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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Scope of deliverable
Description of the state-of-the art of heatdriven appliances.

Context of deliverable
Summary of recent Swedish reports of heatdriven appliances.

Perspective of deliverable
Input for decisionmaking on energy efficient measures in READY.

Involved partners
Energy Agency for Southeast Sweden, ESS - lead

English summary
Heat driven appliances is a technology with fully developed products that can use heat instead of electricity for warming up the process media. In this way cheaper and available heat energy from e.g. district heating, solar energy or industrial rest heat can be used instead of the more expensive electrical energy. It is an opportunity to reduce the energy costs, the environmental impact and to increase the use of district heating in areas where it otherwise would not be profitable.

The products are well tested and installed in several projects in Sweden already. Though there is a hesitant attitude on the market that prolong the timeline for a major breakthrough. There is still a limited number of installed products and only one major supplyer (ASKO/Cylinda) with both washing maschines, dishwashers and tumble dryers/drying cabinets. One other supplyer can as well adjust the appliances to be heat driven in one of their product series (PODAB).

The economy is one reason for the careful approach on the market. The heat driven appliances have been expensive to purchase, but today (May 2015) the price is only 15 % higher compared to a similar conventional maschine. Today in Sweden the electricty prices are low. This means that the difference between the price of heat and electricity is also small and the savings of operation costs are smaller than it would be with higher electricity prices. The electricity prices are expected to increase over time which would make heat driven appliances more profitable. Already today there are pay back calculations where the extra investments are payed back in less than five years for certain products, temperatures and system solutions. Life cycle cost calculations favour heat driven appliances both in a 10 and 30 year perspective with lower costs than for traditional electrical maschines.

There are some investments that have shown to be more profitable than others. It is recommended to go for solutions where the installations costs are as low as possible, i.e. short distances for new pipe installations, to keep down other extra equipment and working costs as well as applications with high usage and long operation times. Common laundries in connection to multiple family apartment buildings fulfill these requirements and here both washing maschines and tumble dryers are in use. Tumble dryers are probably the product that saves most electrical energy. Pree schools with a high usage of drying cabinets for wet clothes can also be a profitable investment. Besides there are projects in new areas where heat driven appliances are tested in individual homes. In new buidlings the extra installation costs can be kept down with smart solutions that are more difficult to achieve when renovating existing buildings.

There is a large potential and a huge market for heat driven appliances. There is need for more marketing and large supplyers that produce larger volumes which will reduce costs. There is need for discussions between property owners, building companies and energy companies in order to find the best solutions for the future. There are figures showing that appliances use 40 % of the energy in the household. Assume that heat driven appliances reduce electricity consumption with 50 % for the appliances. Multiply this with a large share of all households that can be connected to a heating source and this will lead to a huge reduction of the electricity consumption, costs, environmental impact and increase in use of heat.

1. Table of content

1. INTRODUCTION

1.1. Background

This report is a part of the larger READY-project. READY is an acronyme for Resorce Efficient cities implementing ADvanced smart citY solutions. The main priority is to demonstrate optimized energy systems for high performance energy districts. The project include demonstration of residential buildings going through towards zero energy retrofitting, grid balancing/electricity storage solutions for buildings and energy systems, solutions to maximize use of renewble energy, development of energysmart solutions for kitchens, solutions for water efficiency and waste water energy recovery and development and demonstration of new solutions for low temperature district heating.
This report describe the current situation and the potential for heat driven appliances which is one opportunity to decrease the use of electricity in favour of thermal (low temperature) energy such as district heating.
Heat energy is often cheaper than electrical energy and for sure in the summer when the cost of district heating is at its lowest level and when solar heating have the highest production. With lower cost heat driven appliances such as dishwashers, washing maschines and tumble dryers gets more interesting for property owners working with reducing electric energy consumption. This is valid especially if there is access to district heating, solar heating or bio energy.
Using heat instead of electricity for appliances using heat in the process means a reduction of operation costs and primary energy. Heat has a lower value on primary energy than electricity and this is also a driver for use of heat driven appliances.
Also the actors involved in district heating have interest in heat driven appliances but for another reason. The development for district heating in Sweden goes towards more customers but not the corresponding increase of sold heat. One reason is more and more efficient buildings. This leads to lower heat consumption which also means higher return temperatures and higher heat losses in the district heating system. This means lower profitablility for district heating and this is a strong driver for development of new technology which can raise the heat consumption. Heat driven appliances is one opportunity to use the district heating systems even more effective.
District heating is considered as an important sustainable technology both from the economic an environmental perspective due to the use of local resources fuel or heat that could not be used in other ways.
In the county of Blekinge in Sweden there has recently been done a study of the rest heat potential from industrial companies. This rest heat could also be used by heat driven appliances. By reusing the rest heat from industry it would be possible to reduce the total production of energy. This can also lead to new job opportunities in companies using this heat. By making the companies more energy efficient they will also be more competitive on the market. The study shows a great potential of rest heat that is higher than the existing production level of district heating in the county. Though there is need for investments in infrastructure to be able to use this potential of rest heat.

1.2. Purpose

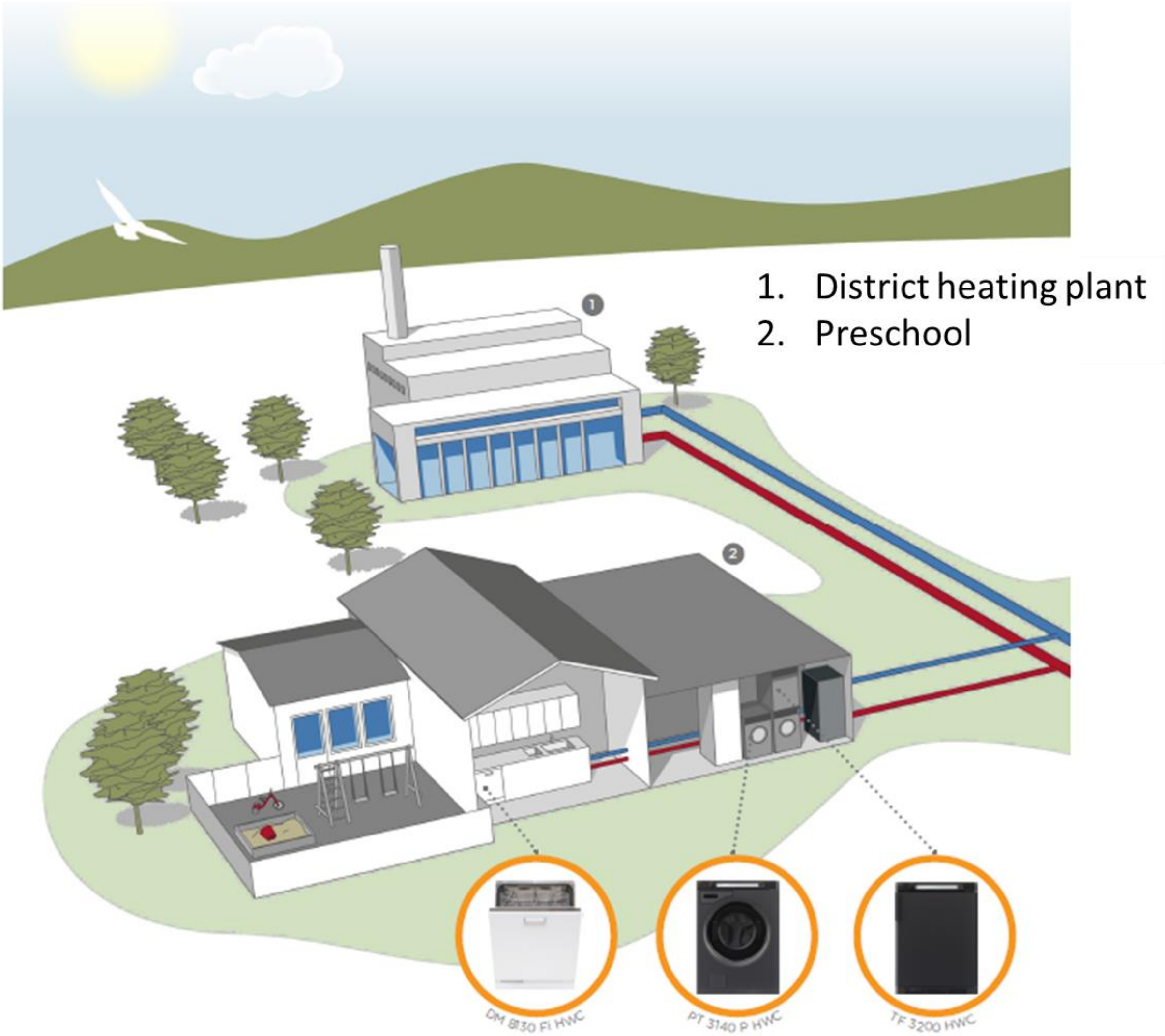
The purpose of this report is to describe the current situation and the potential for heat driven appliances from both a market and technical perspective. It will include the products that exist on the market, the price levels and some comparison between different technical solutions. The report will also include some real project examples. The report will be used as input for decisionmaking on energy efficient measures in READY.

1.3. Method

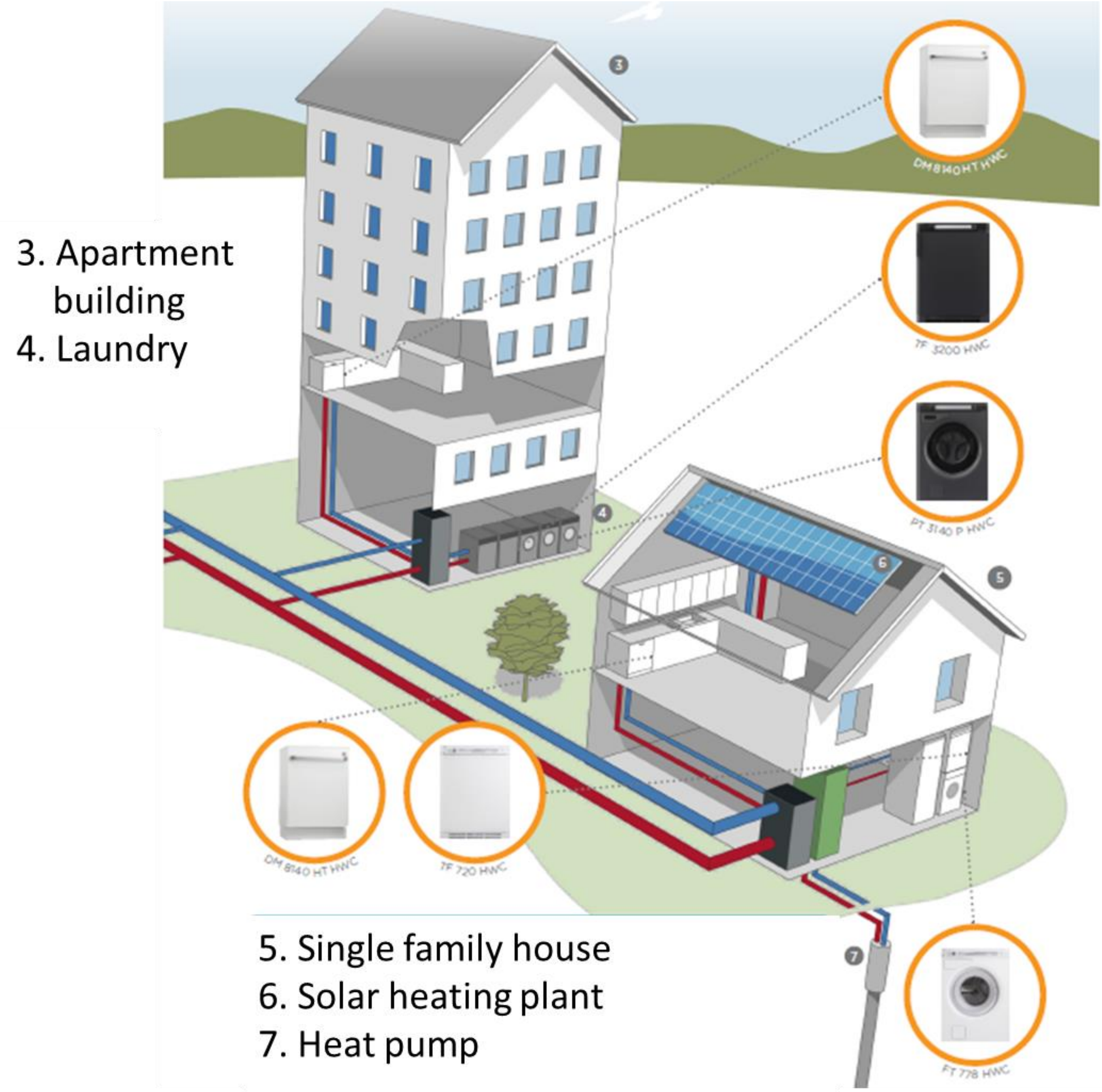
The report is a summary of recent Swedish reports of heatdriven appliances and some information from personal contacts with distributors, project partners and from already implemented projects.

2. HEAT DRIVEN APPLIANCES

Heat driven appliances have a heat exchanger built into the maschine which makes it possible to heat the process water with warm water instead of the regular way with electricity. In this way it is possible to use energy of lower quality and price than electricity. It could be water from district heating but also other sources for hot water such as e.g. water heated from solar energy or hot water from the tapwater system.



