Domestic Hot Water production

HEATING VENTILATION AIR CONDITIONING SYSTEMS
18-03-2025
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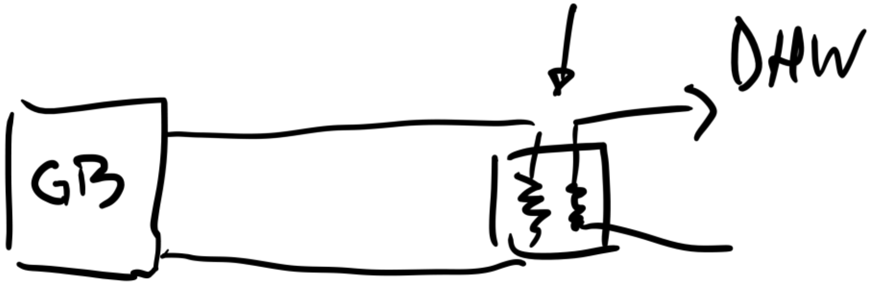
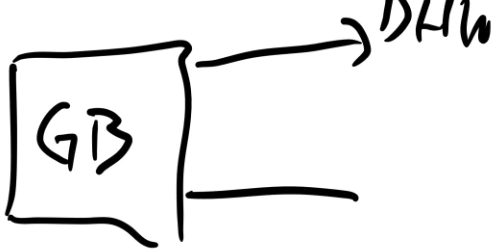
Classification of systems

Direct vs indirect production

- **Direct**: DHW is produced inside the heat generation (e.g. heat pump or gas boiler)
- **Indirect**: there is an intermediate heat exchanger between heat generation and DHW circuit

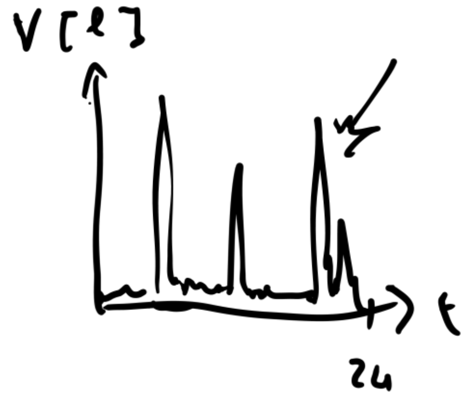




Classification of systems

Instantaneous systems vs systems with storage

- **Instantaneous**: heat generation (e.g. heat pump or gas boiler) supplies heat for DHW production to the users instantaneously (either direct or indirect)
- **With storage**: heat generation (e.g. heat pump or gas boiler) supplies heat to a thermal storage tank, which supplies heat to the users when needed (either direct or indirect)



Instantaneous production

Example

Single family house with 2 baths: 1 shower and 1 sink each.

Sinks: 2 (baths) + 1 (kitchen) + 1 (laundry) + 1 (bidet) = 5

Showers: 2 (baths)

Assume 6 l/min for sinks and 12 l/min for showers

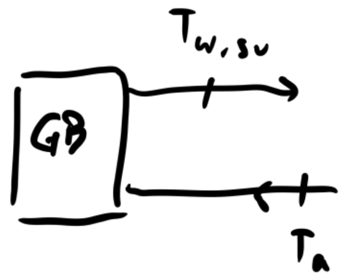
Instantaneous production

Example

Single family house with 2 baths: 1 shower and 1 sink each.

$$\dot{Q}_{v,max} = 2 \cdot 12 + 5 \cdot 6 = 54 \ l/min = 0.9 \ l/s \rightarrow \dot{m} = 0.9 \ kg/s$$

$$q = \dot{m} c_p (T_{w,su} - T_a) = 0.9 \cdot \underbrace{4.18}_{kJ/kgK} (40 - 10) = 113 \ kW$$



↳ unrealistic → oversizing

Instantaneous production

Example

Single family house with 2 baths: 1 shower and 1 sink each.

