



COOL DH: Cool ways of using low grade Heat Sources from Cooling and Surplus Heat for heating of Energy Efficient Buildings with new Low Temperature District Heating (LTDH) Solutions.

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Scope of deliverable

This deliverable shortly describes the technology and history of HWC (Heating Water Circuit) appliances, traditional dishwashers that are connected hot tap water and washing machines with both hot and cold water connections – so called “double tap water connected” – and evaluates them in the context of LTDH (Low Temperature District Heating).

HWC appliances include dishwashers, washing machines and tumble dryers that all have heat exchangers built into them, allowing them to be run partially on thermal energy instead of electric energy. This kind of appliances were developed in different pilot and research projects running from the 1990's until about 2014 but were never commercialized.

An alternative to using HWC appliances can be to connect dishwashers to hot water instead of cold, and to use washing machines with both hot and cold water connections instead of just hot water connection. There is however no alternative that reduces the electric energy need in tumble dryers.

Context of deliverable

Review of recent Swedish and Danish reports on HWC appliances. Follow-up on HWC appliances pilot projects. Theoretical verification and evaluation of HWC appliances as well as hot tap water connected dishwashers and double tap water connected washing machines connected to LTDH.

Perspective of deliverable

Input for decisionmaking on HWC appliances, hot tap water connected dishwashers, double tap water connected washing machines and related measures in COOL DH.

Involved partners

Kraftingen Energi AB, UTIL-SE (Lead) and COWI A/S.

English summary

The aim of this report has been to investigate the feasibility and saving potentials in energy and cost of HWC appliances. These machines have heat exchangers built into them, allowing them to be run partially on thermal energy instead of electric energy. However, it has during the writing of this report been established that the HWC appliances that were developed in different research projects in Sweden in 2004-2014 were never commercialized. In 2013 the appliance company Asko Appliance Ltd (hereinafter referred to as Asko), which was a one of the driving partners in the development of HWC appliances, moved its production of dishwashers, washing machines and tumble dryers from Sweden to Slovenia. In connection with this, the production of HWC appliances stopped and has not been resumed since.

The 65 °C/35 °C LTDH system at the Swedish COOL DH project site will be able to provide about 55 °C to a secondary circuit. Or, more precisely, the possible temperature in the customers' systems will be 55-60 °C depending on the house's heat exchanger. However, the LTDH system at the Danish project site will have supply and return temperatures of 55 °C/30 °C, meaning that a secondary circuit will have a supply temperature of < 55 °C.

Asko recommended a minimum heating water temperature of 55 °C and a maximum temperature of 80 °C for the HWC appliances. Temperatures lower than 55 °C would reduce the efficiency to such an extent that the connection to a heating water circuit would become unprofitable. Temperatures higher than 80 °C would not be good for the PEX-hoses. As such, if the HWC appliances had been on the market today, they would have been suitable for the Swedish COOL DH project site where the temperatures in the secondary circuits will be 55-60 °C, but less for the Danish site

where the corresponding temperature often will be < 55 °C. At least the devices must have supplementary electrical energy for temperature boosting.

The energy consumption in Asko's HWC machines can be seen in Table 1, Table 2 and Table 3.

Table 1 Values of electric energy usage in Asko's heat driven dishwasher

Dishwasher Program	Electric energy usage per cycle (kWh)	Electric energy usage per cycle at 55 °C heating water (kWh)	Reduction of electric energy usage per cycle at 55 °C heating water (kWh)
Normal 60 °C	1.0	0.5	0.5
Eco-program 55 °C	1.0	0.6	0.4
Fast program with optional choices 30 °C	1.0	0.9	0.1
Fast program 30 °C	0.2	-	-

Table 2 Values of electric energy usage in Asko's heat driven washing machine and a prototype.

Washing machine Program	Electric energy usage per cycle (kWh)	Electric energy usage per cycle at 55 °C heating water (kWh)	Reduction of electric energy usage per cycle at 55 °C heating water (kWh)
Normal 60 °C	1.1		
Normal Auto 60 °C		0.5	0.6
Normal Eco 60 °C		0.4	0.7
Normal Quick 60 °C		0.9	0.2
Prototype 40 °C test program	0.6	0.2	0.4
Prototype 90 °C test program	1.95	1.3	0.65

Table 3 Values of electric energy usage in Asko's heat driven tumble dryer.

Tumble dryer Program	Electric energy usage per cycle (kWh)	Electric energy usage per cycle at 55 °C heating water (kWh)	Reduction of electric energy usage per cycle at 55 °C heating water (kWh)
Standard	3.51		
Eco		0.75	2.76
Quick		3.18	0.33

Table 4 shows the average energy consumption in Asko's HWC appliances. At the Swedish project site the annual electric energy reduction in a home with a dishwasher, a washing machine and a tumble dryer would have been approximately 594 kWh. The numbers are built on the following assumptions:

- Washing machines:
 - A percentage distribution between 40 °C , 60 °C and 90 °C washes of roughly 85 %, 10 % and 5 % respectively
 - A percentage distribution between the 60 °C programs Auto and Eco of roughly 80 % and 20 %
 - An annual number of process cycles of 280
- Dishwashers:
 - A percentage distribution between the programs Normal and Eco of roughly 80 % and 20 % respectively
 - An annual number of process cycles of 280
- Tumble dryers:

- A percentage distribution between the Eco and Quick programs of roughly 80 % and 20 % respectively
- An annual number of process cycles of 160

*Table 4 Values of electric energy usage in Asko's heat driven appliances. *Assuming an annual number of process cycles of 280. **Assuming an annual number of process cycles of 280. ***Assuming an annual number of process cycles of 160.*

Asko HWC appliance	Average electric energy usage per cycle (kWh)	Average electric energy usage per cycle at 55 °C heating water (kWh)	Average reduction of electric energy usage per cycle at 55 °C heating water (kWh) (%)	Annual average reduction of electric energy usage (kWh) at 55 °C heating water
HWC dishwasher	1	0.52	0.48 (48 %)	134.4*
HWC washing machine	0.72	0.28	0.43 (74 %)	95.6**
HWC tumble dryer	3.51	1.24	2.27 (65 %)	363.8***
SUM:	5.23	2.04	3.18	593.8

Since the HWC appliances that were developed in different research projects in 2004-2014 were never commercialized – not by Asko or any other manufacturer – this report has investigated other appliance alternatives that could reduce the electric energy need and increase the thermal energy need. An alternative to HWC appliances can be to connect dishwashers to hot water instead of cold, and to use washing machines with both hot and cold water connections instead of just hot water connection. Unfortunately, there is no alternative that reduces the electric energy need in tumble dryers.

Concerning dishwashers; as the process temperature is often continuously > 65 °C anyways, a connection of hot water of about 60 °C can give significant electricity reductions. However, this form of connection requires a machine design that can handle the hot water, especially plastic parts like PEX-hoses. Therefore, before connecting the machine to hot water, the customer should make sure that there are no restrictions from the manufacturer to doing so. After comparing electric energy usage in a number of dishwashers from the manufacturers Miele and Asko – who actively recommend hot water connection in some of their machines – it is shown that this kind of connection can give an average electric energy reduction of about 35 %, from 0.86 kWh to 0.58 or 0.53 kWh per wash cycle. This corresponds to an annual electric energy reduction of about 84 kWh per machine. This can be compared to the HWC dishwasher that could give an average electric energy reduction of about 48 %, from 1 kWh to 0.52 kWh per wash cycle.