Picture 1 – Overview from Cylinda HWC-folder 2014 [1]



Picture 2 – Overview from Cylinda HWC-folder 2014 [1]

2.1 History and development

During the 1980s there were dish- and washingmaschines using hot water available on the market. They were mostly used to increase the energy exchange in solar heating plants. There are not any results or reports from this time and the spread of the technology was low. Later in the 1990s prototypes of heat driven washing maschines and tumble dryers were developed and tested in Holland. There was a report in the year 2000 evaluating these field tests. The results showed that the total energy consumption was 20-40% larger than for a regular electrical maschine even if electrical energy could be reduced with 70-75%. This depended mainly on the construction, the placement of the heat exchanger and that more water had to be used and heated than for the electrical mashine. This also meant higher need for heating and higher energy consumption. Therefore the interest was quite low to continue the testing at that moment. It can be mentioned that the increase on energy consumption did not lead to higher cost due to the higher price on electricity.
A few years later an energy company in Gothenburg showed interest for the dutch project and started a demonstration house with heat driven products in 2005 with the purpose to show different ways of using district heating. There was a cooperation with research engineers at Dalarna University contributing with converted dishwashers and washing machines developed by Asko Appliances Ltd. Those maschines were initially developed to be able to use excess heat from solar heating during the summertime and the technology differed from the dutch maschines in the earlier project. Now all electrical energy used for heating the process water could be replaced without increasing the total energy consumption. The tumble dryer was considered more difficult to make more efficient and the original dutch maschine was installed. Simulations were made to evaluate the reduction of electrical energy in the dishwasher and the washingmaschine and also in tapwater conected dishwashers and washing maschines. Results and conclusions are described in the report from the Swedish distict heating association [2]
In the same period of time as the demonstration project i Gothenburg another cooperation between Karlstad University, a property company in Karlstad (Karlstads Bostads Ltd) and the Swedish Energy Agency developed new technology for heat driven tumble dryer. The maschine had external heat exchangers and was optimized for connection to the property heat pump. Tests were made and in a master thesis [3] was described that the heat exchangers would be possible to make smaller and placed inside the original maschine.

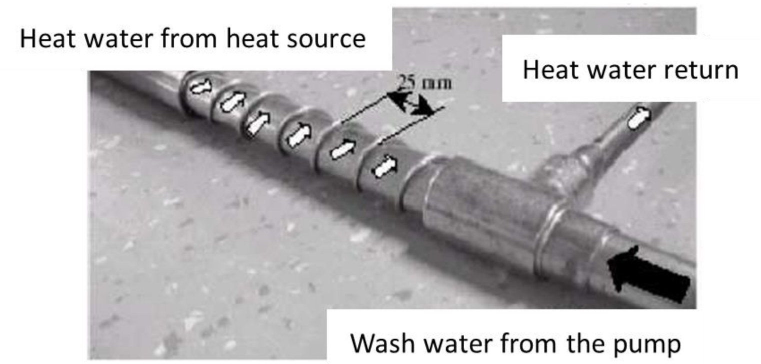
2.2 Technology and function

A majority of all Swedish homes have a conventional technology in their dishwashers, washingmaschines and tumble dryers where electricity heat the incoming process medium.

In many of the new dishwashers and washing maschines on the market today it is possible to connect to hot tapwater and for washingmashines also to both hot and cold tapwater, but today there is no technology for tumble dryers using hot tap water since the temperature is so low that it would take too long time to dry the laundry.
Washingmaschines with connection to both hot and cold water can adjust the temperature to the washing programme and if the temperature on the tap water is too low electricity is used to heat it up more. Connection only to hot tapwater is not recommended both with consideration to the use of energy and e.g. to get the dish clean enough.

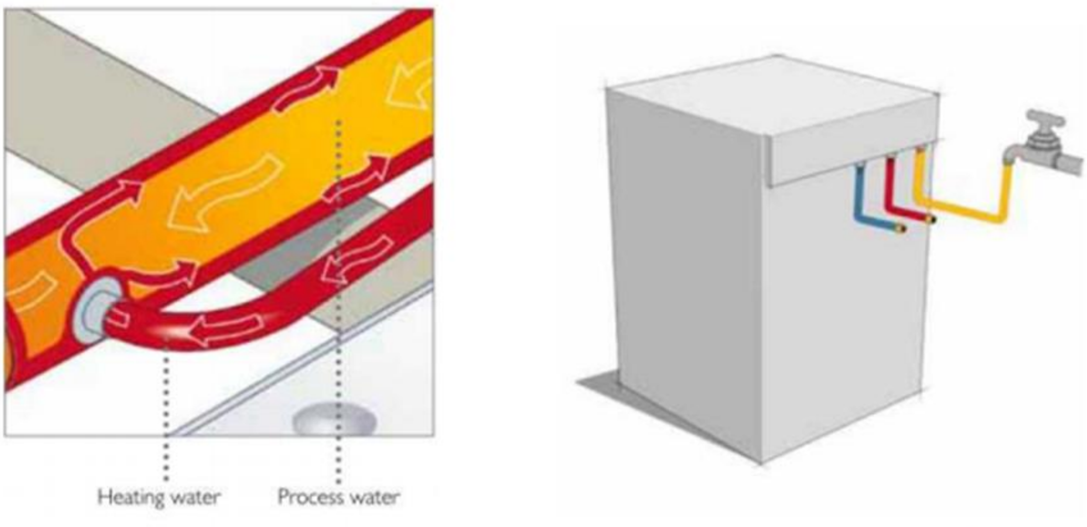
Picture 3 – Connection to both hot tap water (for heating) and cold water (for rinsing)

In heat driven appliances heat water from e.g. solar heating or district heating go through a heat exchanger in the maschine to heat the incoming process medium. Parts of the electrical energy is replaced with heat energy but there will allways be need for some electricity for pumping the process medium and rotating parts in the maschines. If the heat comes from district heating the maschines can either be connected directly to the district heating system or to a secondary district heating circuit. Asko calls the heat driven maschines HWC-maschines (Hot Water Circuit).



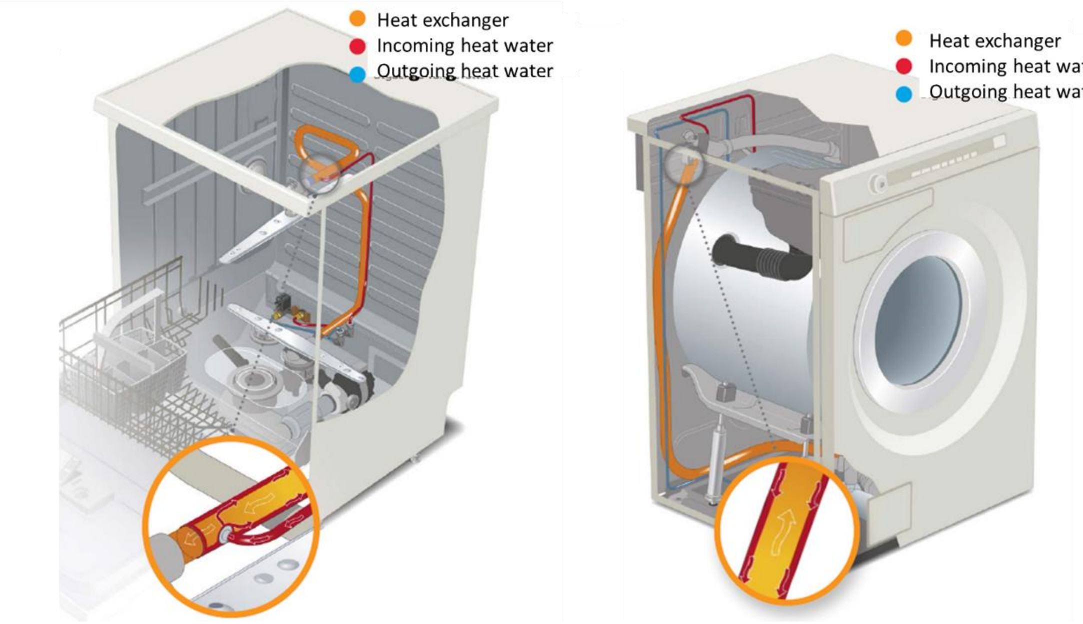
Picture 4 – Construction of coaxial pipe heat exchanger [4]

In the demonstration house in Gothenburg described earlier the heat exchanger in picture 4 was used. Results from these demonstrations showed that at 70° C heat temperature and 60 ° C process temperature, all electricity for heating of the dish or wash process could be replaced by energy from the district heating system.



Picture 5 – The heat water (in red) heats the process water (yellow to orange) [1]

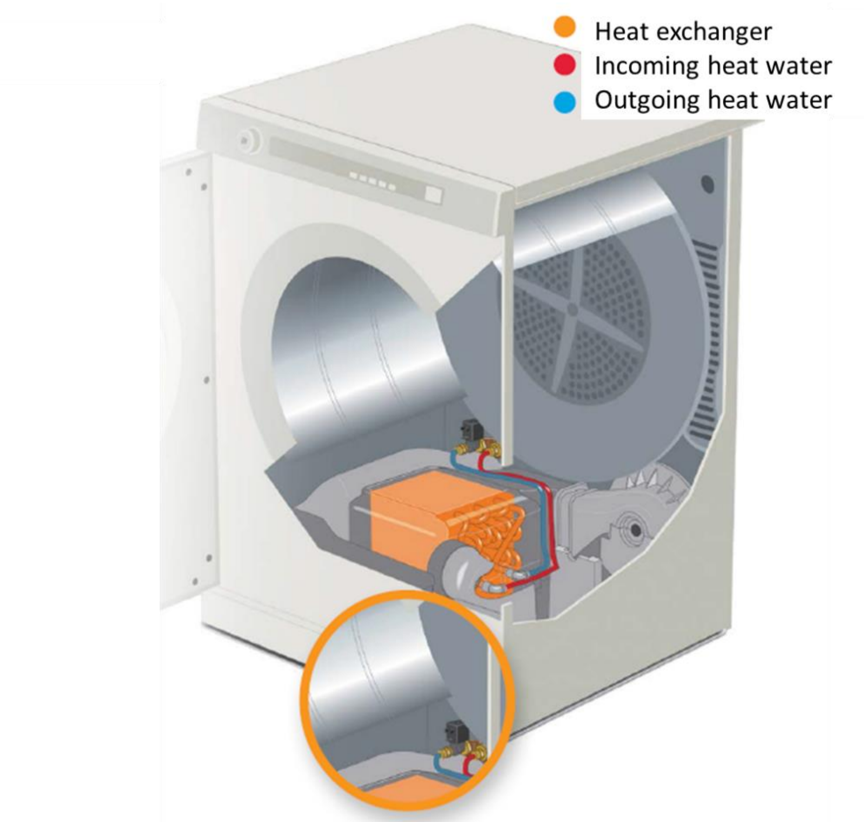
Askos HWC-maschines have two extra connections in the back side compared to the ordinarie electrical versions. One is for incoming heat water and one for outgoing heat water. The process water has a regular connection. With a special automation it is possible to control the activation of the heat water flow only when the maschine is in use. This will save both electrical and heat energy.



Picture 6 – Heat water driven dishwasher and washing maschine from Asko product information sheet [1]

Both the HWC- dishwasher and the washing maschine use the coaxial pipe heat exhanger that can be seen in picture 4 and 5. In the inside pipe the process water flow into the maschine and in the outside pipe the heat water flow in the opposite direction and heat the incoming cold water. The process media circulate continously through the heat exchanger during the different heating phases.

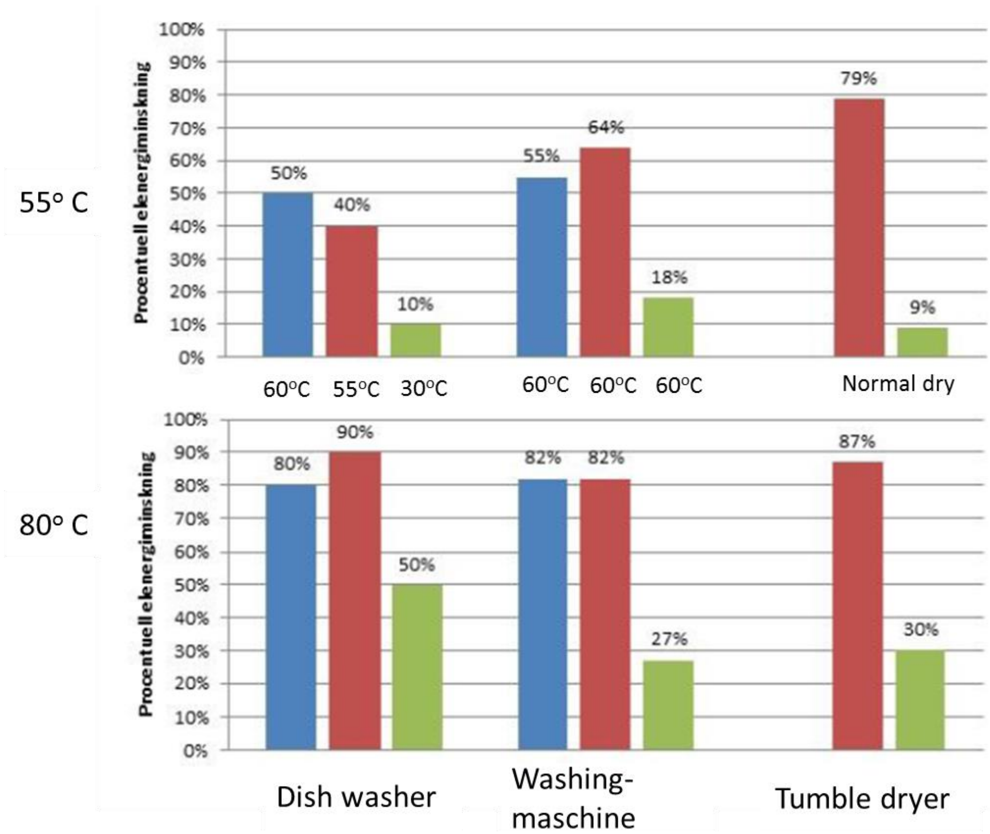
Picture 7 below show Askos exhaust air HWC tumble dryer for private use. In the heat exchanger hot water circulate and heat up the incoming air to the tumble dryer. Asko started to try the new technology in the exhaust air tumble dryer since there was plenty of room for new components. Development of a condense tumble dryer with the new technology is a part of the future plans.



