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Heat Pumps for Domestic Hot Water Preparation in Connection with Low Temperature District Heating

Appendix 5: Domestic Hot water and District Heating water Storage Tanks

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Work Package 03

Note on Domestic Hot water and District Heating water Storage Tanks

This note describes consumption of domestic hot water and energy, needed to heat it up. Furthermore it includes hot water consumption profile, and dimensioning of hot water or district heating water storage tank.

Hot water consumption

Hot water consumption and tapping profile do not depend on different concepts of micro-booster heat pump system, where either 55° C district heating water or 60° C domestic hot water is stored. According to the Danish water standard DS 439 hot water consumption includes the tapping sequence shown in Table 1, repeated every 12 hours.

Table 1 Domestic hot water consumption profile according to DS 439

	q	*Duration*	*Repeated within 12 hours*	*Temperature, T_{hot}*	*Capacity requirement**	*Energy consumption*
	l/s	*s*		*°C*	*kW*	*kWh*
Shower	0.14	300	4	40	17.6	1.47
Kitchen tap	0.10	150	2	45	14.7	0.61
Hand wash	0.056	180	4	40	7.0	0.35

** Cold water temperature is T_{cold}=10°C*

The tapping begins at 6.00 am (Figure 1) and includes 4 showers and use of kitchen tap twice. Two first showers overlap with use of kitchen taps, and define the peak heat load of the hot water system – 32.3 kW. The subsequent hot water consumption includes kitchen taps and hand washes and does not contain a peak load. The full 12 hour hot water consumption ends at 18.00 pm.

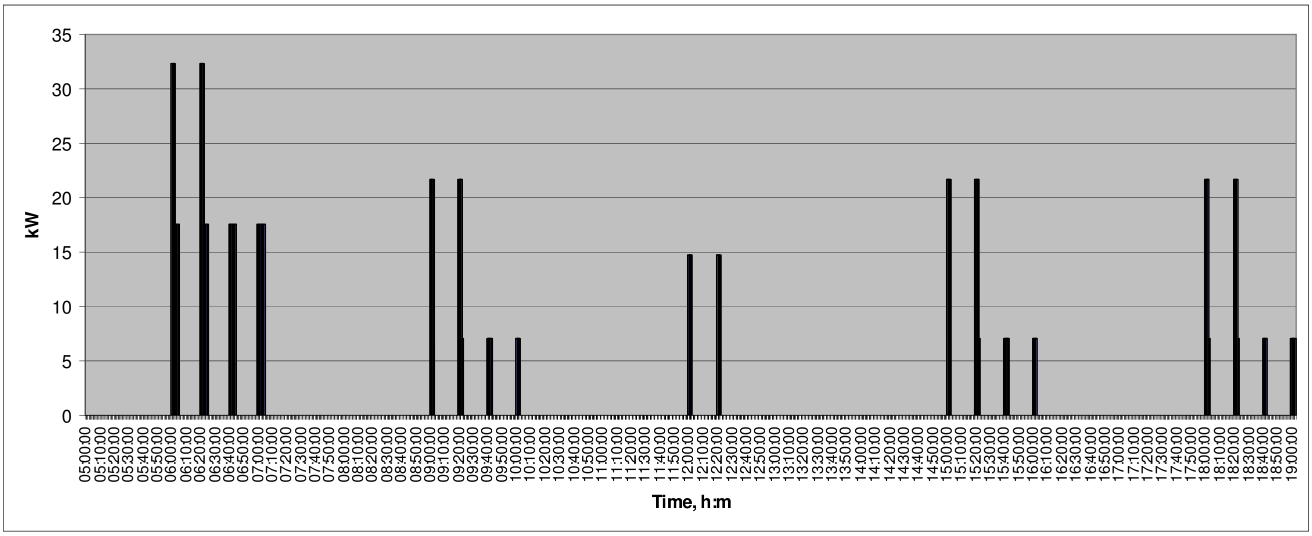

Figure 1 Domestic hot water tapping profile

According to the water standard (DS 439) the described profile should be repeated during the next 12 hours. However it has been assumed that such hot water consumption is not repeated – in stead 2 kitchen washes and 4 hand washes are included in the time period between 18.00 and around 19.00.

Consequently, according to the described hot water consumption profile, **438 litres** of hot water (a mixture of 45 and 40 °C) and **16.2 kWh of energy** is consumed daily.

Dimensioning of the Hot water/District heating water storage tank

According to the DS 439 standard, hot water storage tank should be dimensioned following the domestic hot water consumption sequence, which includes 4 showers and 2 kitchen taps (Figure 2Figure 1).