12 l/min

↓

$\frac{12}{60}$ kg/s

$$q = 0.2 \cdot 4.18 \, (40 - 10) = 25 \text{ kW}$$

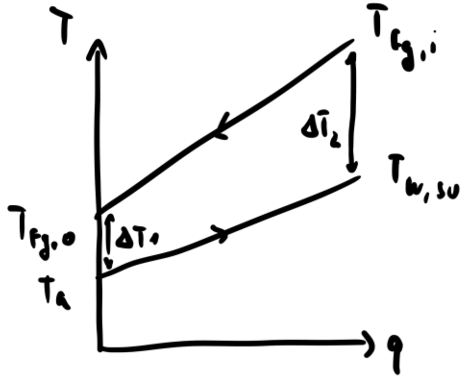
$$\boxed{q \simeq 30 \text{ kW}}$$

SH + <u>DHW</u> prod.

Instantaneous production

Heat source

Flue gases from gas boilers or hot water produced with heat pumps.



$$q_{peak,DHW} > q_{peak,SH}$$

$$\Delta T_1 = T_{fg,o} - T_a$$

$$\Delta T_2 = T_{fg,i} - T_{w,su}$$

$$\Delta T_{ml} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

$$S = \frac{q}{K \cdot \Delta T_{ml}}$$

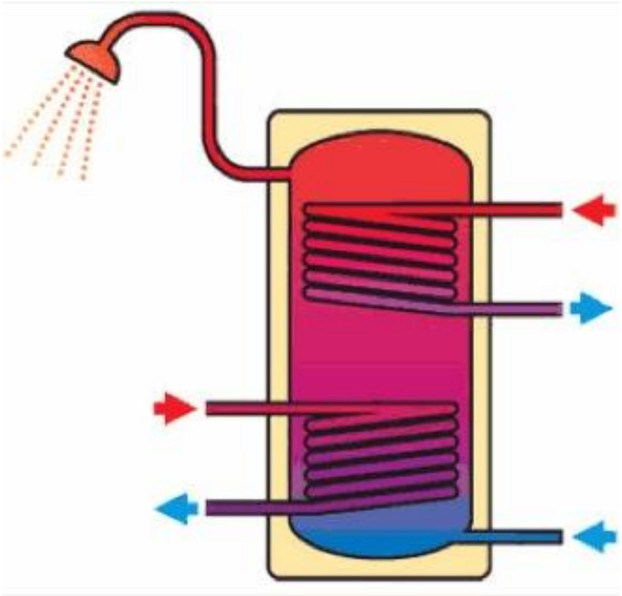
flue - gases
water

$$q = KS \cdot \Delta T_{ml}$$

Systems with storage

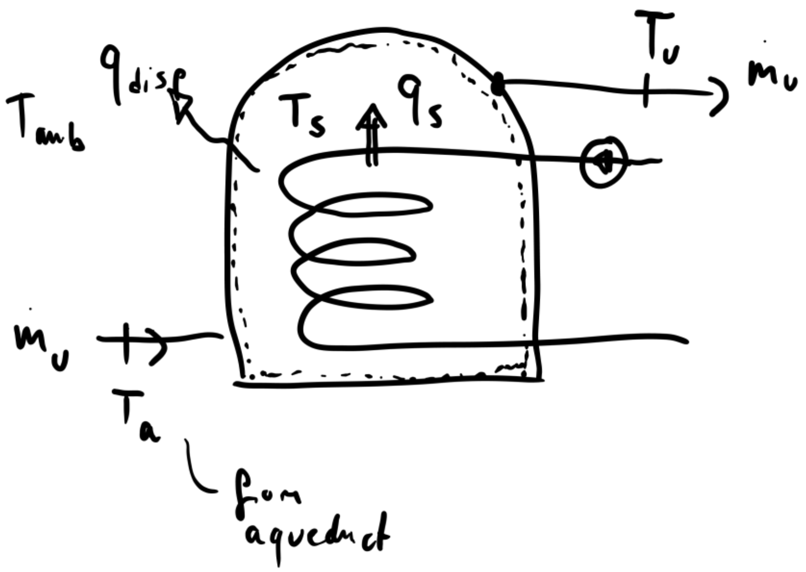
Classification of systems with storage

- **Mixed hot water tank**: the water in the tank is the domestic hot water (*accumulo a miscela*)
- **Thermal storage**: the water in the tank is technical water which heats up the domestic hot water through a coil (termo-*accumulo*)



