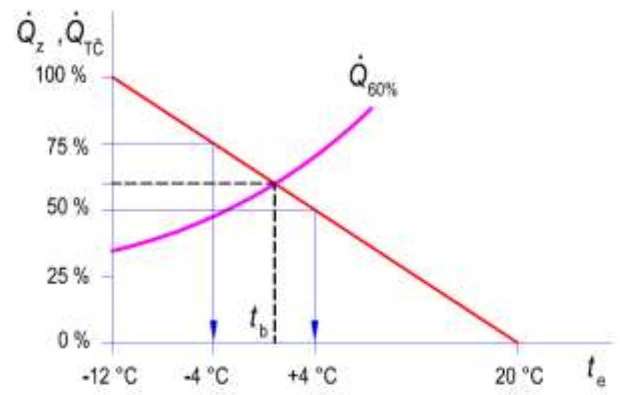
7 Heat pumps sizing

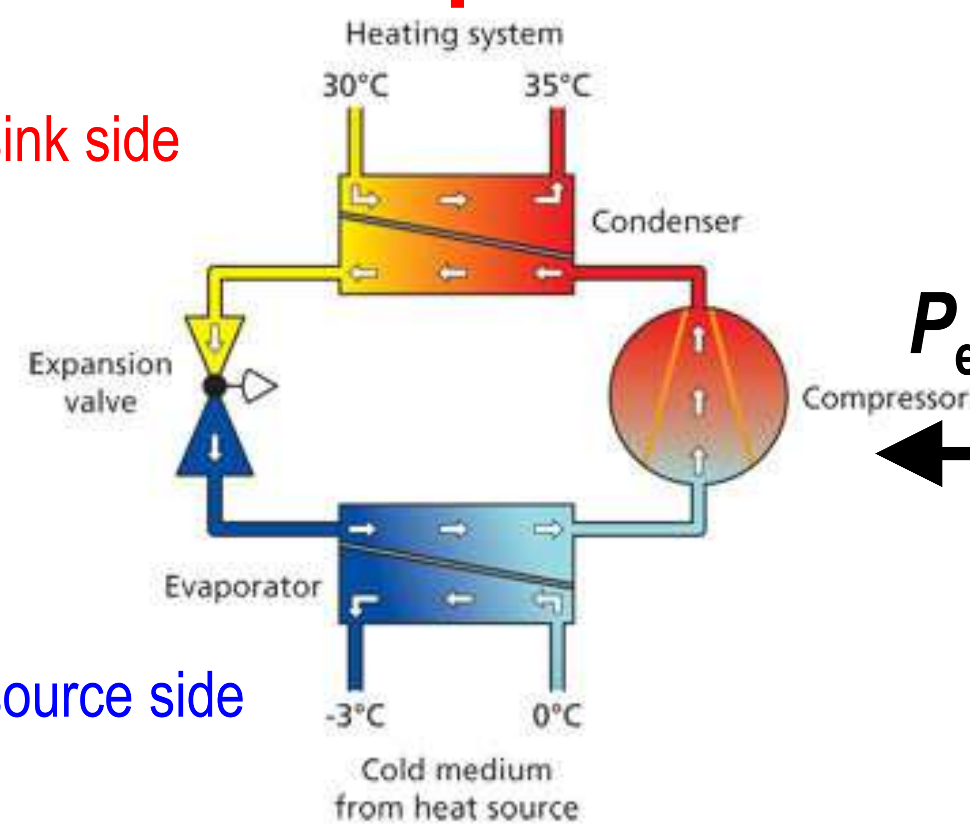
- heat pump characteristics
- testing & operation conditions
- balance point
- storage size
- hydraulics



Heat pump

Q_k rejected heat

sink side



P_{el}

source side

Q_v extracted heat

$$\dot{Q}_k = P_{el} + \dot{Q}_v$$

$$COP = \frac{\dot{Q}_k}{P_{el}}$$

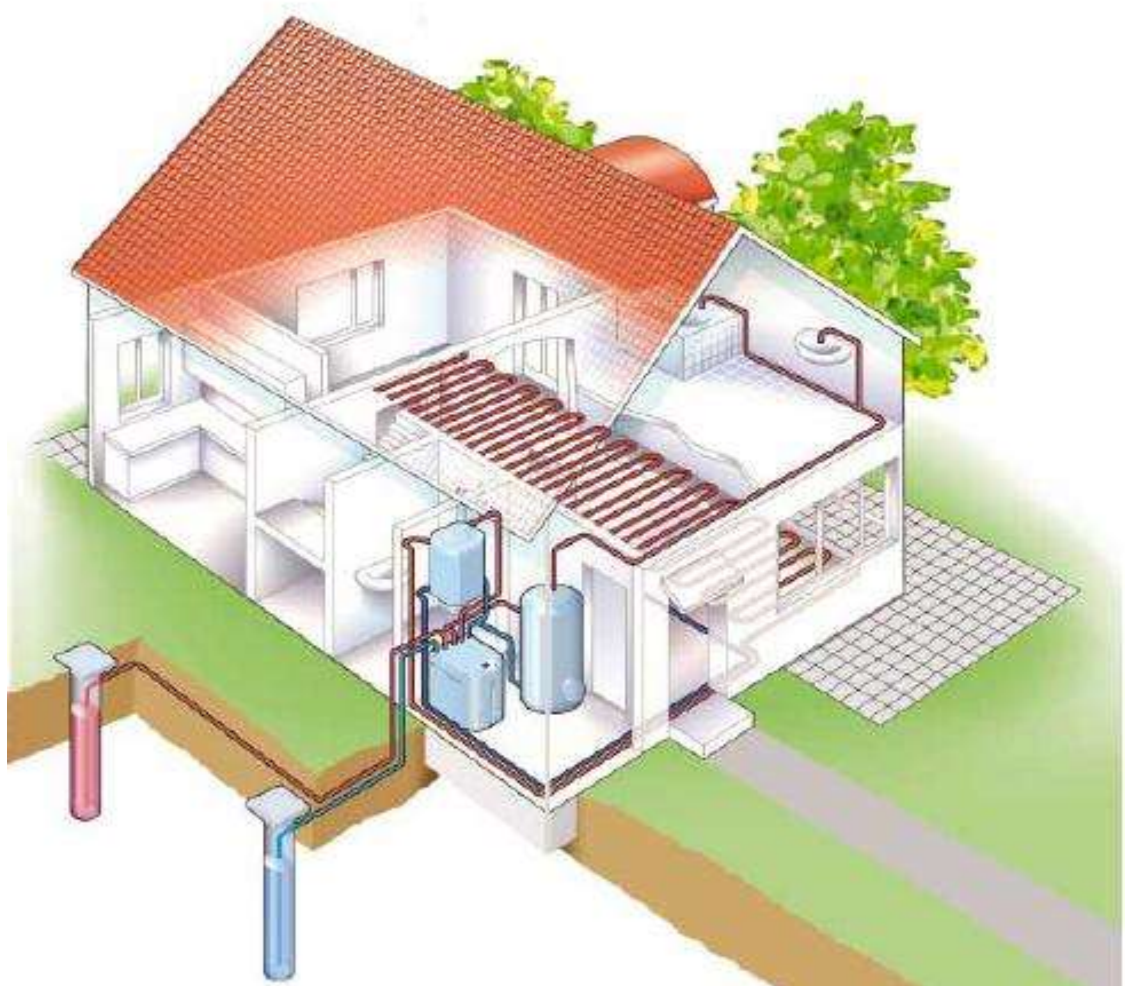
$$\dot{Q}_v = \dot{Q}_k - P_{el}$$

$$\dot{Q}_v = \dot{Q}_k \cdot \left(1 - \frac{1}{COP}\right)$$

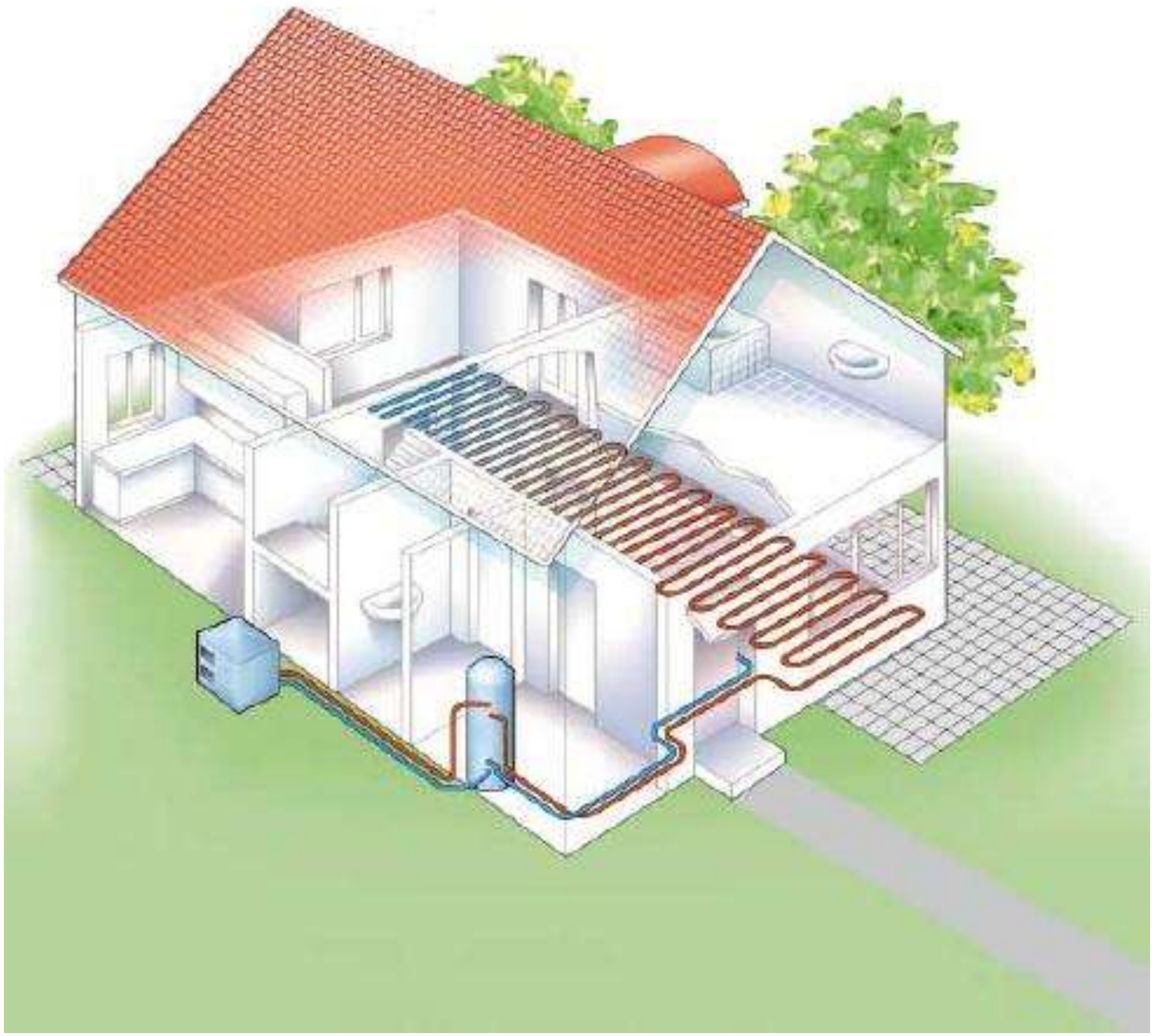
Heat pumps: ground source (borehole)

Heat pumps: ground source (ground HX)

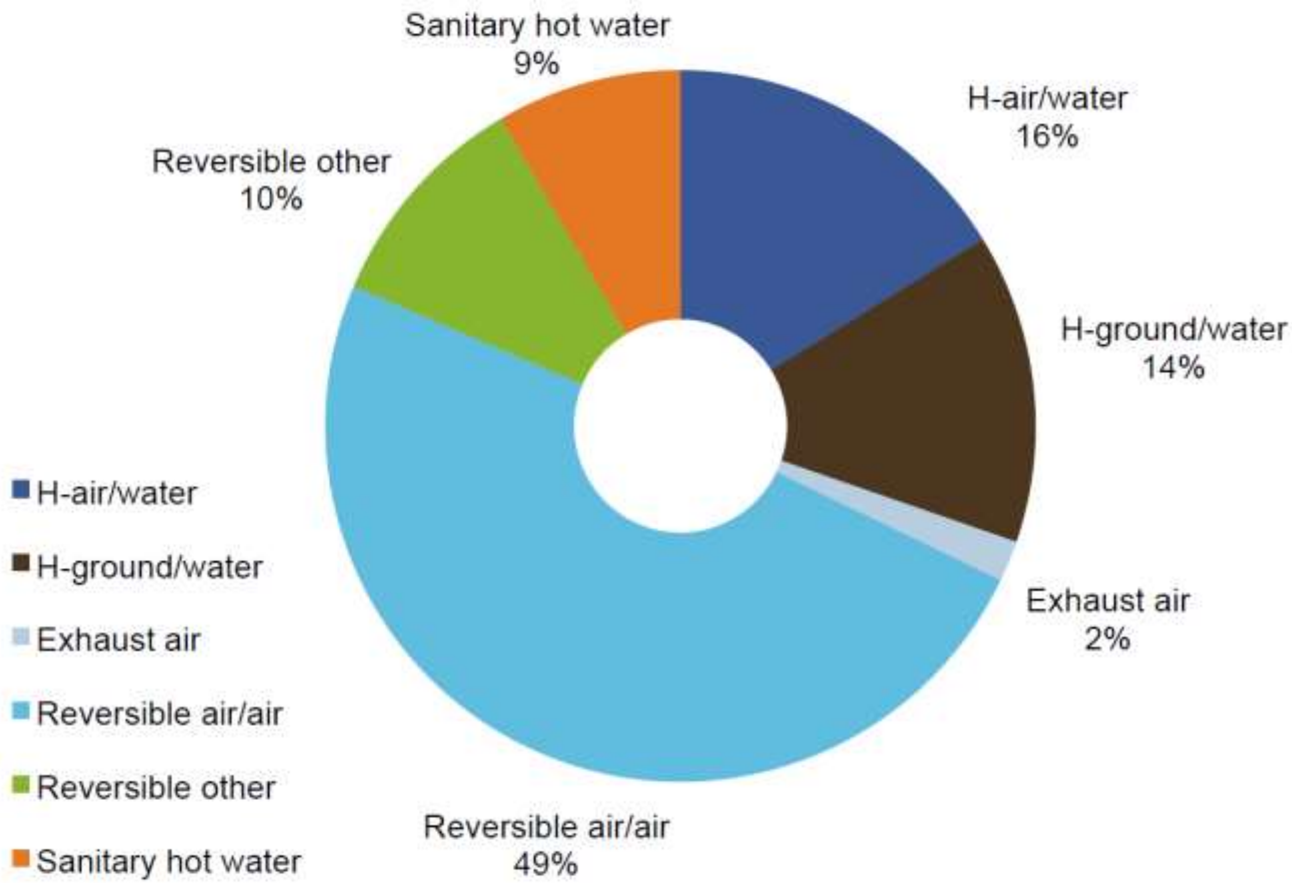
Heat pumps: water source (water well)



