UNIVERSITÀ DEGLI STUDI DI PADOVA

DEPARTMENT OF INDUSTRIAL ENGINEERING
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BETALAB

SIZING OF DOMESTIC HOT WATER PRODUCTION SYSTEMS

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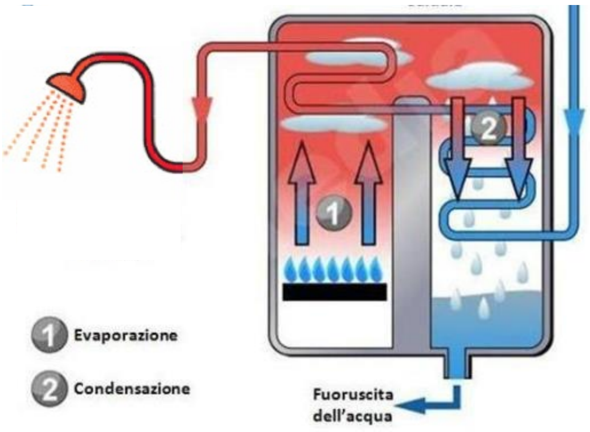
OUTLINE

- Introduction
  - Recap on DHW preparation systems (Istantaneous/ Thermal storage)
  - Recap on direct/indirect storage heat systems
- Sizing
- Energy need and examples
- Main output
- Conclusions and further information

Instantaneous water heater
The heat warms up instantaneously the required water flow rate by means of combustion products or through an electric resistance (gas boiler or electric boiler)

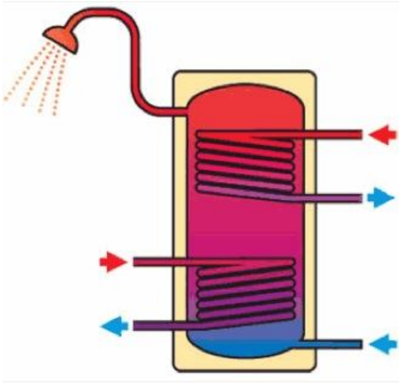


- System with a heat exchanger where water flows and heats up **without storage**.

- Requires **relevant peak power** (increase of water temperature from **10°C** to **40°C)**.

- Limit of the power installed because fixed the maximum power, the flow rate is therefore defined.

- Systems limited to single users



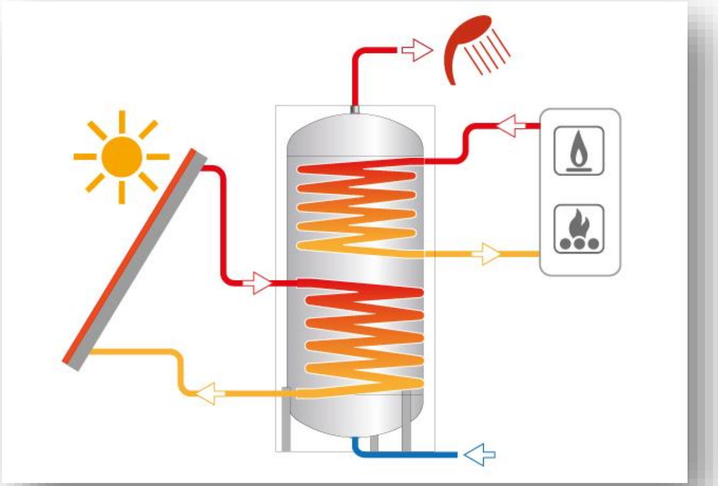
Stored Heat
The hot water is heated by a fluid (direct water or indirect fluid) which has been previously heated in tanks

ADVANTAGE/DISADVANTAGE?