Some professional washing machines are equipped with two water inlets, “double tap water connected”, allowing connection to both hot and cold water. For example, all Miele's professional washing machines are constructed in this way, allowing for up to 60 % reduction of electric energy, from 1 to 0.4 kWh per wash cycle (measured at 5.5-6.5 kg capacity and 60 °C program temperature). This corresponds to a reduction of 0.6 kWh per cycle or 132 kWh per year per machine, assuming that no other programs are run.

Also Podab's professional washing machines allow for double tap water connection, giving up to 87 % reduction of electric energy, from 1.5 to 0.2 kWh per wash cycle (measured at 8 kg capacity and 60 °C program temperature). This corresponds to a reduction of 1.3 kWh per cycle or 286 kWh per year per machine, assuming that no other programs are run.

Asko's professional washing machines are also possible to connect to both hot and cold tap water. During the writing of this report it has however not been possible to determine whether the energy consumption data in Asko's product manuals are valid for cold tap water connection, or double tap water connection.

The energy need in double tap water connected washing machines can be compared to that of HWC washing machines. As can be understood from the previous paragraphs though, the energy needs of Miele's and Podab's washing machines are only available for 60 °C programs, and the comparison needs to be done for this specific temperature. As can be seen in Table 2, the electric energy need per cycle in the HWC washing machine at a 60 °C

Auto program is 1.1 kWh at normal connection, and 0.5 kWh at HWC connection. This means that the energy reduction is 0.6 kWh per cycle, or 55 %. This reduction is very similar to the one in Miele's double tap water connected washing machines, but only about half of the reduction in Podab's machines. However, the deviation from Podab is most likely due to the large size of the Podab machine (8 kg). The energy usage in the hot tap water and double tap water connected appliances can be seen in Table 5.

*Table 5 Values of electric energy usage in different manufacturer's appliances at normal operation as well as and hot or both hot and cold water connection. *Double tap water connected. **Assuming an annual number of process cycles of 280. ***Assuming an annual number of process cycles of 220.*

Manufacturer and type of appliance	Average electric energy usage per cycle (kWh)	Average electric energy usage per cycle at hot water connection (kWh)	Average reduction of electric energy usage per cycle at hot water connection (kWh)	Annual average reduction of electric energy usage per cycle at hot water connection (kWh)**
Asko dishwashers	0.86	0.58	0.27 (32 %)	76.8**
Miele dishwashers	0.86	0.53	0.33 (38 %)	92.5**
Miele washing machines* 5.5-6.5 kg capacity machines 60 °C program	1	0.4	0.6 (60 %)	132***
Podab washing machines* 8 kg capacity machines 60 °C program	1.5	0.2	1.3 (87 %)	286***
Podab washing machines* 8 kg capacity machines 40 °C program	0.8	0.2	0.6 (75 %)	132***

To sum up, hot tap water and double tap water connected appliances can give substantial electric energy reductions if they are installed according to recommendations. One of the main reasons that HWC dishwashers might not be as good as HWC machines at reducing electric energy need is the process of *re-heating*:

Due to the coldness of the appliance casing and the dish/laundry itself, the process water naturally cools down during the washing and cleaning processes. This happens regardless of whether the process water is hot or cold at the time of the inlet and causes a need for re-heating. In hot tap water and double tap water connected appliances, the re-heating is done with electricity. In HWC appliances, both the initial heating and the re-heating of the water would be done with heating water through the built-in heat exchanger. As such, HWC appliances would satisfy a larger part of the energy need with thermal energy than hot tap water and double tap water connected appliances do. Further, the hot tap water technique can not be applied in tumble dryers.

All in all, HWC appliances could have been a good way to reduce the electric energy need and increase the thermal heating need in COOL DH, at least at the Swedish project site. However, since the HWC appliances have not been commercialized, hot tap water and double tap water connected appliances constitute an alternative.

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2 Introduction

2.1 Background

This report is a part of the COOL DH project. COOL DH is an acronym for Cool ways of using low grade Heat Sources from Cooling and Surplus Heat for heating of Energy Efficient Buildings with new Low Temperature District Heating (LTDH) Solutions.

The project aims to investigate and evaluate LTDH from a wide range of aspects and is divided into a number of work packages (WP). This report is written during the initial part of the project, WP2. More specific, this report constitutes the deliverable of Task 2.1.5 in WP2.

The aim of Task 2.1.5 is to investigate the feasibility and saving potentials in energy and cost of appliances that have heat exchangers built into them, so called Heating Water Circuit – or HWC – machines, allowing them to be run partially on thermal energy instead of electric energy. This should be done with a special focus on LTDH systems, for both Danish and Swedish conditions. Further, it is requested that the conclusions in this report can be used to compare the electricity saving in HWC appliances with the possible electricity need for topping of hot water production in LTDH systems.

As it, during the writing of this report, has been found that HWC appliances have not been commercialized in the preassumed extent, the focus of this report has changed from HWC appliances to dishwashers connected to hot water and washing machines with both hot and cold water connections – so called double tap water connected. As will be explained in the following chapters, these appliances constitute an – in terms of electricity savings somewhat less efficient – alternative to HWC appliances.

2.2 Purpose

As the need for heating energy is rather low in newly built, well insulated houses, the interest for HWC appliances has awoken. When the demand for heating energy is low, it is – by simplicity and to avoid investment costs – often met by electric heating. HWC appliances have been seen, not to the least by district heating companies, as a way to even out the needs; to decrease the need of electricity by instead increasing the need of thermal energy as much.

The purpose of this report has been to recap Swedish and Danish reports on HWC appliances and to analyze them in the light of today. Since there are no HWC appliances on the market today, dishwashers connected to hot water and washing machines with both hot and cold water connections are also investigated.

The research questions have been the following:

- What are the today results of the different HWC appliance pilot projects that are described in previous reports?
- What were the saving potentials in energy of HWC appliances?
- How would the energy saving potential of HWC appliances be affected if they were connected to LTDH instead of traditional district heating technology?
- Which hot tap water and double tap water connected appliances are available on the market today?
- What are the saving potentials in energy of hot tap water and double tap water connected appliances?
- How does the energy saving potential of hot tap water and double tap water connected appliances be affected if they are connected to LTDH instead of traditional district heating technology?

The report will be used as input for decisionmaking on whether HWC appliances or hot tap water and double tap water connected appliances can and should be applied in COOL DH in any way, and what the premises in such case are.

3 COOL DH project sites

At Brunnskög in Lund, Sweden, the world's largest low temperature district heating network (65 °C/35 °C) is being built to recover energy from waste heat and cooling from prosumers, for example the science facility MAX IV. The network will distribute heat to the new city district Brunnskög — a European model for sustainable urban planning — where 40.000 people will work and live in the future.

At Høje Taastrup C and Østerby in Høje Taastrup, Denmark, a low temperature district heating network (55 °C/30 °C) is being built in area with mainly existing buildings. The network will distribute waste heat from a number of cooling plants combined with supply of district cooling to major consumers, hereunder a new City Hall.

4 Appliances – basic functions

In order to understand the theory and texts in the following chapters, this chapter addresses some basic functions and features of dishwashers, washing machines and tumble dryers.