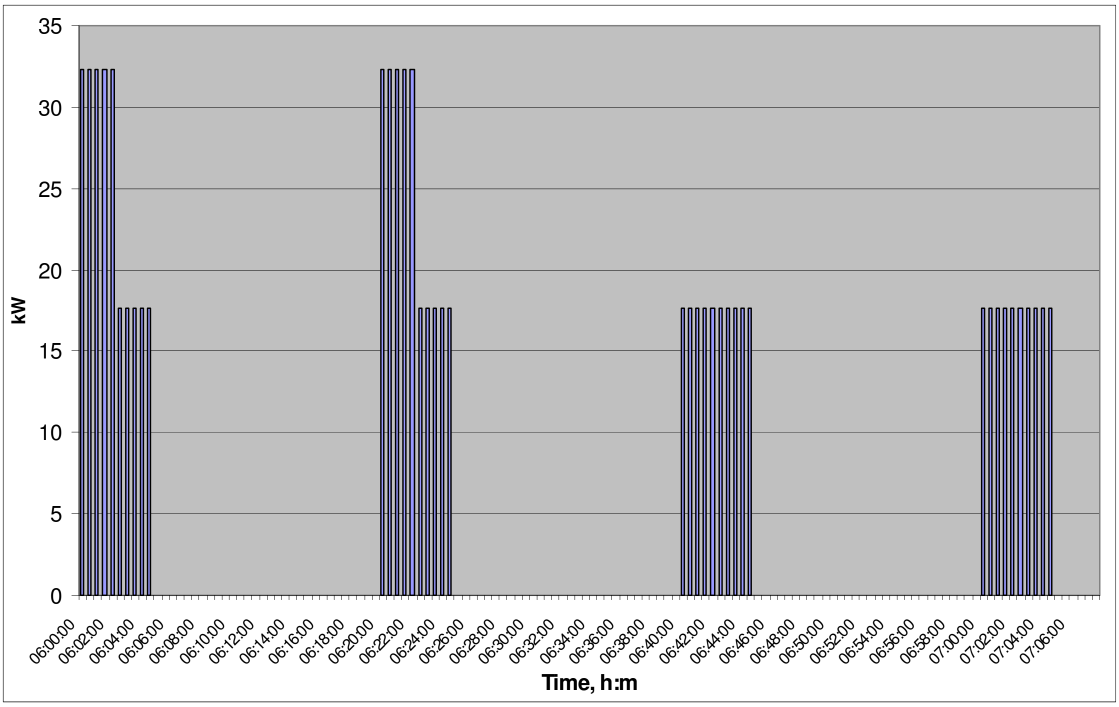

Figure 2 Hot water consumption profile for sizing of storage tank

This means that under peak consumption (4 showers and 2 kitchen taps) in the morning micro-booster heat pump and storage tank have to be able to deliver enough energy, in order to cover this demand ($E_{required}, kWh$).

The effective size of a hot water tank (V_{eff}, l) is calculated according to the following equation:

$$V_{eff} = E_{eff} \cdot \frac{860}{T_w - T_{cold}}$$

Where E_{eff} - is the effective energy content in the storage tank in kWh,

T_w - is the temperature of the hot domestic or district heating water in the tank in °C,

T_{cold} - cold water temperature (or the temperature of the return temperature of the heat exchanger on the primary side) in °C.

The size of storage tank is calculated in two cases – when district heating water is stored (primary side) and when domestic hot water is stored (secondary side). The flow rate from micro-booster heat pump is 50 l/h and supplements the water flow from the storage tank and refills the tank during the whole hot water tapping period. Energy, supplied from the heat pump (E_{hp}, kWh) is subtracted from the amount of required energy ($E_{required}, kWh$) in order to estimate the needed energy (E_{eff}, kWh) content of the full storage tank at the beginning of the tapping sequence in Figure 2. Thus:

$$E_{eff} = E_{required} - E_{hp}$$

The size of the storage tank (V_{eff}, l) is calculated in Table 2. The table also includes peak flow rates from the storage tank only and the total peak flow rate, when the contribution from the heat pump is included.

Table 2 Sizing of hot water/district heating water storage tank

	T_w	T_{cold}	$E_{required}$	E_{hp}	E_{eff}	V_{eff}	*Peak flow rate from storage tank*	*Total peak flow rate (tank+heat pump)*
	℃	℃	kWh	kWh	kWh	*l*	*l/h*	*l/h*
Primary side	55	17	7.1	2.4	4.7	**106**	679	729
Secondary side	60	10	7.1	3.16	3.94	**68**	504	554

Considerations regarding tank charging flow rate

In order to optimise the flow rate for charging of the storage tank a simulation of the hot water tapping and tank charging is required. Such calculations have not been performed yet. However, some indications can be taken from a previous EUDP project on low temperature District Heating (Figure 3).