Mixed hot water storage

Energy balance



$$q_s - q_{disp} = \dot{m}_v h_v - \dot{m}_v h_a + \frac{dU_{sist}}{d\tau} + \cancel{P}^{\,0}$$

$$q_s - \underbrace{UA}_{\text{walls}}(T_s - T_{amb}) = \dot{m}_v c_p (T_v - T_a) + \underline{\underline{m_s}}\, c_v \frac{dT_s}{d\tau}$$

Uniform temp. in storage $\quad T_v = T_s$

$$c_p = c_v = c = 4.186 \frac{kJ}{kg\,K}$$

Mixed hot water storage

Energy balance

$$q_s - UA\,(T_s - T_{amb}) = \dot{m}_u c\,(T_s - T_a) + \rho_w V_s c \frac{dT_s}{dt}$$

$$\rho_w V_s c \frac{dT_s}{dt} + T_s(\dot{m}_u c + UA) = q_s + UA \cdot T_{amb} + \dot{m}_u c T_a$$

$$\rightarrow \frac{dT_s}{dt} + T_s \underbrace{\left(\frac{\dot{m}_u c + UA}{\rho_w V_s c}\right)}_{a} = \underbrace{\frac{q_s + UA \cdot T_{amb} + \dot{m}_u c T_a}{\rho_w V_s c}}_{b}$$

$$\rightarrow \frac{dy(t)}{dt} + a\,y(t) = b \qquad y(t) = \frac{b}{a} + C e^{-at}$$

- sizing
- demand of the user

Mixed hot water storage

Energy balance

$$q_s - UA\,(T_s - T_{amb}) = \dot{m}_u c\,(T_s - T_a) + \rho_w V_s c \frac{dT_s}{dt}$$

$$\rho_w V_s c \frac{dT_s}{dt} + T_s\,(\dot{m}_u c + UA) = q_s + UA \cdot T_{amb} + \dot{m}_u c T_a$$

$$\rightarrow \frac{dT_s}{dt} + T_s \underbrace{\left(\frac{\dot{m}_u c + UA}{\rho_w V_s c}\right)}_{a} = \underbrace{\frac{q_s + UA \cdot T_{amb} + \dot{m}_u c T_a}{\rho_w V_s c}}_{b}$$

- sizing
- demand of the user

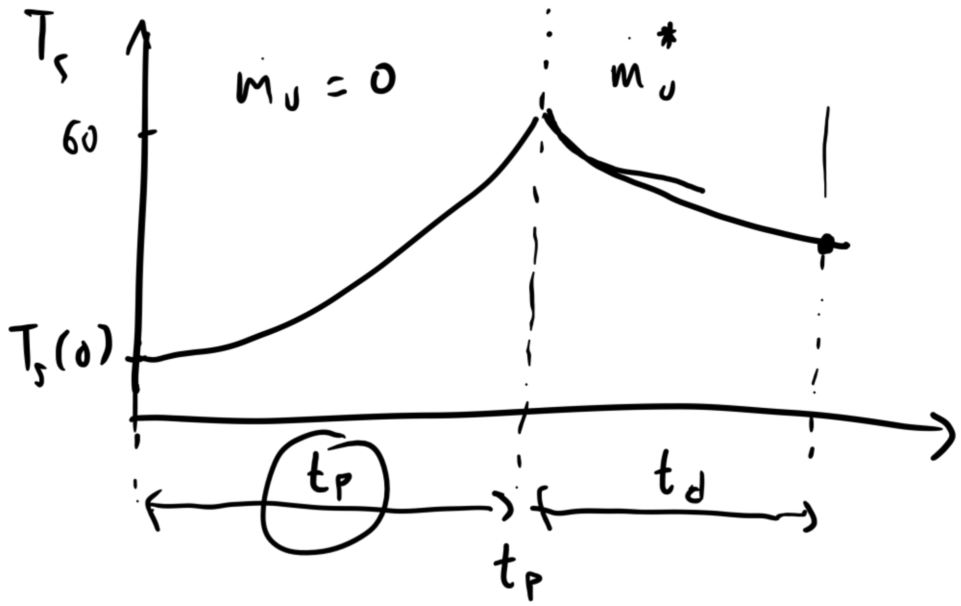
$$\rightarrow \frac{dy(t)}{dt} + a\,y(t) = b \qquad y(t) = \frac{b}{a} + C e^{-at}$$