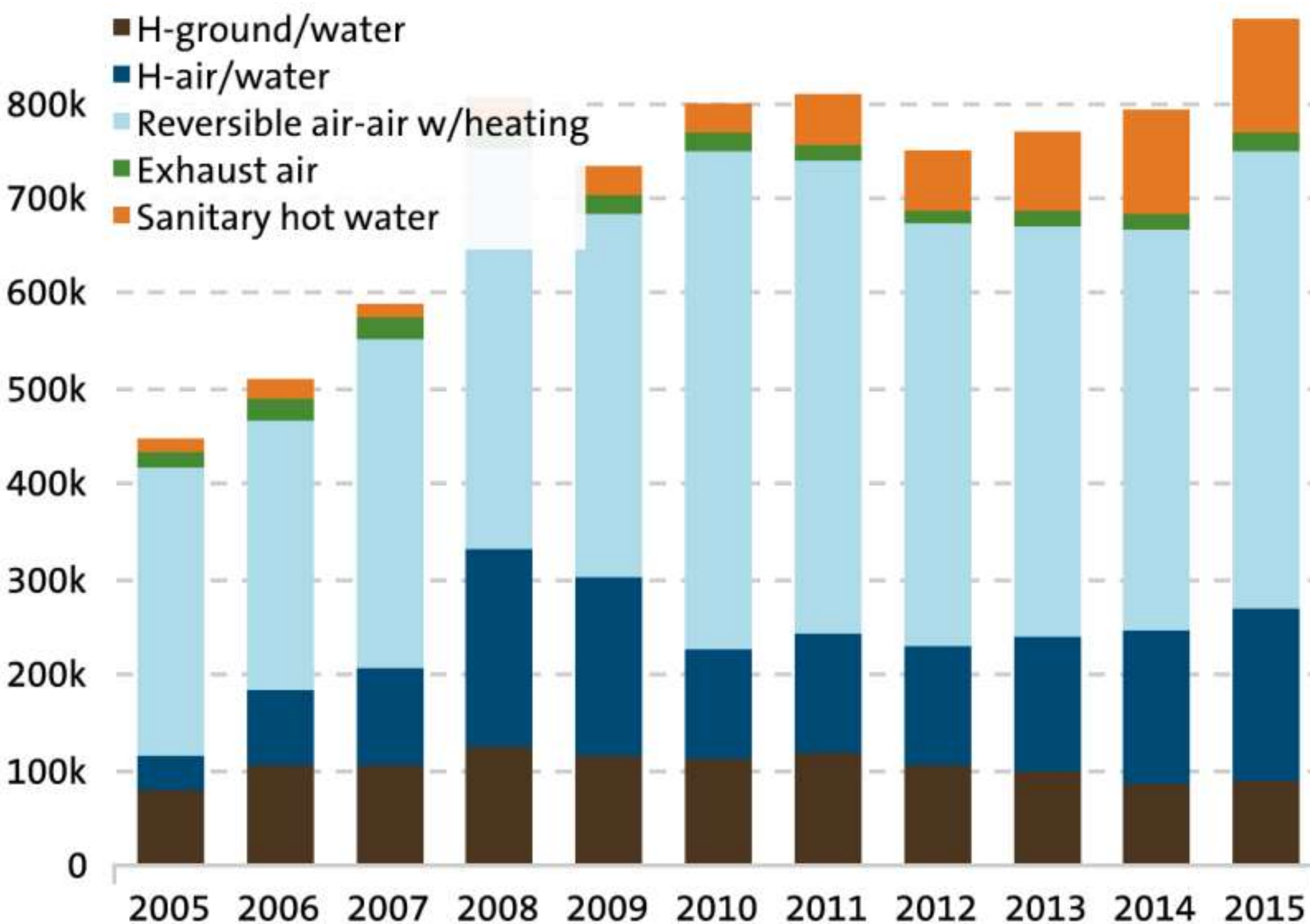
Heat pumps: air source (ambient)



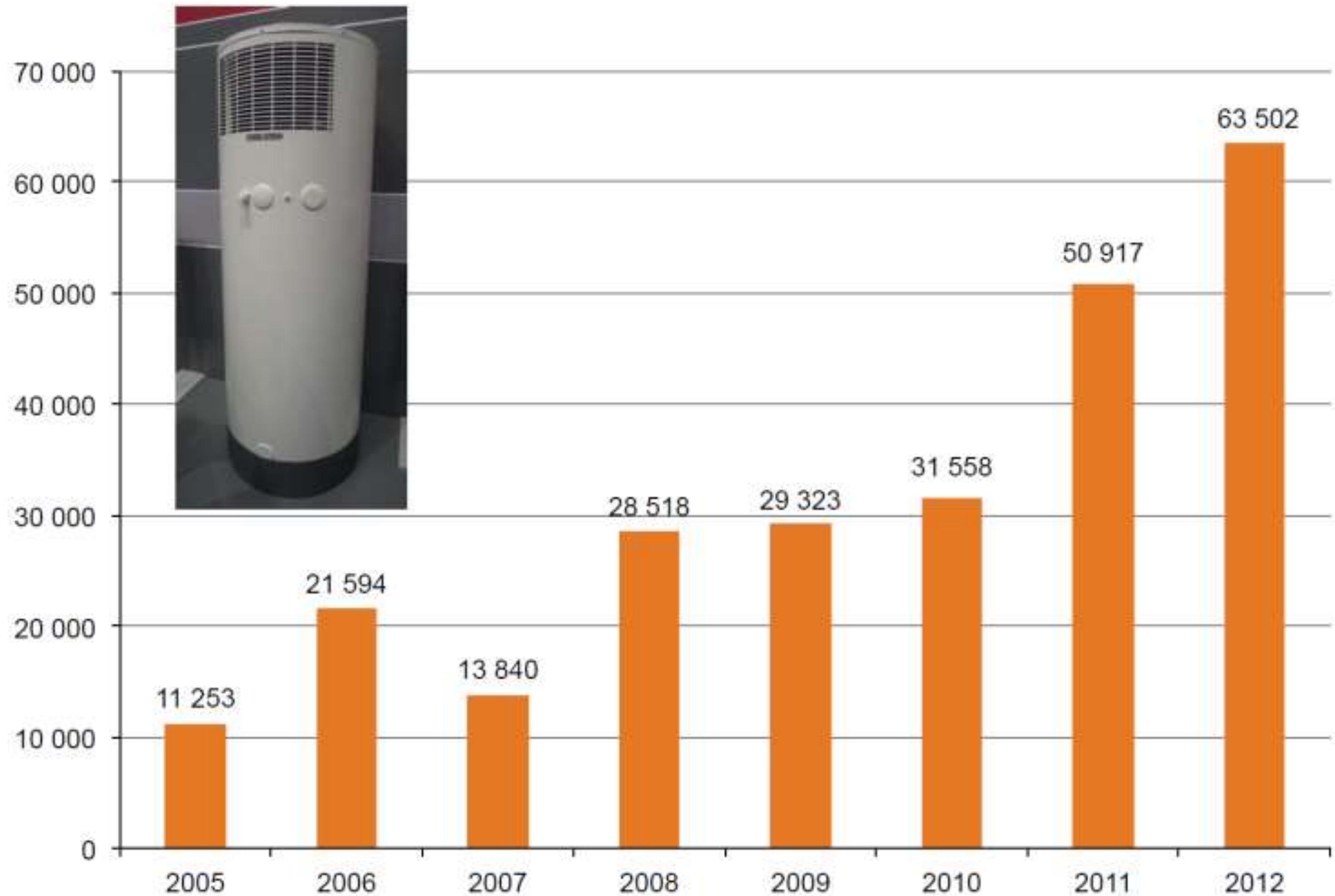
Types of heat pumps on the market



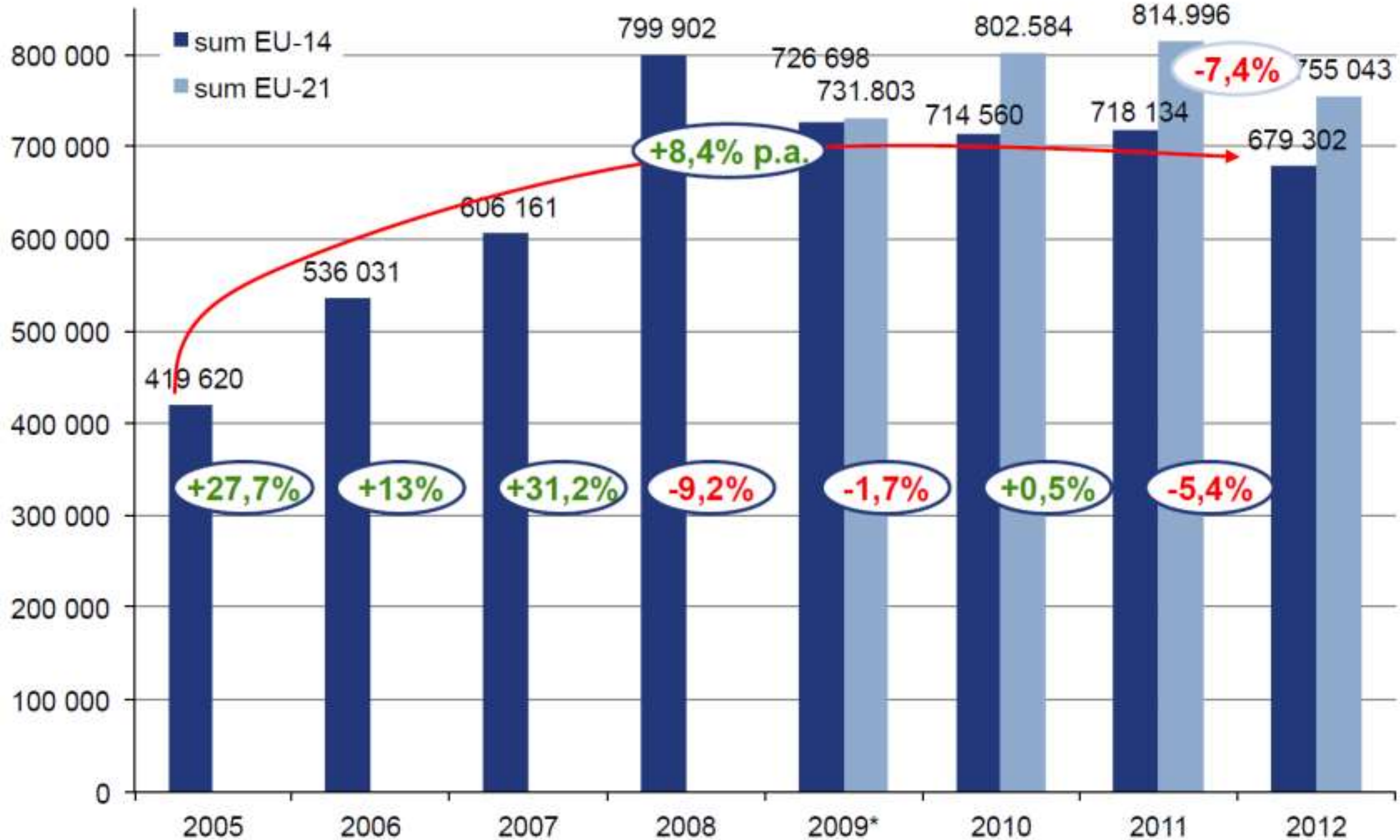
The trend is air source



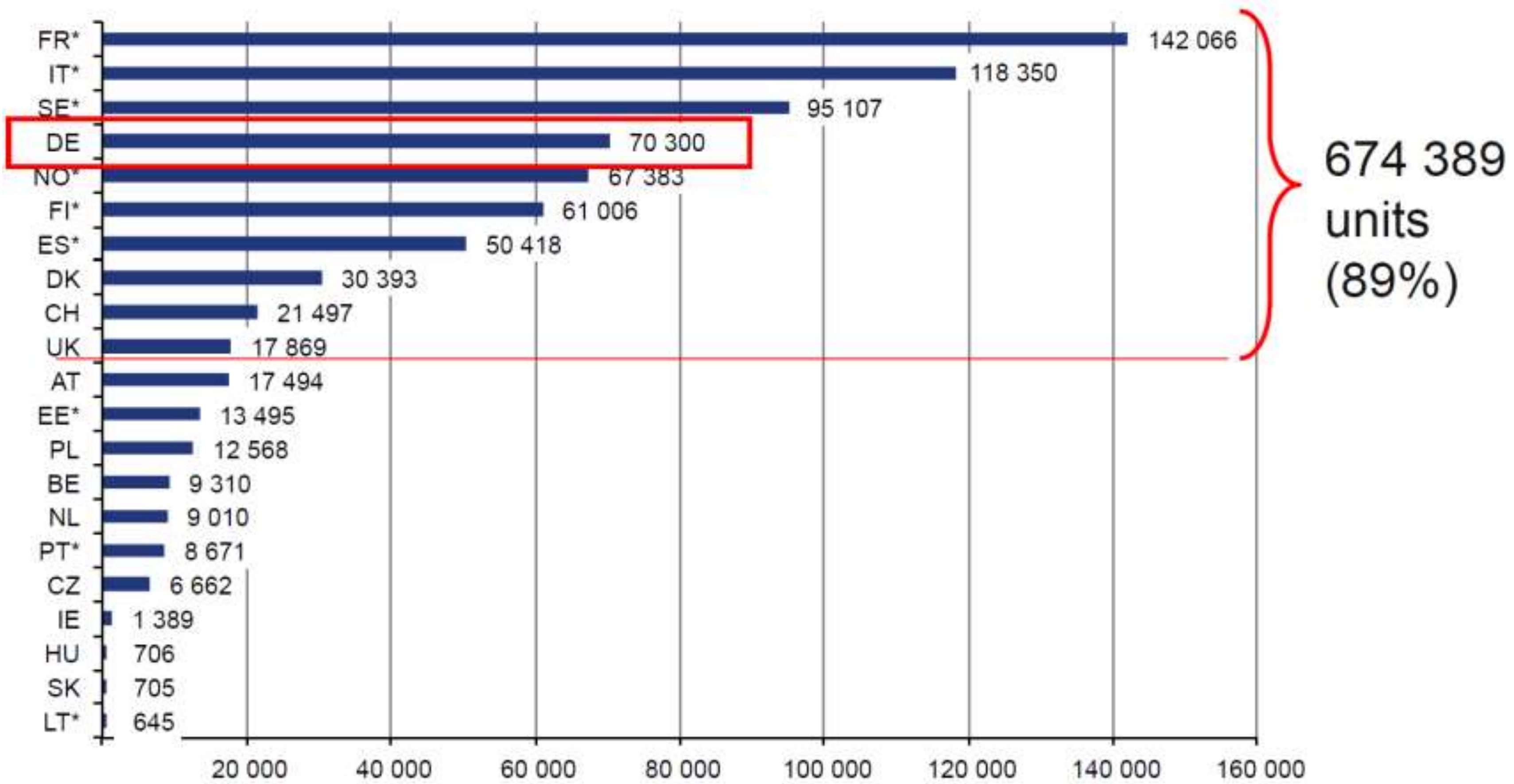
... also sanitary hot water HP increase



Heat pumps market in Europe



Top ten countries is the market



Heat pump parameters

- **heat output, heat capacity** Q_k [kW] – heat output from **condenser**
- **coefficient of performance COP** [-]

