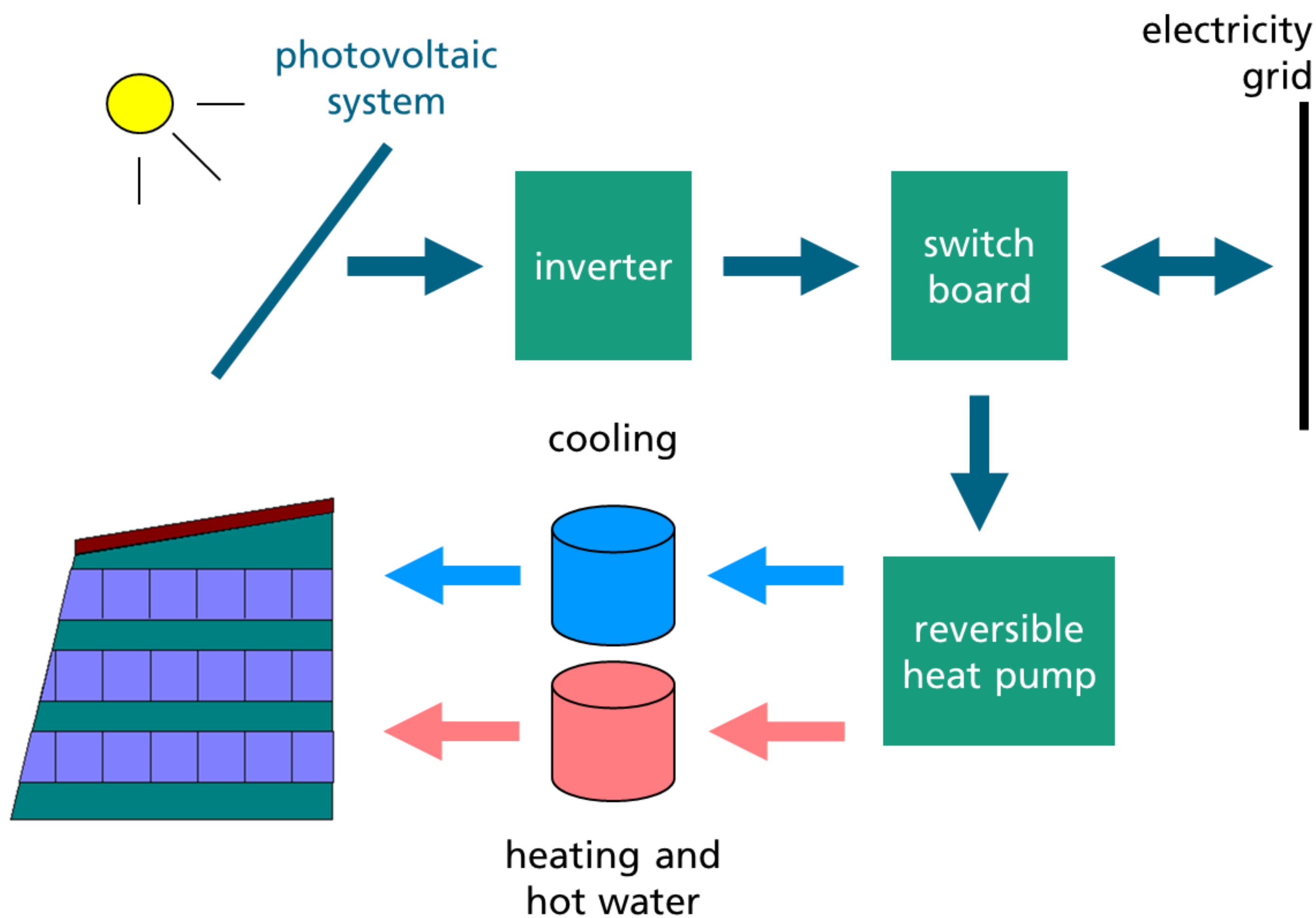
PV: compression chiller + boiler



PV: reversible heat pump + boiler



PV: reversible heat pump only



Solar heating & cooling: thermal versus PV

Solar thermal	PV
+ One single heat buffer for heating and cooling	– Two stores needed: for heating and cooling case

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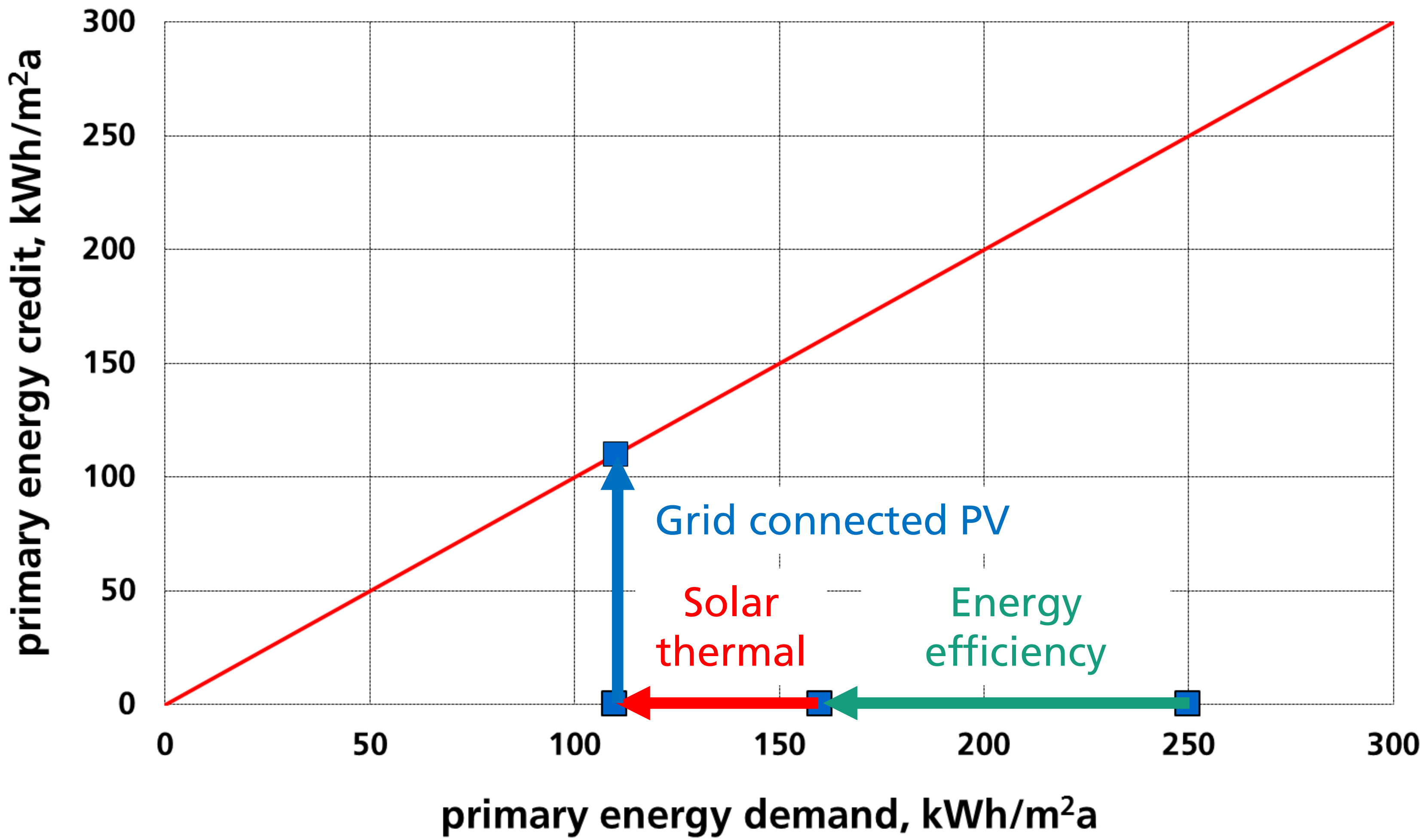
➔ Decision depending on energy-cost performance; typically depending on particular boundary conditions

Solar heating & cooling: thermal versus PV

- Solar heating and cooling today dominated by solar thermal solution
- PV mainly applied in countries with feed-in tariff ➔ all produced electricity fed into public grid
- This will change in future
    - Further cost reduction of PV
    - Decreasing feed-in tariffs
- If feed-in tariff lower than price for purchased electricity on-site solutions for PV will become attractive
- Medium- to longterm: BI-PV-T

Net Zero Energy Buildings – today



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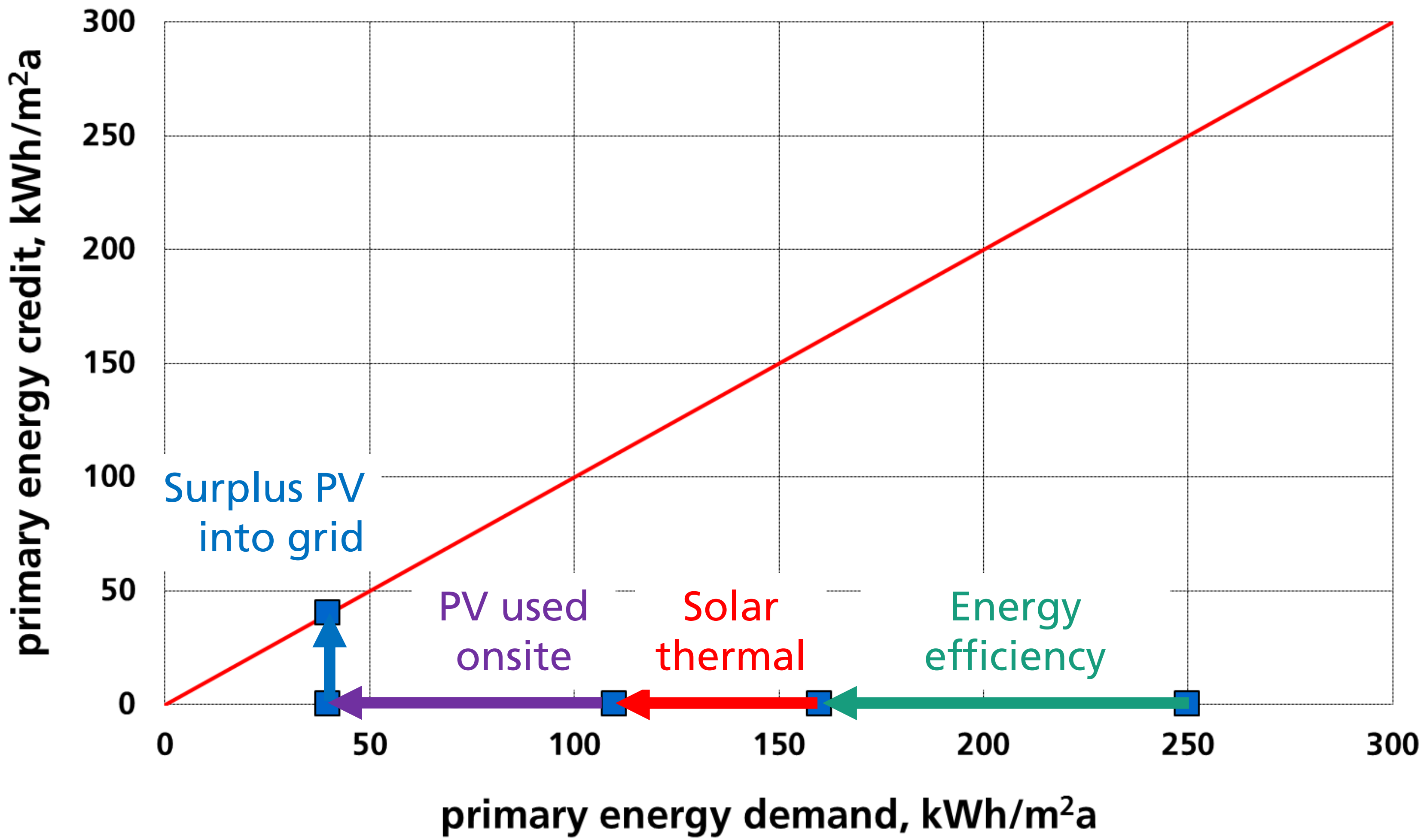
Net Zero Energy Buildings – tomorrow