Mixed hot water storage

Energy balance

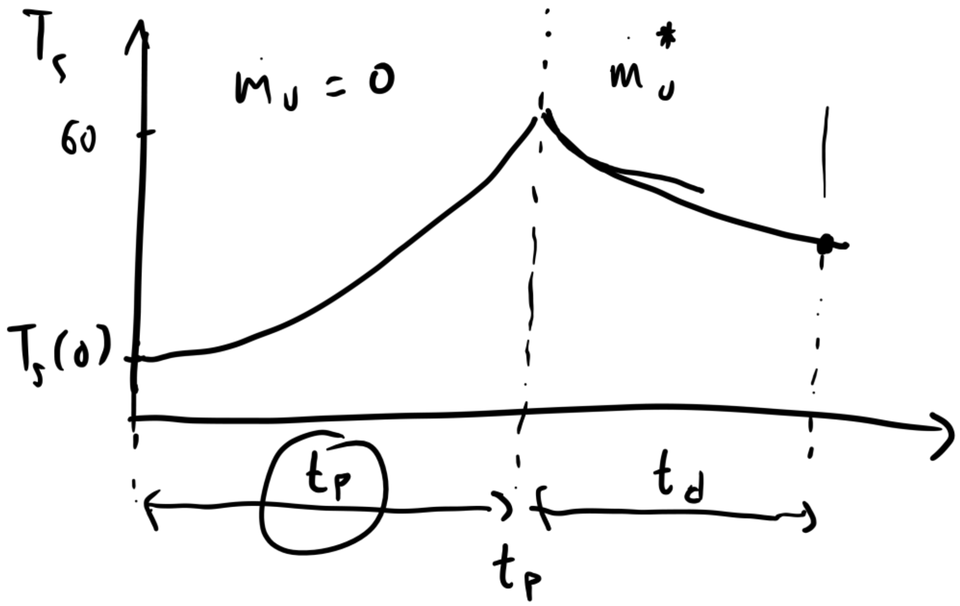
$$\begin{cases} T_s(t) = \frac{b}{a} + C e^{-at} \\ T_s(t=0) = \frac{b}{a} + C \quad \rightarrow \quad C = T_s(0) - \frac{b}{a} \end{cases}$$

$$T_s(t) = \frac{b}{a} + \left(T_s(0) - \frac{b}{a} \right) e^{-at}$$



Mixed hot water storage

Energy balance



$\dot{m}_v = 0$ Pre-heating

$\dot{m}_v \leftarrow ?$ Delivery

Pre-heating	$a = a_p$	$b = b_p$	$(\dot{m}_v = 0)$
Delivery	$a = a_d$	$b = b_d$	$(\dot{m}_v^*)$