---

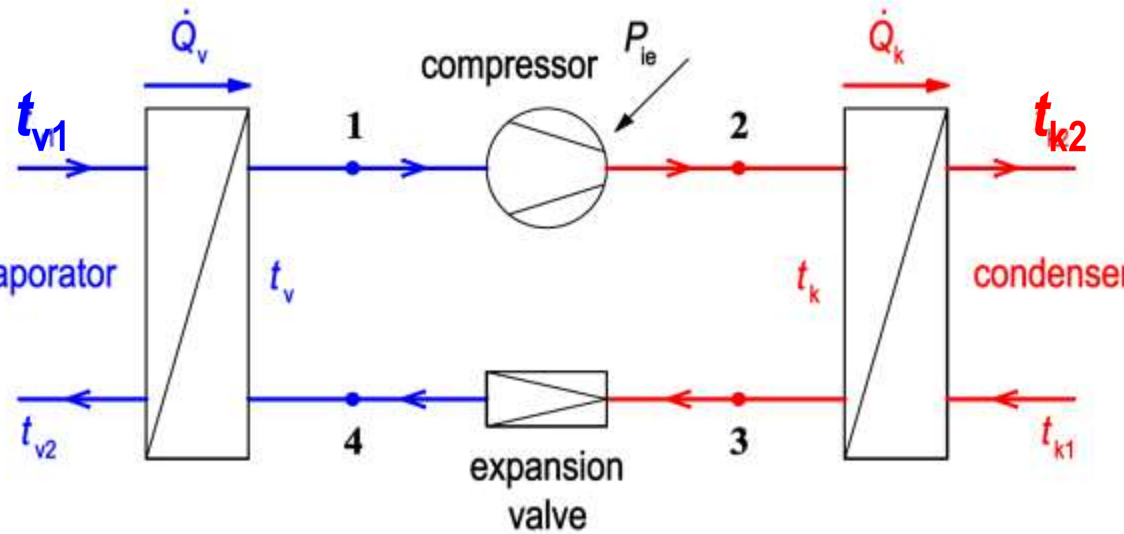
at given boundary conditions

- t_{v1}

and

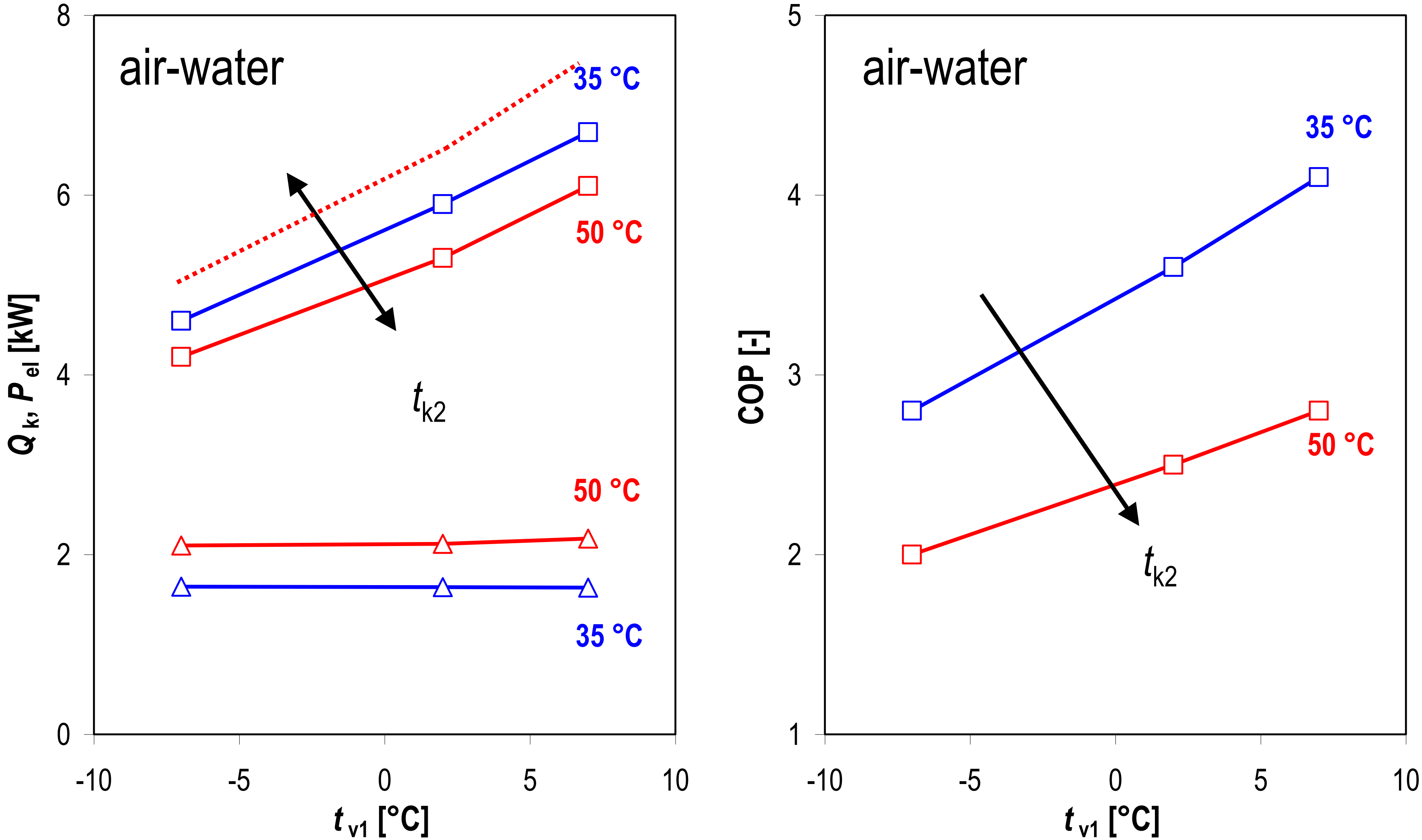
- t_{k2}

- electric power P_{el} [kW]

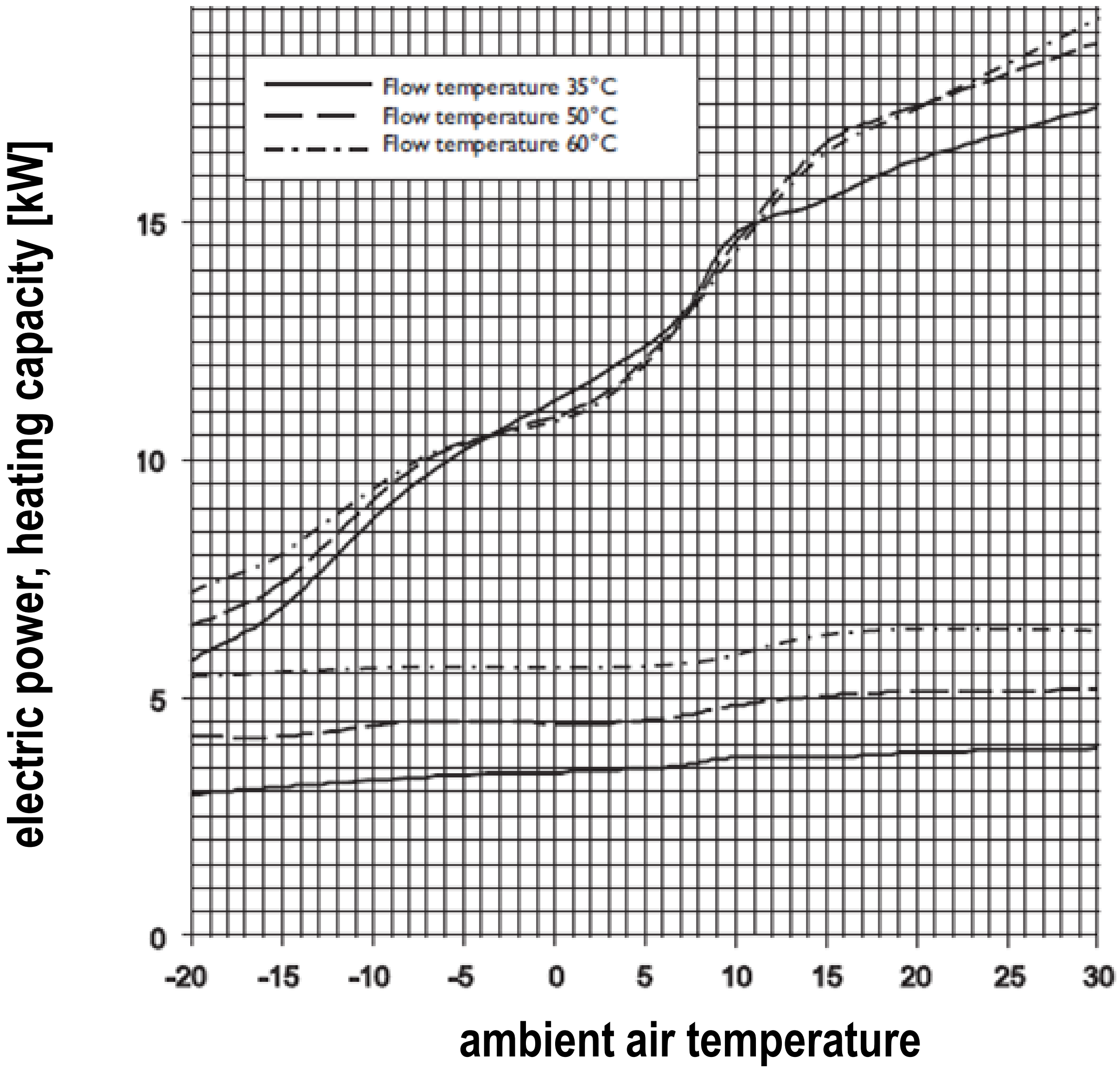


- **evaporator** input = source output Q_v [kW]

