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KPIs and parametric analysis

RE Heat

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Agenda

- **KPIs**

  - Solar thermal (video)

  - Heat pumps

- **Parametric analysis**

  - Example

KPIs

Characterization of Heat pump performance

- **Which indicator(s) you know?**

- **What are their main drawbacks/ limitations?**

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KPIs

Characterization of Heat pump performance

Coefficient of performance, COP

- Easy to calculate, f(Tc, Th)
- Obtainable for some data from data sheets and manufacturer data

→ Static! Only performance at those given conditions
(power, not energy!)

Heat pump efficiency ratio, η_{hp}

- Easy to infer based on manufacturers data
- Assumed to be constant (simplification) for a given heat pump

Heat pump databases:

- **https://opennetzero.org/dataset/heat-pump-database**
- **https://www.energynetworks.org/publications/low-carbon-technologies-heat-pump-database**

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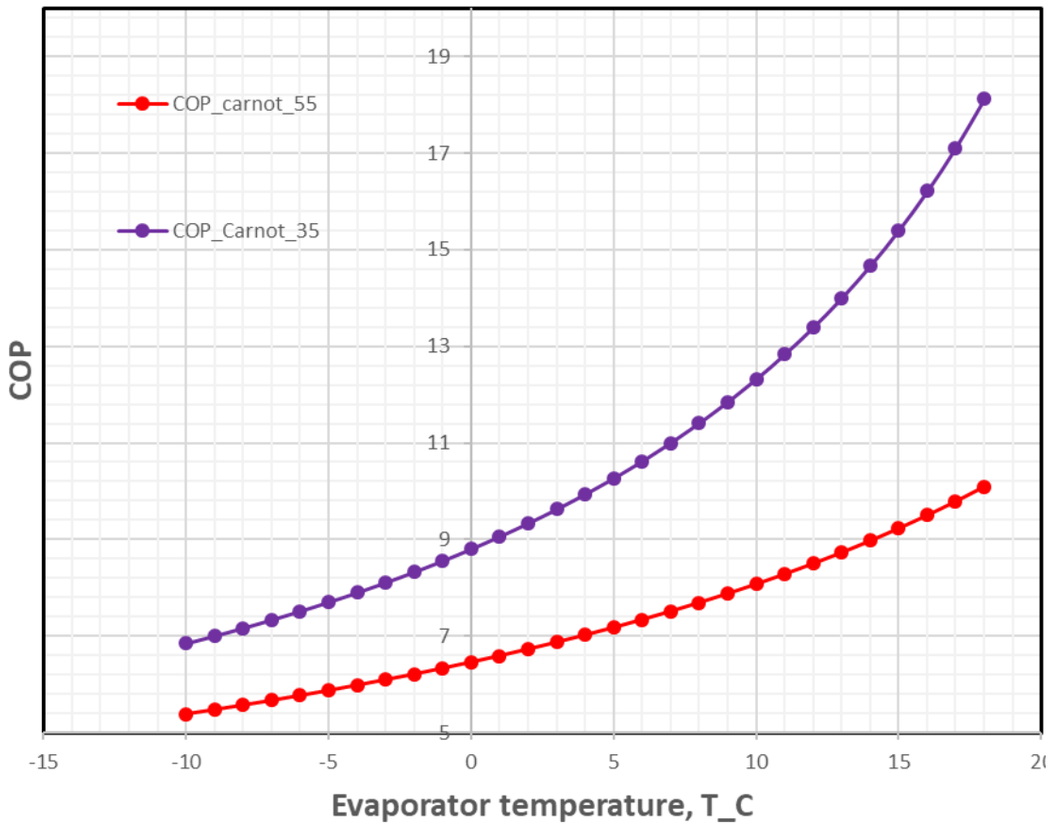
$$\mathrm{COP}_{Carnot} = \frac{T_h}{T_h - T_c} = \frac{T_4}{T_4 - T_2}$$

$$\eta_{hp} = \frac{COP}{COP_{Carnot}}$$

$$COP_i = \frac{Q_c}{P_{el}}$$

Seasonal COP
(energy, instead of power!)

$$COP_{seas} = \frac{\sum_{t=0}^{t} Q_c}{\sum_{t=0}^{t} P_{el}}$$



KPIs

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How to infer the time-based performance (other than with dynamic simulations)?