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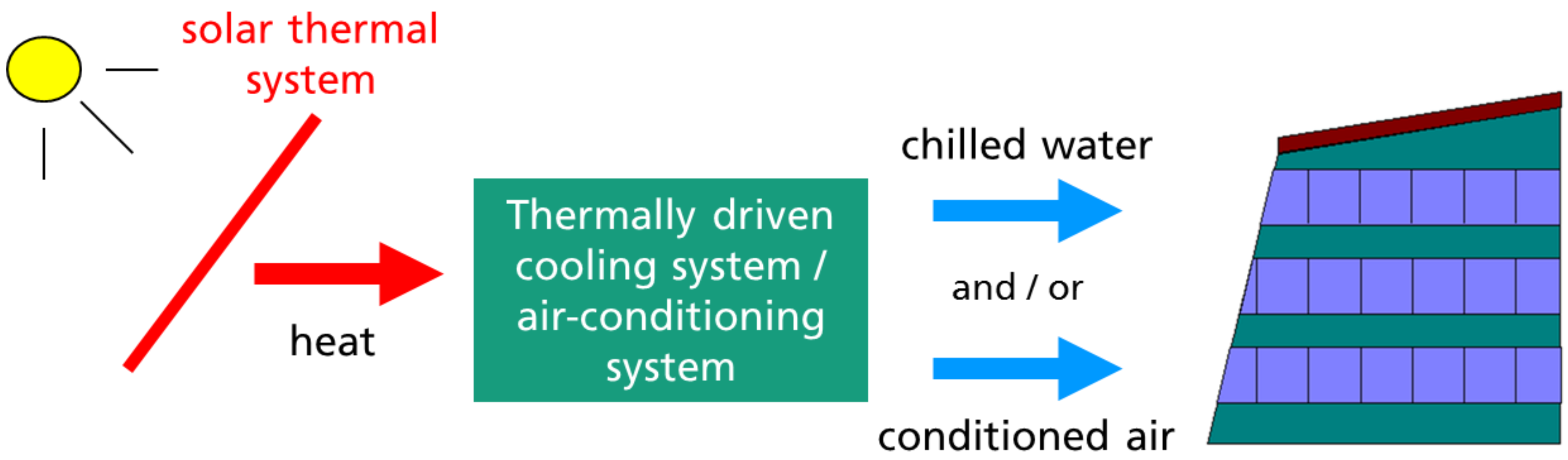
Solar thermal cooling – basic systems and technology status



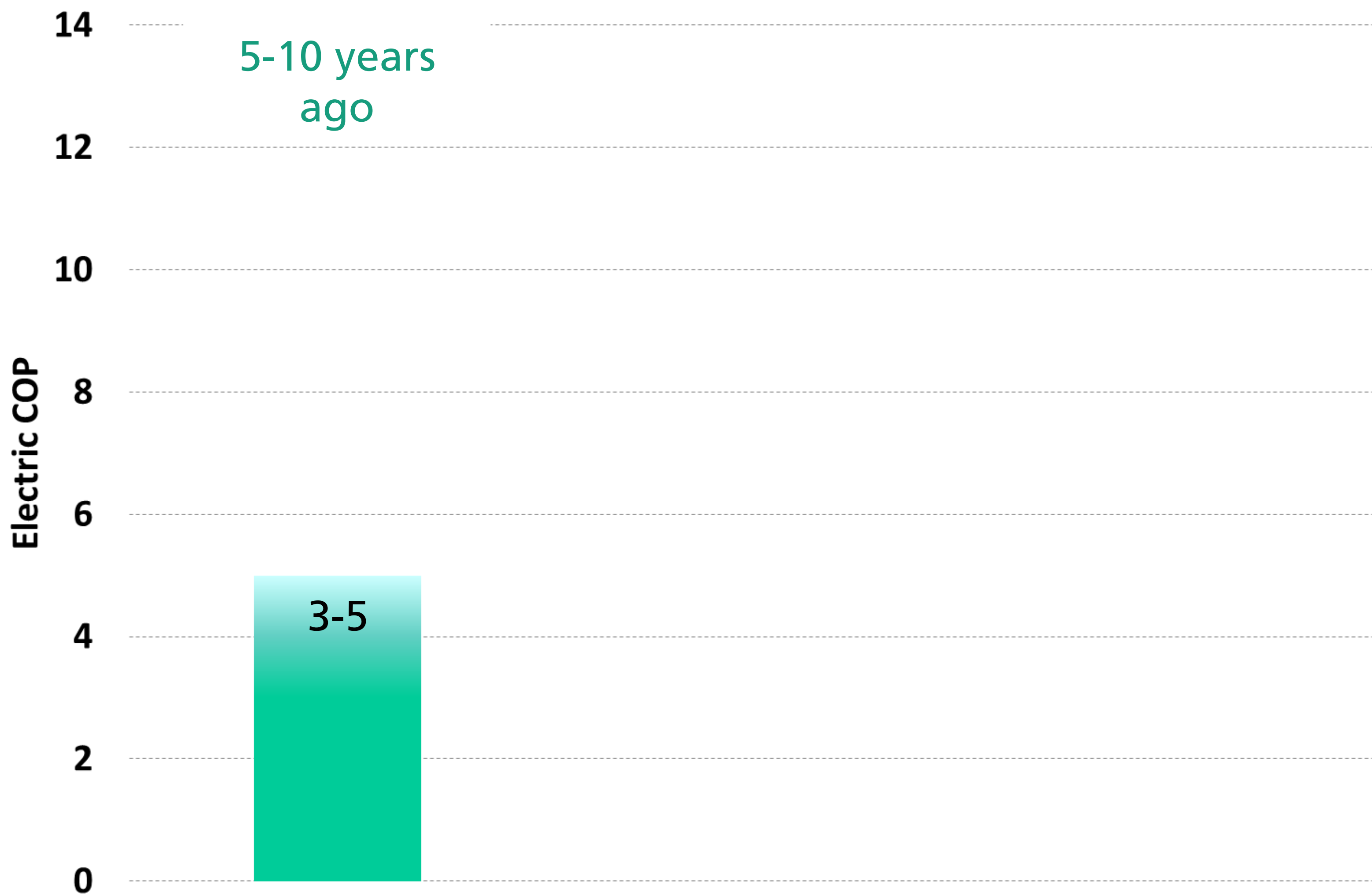
Basic systems categories

- Closed cycles (chillers): chilled water
- Open sorption cycles: direct treatment of fresh air (temperature, humidity)

Technical status

- Mature components available (both solar and refrigeration, A/C)
- Main progress made in last decade
  - Small scale heat driven chillers now available
  - Increasing number of high efficient double and – recently – triple effect absorption chillers
  - Development of systems using single-axis tracking solar collectors
- Main technical shortcomings are still on system level
  - Energy efficient heat rejection (cooling tower)
  - Energy management
  - Bottleneck: good trained technical staff almost not available

Energy performance – electric COP



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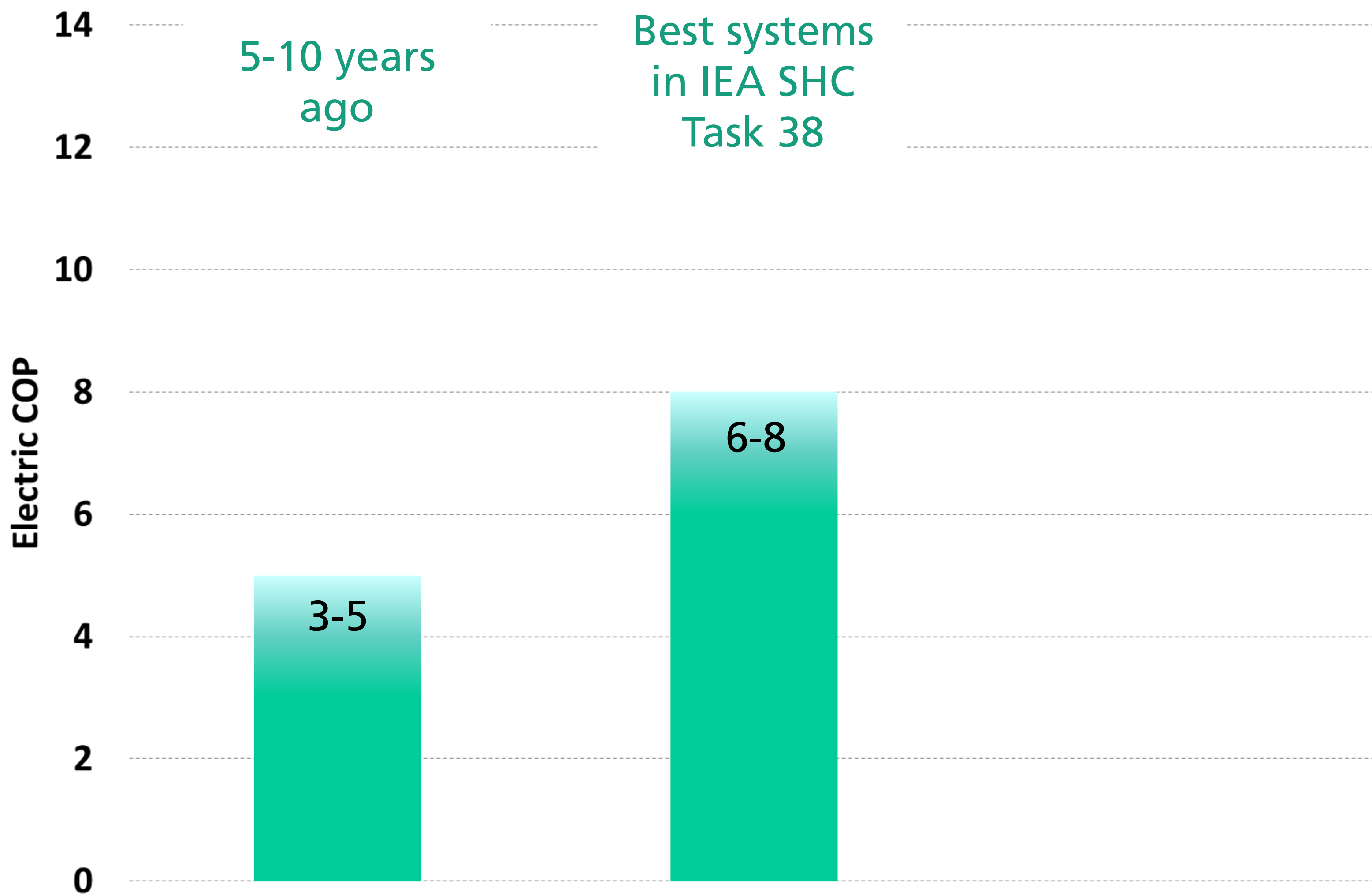
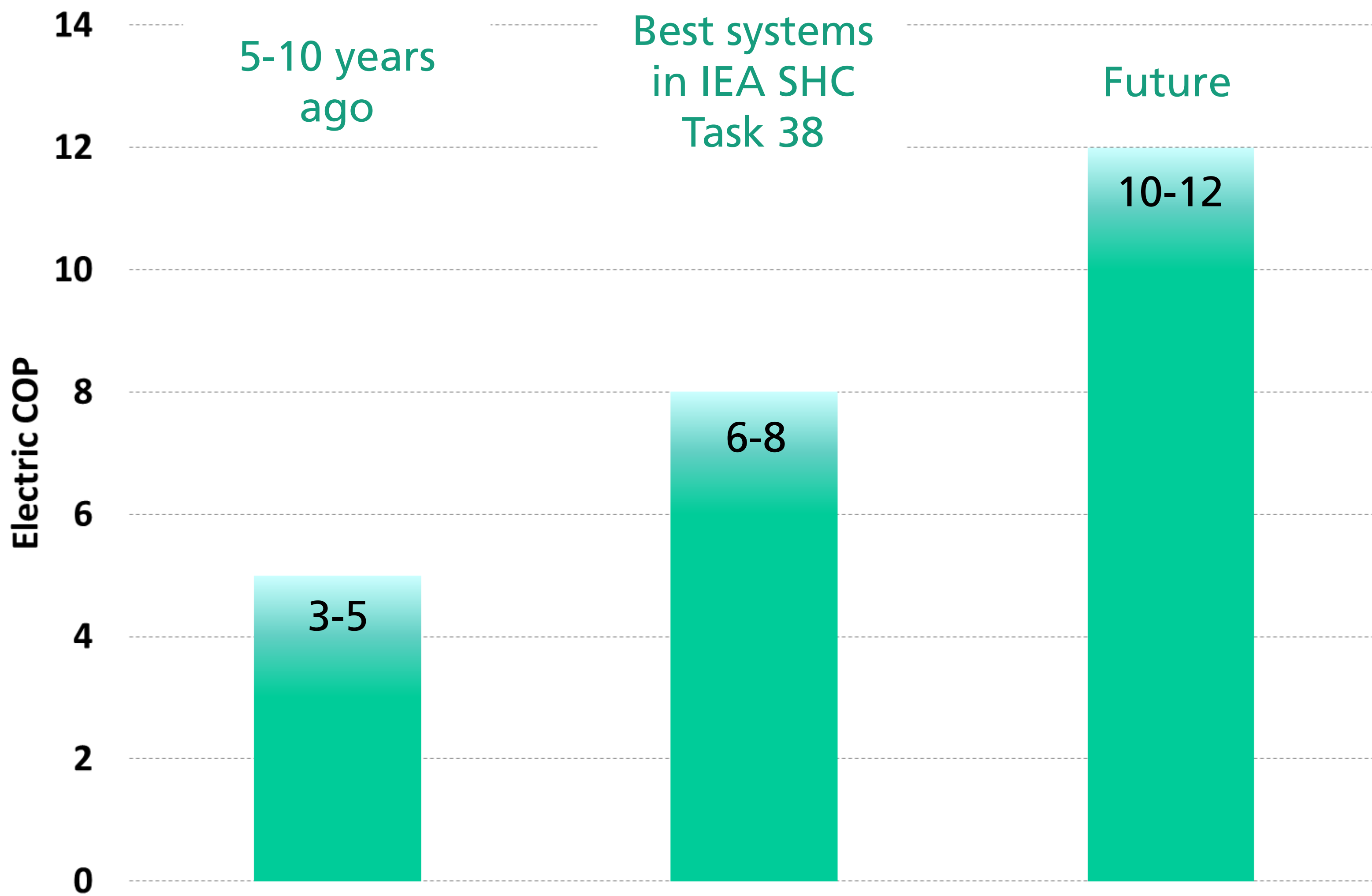
Energy performance – electric COP



