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Energy production

Lecture #12

Domestic water heating

Coordinator: Sašo Medved, UL

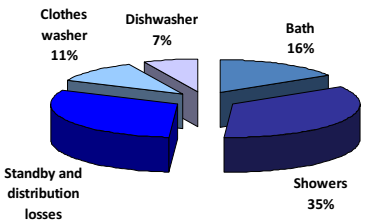
Contributors: Sašo Medved, Ciril Arkar, UL

ntoduction

Domestic hot water is needed for personal hygiene and washing of cloths and dishes. In low-energy and passive buildings energy consumption for tap water heating often exceeded the energy for heating of the building. The energy consumption relating to the tap water heating is by the role included in buildings energy performance indicators.

Domestic water heating systems must be planed in the way to fulfil :

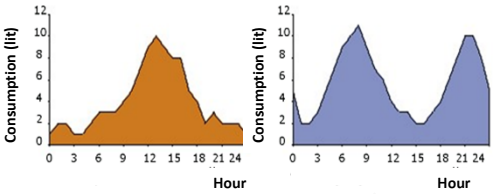
- consumption of the hot water;
- energy efficiency criteria;
- sanitary regulations



Annual energy consumption for DHW in typical single family building.

Domestic hot water consumption

To determine the need for domestic hot water, and thus indirectly related size of the heating system, the time dependant hot water consumption must be known. Two scenarios are most common presumed – day time peak profile and morning/evening peak profile scenario.



As detailed profiles of daily consumption of domestic hot water is often not known, experiential design values are common in use. The values distinguish upon the purpose of the building (at temperature of 60°C) ….

Hospitals	30 to 45 lit/day/person
Elderly homes	30 to 55 lit/day/person
Students residence	20 to 35 lit/day/person
Holiday appartments	15 to 30 lit/day/person
Multy family buildings	20 to 35 lit/day/person
Single family buildings	15 to 55 lit/day/person
Schools	5 to 15 lit/day/person
Gyms	30 lit/user
Restaurants	15 lit/meal; 2 lit/breakfast
Laundry	6 lit/kg laundry

Determination of domestic hot water consumption

- regarding to the size of the dwelling

1 room	30 to 45 lit/day/person
2 rooms	30 to 55 lit/day/person
3 rooms	20 to 35 lit/day/person
4 rooms	15 to 30 lit/day/person
Multy family buildings	20 to 35 lit/day/person

- regarding to the type of the hotels; consumption of the hot water in hotels depends on the number of baths, showers and other consumer and the category of hotel. Luxury hotels use more water than lower category hotels.

1*	Collective showers	70 lit/day/room
2*, 3*	Bath	100 – 140 lit/day/room
4*, 5*	Bath + shower	160 lit/day/room

Energy demand for domestic water heating

Guidelines for energy need for domestic water supply are presented in EN 18599.

Type	Reference ares	Demand per usage	Demand per reference area
Single fammily building	living floor area	-	12 kWh/m^2/year
Multy fammily building	living floor area	-	16 kWh/m^2/year
Office building	office floor area	0,4 kWh/person/day	30 Wh/m^2/day
Schools with showers	classrooms area	0,5 kWh/person/day	170 Wh/m^2/day
Hospitals	wards and rooms area	8 kWh/bed/day	530 Wh/m^2/day
Retail shop	sales area	1 kWh/employee/day	10 Wh/m^2/day
Hotel	bedrooms area	1,5 - 7 kWh/bed/day	190 – 580 Wh/m^2/day
Workshops	area of workshop	1,5 kWh/employee/day	75 Wh/m^2/day
Elderly home	area of rooms	3,5 kWh/person/day	230 Wh/m^2/day

Reducing energy consumption for domestic water heating

Four principles for rational use of energy for domestic water heating are:

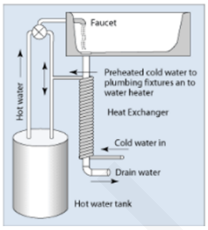
- reduce the amount of consumed hot water using low-flow showerheads and faucets and more efficient washing and dishwashing machines;
- heating water with solar energy; such solar heating systems are most efficient because hot water is needed during the whole year; in some countries solar domestic water heating are prescribed (see Barcelona Solar Ordinance), in most EU countries such systems are financial stimulated;

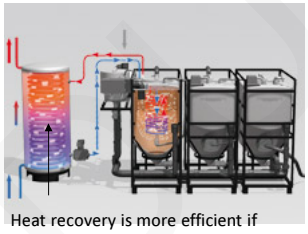
Aerated shower head reduce water flow rate from 15 lit/minute to 5 to 7,5 lit/minute.