Picture 7 – Heat water driven tumble dryer from Asko product information sheet [1]

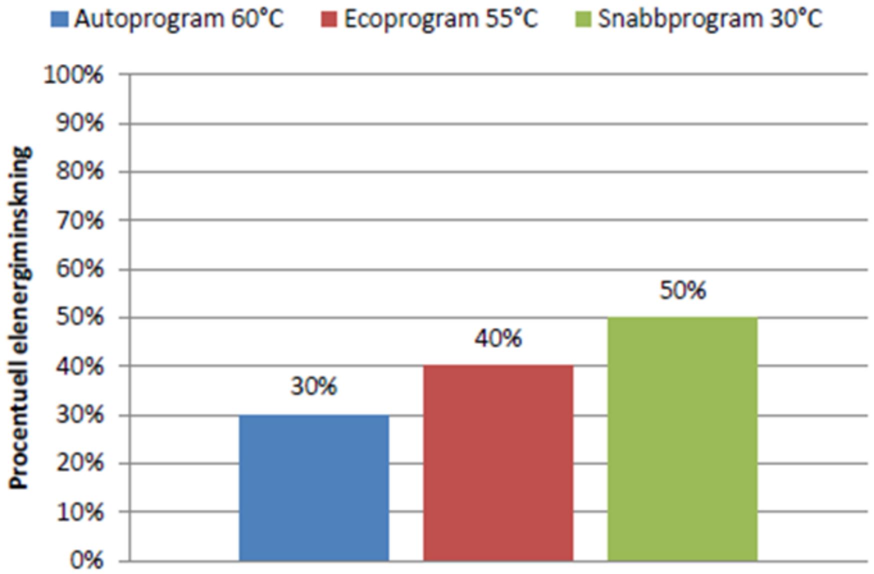
The need of electricity and heat in HWC-maschines can be simulated. Again references are made to the maschines used in the Gothenborg demonstration house. Simulations for the washing maschine show a certain base need for electricity of 0,8 W or 0,2 kWh per washing cycle for pumps and other rotating parts [5]. For the dish washer the corresponding values are 0,4 W or 0,1 kWh. In the washing maschine the necessary heat water temperature would be 55°C to get a washing temperature of 40°C without heating with electricity. To reach 60°C washing temperature the heat water need to be 80°C to avoid heating with electricity and for a washing temperature of 90°C additional electrical heating is necessary. With temperatures over 80°C the regular PEX-connections have to be replaced towards more heat resistent material. For the dishwasher 60°C process water can be reached with heat water of the temperature 70°C. It is possible to avoid electricity for heating but there are also electrical heating radiators in HWC-maschines if it takes too long time to reach the next temperatur level.
For Askos HWC-maschines there is a recommended lower heat water temperature of 55°C with consideration to efficiency and that it should be worth having a heat water connection. Another parameter influencing efficiency is having the right dimensions on the pipes to get a recommended flow of 1,6 litres per minute.

When the process water comes in to the dishwasher or the washingmaschine the mashine and the dish/wash is cold. This means that a lot of energy goes to heat not only the process water but also indirectly the maschine and the dish/wash. As the process water cools down it needs to be reheated and in hot tap water connected appliances this is done with electricity instead of with heat as in heat driven appliances. This is the most important reason for the difference in reduction of electricity between heat driven and hot tap water connected appliances. In hot tap water connected appliances the process water also cools down between the cycles and needs further electrical energy for heating compared to the heat driven appliances using heat water for this.
Another difference is that the fact that heat driven appliances can replace more electricity with heat with a higher heat water temperature. For washing programs with lower temperature the reduction of electricity decrease. Hot tap water connected appliances on the other side can reduce the electricty consumption more at lower washing temperature than at higher temperature. This depends on that there is less electrical needed for heating the processwater (including the maschine and dish/wash) and reheating the process water between cycles.
Measurements of electricity comsumption for Askos products and for different programs show e.g. that heat driven appliances can reduce the electricity consumption compared to electrical appliances with 50/40% (auto/eco program) for dishwasher, 55/64% for washing mashine and 79% for tumble dryer at the heat water temperature 55° C. With heat water of 80° C the corresponding values are 80/90% for dish washer, 82% for washing mashine and 87% for tumble dryer. It can be noted that the dryer has high reduction of electicity also at low process temperature.



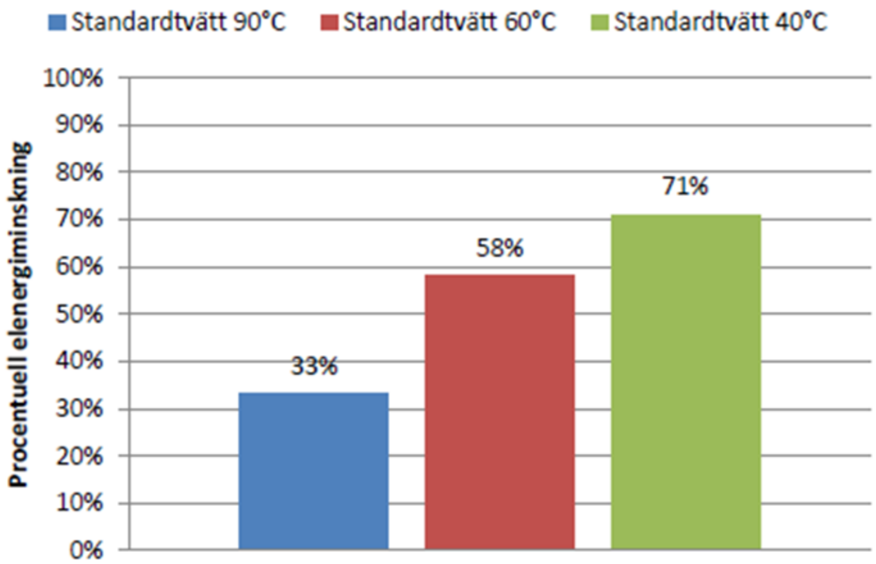
<u>Picture 8 – reduction of electricity consumption for heat driven appliances [5]</u>

Those values can be compared to figures for a hot tap water (60° C) connected dishwasher that can reduce the electricity consumption with 30% with process water of 60° C, 40% at 55° C and 50% at 30° C (auto, eco and fast program). The electricity reduction is increasing with lower temperature. There does not seem to exist any double tap water connected dishwashers and since the water consumption is so low there is no economy in doing that either.



Picture 9 – reduction of electricity consumption for hot tapwater connected appliances [5]

If we look at a double tap water connected washing maschine (connection to both hot and cold tap water) the values the electricity reduction are 33% at process water temperature of 90° C, 58% at 60° C and 71% at 40° C. Also here electricity reduction increase with lower process water temperature. Double connected appliances have potential to save more electrical energy than single connected ones. Single hot water connected washing maschine is not suitable since there are much rinsing with cold water.



Picture 10 – reduction of electrical energy for double tapwater connected appliances [5]

By comparison of heat driven and hot tapwater connected appliances can be seen that heat driven appliances are outstanding in saving electrical energy for higher temperatures of process water but for process water temperatures of 55° C or lower hot tap water connected appliances are competitive or more effective. In average hot tapwater connected appliances do not save as much electrical energy as heat driven alternatives. Though they also mean use of some heat energy instead of electricity and they can be a cheaper alternative and much more easy to install both in existing and new buildings. The problem is that there is no hot tap water connected tumble dryers on the market and the tumble dryer is the heat driven appliance saving the most electrical energy. This mean that a choice with tap water connected appliances in total will give much less reduction of electricity. It would also be a waste of tap water to develop a hot tap water connected tumble dryer and it will problably not happen.

Of course higher tap water temperature than normal to the appliances would make the conditions more similar to the heat driven appliances also at higher temperatures. Then hot tap water might also could be connected to the HWC-circuit instead of other heat water. This could be investigated more.

For heat driven appliances the total energy consumption is not lower since electrical energy is replaced with heat energy.

In the Swedish building regulation the energy consumption of a building include heating, cooling, hot tap water and the more undefined property energy. Energy needed for electrical appliances is counted as house hold electricity and is not included. If on the other hand the electricity used for white goods is replaced by heat this will automatically be included in the total energy of the building. This can influence the ability to follow the energy requirements on the building according to building regulations or different green certificates. To examplify this as an indication a calculation was made. This show that the total energy consumption for an apartment of 70 m^2 (normal isolated building) gets an increase of total energy with 11-26% using heat driven appliances depending on if the heat water temperature was 55°C - 80°C. To show the influence of the size the same calculation was made also for 140 m^2 and then the increase of total energy was 6-13%. Dialogue has been initiated with ambition to change the regulations or on local level allow a raised consumption of heat energy of a certain level when heat driven appliances are installed. [5]

It is possible to go even more into detail of the origin of the energy, the primary energy, and what it means for use of electrical or heat energy for appliances. This discussion will not be included in the report even if some conclusion from the used sources of information can be mentioned.

2.3 Current market situation

Today there is a very limited number of heat driven appliances installed in real buildings. The most known projects are mentioned below in section 3. Currently the electricity prices are very low and the difference between costs for electricity and heat are not that advantageous. The expectation for rising electricity prices will improve the economic conditions for heat driven appliances.

The interest in heat driven appliances can be increased if the manufacturer Asko or the sale and service organisation of cylinda market to constructors in a more extensive way. Appliances may also need to be promoted by other actions, for example special municipal requirements, in energy-labeling and environmental certification systems. [5]

Many actors can benefit from the heat driven technology. The district heating companies will benefit from being able to sell more heat and go into low energy projects that otherwise not would be profitable. This is of importance for the use of future district heating systems as buildings get more and more energy efficient. [6]

Also the property owners will benefit from lower consumption of electrical energy and cheaper energy for the heat energy. Depending on the agreement with the tenants. If they have cold rent they will benefit of both the lower electricity consumption and the cheaper heat energy. On the other hand if the heat is included in the rent the property owner decide how much lower energy costs will effect the rent. The electricity bill will be lower in any case.

Today there are very few supplyers that have products that can be connected to heat water from e.g. district heating. That is Asko which now sell their products through Cylinda and then there is the company PODAB that also have some maschines that can be connected to heat water. If it would be possible to sell heat driven products in a larger scale there would be an increasing interest from more suppliers and a competitive climate that would benefit development and price level.
There are also a non existing or very low availability or request of double tap water connected appliances on the market today.

The Swedish District heating Association encourages to dialogue and cooperation of information efforts between the district heating companies and those producing appliances to boost the market for heat driven appliances.

2.4 Suppliers and products

The Swedish District Heating Association has collected information of producers of heat driven appliances.

Asko Appliances Ltd, Cylinda
From 2015 Asko sell their products through Cylinda. Cylinda sell dishwashers, washing maschines and tumble dryers that can be adjusted for connection to either electricity or heat water. Heat water is the name for water from district heating, solar heating, heat pumps etc which differs from e.g. hot tap water. The heat water is used for heating the process water or the process air. According to Asko is the use of electrical energy reduced with 90%. According to Asko's calculations heat water driven dishwashers and washing maschines use appr. 306 kWh per year less than conventional electrical models. In section 2.2. above are more examples of reduction of electrical energy in percent for different appliances, programes and temperatures.

See pictures 3-5 above.

- Heat driven appliances need the new components:
  - Heat exchanger
  - New connections
  - Heat water valve
  - Updated operation programme
- The washingmaschine also need a new process water valve
- The tumble also dryer need
  - Water to air heat exchanger instead
  - Air channels
  - Air filter

Electrical energy consumption HWC vs. standard products

	STANDARD* Electrical energy consumption	HWC** Electrical energy consumption	Electrical energy saving/cycle	Electrical energy saving/cycle
Dishwasher D5654 XL Normal program, 60°C	1.04 kWh	0.16 kWh	0.88 kWh	85%
Washer W6884 Normal white/colour, 60°C, 8 kg	1.2 kWh	0.2 kWh	1 kWh	85%
Dryer T784 Vented Auto normal dry, 7 kg	3.51 kWh	0.4 kWh	3.11 kWh	89%
Prof. Washer WMC64P Normal white/colour, 60°C	1.2 kWh	0.2 kWh	1 kWh	85%
Prof. Dryer TDC111V Auto normal dry, low temp	3.51 kWh	0.4 kWh	3.11 kWh	89%

* According to European standards: EN50242 (dishwashers), EN60456 (washers), EN61121 (dryers).
** Measured on a heating water inlet of 80°C and HWC washers, dishwashers and dryers in ECO mode. Minimum recommended flow rate is 1.6 liters/minute.