4.1 Tumble dryers

There are different types of tumble dryers on the market. To give some examples, two of the most common dryers are exhaust air dryers and condenser dryers.

Exhaust air dryers pull in dry room air, heats it up and injects it into the tumbler. A blower moves the air through the wet clothes until the air is moist, whereafter it is sucked out from the machine through a vent, either into the room or through a duct to the outdoors.

Condenser dryers work similarly to the exhaust air dryers, but instead of sucking the moist air out of the machine into the room or to the outdoors it is passed through a heat exchanger. The water in the air is then condensed, collected and either drained directly into the sink or into a removable container that needs to be manually emptied. The advantage of this technique compared to exhaust air dryers is that energy is recovered and the climate in the room is kept non-humid.

4.2 Dishwashers and washing machines

There are a few factors that effect the process of making the dishes and laundry clean. Firstly, it is normally advised that dishwashers and washing machines should be connected to cold water, which is then heated to an optimal temperature (65-70 °C) with electricity. The heating of the water ensures that the detergent dissolves. In dishwashers, the rinsing is most often done with hot water (up to 80 °C) to make the dishes properly clean.¹ This is however not the case in washing machines, in which the rinsing is usually done with cold water.

5 Heating Water Circuit (HWC) appliances

In this report, HWC appliances refer to tumble dryers, washing machines and dishwashers that each have a heat exchanger built into them. The heat exchanger enables the heating of the process medium (i.e. air in the tumble dryers and water in the washing machines and dishwashers) to be done partly or completely by the house's own heating system instead of by electricity.

HWC appliances were developed and tested in pilot projects during a ten year period lasting from about 2004 until 2014. In 2014, the appliance manufacturer Asko Appliances Ltd (hereinafter referred to as Asko) that was leading the development of HWC appliances stopped the production and sale of them. Neither Asko nor any other manufacturer has since then resumed the production. In other words, HWC appliances have never been commercialized and they

¹ Finish 2018. *Vissa gillar det hett! En temperaturguide för diskmaskinen*. Retrieved 23/04/18 from <http://www.finishinfo.se/news-and-offers/artiklar-om-maskindisk/tips-och-tricks/vissa-gillar-det-hett!-en-temperaturguide-for-diskmaskinen/>

are currently not possible to purchase anywhere in the world. Chapter 5 will therefore merely describe the technique of HWC appliances and their history.²

5.1 Manufacturer

Asko is the company that is most known for having been developing and manufacturing HWC appliances. The company was founded in Sweden in the 1950's. Since 2010, the company is a part of the Gorenje Group, one of the largest appliance manufacturers in Europe. In 2013, Asko's production of dishwashers, washing machines and tumble dryers was moved from Sweden to Gorenje's plants in Slovenia.³

Unfortunately, Asko stopped developing and selling HWC appliances shortly after they moved their production to Slovenia.⁴ Even though HWC appliances were produced and tested in different pilot projects, starting in 2004 and continuing for about 10 years, they were never fully commercialized and there are no plans to resume HWC products in the assortment.⁵

5.2 Technique

In Figure 1 the principle of HWC appliances is shown; a dishwasher and a washing machine with coaxial heat exchangers and an exhaust air tumble dryer with a plate heat exchanger.



Figure 1 From left to right: Principle of heat driven dishwasher, washing machine and exhaust air tumble dryer. Pictures from the appliance company Asko that was involved in the development of HWC appliances in 2004-2014.

Heat is delivered to the HWC appliances through a heating circuit by so called "heating water" with a minimum temperature of 55 °C and a maximum temperature of 80 °C. The heat of the heating water might come from e.g. solar collectors, geo-energy or (as is the main focus in this report) district heating. Temperatures lower than 55 °C would reduce the efficiency to such an extent that the connection to a heating water circuit would become unprofitable. Temperatures higher than 80 °C would not be good for the PEX-hoses.

The appliance's connection to the heating circuit requires more extensive planning and design of the house's heating system compared to when conventional appliances are installed. However, this extra planning and design can be

² Westberg, Karl-Åke 2018. Asko Appliances Ltd. Global Category Manager Professional. E-mail conversation 24/04/18. E-mail address: karl-ake.westberg@asko.com.

³ Asko 2018. *Om Asko*. Retrieved 27/02/18 from <http://www.asko.se/om-asko>.

⁴ Uppsäll, D. Olsson, S. 2014. *Market and technical status report on heat driven appliances*. Report written as deliverable D2.3 within the project Resource Efficient Cities Implementing Advanced Smart City Solutions – READY, co-funded by the European Commission within the Seventh Framework Programme.

⁵ Westberg, Karl-Åke 2018. Asko Appliances Ltd. Global Category Manager Professional. E-mail conversation 24/04/18. E-mail address: karl-ake.westberg@asko.com.

compensated by the advantages that HWC appliances bring. The recommended minimum heating water flow of the heating water is 1.6 l/min.

To clarify, HWC appliances do not cause energy usage reduction, but merely a change from electric energy to thermal energy. Actually, measurements from pilot projects have shown that because of heat losses in distribution pipes, the total amount of *bought* energy is somewhat *higher* in HWC appliances than in conventional appliances. However, when discussing the environmental benefits of the appliances it is the *primary* energy usage that should be considered.

According to a Fjärrsyn report that was written in 2013 about HWC appliances (presented in detail in chapter 5.3), the primary energy factors of electricity vary from 2.2 to 3.0 depending on the type of generation (renewable or coal based). The CO₂ emissions vary from about 5 to 1 000 kg CO₂ per MWh. As such, the Swedish electricity mix – which is relatively “green” – has emissions of about 20 kg CO₂ per MWh. This can be compared to the Nordic electricity mix, which emits about 100 kg CO₂ per MWh, or the European electricity mix which emits about 400 kg CO₂ per MWh. For district heating, the primary energy factors of marginal production vary from 0.2 to 1.8 and the CO₂ emissions vary from 45 to 300 kg CO₂ per MWh (produced from carbon neutral biofuel in CHP plants).

Depending on which electricity and district heating mix that is chosen when calculating the environmental effects of the appliances, the results will vary. It can however be argued that HWC appliances were developed to – and would – reduce marginal electricity usage. In such case, it would be legitimate to compare the thermal energy production to nuclear or coal based electricity production (which are common electricity production types in Europe). All in all, in cases where thermal energy is cheaper than electric energy, HWC appliances would offer an opportunity to reduce the energy costs, the environmental impact and to increase the use of district heating or other waterborne heat.

The exact amount of electric energy that can be replaced by thermal energy depends on the desired temperature of the process medium, and on the available temperature of the heating water. Since the appliances always need electric power for pumping and rotation, the electricity can never be completely replaced by thermal energy.⁶

5.3 History

The first time the idea of HWC appliances was tested was in a cooperation between the appliance company Miele and the energy and climate consultancy Ecofys in the Netherlands, in the 1990's. A field test with ten dishwashers and ten tumble dryers was performed and documented in a report by Ecofys in the year 2000. The technique from this test was later (years 2004-2006) analyzed by the engineer Tomas Persson at the college Högskolan Dalarna in Sweden in cooperation with the appliance company Asko. Persson was able to optimize the technique of the HWC dishwashers, but not the one of the tumble dryers. Instead, he managed to create a heat driven washing machine. In 2006, Persson's heat driven dishwasher and washing machine, along with one of the ten heat driven tumble dryers from the Netherlands, were installed in a demonstration house in the Swedish city Göteborg. This was done in cooperation with the energy company Göteborg Energi Ltd.⁷

Parallel to the demonstration in Göteborg, Asko continued to push the development of a heat driven tumble dryer. Asko, along with Karlstad University (more specifically, a master student at Karlstad University), the municipally owned housing company Karlstads Bostads Ltd and the Swedish Energy Agency developed, demonstrated and evaluated a swedish version of a heat driven tumble dryer (of the kind “condenser dryer”), with external heat exchangers, in a common laundry room. The prototype also included a self-cleaning lint filter which was later patented.

