

MICRO HEAT PUMPS IN HYBRID –LOW TEMPERATURE DISTRICT HEATING CONCEPTS

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Abstract: Micro Heat Pumps can play a significant role in combination with low temperature district heating having three major advantages: high COP's, eliminating the large heat losses in the distribution system and providing cooling during the summer season. Because the proposed system operates at (the lowest possible) space heating temperatures, distribution losses can be much lower.

The authors discuss in this paper the technical and economical possibilities of an alternative system for collective heat supply for the build environment for several projects using a micro heat pump for domestic hot water with a low temperature district heating as a heat source.

Key Words: Micro DHW Heat Pump, District heating

1 INTRODUCTION

Traditional district heating have large energy losses due to the high temperatures of 80 – 110°C needed to generate domestic hot water (DHW) through heat exchangers at the end user. These high temperatures are required for 8760 hours throughout the entire year to guarantee safe DHW (i.e. legionella free) to the end user, even in summer when no space heating is needed. Heat losses of more than 30% in the system are common. When only space heating has to be supplied, system temperatures can be much lower in summer time and the losses over that period of time practically reduced to zero.

DHW for the end user is produced by a small individual micro heat pump with a storage tank using the low temperature heat from the district heating system as heat source. The hot water is pre-heated by the district heating system (in winter) and the source of the heat pump is provided by the return flow of the floor-heating. In summertime, the extracted heat from the floor delivered to the heat pump provides a limited amount of cooling that can be sufficient in moderate summer-climates like in the Netherlands. An additional option and benefit of the system is that it's possible to combine the heat pump with several storage tanks: one for heat and one for cold (optional). Then only the capacity of the storage (i.e. the volume) determines the level of comfort.

With low temperature district heating any type of excess heat source can be used: industrial, power station rejection or (shallow) geothermal with a heat pump and solar thermal. The Hybrid District Heating System extracts the rejected heat at a temperature of approximately 40-45°C. The heat can be used directly at 35-40°C in low temperature heating systems like floor heating systems in dwellings.

This principle with a heat source like this and a micro heat pump has been tested in a pilot project. Three types of heat pumps were submitted to a lab-test in order to check the heat pump's performance at evaporation temperatures of 20-25°C. Secondly, these heat pumps were installed and monitored in real life practical use in six domestic houses in the city of Nijmegen (NL) simulating a heat supply system of low temperature district heating.

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Results show high heat pump COP's, promising system SPF's and lessons learned out of the field tests. On the basis of these results, several heat pump manufacturers have developed special "micro" heat pumps for this specific application (water/water for domestic hot water production).

Very promising for this concept are small collective heating projects in mixed residential areas using waste heat from a supermarket to heat multi-family buildings and/or apartment buildings with a central heating system.

The authors have examined and quantified the technical and economical possibilities of an alternative system for collective heat supply for the build environment for several projects:

- Exploration of the heat supply for the city of Nijmegen (Ref 3)
- Business case hybrid heat distribution grid Nijmegen (Ref 4)
- Business case hybrid heat distribution grid Dordrecht (for HVC; July 2009)
- Exploration hybrid heat distribution grid Roosendaal (for SITA ReEnergy Roosendaal; January 2010)
- Laboratory tests and performance measurements of micro heat pumps (for Municipality of Nijmegen; December 2010)
- Monitoring of energy performance of the hybrid heat distribution grid in 6 inhabited dwellings (by order of the Municipality of Nijmegen; May 2011)

2 PRINCIPLES OF THE HYBRID HEAT DISTRIBUTION NETWORK

As this new concept is based upon two technologies, i.e. (very) low temperature industrial excess heat for space heating and micro-heat pumps for domestic hot water (and space cooling), the term 'hybrid low temperature heat network' is used.

This concept uses 'true' waste heat of industries, waste incineration plants (WtE) and/or power plants to heat and/or cool dwellings. True waste heat from a fully optimized process consists of thermal losses and/or emissions that are no longer of value or have no potential for re-use in the initial process. This waste heat is traditionally cooled down in air cooled condensers (cooling towers) or by surface and ground water.

The main differences between the hybrid concept and traditional district heating are:

1. Much lower supply and return temperatures. Due to this, e.g. at a WtE-plant, no steam is required to feed the heat network and thus an increased power generation efficiency.
2. With the local application of micro heat pumps for domestic hot water (DHW) production it is very easy to produce cold within dwellings as a byproduct of DHW.