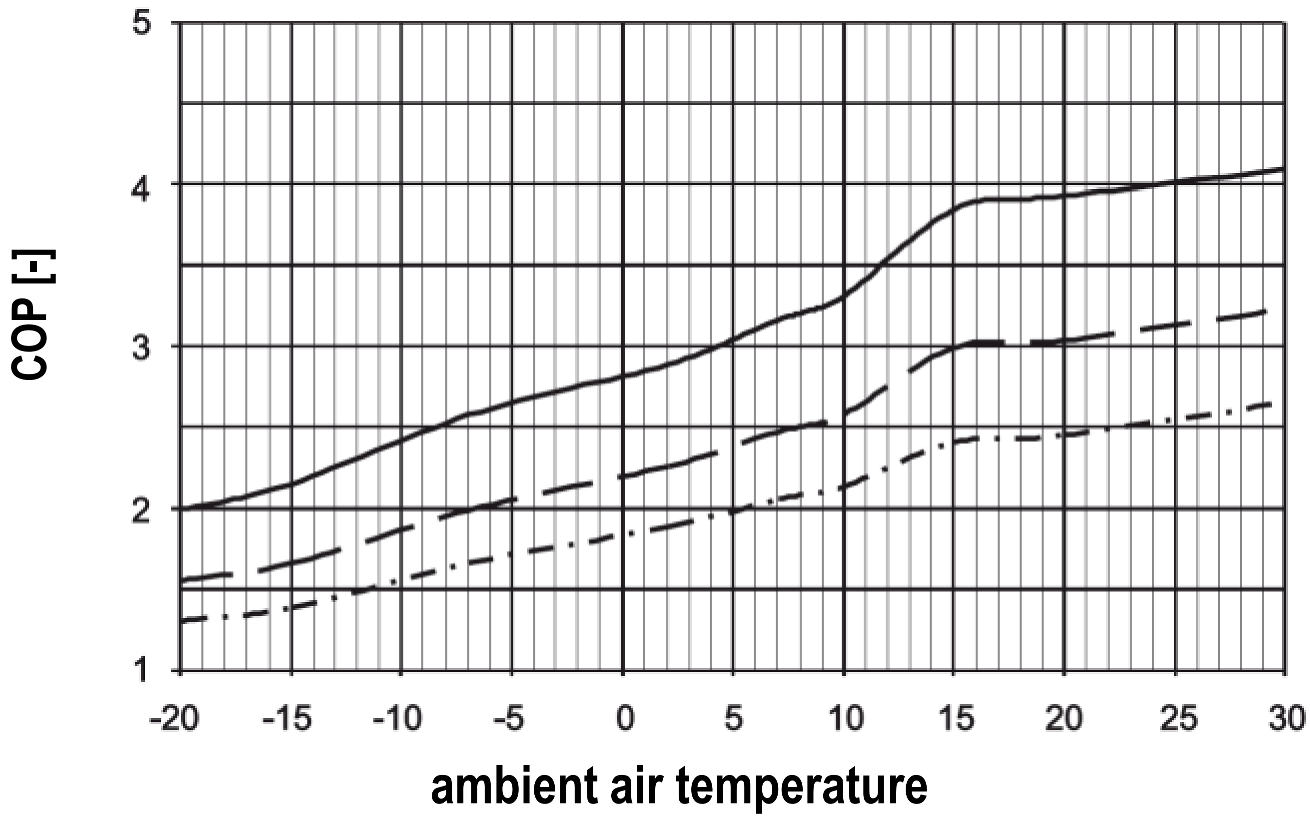
Air-water heat pump characteristics



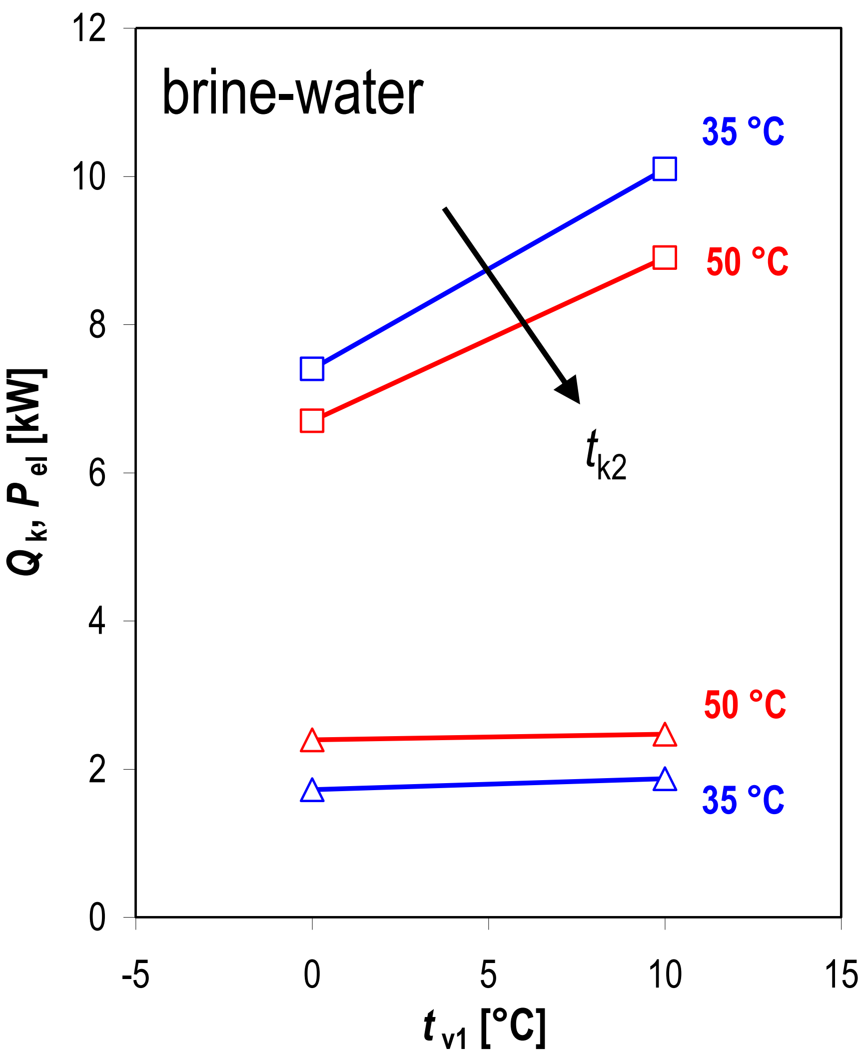
Air-water heat pump characteristics

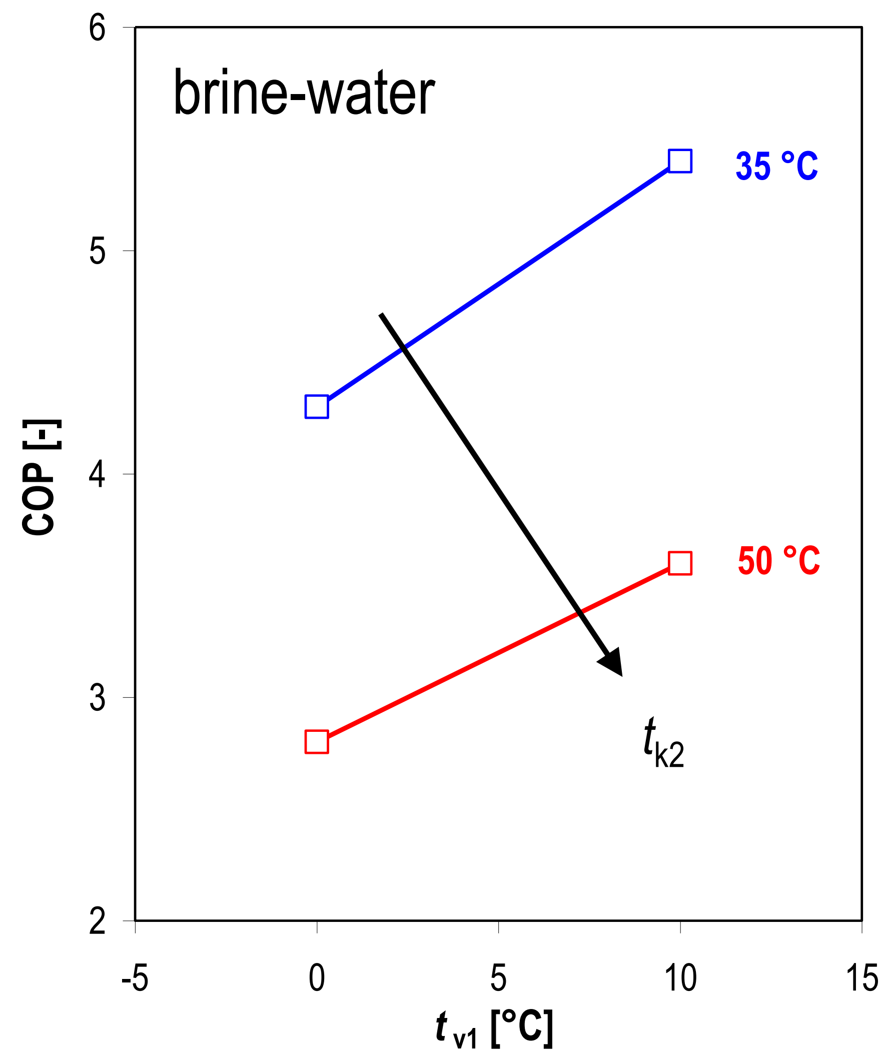


Air-water heat pump characteristics

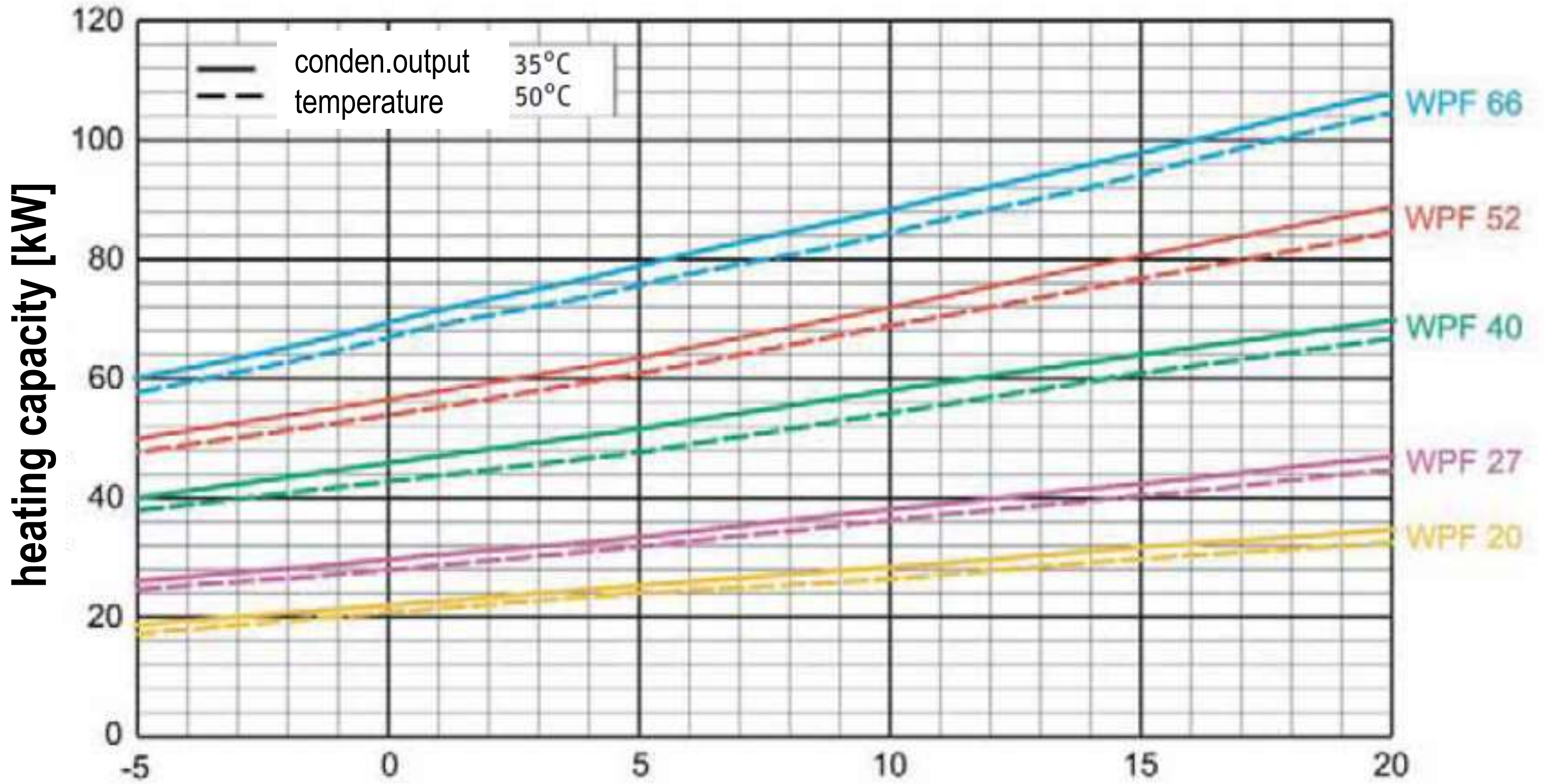


Brine-water heat pump (ground source)



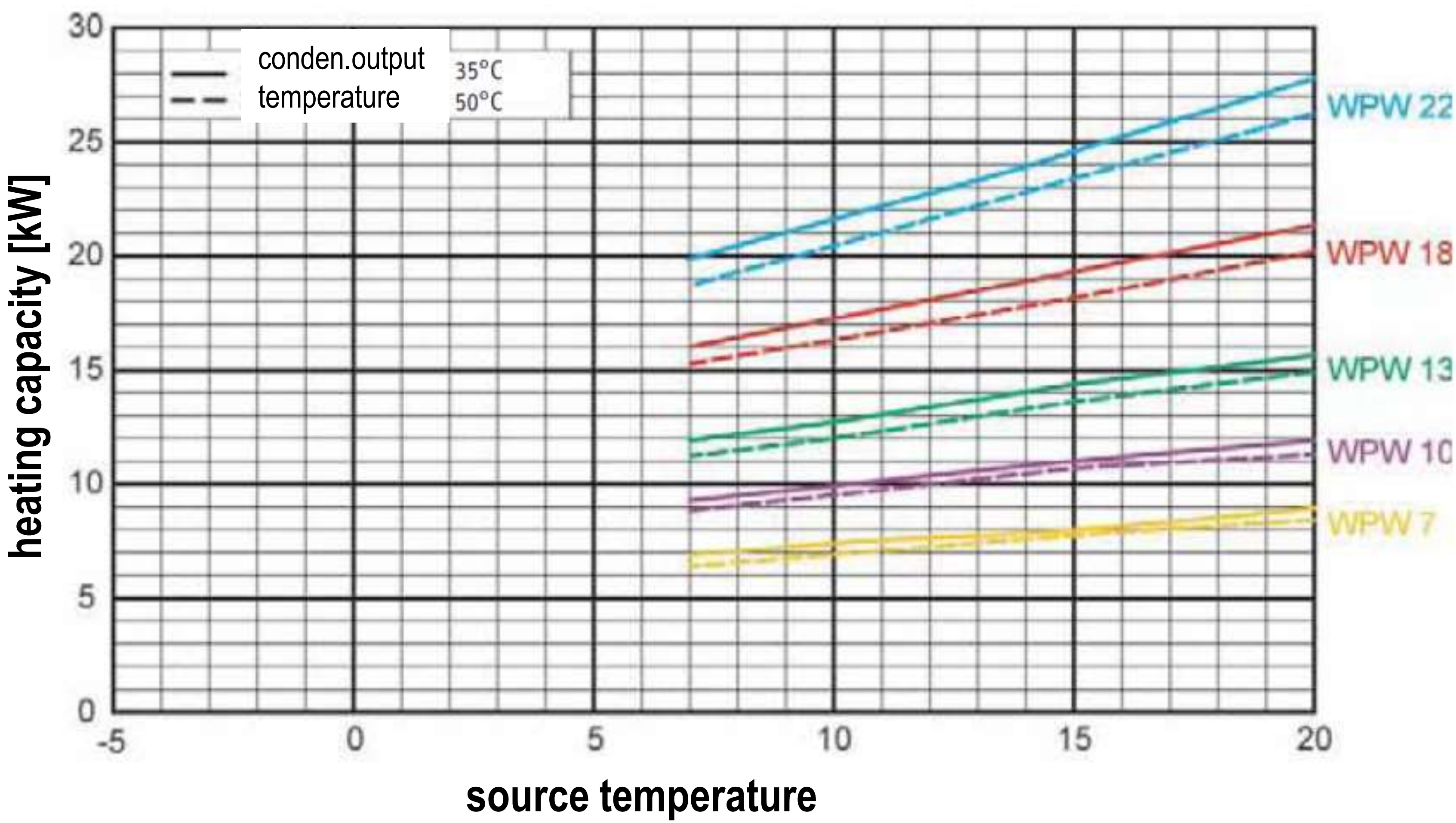


Brine-water heat pump (ground source)



source temperature

Water-water heat pump



Testing of heat pumps

- EN **14511** - Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.
  - EN 14511-1: dtto - Terms and definitions
  - EN 14511-2: dtto - Test conditions
  - EN 14511-3: dtto – Test methods
  - EN 14511-4: dtto - Requirements

- EN **16147** – Heat pumps with electrically driven compressors. Testing and requirements for marking of domestic hot water units

Testing conditions

- EN 14511: water-water **W/W** (W10 / W35)
  - **nominal: 10/35 °C** 10/45 °C
  - operation: 15/45 °C 10/55 °C
- EN 14511: brine-water (ground-water) **B/W** (B0 / W35)
  - **nominal: 0/35 °C** 0/45 °C
  - operation: 5/35 °C 5/45 °C 0/55 °C
    -5/45 °C
- EN 14511: air-water (ambient air) **A/W** (A2 / W35)
  - **nominal: 7/35 °C** 7/45 °C
  - operation: **2/35 °C** 2/45 °C 7/55 °C
    -7/35 °C -7/45 °C -7/55 °C
    -15/35 °C -15/45 °C

Requirements on heat pump

- **Quality label EHPA (European Heat Pump Association)**
- minimum *COP* from testing according to EN 14511 in respected lab

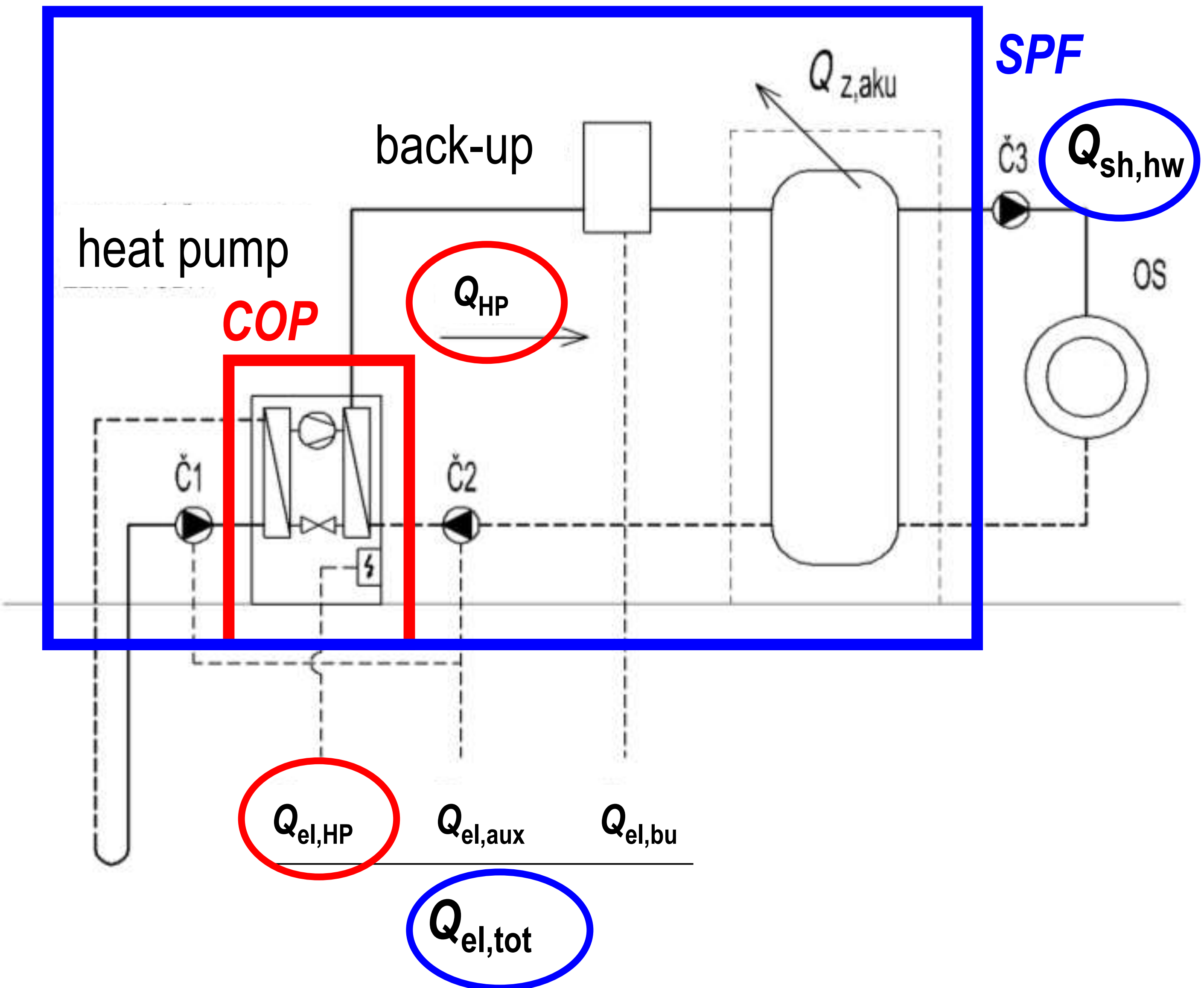
brine-water	**B0/W35**	***COP* > 4.3**
water-water	**W10/W35**	***COP* > 5.1**
air-water	**A2/W35**	***COP* > 3.1**

- declaration of sound power level
- documentation: planning, service and operation guides in local language
- customer service network, 24 h reaction time on customer complaints
- 2 years full warranty, spare parts inventory available for 10 years in stock

Seasonal performance factor

hot water

space heating



$$COP = \frac{Q_{HP}}{Q_{el,HP}}$$

$$SPF = \frac{Q_{sh,hw}}{Q_{el,tot}}$$

RES directive, minimum SPF

- **heat pumps consume electric energy**
  - produced mainly from fossil fuels (primary non-renewable energy source)

$$SPF > 1{,}15\,\frac{1}{\eta_e}$$

η_e electricity production efficiency
european average 45.5 %

***SPF* > 2.5**

if *SPF* < 2.5 ... better to use fossil fuels directly by combustion

EN 15450 – Annex C (informative)

Table C.1 — Default minimum and target values for SPF for heat pump systems employed for space heating and domestic hot water production in new buildings (typical for Central Europe)

energy source / sink	minimum value for SPF	target value for SPF
air / water	2,7	3,0
ground / water	3,5	4,0
water / water	3,8	4,5

Table C.2 — Default minimum and target values for SPF for heat pump systems employed for space heating and domestic hot water production in retrofit buildings (typical for Central Europe)

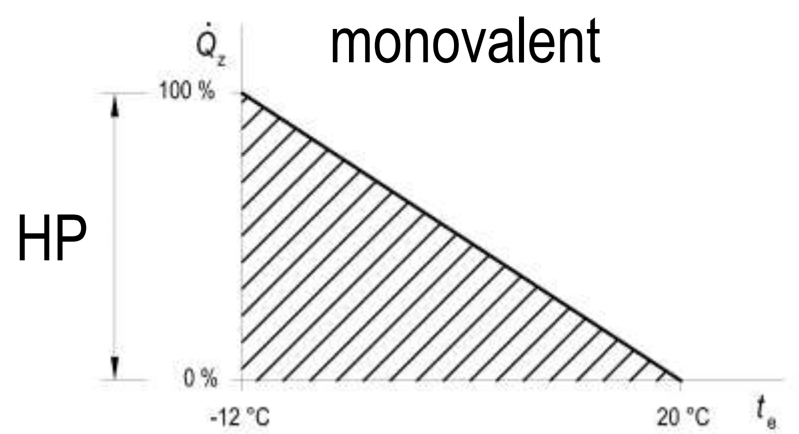
energy source / sink	minimum value for SPF	target value for SPF
air / water	2,5	2,8
ground / water	3,3	3,7
water / water	3,5	4,2

Table C.3 — Default minimum and target values for SPF for heat pump systems employed for domestic hot water production only (typical for Central Europe)

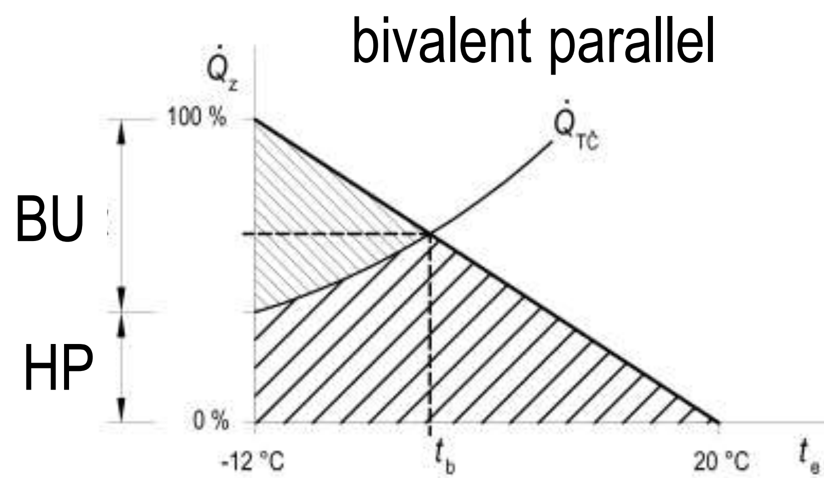
energy source / sink	minimum value for SPF	target value for SPF
air / water	2,3	2,8
ground / water	3,0	3,5
water / water	3,2	3,8

