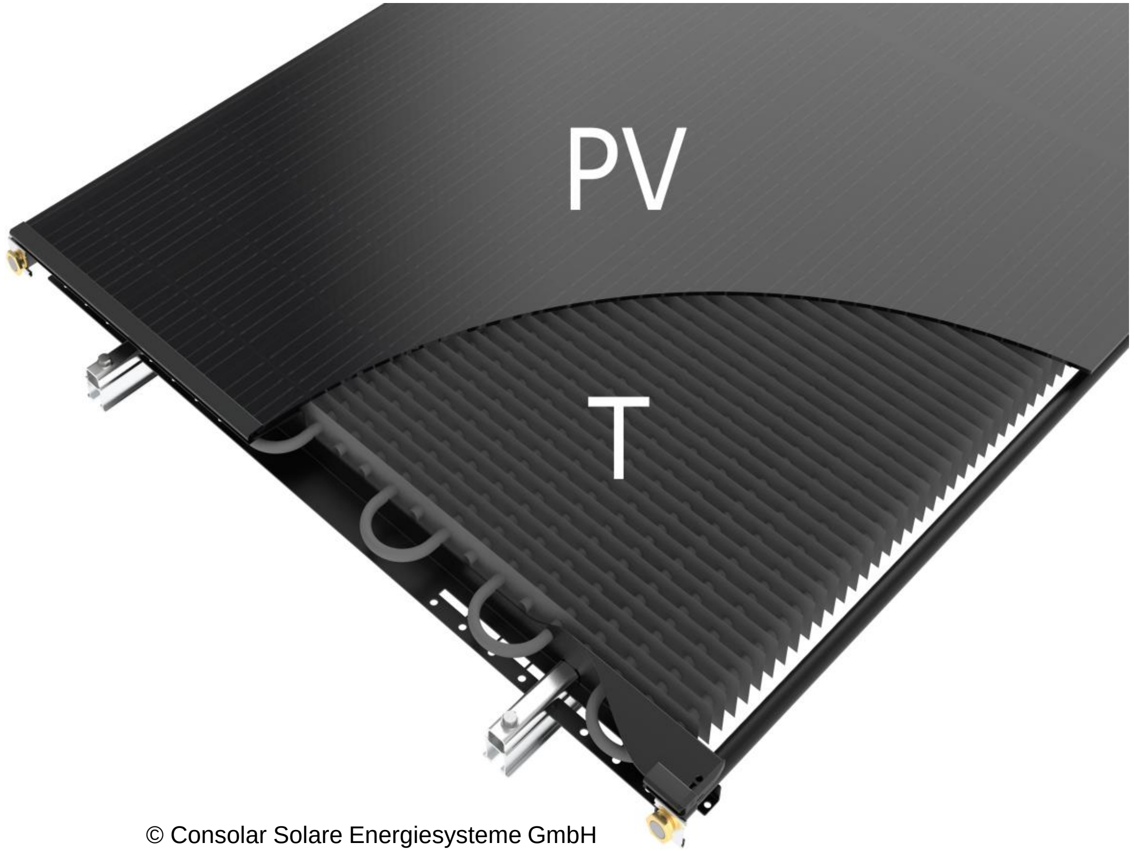

Dimensioning Method for PVT Collectors as Heat Source of Heat Pumps for Residential Buildings

