Domestic hot water recirculation within public buildings. Confort and water saving vs. Energy savings

Recircularea apei calde menajere în clădiri publice. Confort și economie de apă vs. Economie de energie

Ing drd. Szilveszter-Zoltan Geyer Ehrenberg
Universitatea Politehnica Timișoara, Romania

Abstract:
We always look to save energy over the heating and cooling of a building, but often the Domestic Hot Water is overlooked, as being considered a minor fact. A good example is, that even EC641/2009 treating the issue of circulating pumps is not considering important the DHW recirculating pumps. The paper is building up a theoretical comparison between a Domestic Hot Water system annual cost on system losses with and without recirculation. A deeper study over Life Cycle Cost analyse and improvement recommendation will be the subject of a more detailed study later. This will include also measured data proving theoretical calculations.

Keywords: *Water saving, Comfort, Domestic Hot Water, Energy Saving,*

Rezumat:
Întotdeauna încercăm să economisim energie la sistemele de încălzire și răcire a clădirilor, dar adesea subiectul Apei Calde de Consum este tratat superficial. Un exemplu bun este chiar și directiva europeană EC641/2009 care tratează tematica pompelor de circulație fără etanșare mecanică, unde pompele de recirculare Apă Caldă de Consum sunt doar amintite. Prezenta lucrare abordează comparația teoretică a unui sistem de alimentară Apă Caldă de Consum al unui hotel. Comparația este realizată între sistemul cu și fără recirculare. O analiză mai detailată, incluzând și o analiză detailată a Cost Ciclu de Viață și set de recomandări va fi subiectul unei lucrări viitoare, bazate inclusiv pe măsurători.

Cuvinte cheie: *economie de apă, confort, apa caldă menajera, economie de energie.*

1. Introduction

Water is essential for our everyday life. We do use a large amount of water every day consumption, washing, irrigation and all hygienical propose. In average we use over 140-150l of water a day each person, what is a huge amount of daily water use globally, while many parts of the world does not have drinkable water and is a huge challenge to ensure adequate water quality.

According to global organisation statistics, our drinkable water stocks worldwide count only 2% of the total water stocks, so water supply companies invests in technologies of water treatment, disposal of waste from sewage water.

We luckily live in area of the world, where drinkable water supply is not an issue, and also cost of water is not very high, however we must still think responsible about environment and our natural resources, nevertheless think about our costs spent for these.

From a daily average use of individuals, about 50l of water means every day domestic hot water usage. Domestic hot water is a result of heated cold water up to the temperature suitable for use for cleaning and washing. When we talk about Domestic Hot Water, we generally refer to water with temperatures around 38-45°C at the tap, while as reference for sizing we use 45°C or 60°C.

The paper is trying to sum up different criteria of evaluation of cost for Domestic Hot Water recirculation in holistic way.

2. Domestic Hot Water at the Tap.

When we want to use hot water for hand washing or for taking a shower, we expect to get the water immediately as we open the tap, mixing it with cold water if needed. Domestic Hot Water (DHW) temperature at the tap depends on each people, but in general the mixture temperature varies between 38-42°C. Obviously, if the DHW supplied at tap is hotter than this temperature, it will need extra cold water to mix it and cool down to desired temperature.

If we prepare the DHW with local boilers next to the tap, availability of DHW as matter of time is not critical. However, overall Life Cycle Cost (LCC) of these solutions might be high if we have several points to consider.

Which solution is the best it always depends on the entire picture, week-end houses or bathrooms with intermittent use, might be well equipped with local production, however, from efficiency point of view, in cases, where we have to serve various bathrooms, toilets within one building, the centralised DHW production always will be the best solution.

For this reason the following pages will only focus on the Domestic Hot Water Centralised production solution, more exactly, the recirculation of the water.

3. The Centralised DHW Production System.

When we have a centralised system we can cover the production of DHW from one plantroom, and have to deal with a distribution network of the Domestic Hot Water.

What the challenges are in this centralised case?

- We generate the DHW with direct production – instantaneous DHW production or we use a buffer tank to store the hot water? Can we use a mix of these 2 systems?
- What is the peak load of the system?
- If there is no use of water for a certain amount of time, the steady water in the distribution pipe will cool down. When tap is opened, first the cool water will flow and depending on the length of pipes, the hotter water will come later. The longer the pipe is, the more we will have to wait for it.

Focusing on the last point of the list of challenges we have to admit, that waiting long time for hot water is unpleasant, and nevertheless wasting activity, as the water which flow off the drainage is a clean, most of the time drinkable water, which we will have to pay, first as row water, secondary as water already heated up.