- (−) certain time to heat up the water of the tank before using the water at the required temperature
- (−) certain volume
- (+) sensible reduction of the peak power installed

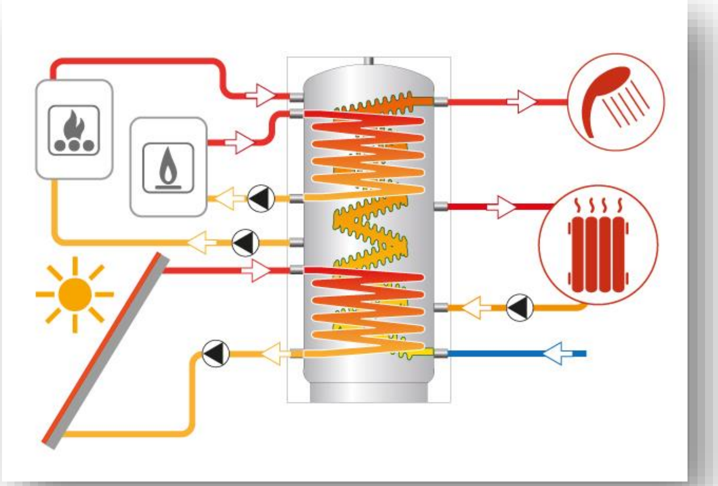
Direct systems

Cold water from the aqueduct is directly supplied in the water tank and mixed with the already present warm water



Indirect systems with internal heat exchanger

Cold water can flow inside a heat exchanger installed inside the water tank. The water tank could be the same as the one for the heating system circuit or separated from the heating system circuit