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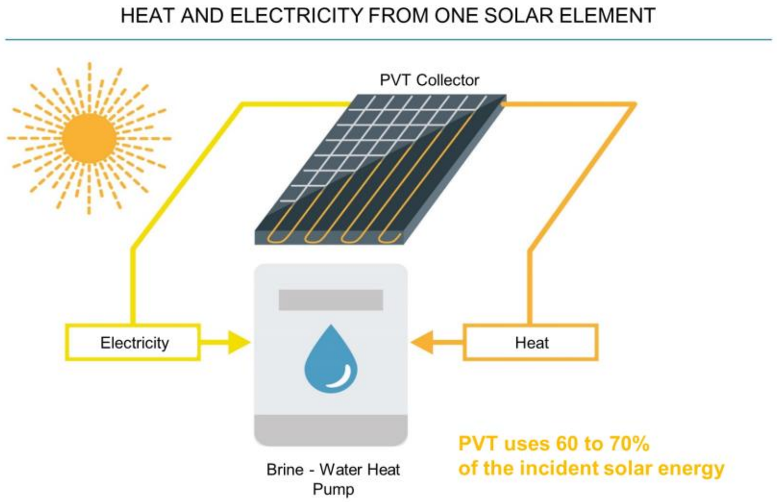
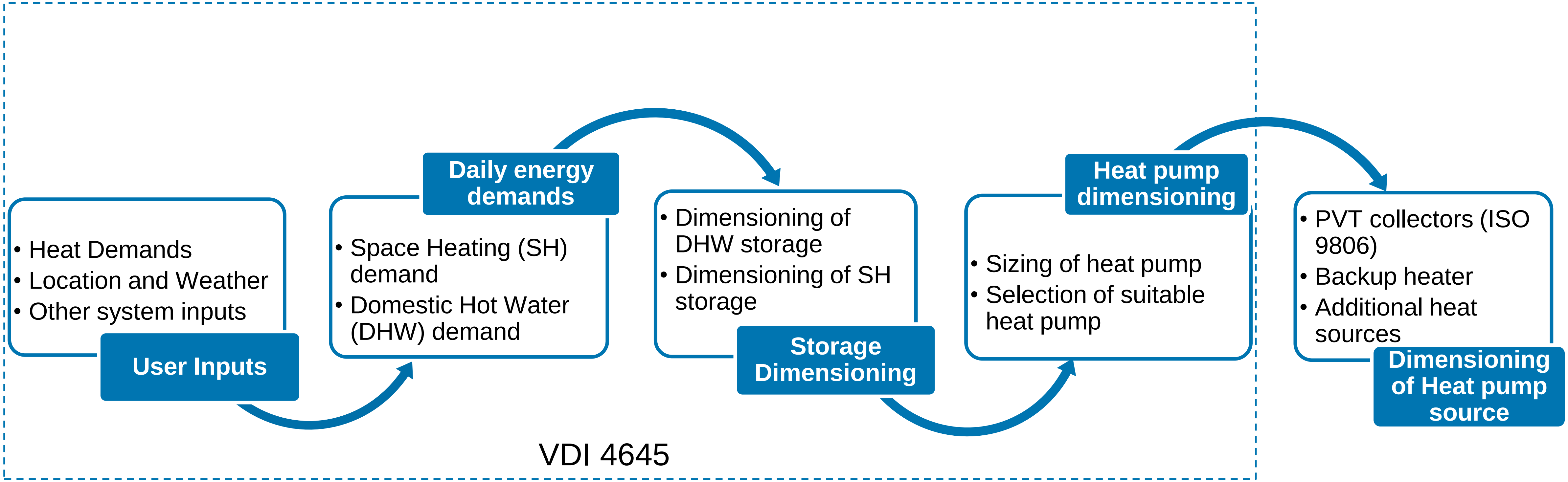
PVT project "integraTE"



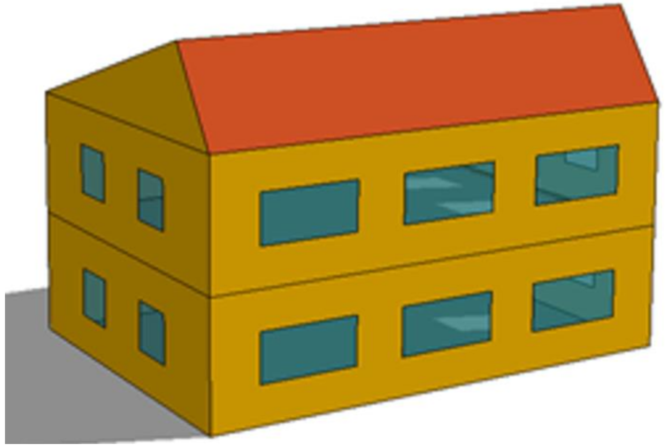
- Monitoring of 10 demo PVT – HP systems
- Simulations of different heat supply concepts
- Development of "*decision support tool*" and "*design tool*"
- Marketing of PVT-HP systems

Introduction to the methodology



- VDI 4645 focusses mainly on heat pumps with outdoor air as heat source (air-to-air/air-to-water heat pumps)
- Extended for PVT as a single heat source for brine-water heat pumps