If we ensure a recirculating loop from the last consumer back to the DHW production and storage system, we will be able to ensure correct water temperature at the tap, which results no loss of clean water. With a typical flow of 0.20l/s for one sink tap or shower tap, waiting only one minute for the hot water each time will result 12l of waste of clean water.

However, if we install a recirculating pump to ensure DHW recirculation, we will have to deal with the fact that heat loss through the piping will occur, which might result in waste of energy as well.

For this reason, let's study what the losses might be in each case.

Our subject for evaluation will be a centralised DHW system for a smaller hotel with storage tank. DHW is prepared using gas fired boiler, DHW production temperature is 80/60°C, storage tank is 1000l, with insulated shell with external heat exchanger. Water in tank is stored at 60°C.

The fresh water is heated up by a heat exchanger, that has got 210 kW power with 1.5 l/s flow rate. This can ensure to rebuild Domestic Hot Water stocks within 15-18 minutes.

Each tap in bathrooms is equipped with thermostatic mixing taps, ensuring proper use of temperature mixture for users.

Peak flow is 1.5l/s for hot water, main distribution pipe is copper pipe 42x1.5mm with insulation shell of 9mm thickness, EF type insulation. Return pipe for recirculation we will consider a pipe of 28x1 mm overall pipe length is 200m for main distribution + 200m return pipe. *Figure 1* is showing a typical schematic of the above described system.

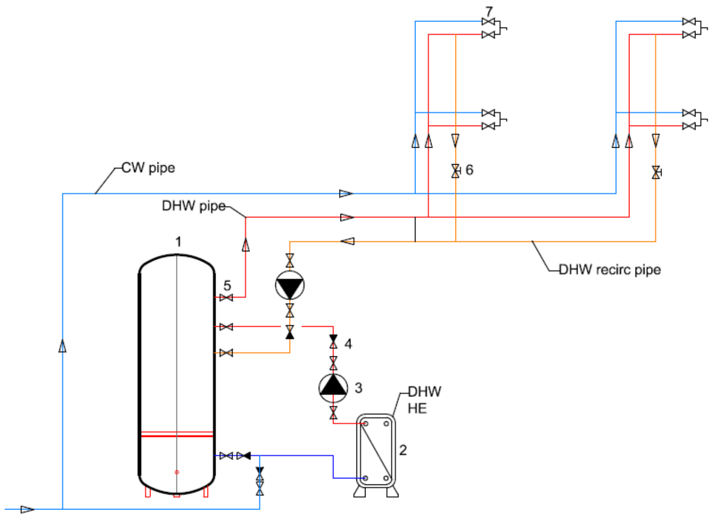

Figure 1 – Domestic Hot Water Distribution scheme with recirculation
1 – Domestic Hot Water Storage tank; 2 – DHW production Heat Exchanger; 3 – Circulating Pump; 4 – Non Return Valve; 5 – Closing Valve; 6 – Balancing Valve; CW Pipe – Cold water pipe from main supply; DHW Pipe – Domestic Hot Water distribution pipe; DHW recirc pipe – Domestic Hot water recirculation Pipe

For defining the heat loss of the distribution pipe we considered to use the Kaimann dimensioning software for insulation types.

According to its calculations for a copper pipe covered by EF type 9mm thickness insulation the heat loss is 20.4W/m for a temperature gradient of 40C, where water temperature is calculated as 60°C and ambient temperature, where the main pipe is running is 20°C.

The typical water use is calculated according to the VDI 6003.1 shown on *Figure 2*. This load profile is typical load profile for working days, but for simplicity of calculations, taking in consideration that is a hotel, we are going to use the same load profile also for weekends.