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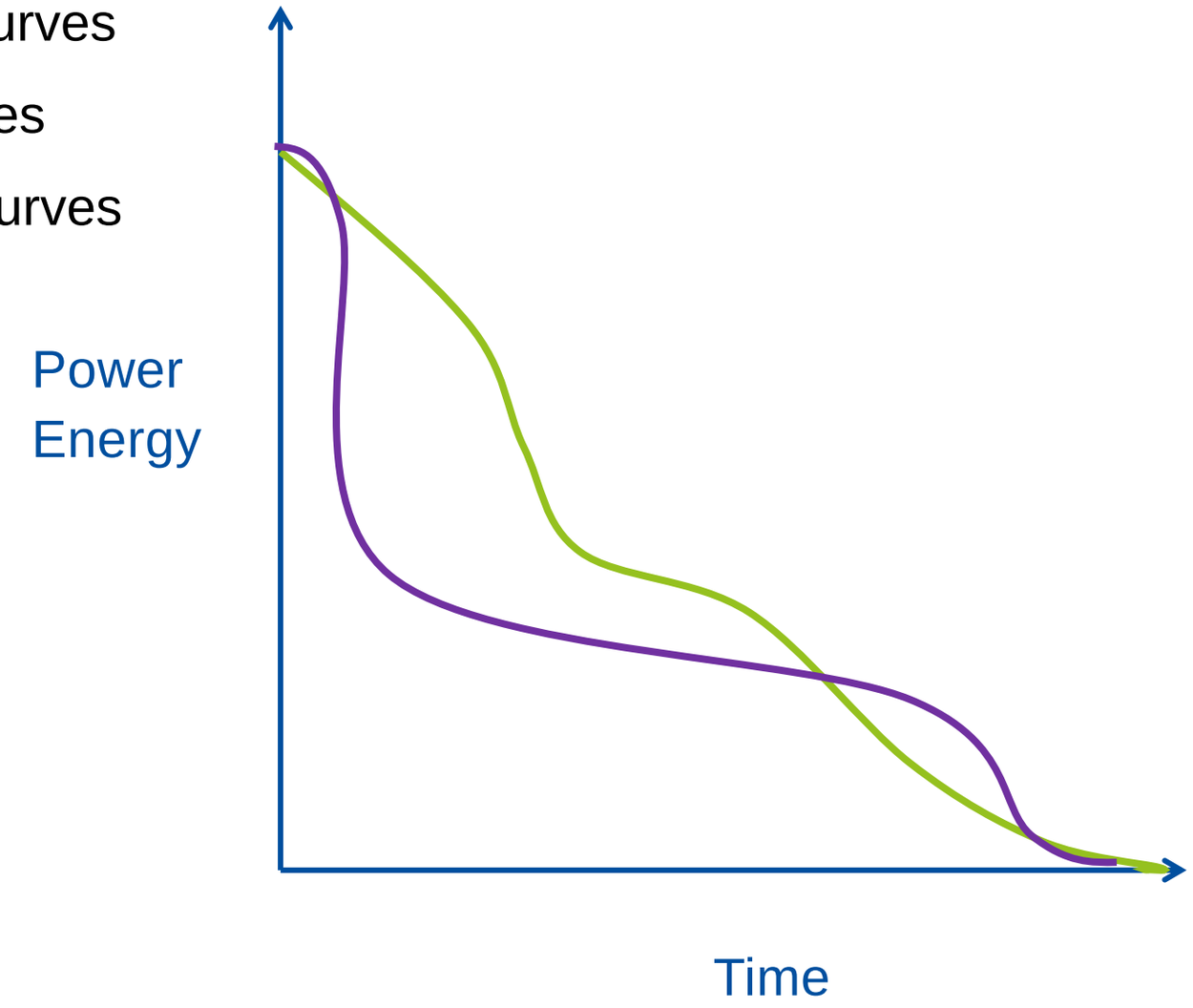
KPIs

Characterization of Heat pump performance

Duration curves

- Load duration curves
- Temperature duration curves
- Resource duration curves
- Performance duration curves



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Agenda

- **KPIs**

  - Solar thermal (video)