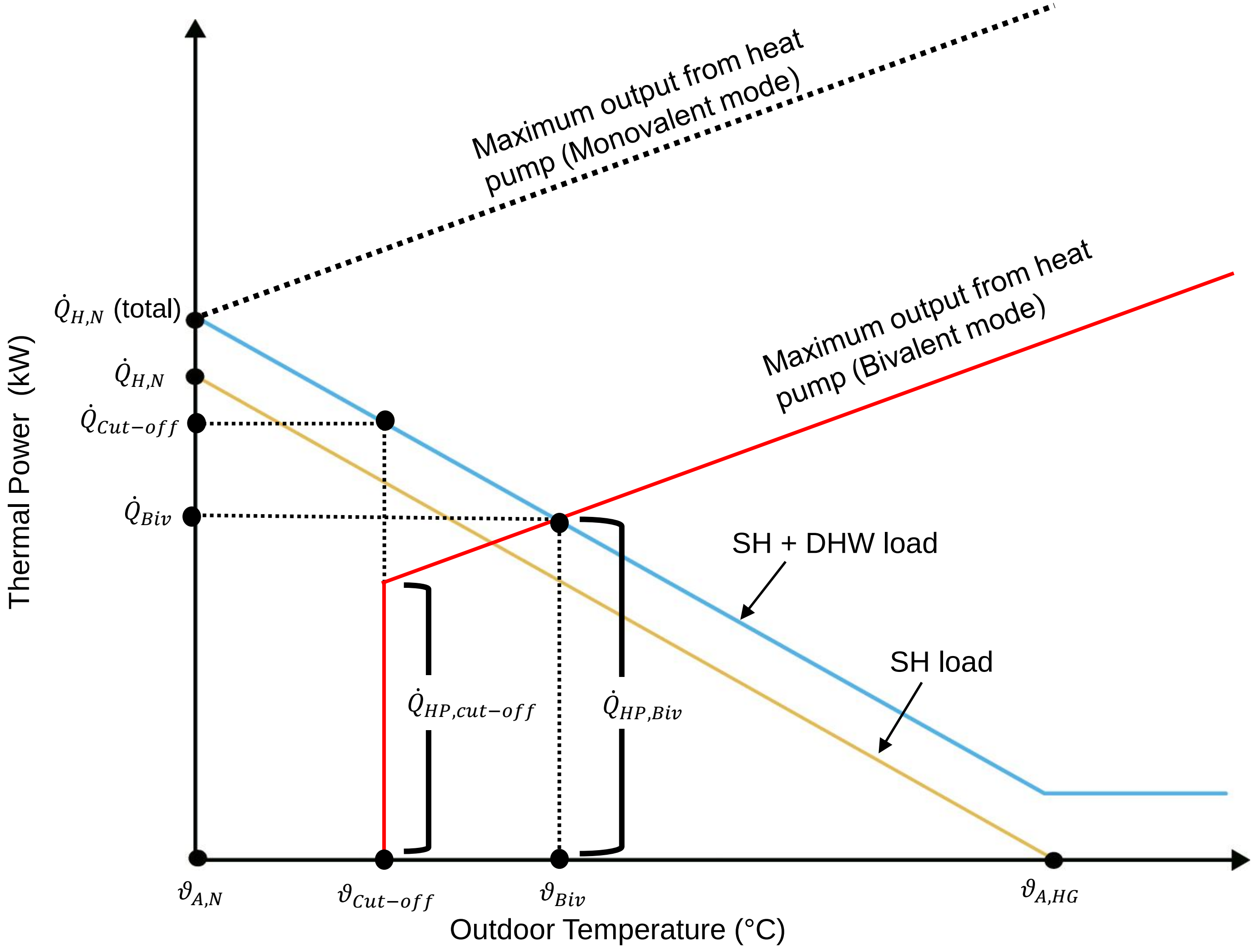
Example Case: SFH100



- Existing single family house based on IEA SHC TASK 44 located in Würzburg, Germany
- Daily heat demands
  - Space heating: **183 kWh**
  - DHW preparation: **5.85 kWh** (145 l)