Operation modes

- **monovalent operation**
  - only heating device

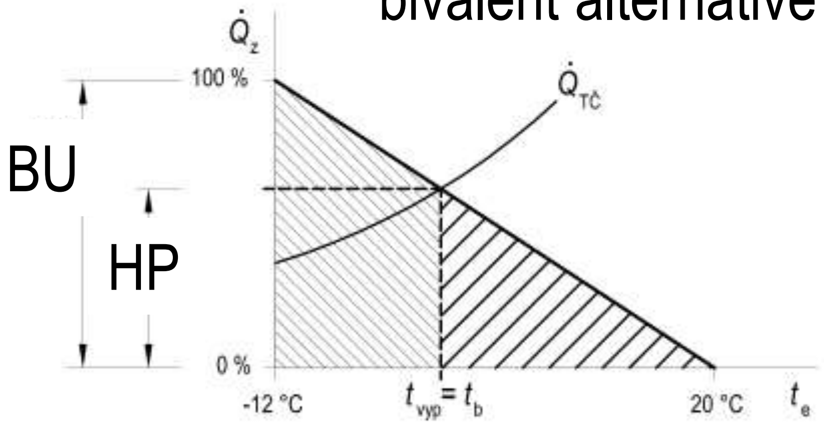


- **parallel bivalent operation**
  - under bivalent temperature (**balance point**) back-up heater is switched-on
  - low temperature systems



Operation modes

- **alternatively bivalent operation**
  - under bivalent temperature back-up replaced heat pump. for high temperature heating systems



the balance point = temperature

under which the back-up heater is required

Operation modes

- **monoenergetic operation**
  - e.g. bivalent operation of electric heat pump with electroboiler (integrated in one device)

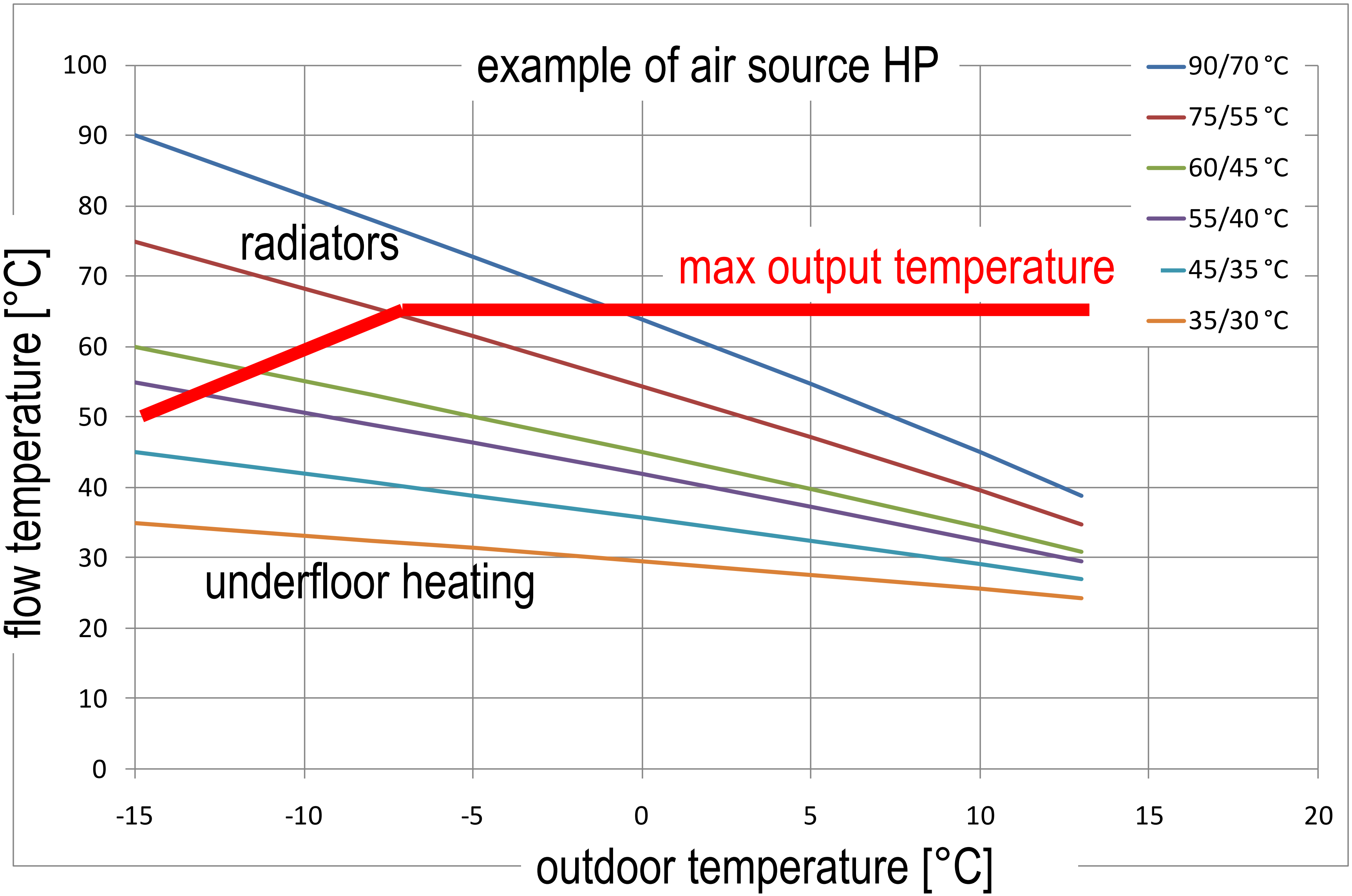
- **balance point**
  - according to heat output (dimensioning)
  - acc. heating water temperature
    - sufficient heat output from heat pump
    - high temperatures of heating water needed, which couldnt be supplied by heat pump, esp. in extreme winter

Heat pump sizing

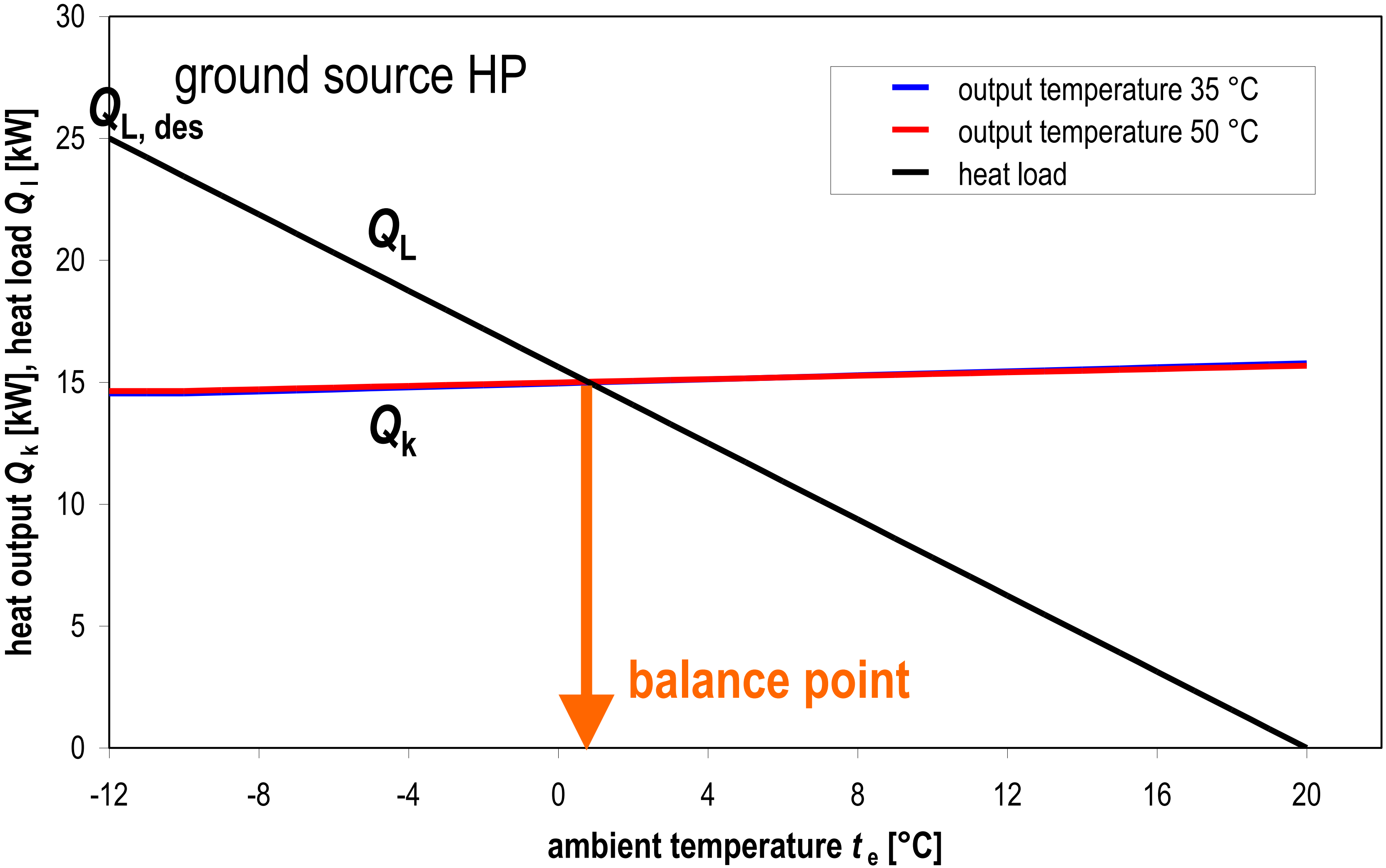
- **determination of heat pump type**
  - available heat source

- **determination of (condenser) heat output Q_k (for space heating)**
  - building heat loss
  - heat output for hot water
  - design flow temperature
  - design source temperature

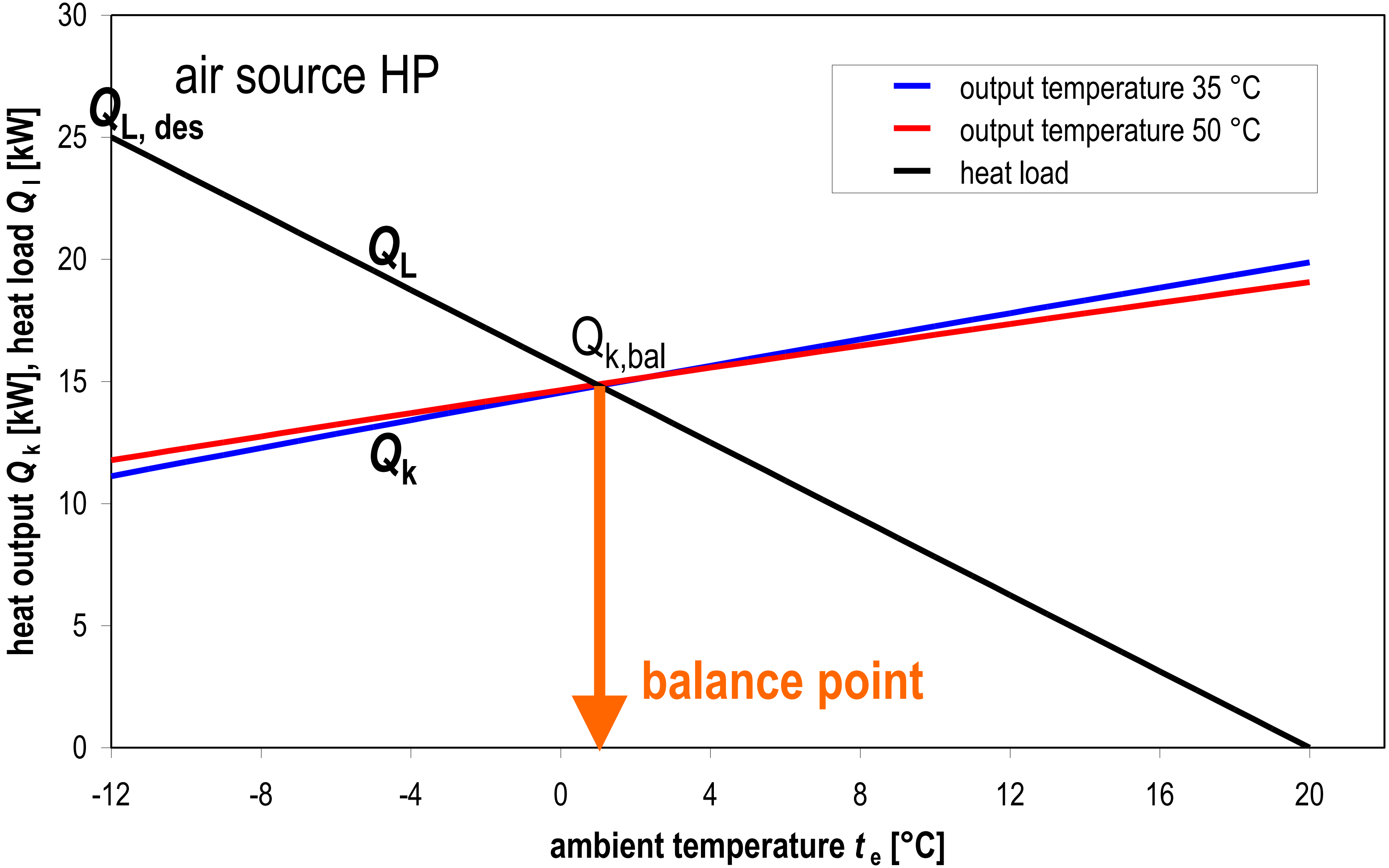
Balance point according to temperature



Balance point according to heat output



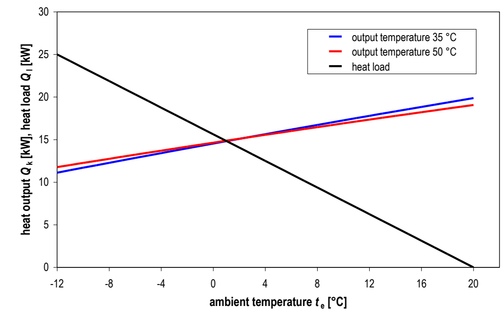
Balance point according to heat output



Balance point determination

- **design heat load $Q_{L,des}$**
  - calculation according to EN 12 831 for design external temperature (e.g. -12 °C, -15 °C, -18 °C in CZ)
- **heat output at balance point $Q_k = Q_L$**
  - e.g. from desired fraction 60 to 100 % $Q_{k,bal} / Q_{L,des}$

$$\frac{Q_{L,des}}{(t_i - t_{e,des})} = \frac{Q_L}{(t_i - t_e)} = \frac{Q_{k,bal}}{(t_i - t_{e,bal})}$$



$$t_{e,bal} = t_i - \frac{Q_{k,bal}}{Q_{L,des}}(t_i - t_{e,des})$$

if Q_k = konst

if $Q_k \neq$ konst - graph

Example

family house

design load 15 kW for

design temperature -15 °C

heat pump (SE WPL18)