Energy performance – electric COP



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Recently large and very large installations (examples)

CGD Bank Headquarter

Lisbon, Portugal

1560 m² collector area

400 kW absorption chiller

Source: SOLID, Graz/Austria

FESTO Factory

Berkheim, Germany

1218 m² collector area

1.05 MW (3 adsorption chillers)

Source: Paradigma, Festo

United World College (UWC) (in planning)

Singapore

3900 m² collector area

1.47 MW absorption chiller

Source: SOLID, Graz/Austria

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Case study

- Load: Hotel (total area 3050 m²; 4 zones: guest rooms, lobby+floors, restaurant, kitchen)
- Annual simulation based on hourly load and meteo data (Meteonorm) ➔ hourly load file for various locations
- Components (parameter variation)
  - Advanced flat plate collector (150 m^2 … 750 m^2)
  - Heat buffer storage (30 litre/m^2 … 80 litre/m^2)
  - Thermally driven chiller (average $COP_{thermal}$ 0.68) (0 kW … 60 kW)
  - Cooling tower with a nominal COP of 25 (➔ 25 kWh of rejected heat per 1 kWh of consumed electricity)
  - Backup vapour compression chiller with average EER of 3.0
  - Backup natural gas boiler with efficiency of 0.9

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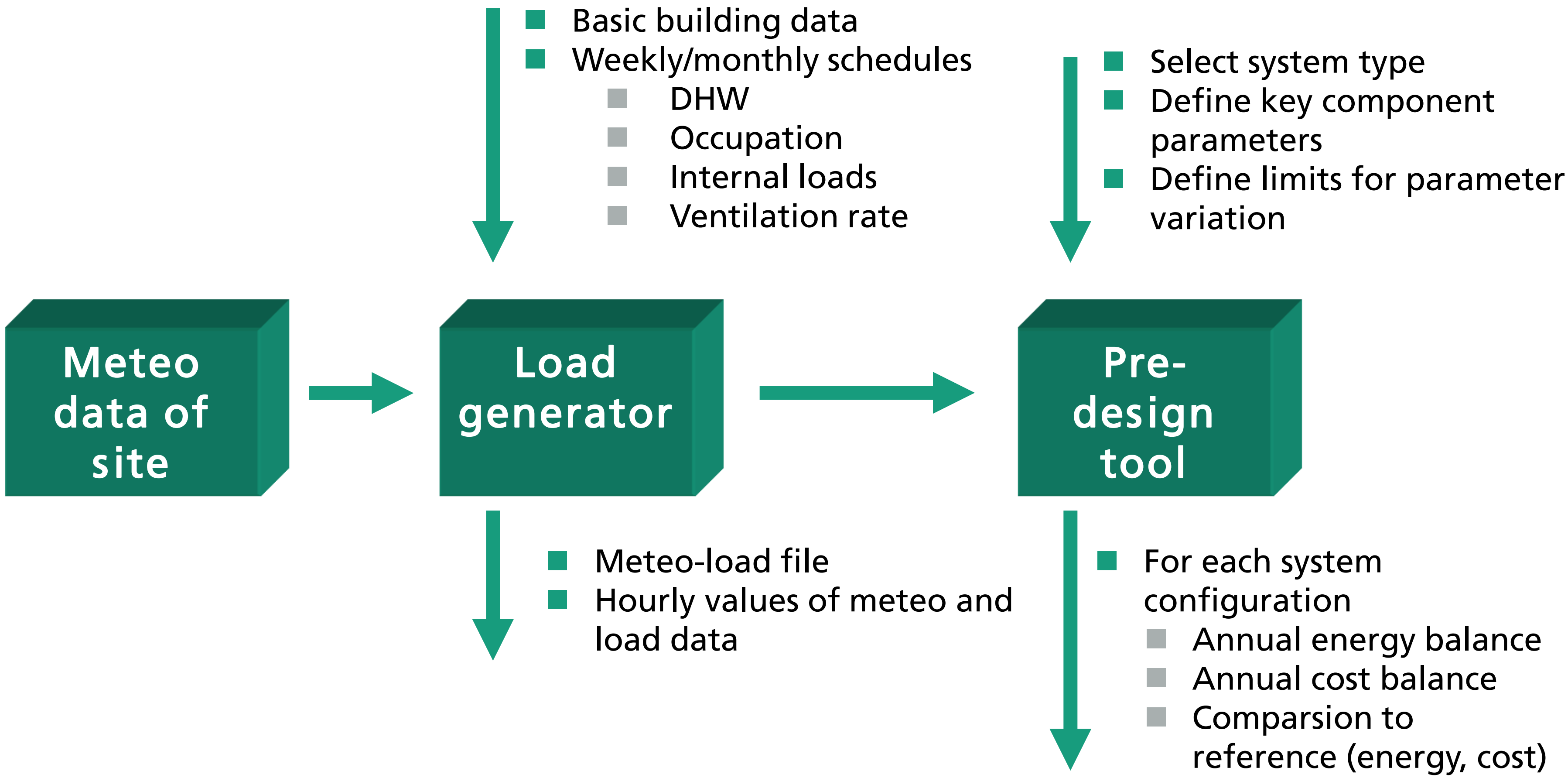
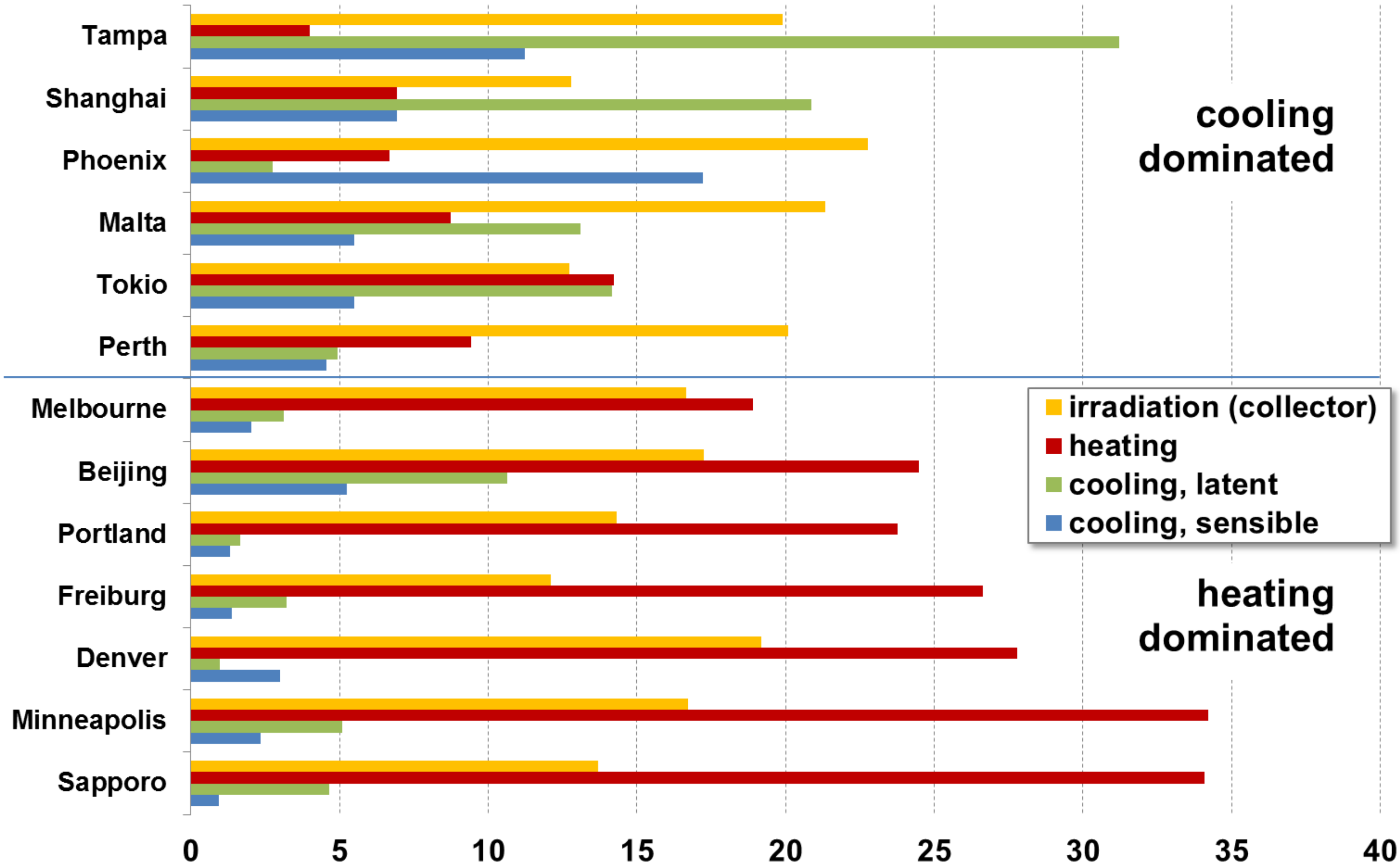
Simulation approach



Investigated locations



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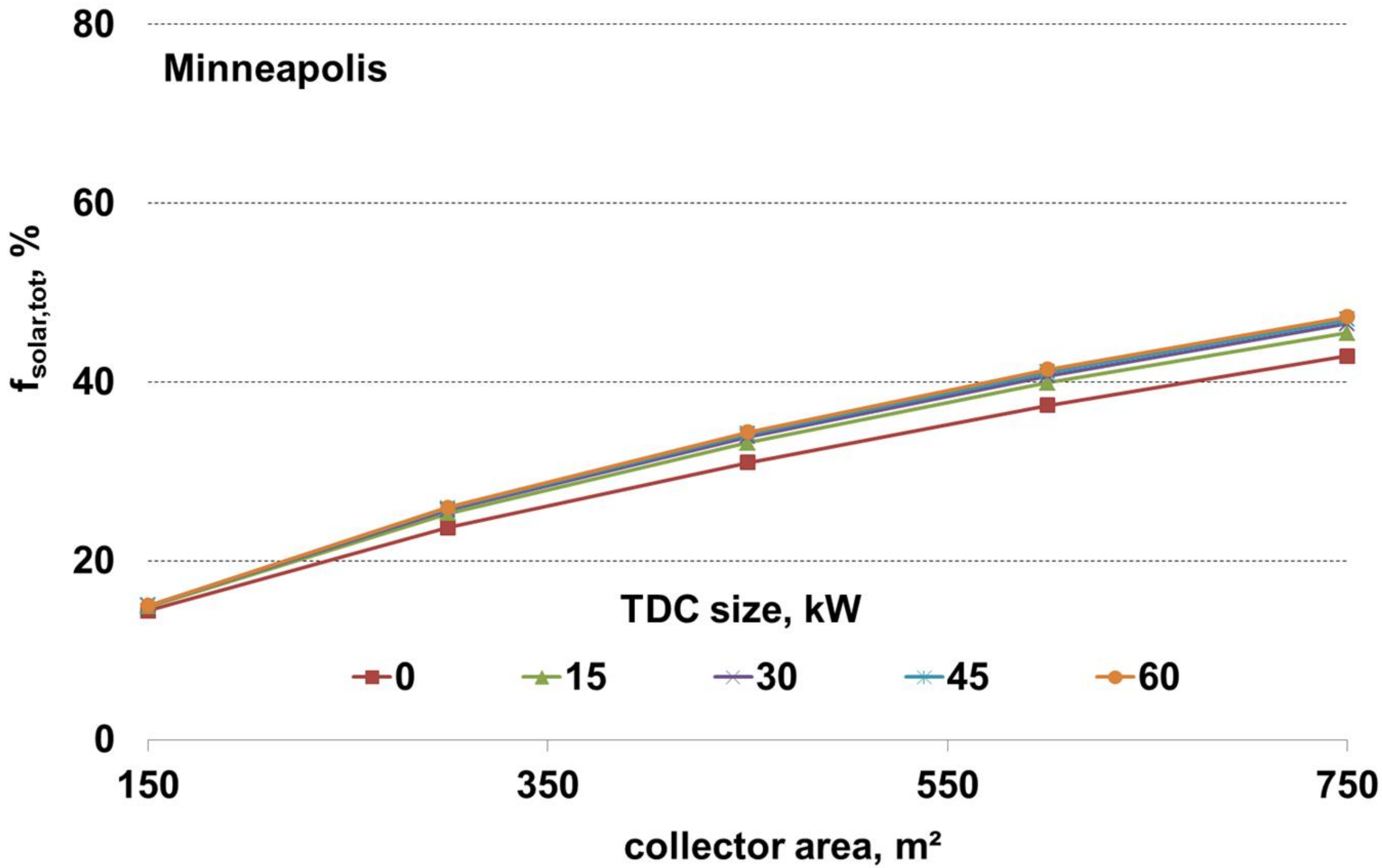
Solar fraction for final energy (heating, cooling , DHW)