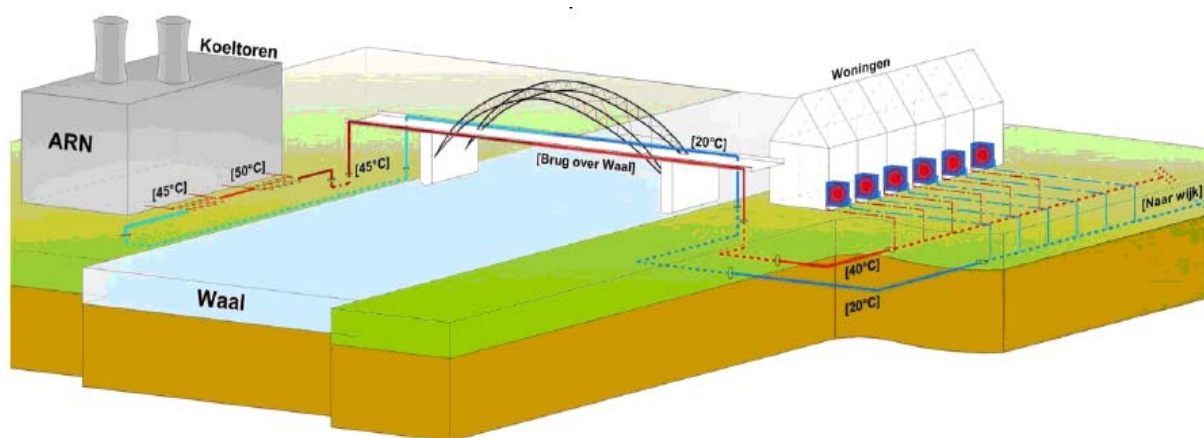


Figure 1: Overall impression of the hybrid heating network at regional level Nijmegen Waalsprong (2008-2010) *(picture only available in Dutch).*

The combination of aspects makes the hybrid heat distribution concept more sustainable and more versatile than traditional heat supply concepts. In comparison with common DH-networks (90°C and higher) the temperature of the medium for hybrid heat distribution (HHD) is only 40-45°C. Extra pumping energy is reduced by (somewhat) larger diameters in the transport and distribution grids.

From the main grid, water at 40°C is used in an individual domestic house for the floor heating system with a return temperature of approximately 25°C. This flow passes through a second heat exchanger and pre-heats the domestic hot water, up to approximately 35°C before it enters the storage tank. With a small heat pump (1-1.5 kW thermal power) the water in the storage tank is heated up to 60°C. The charging time of a 200 liter tank is approximately 4,5 hours (preferably once a day during evening and night hours), which is suitable and acceptable for Dutch dwellings. Moreover, due to the main grid and the pre-heating consumers always have DHW of 32-35°C at their disposal even with an empty tank. The heat pump uses the return flow of the floor heating system as heat source, thus having a high COP. In the mid-season and summer periods when no space heating is needed it is possible to generate some cooling comfort during the charging cycle of the water storage. Figure 2 shows the principle of the system inside the home.

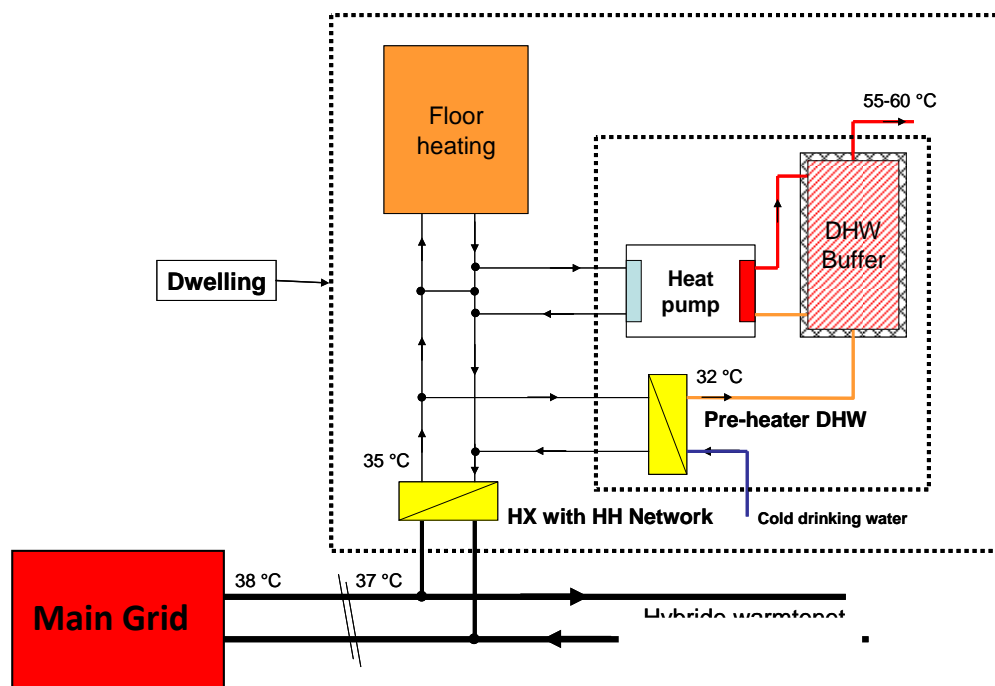


Figure 2: Installations belonging to the hybrid heating network within the home

The innovation lies in:

- The application of a very low capacity water/water-heat pump, which is able to use heat sources of 25 to 40 °C at the evaporator side for the DHW-production;
- Unique combination of heat supply in combination with (limited) cooling at the level of an individual domestic house avoiding a separate cold distribution grid;
- Very low primary energy demand compared to traditional solutions: in new housing areas like the Waalsprong the use of fossil energy sources for heating and comfort cooling is reduced by 75%;
- The hybrid heat concept enables the use of pure industrial excess heat at relatively low temperature (40-45 °C) in the built environment;
- The small capacity of the micro heat pump avoids the use of 'heavy duty' electrical networks as could be the case with individual heat pumps also providing space heating;

- Optimal use of the heat supply by controlling the heat pumps: at daytime space heating is supplied, at nighttime DHW is produced (in summertime also during daytime in conjunction with cooling if necessary);
- The highly disparate patterns and different capacities for space heating (only in heating season, high concurrency, ever decreasing capacity due to better insulation) are separated from those of DHW-production (all year round, low concurrency, high and rising capacity for increased hot water comfort and frequently small quantities).