In 2009 a four-year project was started within the association Energiföretagen's (Svensk Fjärrvärme at the time) research program Fjärrsyn. The project involved Persson at Högskolan Dalarna, Roger Renström at Karlstad University,

⁶ Persson, T. Renström, R. 2013. *Fjärrvärmedrivna vitvaror – Erfarenheter från utveckling, installationer och kostnadsberäkningar*. Fjärrsyn report 2013:21.

⁷ Kralmark, S och Hess, A, 2013. *Värmedrivna vitvaror – Utvärdering ur ett tekniskt, ekonomiskt, klimat- och kundperspektiv med fokus på den hållbara stadsdelen Solbjer i Lund*. LTH Department of Energy Science, report number 5279.

Asko, the energy companies Göteborg Energi Ltd and Mälarenergi Ltd (the latter owned by Västerås municipality), the Rösegård preschool in Västerås and the two housing companies Mimer and Aroseken.

The results of the project was presented in the Fjärrsyn report 2013:21 “Fjärrvärmedrivna vitvaror – Erfarenheter från utveckling, installationer och kostnadsberäkningar” in 2013, written by Persson and Renström. The purpose was to generate a test series of HWC appliances and test them in new or existing residential buildings with district heating in Västerås. The different parts of the project were the following:

1. Optimize the previously developed appliance techniques (developed at Högskolan Dalarna and Karlstad University), including heat driven dishwashers, washing machines and tumble dryers:
 - a. **Dishwasher:**
Develop a coaxial heat exchanger in stainless steel (instead of copper) and reduce the pressure drop on its hot water side. Also change its geometry so that it would fit better into the machine, and do laboratory tests to see how much the electricity need could be reduced.
 - b. **Washing machine:**
Develop a coaxial heat exchanger in stainless steel (instead of copper) and reduce the pressure drop on its hot water side. Also increase its dimensions compared to the one in the dishwasher, and do laboratory tests to see how much the electricity need could be reduced.
 - c. **Tumble dryer:**
Develop a prototype exhaust air dryer instead of the prototype condenser tumble dryer that had already been developed and tested in a common laundry room in Karlstad. Also do laboratory tests to see how much the electricity need could be reduced.
2. Develop two heat driven drying cabinets and do a small scale pilot test at the Rösegård preschool in Västerås (october 2012 to february 2013) and measure how much the electricity need could be reduced.
3. Theoretically investigate different possibilities to build heating water distribution systems and calculate their cost and energy performances, including heat losses in distribution pipes outside the apartments. (Six different system solutions.)
 - a. Two different system solutions, in a residential area and in multi-family houses that were either normally isolated or passive houses
 - b. The so called “Separate heating circuit” model
 - c. The so called “Västerås” model, replacing the conventional hot water circulation system and radiator circuit with a secondary heating circuit with constant flow temperature
4. Demonstrate and evaluate the energy usage of the appliances at two different places in the city Västerås in Sweden:
 - a. 160 apartments built by Mimer in the neighborhood Råseglet, each with a heat driven washing machine, dishwasher and tumble dryer
 - b. Five heat driven washing machines and four tumble dryers in Mälarenergi Ltd’s and Göteborg Energi Ltd’s changing rooms in the cities of Västerås and Göteborg

Parallell to the Fjärrsyn project, Asko started delivering HWC appliances to other pilot projects around the country. For example, the municipally owned energy company Kraftringen Energi Ltd (Lunds Energikoncernen Ltd at the time) installed heat driven dishwashers in one of the company’s kitchens. Also, the housing company of Lund municipality, LKF, installed HWC appliances in different housing projects, i.e. in a shared laundry room in a multifamilyhouse in the city district Linero.⁸ The Linero pilot test was a part of the EU-project CITYFIED where Kraftringen Energi Ltd is also, currently, involved.⁹

⁸ Persson, T. Renström, R.

⁹ Cityfied 2018. *About*. Retrieved 02/03/18 from <http://www.cityfied.eu/The-CITYfied-Project/About.kl>.

5.4 Results from laboratory and pilot tests

Unfortunately, the results from the Fjärrsyn project described in the previous chapter did not become as detailed as planned. The experiences from field testing were very limited as the construction of the intended houses was delayed and not completed until after the final project report was published. Thus, most of the energy usage data of the HWC machines was retrieved from laboratory tests and simulations.

However, some of the conclusions of the project were the following:

- The pay-off time, calculated as the time it would take before the cost of purchasing and installing HWC machines had been covered by the reduced energy costs, was a bit long, meaning that long HWC service lives would be important
- HWC washing machines and tumble dryers would be particularly competitive in multiple-unit dwellings with communal laundry rooms, preferably in high-occupancy areas
- The price of HWC appliances would have to be lower for them to be economically competitive as individual machines. However, in municipalities with competitive district heating prices it would be economically viable to install multiple HWC appliances, along with underfloor heating and heated towel rails in accordance with the Västerås model

5.4.1 HWC dishwasher lab results

Asko's heat driven dishwasher was called D565 SOF HWC and its energy usage, measured in a laboratory and printed in Asko's product sheet, can be seen in Table 6.

When comparing the different operation conditions a percentage distribution between the programs Normal and Eco of roughly 80 % and 20 % respectively is assumed. At normal operation, this distribution results in an average electric energy usage of 1 kWh per cycle. At operation with 55 °C heating water the corresponding number becomes 0.52 kWh per cycle. Thus, the average reduction of electric energy usage can be calculated to **0.48 kWh per cycle** or 48 %. Assuming further that the number of wash cycles during a year is 280, which is recommended by the European Union regarding energy labeling, the total reduction becomes **134.4 kWh per year**.

The lab results also showed that a 60 °C dishwashing cycle required heating water of 70 °C to avoid heating with electric energy.¹⁰

Table 6 Values of electric energy usage in Asko's heat driven dishwasher

Program	Electric energy usage per cycle (kWh)	Electric energy usage per cycle at 55 °C heating water (kWh)	Reduction of electric energy usage per cycle at 55 °C heating water (kWh)
Normal 60 °C	1.0	0.5	0.5
Eco-program 55 °C	1.0	0.6	0.4
Fast program with optional choices 30 °C	1.0	0.9	0.1
Fast program 30 °C	0.2	-	-

5.4.2 HWC washing machine lab results

Asko's heat driven washing machine was called W6884 HWC and its energy usage, measured in a laboratory and printed in Asko's product sheet, can be seen in Table 7. Since the product sheet only contained information about the 60 °C programs, the table has been complimented with data about the 40 °C and 90 °C programs collected directly from the developer and scientist Tomas Persson.

¹⁰ Kralmark, S och Hess, A.