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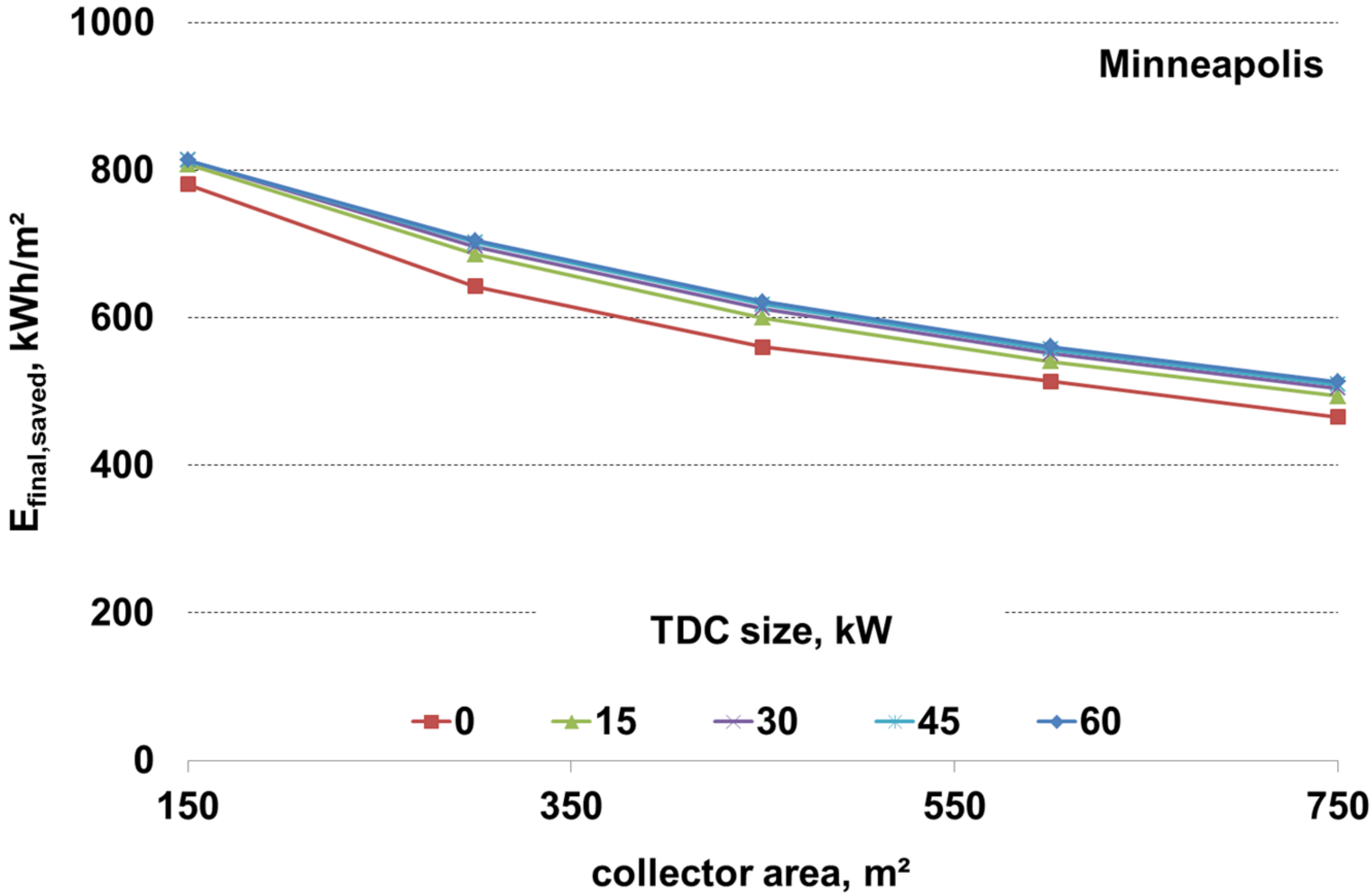
Final energy saving per collector area



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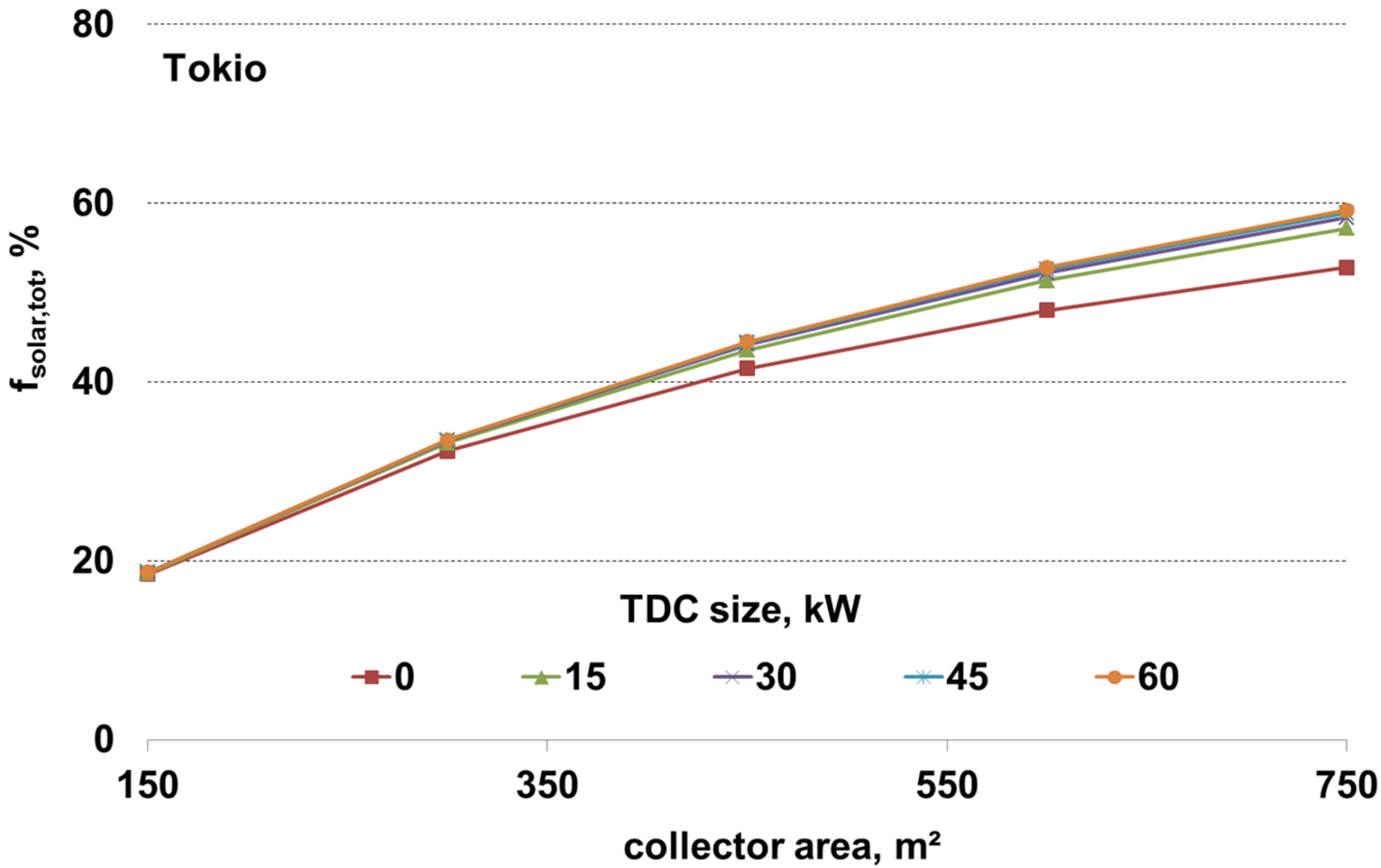

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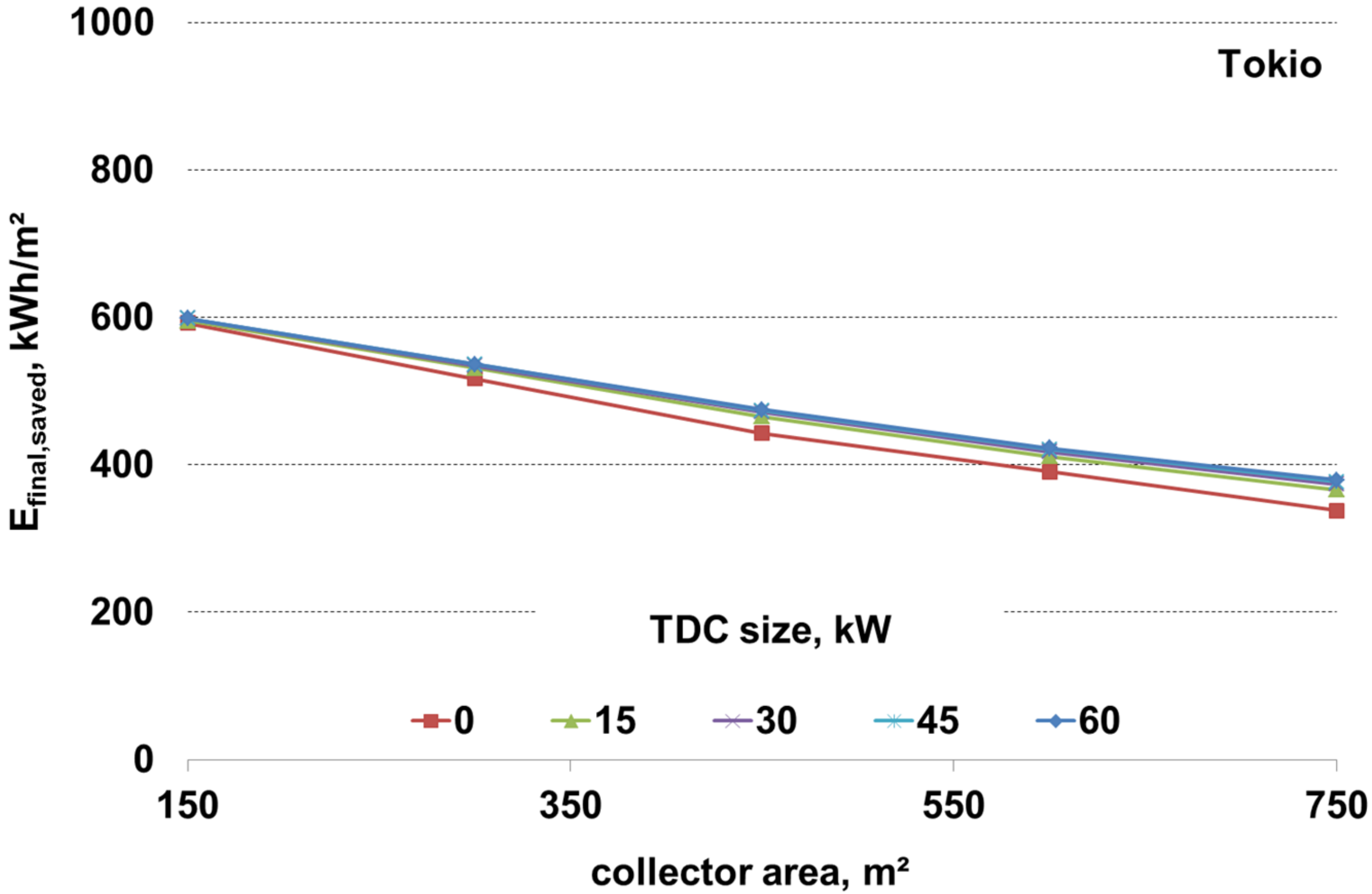