Example: in Slovenia 6 m^2 of installed solar collectors in single family buildings for DWH is most simple way to fulfil the requirement regarding to minimum share of renewable energy sources in energy supply of the buildings !

Reducing energy consumption for domestic water heating

- recovery waste heat from drain-water (greywater); waste heat can be extracted in compact counter flow heat exchanger or with heat exchanger integrated in storage tank; heat pump can be used as well;
- reducing standby, distribution and parasitic losses; standby by and distribution losses are results of heat transfer from heat storages and pipes; they can be reduced by placing supply systems, kitchen and bathroom close together and by well insulated heat storages (with thermal insulation thickness 100 mm at least) and pipes (thickness of thermal insulation at least equal to inner pipe diameter); parasitic losses are related to electivity consumption if circulation pump is installed.





Heat recovery is more efficient if waste heat is stored in heat storage (bottom);

Design thermal power of heat generator in DHS

Planning of the domestic hot water supply system is based on maximal heat demand which depends of faucets, pipes etc. flow rate, design temperature of tap water and temperature of cold water in water supply system:

$$Qw = \dot{V}_w \cdot \rho \cdot c_p \cdot (t_w - t_s) \frac{1}{1000} \left[\frac{lit}{s} \frac{kg}{m^3} \frac{J}{kgK} K \frac{m^3}{lit} = \frac{J}{s} \equiv W \right]$$

where $V_{w,out}$ is flow rate of water demand (typical value for one faucet is 0,2 lit/s),
t_w is temperature of tap water (typical 60°C)
t_s is temperature of cold water (typical 10 to 12°C) and
ρ, c_p are density and specific heat of water (1000kg/m^3, 4200 J/kgK)

Example: Calculate design heating power of water heater if one faucet is used in single family passive building having area of 100 m^2 !

$$Qw = \dot{V}_w \cdot \rho \cdot c_p \cdot (t_w - t_s) \frac{1}{1000} = 0{,}2 \cdot 1000 \cdot 4200 \cdot (60 - 12) = 17{,}5 kW$$

It can be seen that design heating power of DWH is much greater comparing to teh design thermal power of heating system (10 W/m^2 . 100 m^2 = 1 kW)

Reducing design thermal power of heat generator in DHS

Regarding to high required heating power of water heater, only in the small systems tap water can be heated by flow-through heat exchanger. Such heat exchanger is often integrated in heat generator of heating system.

Gas boiler with integrated flow-through heat exchanger for DHW

In all other systems, heating power of the heater can be reduced using heat storage. For DWH in single family buildings, heat storage can be integrated into the boiler of heating system, in larger buildings, heat storage is self-standing element.

Gas condensation boiler with integrated heat storage (86 lit). Tap water is heated in plate heat exchanger with water from heat storage. Such appliance can be used if water hardness is low.

Gas condensation boiler with integrated heat storage (130 lit) and tube heat exchanger. Because heating water in the boiler is separated from fresh inflow water this limit the possible composition of minerals in the boiler.

Reducing design thermal power of the heat generator in DHS

In case of large domestic hot water consumption, heat storage must be integrated into the DHW system. The volume of the heat storage can be determinate regarding to the number of flats (n), simultaneously factor (φ), because all of the faucets are not in the same time and time needed for water heating in the storage (Z_A, values of 2 hour are typical)

No of flats n	Simultaneously factor φ	Heating power without heat storage (kW)	Heating power with heat storage (kW)	Volume of heat storage (kW)
1	1,25	**8**	**4**	**200**
2	0,86	**12**	**6**	**300**
4	0,65	**18**	**9**	**450**
8	0,50	**28**	**12**	**690**
20	0,40	**56**	**28**	**1400**
40	0,33	**93**	**46**	**2300**
60	0,31	**130**	**65**	**3200**
80	0,29	**160**	**80**	**4000**
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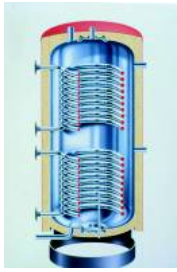


In smaller heat storage with volume less than 1000 lit., domestic water is heated by integrated tube heat exchangers (lower for solar heating, upper for backup heating), in case of larger heat storage, heat exchangers are separated from heat storage.