There is a large potential of low temperature heat sources: shallow geothermal energy becomes interesting (about 1 km drilling is significantly cheaper than deep geothermal) and the concept is also applicable in cascade with higher temperature systems. The low temperatures in transport and distribution result in much lower heat losses. Unlike traditional district heating networks, the hybrid heating network can be 'switched off' outside the heating season (when there's no demand for space heating) with advantages of a further reduction (by 35-50%) of the already low heat losses in the transmission and distribution system and a significant reduction of pump energy.

3 RESULTS OF THE BUSINESS CASE OF HYBRID HEATING NETWORK NIJMEGEN

Because of the interesting perspectives of the hybrid heating grid and the presence of a residual heat source from the waste incinerator of ARN, the Province of Gelderland decided to work on a the business case for the hybrid heating network. The design principles of the houses and installations for the business case are shown in table 1.

Table 1: Key figures of the hybrid heating and cooling concept of Waalsprong Nijmegen

Design principles	Years/Periods of construction		
	Until 2011	2011-2015	2016-2020
EPC-targets: Building Decree and "Lente-akkoord"	0,80	0,60	0,40
EPC realized with the hybrid heat / cold concept (in accordance with EPC standard)	Ca. 0,45 (indication)	Ca. 0,35	Ca. 0,25
Capacity of the heat pump utilized	1000 W (thermal)		
COP of the heat pump utilized	3	4	5
Supply- and return temperature in the dwelling	Underfloor heating at 40°C - 25°C		
Weighted average of the heat demand for space heating (10% high rise dwellings)	19 GJ	14 GJ	12 GJ
Weighted average of the heat demand for DHW-production (10% high rise dwellings)	8,1 GJ	8,4 GJ	8,6 GJ
Size storage tank DHW	200 liters	200 liters	200 liters
Energy demand space cooling (comfort cooling)	3,7 GJ	3,7 GJ	3,7 GJ
Type of cooling	Cooling via the underfloor heating system incl. dew point control		
Floor, wall and roof insulation **	Rc>3,5 m ² K/W	Rc>3,5 m ² K/W	Rc>4,5 m ² K/W
Glass and frame insulation **	U<1,6 W/m ² K	U<1,5 W/m ² K	U<1,3 W/m ² K
Investment costs hybrid home installation	€ 9.000	€ 8.700	€ 7.900

Due to the small differences between the high source temperature (25°C) and storage tank temperature of 60°C it is possible to get a high COP of >5 for the heat pump. In the calculation model conservative COP's were used, starting at 3 in the year 2009 and ending at 5 after 2016. The business case for Waalsprong Nijmegen (8500 dwellings) was based on investment costs as in table 2.

Table 2: Key figures regarding investment costs

Item	Investment (M€)
Installations in the houses with EPC = 0,8 (3115 dwellings)	28,0
Installations in the houses with EPC = 0,6 (4219 dwellings)	36,7
Installations in the houses with EPC = 0,4 (1171 dwellings)	11,5
Distribution grid within the district	6,7
Temporary heating plants (only during construction phase)	1,6
Transport conduits - secondary system (main pipes to districts)	2,8
Transport conduits - primary system incl. extra costs for civil works (rail, road crossings) and crossing the river Waal	16,3
"Withdrawal" of waste heat at the waste incinerator ARN	1,9
Overall project costs (engineering, project management, unforeseen)	8,4
TOTAL	113,9 M€

The business model is based on an operation where the complete heat transmission and distribution system, including the house installation and its ownership, management and maintenance is assigned to an operating company (i.e. ESCO). The operator also operates the auxiliary heating boilers for peak demand, backup and/or emergency situations.

Cash flow calculations show the substantial amount of investments the operator needs to do. As a function of time, these investments are shown in the graph below.