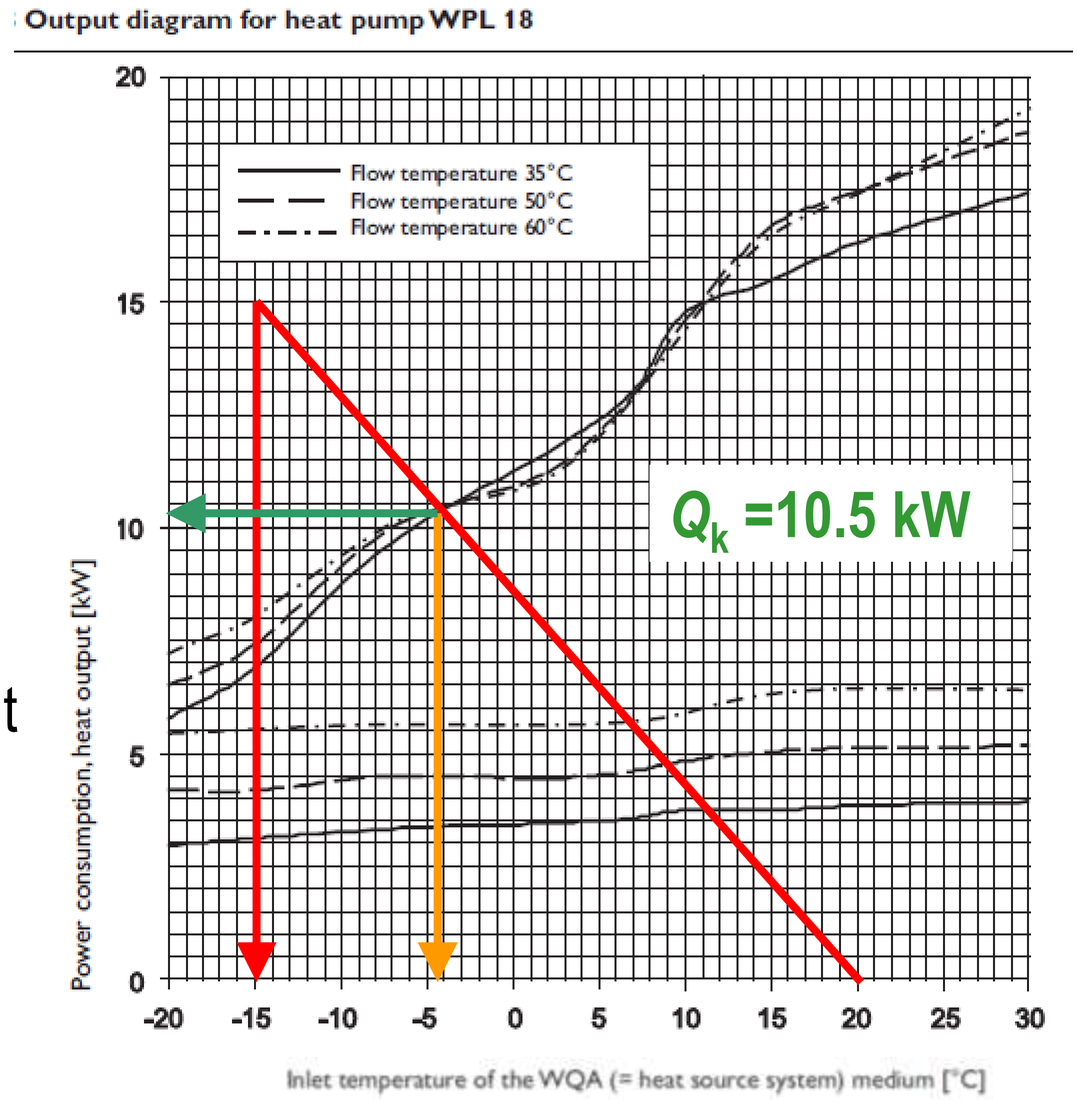
heating system 50/40 °C

determine the balance point

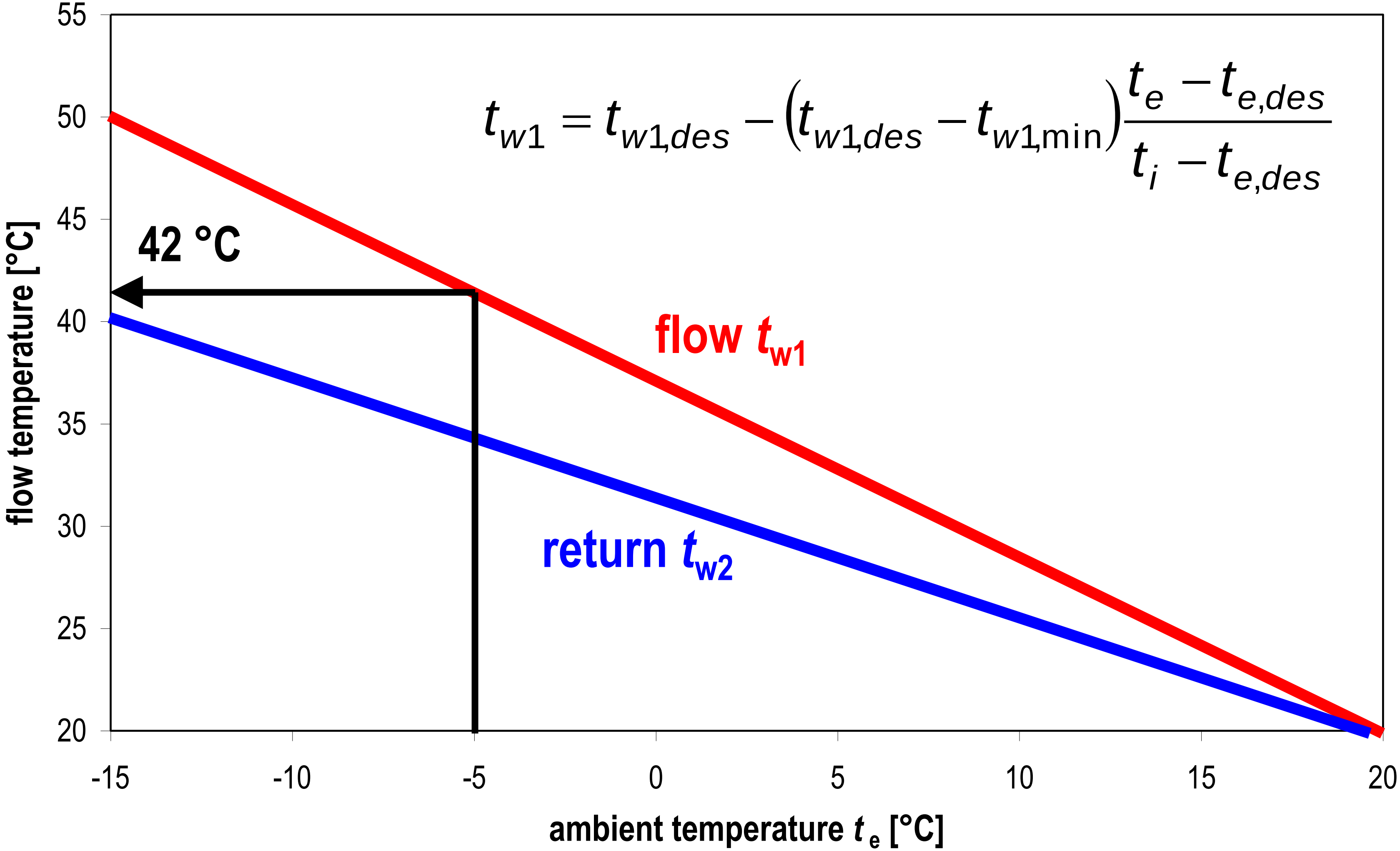
balance point heat output

balance point power input

balance point COP



Flow temperature



$$t_{w1} = t_{w1,des} - \left(t_{w1,des} - t_{w1,\min}\right)\frac{t_e - t_{e,des}}{t_i - t_{e,des}}$$

Power input at balance point

for balance power point

t_{v1} = -5 °C, t_{k2} = 42 °C

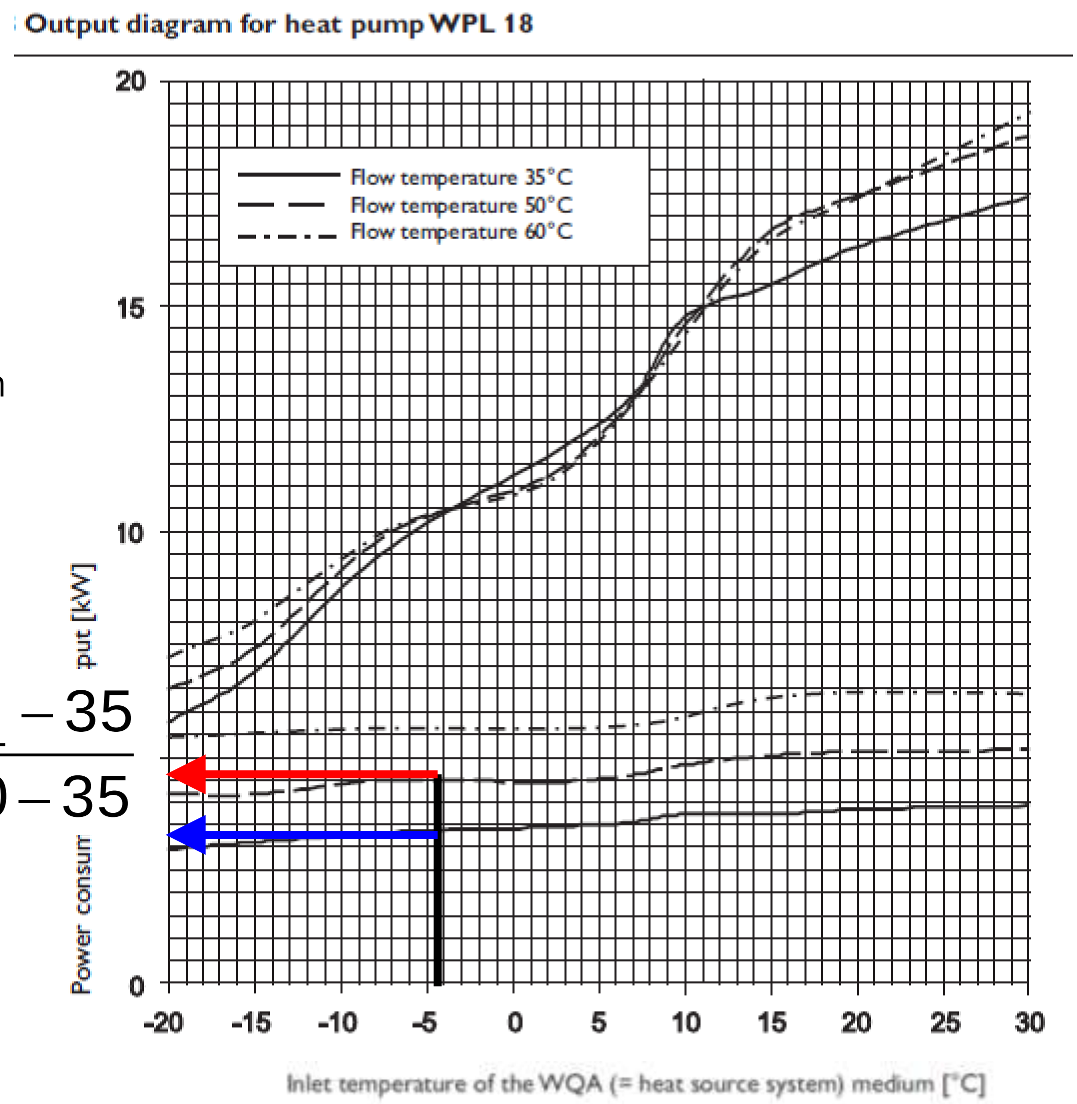
P_{35} = 3.3 kW

P_{50} = 4.5 kW

interpolation

$$\frac{P_{tw1} - P_{35}}{t_{w1} - 35} = \frac{P_{50} - P_{35}}{50 - 35}$$

$$P_{tw1} = P_{35} + \left(P_{50} - P_{35}\right)\frac{t_{w1} - 35}{50 - 35}$$

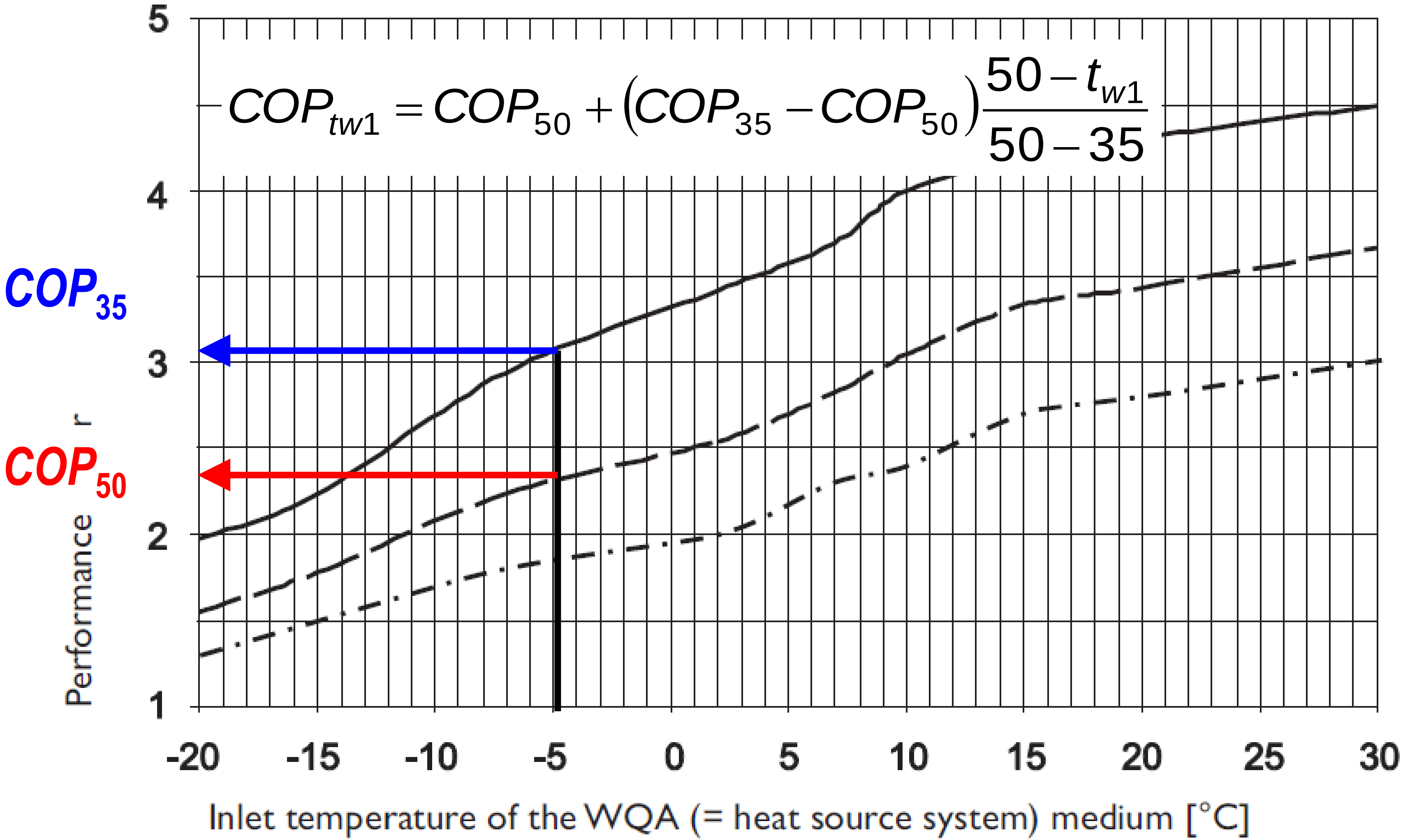


balance power point

P_{42} = 3.9 kW

Example

$$COP_{tw1} = COP_{50} + \left(COP_{35} - COP_{50}\right)\frac{50 - t_{w1}}{50 - 35}$$



Example

family house

design load 15 kW for

design temperature -15 °C

heat pump (SE WPL18)