Sanitary regulations regarding to domestic water heating

Sanitary regulations concerning:

- treatment of cold supply water before it flows into heat generator or heat storage;
- treatment of hot water to prevent growth of legionella microorganisms in heat storage and pipelines.

Cold water must be treated because supply water from network contents substances that can cause the problems in the operation of DHW systems. Such substances are:

- coarse particles, this could be inorganic or organic maters; using back-washing filters, the large particles (> 100 μm) can be hold. Filters should be cleaned by hand or automatically by back-flushing at least once per month using the ball-valve at the bottom of the filter case;

Sanitary regulations regarding to domestic water heating

- colloidal solution originate from small particles with size of 1 μm to 100 μm dispersed in the water; such particles can be grease, silica, iron and manganese compounds and can be removed by fine filters;
- chlorine, nitrates, pesticides and very small particles can be removed by active carbon filters;

dissolved salts of calcium (Ca) and magnesium (Mg); the amount of dissolved salts ($CaCO_3$, $MgCO_3$,..) define the hardness of water; it is called total permanent hardness if it is expressed by amount of calcium and magnesium ions as equivalent of calcium carbonate $CaCO_3$. Total water hardness can be expressed in other units, in German degree of hardness (°dH). Concentration of $CaCO_3$ (mg/lit) in the water define the hardness of the water :

Sanitary regulations regarding to domestic water heating

- 0 to 60 mg/lit (0 – 4°dH) soft water
- 60 to 120 mg/lit (4 – 8°dH) moderately hard water
- 120 to 180 mg/lit (8 – 18°dH) hard water
- 180 mg/lit (18 – 30°dH) ; very hard water

In contrary to solubility of most salts, $CaCO_3$ is less soluble as the temperature of the water increases. From hard water 130 mg $CaCO_3$ per litre of water deposits if water is heated from 30°C to 80 °C. Deposits can results in malfunctioning or additional energy losses of water heaters.

To avoid the problems with the decomposition of salts, temperature of water should be lowered, heat exchangers made from titanium could be used, or more common, water softening device could be used.

Water can be softened by:

- chemical treatment of the water with adding of polyphosphates. This prevent the growth of crystals of calcium carbonate and create a corrosion protective layer on surfaces;

Sanitary regulations regarding to domestic water heating

- permanent magnets; as result of water flowing thought magnetic field, decomposition of solid maters and corrosion problems are reduced;

- ion exchangers are water-insoluble synthetic resins, polymers, which react as acids, bases or salts. Ion exchangers have the ability to replace its free ions in the water. Operation of ion exchange is electronically controlled.

Sanitary regulations regarding to domestic water heating

- reverse osmosis is the physical process of demineralization and removal of salt from the water; demineralization of water takes place at elevated pressure during the transition through semi-permeable membrane, which leaves the water molecules and keeps the ions of dissolved salts. A reverse osmosis is the most efficient way to clean water because impurities, odours and flavours, hazardous chemicals and salt are removed.

Avoiding the harmful microorganisms in domestic hot water

In the domestic hot water system at certain conditions, rapid growth of undesirable microorganisms called legionellas can occur. Causes and favourable conditions for the existence and reproduction of legionellas in the network are:

- the water temperature in the piping network between 20 °C and 50 °C;
- stagnation of the water in the network due to longer periods of none usage,
- disruptions in water supply,
- presence of iron and organic matter in water,
- lack of disinfectant additive (where it is needed)

Example: in Slovenia “Rules on Drinking Water”, Official RS, no. 19/2004 define the requirements to be met for drinking water in order to protect human health from the adverse effects of any contamination of drinking water.