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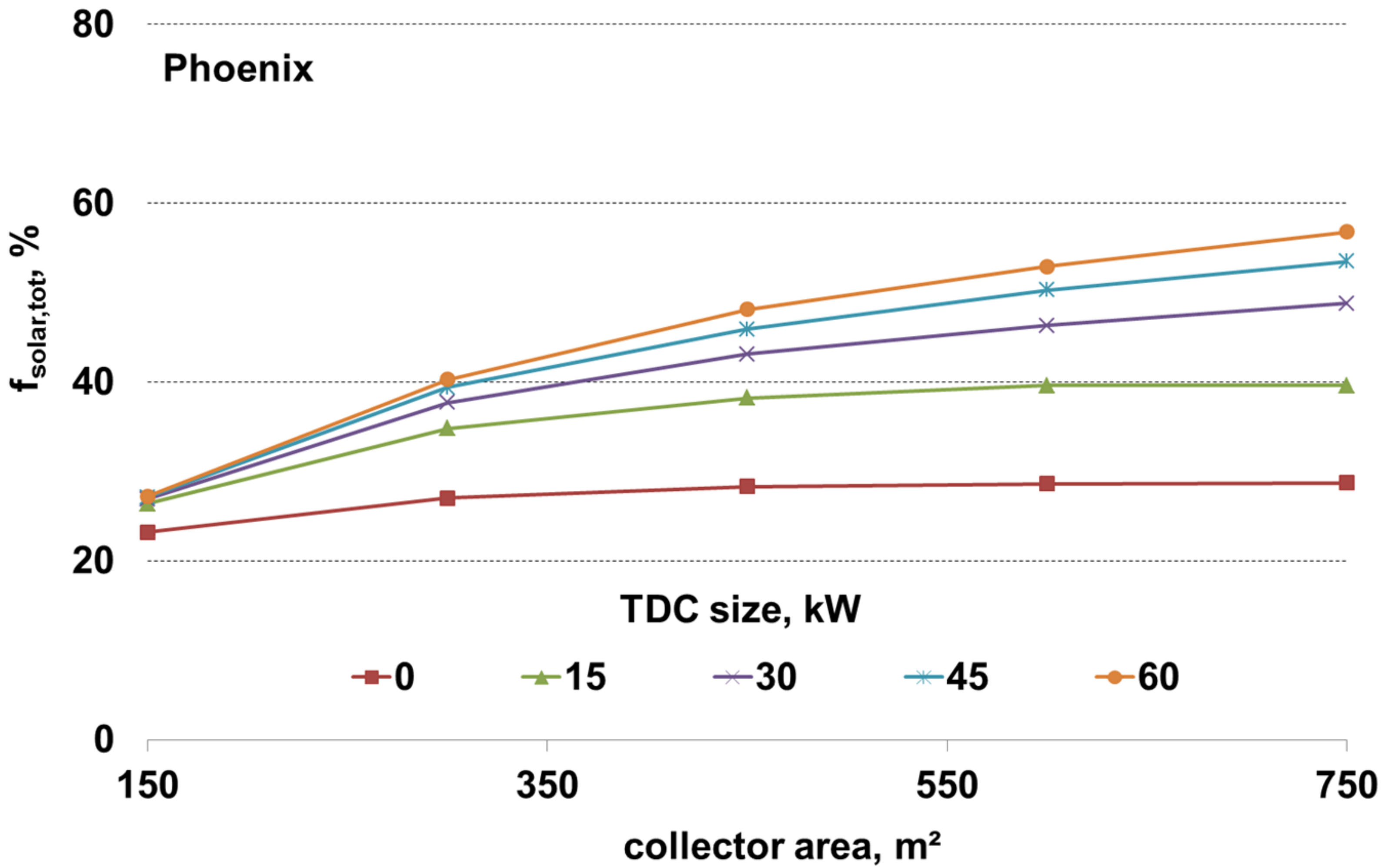

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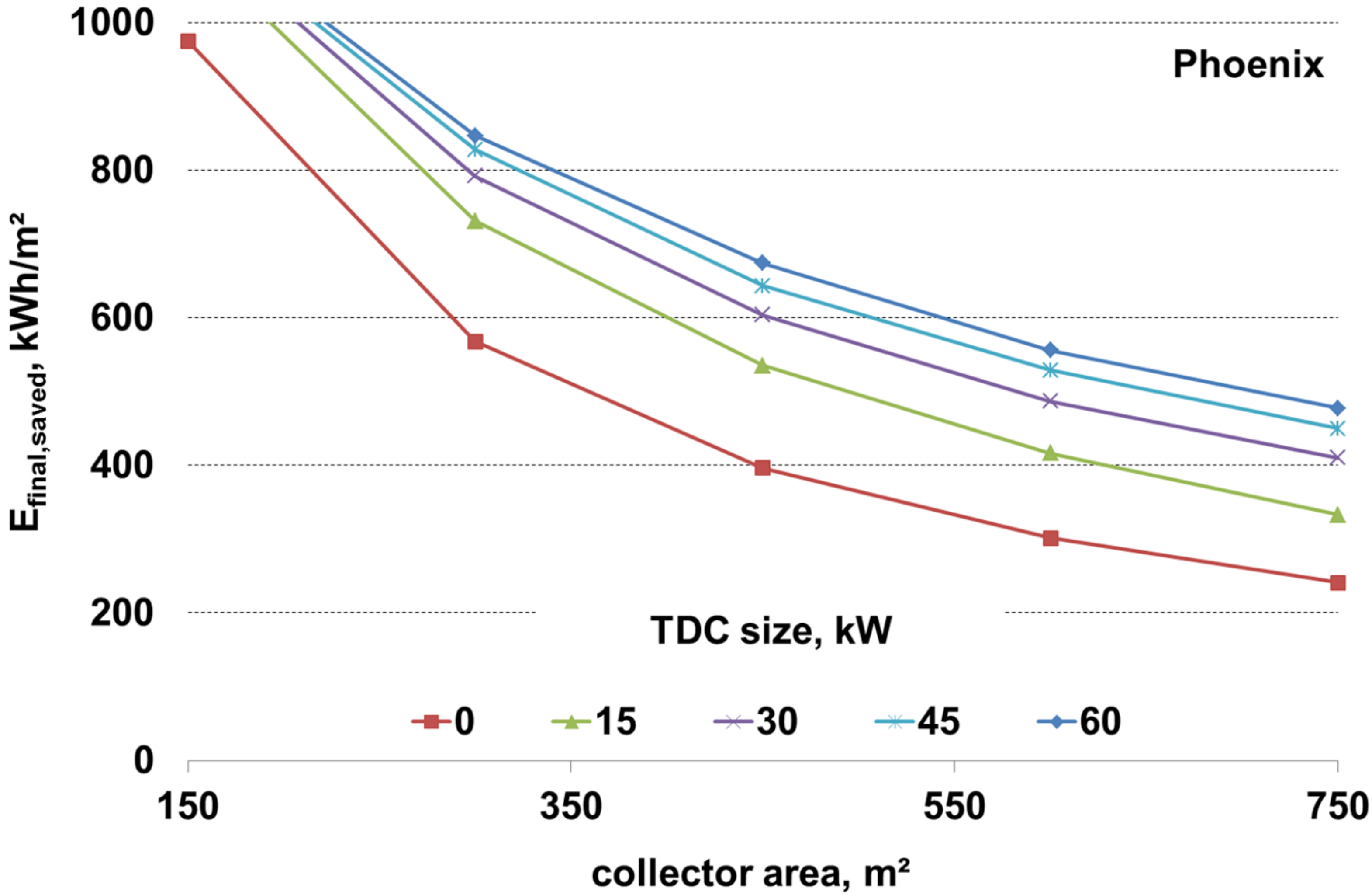

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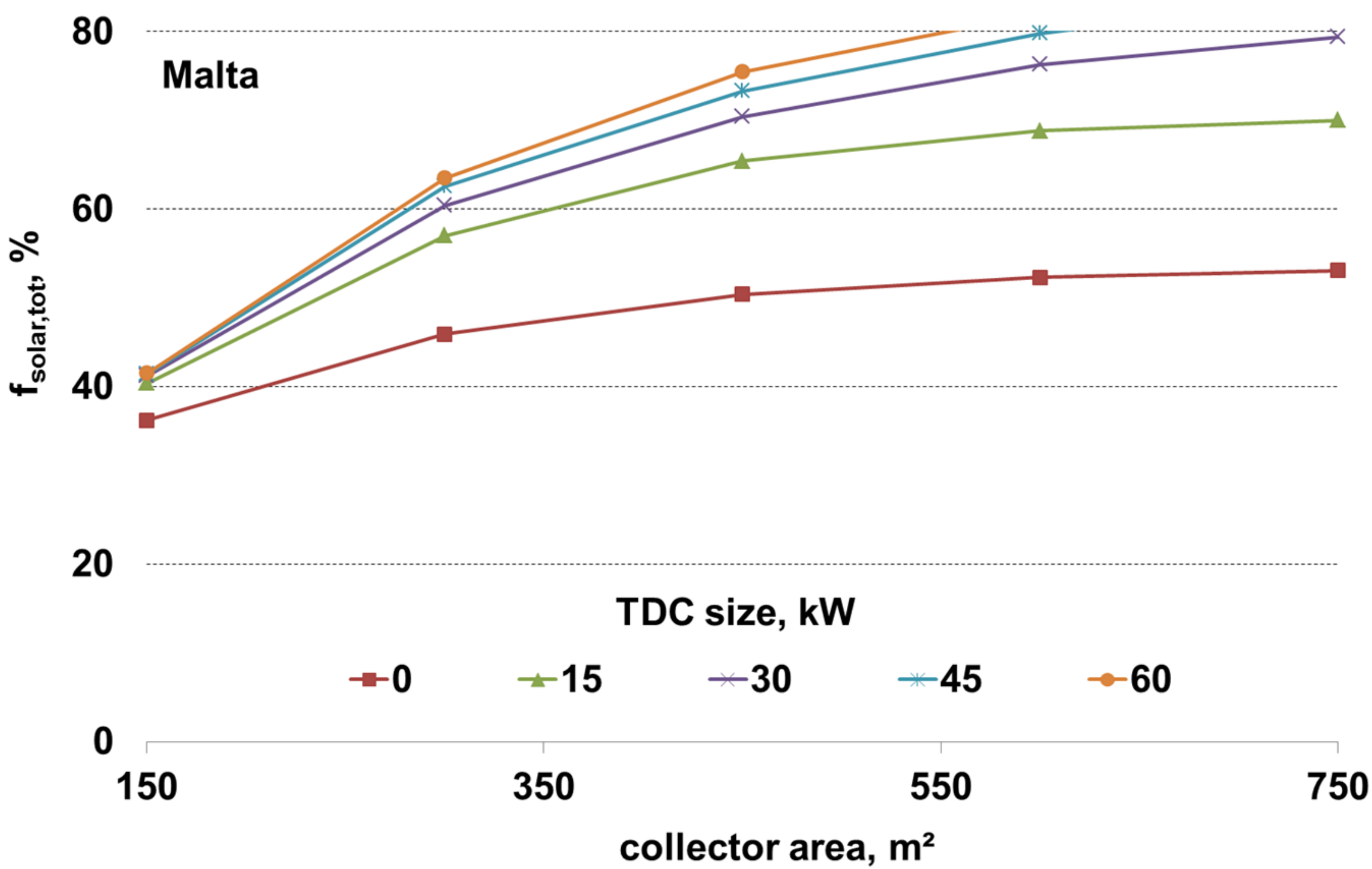