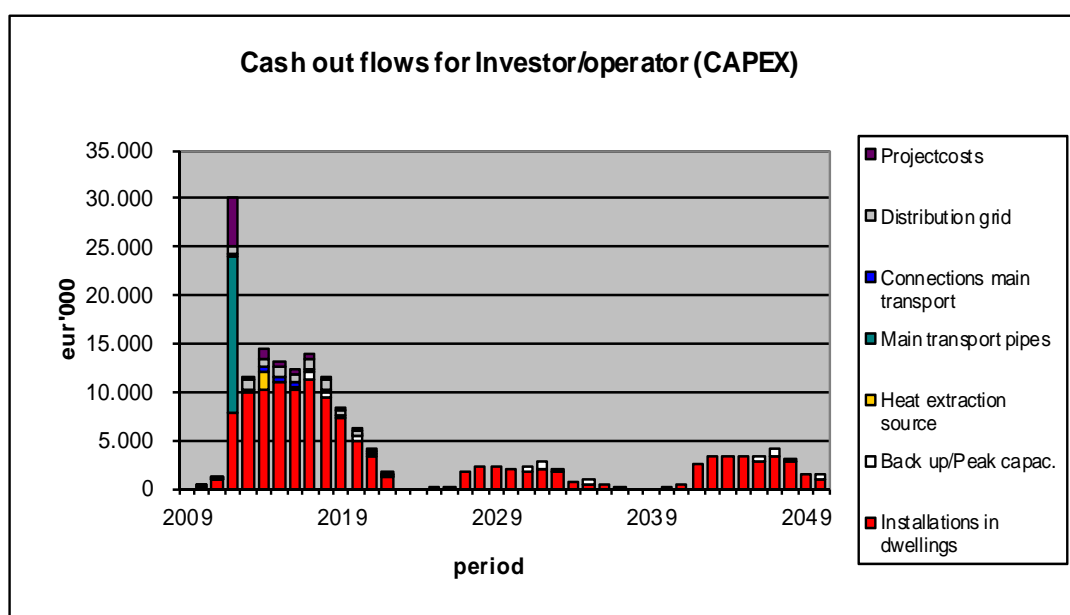


Figure 3: Cash outflows for the operator (Capital Expenditure (CAPEX))

Some components in the energy system have to be replaced after 15 respectively 30 years. This explains the investments in 2030 and 2045. The operator also has several ongoing expenses for billing, maintenance, management, etc.. Revenues arise from the initial contribution to the connection costs ("BAK") that developers (and effectively home owners) have to pay and from the sale of heat (heat price in EUR /GJ).

In discussions on projects with traditional district heating, it is often unclear how the BAK is exactly calculated. On the amount of the costs which a developer in reference houses (which would have no hybrid heat/cold network) would or may not have had, the opinions may differ. The tariffs for heat are based on the sum of the fixed and variable costs that residents would have had with high efficiency boilers (until 2011) or individual heat pumps with ground source heat exchanger (from 2011). Furthermore, a price scenario is assumed with presumptions of 5.5% growth per year of gas tariffs and 3.5% growth per year in electricity prices. The cost of the annual electricity requirements for the micro heat pump (only about 500 kWh / year,

largely at off-peak rates) are discounted in the heat tariffs. This, in combination with the investment costs, results in the following overview of the business case and the development of the net present value from the viewpoint of the operator:

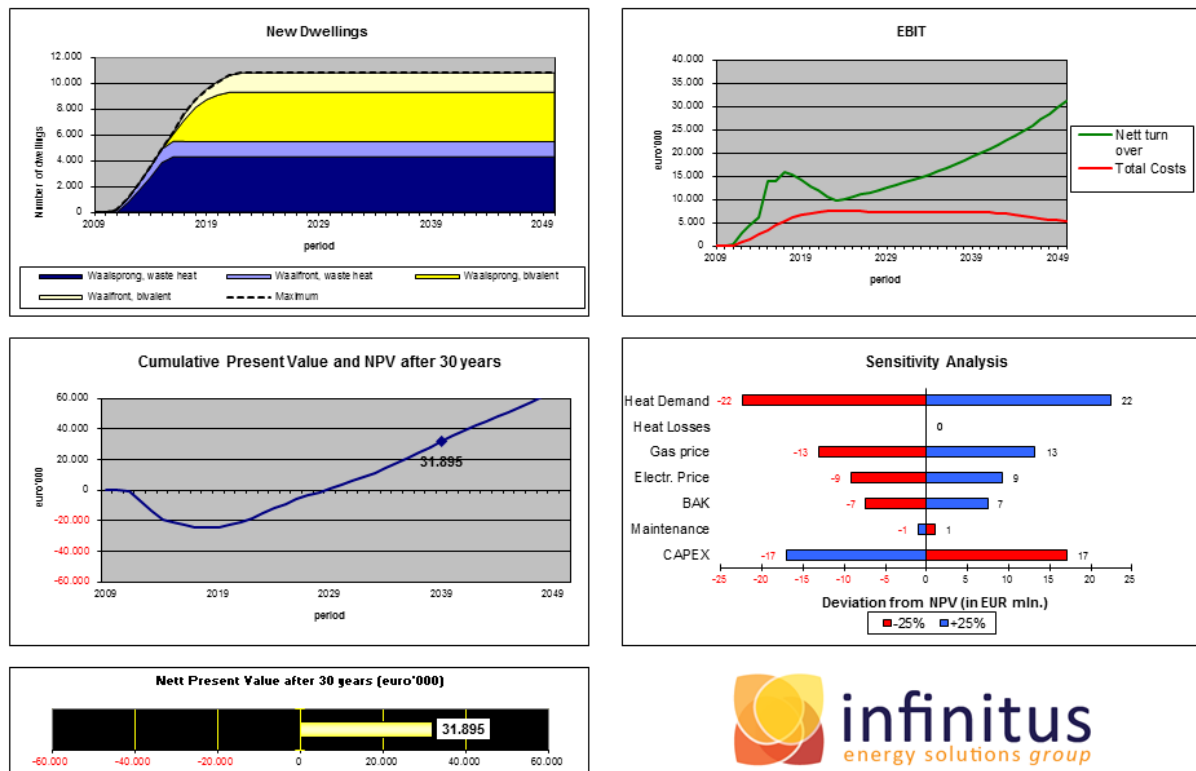


Figure 4: Dashboard of the calculation model for the business case

An operator of a hybrid heat/cold concept is, as are operators of conventional heating networks (or even power plants), facing a deep financial dip, getting out of this only after about 20 years. However, the leverage in earnings (figure upper right hand) is such that the hybrid heat network technology -with the current long-term contracts- is nevertheless an extremely interesting investment. Project financing is met by equity (share capital) and/or debt (long-term debt). Initially, a ratio of equity/debt of 30% -70% is assumed. In that case, the operator has to invest, respectively attract, €14.1 million in equity and €32.8 million in debt, spanning the period 2011-2014. Long-term debt is to be repaid in 25 years. The annual interest costs are estimated at 4.4% (public funding).

4 RESULTS LAB TESTS MICRO HEAT PUMPS

In preparation of the political decision making process concerning the large-scale application of the hybrid heating network in Waalsprong, Nijmegen Municipality required sufficient assurance of the reliability and energy performance of this new concept. To this end, a process of testing and monitoring of three different micro heat pumps in both the laboratory and in six test houses was started. At that stage (2010), there were still not enough fully developed (water/water) micro heat pumps available on the market. Therefore, some heat pump manufacturers have modified their most suitable product for laboratory and field testing in order to enable these to use up to 40 °C as source side of the heat pump (evaporator). From these, the Municipality of Nijmegen has selected three different systems to be tested at TNO under the guidance of Infinitus. The three primary goals were:

- ‘proof of principle’: to demonstrate that the concept can function as conceived in earlier desk studies including the effect of heating with waste heat, the cooling effect and system control;
- The quantitative assessment of the performance of the concept under different operating conditions (particularly summer operation with cooling and winter operation without) regarding DHW-production (hot water comfort), tapping characteristics, standby losses, energy efficiency, charging time of the storage, etc.;
- Comparison of the test performances with the assumptions made in the business case.

The results of the lab tests showed that all system configurations can function in a hybrid heating network and that two concepts were already suitable for the connection to the return of the underfloor heating system (heat source: LT-UFH) and able to supply cooling comfort while making hot water. Furthermore, one of these two concepts was also suitable for supply of cooling, even if no DHW is prepared, the other concept is easy to adapt to this end.

The concept with ventilation air as heat source (concept 1; air-to-water heat pump boiler) only makes indirect use of heat from the underfloor heating. For a more substantial cooling effect, this concept requires a more extensive adaptation of the air system in homes. For that reason, this system was not selected for the next phase of testing in six test houses. The energetic performances of the micro heat pumps are summarized in the next table.

Table 3: Energy performance of micro heat pumps operating in a hybrid heating concept

	Heat source	COP without pre-heating	COP with pre-heating	Maximum cooling per day	Storage volume (liter)	DHW-supply (> 40 °C; with pre-heating)
Concept 1	Ventilation air	2,8	4,7	25-30 MJ *)	285	420 ltr ***)
Concept 2	Return LT-UFH	2,2	4,0	90 MJ **)	300	380 ltr ***)
Concept 3	Return LT-UFH	3,7	5,7	60-70 MJ **)	150	140 ltr

*) during DHW-production

**) in continuous operation

***) concept 1 and 2 use direct preheating. Hence, they are able to extract more DHW from the boiler

The energy performances –and particularly those of the best concept (no. 3)- are fitting well with the assumptions made in the business case, while no further optimizations were made to the (modified) systems.

5 MONITORING TEST DWELLINGS AND RESULTS

For the field tests, the hybrid heating concept was simulated in 6 inhabited standard Dutch type of domestic houses (three apartments and three terraced houses in Nijmegen), using two (concept 2 and 3) of the three heat pumps that were already tested in the laboratory. All test houses were equipped with floor heating. The waste heat from the ARN is mimicked by a boiler filling an auxiliary storage vessel generating the supply temperature of about 40°C. From this tank, the house is heated and the DHW is preheated using a heat exchanger. Subsequently, the DHW is reheated by the heat pump.

The control system was extended to switch to “cooling operation” in summer. The apartments only have comfort cooling available during DHW-production with the heat pump. The terraced houses have extra, continuous cooling available by dumping the waste heat of the heat pump in summer to the grid, even when the DHW-storage is full. Figure 5 shows the installations in one of the test dwellings.



Figure 5: The installations in one of the terraced houses.

The black components in the right hand picture (ceiling) are extra parts to simulate the option of “extra, continuous cooling”. The white parts in this picture are the storage tank (left) and the HE-boiler (right) simulating the hybrid concept. All these components won’t be necessary in the real situation of a hybrid LT-heating network. The picture on the left hand shows the micro heat pump with integrated DHW storage tank in this same dwelling.

Finally, all homes were equipped with various controls, gauges and sensors, which can be remotely read (thermal, flow and temperature gauges). The installation diagram of the concept including the monitoring system is shown in Figure 6 (below).