When comparing the different operation conditions a percentage distribution between 40 °C , 60 °C and 90 °C washes of roughly 85 %, 10 % and 5 % respectively is assumed. Further – at HWC operation – a distribution between the 60 °C programs Auto and Eco of roughly 80 % and 20 % is applied. At normal operation, this distribution results in an average electric energy usage of 0.72 kWh per cycle. At operation with 55 °C heating water the corresponding number becomes 0.28 kWh per cycle. Thus, the average reduction of electric energy usage can be calculated to **0.43 kWh per cycle** or 74 %. Assuming further that the number of wash cycles during a year is 220, which is recommended by the European Union regarding energy labeling, the total reduction becomes **95.6 kWh per year**.

The lab results also showed that a the heating of a 40 °C washing cycle could be covered by the heat from 55 °C heating water. A 60 °C washing cycle required heating water of 80 °C to avoid heating with electric energy.¹¹

Table 7 Values of electric energy usage in Asko's heat driven washing machine and the prototype machine that Tomas Persson built.

Program	Electric energy usage per cycle (kWh)	Electric energy usage per cycle at 55 °C heating water (kWh)	Reduction of electric energy usage per cycle at 55 °C heating water (kWh)
Normal 60 °C	1.1		
Normal Auto 60 °C		0.5	0.6
Normal Eco 60 °C		0.4	0.7
Normal Quick 60 °C		0.9	0.2
Prototype 40 °C test program	0.6	0.2	0.4
Prototype 90 °C test program	1.95	1.3	0.65

5.4.3 HWC Tumble dryer lab results

A part of the Fjärrsyn project described in chapter 5.3 was to develop a prototype exhaust air dryer. This was done and the machine was tested in a lab environment with nice test results concerning energy consumption as well as drying times. However, when the machine was tested in the changing rooms of Mälarenergi Ltd and Göterborg Energi Ltd, the test results became worse. This seems to have been due to a number of interfering parameters (i.e. too few cycles, variations in laundry load and electric energy consumption in standby mode) and the results were to be considered too insecure to draw any conclusions from Table 8 shows the lab results.

At normal operation and standard program the electric energy usage is 3.51 kWh per cycle. At operation with 55 °C heating water a percentage distribution between the Eco and Quick programs of roughly 80 % and 20 % respectively is assumed. This results in an average electric energy usage of 1.24 kWh per cycle. Thus, the average reduction of electric energy usage can be calculated to **2.27 kWh per cycle** or 65 %. During operation the heating water flow is 1.6 l/min and the program duration is 3:40 and 1:30 for the Eco and Quick programs respectively. Assuming further that the number of drying cycles during a year is 160, which is recommended by the European Union regarding energy labeling, the total reduction becomes **363.8 kWh per year**.

Table 8 Values of electric energy usage in Asko's heat driven tumble dryer.

Program	Electric energy usage per cycle (kWh)	Electric energy usage per cycle at 55 °C heating water (kWh)	Reduction of electric energy usage per cycle at 55 °C heating water (kWh)
Standard	3.51		
Eco		0.75	2.76
Quick		3.18	0.33

¹¹ Kralmark, S och Hess, A.

One general conclusion that could be drawn from the lab tests was that the heating water temperature has an inverse relationship to the drying time, but a direct relationship to the total energy consumption. A high heating water temperature shortens the drying time, but it also leads to significant heat losses. A lower heating water temperature reduces the heat losses and – due to the increased process time – increases the time for the laundry to “self dry”. Of course the increased process time also increases the time that electricity is needed to run the fan and the motor, making the proportion of electric energy in the total energy usage larger. The total energy consumption is however still at its lowest when the heating water temperature is low.

5.4.4 HWC Drying cabinets lab results

A part of the Fjärrsyn project described in chapter 5.3 was to develop two prototype drying cabinets. The cabinets were developed by the drying cabinet manufacturer Nimo and Karlstad University and the steering electronics was provided by Asko. Two cabinets were field tested during four months at a preschool in Västerås. The user data and the physical conditions at the preschool were copied and used to perform detailed tests on an identical cabinet at Karlstad University.

In the laboratory tests, it was concluded that the cabinets’ electric energy usage could be reduced by 93 % at a heating water temperature of 50 °C. This was concluded on cabinets with an installed effect of 2 kW. However, drying cabinets are programmed to work until a certain dryness is reached, meaning that the process time and thus the total energy need varies a lot depending on the load. As such, it is not possible to translate the reduction of electric energy need given in percentage to a general number of kWh needed per drying cycle.

In the laboratory tests it was also established that it would be necessary but hard to develop steering technology that can handle all the various kinds of loads.¹²

5.4.5 System solutions

A part of the Fjärrsyn project described in chapter 5.3 was to theoretically investigate six different system solutions for heating water distribution systems and calculate their cost and energy performances, including heat losses in distribution pipes outside the apartments.

HWC appliances could be installed in different ways. One way would be to provide them with heating water through a separate circuit – just like the tap water and radiators have their own circuits – originating from a substation in e.g. the basement. This method is the most convenient in existing buildings. In multistorey multifamily houses the number and length of pipes would, as one can imagine, be substantial and take up a lot of shaft space. As such, it would be more convenient to use this method in buildings where similar pipes are installed and take up space anyways, as in buildings with radiators. In e.g. low energy buildings, which normally don’t have radiators or any separate circuits except for the tap water, the heating water piping would be claiming precious space. In other words, the choice of system solution is to a great extent a balance between efficiency and uptake of shaft space.

One possibility would be to connect the HWC appliances to the hot tap water circulation (HWC) system that is commonly found in multi-family houses. In a HWC system a pump is constantly working to circulate tap water from the water heater, to joints where tapping point are connected, and back again. In this way the hot water never has a chance to cool down waiting in the pipes and the hot water is kept at a constant temperature. However, connecting HWC appliances in this way would – according to the Fjärrsyn project – create unpermitted return temperatures in the HWC system and create risk of Legionella growth. According to Swedish building regulations the return temperatures may never be lower than 50°C. Further, the HWC system might not have the right dimensions.

Another possibility to reduce the amount of extra piping for the HWC appliances would – in houses with radiators – be to extend the radiator circuit so that it provides the appliances with heat as well. However, as the appliances would need a constant supply temperature, this method would reduce the possibility to adjust the radiator temperature to the outdoor temperature, which is not a realistic alternative.

¹² Persson, T. Renström, R.

Another way to reduce the uptake of pipe space in shafts would be to build a secondary heating system. In other words, a common secondary distribution line would be drawn between the main substation and the individual houses/apartments. In turn, the houses/apartments would all have their own “extra” substations/heat exchangers that could provide them with hot tap water. The secondary system could be used directly by the respective users for radiators and HWC appliances. This method would – compared to the method with separate circuits – reduce the amount of pipes and sizes of shafts needed, but at the same increase the equipment space needed in every apartment.

In the Fjärrsyn project, the “separate circuit” method and the “secondary heating system” method, later called the Västerås model, were investigated in normally insulated as well as low energy houses. Theoretical simulations and calculations were made but could not be confirmed through actual meterings as the construction of the houses was delayed.