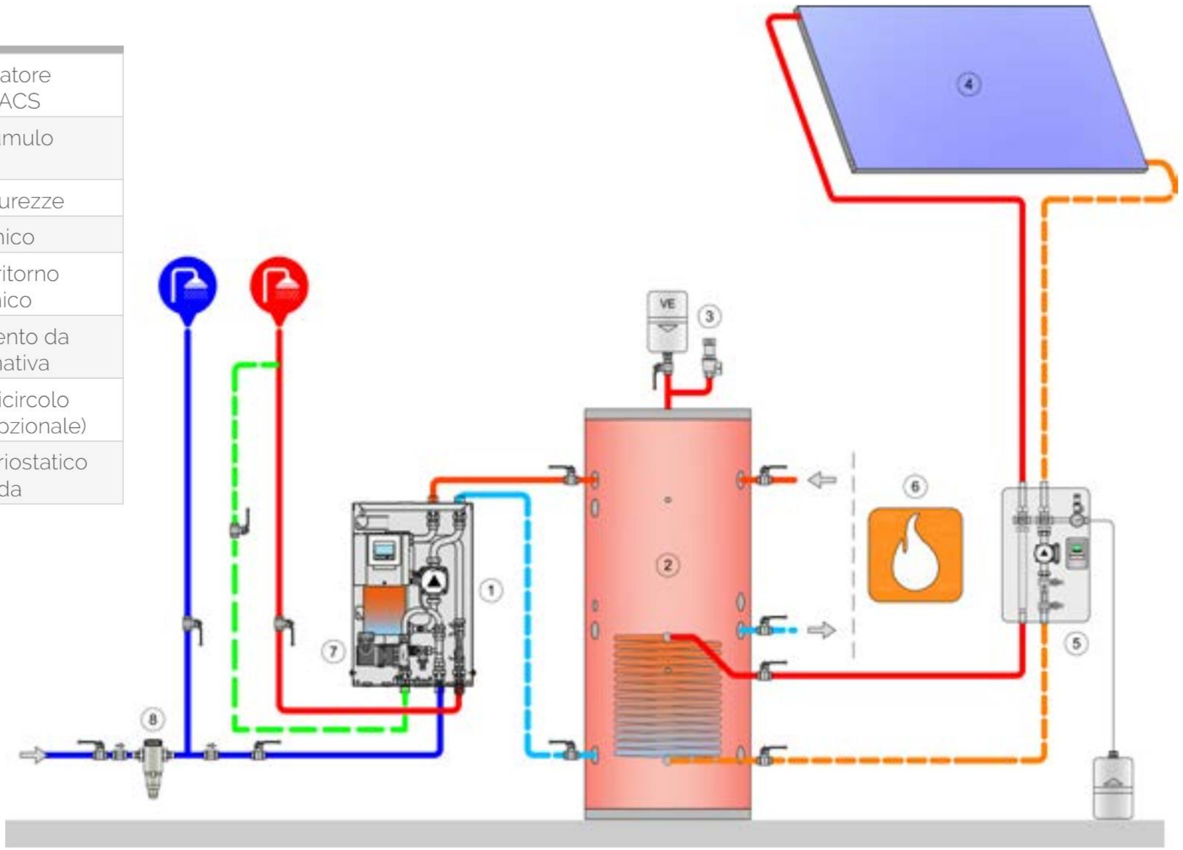


Indirect systems with external heat exchanger

Cold water from the aqueduct is heated inside a separated heat exchanger where hot water comes from the water tank

Legenda

1	SET preparatore istantaneo ACS
2	Termoaccumulo Fiorini PFB
3	Gruppo sicurezze
4	Solare termico
5	Gruppo di ritorno solare termico
6	Riscaldamento da fonte alternativa
7	Pompa di ricircolo sanitario (opzionale)
8	Filtro batteriostatico acqua fredda



These two equations can be solved together in order to achieve q_R and C, once defined the pre-heating tome t_p and the supply time t_e

DIRECT SYSTEM

$$q_R\,(\tau_p + \tau_e) = m_e \cdot c_A\,(t_e - t_A) + q_{dp} \cdot \tau_p + q_{de} \cdot \tau_e + C \cdot c_A \cdot (t_e - t_A)$$

$$q_R \cdot \tau_p = C \cdot c_A \cdot (t_{max} - t_A) + q_{dp} \cdot \tau_p$$

INDIRECT SYSTEM WITH INTERNAL HEAT EXCHANGER

$$(q_R - q_{dp}) \cdot \tau_p = C \cdot c_A \cdot (t_{max} - t_A)$$

$$(q_R - q_{de}) \cdot \tau_e + C \cdot c_A \cdot (t_{max} - t_{min}) = m_e \cdot c_A \cdot (t_e - t_A)$$

PEAK LOAD – DETAILED METHOD

Hypothesis:

Net area of the building 125 m^2

τ_p = 2h

	L per use	Number of fixtures (numero di sanitari)	Amount of water used at 40° [L]	Times of use during the reference peak period	Total volume per fixture [L]
Bath tub	100	0	0	1.00	0
Shower	60	2	120	1.00	120
Toilet sink	10	2	20	4.00	80
Bidet	8	2	16	2.00	32
Kitchen sink	15	1	15	1.00	15
TOTAL					**247**

PEAK LOAD – SIMPLIFIED METHOD

Hypothesis:

Net area of the building, $S_u = 125\ m^2$

$\tau p = 2h$

$m_e = 1.9918\ S_u + 70.823$

S_u [m²]	τ_e [h]
50 – 90	1
90 - 120	1.5
> 120	2

In order to obtain different results from your collegues, you are supposed to use the net area of your house to determine m_e and τ_e from the equation and the table!!
NB: mimimum area to be considered 50 m² with minimum 3 rooms

Then, we should solve the system of equations to calculate C and q_R

NET ENERGY DEMAND FOR A RESIDENTIAL BUILDING

For residential buildings, the water volume V_w [L/d] is calculated as:

$$V_w = a \, x \, S_u + b$$

a [L/(d m²)] S_u [m²]   b [L/d]

Net surface [m²]	Su ≤ 35	35 < Su < 50	50 < Su < 200	Su > 200
a	0	2.667	1.607	0
b	50	-43.33	36.67	250

EXAMPLE 1 - ENERGY NEED FOR DHW

Case study

Single unit residential building

1 unit hosting 6 people

Net surface area of 180 m^2

Calculation

From Table 30 of the standard 11300-2:

a=1,067

b= 36,67

The daily volume of DHW is:

$$V_w = a \, x \, S_u + b$$

$$= 1{,}067 \times 180 + 36{,}67$$

$$= 228{,}73 \quad L/d$$

NET ENERGY DEMAND FOR A NON-RESIDENTIAL BUILDING

In the Italian standard the daily volume of water is expressed as:

$$V_w = a \; x \; N_u \quad [\mathrm{L/d}]$$

a: parameter in [L/(d x N_u)]