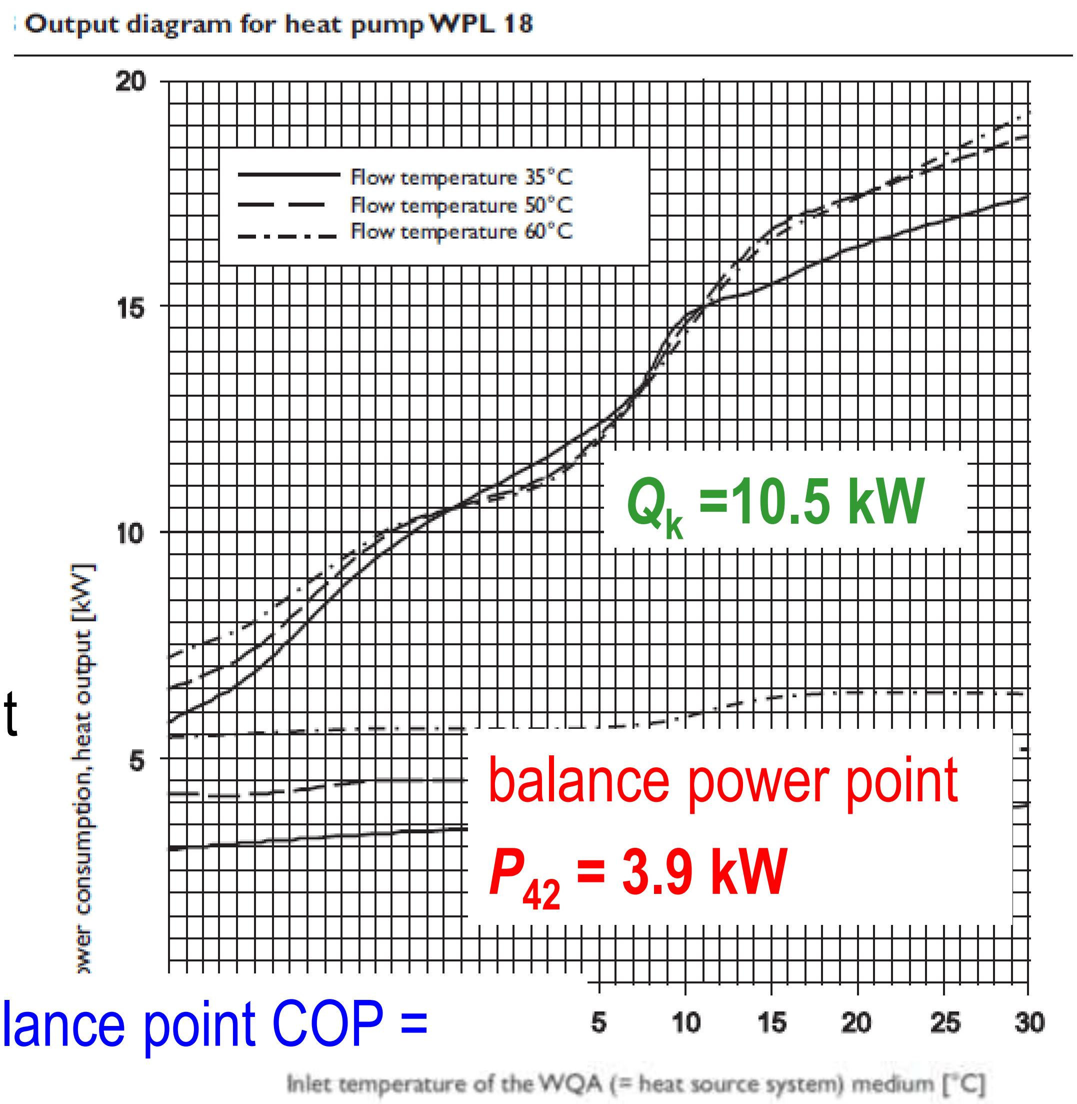
heating system 50/40 °C

determine the balance point

balance point heat output

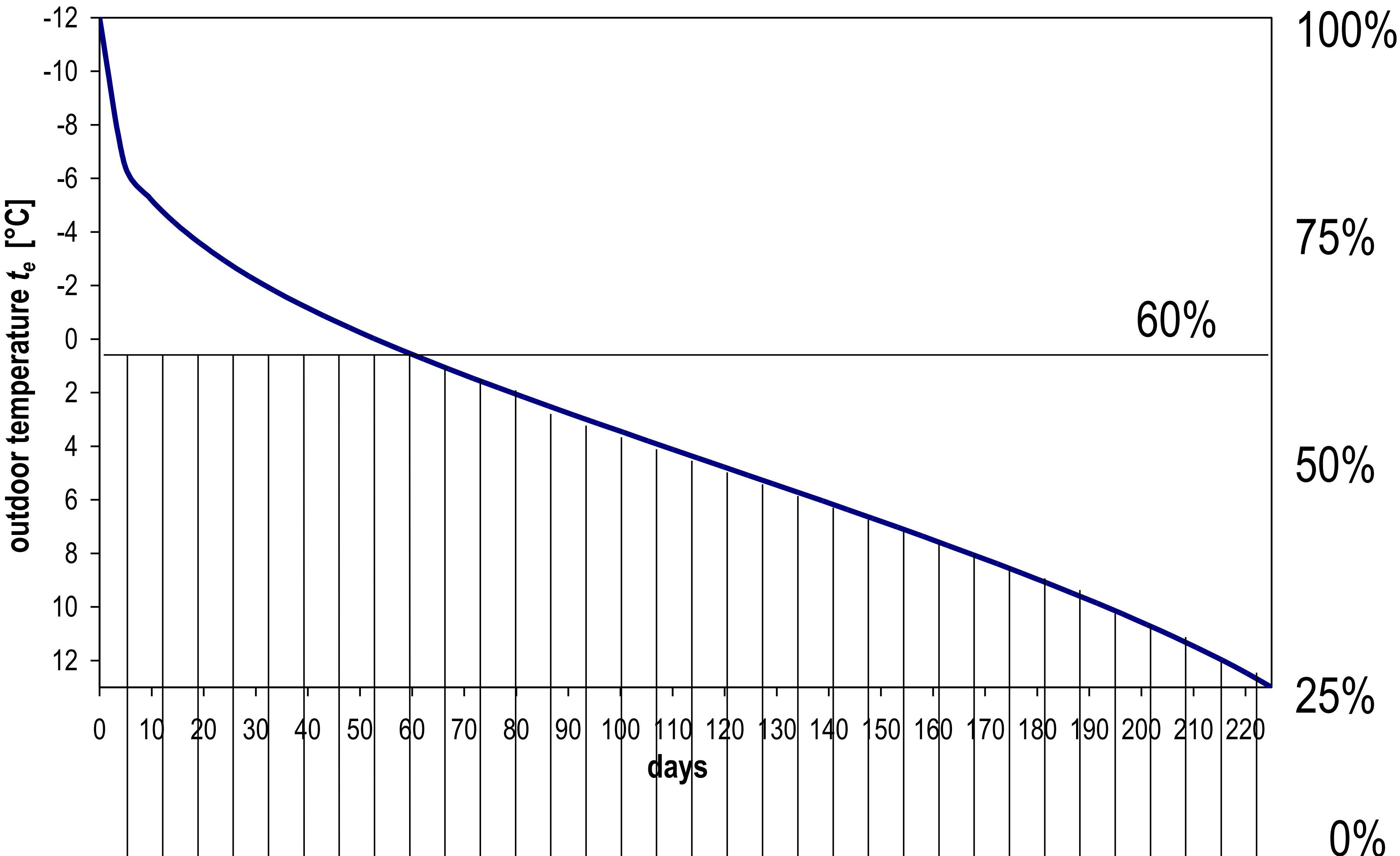
balance point power input

balance point COP

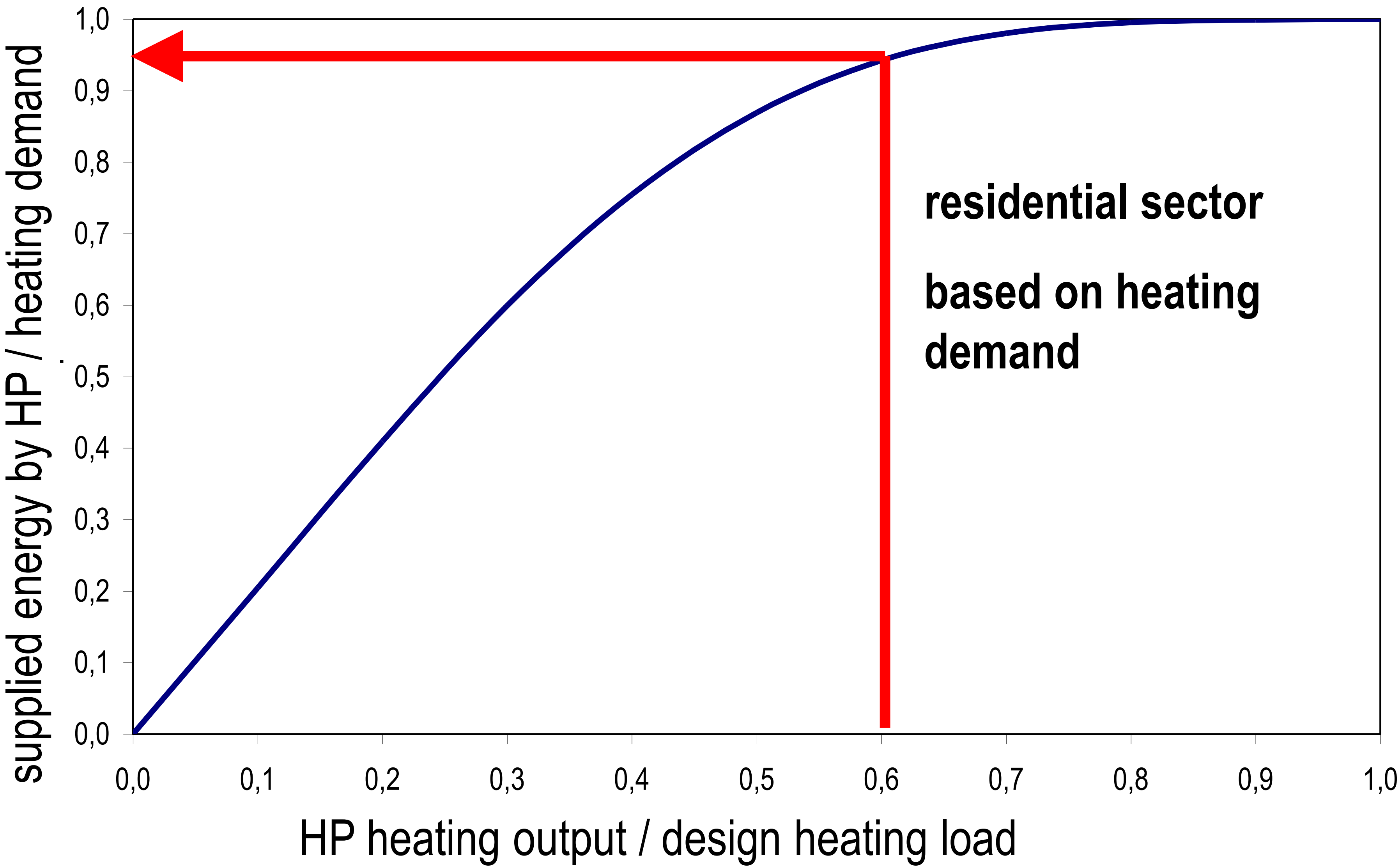


balance point COP =

Heat pump sizing – coverage of demand

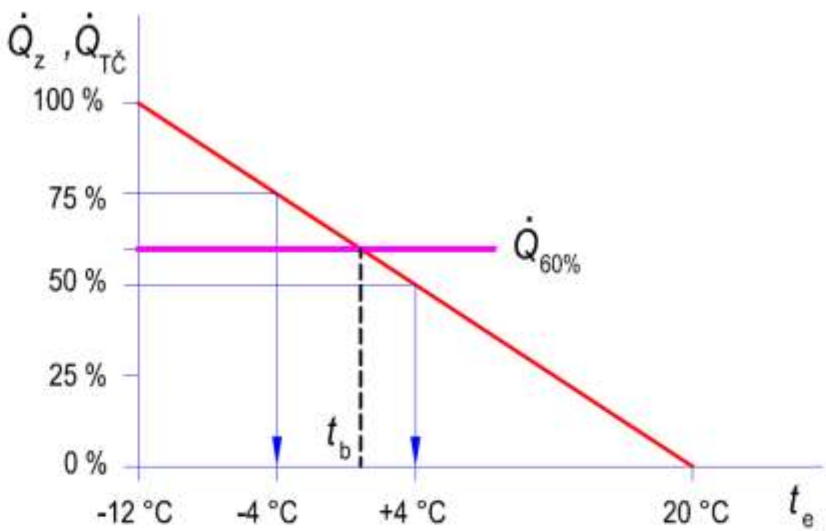


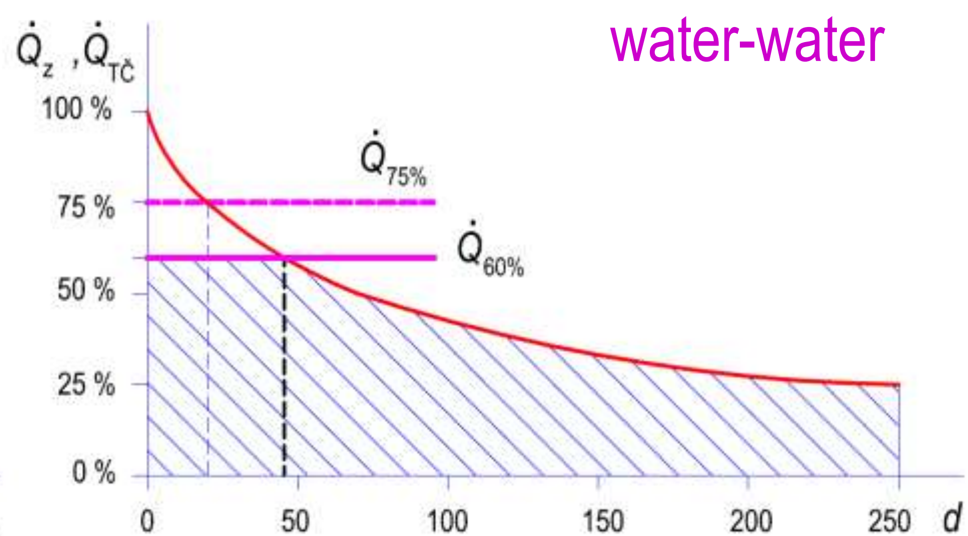
Heat pump sizing – coverage of demand



Heat pump sizing (ground source)

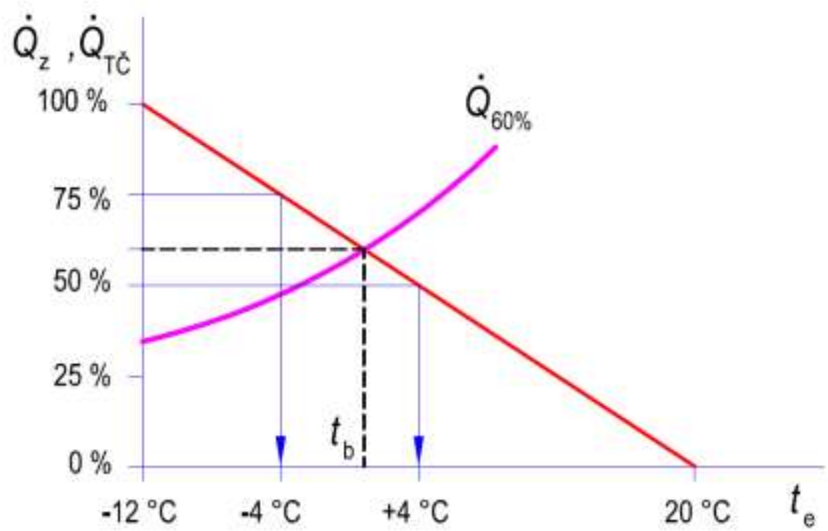
- **dimensioning heat output (independent on ambient conditions)**
  - 50 % heat loss - coverage 85 % heat demand
  - 60 % heat loss – coverage 93 % heat demand
  - 70 % heat loss - coverage 97 % heat demand

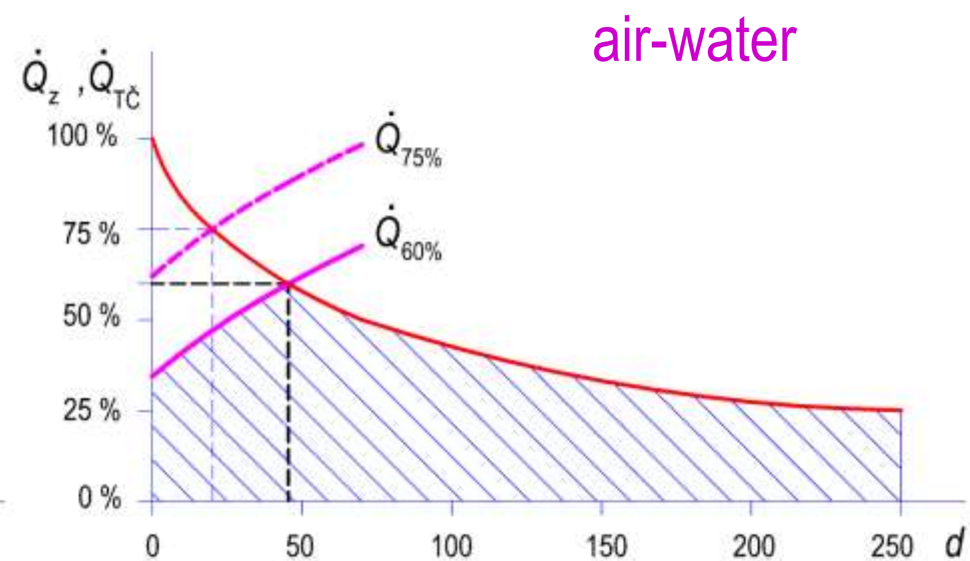




Heat pump sizing (air source)

- **dimensioning heat output (dependent on ambient conditions)**
  - 50 % heat loss - coverage 75 % heat demand
  - 60 % heat loss – coverage 85 % heat demand
  - 70 % heat loss - coverage 92 % heat demand