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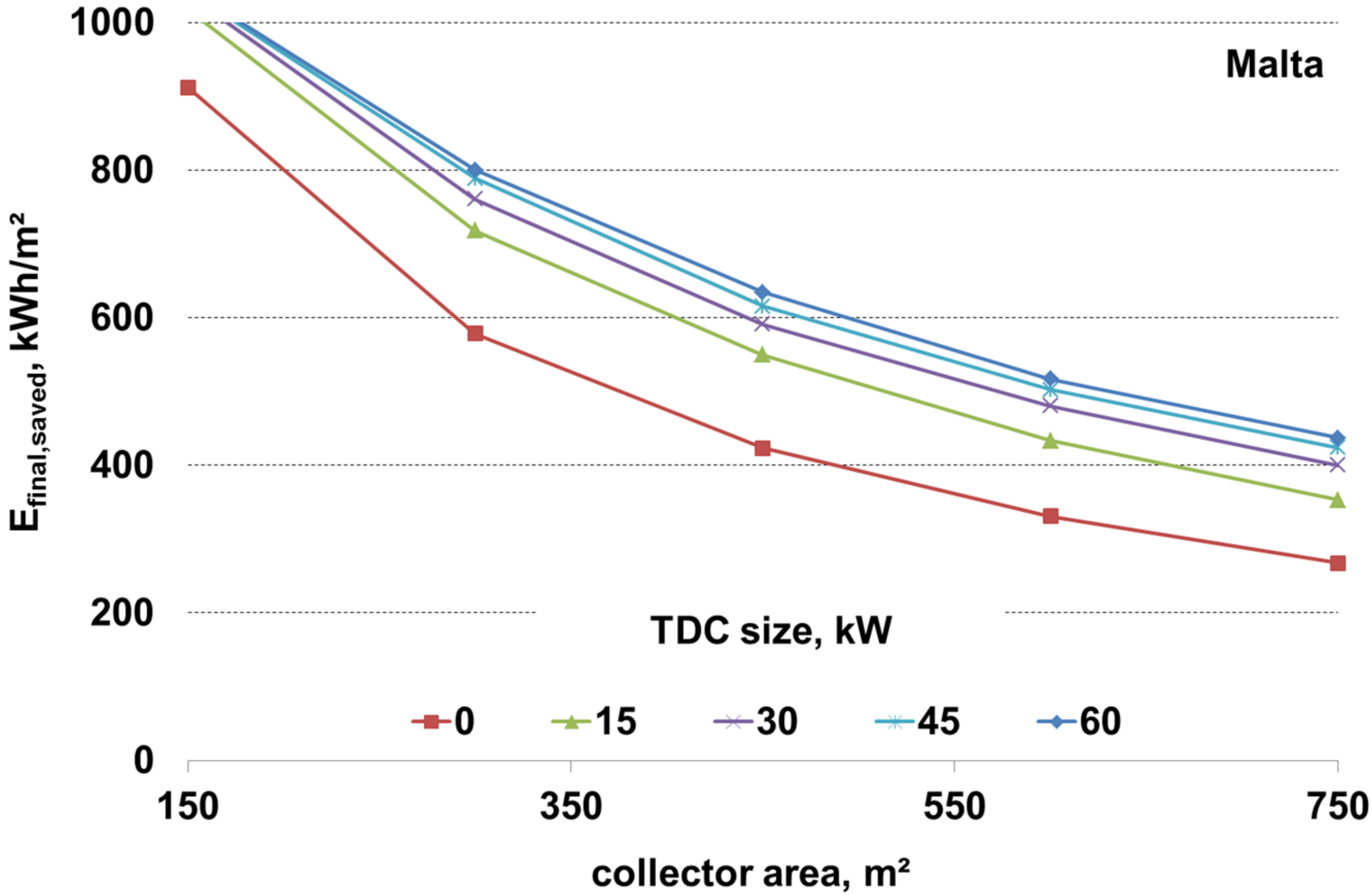

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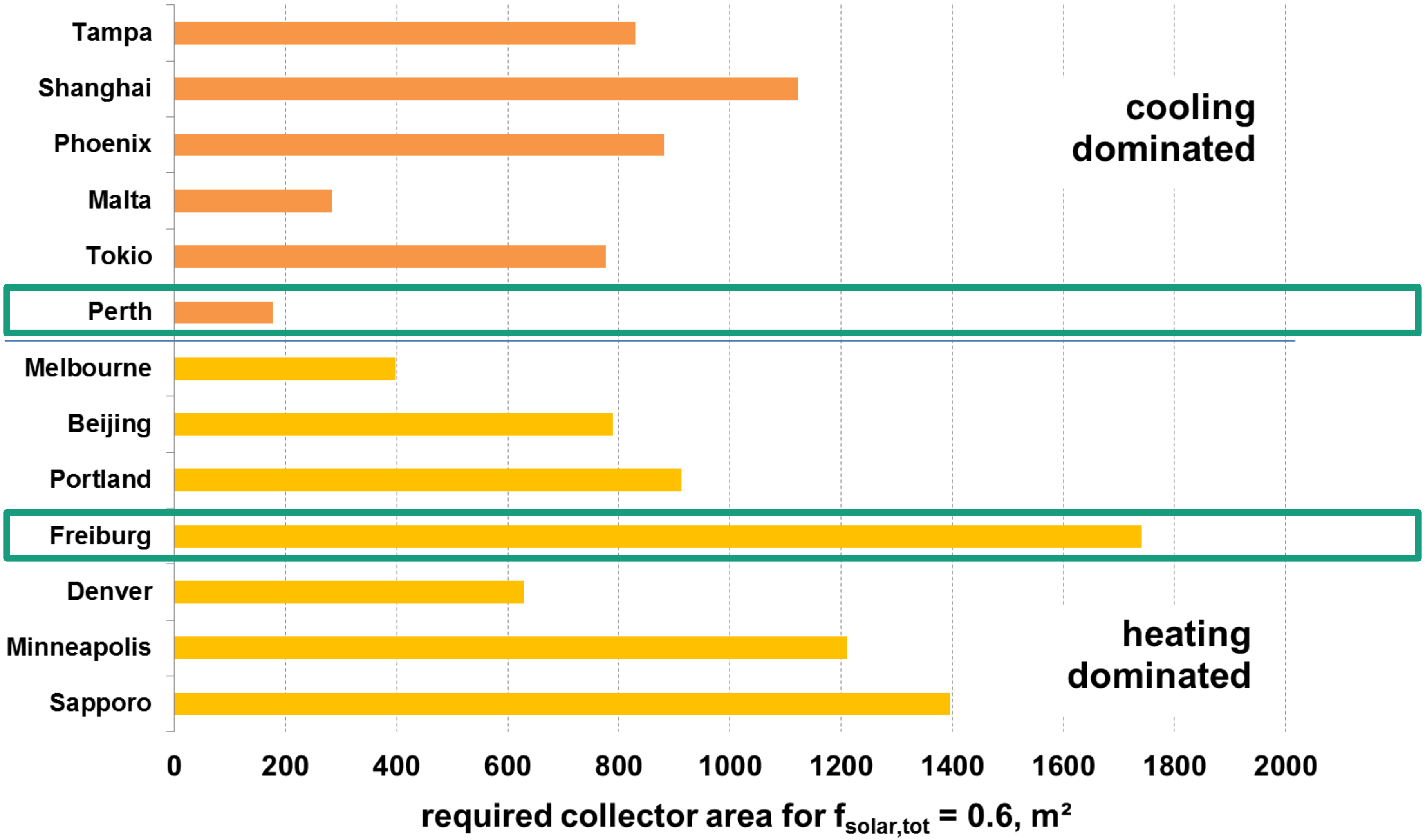
Needed collector area for a total solar fraction of 60 %



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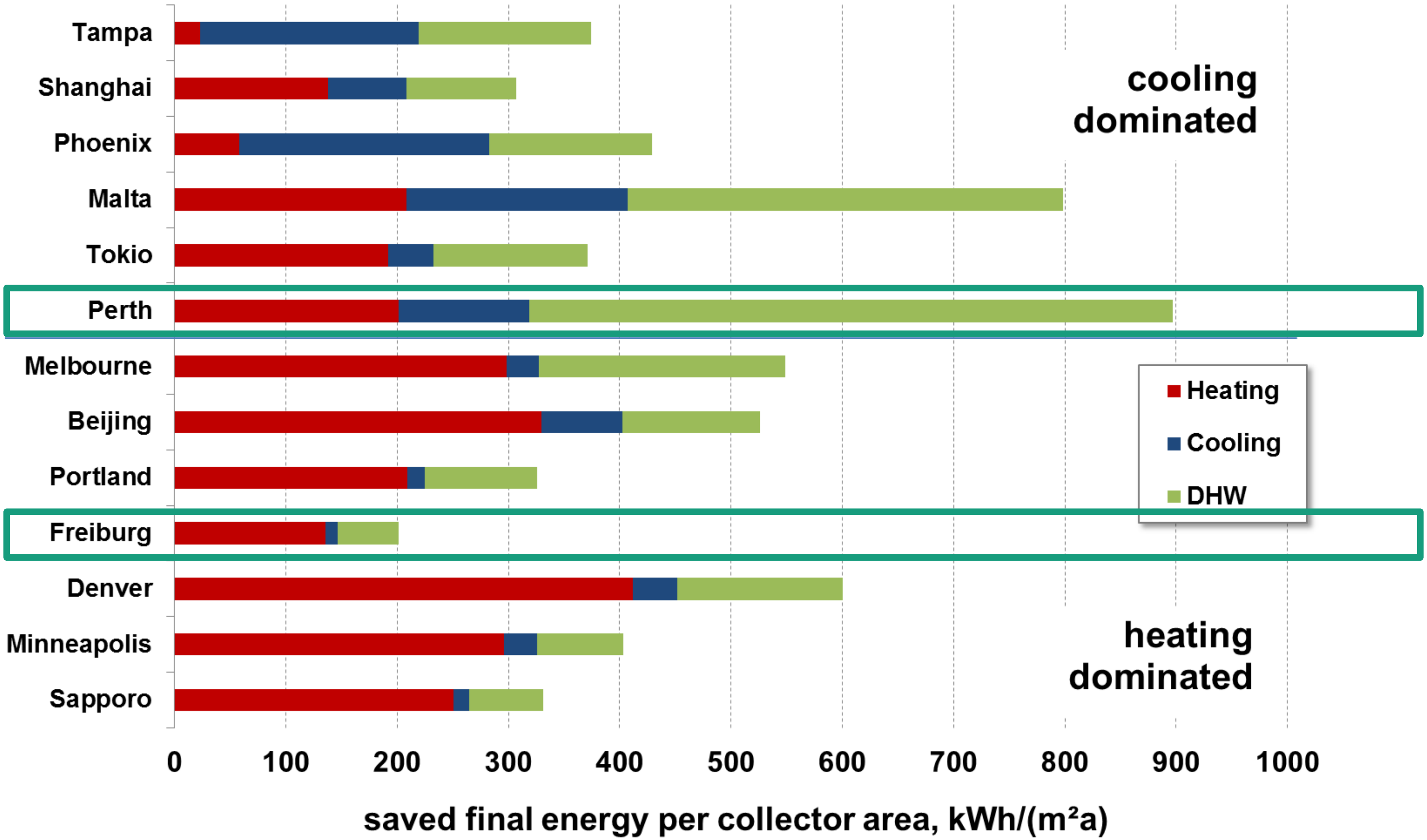
Final energy saving per collector area ($f_{solar,tot}$ = 60 %)