Avoiding the harmful microorganisms in domestic hot water

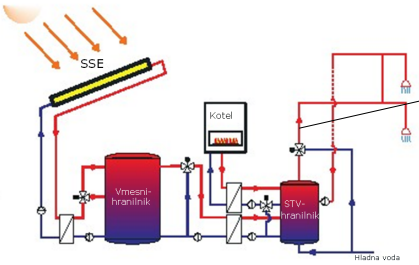
Following measures must be implemented to prevent the presents of legionella microorganisms in the pipeline network of DHW systems:

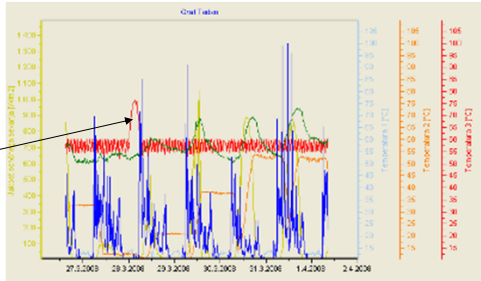
- temperature of cold supply water in the pipeline should be below 20 °C
- hot water temperature at all (even the most remote) taps and showers should be at least 50 °C (recommended mere than 55 °C)
- temperature of the water in the heat storage should be more than 60 °C and at least 1 hour per day such temperature should be at the bottom of the HT as well;
- meshes on the taps and shower heads must be cleaned (from sediment, dirt, stone) – at least 4 times per year;
- regular inspection and cleaning of heat storage once per year;
- chlorine shock treatment for disinfection must be done after each intervention in network system.

Avoiding the harmful microorganisms in domestic hot water

For the prevention from legionella microorganisms in large systems such as DHW systems in hotels or multi-family buildings with central DHW heating system, it is recommended to implement so called temperature shock disinfection on daily or weekly basis.

“Temperature shock" is done by hot water with temperature 70°C circulating throughout the system for at least of one hour. It is recommended to record the history of temperatures in hot water system to proves the regular performing of temperature shocks.





Plot of history temperatures indicating the temperature shock performing once per week.

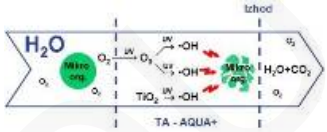
Avoiding the harmful microorganisms in domestic hot water

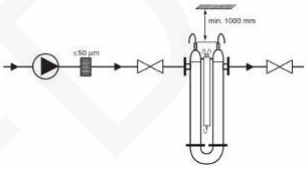
In addition to the temperature shock, protection against the growth of undesirable microorganisms can be achieve with UV disinfection using UV lamp.

UV radiation in water generates hydroxyl radicals (-OH). They are highly aggressive and rapidly react with microorganisms. The life time of microorganisms is reduce to the few nanoseconds.

Maintenance of the system includes regular (annual) replacement lamps and cleaning of particle filter.

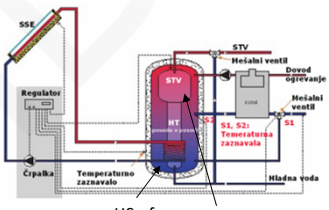
UV disinfection is always used in addition of temperature shock protection.





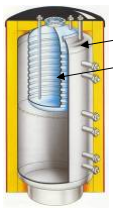
Avoiding the harmful microorganisms in domestic hot water

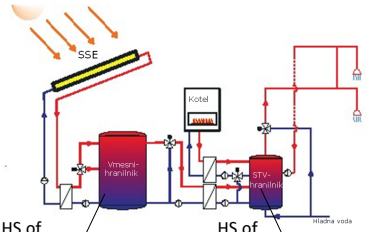
Risk for presents of harmful microorganisms can be reduced by decreasing of the amount of hot water in the supply system. For this reason, DHW heat storage (HS) should be separated from heat store of the heating system.



HS of heating system

HS of DHW system





HS of heating system

HS of DHW system

Self evaluation

- Describe the methods for determination of hot tap water consumption in buildings
- Explain the measures for lowering hot water consumption !
- Explain the measures and technologies for lowering energy consumption by tap water heating !
- Describe basics of sanitary regulations regarding to the tap water supply !
- Describe the technologies for hot tap watewr treatment in water supply system in the buildings

Literature/References

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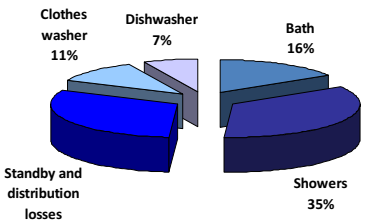

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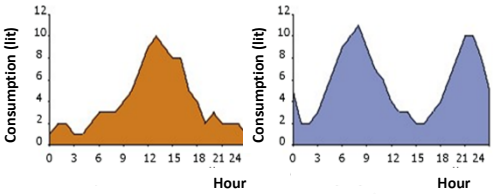