General		
Nominal ambient temperature	$\vartheta_{A,N}$	-10.1 °C
Number of person	n_{NE}	4
Shut-off period	$\sum t_{SD}$	0
Balance point temperature (Heating limit)	$\vartheta_{A,HG}$	17 °C
Space heating		
Heat load at Nominal ambient temp.	$\dot{Q}_{H,N}$	7.6 kW
Type of heating		Radiator
Supply temperature at $\vartheta_{A,N}$	$\vartheta_{VL,RH}$	55 °C
Domestic hot water		
Cold water temperature	ϑ_{KW}	10 °C
Tapping temperature	$\vartheta_{SP,TWW}$	45 °C

Heat pump design



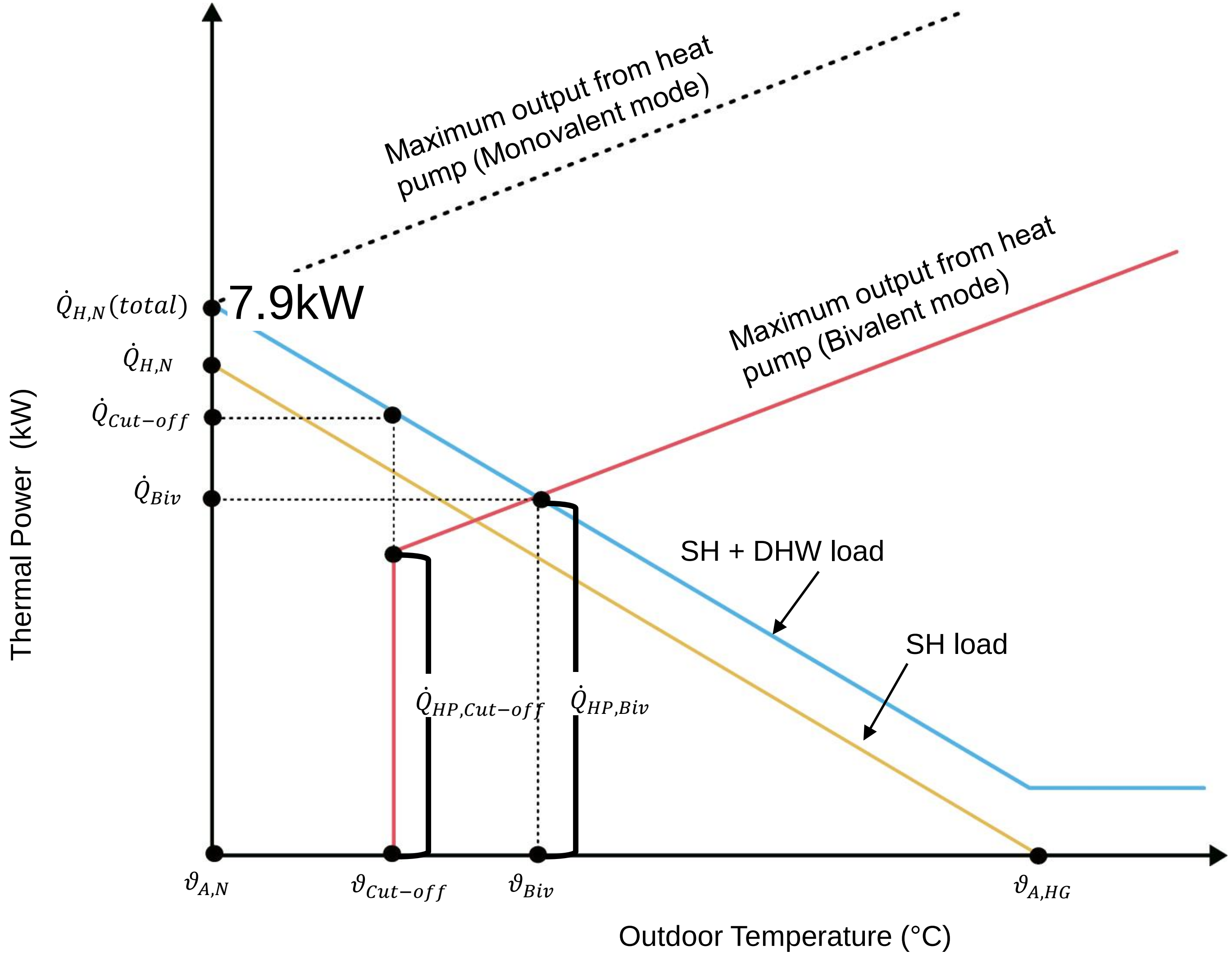
Monovalent design:

- Avoids second heat source
- Leads to more on-off-operation in part load
- Increases investment costs

Bivalent design:

- Heat pump operation down to cut-off temperature (positive, if heat pump can go down to -15 °C)
- Heat pump design for bivalence temperature, e.g. for limited roof area

Heat pump dimensioning



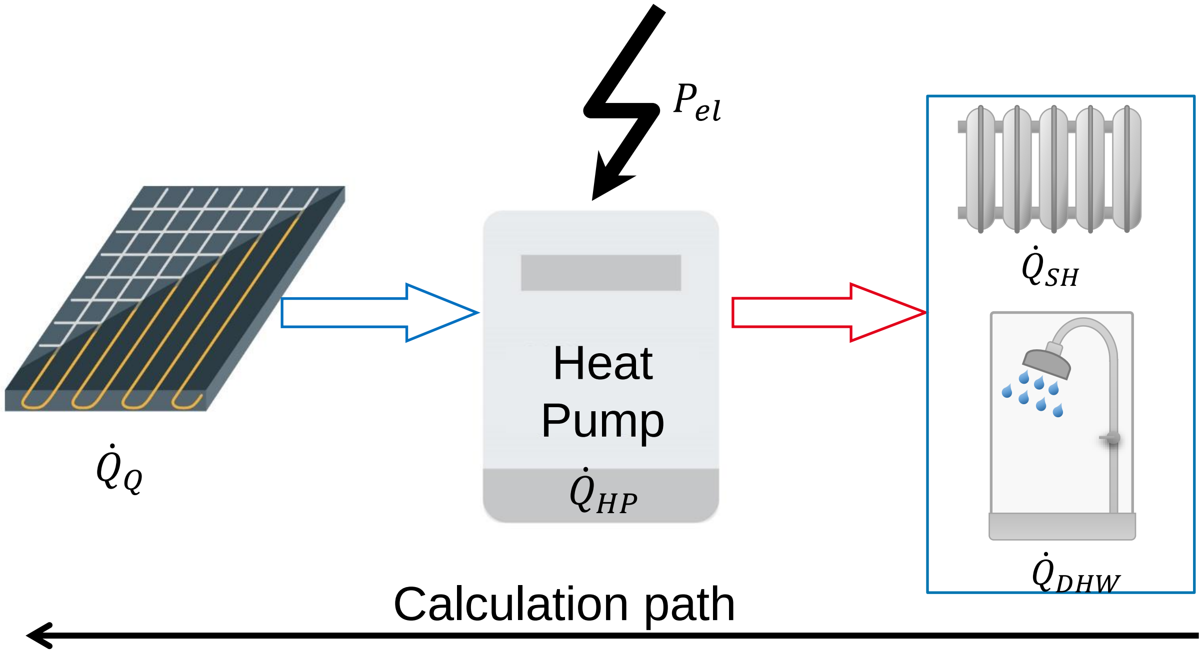
- Required heat pump power has to deliver the demand at design point

$$\dot{Q}_{HP,req} = \frac{Q_{H,AP} + Q_{DP,ges} + Q_{Sonst}}{d - \sum t_{SD}}$$

- $Q_{H,AP}$ varies with the variation in the design point
- $Q_{DP,ges}$ considers heat losses like circulation and standby; also the storage efficiency

⇨ **7.9 kW at nominal ambient temperature (monovalent design)**

Dimensioning of the heat source



- Factors affecting heat source design
  - Heat demand at sink
  - Heat pump characteristics (capacity and efficiency)
  - Temperature of heat source