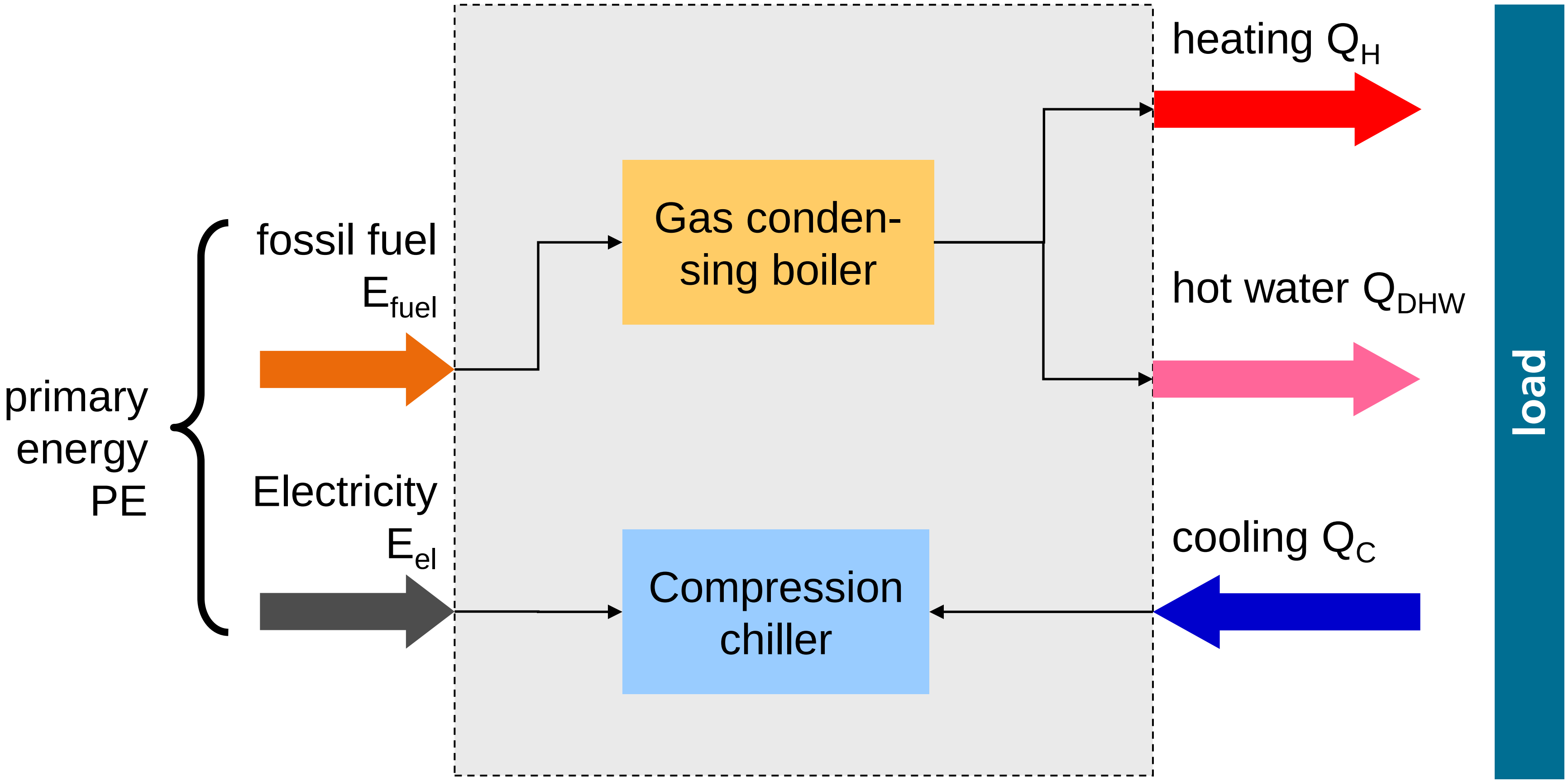


First results

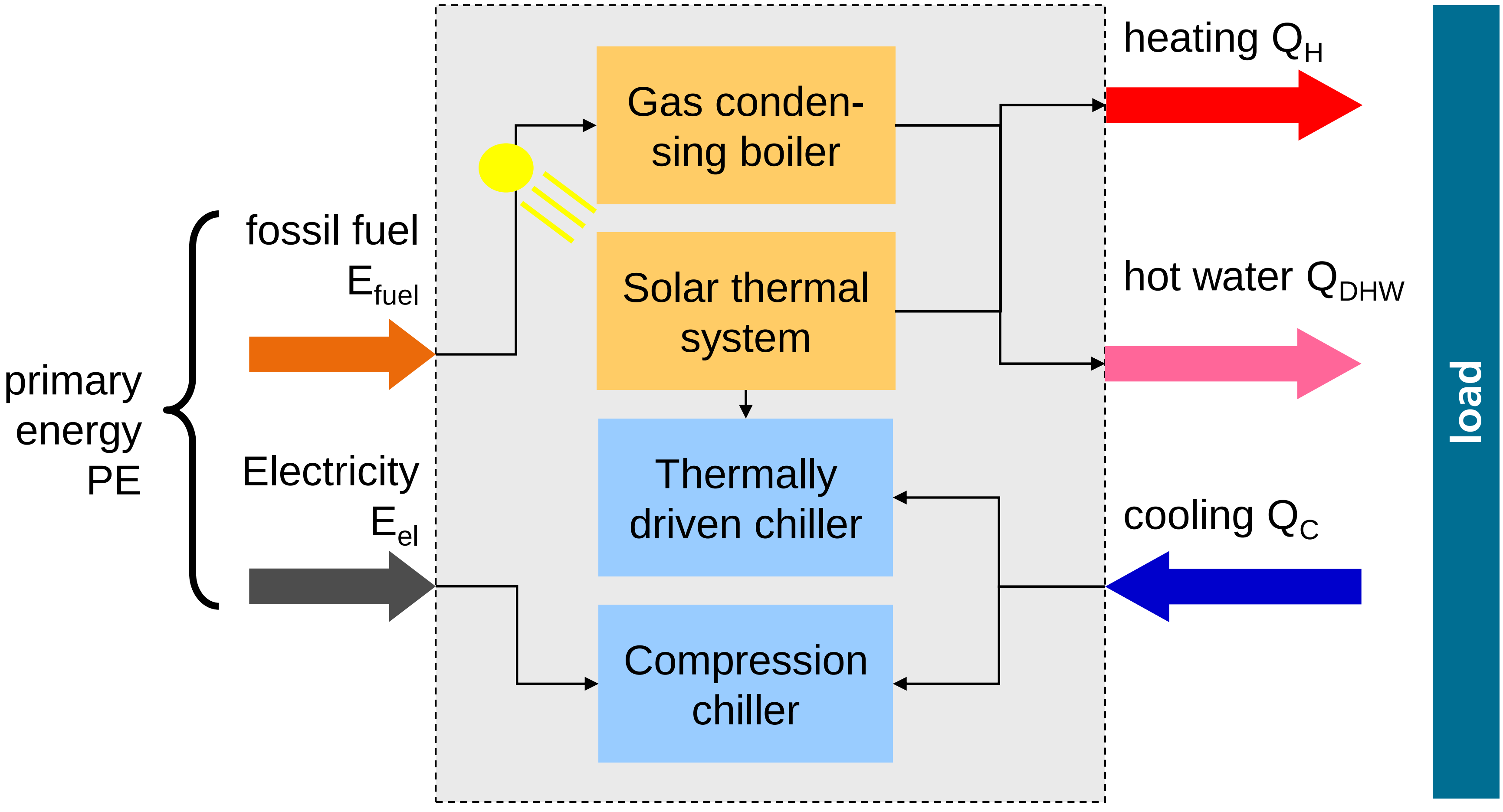
- Using a thermally driven chiller is mainly interesting in cooling dominated climates ➔ significant increase in solar fraction **and** good exploitation of the solar collector
- Small thermally driven chiller seems sensible ➔ cover part of the base load, conventional chiller for peak load (TDC capacity about 25-30 % of peak cooling load covers > 50 % of annual cooling)
- Solar fraction and energy saving per collector are competing design parameters ➔ compromise needed
- In particular for cooling electricity needs can not be neglected (heat rejection)

➔ Primary energy and cost balance leads to system optimization in comparsion to conventional reference

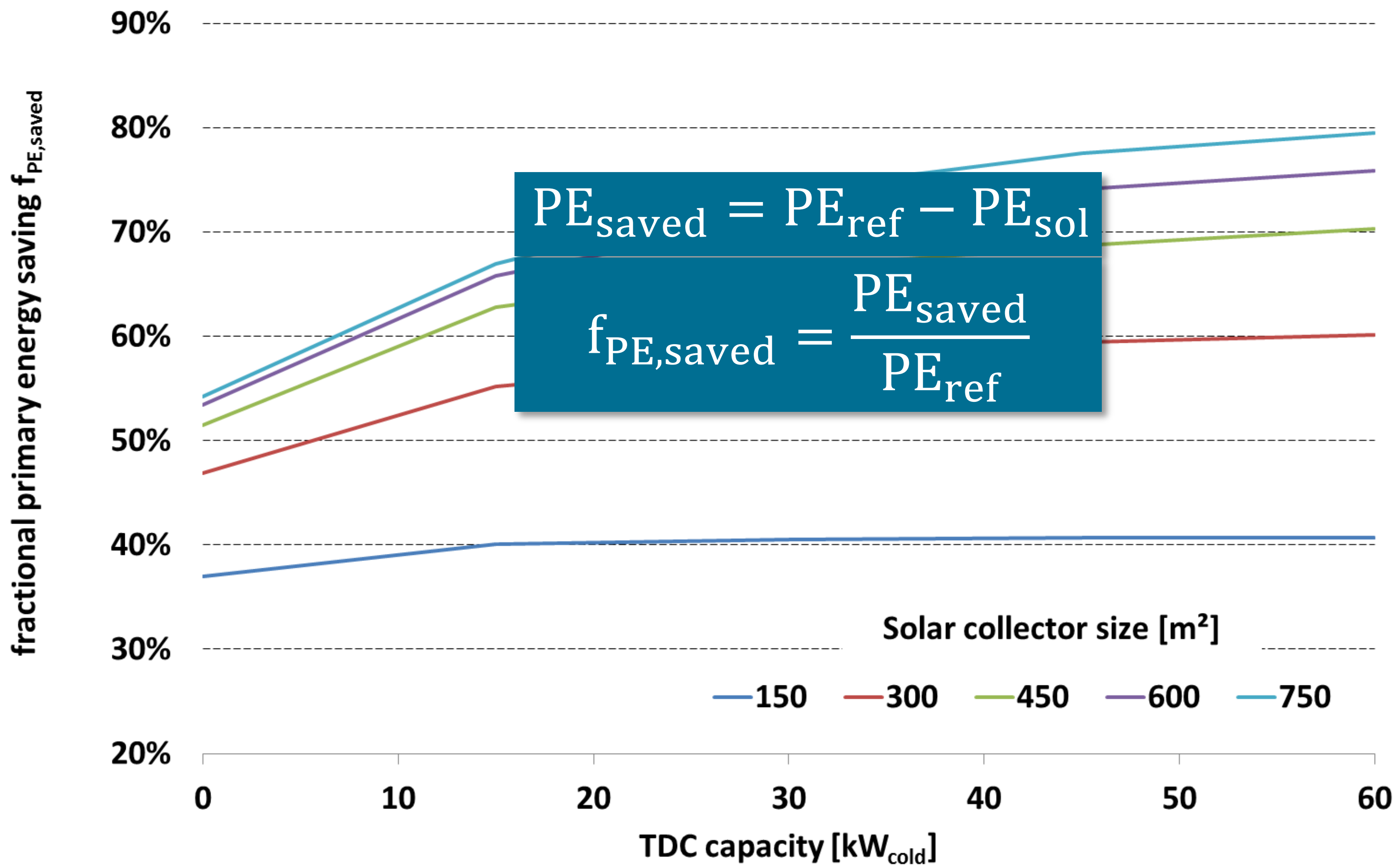
Primary energy balance – conventional reference