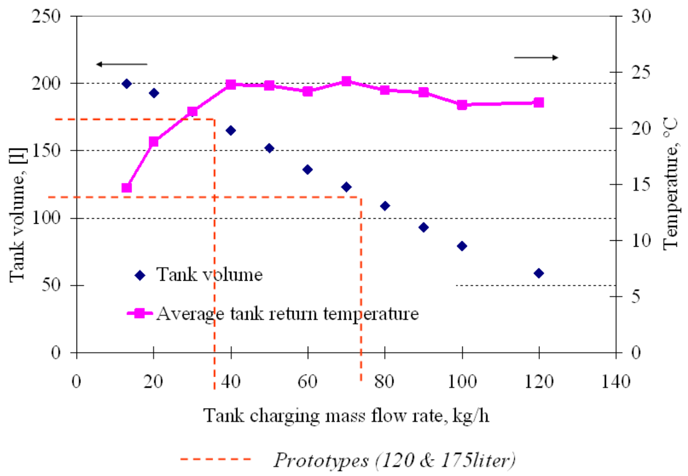

Figure 3 Trade off between tank volume and charging flow rate

Here the district heating water of 50°C is stored in the tank and the return temperature from heat exchanger is 16°C ($\Delta T_{LTDH} = 34K$). Charging flow is 50 l/hr for $V_{LTDH} = 152l$ storage tank. In the case of storage tank on the primary tank, a 55°C district heating water is stored in the tank and return temperature is 17°C ($\Delta T_{prim} = 38K$). For secondary side the temperatures are 60°C and 10°C ($\Delta T_{\sec} = 50K$). The ratios ($\Delta T_{LTDH} / \Delta T_{prim(\sec)}$) of temperature differences have been calculated and applied to the size of the storage tank in each – primary or secondary – case ($V_{prim(\sec)}, l$) and compared to the tank size calculated (V_{eff}, l) in Table 2 (Table 3).

Table 3 Comparison of calculated storage tank size with LTDH EUDP project with 50 l/h charging flow rate

	$\Delta T_{LTDH} / \Delta T_{prim(\sec)}$	V_{LTDH}, l	$V_{prim(\sec)}, l$	V_{eff}, l
Primary	0.89	152	152·0.89=135.3	106
Secondary	0.68	152	152·0.68=103	68

According to the relations in the simulations, performed for LTDH EUDP project the final size of a storage tank has to be around 30l higher than it is calculated in Table 2. Such increase is considered to be due to more realistic modelling of the storage tank (where tank stratification is considered) and due to tank heat losses. The difference in tank size increase between primary and secondary cases can be due to simplification of the relation between storage tank, charging flow rate and water temperatures.

From Table 2 it is clear that the size of the domestic hot water or district heating water also depends on the flow rate from micro-booster heat pump, which supplements the flow from the tank during hot water tapping. The higher the flow from micro-booster, the smaller storage tank can be used (Figure 4).

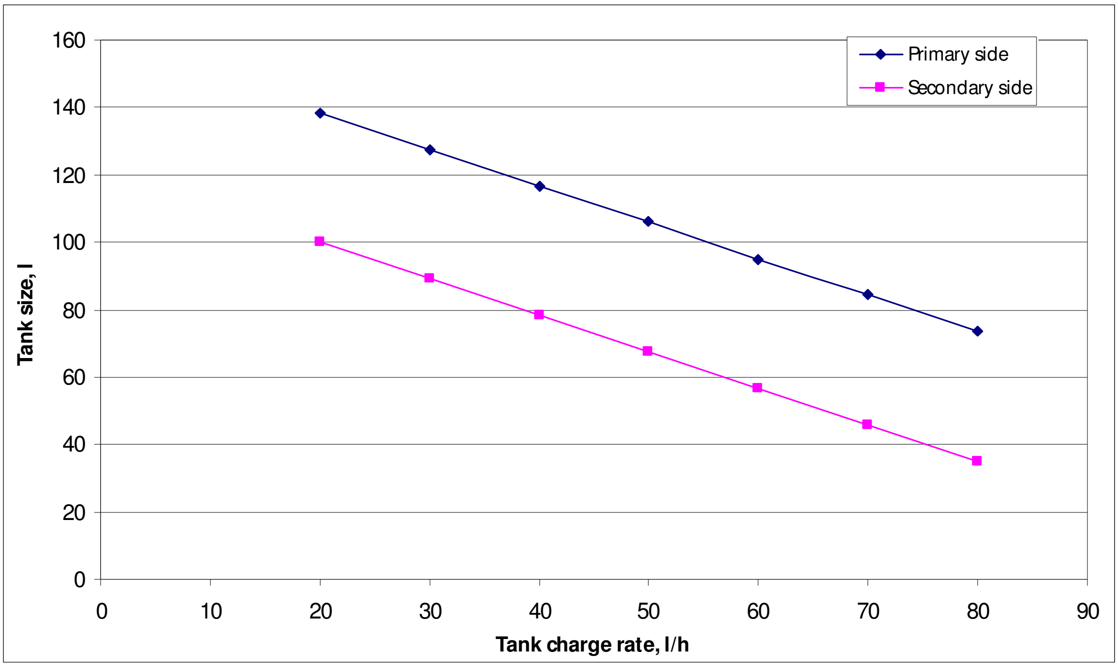

Figure 4 Hot water and DH water storage tank dependency on the complementary flow from micro-booster heat pump during hot water tapping