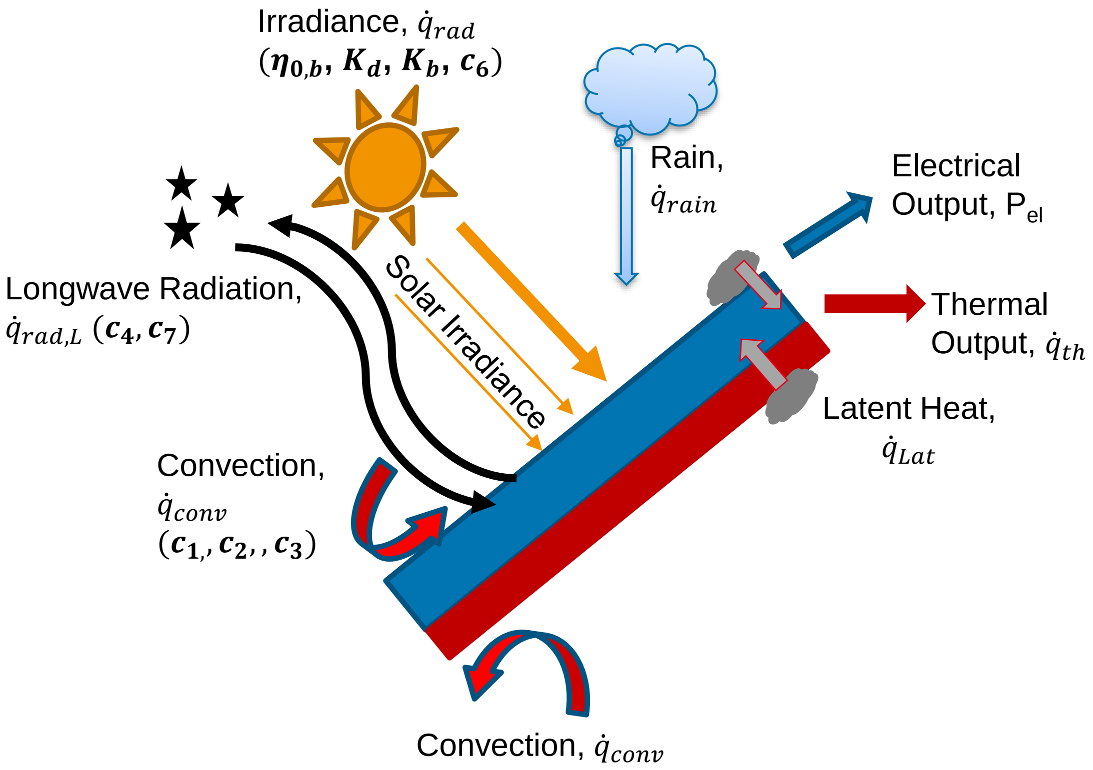
$$\dot{Q}_{PVT} = \dot{Q}_Q = \dot{Q}_{HP} - \frac{\dot{Q}_{HP}}{\varepsilon}$$

⇩

$$\dot{Q}_Q = \dot{Q}_{SH}\left(1 - \frac{1}{\varepsilon_{SH}}\right) + \dot{Q}_{DHW}\left(1 - \frac{1}{\varepsilon_{DHW}}\right) + \sum_i \dot{Q}_{Losses,i}\left(1 - \frac{1}{\varepsilon_{Losses,i}}\right)$$