N_u: parameter depending on the user

User/activity	a	N_u
Residences and B&B	40	Per bed
Hotels *, **, ***	60	Per bed
Hotels **** & *****	80	Per bed
Hospitals (night)	80	Per bed
Day hospital	15	Per bed
Sporthall	50	Per shower
School	0.2	Per child
Kindergarden	8	Per child
Offices	0.2	Net floor area

NET ENERGY DEMAND FOR A NON-RESIDENTIAL BUILDING

In the Italian standard the daily volume of water is expressed as:

$$V_w = a\ x\ N_u \quad [\text{L/d}]$$

a: parameter in [L/(d x N_u)]

N_u: parameter depending on the user

Example 2 – Energy need for DHW

3 star hotel - 10 beds
a = 60 (L/d x Nu)
Nu = 10 beds

The daily volume of DHW is:
V_w= a x N_u = 600 L/d

The energy need to supply the domestic hot water of a bulding is calculated from the volume required ans the temperature difference between the water supplied to the building and the cold water supplied by the acqueduct

kWh/(kg K)   m³/day   N. days

$$Q_w = \rho_w \times c_w \times \Sigma_i \left[V_{w,i} \times (\theta_{er,i} - \theta_0) \right] \times G \quad [\text{kWh}]$$

ρ_w	water density, 1000 [kg/m^3]
c_w	water specific heat 1.162 * 10^{-3} [kWh/(kg K)]
$V_{w,i}$	daily water volume for the i-th activity or service required [m^3/d]
$\vartheta_{er,i}$	water supply temperature for the i-th activity or service required [°C]
ϑ_0	cold water supply temperature (from the acqueduct) [°C]
G	number of days considered in the calculation [d]

EXAMPLES

Example 1 – Energy need for DHW (Residential)

Single unit residential building in Padova, 1 unit hosting 6 people, net surface area of 180 m^2

Daily volume of DHW: $V_w = a \times S_u + b = 1{,}067 \times 180 + 36{,}67$

$= 228{,}73$ L/d

$Q_w = 1000 * 1{,}162*10^{-3} * 0{,}229 * (40-14) * 365 = 2257$ kWh

Example 2 – Energy need for DHW (Non Residential)

3 star hotel in Padova - 10 beds

Daily volume of DHW: $V_w = a \times N_u = 600$ L/d

$Q_w = 1000 * 1{,}162*10^{-3} * 0{,}6 * (40-14) * 365 = 6616$ kWh

OUTPUT

1. Size the storage for the DHW ***of your home***, defining capacity (C) [L] and the required power q_R [W] – the peak load must be defined according to the equation given

2. Calculate the yearly energy need for domestic hot water ***of your home***

3. Define the ***size of the heat pump (once the space heating energy demand has been calculated)***

4. Calculations has to be done with an excel file that will be submitted with the final report. **ALL** the calculations must be included

FURTHER INFORMATION AND SUGGESTIONS

- Files uploaded with «values» inside the cells (excluding the hypothesis of course) without the calculation process will **NOT** be considered, thus the score for the DHW part of the report will be 0
- Excel files must have PERSONAL values
- Wrong units -> penalization
- Exercise developed with the more complex system -> if correct, will be positively evaluated
- Reports should be written using the 3rd person singular.
  «I have done, I have supposed, etc» should be replaced by «Calculations have been done, the parameters have been supposed equal to.. Etc»
- The report is a chance of «learning by doing» – ***it's not supposed to be easy, it's supposed to be useful*** to understand how the system sizing works.
- DISCLAIMER: It's the first year we try to propose this exercise: critical comments are welcome

THANK YOU FOR YOUR KIND ATTENTION

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