6 Appliances with alternative tap water connections

Because Asko stopped the development and commercialization of HWC appliances in 2014 there is no possibility to buy them any longer. Instead, the possibility of utilizing heat from district heating in appliances in other ways need to be investigated. For example, a connection of hot – or both hot and cold – tap water instead of the traditional cold tap water connection, can reduce some of the initial need for heating electricity in washing machines and dishwashers. However, the technique is not as efficient as the one in HWC appliances. This is due to the process of *re-heating*:

Due to the coldness of the appliance casing and the dish/laundry itself, the process water naturally cools down during the washing and cleaning processes. This happens regardless of whether the process water is hot or cold at the time of the inlet and causes a need for re-heating.

In hot tap water and double tap water connected appliances, the re-heating is done with electricity. In HWC appliances, both the initial heating and the re-heating of the water would be done with heating water through the built-in heat exchanger. A such, HWC appliances would satisfy a larger part of the energy need with thermal energy than hot tap water and double tap water connected appliances do. Further, the hot tap water technique can not be applied in tumble dryers.

6.1 Dishwashers connected to hot water

Dishwashers can be connected to hot water instead of cold water. Some suppliers even recommend this kind of connection as the process temperature is often continuously > 65 °C anyways.

For example, Asko claims that hot tap water connection (up to max 70 °C) reduces the need of electricity in their dishwashers by as much as 32 %.¹³ After studying 26 of Asko’s dishwashers it becomes clear that the machines’ standard need for electric energy varies between 0.82 and 0.95 kWh per cycle with cold water connection, depending on the machine model. The average electric energy need is calculated to 0.86 kWh per cycle. Thus, stated in kWh, a 32 % energy reduction at hot water connection corresponds to **0.27 kWh per cycle**, resulting in a remaining electric energy need of 0.58 kWh. Assuming a standard number of wash cycles per year of 280, which is recommended by the European Union regarding energy labeling, the annual electricity reduction caused by hot water connection becomes **76.8 kWh per year**.¹⁴ The calculations that were done to reach this conclusion can be seen in APPENDIX 1.

Also Miele states that all their dishwashers can be connected to hot water. The dishwashers are equipped with ThermoSpar®, which allows them to be connected to hot water up to 60 °C. According to Miele, this enables a reduction of electricity need by up to 50 %.¹⁵ After a review including 28 of Miele’s dishwashers (of varying energy

¹³ Asko 2018. *ECO – Varmvattenanslutning*. Retrieved 28/06/18 from <http://www.asko.se/produkter/diskmaskiner/funktioner>

¹⁴ Asko 2018. Comparison of product sheets through comparison function on homepage. Retrieved 28/06/18 from http://www.asko.se/product_compare?productId=7158

¹⁵ Miele 2018. *Varmvattenanslutning*. Retrieved 04/07/18 from <https://www.miele.se/konsument/1752.htm?info=200001434-ZPV>

labels), it is shown that the machines' standard need for electric energy varies between 0.67 and 1.05 kWh per cycle with cold water connection, giving an average need of 0.86 kWh per cycle, just like in the Asko machines. However, at hot water connection the need is between 0.49 and 0.59 kWh, giving an average need of 0.53 kWh per cycle. This corresponds to an electric energy reduction of between 27 % and 44 %, giving an average of 38 % or **0.33 kWh per cycle** (measured on the ECO programs).¹⁶ In other words, the 50 % reduction that Miele states does not match the reductions that can be calculated from their product sheets.

Assuming a standard number of wash cycles per year of 280, which is recommended by the European Union regarding energy labeling, the average electricity reduction can be calculated to approximately **92.5 kWh per year**. The calculations that were done to reach this conclusion can be seen in APPENDIX 2.

Also Bosch has dishwashers that can be connected to hot tap water up to 60 °C. It is the type of water supply hose that determines what kind of supply water temperature that can be used. Bosch states that the hot tap water connection is recommended "when using energy-efficient hot water preparation and suitable installation, eg. a solar heating system". They also state that "hot water connection is not recommended if the water is prepared in an electric water heater."¹⁷

However, not all suppliers recommend hot tap water connection. Their arguments are mostly based on warranty and operational reasons. For example, the appliance's plastic parts might not be designed to withstand only hot water.¹⁸

*Table 9 Electric energy need and reduction in dishwashers at hot water connection. *Assuming a standard number of wash cycles per year of 280.*

Manufacturer	Average electric energy usage per cycle (kWh)	Average electric energy usage per cycle at hot water connection (kWh)	Average reduction of electric energy usage per cycle at water connection (kWh)	Annual average reduction of electric energy usage at hot water connection (kWh)*
Asko	0.86	0.58	0.27 (32 %)	76.8
Miele	0.86	0.53	0.33 (38 %)	92.5

6.2 Washing machines connected to both hot and cold water

Theoretically, washing machines can be connected to only hot water. There are however a few reasons why it might not be a good idea. As in the case of dishwashers, the washing machine's plastic parts might not be designed to withstand only hot water. This argument could however, as it is proven by the manufacturers mentioned in the previous chapter, be overcome by the appropriate design. The strongest reasons not to connect washing machines to only hot water are the following:

- Albumins dissolve better in cold water than in hot, making it important that at least the first few minutes of the wash cycle is run with cold water in order to remove stains from the fabrics¹⁹
- With a hot water connection the need for heating electricity is reduced, but the total usage of energy becomes higher as the rinsing – which does not require heat at all and is normally done with cold water – is done in hot water

¹⁶ Miele 2018. Comparison of product sheets through comparison function on homepage. Retrieved 29/06/18 from <https://www.miele.se/konsument/min-broschyr-2580.htm>

¹⁷ Bosch. Diskmaskin SM... SB.... Retrieved 21/09/18 from https://media3.bosch-home.com/Documents/9001224643_C.pdf

¹⁸ Kralmark, S och Hess, A.

¹⁹ Wedberg, Patrik 2018. Podab AB, technical specialist. Phone conversation 04/07/18. Phone number +46 (0) 31-752 01 70

- A hot water connection reduces the possibility to control the process temperature and risks destruction of laundry that is sensitive to temperature

Instead of connecting washing machines to only hot water they could be connected to both hot and cold water connections. This approach reduces the need for heating electricity, but keeps the advantage of being able to control the temperature and rinse with cold water. However, this solution requires a machine design with both hot and cold water connections.²⁰

For example, three well known specialists in *professional* laundry equipment that sell double tap water connected washing machines are Asko, Miele and Podab:

According to Asko, all their professional washing machines can be double tap water connected, giving electricity reductions of up to 70 % and program time reductions of up to 20 %. In the instruction manuals of all Asko's eight professional washing machines it is however not possible to determine whether the stated energy consumptions are valid for cold water connection, or both hot and cold water connection.²¹

According to Miele, all their professional washing machines can be double tap water connected. Their machines with **capacity of 5.5-6.5 kg** are delivered with a cold water inlet connected to a hose, a plugged hot water inlet and a separate hose supplied in the kit. A comparison between cold water connection and double tap water connection shows that the latter can reduce the electricity need by approximately 60 %, **from 1 kWh to 0.4 kWh per cycle**. This is valid for a 60 °C normal wash cycle, a hot water supply of 70 °C and a cold water supply of 15°C. Also, the duration of the wash cycle is reduced by 5-10 minutes depending on the chosen program temperature. Assuming a standard number of wash cycles per year of 220, which is recommended by the European Union regarding energy labeling, the electricity reduction can be calculated to approximately **132 kWh per year**.²²

Also Podab states that all their professional washing machines can be double tap water connected. The service technician who installs the machine needs to enter the configuration menu and set one or a couple of parameters to make the connections work properly. Since Podab only wants qualified personnel to make the configuration changes, they teach service courses aimed at authorized service partners, and a password is needed to enter the washing machine menu. The temperature of the hot water can be maximum 70 °C.