Primary energy balance – solar heating and cooling



Example Malta – fractional primary energy saving



$$PE_{saved} = PE_{ref} - PE_{sol}$$

$$f_{PE,saved} = \frac{PE_{saved}}{PE_{ref}}$$

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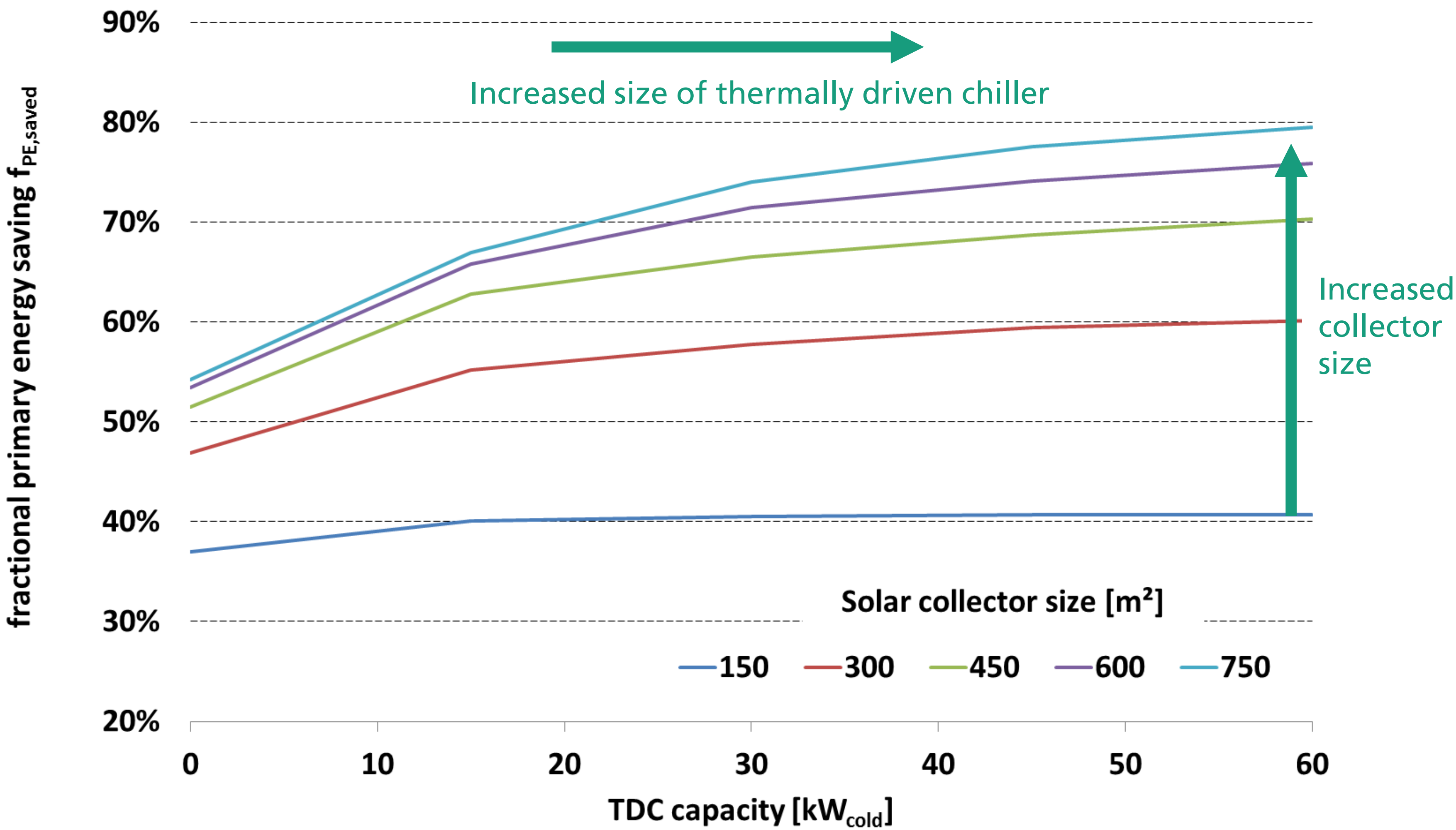
Example Malta – primary energy balance



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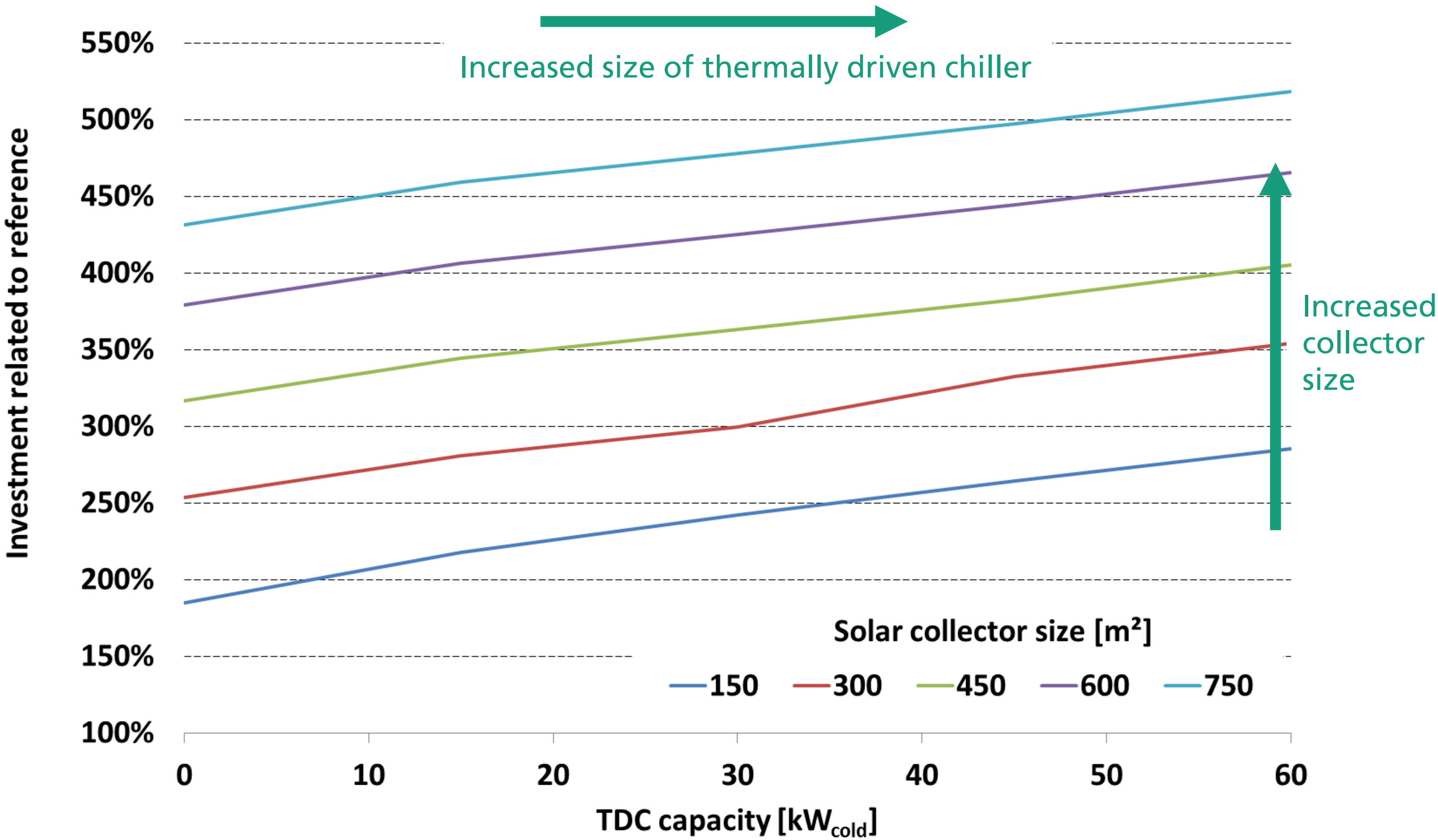
Example Malta – investment (first cost) (100 % = ref.)



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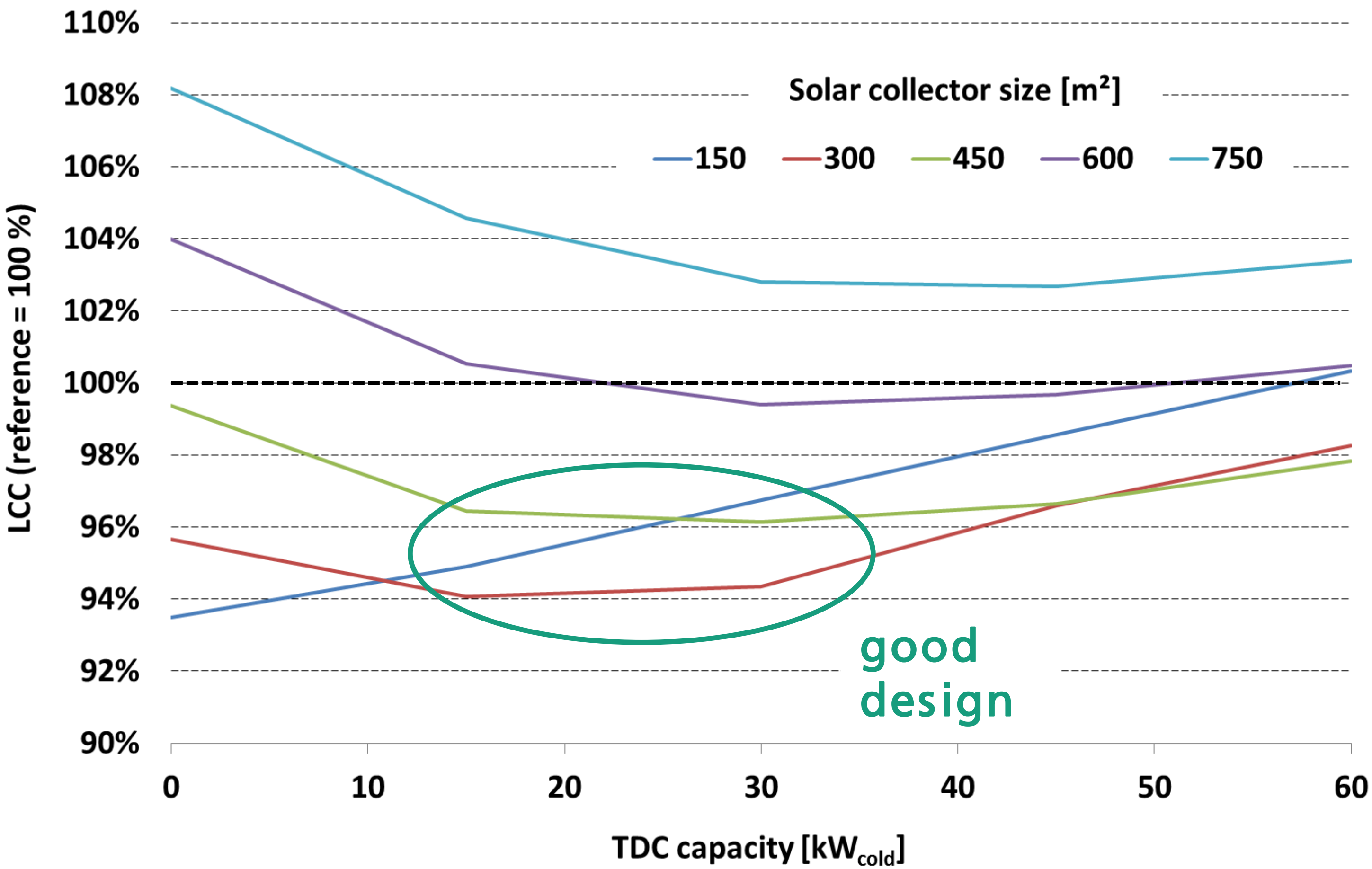
Example Malta: life cycle cost (LCC) (100 % = ref.)



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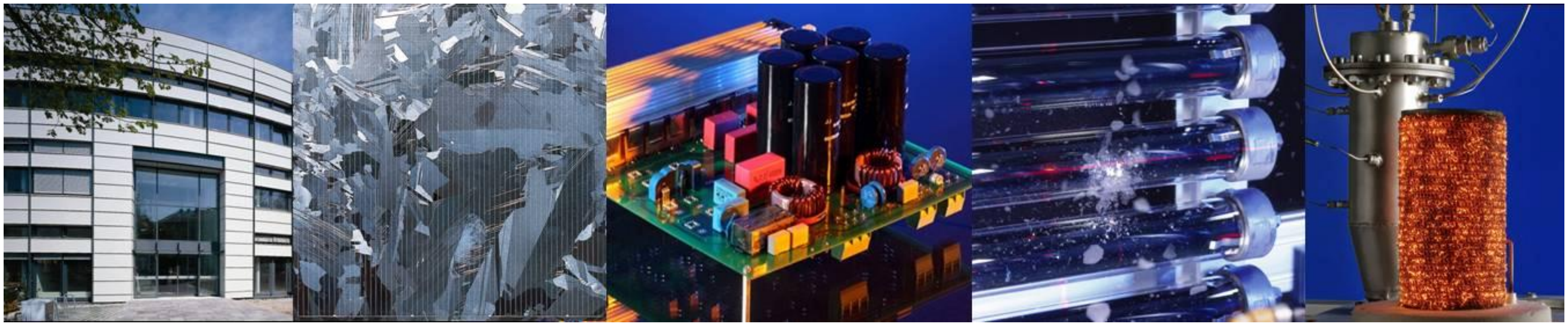
Summary, conclusions

- Solar heating **and** air-conditioning (and domestic hot water)
- Climates with high cooling loads
- Open cooling cycles for dehumidification of ventilation air ➔ in particular for sites with high latent loads
- Examples with high primary energy saving **and** lower life cycle cost compared to standard solutions possible
- Main challenge: high quality systems (➔ IEA SHC Task 48 „Quality Assurance and Support Measures for Solar Cooling “)
- Provide solutions, not technologies
- Large investment (like for most RE) ➔ supporting programmes have to address this
- Future: also PV solutions ➔ system approach needed

Thank you for your attention



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