Picture 11 – Comparison for consumption of electrical energy, Asko appliances Ltd [7]

The maschines in picture 8 in Cylindas product portfolio have the names:
- Dishwasher DM 8140 HT HWC
- Washer FT 778 HWC
- Dryer TF 720 HWC
- Prof. washer PT 3140 P HWC
- Prof. dryer TF 3200 HWC

Picture 12 – Products showed in Cylindas HWC-folder 2014 [1]

85% of Cylindas products can stand 80° C water temperature and pressure from 0,3 to 10 bar. For dishwashers there is risk for expansion of holes for other material than stainless steel. Cylinda have many products adjusted for private customers

Miele
Miele has a washing maschine developed for private use and many professional models that can stand hot water. All of Mieles dishwashers can stand connection to hot tap water (60° C). Miele has noticed interest for heat water connected appliances by new production of buidlings where the total energy consumption has high priority.

Whirlpool
In Whirlpools AWO ECO-serie there are three washing maschines that can be connected to both cold and hot water. The dishwashers has not the same solution since there are difficulties to solve the problem with protein coagulation.

Electrolux
Electrolux dishwashers are all prepared for connection to both cold and hot water (60° C). There are many professional maschines that can be connected to both hot and cold water and one washing maschine for private use that can be connected to the hot tapwater. This maschine can reduce the electricity consumption with 50%.

Bosch and Siemens
Bosch has one and siemens have two dishwashers with both hot and cold water connection and switch between hot and cold water can be made on a digital display. Most of the dischwashers produced today can be conected to hot water (maximum 60° C)

PODAB
Many of PODABS washing maschines can be connected to both hot and cold water. PODAB have products for proffessional washing. The product serie Streamline can be connected directly to the district heating system but the other products need adjustments. It is possible to connect many maschines if the washing times are adjusted manually.

Picture 13 – View from PODABs website [8]

2.5 Economy

2.5.1 Price of heat and electricity

The energy prices are important from the economic perspective and decisions of which technologies to invest in. For the moment the electricity prices in Sweden are very low. The expectations have been that the electricity prices should have been much higher already today and they they will increase in the future. Heat energy is much cheaper then the electricity and sometimes the price can be almost half the price of electricity. A high price of electricity or a large difference between the price on electricty and heat will make investments in heat driven appliances and system solutions more attractive and profitable.
In next section (2.5.2) calculations are made for a new city area Solbjers close to Lund in southern Sweden. The calculations from 2013 are based on the following price levels for electricity and heat:

- Price of district heating 1 SEK/kWh (appr. 10 EUR cents)
- Price of electricty consumption 1,4 SEK/kWh
- Fixed price of electricty net 1681 SEK/year
- Total price of electricity 2 SEK/kWh (appr. 21 EUR cents)

(total electricty price including net, consumption and taxes based on a consumption of 3000 kWh/year)

In the payback calculations in the next section the example above is used as one realistic price level in 2013 (case 2). One example is made with lower prices (case 1) and two examples (case 3 and 4) are made with expected higher prices electricity prices in 5 to ten years of time. In the four examples the electricity price differ from 1,25 to 2,8 SEK/kWh. The price of district heating is 0,5 SEK/kWh and then kept on 1 SEK/kWh. The electicity price is assumed to increase with 0,08 SEK/year. The price of district heating is kept constant in case 2-4 to only show the difference to the electricity price. In reality an increase of the district heating price is expected but it is assumed to be much lower than the electricity price.

It is not covered in this report but it would be of great interest to have a realistic calculation example with certain fixed parameters where only prices were changed. Then it would be easy to compare the situation in different countries. Higher electricity prices in other european countries can make it more profitable to invest there than in countries with lower price levels. This calculation example could then be updated during the project with the real project costs and other parameters.

Energy prices (EUR cents/kWh)	**Heat**	**Electricity**	**Difference**
Sweden	10,2	20,5	10,3
Denmark	7,3	29,4	22,1
Lithuania	6,8	14,1	7,3

Table 2 - Total energy prices in Sweden, Denmark and Lithuania [9,10]

The table above show that the prices are on a similar level between the countries. Sweden has a little bit higher prices on heat and Denmark has the highest electricity price and also the largest difference between price och heat and electricity. Maybe Denmark has electricity prices more representative for western Europé and in Sweden there is expectations of prices getting closer to the European higher prices. In the price comparison between the three countries Denmark seems to be the most profitable for investments in heat driven appliances if the prices are interpreted and changed to EUR in the right way.
For Lithuania some kind of average price of heat is used but there is one district that have significantly lower prices i.e. due to a conversion of fuel from natural gas into bio fuel toghether with an increasing competition between heat producers.

2.5.2 Profitability

In a report from the Swedish District Heating Association the economic aspects in the were investigated for two different system concepts. One used an extra circuit with constant supply water temperature (separate appliance circuit model, see section 4) and the other one replaced the ordinary hot water circulation with a circuit with constant supply water temperatur system and the radiator circuit (the Västerås model, see section 4). The Västerås model seems to be the most economic advantageous for heat driven appliances, heated towel rails and comfort floor heating in bathrooms. In 2013 the Västerås model was economically competitive against the conventional electrically heated components if the price difference between electricity and district heating was higher than 0.7 SEK/kWh (appr. 7,2 EUR cents) including VAT. Since the capital cost is quite high compared to the cost of energy it is important that the products have a long life time.
The report also show that the whole concept of the Västerås model can be profitable with a competitive district heating price, but it is more difficult with individual appliances if the costs for the heat fed machines and installation can´t be reduced. In multifamily laundries heat fed machines can be more competitive if there is a high usage and if several machines can share the cost for connection to the district heating central.
The expectation for rising electricity prices will improve the economic conditions for heat driven appliances. The district heating companies will most probably have the greatest benefits from the heat driven technology since they will be able to sell more heat. This can also be of importance for the use of future district heating systems as buildings get more and more energy efficient. [6]

In another report from the energy company of Lunds municipality, looking at the new city area Solbjers, the conclusion also is that the energy prices used in profitability calculations are crucial for the results. This example is described more in detail in section 3.4 and include plans for 700 homes. In this specific example the municipality ows both the net for electricity and district heating and the actual prices for heat and the electricity have been used. For the electricity consumption national statistical average prices have been used. The prices used in the Solbjers example is described in section 2.5.1

2.5.2.1 Payback time - Solbjers

The payback calculations in table 2 and 3 are based on a reduction of operational costs that can be seen in table 1.

Operational costs	SC	VM	LEVM
Decrease with HWC (%)	-15%	-15%	-21%
Decrease with (SEK)	-72427	-74463	-52798
Electrical appliances (SEK)	485134	490186	252602
In the total costs are included costs for heating, heat losses, pump operation,			
comfort floor heating, towel dryer, washing maschine and tumble dryer			

Table 3 – Decrease of operational costs with HWC compared to electrical appliances

Calculations of payback of installation of heat driven appliances compared to the electrical ones have been made for several energy prices as described more in detail in section 2.5.1. Pay back is shown for three system solutions (SC, VM and LEVM as explained under table 2).

	Price E (SEK/kWh)	Price DH (SEK/kWh)	Payback SC (years)	Payback VM (years)	Payback LEVM (years)
Case 1	1,25	0,5	8,5	3,4	4,9
Case 2	2	1	6,5	2,6	3,7
Case 3	2,4	1	4,5	1,8	2,6
Case 4	2,8	1	3,5	1,4	2
	E - Electricity				
	DH - District heating				
	SC - Separate circuit model, normal isolated houses				
	VM - Västerås model, normal isolated houses				
	LEVM - Västerås model, low energy houses				

Table 4 – Energy prices and payback times of extra installation costs

The payback time has a large influence from the energy prices and the difference beteween price on electricity and heat. The Västerås model has shorter payback time (only 1,5-3,5 years) than the separate circuit model due to lower installation costs. With a larger difference between price on electricity and heat also the separate circuit model has a payback time under 5 years. The payback time is longer for low energy houses due than normal isolated houses due to the lower energy consumption. If the prices on the heat driven products are higher this will effect the payback time negative. If each heat driven maschine costs 2000 SEK more than a conventional the payback time will change as in table 2 below.

	Price E (SEK/kWh)	Price DH (SEK/kWh)	Payback SC (years)	Payback VM (years)	Payback LEVM (years)
Case 1	1,25	0,5	11	6	8,5
Case 2	2	1	8,5	4,5	6,5
Case 3	2,4	1	5,9	3,2	4,6
Case 4	2,8	1	4,6	2,5	3,5

Table 5 – Payback times if higher prices on HWC-appliances (2000 SEK/maschine)

It is important for the payback times that the prices for heat driven appliances do not differ to much from conventional electrical maschines.

2.5.2.2 Life cycle costs - Solbjers

In the report of the city part, Solbjers, life cycle calculations have been made for 10 and for 30 years to give some perspective of both short term an long term costs. The total life cycle cost include costs of investment, costs of reinvestment and the energy costs. In the calculations the assumption in made that there is no maintenance cost.

Life cycle costs 10 years	SC	VM	LEVM
Decrease with HWC (%)	-3%	-8%	-6%
Decrease with HWC (SEK)	-200000	-600000	-300000
Electrical appliances (SEK)	7900000	8000000	5000000
SC - Separate circuit model, normal isolated houses			
VM - Västerås model, normal isolated houses			
LEVM - Västerås model, low energy houses			

Table 6 – Decrease of life cycle costs (10 years) with HWC compared to electrical appliances

After 10 years there is smaller advantage with lower life cycle costs of the heat driven system compared to the electrical system. The difference is mainly depending on the lower consumption of electrical energy.

Life cycle costs 30 years	SC	VM	LEVM
Decrease with HWC (%)	-9%	-11%	-13%
Decrease with HWC (SEK)	-1700000	-2000000	-1310000
Electrical appliances (SEK)	18000000	18200000	10400000
SC - Separate circuit model, normal isolated houses			
VM - Västerås model, normal isolated houses			
LEVM - Västerås model, low energy houses			

Table 7 – Decrease of life cycle costs (30 years) with HWC compared to electrical appliances

After 30 years the lifecycle costs are much lower for a heatwater driven system than for an electrical system. The largest reduction in SEK is 2 MSEK for the Västerås model for normal isolated houses but both the Västerås model for low-energy houses has both the largest relative reduction of life cycle cost (13%) and the lowest actual lifecycle cost of 9 090 000 SEK.

The life cycle costs have been made with the resonable assumption that the the choice of electronic alternative to a heat driven will not be a product with the same quality and life time as the heat driven one. It is more probable to buy a cheaper alternative with lower quality. If on the other hand calculation is made with a fully comparable electronic maschine the reduction of a heat driven system is slightly lower.

Life cycle costs 30 years	SC	VM	LEVM
Decrease with HWC (%)	-8%	-9%	-10%
Decrease with HWC (SEK)	-1400000	-1700000	-1010000
Electrical appliances (SEK)	17700000	17900000	10100000

Table 8 – Decrease of life cycle costs (30 years) with HWC compared to electrical appliances of comparable quality and lifetime.

If the lifecycle cost calculation in table 5 was made for double (hot and cold) tapwater connected appliances instead the cost would be 100 000 SEK lower compared to a similar electric maschine without hot water connection.

The life cycle cost is based on an inflation rate of 2% per year and internal interest rate of 4% per year. The prices on the products are described in section 2.5.4

2.5.3 Installation costs

A summary of the installation costs in the payback calculations in 2.5.1 is shown in table 6 below. The cost for electrical appliances is shown and the increase of cost for installation of heat driven appliances both in SEK and in percent.

Installation costs	SC	VM	LEVM
Increase with HWC (%)	19%	8%	10%
Increase with HWC (SEK)	468600	192800	197800
Electrical appliances (SEK)	2480100	2520200	1898200

Table 9 – Increase of installation costs with HWC compared to electrical appliances

2.5.4 Prices on heat driven appliances

In the calculations from 2013 for the Solbjers example the following product prices was used:

- Heat driven washingmaschine 9000 SEK (appr 1000 EUR)
- Electrical washingmaschine 5000 SEK (appr 556 EUR)
- Heat driven tumble dryer 7000 SEK (appr 778 EUR)
- Electrical tumble dryer 3000 SEK (appr 333 EUR)

It was assumed that a cheaper electrical alternative was chosen with lower quality and shorter life time than the heat driven maschine. The price difference in this case is 4000 SEK and if we compare with an electrical maschine of comparable quality and life time the difference would be appr. 2000 SEK.