⇨ **4.78 kW at nominal ambient temperature**

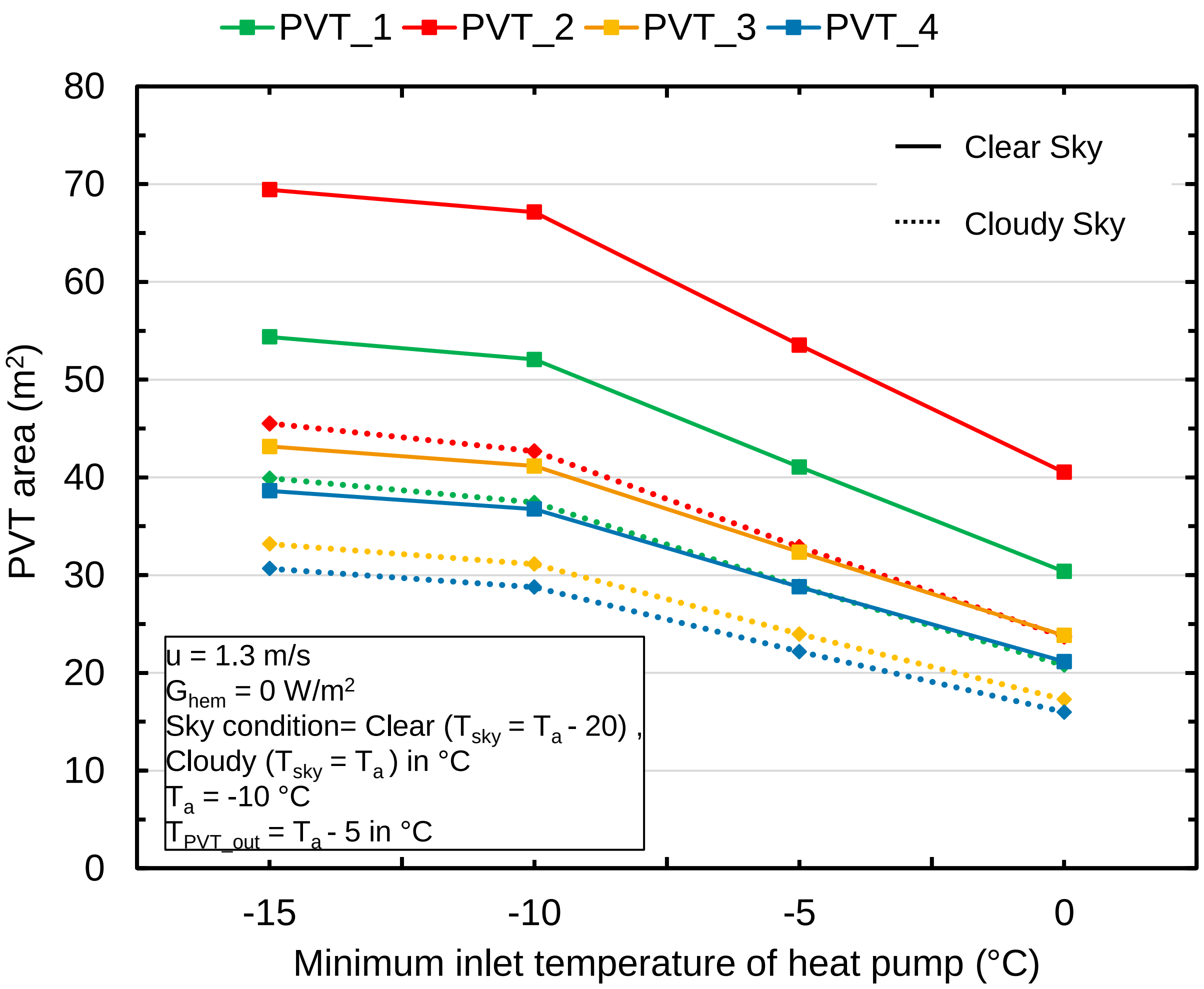
PVT-Model based on ISO 9806:2013



- Design temperatures based on heat pump characteristic curves
- Weather conditions
  - Irradiance, wind speed, sky temperature
  - Neglecting rain and latent gains
- Thermal performance parameters
  - Solar Keymark Test
  - Safety margin due to limited validity

$$\frac{\dot{Q}_{PVT}}{A_G} = \dot{q}_{th} = \eta_{0,b}K_b(\theta_L, \theta_T)G_b + \eta_{0,b}K_dG_d - c_1(\vartheta_m - \vartheta_a) - c_2(\vartheta_m - \vartheta_a)^2 - c_3u(\vartheta_m - \vartheta_a) + c_4(E_L - \sigma T_m^4) - c_6uG_{hem} - c_7u(E_L - \sigma T_m^4) - c_8(\vartheta_m - \vartheta_a)^4$$