Table 10 sums up the program times and electric energy need in two of Podab's 7-8 kg capacity washing machines; StreamLine model 9070 and BaseLine model 8060. The table is not complete but gives a hint about the general effect of double tap water connection, with tap water temperatures of 15 °C and 60 °C.

For the **8 kg capacity** StreamLine model 9070, the electric energy consumption is reduced by 87 %, **from 1.5 to 0.2 kWh per cycle** for a 60 °C normal program, at double tap water connection. At the same time the program time decreases by 17 min. Assuming a standard number of wash cycles per year of 220, which is recommended by the European Union regarding energy labeling, the electricity reduction can be calculated to approximately **286 kWh per year**. The corresponding numbers for a 40 °C normal wash is 75 % reduction, **from 0.8 to 0.2 kWh per cycle** and **132 kWh per year**.

Table 10 Electric energy need in Podab's professional washing machines at cold tap water connection and double tap water connection.

Wash temperature	7 kg capacity StreamLine model 9070 BaseLine model 8060	8 kg capacity StreamLine model 9070
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²⁰ Mölndal Energi Ltd, product sheet. *Anslut dina vitvaror till varmvattnet*. Retrieved 23/04/18 from <https://www.molndalenergi.se/Portals/0/MILJ%C3%96/Produktblad%5B1%5D.pdf>

²¹ Asko 2018. *Fördelarna med ASKO professionella tvättmaskiner – Kall- och varmvattenanslutning*. Retrieved 21/09/18 from <http://www.asko.se/professional/tvattmaskiner/unika-fordelar>

²² Miele 2013. *Miele Professional – Inkoppling av tvättmaskin PW6055, PW6065 och PW5065 till kall- och varmvatten*.

	Program time		Electric energy consumption (kWh)		Program time		Electric energy consumption (kWh)	
	Cold tap water connection	Double tap water connection	Cold tap water connection	Double tap water connection	Cold tap water connection	Double tap water connection	Cold tap water connection	Double tap water connection
20 °C	44	44	0.35	-	44	44	0.35	
30 °C	47	47	0.5	-	47	47	0.5	
40 °C	50	40	0.75	-	50	40	0.8	0.2
60 °C	60	43	1.3	-	60	43	1.5	0.2

Table 11 sums up the electric energy need in both Podab's and Miele's washing machines.

*Table 11 Electric energy need and reduction in dishwashers at double tap water connection. *Assuming a standard number of wash cycles per year of 220.*

Manufacturer Washing machine capacity Program temperature	Average electric energy usage per cycle (kWh)	Average electric energy usage per cycle at double tap water connection (kWh)	Average reduction of electric energy usage per cycle at double tap water connection (kWh)	Annual average reduction of electric energy usage at double tap water connection (kWh)*
Miele 5.5-6.5 kg capacity machines 60 °C program	1	0.4	0.6 (60 %)	132
Podab 8 kg capacity machine 60 °C program	1.5	0.2	1.3 (87 %)	286
Podab 8 kg capacity machine 40 °C program	0.8	0.2	0.6 (75 %)	132

7 Discussion

The previous chapters have explained the techniques and electric energy saving potential of HWC as well as hot tap water and double tap water connected appliances. In COOL DH, two different LTDH networks are being built, in Sweden and Denmark. The following subchapters will explain how the different appliances and their energy needs would be affected if they were installed at any of these project sites.

7.1 LTDH and HWC appliances

As HWC appliances are not available on the market, the only conclusions that can be made are theoretical and speculative.

To summarize, Asko recommended a minimum heating water flow of 1.6 l/min, a minimum heating water temperature of 55 °C and a maximum temperature of 80 °C for the HWC washing machine, dishwasher and tumble dryer. Temperatures lower than 55 °C would reduce the efficiency to such an extent that the connection to a heating water circuit would become unprofitable. Temperatures higher than 80 °C would not be good for the PEX-hoses.

The first question is how well the HWC appliances would do at the project sites of COOL DH. The 65 °C/35 °C LTDH system at the Swedish project site will be able to provide about 55 °C to a secondary circuit. Or, more precisely, the possible temperature in the customers' systems will be 55-60 °C depending on the house's heat exchanger.²³ However, the LTDH system at the Danish project site will have supply and return temperatures of 55 °C / 30 °C, meaning that the heating water would need extra heating to reach the minimum temperature of 55 °C before entering the HWC machines.

Further, the higher the temperature of the HWC process medium, the higher the temperature of the heating water would be needed to avoid a need for electric energy. For example, a heating water temperature of 55 °C would be able to "cover" the heating need in the HWC washing machines' 40 °C cycles, but the 60 °C cycles. In HWC dishwashers, where the process temperature would most often be > 55 °C, the heating water would always have to be complemented by electric heating. The possible reduction of electric energy need is greatest in HWC tumble dryers, up to 80 % at 55 °C heating water and ECO program, but the process time is negatively influenced when no electricity is used.

The theoretical average energy need in HWC dishwashers, washing machines and tumble dryers are summarized in Table 12.

*Table 12 Values of electric energy usage in Asko's heat driven appliances. *Assuming an annual number of process cycles of 280. **Assuming an annual number of process cycles of 280. ***Assuming an annual number of process cycles of 160.*

Asko HWC appliance	Average electric energy usage per cycle (kWh)	Average electric energy usage per cycle at 55 °C heating water (kWh)	Average reduction of electric energy usage per cycle at 55 °C heating water (kWh) (%)	Annual average reduction of electric energy usage (kWh) at 55 °C heating water
HWC dishwasher	1	0.52	0.48 (48 %)	134.4*
HWC washing machine	0.72	0.28	0.43 (74 %)	95.6**
HWC tumble dryer	3.51	1.24	2.27 (65 %)	363.8***
SUM:	5.23	2.04	3.18	593.8

The above stated means that even if it was possible to purchase HWC appliances, they would only be suitable at the Swedish COOL DH demo site, where the district heating supply temperature will be 65 °C. The HWC appliances would probably not be suitable at the Danish site where the supply temperature will be 55 °C. If so, the appliances must have

²³ Gierow, Martin 2018. Kraftringen Energi Ltd, technical specialist. E-mail conversation 27/02/18, E-mail address: martin.gierow@kraftringen.se.

supplementary electrical energy for temperature boost. Assuming that each customer at the Swedish site will have one dishwasher, one washing machine and one tumble dryer, the HWC technique would be able to reduce the electric energy need – and increase the thermal energy need as much – by approximately **594 kWh per year, or 61 % compared to normal operation.**

7.2 LTDH and appliances with alternative tap water connection

In this report two appliance manufacturers selling dishwashers that can be connected to hot tap water have been presented; Asko and Miele. Their recommended maximum supply water temperatures are 70 °C and 60 °C respectively. Further, the two manufacturers Miele and Podab selling professional double tap water connected washing machines have been presented. Their recommended maximum supply water temperatures are both 70 °C.