Mixed hot water storage

Sizing

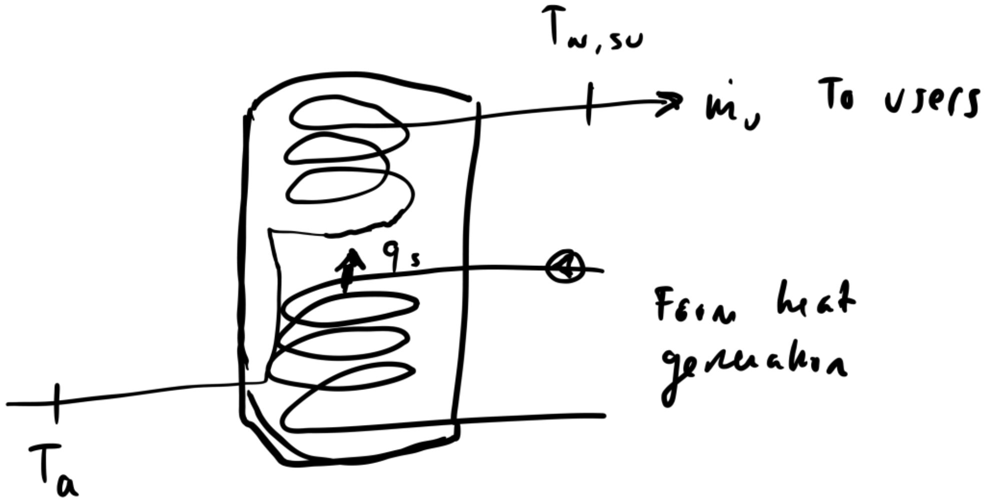
Fix pre-heating time (t_p) and delivery time (t_d)

→

find hot water storage volume (V_s) and thermal power of the coil (q_s)

Thermal storage

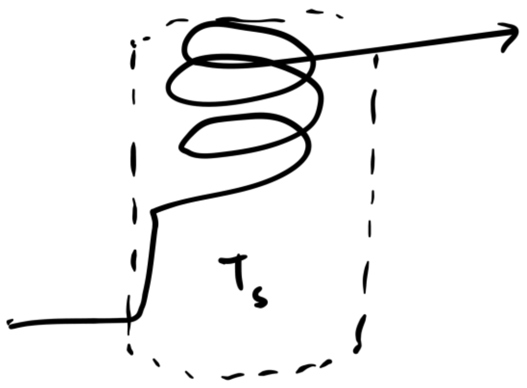
Energy balance

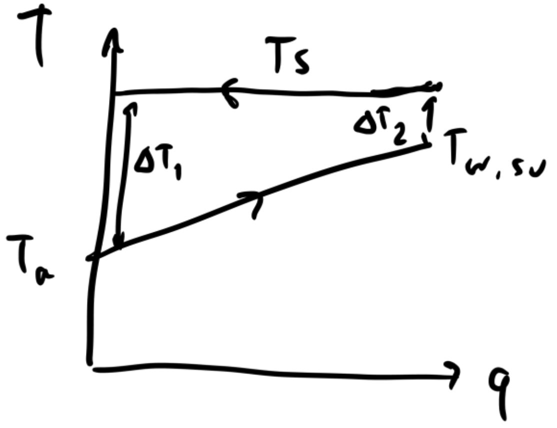


$$q_s - UA\,(T_s - T_{amb}) = \dot{m}_u c\,(T_{w,su} - T_a) + m_s c \frac{dT_s}{dt}$$

Thermal storage

Energy balance





$$q_{st \to w} = \dot{m}_w c_p (T_{w,su} - T_a)$$

$$q_{st \to w} = KS \frac{T_{w,su} - T_a}{\ln \frac{T_s - T_a}{T_s - T_{w,su}}}$$

$$\dot{m}_w c (T_{w,su} - T_a) = KS \frac{T_{w,su} - T_a}{\ln \frac{T_s - T_a}{T_s - T}}$$

$$\ln \frac{T_s - T_a}{T_s - T_{w,su}} = \frac{KS}{\dot{m}_w c}$$

Thermal storage

Energy balance

$$\frac{T_s - T_a}{T_s - T_{w,su}} = e^{\frac{KS}{\dot{m}_w c}}$$

$$T_{w,su} = f(T_s)$$

[for mixed hot water st: $T_w = T_s$]

$$\hookrightarrow T_{w,su} = T_s - (T_s - T_{w,c})\, e^{\frac{-KS}{\dot{m}_w c}} \leftarrow$$

$$q_s - UA(T_s - T_{amb}) = \dot{m}_w c\,(T_{w,su} - T_a) + m_s c \frac{dT_s}{dt}$$