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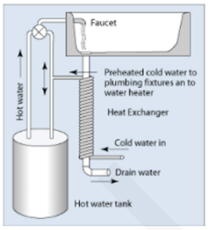

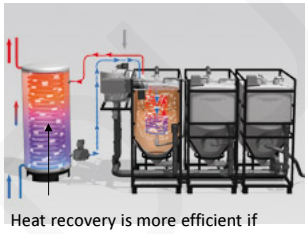

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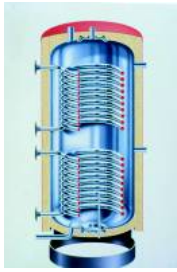
80	0,29	**160**	**80**	**4000**
100	0,28	**190**	**100**	**5000**



In smaller heat storage with volume less than 1000 lit., domestic water is heated by integrated tube heat exchangers (lower for solar heating, upper for backup heating), in case of larger heat storage, heat exchangers are separated from heat storage.

Sanitary regulations regarding to domestic water heating

Sanitary regulations concerning:

- treatment of cold supply water before it flows into heat generator or heat storage;
- treatment of hot water to prevent growth of legionella microorganisms in heat storage and pipelines.

Cold water must be treated because supply water from network contents substances that can cause the problems in the operation of DHW systems. Such substances are:

- coarse particles, this could be inorganic or organic maters; using back-washing filters, the large particles (> 100 μm) can be hold. Filters should be cleaned by hand or automatically by back-flushing at least once per month using the ball-valve at the bottom of the filter case;

Sanitary regulations regarding to domestic water heating

- colloidal solution originate from small particles with size of 1 μm to 100 μm dispersed in the water; such particles can be grease, silica, iron and manganese compounds and can be removed by fine filters;
- chlorine, nitrates, pesticides and very small particles can be removed by active carbon filters;

dissolved salts of calcium (Ca) and magnesium (Mg); the amount of dissolved salts ($CaCO_3$, $MgCO_3$,..) define the hardness of water; it is called total permanent hardness if it is expressed by amount of calcium and magnesium ions as equivalent of calcium carbonate $CaCO_3$. Total water hardness can be expressed in other units, in German degree of hardness (°dH). Concentration of $CaCO_3$ (mg/lit) in the water define the hardness of the water :

Sanitary regulations regarding to domestic water heating

- 0 to 60 mg/lit (0 – 4°dH) soft water
- 60 to 120 mg/lit (4 – 8°dH) moderately hard water
- 120 to 180 mg/lit (8 – 18°dH) hard water
- 180 mg/lit (18 – 30°dH) ; very hard water

In contrary to solubility of most salts, $CaCO_3$ is less soluble as the temperature of the water increases. From hard water 130 mg $CaCO_3$ per litre of water deposits if water is heated from 30°C to 80 °C. Deposits can results in malfunctioning or additional energy losses of water heaters.

To avoid the problems with the decomposition of salts, temperature of water should be lowered, heat exchangers made from titanium could be used, or more common, water softening device could be used.

Water can be softened by:

- chemical treatment of the water with adding of polyphosphates. This prevent the growth of crystals of calcium carbonate and create a corrosion protective layer on surfaces;

Sanitary regulations regarding to domestic water heating

- permanent magnets; as result of water flowing thought magnetic field, decomposition of solid maters and corrosion problems are reduced;

- ion exchangers are water-insoluble synthetic resins, polymers, which react as acids, bases or salts. Ion exchangers have the ability to replace its free ions in the water. Operation of ion exchange is electronically controlled.

Sanitary regulations regarding to domestic water heating

- reverse osmosis is the physical process of demineralization and removal of salt from the water; demineralization of water takes place at elevated pressure during the transition through semi-permeable membrane, which leaves the water molecules and keeps the ions of dissolved salts. A reverse osmosis is the most efficient way to clean water because impurities, odours and flavours, hazardous chemicals and salt are removed.

Avoiding the harmful microorganisms in domestic hot water

In the domestic hot water system at certain conditions, rapid growth of undesirable microorganisms called legionellas can occur. Causes and favourable conditions for the existence and reproduction of legionellas in the network are:

- the water temperature in the piping network between 20 °C and 50 °C;
- stagnation of the water in the network due to longer periods of none usage,
- disruptions in water supply,
- presence of iron and organic matter in water,
- lack of disinfectant additive (where it is needed)

Example: in Slovenia “Rules on Drinking Water”, Official RS, no. 19/2004 define the requirements to be met for drinking water in order to protect human health from the adverse effects of any contamination of drinking water.