  - Heat pumps

- **Parametric analysis**

  - Example

  - Proposal

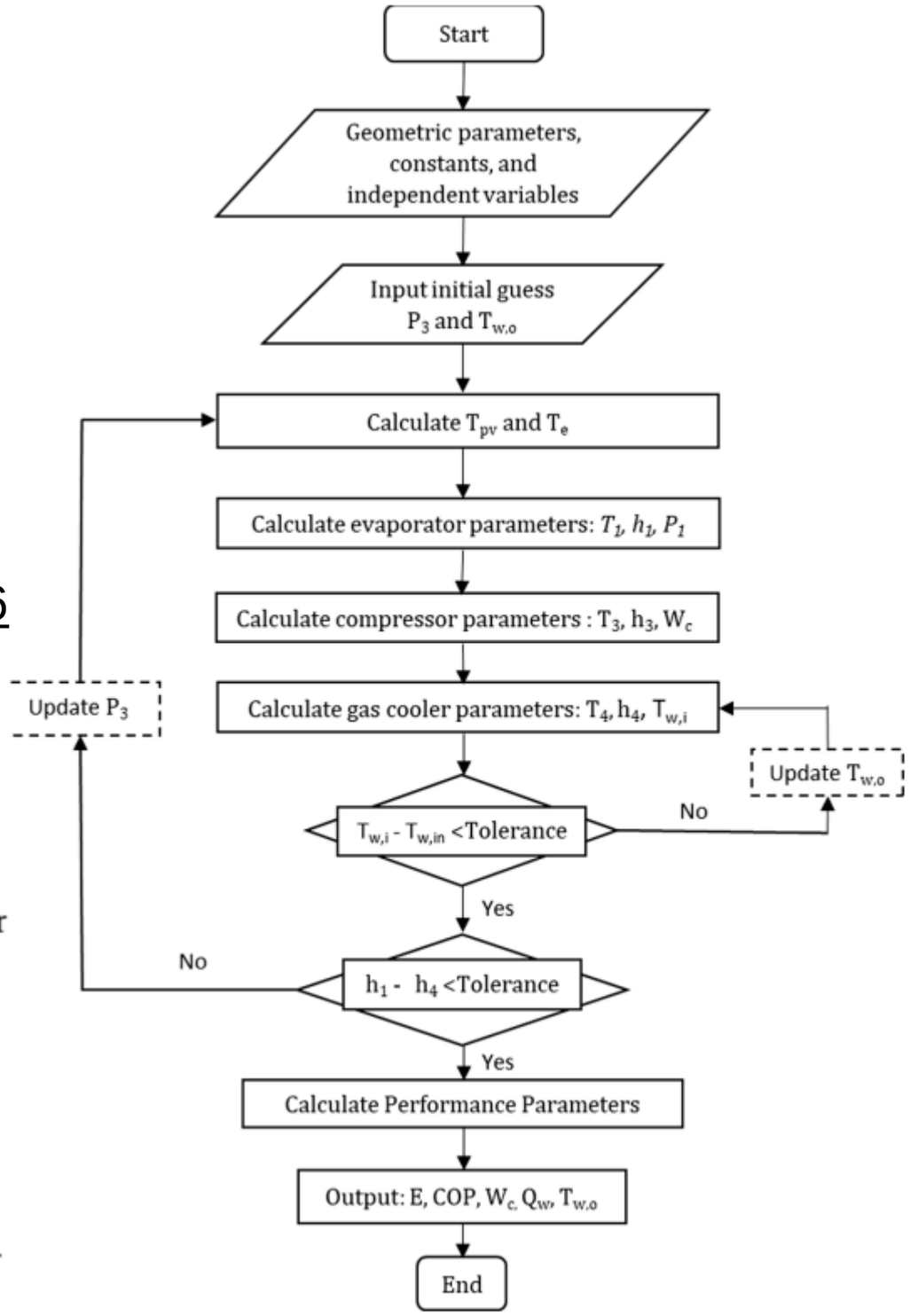
Parametric analysis

Definition

Sort of simplified sensitivity analysis

- Check the trend on the performance of a system

Source:
https://doi.org/10.1016/j.solener.2021.02.006



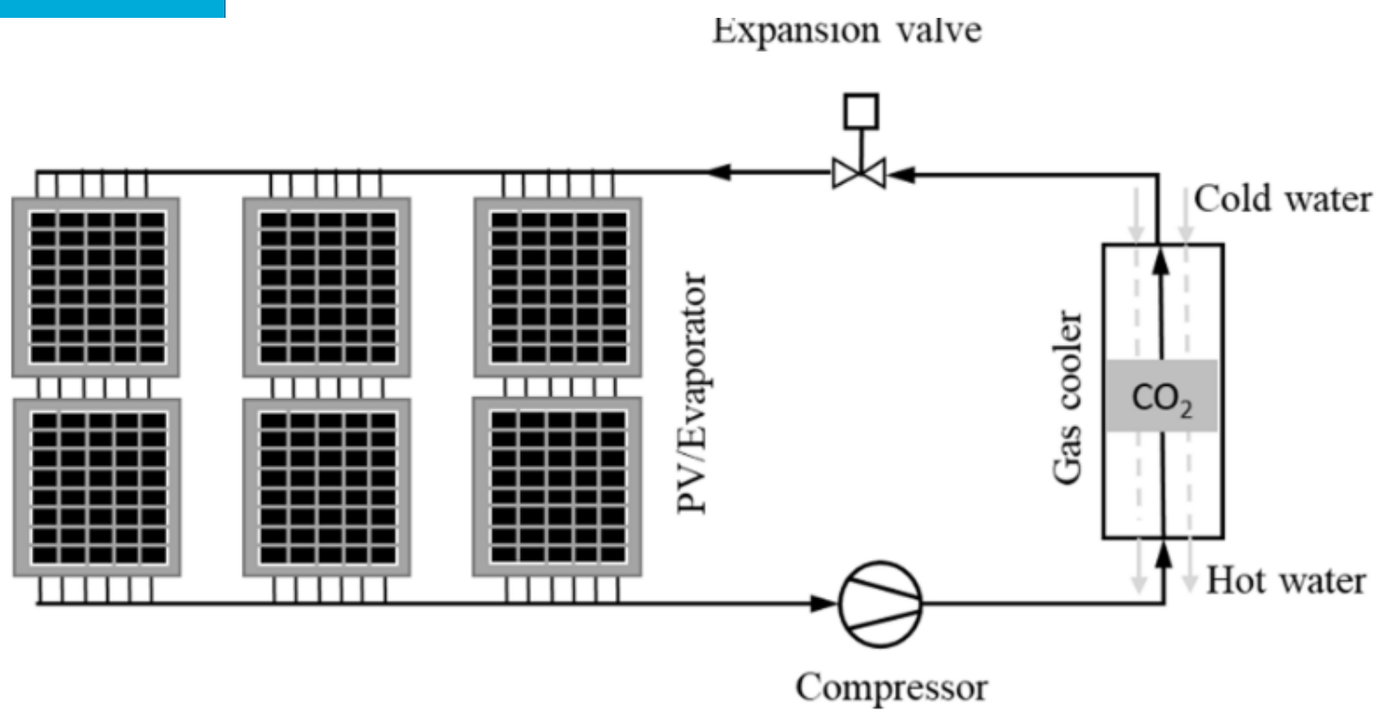


Fig. 2. Schematic diagram of the heat pump with PV/evaporator arrangement.