Below is more up to date but still approximative net prices [11] from 2015 for products Cylinda sell for Asko:

- DisherDM 8140 HWC 8.300 SEK (appr 922 EUR)
- Disher DM 8130FI HWC 8.000 SEK (appr 889 EUR)
- Washer FT 778 HWC 8.900 SEK (appr 989 EUR)
- Washer PT 3140P 16.500 SEK (appr 1833 EUR)
- Dryer TF 720 HWC 7.900 SEK (appr 878 EUR)
- Dryer TF 3200 HWC 10.900 SEK appr 1211 EUR)

The heat driven appliances is sad to be approximatly 15% more expensive compared to similar quality of electrical maschines. For the disher 15% difference in price mean 1000 SEK or appr. 111 EUR. This is half the sum of the price difference used in the calculations 2013 which also gives better economic conditions in the life cycle cost calculations

The prices are net prices and are today only sold to property owners or energy companies and not to private households. On the private market the prices would be higher with VAT etc. included.

2.6 Potential

The Swedish District Heating Association has made an estimation of the potential for heat driven appliances in Sweden and Europe.
By using statistics over how many that owns a dishwasher and a washingmashine, assumptions how many persons sharing an apartment and of the distribution between small single houses and residential apartment buildings give a total potential of around 2,9 million washing maschines and 2,1 million dishwashers. Similar estimations and assumptions for drying cabinets and tumble dryers give around 1 million drying units.

The Swedish District Heating Association estimates a significant potential for district heat driven appliances.
Another estimation of how many dishwashers and washing mashines that are installed in single family houses and residential apartment buildings connectedto district heating give an estimation of around 500 000 appliances or a district heating potential of 360 Gwh per year. The same number of units for dryers give the district heating potential of 165 GWh per year.
With consideration to the product lifetime and replacement pace of old appliances it would be possible to deliver around 90 000 washing maschines and 90 000 dishwashers to the Swedish market every year.

For the European potential an assumption can be made that the Swedish market is below 10% of the European market. From this there should be a market of millions of district heating driven dishwashers and washing maschines in Europe.

In addition to the market for district heating there is a market for other heating systems such as solar heating, pellet heating, heat pumps etc. This raise the potential even more.

The heat driven appliances will be some what more expensive than the conventional electrical products. The savings comes from lower electricity consumption (heat is cheaper than electricity) and a better environmental footprint due to a significant reduction of CO_2-emissions per year.

Another report [2] comes up to a potential for white goods of 0,5 TWh per year. The Swedish District Heating Association means that a change from use of electricity to heat for this market share will not increase the total use of energy and it will at the same time reduce the electrical consumption with 0,4 TWh per year. In this way there is also a national economically interest and motive for heat driven appliances.

One projekt leader [12] in the energy company Mälarenergi in Västerås has been involved in the projects in Västerås with heat driven appliances. In 2013 he estimated that it would be some hundred homes with heat driven appliances installed within three years. This estimation still has potential to be fulfilled.

3. Project examples

In this section a couple of real Swedish projects will be presented out from available data, information and interviews. [13]

3.1 Åsaliden ”The environmental smart energy plus house”, VEAB, Växjö

Picture 14 – Åsaliden, Växjö - An energy plus house with heat driven appliances [14]

Åsaliden is by first sight a traditional built wooden house but underneath the surface it is very modern and an environmentally smart house where every detail is important.
The house is situated in the area Östra Lugnet in Växjö and it is not only energy efficient. It is also built with a material and a technology that makes the house carbon dioxide neutral. The house is built from wood. The roof has sheet aluminium produced from recycled material. The walls are isolated with chips of news papers and with sheep wool. Beneath or in the ground construction is not styrofoam as usual. Instead there is a kind of glass foam from recycled glass bottles and cans. The house is free from leakage without using plastic foil. The house is built healthy without any glue products and chemicals that can cause allergies and other deseases.

The house has very efficient appliances that are connected to the district heating system. The dishwasher, the washing maschine and the tumble dryer in the house comes from Asko.
During the period of june 2013 until march 2015 there has been a test family of two parents and two children living in the house. We have energy data for the all three appliances during the period that shows the normal use of the appliances for a quite normal family in the daily life.

Picture 15 – The test family Provencher living in the environmental smart house Åsaliden [14]

If we look an the whole period the three maschines used in average 170 kWh per month from which 62% was electrical energy and 38% heat energy. Though this figures are not correct since there were wrong values on the heat meters for a couple of monts in the autumn 2014. If we instead look att one full year from june 2013 until may 2014 the average per months was 178 kWh from which 56% was electrical energy and 44% heat energy. For the whole year this example gives an energy consumption for dishwasher, washing maschine and tumble dryer of 2141 kWh of which 1193 kWh was electrical energy and 948 kWh heat energy.
Assume a price of 1 SEK/kWh for district heating and 2 SEK/kWh for electricity as in the calculations in section 2.5. The electricity cost for 2141 kWh is then 4282 SEK and separated in electricity and heat energy the cost would be 3334 SEK. This is a cost reduction of 22%.

During the project time the test family has payed a rent for the house and the energy company VEAB has sold and bought heat and electrical energy to themselves (due to production of both solar heat and electricity). Now the house will be sold and the new owner will sell and by district heating from VEAB and then by and sell electricity to an energy company on the free Swedish electricity market.

A short and general report will soon be finished with some information and conclusions from the project time with a test family.

3.2 Examples from Västerås

During years of research, development and demonstration projects there was an interest to find property owners who were interested in testing the new developed products in real projects. In Västerås there was some interest and they today have tree projects with heatdriven appliances.

On project in the area Råseglet, Öster Mälarstrand has 160 apartments i 4 buildings. They are built by the municipality property company Mimer in cooperation with the municipality energy company Mälarenergi.

Picture 16 – Råseglet, Öster Mälarstrand, Västerås – Low energy apartment buildings

It is usually not profitable to connect district heating to low-energy or passive house buildings. The energy company has solved this problem by building a local district heating system to a low cost and few energy losses. This system is called The Västerås model (see section 4.2) and is used as a good example in many other similar projects. The temperature from the central in the local district heating system to the apartment heat exchangers is 60° C. The heat exchangers are placed in the staircases to avoid the need to go in to the apartments by service and maintenance. The apartments have heat driven dishwashers, washingmaschines, tumble dryers and a heat driven towel dryer. The tenants moved in in the beginning of 2013
The apartments costs have not been much more expensive with heat driven appliances and use of the Västerås model in compariosn to conventional technology and electrical appliances. This depends on that a lot of costs for pipes and installation of pipes could be avoided. The tenants rents are not higher due to the chosen system with the Västerås model. On the other hand the living cost is expected to be reduced over time since the use of cheaper heat energy will increase and the more expensive electric energy will decrease. There is calculations of a reduction of the electricity costs with 2000 SEK per apartment and year and from this the higher investment in heat driven appliances has a pay off of five years.

Another buidling company, Aroseken, in Västerås planned in 2013 to build a new residential area i Gotö Källa with 86 low-energy houses that should have heat driven appliances. The first 20 houses will only have heat driven washing maschines but the rest will probably have dishwasher, washingmaschine and drying cabinet in combination with heat driven floor heating and towel dryer.

In the preschool ”Rösegårdsskolan” in Västerås two heat driven drying cabinets have been installed. The system is constructed to be able to replace all conventional electrical drying cabinets in the pre school (totally 12). The cabinets have meters for electricity and can be switched over to electrical operation to be able to measure the difference between electric and heat driven operation.

Interviews [12, 15] with reprepresentatives both from the energy company Mälarenergi and from the property owner MIMER show that they are quite satisfied with the project Råseglet and think about doing more projects with heatdriven appliances. The customers have cold rent and pay their heat indirect via the energy company on behalf of the property owner on the same bill as the net fee for electricity. The energy company then adjust the bill for the property owner in the next step. Maybe it would be possible for the private customer to by heat directly from the energy company.
The energy company look optimistic in larger sales of heat and especially in the summer. The property owner comment that the profitability is not that large for multifamily apartment buildings with individual appliances. They see larger profitability for properties with common laundryrooms where there is a high usage of each maschine and e.g. in preschools where drying cabinets are used a lot.
The property owner finds a larger freedom for the customer with cold rent and an opportunity to individually also choose the temperature in the apartment. This is a freedom that will not allways lead to lower energy consumption.
This project is a new low energy building without radiators and it would be more expensive and difficult with individual solutions in existing buildings. There was some initial problems that needed adjustments. E.g. the dryer techology was different with higher effect and temperature in the heat driven tumble dryer which led to a lot of steam. This could bea adjusted though.

3.4 Solbjers ”A sustainable city part”, Lunds Energi, Brunnshög Lund

Picture 17 – Solbjers, future planes [19]

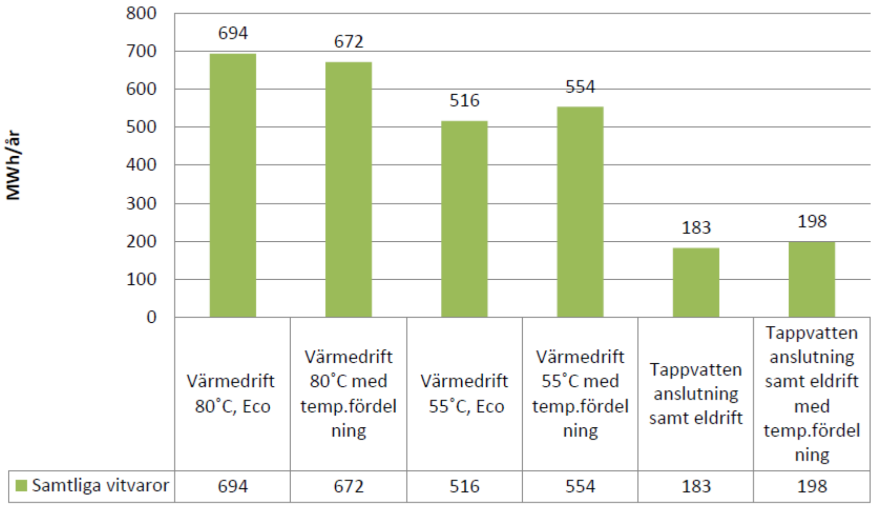
A new sustainable city part is planned in the northeast part of Lund and there are great expectations that the development of the area will lead to significant steps forward within sustainable development of cities with consideration of ecological, economical and social aspects.

Picture 18 – Solbjers, future visions [19]

One part of the visions is of course a sustainable energy system. The organisation for energy questions in the municipality ”Lunds Energi” has made different analyzes of how goals and visions can be fulfilled.
One conclusion is that it will be difficult to supply all the need of energy from local and renewable energy sources. There is also an interest in increasing the heat load in the district heating system and there will be rest heat available from large research projects in the area. Analyzes, calculations and simulations have been made to evaluate the situation for the future city part.
Investigations of how to reduce the electrical energy consumption and at the same time take care of available rest heat has led to an interest for heat driven appliances.

In Solbjers it is planned to build 700 homes. Every home is supposed to have one washing maschine, one dish washer and one tumble dryer and the total reduction of electrical energy is calculated from the total number of cycles of use of the appliances and the difference between use of electrical energy in conventional electrical appliances compared to the heat driven appliances or appliances conected to hot tapwater or connected to both hot and cold tap water.

After several assumptions, limitations and use of relevant simulations the potential reduction of electrical energy using heat driven apliances can be illustrated in the picture below.



Picture 19 – reduction of electrical energy [5]

The potential electrical energy reduction is illustrated for several temperatures and temperature distributions and goes from 694 MWh/year for heat water operation at 80° C to 516 MWh/year att 55° C down to 183 MWh/year for hot tap water connected maschines also using some electricity for heating the process water.

More general calculations give a total need for elecrical energy for Solbjers of 5,7 GWh/year and the corresponding value for heat energy is 2,6 GWh. If the potential energy reduction for electricity or heat is compared to the total need of energy it is possible to calculate a percentage of reduction of electrical energy and corresponding increase of heat energy connected to heat driven appliances.
The electrical energy reduction is between 10-12% of the total electrical energy need with heat driven appliances and just over 3% for tapwater heated appliances.
The corresponding increase of heat energy is between 20-27% of the total heat energy need for heat driven appliances and 7-8% for tapwater heated appliances.
Since Solbjers have such large ambitions for a sustainable city there have also been calculations of the climate impact with heat driven appliances. The calculations for a

certain scenario show a reduction of CO_2-emissions with 60-70%. Probably will ther not be only rest heat but a mix with some normal district heating as well. [5]