Table 13 summarizes the average energy need in Asko's and Miele's dishwashers as well as Miele's and Podab's washing machines. The average electric energy reduction in the dishwashers can be calculated to 35 %, corresponding to 0.3 kWh per cycle or 84 kWh per year and machine. The energy reduction of Miele's double tap water connected washing machine is 0.6 kWh or 60 % at its 60 °C program. The reduction in Podab's washing machine at the same temperature is 1.3 kWh or 87 %. Podab's washing machine is however quite larger than Miele's machine – 8 kg capacity compared to 5.5-6.5 kg.

*Table 13 Values of electric energy usage in different manufacturer's appliances at normal operation as well as and hot or both hot and cold water connection. *Double tap water connected. **Assuming an annual number of process cycles of 280. ***Assuming an annual number of process cycles of 220.*

Manufacturer and type of appliance	Average electric energy usage per cycle (kWh)	Average electric energy usage per cycle at hot water connection (kWh)	Average reduction of electric energy usage per cycle at hot water connection (kWh)	Annual average reduction of electric energy usage per cycle at hot water connection (kWh)**
Asko dishwashers	0.86	0.58	0.27 (32 %)	76.8**
Miele dishwashers	0.86	0.53	0.33 (38 %)	92.5**
Miele washing machines* 5.5-6.5 kg capacity machines 60 °C program	1	0.4	0.6 (60 %)	132***
Podab washing machines* 8 kg capacity machines 60 °C program	1.5	0.2	1.3 (87 %)	286***
Podab washing machines* 8 kg capacity machines 40 °C program	0.8	0.2	0.6 (75 %)	132***

The above stated means that hot tap water connected dishwashers and double tap water connected washing machines could, as opposed to HWC appliances, be suitable to install at both the Swedish and the Danish COOL DH project sites. The numbers presented in Table 13 are measured at an unknown hot water temperature, but it can be assumed that the temperature is at least 55 °C.

The installation of hot water connected dishwashers in the homes of the COOL DH project sites would be able to reduce the electric energy need – and increase the thermal energy need as much – by approximately **84 kWh per year, or 35 % compared to normal operation.**

The installation of Miele's and Podab's double tap water connected washing machines would – as the machines are professional – only be suitable in laundry rooms in multifamily houses. Assuming an annual number of process cycles of 220, which is recommended by the European Union regarding energy labeling, the reduction of electric energy

need would be **132-286 kWh per year, or 60-87 % compared to normal operation, assuming that only 60 °C programs would be used.** It can however be questioned whether 220 is an accurate number to use in the case of common laundry rooms. Also it is incorrect to assume that only 60°C programs would be used.

8 APPENDIX 1

Asko dishwashers (able to connect to hot tap water)				
Model	Electricity usage Standard program with cold water inlet (kWh)	32 % reduction of electricity usage for Standard program, corresponding to the amount of electricity reduction with hot water inlet (kWh)	Diff.	32 % reduction /year (kWh) with 280 cycles/year
D5436IS	0.93	0.30	0.63	83.3
D5436IW	0.93	0.30	0.63	83.3
D5438IB	0.82	0.26	0.56	73.5
D5438IS	0.82	0.26	0.56	73.5
D5438IW	0.82	0.26	0.56	73.5
D5548IW	0.95	0.30	0.65	85.1
D6100IB	0.82	0.26	0.56	73.5
D6100IS	0.82	0.26	0.56	73.5
D6100IW	0.82	0.26	0.56	73.5
D6300IS	0.93	0.30	0.63	83.3
D6300IW	0.93	0.30	0.63	83.3
D7100IS	0.95	0.30	0.65	85.1
D7100IW	0.95	0.30	0.65	85.1
D8437IB	0.82	0.26	0.56	73.5
D8437IS	0.82	0.26	0.56	73.5
D8437IW	0.82	0.26	0.56	73.5
DBI133IW	0.82	0.26	0.56	73.5
DBI644IGB	0.83	0.27	0.56	74.4
DBI644IGS	0.83	0.27	0.56	74.4
DBI644IGW	0.83	0.27	0.56	74.4
DBI654IGS	0.84	0.27	0.57	75.3
DBI654IGW	0.84	0.27	0.57	75.3
DBI8557S	0.84	0.27	0.57	75.3
DBI8557W	0.84	0.27	0.57	75.3
DBI654IGW	0.84	0.27	0.57	75.3
DBI8557S	0.84	0.27	0.57	75.3
MIN:	0.82	0.26	0.56	73.5
MAX:	0.95	0.30	0.65	85.1
AVERAGE:	0.86	0.27	0.58	76.8

9 APPENDIX 2

Miele dishwashers (able to connect to hot tap water)						
Model	Energy label	Electricity usage ECO-program with cold water inlet (kWh)	Electricity usage ECO-program with cold water inlet (kWh)	Reduction kWh electricity	Reduction kWh %	Annual reduction with 280 cycles/year (kWh)
G 6825 SCU XXL	A+++	0.67	0.49	0.18	27 %	50.4
G 6820 SCU	A+++	0.67	0.49	0.18	27 %	50.4
G 6825 SCU XXL	A+++	0.67	0.49	0.18	27 %	50.4
G 6820 SCU	A+++	0.67	0.49	0.18	27 %	50.4
G 6720 SCU	A+++	0.67	0.49	0.18	27 %	50.4
G 6635 SCU XXL	A+++	0.84	0.49	0.35	42 %	98.0
G 6720 SCU	A+++	0.67	0.49	0.18	27 %	50.4
G 6620 SCU	A+++	0.75	0.45	0.30	40 %	84.0
G 6640 SCU	A+++	0.84	0.49	0.35	42 %	98.0
G 6630 SCU	A+++	0.84	0.49	0.35	42 %	98.0
G 6635 SCU XXL	A+++	0.84	0.49	0.35	42 %	98.0
G 6000 SCU Jubilee A+++	A+++	0.84	0.49	0.35	42 %	98.0
G 6630 SCU	A+++	0.84	0.49	0.35	42 %	98.0
G 6640 SCU	A+++	0.84	0.49	0.35	42 %	98.0
G 6620 SCU	A+++	0.75	0.45	0.30	40 %	84.0
G 4935 SCU XXL Jubilee	A++	0.94	0.58	0.36	38 %	100.8
G 4930 SCU Jubilee	A++	0.94	0.59	0.35	37 %	98.0
G 4931 SCU Jubilee	A++	0.94	0.59	0.35	37 %	98.0
G 6000 SCU Jubilee A+++	A+++	0.84	0.49	0.35	42 %	98.0
G 4935 SCU XXL Jubilee	A++	0.94	0.58	0.36	38 %	100.8
G 4931 SCU Jubilee	A++	0.94	0.59	0.35	37 %	98.0
G 4930 SCU Jubilee	A++	0.94	0.59	0.35	37 %	98.0
G 4203 SCU	A+	1.05	0.59	0.46	44 %	128.8
G 4930 U Jubilee	A++	0.93	0.58	0.35	38 %	98.0
G 4203 SCU	A+	1.05	0.59	0.46	44 %	128.8
G 4203 U	A+	1.04	0.58	0.46	44 %	128.8
G 4204 SCU	A+	1.05	0.59	0.46	44 %	128.8
G 4202 U	A+	1.04	0.58	0.46	44 %	128.8
MIN:		0.67	0.45	0.18	27 %	50.4
MAX:		1.05	0.59	0.46	44 %	128.8
AVERAGE:		0.86	0.53	0.33	38 %	92.5