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Parametric analysis

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Sort of simplified sensitivity analysis

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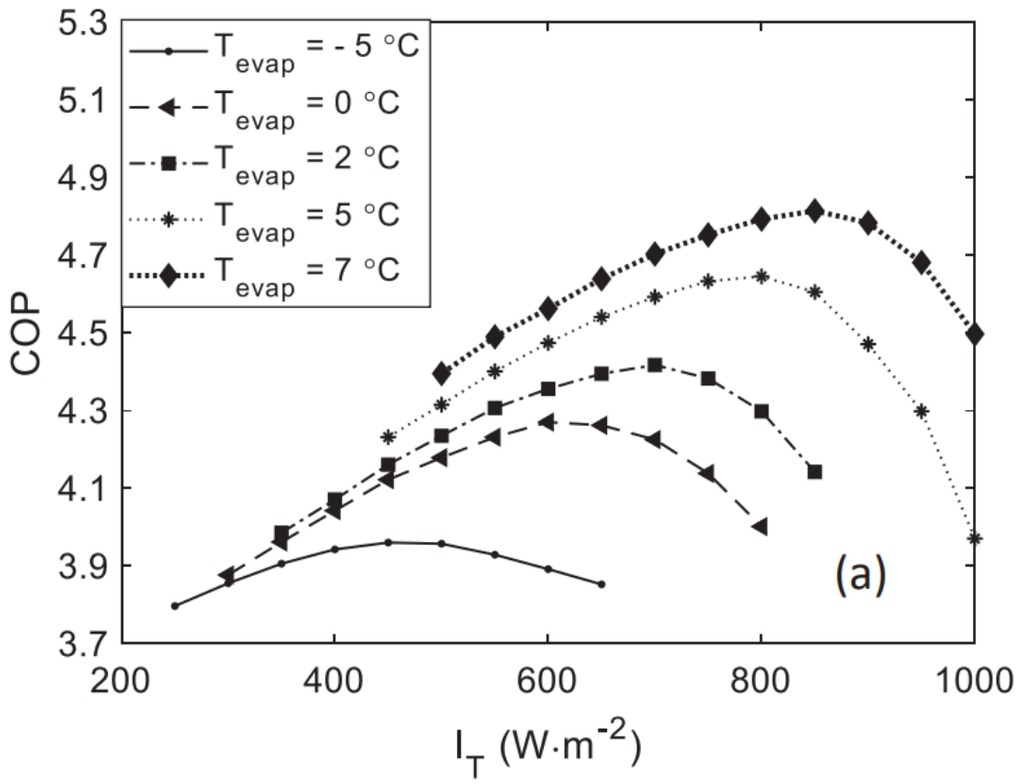