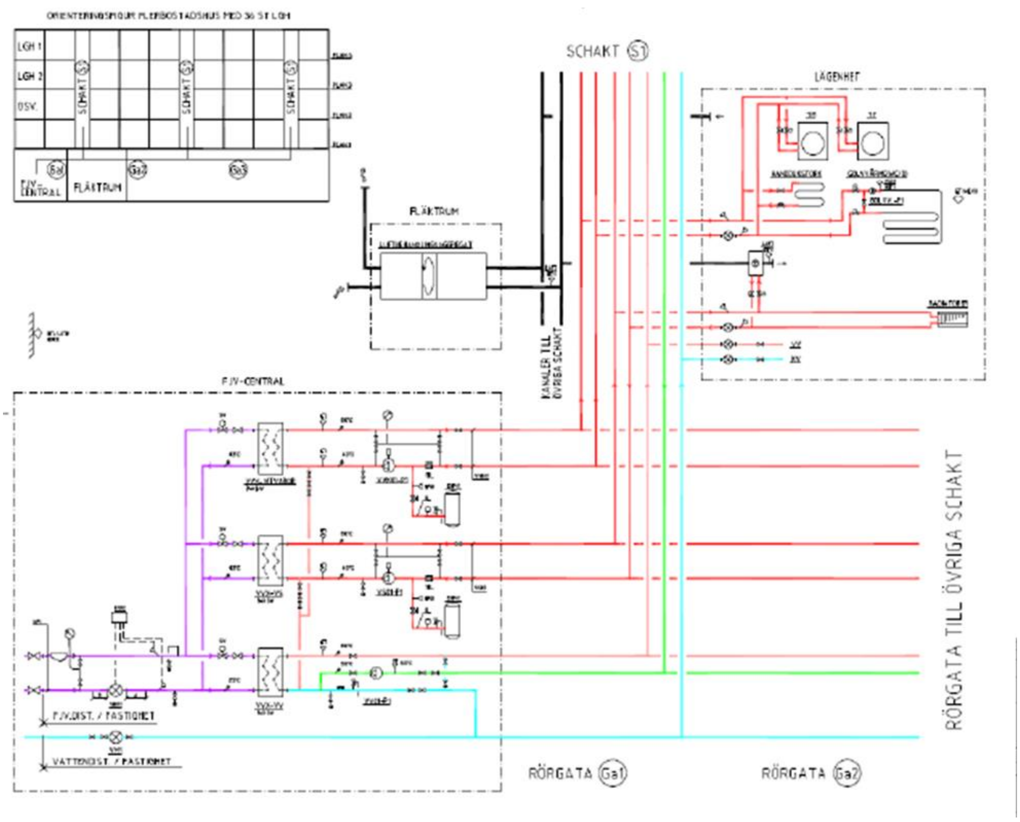
Representative at Lunds municipality responsible for planning the project and from the municipal property company (LKF) [16] have been interviewed and the project is in the phase now to start prepairing the ground for building and they will start to build next year. The energy company have tested heat driven appliances in som other projects as well. One project in the area Råby they have installed heat driven appliances in each apartment and in antoher area Oden 1, they have installed heat driven waschingmaschines in common laundry rooms for multiple family houses and then they have another laundry room with electrical appliances and the same type of customer group and consumption. This project will be interesting to follow up and compare operation with heat and electricity. Both projects are about one year and will be followed up more in detail in a couple of months.

3.5 Gårdstensbostäder

In april 2015 a restoration of an existing building have been finished. Intervwievs hav been made with the energy company Göteborgs Energi and with responsible for the houses in Gårdstensbostäder. They have invested in heat driven appliances in common laundry rooms and find it important to choose heat driven appliances where the maschines are used a lot. They also find it importan for profitablility to put the central for district heating close to the laundry room. They find it to expensive to gor for individual maschines when rebuilding existing buildings. The calculations show large difference in energy consumption since the old appliances had an effect of 10 kW. Now the new maschines have an effect of 3 kW and then the heat has half the price of the electricity. In this project the heat is included in the rent and the property owner can choose how much of the energy savings the customer enjoy in a lower rent.
Göteborgs Energi are very good at district heating and the project in Gårdstensbostäder is included in a larger EU-project Celcius of which this part with heat driven appliances is one part. There will be a lot of opportunity to share results and experiences from Gårdstensbostäder in the READY project. [17, 18]

4. SMART INTEGRATION AND BUSINESS MODEL OPTIONS

The most common system solutions by installation of heat driven white goods are called ”Separat vitvarukretsmodellen” (separate appliance circuit model) and ”Västeråsmodellen” (the Västerås model). Other solutions such as direct connection to tap water and a solution for a common laundry will also shortly be mentioned.



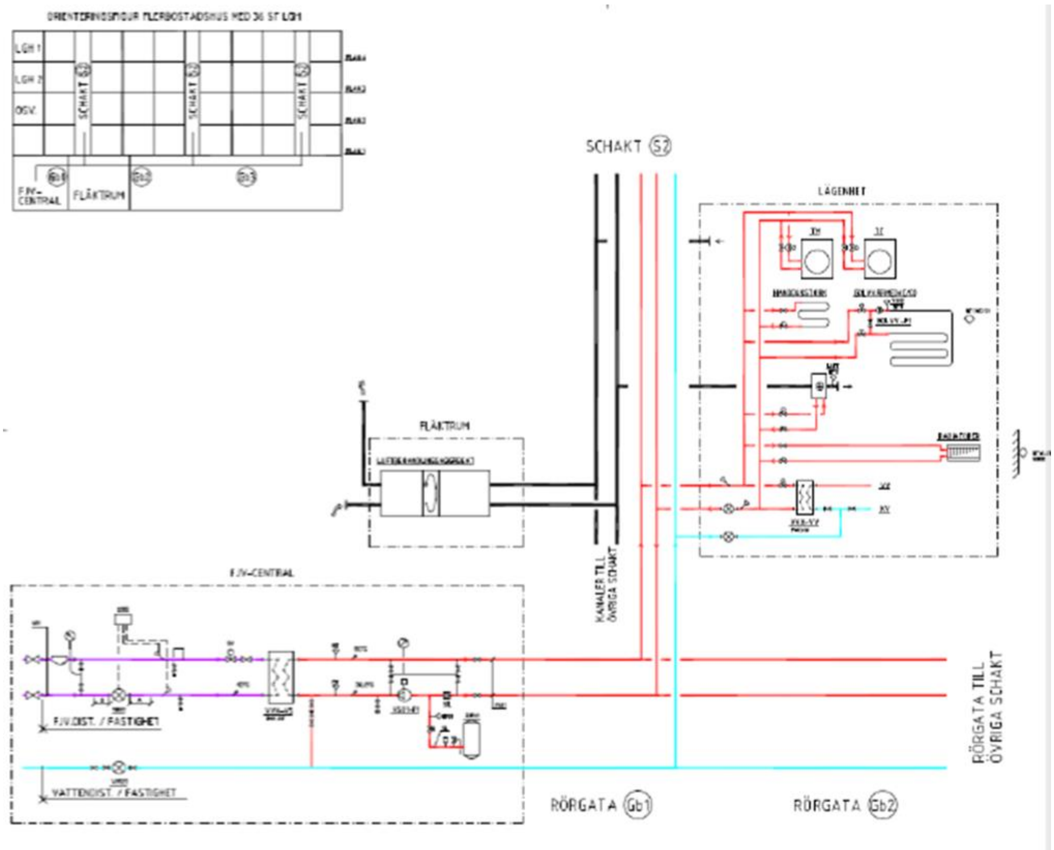
Picture 20 – schematic view of the separate appliance circuit model [5]

4.1 Separate appliance circuit model

When using this model there is a kind of central in e.g. a basement in a residential apartment building or in a separate building in an area with single family houses. Here the district heating system is switched over to three secondary ciruits for hot tap water, heating and appliances. Pipes from the switching central goes to each customer. This model with a separate appliance circuit is most suitable in existing buildings which already have separate circuits for hot tapwater and for heating since it can be difficult to connect the appliances on the existing circuits. Though is is more complicated to install new curcuits in existing buildings than when building something new.
On the negative side for this model with a separate circuit is longer pipes and therefore higher installation costs for the pipes and also higher heat losses compared to the Västerås model described in the nect section. On the positive side can be mentioned that it is possible to have different temperature in all three circuits. This means that the appliances can use a high temperature on the incoming water and by this a larger amount of electrical energy can be replaced with heat energy.
In low-energy houses it is not allways applicable with three different circuits since the houses sometimes do not have normal heating with radiators. In these houses one option is to only use two circuits and eventually a heating air battery for the incoming air.
See a more schematic view of this model in the previous picture.

4.2 The Västerås model

The name of this model comes from the way the Västerås municipality housing company have implemented heat driven appliances in several projects in the city Västerås. In one of the projects ”Gotö Källa” the buidlings have much lower energy consumption than the Swedish building regulation. The total energy consumption is calculated to 50-60 kWh per sqm and year for the single family houses in the area.
In the Västerås model there is a similar central as in the previous model in a basement or a separate building. Here the district heating is switched over to a secondary heating system. The secondary circuit goes to each customer were it is switched to hot tapwater and then used directly for heating and for the appliances.
Low-energy houses with no radiators also here use a heating air battery connected to hte heat water for heating the incoming air. When using the Västerås model in residential apartment buildings every apartment has a heat exchanger. There is an extra cost for the heat exchanger but this is compensated with lower costs for shorter pipedistance compared to the separate appliance circuit model. The pumpcosts are also higher with the Västerås model to keep the right pressure over the heat exchangers.
When comparing the measuring between the two models there is need for less meters in the Västerås model to get individual metering of cold and hot water, heating and heat water to the appliances. The Västerås model need only two meters on the flow for cold water and amount of heat on the heating system. In the separate appliance circuit model four meters are necessary with flow meters for both hot and cold water and amount of heat to the heating system and the appliance circuit. The advantage with more meters is the opportunity to follow how much each unit use but on the negative side there is more measuring values to deal with.
See a more schematic view of the Västerås model in the following picture.



Picture 21 – schematic view of the Västerås model [5]

4.3 Common laundry

The separate appliance circuit model and the Västerås model are often used in residential apartment buildings and single family houses where all heat driven white goods are placed in each house or apartment. In residential apartment buildings one alternative solution is to have the appliances in a common laundry in the basement or a separate room in another part of the building. With heat driven washingmaschines and dryers in the common laundry and electrical dishwashers in the apartments it is only necessary with a separate circuit to the common laundry and no need for extra pipes to each apartment. Eventually it would be possible to combine the common laundry with heat driven dish washers in the apartments and to install separate appliance circuits for those. No evaluation is made if this last option would be profitable or not.

4.4 Direct from hot tap water

On other solution is to use the hot water circulation system for the heat driven appliances. Though it requires that the legionella colonization risks can be eliminated and in 2013 there was no solution that fulfilled the Swedish building regulations. Unlike heat driven appliances, where the reheating of the process medium is done in the heat exchangers with heating water, the reheating in tap water connected appliances is done with electricity. This means that the electrical energy reduction usually is smaller in tap water connected appliances than in heat driven appliances. As can be seen in section 1.4 there are many appliances ont he market today that can be connected to hot tap water.

4.5 Business model options

From the project that have been done so far there are not so many business model options to gain experiences from. Some projects have been made only with purpose to reduce the total energy consumption and other have had the ambition to use the full potential of district heating as energy source.

Towards the customers living in the houses or apartments it is possible to include electricity, heat and water in the rent. Then the property owner take full advantage of the savings and can choose to let the customer share this savings in a reduction of the rent.
Another solution is ”cold” rent. Here the customer pay electricity, heat and water and get full advantage of electricity reduction and cheaper heat energy for the appliances.
The alternative ”warm” rent include the heating costs in the rent. The customer pay electricity and water and get a reduced electricity consumption.

It may be difficult to include the cost for used electricity in the rent on a free electricity market where the customer can choose energy company.

Another question in concern to busines models is who is going to own the appliances in the case of individual heat driven appliances. Will it be a fixed appliance that belong to the property owner and the apartment or should the customer living there own the appliance, buy it and replace it. Probably it will be most common for the property owner to own it if you make invetments in a heat driven system in an apartment building and want payback on those investments.

5. CONCLUSION AND DISCUSSION

From this report there are some conclusions and some questions to discuss and to look into more in the future.

Products and market

Heat driven appliances exist as full developed products and are installed in buildings in several projects in Sweden. In heat driven appliances heat water warm the process water through a heat exchanger in a special heating ciruit in the machine. The number of products is limited compared to conventional appliances and there are only two known suppliers at the moment (ASKO/Cylinda and PODAB).
If we look into hot tapwater connected appliances there are many suppliers with products that could handle connection to hot tapwater. Though this is mainly suitable for dishwashers since there is a very low consumption of water and not that many rinsing cycles. For washing maschines there are many more rinsing cycles that usually need cold water. For washing maschines double tapwater connection to both hot and cold water is an alternative. For dishwashers the low comsumption of water makes it hard to motivate the extra cost for double tapwater connection. The market for hot tap water appliances today seem to be non existing or very low. For tumble dryers and drying cabinets there is way to high water consumption when using hot tapwater to consider it as a possible alternative at all.

Technology and energy savings

Testing results from the suppliers, calculations and simulations show a remarkable potential for the reduction of electricity using heat driven appliances with increasing replacement of electricity with heat with higher temperature. Up to 80-90% reduction is possible comparing a single heat driven product with conventional technology. With decreasing temperature the decrease of electricity consumption is lower and for process temperatures from 55° C and below, hot tapwater connected appliances are competitive or even better in saving electricity.
Hot tapwater connected appliances have in average lower reduction of electricity (up to 50-60% in the best cases) but they have the advantage to have cheaper and easier installation. Hot tapwater is only suitable for dishwashers and to be an alternative for washing maschines. In these cases the double tapwater connection with both hot and cold water is necessary. Hot tap water is not a defendable product alternative for dryers.

Of all appliances tumble dryers show the largest potential for reduction of electricity. This is the reason for making heat driven to the most attractive solution for comparison on a larger scale with many appliances in a residential area. Since hot tap water cannot be used for dryers the total reduction of electricity is much higher for heat driven than for hot tapwater connected appliances when compared on a larger scale than only for individual products.
One technical solution that might be investigated more in the furure is if there are solutions to raise the tap water temperature for a circuit to the appliances e.g. with solar heating to get a larger reduction of electrical energy for hot tapwater connected appliances. One other opportunity to investigate is if hot tapwater could be connected to the heating circuit of heat driven appliances and if this solution has any advantages compared to existing alternatives.