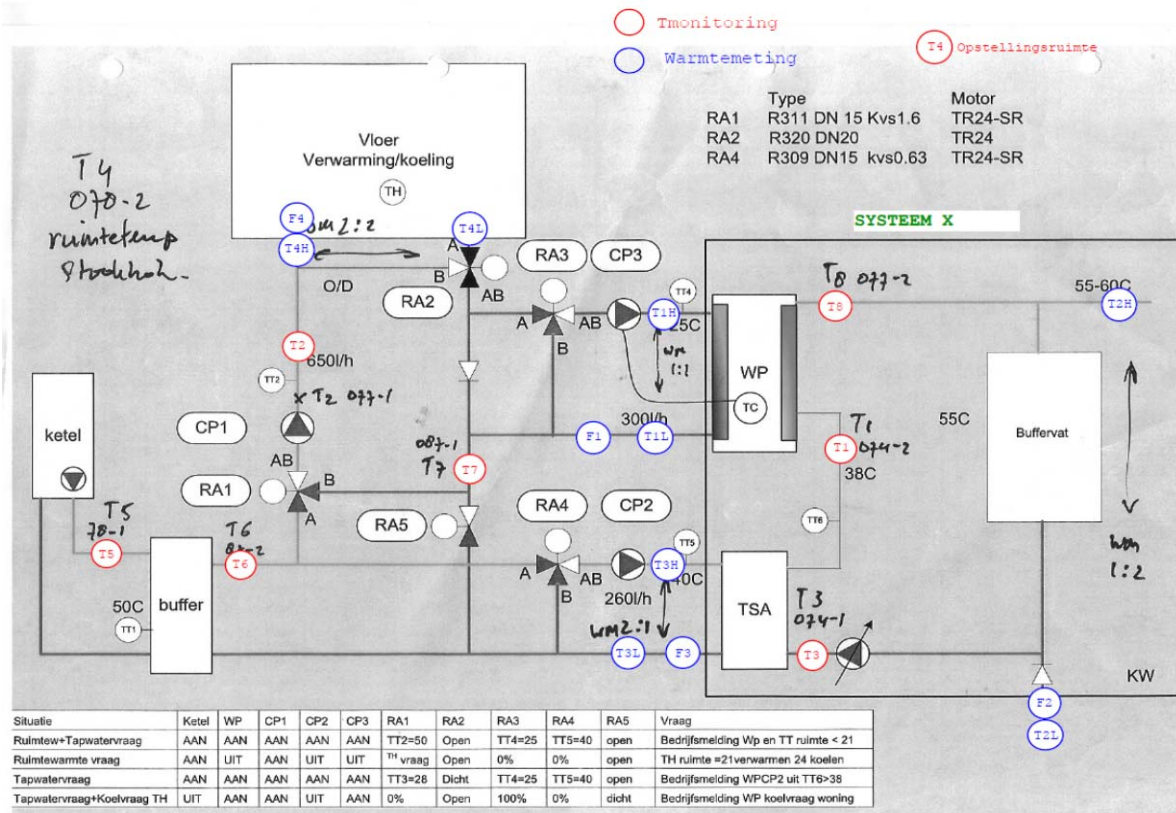


Figure 6: Schematic overview of installation and monitoring components (in Dutch)

Figure 7 shows the SPF's of the various systems in the test dwellings plotted against the consumption of hot water (in liters per week).