Thermal storage

Sizing

Fix pre-heating time (t_p) and delivery time (t_d)

→

find hot water storage volume (V_s) and thermal power of the coil (q_s)

Operating temperature

The problem of legionella

Legionella is an aerobic bacterium that grows in warm (20-50°C) aquatic habitats.

It is a problem in case of stagnating water → mixed hot water storage systems.

Operating temperature

The problem of legionella

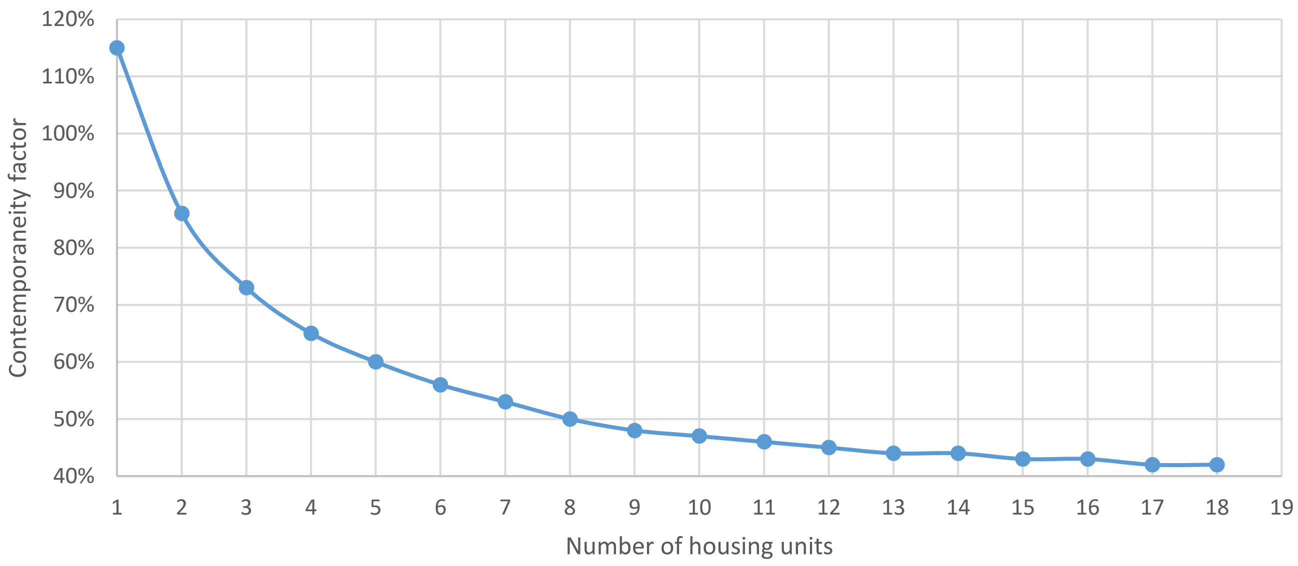
Can be prevented by:

- Avoiding stagnation
- Keeping Ts > 60°C (threshold depending on the Standard)
- Thermal shocks or anti-legionella cycles (bringing Ts to 70-80°C every day for 30 minutes)
- Hyper-cloarting hot water (disinfecting action)

Sizing for multiple units

Contemporaneity factor

Users do not ask for DHW exactly in the same moment



Integration of renewables

Solar heat

Heat from solar collectors into systems with storage