System solutions
The two most common system solutions for heat driven appliances described in this report are the separate circuit model and the Västerås model. The separate circuit model is more suitable in existing buildings where there already exist separate circuits for hot tap water and for heating. Though this model means longer pipe installations, more installation work and higher installation costs. An advantage with separate pipes is the opportunity to have different temperatures in the pipes. Higher temperature to the heat driven appliances can save more elecrical energy.
The Västerås model is more suitable in new buildings where the system can be planned and optimized before the building starts. Here the district heating is switched to a secondary heating system with the same temperatur for heating and for the heat driven appliances which also heat the tapwater through a heat exchanger. There are extra costs for more heat exchangers but lower costs for less and shorter pipe installations. Pump costs are higher and less measuring is needed.
In profitability calculations the Västerås model has shorter payback mostly due to lower installations costs.

Profitability
The energy prices and the difference between the price on heat and electricity is one important parameter influencing the payback and profitability of heat driven appliances. Higher electricity prices or larger difference between the prices of heat and electricity favour investments in heat driven appliances. In Sweden the electricity prices are low today but they are expected to increase. The prices in Denmark differ a lot and the price difference are almost twice the Swedish one. One report from 2013 (se section 2.5.2) showed that a price difference of more than 0,72 EUR/kWh between heat and electricity would make heat driven appliances with the Västerås model competitive compared to conventional electrical maschines.
Also the price on heat driven aplliances affect the profitability and how fast investments pay off. Today the prices are only around 15 % higher than for conventional electrical appliances and with a larger market and production on larger scale prices will be reduced even more.
Other parameters that influence the profitablity is the installation costs were the length of the pipe installations is crucial. Of course individual solutions will need higher installation costs than common areas that are used by many people sharing the costs for common equipment. Also high usage and long operation times increase the profitability which also favour common solutions such as common laundries or e.g. preeschools with high usage of dryers for wet clothes.
The calculations of payback and life cycle costs in section 2.5.2 show payback times for extra investments of less than five years for certain products, temperatures and system solutions and life cycle cost calculations favour heat driven appliances both in a 10 and 30 year perspective with lower costs than for traditional electrical maschines.

Other projects
Some other projects with installed heat driven appliances are described in section 3 and many of those are rather new but it is recommended to follow them and their experiences and energy data and choose to try either the best solutions that already have been tried or new alternative solutions that not yeat have been tried before.

Potential and market
There is a great potential for heat driven appliances described more in section 2.6. One estimation show a district heating potential for dishwashers, washing maschines and dryers of 525 GWh per year in Sweden and an opportunity to sell around 90 000 washing maschines and the same amount of dishwashers every year. The numbers could be mutliplied by ten to get some estimation on the european market.
In addition to the market for district heating there is a market for other heating systems such as solar heating, pellet heating, heat pumps etc. This raise the potential even more. Another estimation comes up to a potential in Sweden of 0,5 tWh per year and a change of use of electricity to heat for this market share reduce the electrical consumption with 0,4 TWh per year

The market in Sweden is very limited to the number of installed products and there is one major supplier (ASKO/Cylinda) with dishwashers, washing maschines and dryers in the product range. One other supplier also has one heat driven product serie (PODAB). It would be good for the market if there were more suppliers and production on a larger scale that also would lead to lower prices. There is also need for marketing and discussions between all involved of this market including proprty owners, building companies, energy companies and other actors within district heating and other parts of the energy sector.

Business models
After the review of material and personal contacts within the field of heat driven appliances it seems as there is a large potential to develop more business models. So far the existing business models are based on the rent and if heat or electricity is included or not and how the property owner or the customer or both can benefit from lower electricity comsumption and lower prices on heat than electricity.
Another question that can be investigated is the ownership of the heat driven appliances. In Sweden it is common that the appliances belong to the apartment and when you move you leave them and you take over the appliances in the new apartment. This can be different in other countries. If the property owner invest in a system for heat driven appliances it will probably be best if he also owns the appliances since he want to use the system as much as possible to get better savings and faster payback.

6. REFERENCES

Numbered references

[1] – HWC-folder, ”Cylinda HWC-produkter” 141028, by email from anders.starck@cylinda.se, Key Account Manager Cylinda

[2] – Swedish District heating Association report, ”Svensk Fjärrvärme-rapporten *Demonstrationsprojekt fjärrvärmeanpassade småhus Göteborg - Avancerad fjärrvärmeanvändning i småhus”, Forskning och utvreckling, Värmegles 2006:29*

[3] - Study of the heating, cooling and condensing capacity of an external unit of two heat exchangers attached to a tumble dryer, Karlstads University, 2006

[4] – Report heatdriven appliances, ”Värmedrivna vitvaror, ett energieffektivt alternativ”, Charlotta Winkler WSP 2013, BeBo – Energimyndighetens beställargrupp för energieffektiva flerbostadshus.

[5] – Report heatdriven appliances, ”Värmedrivna vitvaror, Utvärdering ur ett tekniskt, ekonmiskt, klimat- och kundperspektiv med fokus på den hållbara stadsdelen Solbjers i Lund, Alma Hess, Sara Kralmark, Lunds Energikoncernen AB, Lunds University, 2013

[6] – Report district heatdriven appliances, ”Fjärrvärmedrivna vitvaror, Rapport 2013:21, Fjärrsyn

[7] - Report heatdriven appliances, ”Värmedrivna vitvaror, ett energieffektivt alternativ”, Charlotta Winkler WSP 2013, BeBo – Energimyndighetens beställargrupp för energieffektiva flerbostadshus, page 21

[8] – www.podab.se

[9] – Bent Olsen, Senior adviser heat, Aarhus municipality, bkol@aarhus.dk

[10] – Ramūnas Gatautis, Lithuanian Energy Institute, Ramunas.Gatautis@lei.lt

[11] – anders.starck@cylinda.se, Key Account Manager Cylinda

[12] – Kjell Andersson (+46 21 39 51 05), Mälar Energi AB, Västerås

[13] – Magnus Fransson, VEAB, magnus.fransson@veab.se

[14] - http://www.miljosmartahus.se/vara-hus/hustyper/1--asaliden/, http://veabmiljosmarthus.blogg.artisan.se/?page_id=2

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[18] – Zarif Ljubijankic, Head of houses, Gårdstensbostäder, +46 31 332 60 52,
Zarif.Ljubijankic@gardstensbostader.se

[19] – http://www.lund.se/Brunnshog/Framtidens-Brunnshog/Etappindelning/Kvarteret-Solbjer/ ,
http://www.lund.se/Global/F%C3%B6rvaltningar/Stadsbyggnadskontoret/Brunnsh%C3%B6g/pdf-filer/M%C3%A5l%20och%20vision/M%C3%A5l%20och%20vision_Lund_NEBrunnshog_120930_lowres_enkelsidor,%20tryckversion.pdf

General references without numbers

Pehr Bohman, Asko, Pehr.Bohman@asko.se

Report energy scenario for new city part, ” Tillförsel utifrån eller nästan självförsörjande - Energiscenarier för den nya stadsdelen Södra Butängen i Norrköping, Dag Henning, Opten Energianalys, 2012

Presentation heat water for appliances, ”Hetvatten till hushållsmaskiner, Jan Norrström, Bostads AB Mimer

Report next generation district heating, ”Nästa generations fjärrvärme, Rapport 2013:1, Fjärrsyn

Presentation district heatdriven appliances, ”Fjärrvärmedrivna vitvaror”, Tomas Persson, University of Dalarna

Presentation heatdriven appliances, ”Värmedrivna vitvaror”, Mälarenergi 2013

Länsstyrelserna i Östergötland och Örebro län (2011), *Restvärme som resurs – Potential för tillvaratagande av restvärme i Östergötlands och Örebro län.*

Svensk fjärrvärme (2009:12), *Spillvärme från industrier och värmeåtervinning från lokaler.*

Statens offentliga utredningar (SOU 2011:44), *Fjärrvärme i konkurrens*

Länsstyrelsen i Blekinge (2012:15), *Energibalans 2010 - Blekinge Län*

Svensk Fjärrvärme (2009:12), *Spillvärme från industrier och lokaler*

Other references used in the Solbjers report ([5] in the referenc list above)

[1] Fjärrsyn 2009. Ansökan om bidrag för projekt: Hetvattendrivna vitvaror säkrar framtida fjärrvärmeutbyggnad i lågenergihus. Opublicerat dokument. Sökande: Erhållen via mejl 2013-01-24 från Kjell Andersson.

[2] Boverket 2013. BBR – Byggregler. Hämtad 2013-04-22 från World Wide Web http://www.boverket.se/Lag-ratt/Boverkets-forfattningssamling/BFS-efter-forkortning/BBR/

[3] Rikstermbanken 2013. BOA. Hämtad 2013-05-17 från World Wide Web http://rikstermbanken.se/rtb/visaTermpost.html?id=196685

[4] Rikstermbanken 2013. BTA. Hämtad 2013-05-17 från World Wide Web http://rikstermbanken.se/rtb/visaTermpost.html?id=161168

[5] Boverket 2013. PBL Kunskapsbanken – Boverkets vägledning för plan- och bygglagen. Utnyttjandegrad. Hämtad 2013-04-22 från World Wide Web http://www.boverket.se/Vagledningar/PBL-kunskapsbanken/Detaljplanering/Planbestammelser/Egenskapsbestammelser/Utnyttjandegrad/

[6] Kommissionens delegerade förordning (EU) nr 1059/2010 av den 28 september 2010 om komplettering av Europaparlamentets och rådets direktiv 2010/30/EU vad gäller energimärkning av diskmaskiner för hushållsbruk. Publicerad 2010-11-30 i Europeiska unionens officiella tidning L 314/1.

[7] Kommissionens delegerade förordning (EU) nr 392/2012 av den 1 mars 2012 om komplettering av Europaparlamentets och rådets direktiv 2010/30/EU vad gäller energimärkning av torktumlare för hushållsbruk. Publicerad 2012-05-09 i Europeiska unionens officiella tidning L 123/1.

[8] Kommissionens delegerade förordning (EU) nr 1061/2010 av den 28 september 2010 om komplettering av Europaparlamentets och rådets direktiv 2010/30/EU vad gäller energimärkning av tvättmaskiner för hushållsbruk. Publicerad 2010-11-30 i Europeiska unionens officiella tidning L 314/47.

[9] Klimatkompassen 2013. Beräkningsmetodik och grundantaganden. Hämtad 2013-04-08 från http://www.klimatkompassen.se/index.php?id=348257

[10] Energimarknadsinspektionen 2013. Ursprungsmärkning av el. Hämtad 2013-05-08 från World Wide Web http://www.energimarknadsinspektionen.se/sv/el/elmarknader-och-elhandel/ursprungsmarkning-av-el/

[11] Boverket 2006. Regelsamling för byggande- Boverkets byggregler, BBR, BFS 1993:57 med ändringar till och med 2006:12. Avsnitt 9:12.

[12] Olsson, Daniel 2003. Tappvarmvatten i flerbostadshus. Effektiv: Rapport nr 2003:04. ISBN 91-7848-952-0. ISSN 1650-1489.

[13] Energimyndigheten 2011. Energistatistik för småhus, flerbostadshus och lokaler 2011. Hämtad 2013-02-14 från World Wide Web http://webbshop.cm.se/System/TemplateView.aspx?p=Energimyndigheten&view=default&id=5de8ac74c98a4090ba9d6d33fdc0f91d

[14] Frederiksen, S. och Werner, S. 2012. District Heating and Cooling. 6th draft merger: August 13, 2012.

[15] Stadsbyggnadskontoret Lund 2012. Detaljplan för del av Östra Torn 27:2 m.fl. i Lund, Lunds kommun (Solbjersområdet). Samrådshandling för Solbjer. Hämtad 2013-05-17 från World Wide Web http://web.lund.se/upload/Stadsbyggnadskontoret/LundNE_Brunnsh%C3%B6g/pdf-filer/Detaljplan%20Solbjer/BN%20Planbeskrivning%202012-10-30%20Dpl%20f%C3%B6r%20del%20av%20%C3%96stra%20Torn%2027_2%20m%20fl%20(Solbjersomr%C3%A5det).pdf

[16] Lunds Energikoncernen AB 2011. Rapport Hållbar stadsdel – Brunnshög Hållbar energi. Skriven av WSP på uppdrag av Lunds Energikoncernen.

[17] Lund Northeast 2012. Strukturbild. Hämtad 2013-04-09 från World Wide Web http://web.lund.se/kultur2/kulturpage____108719.aspx

[18] Fransson, Liisa 2012. Lunds Energikoncernen AB, affärsutvecklare. Mejlkonversation 2012-11-15. Mejladress liisa.fransson@lundsenergikoncernen.se

[19] ESS 2013. The European Spallation Source. Hämtad 2013-03-07 från World Wide Web http://europeanspallationsource.se/european-spallation-source-0

[20] Max IV Laboratory 2013. About us. Hämtad 2013-01-22 från World Wide Web. https://www.maxlab.lu.se/about

[21] Gierow, Martin 2013. Lunds Energikoncernen AB, projektingenjör. Mejlkonversation 2013-02-08. Mejladress martin.gierow@lundsenergi.se.