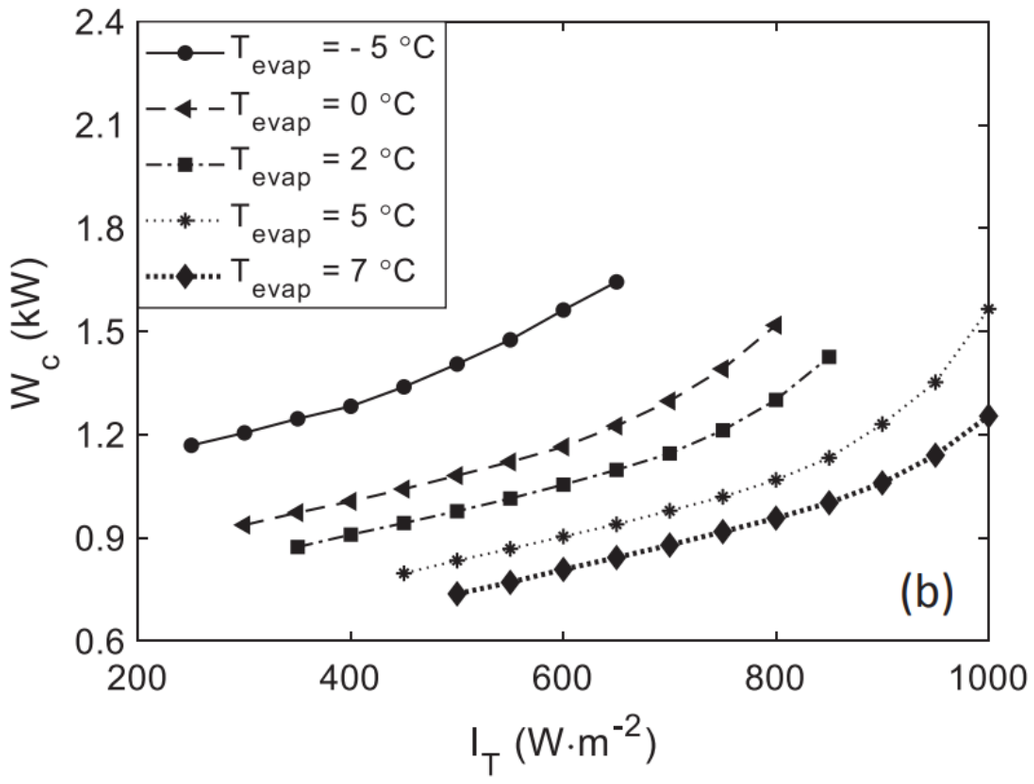

Parametric analysis

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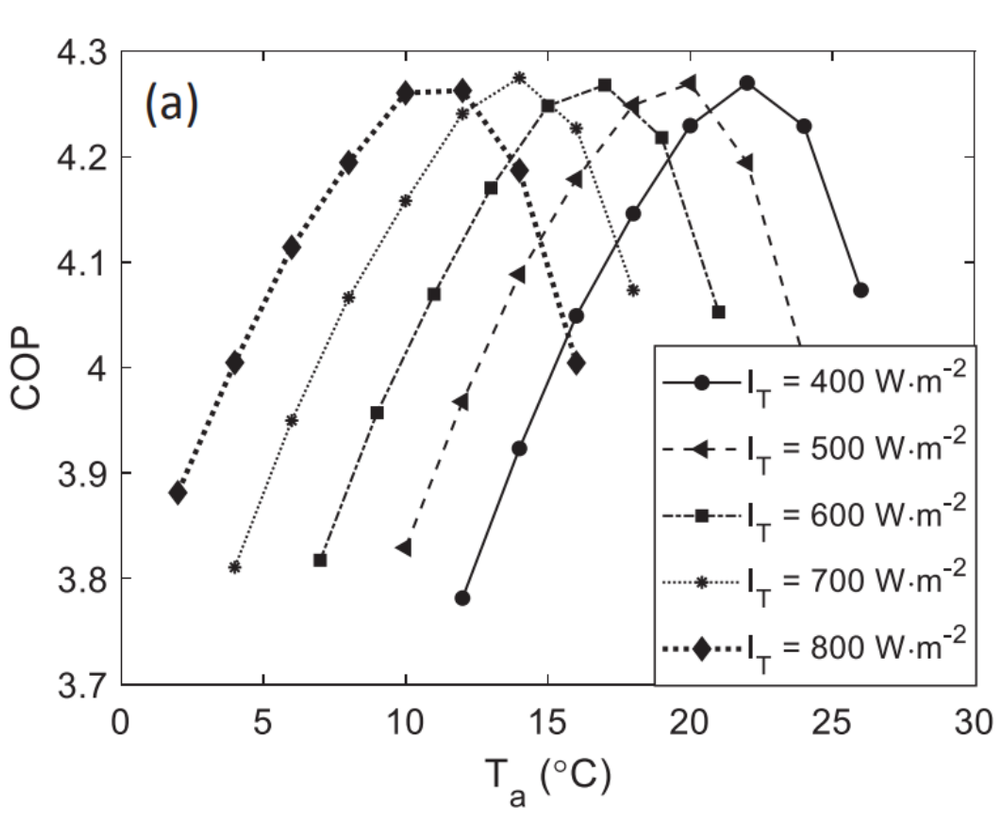
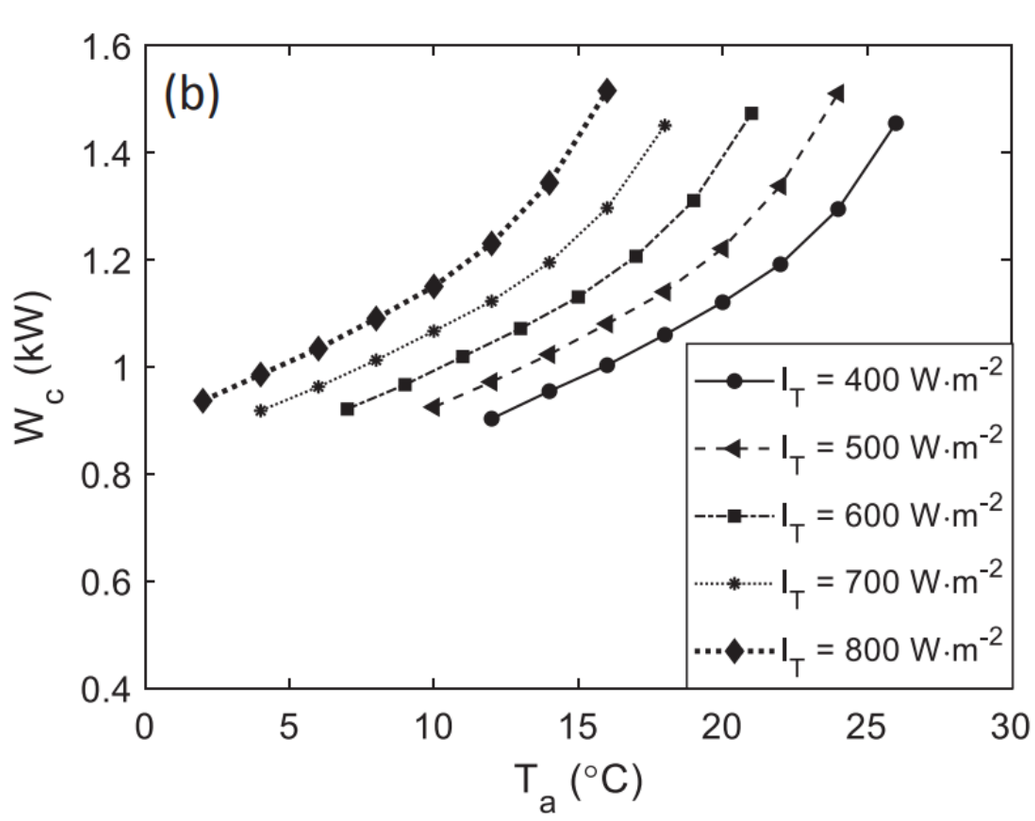