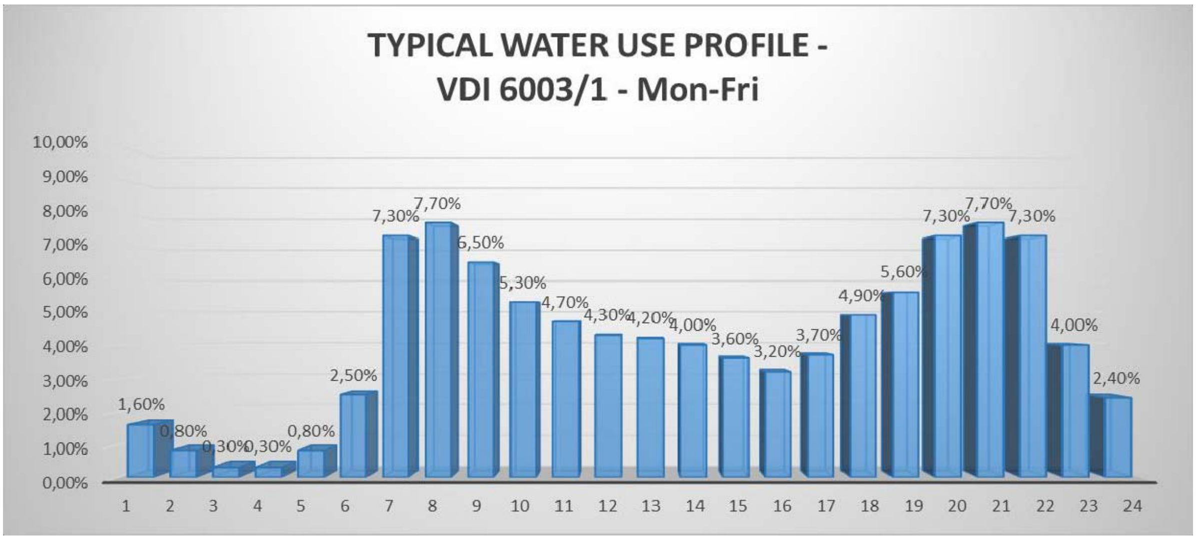

Figure 2 – Water Load Profile – according to VDI 6003/1 – Monday-Friday

Analyzing the DHW Load over the daily time, we can see there is a peak load in the mornings, mainly by hygienic reason, as well as on evening, while during the daytime, water consumption is generated by cleaning and kitchen activities related to restaurant.

If we do a comparison between non recirculating system against the recirculating system, we can see that, during the night time, with a very low use of water, the water in the pipes are going to cool down, which is cooling down by 6K/hour in case of the above described insulation. This means, that in 4 hours of non use of water, temperature can drop below comfortable DHW temperature, while in case of long periods of pipe not used, water will go down to ambient temperature. If by the end of the piping there will be rooms not used for some days, the steady water will facilitate the growth of the Legionella bacteria, which can be harmful for people.

Legionella bacteria is growing in waters with temperature between 20-45°C. To avoid forming of Legionella, water must be kept over 52°C. Any form of Legionella can be destroyed at temperatures over 60°C.

Another argument against non recirculating the DHW is that water cooled down in pipes will need to be drained, which consequently needs to be replaced by fresh water. This leads by one hand to increased use of heat exchanger.

During recirculation, the Heat exchanger is used only to compensate heat losses over the piping surface, while the fresh water is coming with 10°C, needs to be heated up to 60°C.

Figure 3 is showing the temperature decrease by the time in accordance with the average use of water as well as the evolution of the extra water needed to add by running water until it gets to nominal temperature. It must be considered, *that Figure 3* is showing averages. If we consider that rooms might not be used until late evening, the piping until rooms will cool down in lack of recirculation, what will increase locally the amount of hot water drained until temperature.

In general calculations, on a daily base on the above given scenario almost 400 l of water will be wasted just because hot water is not hot at the tap.