Avoiding the harmful microorganisms in domestic hot water

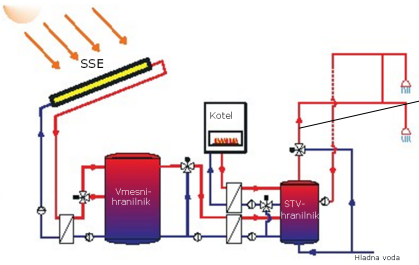
Following measures must be implemented to prevent the presents of legionella microorganisms in the pipeline network of DHW systems:

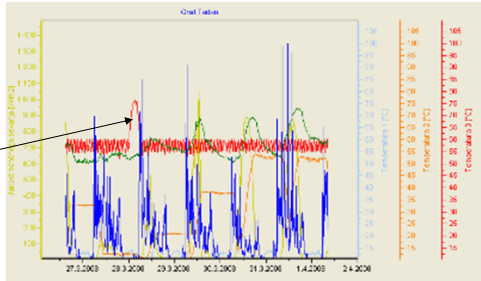
- temperature of cold supply water in the pipeline should be below 20 °C
- hot water temperature at all (even the most remote) taps and showers should be at least 50 °C (recommended mere than 55 °C)
- temperature of the water in the heat storage should be more than 60 °C and at least 1 hour per day such temperature should be at the bottom of the HT as well;
- meshes on the taps and shower heads must be cleaned (from sediment, dirt, stone) – at least 4 times per year;
- regular inspection and cleaning of heat storage once per year;
- chlorine shock treatment for disinfection must be done after each intervention in network system.

Avoiding the harmful microorganisms in domestic hot water

For the prevention from legionella microorganisms in large systems such as DHW systems in hotels or multi-family buildings with central DHW heating system, it is recommended to implement so called temperature shock disinfection on daily or weekly basis.

“Temperature shock" is done by hot water with temperature 70°C circulating throughout the system for at least of one hour. It is recommended to record the history of temperatures in hot water system to proves the regular performing of temperature shocks.





Plot of history temperatures indicating the temperature shock performing once per week.

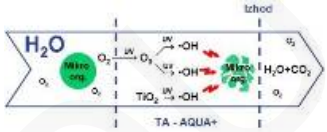
Avoiding the harmful microorganisms in domestic hot water

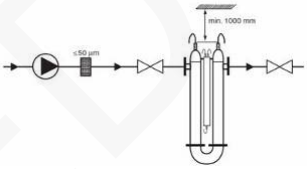
In addition to the temperature shock, protection against the growth of undesirable microorganisms can be achieve with UV disinfection using UV lamp.

UV radiation in water generates hydroxyl radicals (-OH). They are highly aggressive and rapidly react with microorganisms. The life time of microorganisms is reduce to the few nanoseconds.

Maintenance of the system includes regular (annual) replacement lamps and cleaning of particle filter.

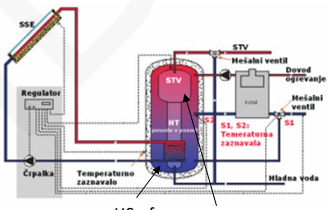
UV disinfection is always used in addition of temperature shock protection.





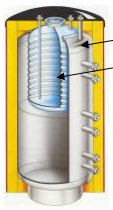
Avoiding the harmful microorganisms in domestic hot water

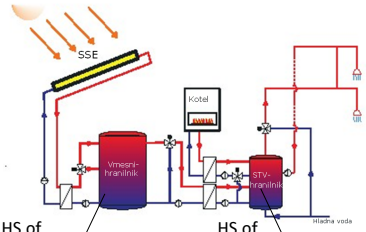
Risk for presents of harmful microorganisms can be reduced by decreasing of the amount of hot water in the supply system. For this reason, DHW heat storage (HS) should be separated from heat store of the heating system.



HS of heating system

HS of DHW system





HS of heating system

HS of DHW system

Self evaluation

- Describe the methods for determination of hot tap water consumption in buildings
- Explain the measures for lowering hot water consumption !
- Explain the measures and technologies for lowering energy consumption by tap water heating !
- Describe basics of sanitary regulations regarding to the tap water supply !
- Describe the technologies for hot tap watewr treatment in water supply system in the buildings

Literature/References

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