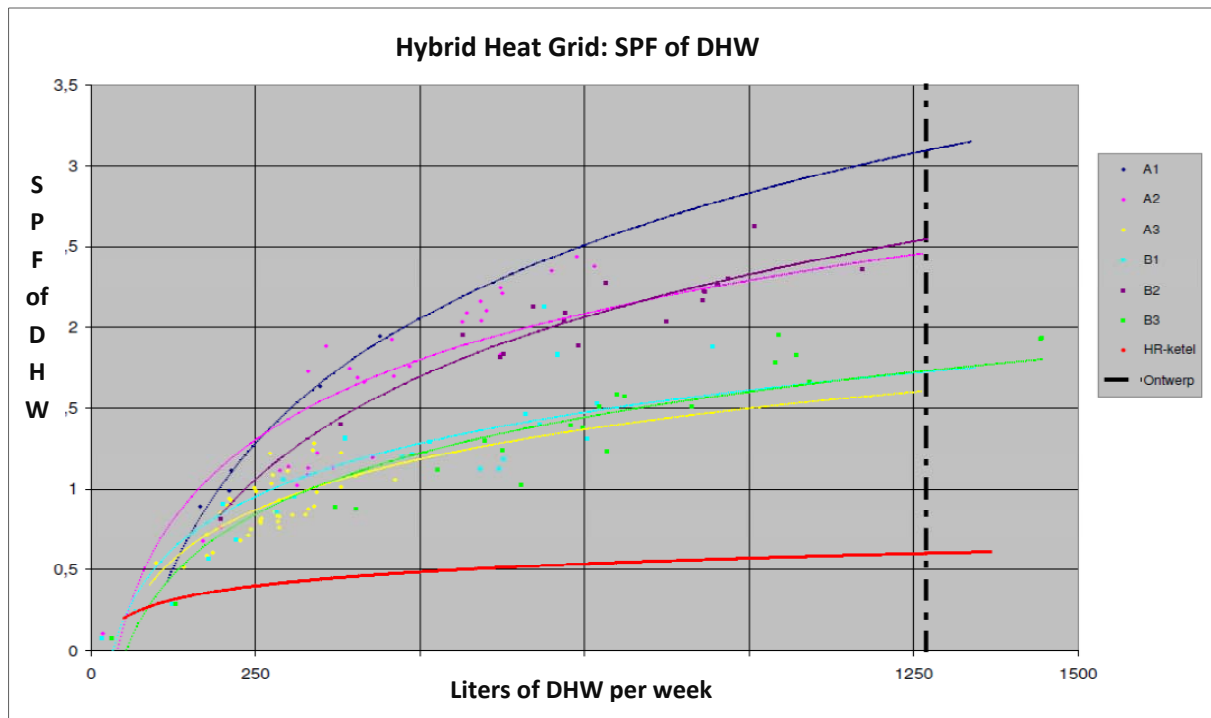


Figure 7: SPF (seasonal performance factor) of DHW-production in the test dwellings

From this graph, the following can be concluded:

- In general, the higher the hot water consumption, the higher the SPF (defined as $Q_{\text{DHW, used}}/E_{\text{electricity}}$);
- Practical SPF's are both over and below 1.0 (equivalent to a PER (Primary Energy Ratio) of about 0.4-0.5, a value comparable to the practical efficiency of DHW-production by an average HE-boiler, red line in the lower part of the graph). There are more results measured above the line than below. Already at a low DHW-consumption of 300 to 400 liters per week, the values are better than the performance of standard gas boilers. The graph also shows the design DHW-consumption of more than 1,250 liters per week (vertical dashed line on the right). Note: a comparison of different systems for DHW-production [ref. 1] shows that the energy performance of the best traditional DH-networks are approximately equal to that of a High Efficiency gas-boiler.
- The lowest SPF's are mainly related to a (very) low hot water consumption. This can be explained because in that case the downtime losses (storage tank and pipes) are dominant compared to the hot water use. This also applies to conventional storage systems, including all types of boilers. Even with conventional heaters such as condensing boilers, the efficiency in a practical situation, is sensitive to the water quantity and tapping pattern (red line). The practical SPF-results for High Efficiency gas-boilers are often lower than the lower curve in Figure 7.
- At higher DHW-consumption several systems show practice-SPF's by up to 2 to 2.5; this is lower compared to the laboratory-SPF's of 4-5 (table 3) mainly because of the much higher tapping patterns used during the lab-tests (thus minimizing the impact of downtime losses from poorly insulated tanks).
- The highest SPF's are around 2.5 corresponding to a PER of approximately 1.0. Based on primary energy, these systems are thus a factor of 2 to 2.5 times better than a condensing boiler with regard to the domestic hot water efficiency;

- Dwellings A2, A3, B1 and B2 have a micro heat pump from the same supplier, but clearly show different performances. This is because in the homes A3 and B1 (yellow and light blue line) the electric back up heater (for extra comfort) already automatically engages during moderate hot water demand. In the other two properties A2 and B2 (pink and purple line), the manufacturer (or residents) -as default- have chosen for an 'eco'-setting, so that the electric heater does not turn on automatically. Switching on the electric heater has a large effect on the electricity consumption, with obvious consequences for the total efficiency of the system.
- For house A1, where initially promising results were observed, less data points are available, because after a technical failure the product was no longer supported by the manufacturer.

The following functional requirements were imposed on the supply of hot water:

- up to 7.5 liters/minute of DHW with a temperature of 40 °C can be tapped (class CW4);
- at the tap the water temperature must be at least 55 °C (legal requirement).

In all test houses these requirements were met.

6 STATUS HYBRID HEATING CONCEPT & AVAILABILITY MICRO HEAT PUMPS 2014

Despite positive monitoring results and positive business cases for Nijmegen, Roosendaal and Dordrecht the concept is still not yet implemented due to various reasons:

- The economic crisis since 2008: the sharp fall in house prices and the problems of unprofitable land development in municipalities has halted large-scale building projects;
- At the time of the political decision making (2010-2011) in Nijmegen, not enough fully developed ("proven") and commercial products were available on the market in order to apply them on this scale (10,000 homes!).
- The lack of confidence of potential energy operators that such an innovative concept on this scale is technically adequate and reliable and that it will be more cost effective than conventional district heating.

Although not entirely according to the original concept of the hybrid heating network, the basic principles are being implemented in the Netherlands in 2014 in the "Mine Water 3.0"-project in Heerlen, the "Nieuw Delft"-development (formerly "Spoorzone Delft") and the multi-family building Emmastaete.

Since 2012, the manufacturers of heat pumps have not been idle, and understand that there is a clear market perspective for the hybrid heating network concept and the required micro heat pump. This concept is applicable to all forms of industrial waste heat of around 40°C, which is available in many locations near residential areas, but also for relatively "shallow" (as compared to 2-4 km deep wells) geothermal energy of approximately 700-1000m depth. Four manufacturers now have developed a suitable product (water-water heat pump (with or without integrated storage tank)) for hybrid heating networks and are marketing them:

- Ecoon / Itho-Daalderop
- Nathan / Alpha-Innotec
- Danfoss [Ref. 2]
- Techneco / Aqua-WW

The Dutch company Ecoon was the first to develop a small individual 'water/water heat pump' (booster heat pump) for this market segment, which, in combination with a boiler, is able to make legionella-safe DHW using the hybrid heating network. This solution solves the problem of the low temperature of pure waste heat, which is sufficient to heat a house, but too low to make DHW.