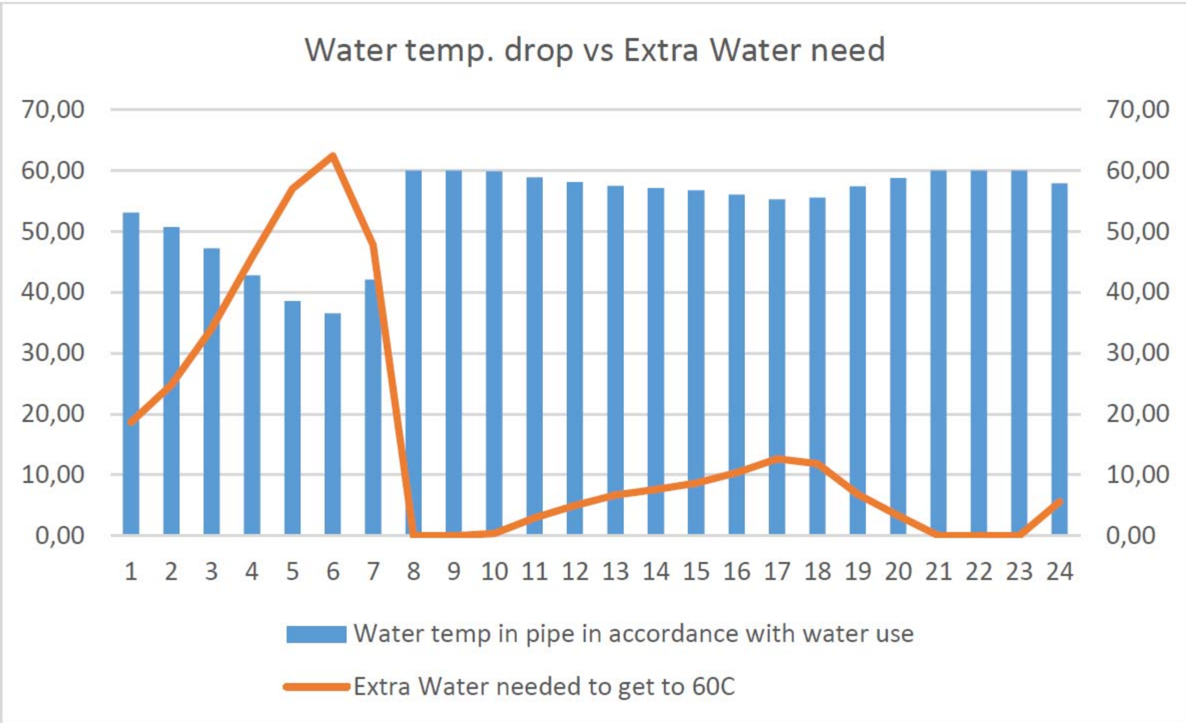

Figure 3 – Average Water temperature drop on steady water in piping vs extra water run over first use.

Table nr.1 is showing the comparison of the two systems by means of energy demand and costs.

It can be clearly seen, that there is a big difference on the overall energy consumption from the two systems. As long as we might consider that longer routing (including return pipe) will increase radiant heat loss surfaces, which is true, however, we shouldn't overlook the fact, that for longer time of inactivity in some areas will increase the volume flow of water which has to be drained until desired temperature starts running. As this water si used as not proper temperature "hot water", system must replace this amount with fresh water. This fresh water will be heated up with higher energy demand than compensating losses over pipes.

A very important fact to be considered in case of the hotel is the customer satisfaction, where 100l of water to drain results about more than 8 minutes of waiting to take a shower.

This will make customers unhappy, while significant amount of drinkable water and energy is wasted.

Table 1

Comparison of DHW system costs with and without recirculation

		No recirculation	**W. Recirculation**
Energy Demand			
For wasted water to heat up from 10 to	[kWh]	315,00	0,00
Heat losses on recirculation	[kWh]	0,00	193,92
Circulatin pump consumption	[kWh]		0,96
Extra Water losses	[m3/day]	0,37	
Sum of Energy & Resource need			
Annual Heat loss from DHW Distrib.	[kWh]	114975,00	70780,80
Gas boiler efficiency	[%]	97,00	97,00
Total energy need	[kWh]	118530,93	72969,90
Annual En. Consumption pump	[kWh]	0,00	350,40
Annual Water losses	[m3]	135,88	0,00
Rates			
Natural gas	EUR/MWh	24,28	24,28
Electricity	EUR/kWh	0,10	0,10
Fresh Water	EUR/m3	0,65	0,65
Waste Water (applied to each m3 of water)	EUR/m3	0,64	0,64
Annual Costs			
Gas	[EUR]	2791,59	1718,56
Electricity	[EUR]	0	35,04
Water	[EUR]	88,77	0,00
Waste Water	[EUR]	86,36	0
TOTAL ANNUAL COSTS	**[EUR]**	**2966,73**	**1753,59**

Table does not refer to the total costs of used DHW production, only the distribution

4. Conclusions

Domestic Hot Water could be an important part of a HVAC system. Despite the fact the paper does not talk about different DHW production solutions (only gas fired boiler solution been considered) the need of recirculation must be considered for different reasons as follows:

- Energy savings

- Water Savings
- Hygienically reasons – avoiding Legionella forming.
- Customer/User comfort and satisfaction – longer waiting time for hot water might reduce customer satisfaction in case of presented hotel.

As shown in *Table 1*, by using recirculation we can save a large amount of energy, about 40%, which in total is a significant amount of money for any customer. In meanwhile, any hotel can upgrade its rating by proving energy efficiency of its working. Large hotel chains are constantly running programs for improving their Carbon Footprint.

However, the presented solution is a basic solution, with 24/7 running recirculation pump. To present higher savings and energy reduction some improvements might be considered as follows:

- Increased insulation quality over the pipings
- Lowering pipe temperature from 60°C to 55°C
- Lowering even more the temperature, down to 45-50°C with combined anti-Legionella disinfection program (running recirculation at high temperature once a day for a certain period of time)
- Control of recirculating pump based on constant return temperature (eg. 52°C)
- Use of alternative heat sources for DHW production

As for simple example, if we reconsider our calculations for hot water in recirculation 50°C instead of 60°, annual costs can drop down by about 20%, a significant value to consider.

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