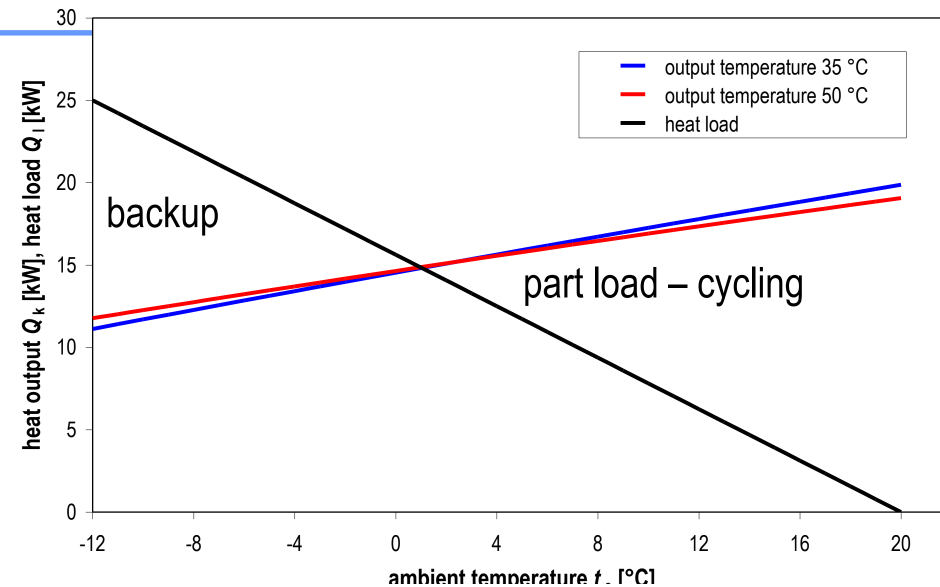


Heating capacity control

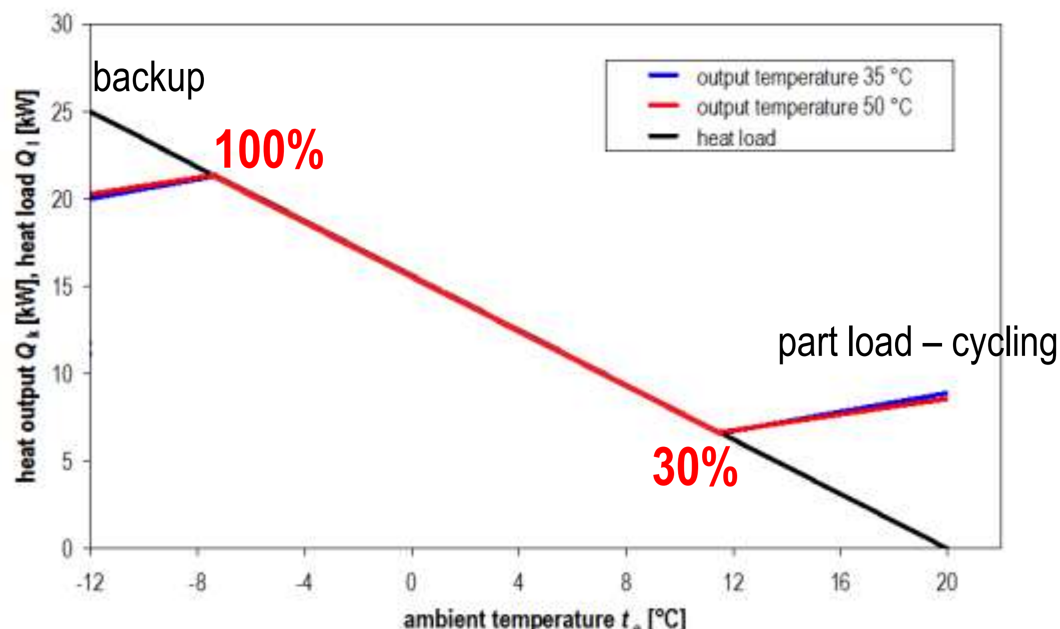
- **usual heat pumps**
  - start-stop regime
  - cycling = reduction of durability compressor
  - elimination cycling
    - undersizing
    - heat storage – sizing of store for minimum operation time of heat pump
- **heat pump with heating capacity control**
  - compressor speed control
  - possibility for monovalent operation

Heating capacity control

Without capacity control



With capacity control

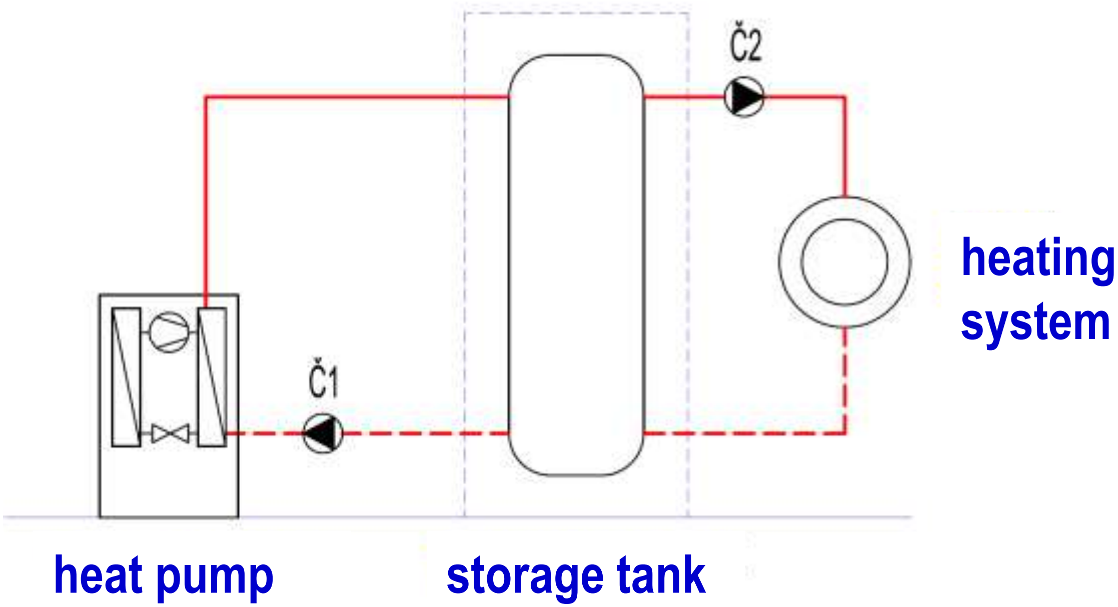


Heat storage for heat pump

- **oversized storage** for most of operation time
  - balancing heat output and heat load
- **reduction of frequency compressor on/off** (1 x 10 min)
  - longer durability of compressor
- **heat source for outdoor units** (air-water)
  - antifreeze protection

Heat storage for heat pump

- **hydraulic decoupling of heat pump** from load circuit
  - hydraulic shunt
  - heating systems can't influence HP circuit
  - providing required (higher) flowrates at condenser



Sizing of storage tank

- **balance** to reduce on/off frequency
  - minimum operation time period $\Delta\tau$
  - increase of temperature Δt in store during operation of heat pump
- heat stored during operation of heat pump

$$Q_{stored} = \dot{Q}_{HP} \cdot \Delta\tau = V \cdot \rho \cdot c \cdot \Delta t$$

Sizing of storage tank

specific volume

$$\frac{V}{\dot{Q}_{HP}} = \frac{1000 \cdot \Delta\tau}{\rho \cdot c \cdot \Delta t}$$

$\Delta\tau$ [s]	minimum operation time:	15 min
Δt [K]	increase of store temperature:	3 - 5 K

usually **15 to 30 l/kW**

thermal capacity (momentum) of heating system results in lower volume requirement

Example

- **calculate** heat storage volume for balance point heat output **10.5 kW**
  - minimum operation time period $\Delta\tau$ = 15 min
  - increase of temperature Δt in store 3 K

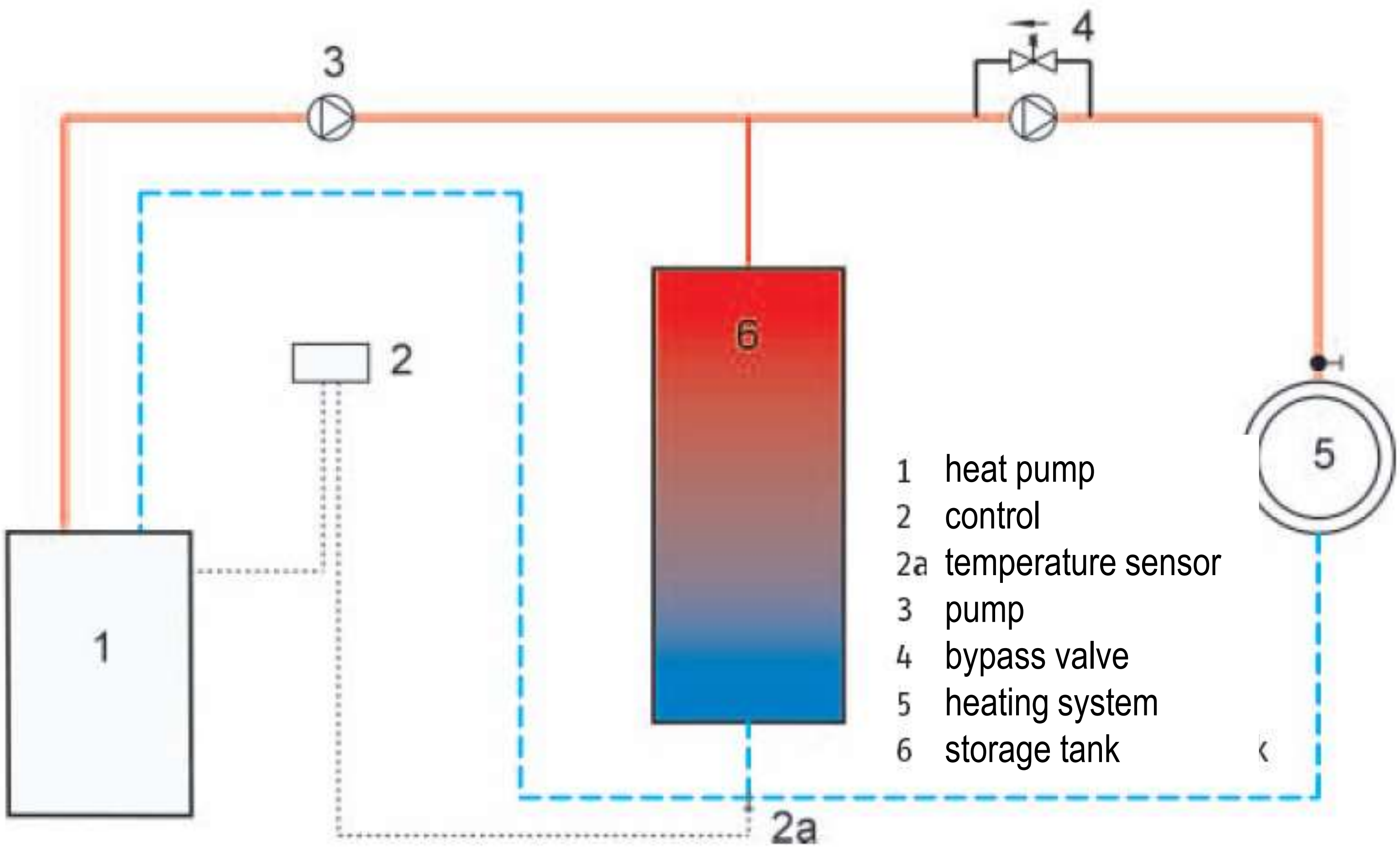
$$V = \dot{Q}_{HP} \frac{1000 \cdot \Delta\tau}{\rho \cdot c \cdot \Delta t}$$

$$V\ [\mathrm{m}^3] = \dot{Q}_{HP}\ [\mathrm{kW}] \cdot \frac{1000 \cdot 15 \cdot 60}{998 \cdot 4187 \cdot 3}$$

***V* = 754 l**

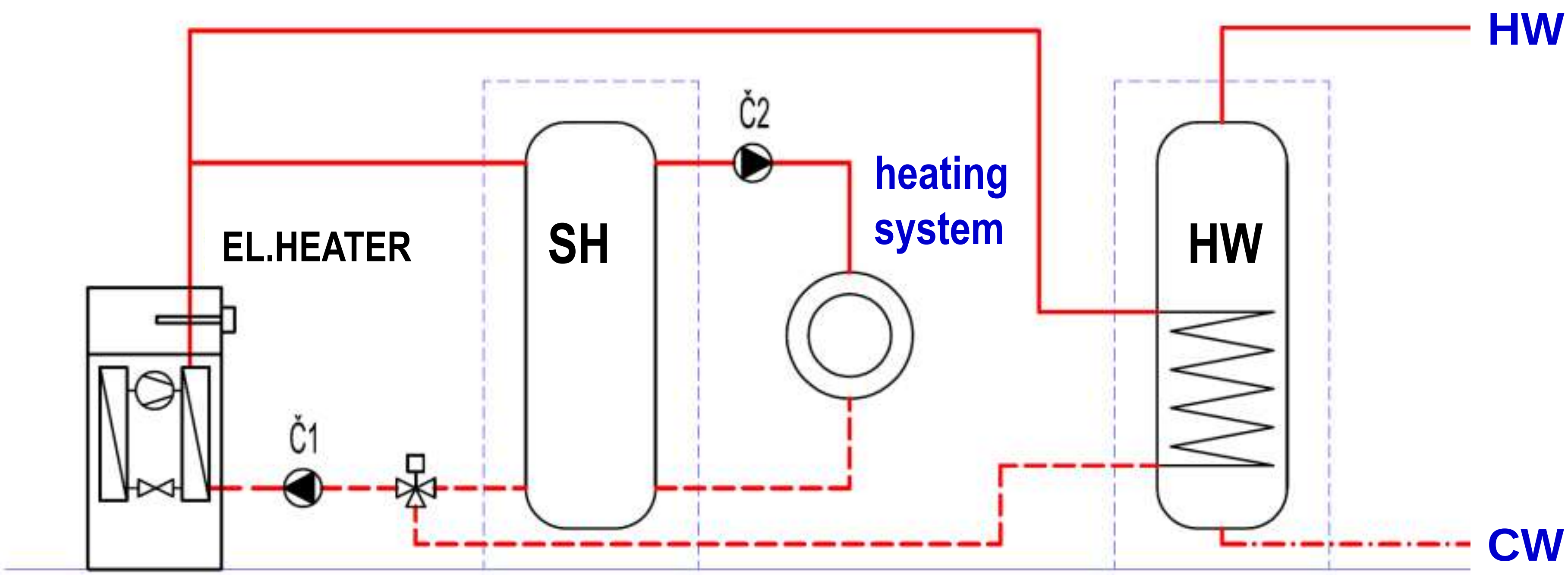
Integration of store

electronically
controlled pump



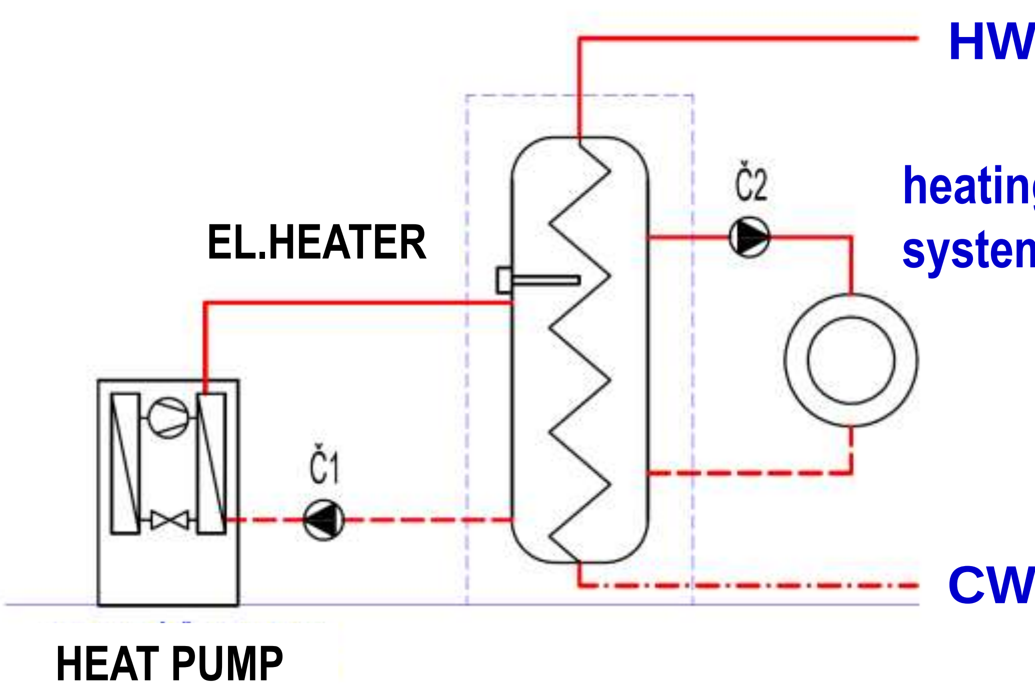
Hydraulics

- **with two stores**
  - heating water store, hot water store
  - bivalent (back-up) heater inside heat pump



Hydraulics

- **with central store**
  - hot water heated in heat exchanger immersed in heating water store volume
  - bivalent (back-up) heater: immersed in store



Guides for design

- **low temperature heating < 45 °C**
  - floor heating, wall heating
  - radiators with larger surface

- **pool water heating**
- **hot water**
  - low temperature 45 °C
  - air-water: advantage in summer, high ambient temperatures
  - brine-water: reduction of borehole regeneration (!)