Figure 8: ECOON DHW micro heat pump (or: "Booster heat pump")

7 CHALLENGES, CONCLUSIONS AND RECOMMENDATIONS

Despite the very positive monitoring results and the positive business cases this innovative concept still faces some serious challenges. The main challenges have to deal with "market acceptance", (un)suitability of the regular testing procedures, unsuitability of calculation models, norms and standards. Currently, in the Netherlands the development of the right 'tools' is taken up by a working group of manufacturers with the support of the Netherlands Enterprise Agency. This has resulted in a test procedure in line with EN14511 and a calculation standard which is developed in an Excel model for the Dutch housing standard in order to calculate the energy performance for houses under the Dutch Energy standard NEN7120. The conditions are important to enable the rapid breakthrough of this extremely promising concept as investments in new buildings or renovation are decided upon the energy performance standards in the building regulation.

We can consider the testing and monitoring results as an actual "proof of concept" of the hybrid heating network in a practical situation. Hence, the main conclusions are as follows:

- After some initial difficulties, the hybrid heating grid concept technically works properly and to the satisfaction of the residents;
- The concept achieves a very high energy performance with CO₂ reductions up to 75 % compared to a conventional heating concept in the Netherlands with condensing boilers;
- Especially in the field of DHW, the energy performance is unmatched due to the pre-heating of the DHW with pure waste heat in combination with the high source temperature for the micro heat pump. Compared to the DHW-efficiency of condensing boilers the system scores up to 4 times better on SPF and a factor of 2 on the basis of the Primary Energy Ratio (PER);
- The concept achieves the expected cooling results (1 kW at 1,35 kW heating capacity) as byproduct of DHW-production, within the limitations of this monitoring project;
- There are clear opportunities for optimization based upon the measurement results.

From the results of the monitoring, the following recommendations can be derived:

- Provide simplification and standardization of equipment. This lowers product costs, improves the economic feasibility and reduces failures both in design and in execution.

- Reduce downtime losses and optimize energy efficiency drastically by ensuring that:
 - a. manufacturers produce better insulated storage tanks for DHW (especially on the side with flanges and connections). Down time losses of the storage tanks should be less than 50 W, especially in combination with micro heat pumps;
 - b. the electrical auxiliary as default (manufacturers!) can NOT operate automatically - except for weekly Legionella prevention- and that the users have to choose to turn this "on" consciously for higher DHW-comfort (preferably just for one charge). After their (temporary) higher comfort requirement, the micro heat pump automatically returns to 'default' (= auxiliary OFF);
 - c. designers of the installation prescribe appropriate insulation measures around the pipes at relevant places (within the scope of the (prevailing) Legionella regulations);
 - d. installers actually apply the insulation as prescribed by the designers.
- In practice, the limited cooling capacity (1 kW) of the micro heat pump should be used wisely. For example, not applying this for the whole house, but only in the main occupied areas where comfort cooling is most appreciated;
- It is recommended to provide future residents relevant information and a residents instruction on how to be energy conscious and how to deal with this particular installation for heating and DHW (e.g. not applying temperature setback at night, etc.).
- The heat pump water heaters used during these test and monitoring project were modified, existing devices. By testing them in practice, knowledge was gained by manufacturers, designers and installers enabling them to further optimize (the control of) the hybrid concept (manufacturers have actually done this). When they are further developed for this hybrid concept, the energy performance could even increase.

8 REFERENCES

- [Ref 1] Charles Geelen and Krijn Braber (Infinitus Energy Solutions): Efficiencies of Domestic Hot Water Production; 11th IEA Heat Pump Conference, Montreal Canada; May 2014.
- [Ref 2] E.Zvingilaite, T.Ommen, B. Elmegaard and M.L.Franck (Danfoss/Technical University of Denmark): Low temperature district heating consumer unit with micro heat pump for domestic hot water preparation; DHC13, 13th International Symposium on District Heating and Cooling, Copenhagen, Denmark; September 2012.
- [Ref 3] "Energiesprong aan de Waal"; for the Province of Gelderland in co-operation with the Municipality of Nijmegen; in Dutch; July 2008)
- [Ref 4] "Business Case Hybrid heat distribution grid Waalsprong Nijmegen"; by order of the Province of Gelderland; in Dutch; December 2008)

Further information on the internet:

- Ecoon / Itho-Daalderop: <http://www.ecoon.nl/toepassingen.html> en <http://www.ecoon.nl/en/main>
- Nathan / Alpha-Innotec (<http://www.nathan.nl/nl/boosterwarmtepomp.html>)
- Danfoss (http://www.fvu-center.dk/sites/default/files/8_low_temperature_district_heating_consumer_unit_with_micro_heat_pump_for_domestic_hot_water_preparation_.pdf) [Ref. 2]
- Techneco / Aqua-WW (<http://www.techneco.nl/producten/warmtepompboilers/aqua>)