Parametric analysis

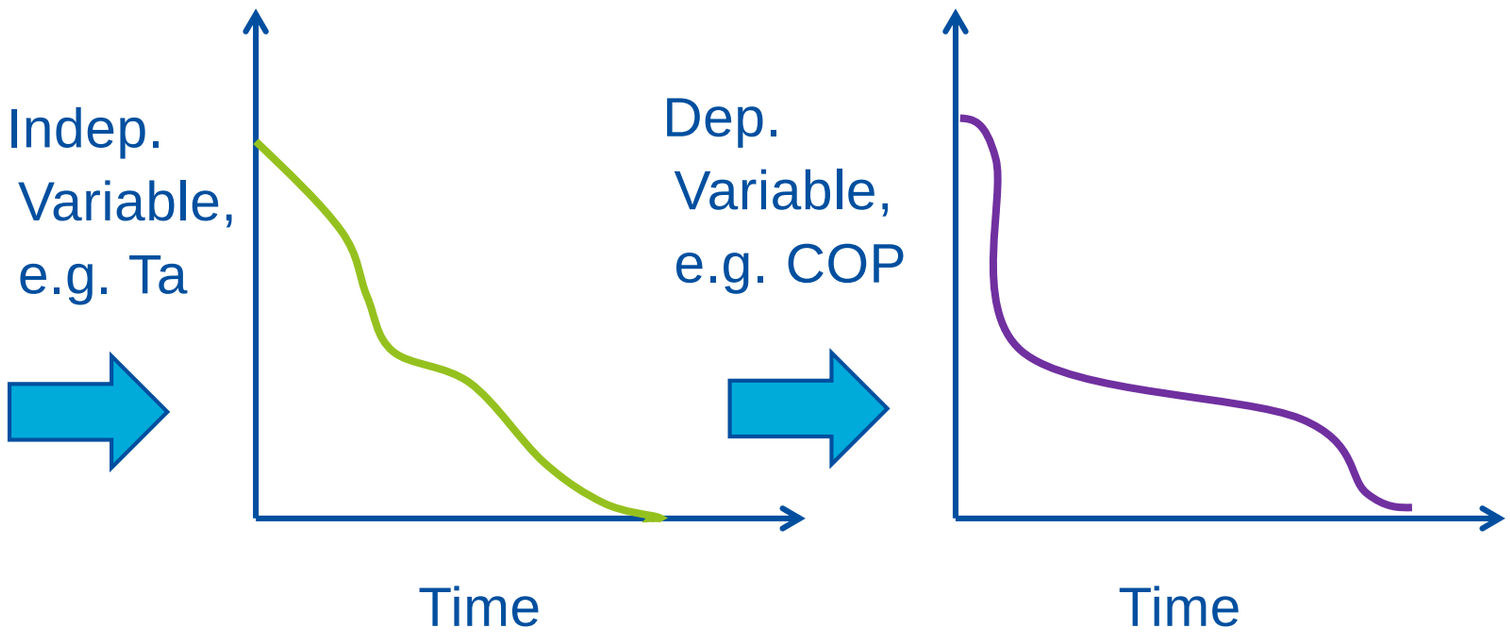
Proposal

1. Application to your heat pump project

1. Calculate the COP under different conditions: Tsource, Tdemand,Gsolar…
2. Plot the duration curves for your varying conditions: Qdemand, Tsource,…
   First step: choose only ONE variable for your parametric analysis and assume everything else to be constant

   → duration curves of two variables cannot be combined with one another!!!
3. Plot the duration curves for the performance of the heat pump

Static input values, desing conditions, e.g. COP,



Parametric analysis

Proposal

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   → duration curves of two variables cannot be combined with one another!!!

CAUTION:
Assuming a constant demand!
Simultaneity cannot be guaranteed with duration curves!

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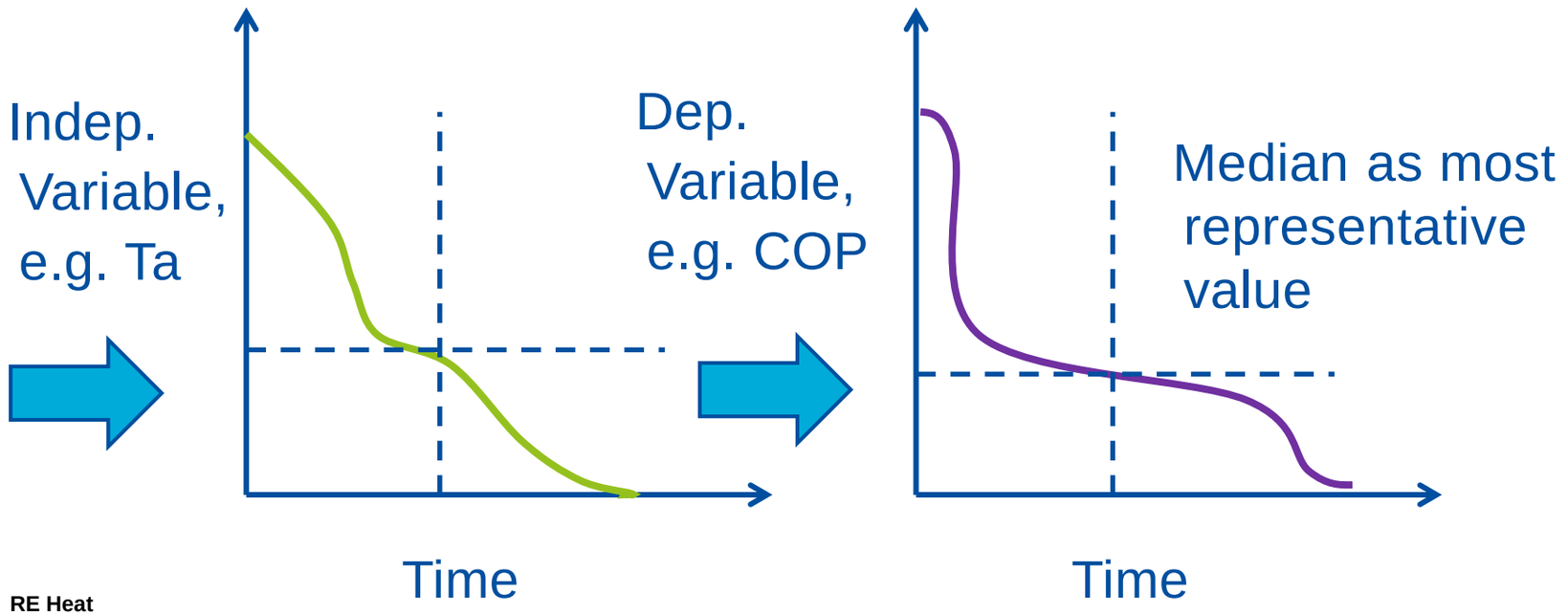
Static input values, desing conditions, e.g. COP,