PVT Selection



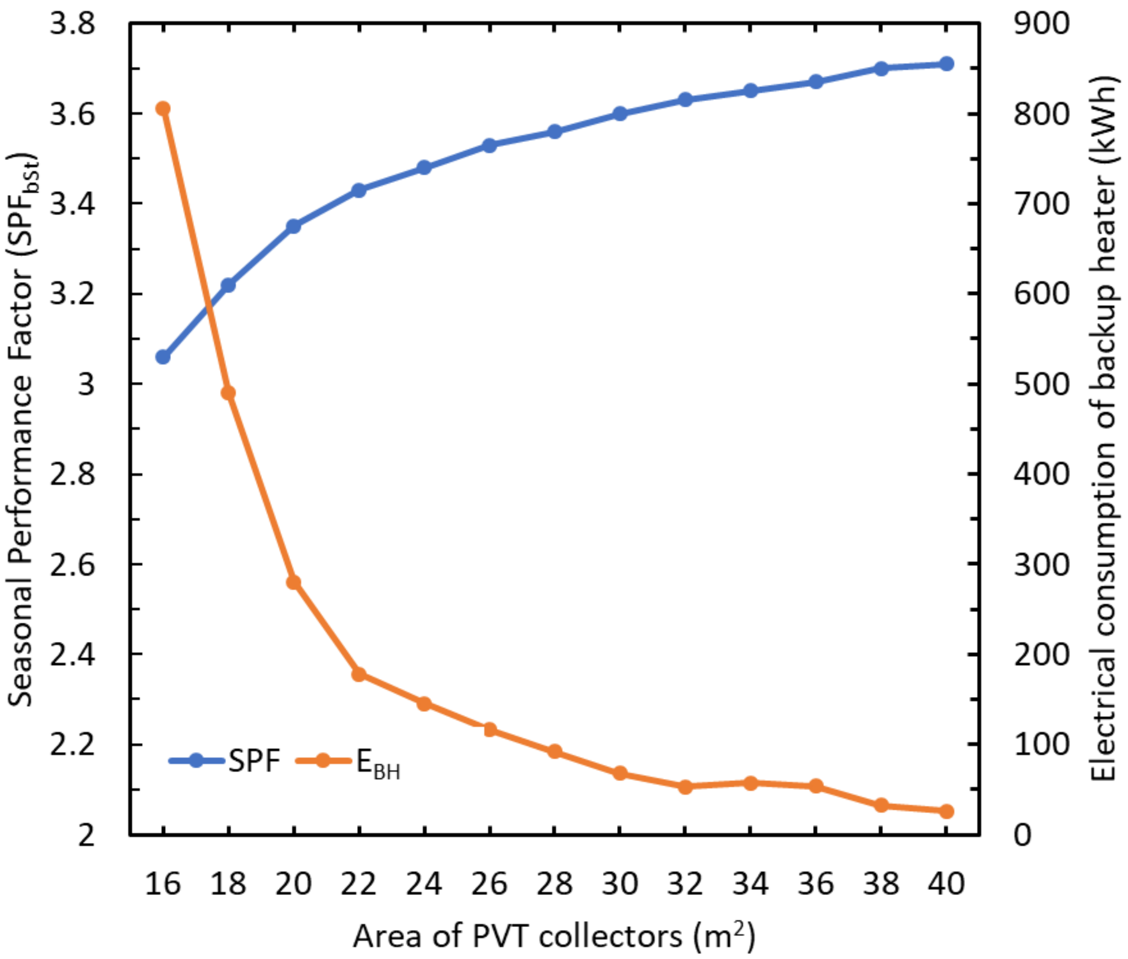
- 4 different PVT designs with different characteristics

$$A_{PVT} = \frac{(1 + f_{safety}).\dot{Q}_Q}{\dot{q}_{th}}$$

- Consideration of safety factor (15 %) [1]
- Required PVT_4 with area of 38.63 m² to meet 98 % of the heat demand
- PVT sizing very sensitive to weather conditions and parameters

[1]TwinPower, Institut für Solarenergieforschung Hameln GmbH (ISFH), Abschlussbericht, 2020.

Yearly simulations in TRNSYS



- Same inputs as in the example and the size of heat pump and PVT obtained using the method
- Yearly performance of the system
  - SPF_{bSt} = 3.7
  - Backup heater supplied only 0.2 % heat
- SPF an increasing monotone of PVT area
- Optimal design/selection conditions has to be chosen for e.g. cost consideration

Summary

- Extended method for VDI guideline to dimension PVT collector-Heat pump systems in EFH and smaller MFHs
- Resulting PVT dimensions are plausible but optimality needs to be considered
- Use of ISO 9806 in combination with VDI 4645 needs to be validated
  - Standard weather conditions and thermal parameters for PVT design
- First version of the web-tool online for internal feedback and discussions (published soon)

Future Outlook:

- Integration of larger MFHs to the methodology
- Simplification of choice of weather condition, heat load calculations, systems with PVT as additional heat source

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BDH Bundesverband der Deutschen Heizungsindustrie

BSW German Solar Association

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