[22] ESS Energy Solution 2011. Energy for Sustainable Science. Hämtad 2013-02-06 från World Wide Web. http://www.lundsenergi.se/Global/Lunds_Energikoncernen/Pdfer/ESSrapport_engelska.pdf

[23] Miljöbyggprogram Syd 2013. Om programmet. Hämtad 2013-02-05 från World Wide Web http://web.lund.se/program/page____109534.aspx

[24] Malmö Stad, Lunds kommun och Lunds universitet 2012. Miljöbyggprogram SYD version 2. Hämtad 2013-05-16 från World Wilde Web http://web.lund.se/upload/Stadsbyggnadskontoret/milj%C3%B6byggprogram/pdf-er/Milj%C3%B6byggprogram%20SYD%20version%202%2020120903%20rev%2020121211.pdf

[25] Tekniska förvaltningen Lund 2011. Tjänsteskrivelse 2011-05-18. Dnr 11/312. Preliminära markanvisningar på Solbjer i Lund. Mark- och exploateringskontoret.

[26] Projektkontoret Lund NE/Brunnshög 2012. Lund NE/Brunnshög, Vision- och mål. Reviderad upplaga maj 2012. Hämtad 2013-02-05 från World Wide Web http://web.lund.se/upload/Stadsbyggnadskontoret/LundNE_Brunnsh%C3%B6g/pdf-filer/m%C3%A5l%20och%20vision/Vision_M%C3%A5l_Lund_NE_120528%20sidorna%2057-74.pdf

[27] Zegers, F.T.S och Molenbroek, E.C, 2000. Field test of heat-fed washing machines and tumble dryers. Ecofys E400/E4068.

[28] Zinko, Heimo et al. 2006. Demonstrationsprojekt fjärrvärmeanpassade småhus Göteborg - Avancerad fjärrvärmeanvändning i småhus. Värmegles 2006:29.

[29] Persson, Tomas 2013. Högskolan i Dalarna, teknisk forskningsingenjör inom energi och miljöteknik. Mejlkonversation 2013-02-21/2013-03-04/2013-02-01 och telefonintervju 2013-02-26. Mejladress tpe@du.se. Telefonnummer 023-77 87 17.
73

[30] Persson, Tomas 2007. Dishwasher and washing machine heated by a hot water circulation loop. s. 120-128, Återgivet material från Applied Thermal Engineering, Vol. 27. Copyright (2007), med tillåtelse från Elsevier.
[31] Rezk, Kamal 2006. Studie över värme-, kyl- och kondenseringsförmågan på ett externt
värme- och kylpaket kopplat till en torktumlare. Examensarbete 10 P. Institutionen för ingenjörsvetenskap,
fysik och matematik. Karlstads universitet.

[32] Larsson, Joel 2011. Förstudie: Riktlinjer angående val av systemlösning för vitvarukretsar. Opublicerat dokument. VCON VVS-konsult AB.

[33] Widlund, Rasmus 2010. Simulering av värmeförlusterna i ett värmevattensystem för distribution av värmevatten till disk-, tvättmaskin samt torktumlare. Examensarbete 22,5 hp. Fakulteten för teknik- och naturvetenskap, Energi- och miljöteknik. Karlstads universitet.

[34] Norrström, Jan 2013. Mimer Bygg AB, driftingenjör. Telefonintervju 2013-03-14. Telefonnummer 021-39 71 92.

[35] Andersson, Kjell 2013. Mälarenergi AB. Mejlkonversation 2013-01-24/2013-03-12/2013-04-23 och telefonintervju 2013-02-25/2013-04-10. Mejladress kjell.andersson@malarenergi.se. Telefonnummer 021- 39 51 05.

[36] Grefberg, Kristina 2012. Fjärrvärmedrivna torkskåp kan sänka driftkostnaden till hälften. Artikel ur Mälarenergis tidning NONSTOP nr 4/2012. Hämtad 2013-05-19 från World Wide Web http://www.malarenergi.se/Documents/Nonstop/nonstop-4-2012.pdf

[37] Ottosson, Ulrika, Wollerstrand, Janusz, Lauenburg, Patrick, Zinko, Heimo och Brand, Marek 2012. Nästa generations fjärrvärme. Fjärrsyn: Rapport 2012:1.

[38] Asko Appliances AB 2013. ASKOs historia. Hämtad 2013-05-06 från World Wide Web http://www.asko.se/om-asko/historia/

[39] Bohman, Pehr 2013. Asko Appliances AB, Business Manager Professional. Mejlkonversation 2013-05-05 och telefonintervju 2013-02-11/2013-02-22/2013-05-03. Mejladress pehr.bohman@asko.se. Telefonnummer 0512- 78 52 66.

[40] Helmerson, Mats 2013. Cylinda Elektroskandia Sverige AB, produktinformatör. Telefonintervju 2013-02-01. Telefonnummer 023-77 87 17.

[41] Asko Appliances AB 2013. Bruksanvisning tvättmaskin Asko W6884 HWC. Opublicerat dokument. Erhållen via mejl 2013-02-11 från Pehr Bohman. [42] Energimyndigheten 2010. Energimärkning av torktumlare. Hämtad 2013-02-14 från World Wide Web http://www.energimyndigheten.se/sv/Hushall/Din-ovriga-energianvandning-i-hemmet/Energimarkning/Produkter-med-energimarkning/Torktumlare/ [43] Ljungby fuktighetskontroll och sanering AB 2013. Avfuktare integrerad i torktumlare. Hämtad 2013-02-14 från World Wide Web http://www.lfs-web.se/avfuktare-torktumlare.htm

[44] Berghel, Jonas, Brunzell, Lena och Bengtsson, Peder 2004. Performance analysis of a tumble dryer. Institutionen för ingenjörsvetenskap, fysik och matematik. Karlstads universitet.

[45] Energimyndigheten 2012. Energimyndigheten 2012. Ny torktumlare drar halva energin, Hämtad 2013-02-14 från World Wide Web http://www.energimyndigheten.se/PageFiles/18095/Torktumlare%20Infoblad%204121-99-1607.pdf

[46] Svensk Fjärrvärme 2013. Fjärrvärmedrivna vitvaror och vitvaror med varmvattenanslutning. Hämtad 2013-01-30 från World Wide Web http://www.svenskfjarrvarme.se/Medlem/Fokusomraden-/Fjarrvarldens-omvarld/Energieffektivistering/Energieffektiviseringsexempel/Bostader/vitvaror/

[47] Asko Appliances AB 2013. Produktspecifikation W6884ECO. Hämtad 2013-03-05 från World Wide Web http://www.asko.se/tvattstuga/tvattmaskiner/w6884-eco/

[48] Energimyndigheten 2011. Fastighetstvättmaskiner- Tabell testresultat. Hämtad 2013-05-16 från World Wide Web http://www.energimyndigheten.se/sv/Hushall/Testerresultat/Testresultat/Fastighetstvattmaskiner/?productGroupId=119&productTypeVersionID=119&productTestId=724&tab=2

[49] Asko Appliances AB 2012. HWC maskiner. Hämtad 2013-01-31 från World Wide Web http://www.asko.se/om-asko/miljo-och-halsa/hwc-maskiner/

[50] Asko Appliances AB 2013. Installationsanvisning värmevattenansluten torktumlare. Opublicerat dokument. Erhållen via mejl 2013-02-11 Pehr Bohman.

[51] Asko Appliances AB 2013. Installationsanvisning värmevattenansluten tvättmaskin. Opublicerat dokument. Erhållen via mejl 2013-02-11 Pehr Bohman.

[52] Sahlén, Anders 2013. Asko Appliances AB, FoU-ansvarig. Mejlkonversation 2013-03-05/2013-03-08. Mejladress anders.sahlen@asko.se.

[53] Asko Appliances AB 2013. HWC-folder online. Hämtad 2013-03-05 från World Wide Web http://www.asko.se/_includes/flash/asko_online_pdf.swf?pubID=3AB3707F-B1B7-F1CC-4F2BC068D2940E58

[54] Asko Appliances AB 2012. HWC diskmaskiner. Hämtad 2013-01-31 från World Wide Web http://www.asko.se/om-asko/miljo-och-halsa/hwc-maskiner/hwc-produkter/

[55] Asko Appliances AB 2013. Bruksanvisning diskmaskin Asko D5654 SOF HWC. Opublicerat dokument. Erhållen via mejl 2013-02-11 från Pehr Bohman.

[56] Asko Appliances AB 2013. Bruksanvisning torktumlare Asko T784 HWC. Opublicerat dokument. Erhållen via mejl 2013-02-11 från Pehr Bohman.

[57] Johansson, Christine 2013. Asko Appliances AB, sakkunnig på VF-logistik. Mejlkonversation 2013-03-07/2013-03-18 och telefonintervju 2013-04-05. Mejladress christine.johansson@asko.se.

[58] Skoglund Carlsson, Ida 2013. Asko Appliances AB, sakkunnig på utveckling/prestanda labb. Mejlkonversation 2013-03-07. Mejladress ida.skoglundcarlsson@asko.se.

[59] Energimyndigheten 2011. Torkskåp. Tabell. Testresultat. Hämtad 2013-03-11 från http://www.energimyndigheten.se/sv/Hushall/Testerresultat/Testresultat/Torkskap/?tab=2

[60] Energimyndigheten 2011. Torkskåp. Mer om testet av torkskåp. Hämtad 2013-03-11 från World Wide Web http://www.energimyndigheten.se/sv/Hushall/Testerresultat/Testresultat/Torkskap/?tab=1

[61] Ragazzo, Johnny 2013. Lunds Energikoncernen AB, drifttekniker. Personlig kommunikation 2013-04-25. Mejladress johnny.ragazzo@lundsenergi.se.

[62] Andersson, Susanne 2013. Lunds Energikoncernen AB, säljare fjärrvärme. Personlig kommunikation 2013-02-26. Mejladress susanne.andersson@kraftringen-forsaljning.se.

[63] Lunds Energikoncernen AB 2013. Fjärrvärmepriser för privatpersoner. Hämtad 2013-02-22 från World Wide Web http://www.lundsenergi.se/Privat/Varme/Fjarrvarme/Fjarrvarmepriser-2013/

[64] Lunds Energikoncernen AB 2013. Intensiva förberedelser – turbinen kommer snart. Hämtad 3013-05-08 från World Wide Web http://www.lundsenergikoncernen.se/Ortoftaverket/Ortofta/

[65] Statistiska centralbyrån 2013. Priser på elenergi och på överföring av el (nättariffer). Hämtad 2013-02-22 från World Wide Web http://www.scb.se/Pages/ProductTables____6429.aspx Excelfilen har följande länk: http://www.scb.se/Statistik/EN/EN0301/2013M01/Manadsvarden_apr2004_(jan1996)-jan2013.xls

[66] Lunds Energikoncernen AB 2013. Elnätsavgifter. Hämtad 2013-02-22 från World Wide Web http://www.lundsenergi.se/Privat/El/Elnat/Elnatsavgifter/

[67] Skatteverket 2013. Ändrade skattesatser på bränslen och el fr.o.m. 1 januari 2013. Hämtad 2013-02-21 från World Wide Web http://www.skatteverket.se/download/18.2b543913a42158acf800016263/1354780124382/Skattesatser+2013+RA.pdf

[68] Skatteverket 2013. 25 procents moms. Hämtad 2013-02-21 från World Wide Web http://www.skatteverket.se/foretagorganisationer/moms/vadarmoms/2512eller6procentsmoms/25procent.4.58d555751259e4d66168000342.html

[69] E.ON Sverige AB 2013. Jämför din förbrukning. Hämtad 2013-03-07 från World Wide Web http://www.eon.se/privatkund/Energiradgivning/Bra-att-veta/Andras-elforbrukning/

[70] Pettersson, Maria 2013. Lunds Energikoncernen AB, projektledare. Mejlkonversation 2013-03-21 och personlig kommunikation 2013-05-07. Mejladress maria.petterson@lundsenergikoncernen.se.

[71] Arbetsmiljöverket 2013. Hur stor arbetsyta bör man ha på ett kontor? Hämtad 2013-03-20 från World Wide Web: http://www.av.se/fragorochsvar/475.aspx?AspxAutoDetectCookieSupport=1

[72] Lauenburg, Patrick 2013. Lunds Tekniska Högskola, doktor inom fjärrvärme. Telefonintervju 2013-04-09. Telefonnummer 046-222 92 73.

[73] Larsson, Joel 2013. VCON, VVS-konsult. Telefonintervju 2013-02-15. Telefonnummer 031-69 68 77.

[74] Energimyndigheten 2012. Energiläget i siffror. Hämtad 2013-05-09 från World Wide Web
http://webbshop.cm.se/System/TemplateView.aspx?p=Energimyndigheten&view=default&id=ac3bcc6d1511459390d08f89568c2415

[75] Energimyndigheten 2010. Beräkna LCC. Hämtad 2013-04-05 från World Wide Web http://www.energimyndigheten.se/sv/Foretag/Energieffektivisering-i-foretag/Finansiering-och-inkop/Livscykelkostnad/Berakna-LCC/

[76] Svensk Energi 2013. Hur mycket koldioxid medför din elanvändning? Hämtad 2013-05-08 från World Wide Web http://www.svenskenergi.se/Elfakta/Miljo-och-klimat/Klimatpaverkan/Hur-mycket-koldioxid-medfor-din-elanvandning/