Estimation for annual/seasonal performance

Repeat for different conditions

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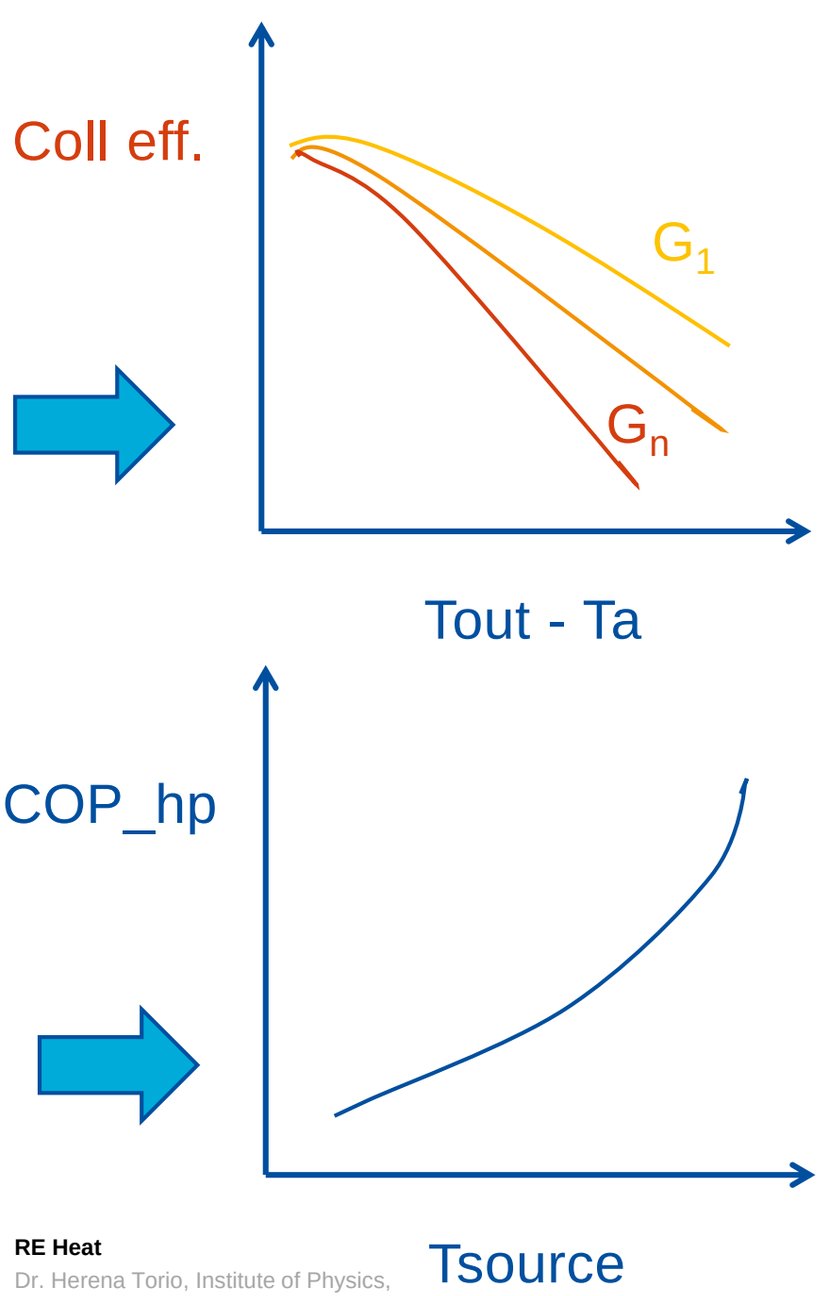
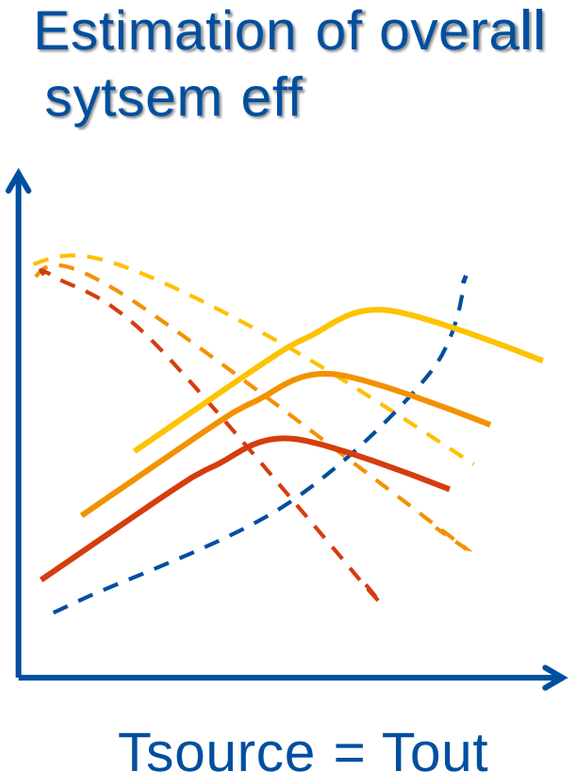
Parametric analysis

Proposal

2. Application to your heat pump+ solar thermal project

Static input values, desing conditions, e.g. COP,





Estimation for best operation point, static analysis, no annual performance inferred

Parametric analysis

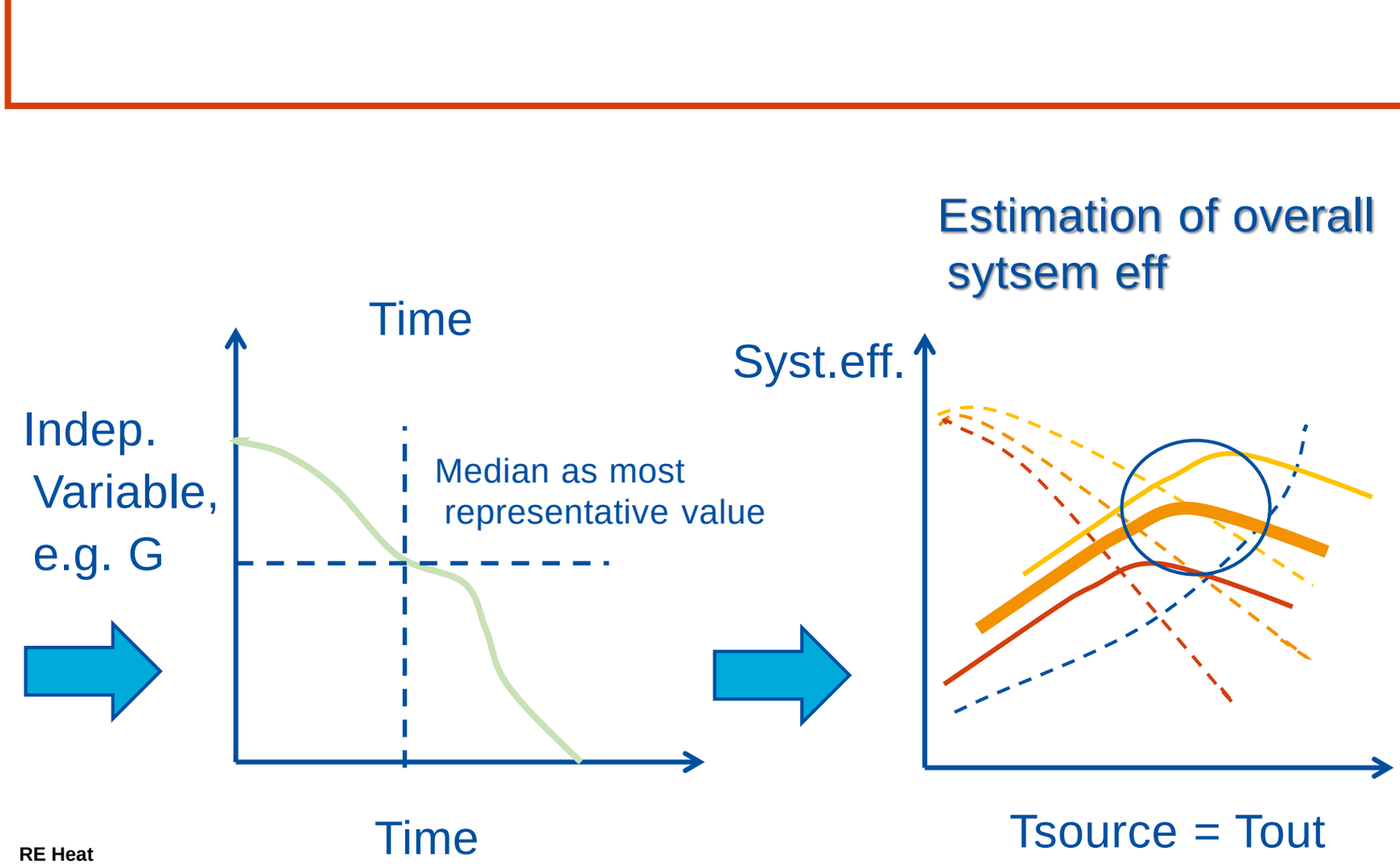
Proposal

2. Application to your heat pump+ solar thermal project

CAUTION: No demand considered so far! – only efficiencies, indep of energy flows!

→ For annual performance „estimation“: typical radiation in the demand season (E.g. winter)

Static input values, desing conditions, e.g. COP,



Estimation of frequent operation eff.

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References

IEA 2023. Renewables 2022 Analysis and forecast to 2027. Link: https://iea.blob.core.windows.net/assets/ada7af90-e280-46c4-a577-df2e4fb44254/Renewables2022.pdf Last accessed: Oct. 2023

SHC 2022 (W.Weiss):SOLAR HEAT WORLD WIDE, Global Market Development and Trends 2022 Detailed Market Figures 2021, Link: https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2023.pdf Last accessed: Oct. 2023