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The transition to a low-CO2 energy supply requires great effort from citizens, businesses and governments. It involves the timely development of sustainable alternatives, major investments in insulation, production facilities, other facilities and infrastructure, and – in our densely populated country – continuous consideration of the spatial impacts. Above all, the energy transition involves a major societal challenge: the transition is directly linked to daily life and people’s living environment. A transition of this magnitude can only take place when the energy supply remains affordable, reliable and safe.

This requires a clear long-term perspective that offers security to companies that need to invest, to officials who have to make decisions and to citizens who are faced with important choices. The Dutch Energy Agreement, signed in 2013 as a result of a joined negotiation of NGO’s, government and businesses has played an important role in this perspective with clear objectives for 2020/2023. The Dutch Energy Agenda, following the Energy report and the Energy dialogue earlier in 2016, outlines the main features of the future Dutch energy policy for the period until 2050 targeting a single goal: reducing emissions of greenhouse gases by developing transition pathways for the functions or services that we use energy for. These are low temperature heat for space heating, high temperature heat for the process industry, mobility and energy for lighting, ICT and mechanics. With this agenda, which was presented in December 2016, the Dutch government intends to present a clear and ambitious policy perspective leading up to 2030 and 2050. In the built environment efforts will be made to achieve a drastic reduction in heating demand by encouraging energy savings and to strongly reduce the use of natural gas for heating through incentives and implementing low-CO2 electricity and heat alternatives. The heat pump technology will play an important role in this transition. The Gas Act will be amended accordingly in order to allow a more integral consideration between the heat, gas and electricity networks.

Innovations are important to reduce the costs for a huge transition as big as the Delta Works and to help motivate consumers to take the next step. That is why we are so glad that you have come to the Netherlands to share your knowledge and discuss the solution for a low-CO2 energy supply in nearby future.

Let’s work together and act Now!
Dutch innovation in the heat pump market, ‘hidden gems uncovered’

When I first participated in the third IEA Heat Pump Conference in 1990 I had already been active developing heat pumps ten years before. However the market development in Netherlands completely blocked and failed to develop in that period. Coming to this third Conference my eyes were opened seeing the successful markets in Japan, Switzerland and some other countries. Coming back home we set up a national expert group and in my function as policy consultant with the ministry I advised to get the fourth Heat Pump Conference to Maastricht in 1993 to show my country what was possible and how to learn from others.

At the 11th Conference in Montreal 2014 people asked me why all the innovations in Netherlands in the application of heat pumping technologies were kept as a hidden gem for internal use only. Innovative? I thought, what innovation, we are just doing it. But they were right, the innovation is not so much in the technology itself but in the way in which it is applied. So we then decided to organize the 12th Conference in Netherlands again to show what we are doing. Look around in the host-city of Rotterdam where almost all high rise buildings are heated with heat pumps. But that is not all to discover.

Especially in domestic applications the governmental policy has been focusing on reducing the energy use by legislation with a long term tightening towards energy zero. This started of the developments in the first place in newly constructed buildings. Secondly the stiff economic competition with cheap gas boilers, the extensive gas-grid and the small space available in the domestic applications triggered the innovation. The result is a number of smart solutions in size of the technology and simplicity to install resulting in industrialisation of the building process for new domestic buildings and for renovation of existing buildings. Energy Costs Zero projects are becoming the next thing in the market with more and more interesting examples making Netherland ready for 2020 and the next decades.

The extensive gas-grid and the rather ‘weak’ electric infrastructure resulted in the development and application of the first hybrid heat pumps. I even installed one of the first experimental ones at my own house. Great experience. But also the question of low temperature heat distribution systems in relation to hot water demand and legionella was ‘solved’ with the first booster heat pumps. The major part of these developments were in application development and system approach, not so much fundamental research.

So in this issue of the Dutch Heat Pumping Technologies Journal you can enjoy reading about this developments and get inspired!
A densely populated country that is largely below sea level must be innovative to ensure its own survival. Adding fuel to the fire, natural gas mining has in recent years been deemed unsafe (it causes earthquakes) and there is a national commitment to implement the COP21 Paris agreement. The Dutch believe the transition to sustainable energy is an urgent challenge that will have an immediate impact on daily life and presents a business opportunity for the future. Top knowledge institutions and businesses are embarking upon this challenge together through their participation in the Topconsortium for Knowledge and Innovation (TKI) Urban Energy. Joint projects by the TKI continue to develop new technologies, products and services across the field of sustainable energy: from solar energy, hvac, building solutions, and energy storage to smart grids. In our innovation program, heat pumps are important for indoor climate, heating and cooling systems and for their role in a new sustainable electricity system. Innovations include new technologies such as magnetocaloric materials. The “heat battery” with heat pump and thermal storage working in a “power to heat” system adds to further system integration. Guaranteed performances in dynamic energy conditions, compact solutions for building integration and further price/performance improvements are all key elements to this approach.

In order to meet the COP21 Paris climate goals, the energy to power cities worldwide will need to be generated by almost 100% renewable resources. And soon. Successfully transitioning to new, sustainable sources of power within roughly 30 years will require an effective innovation and deployment process. This means that an unprecedented amount of existing buildings need an “energy makeover.” The heating and cooling of buildings is responsible for most of urban energy consumption (in the Netherlands for ..%). In the Netherlands in the 1960s, we successfully connected the heating of almost all individual buildings to natural gas sources in only 15 years. Today, 95% of Dutch buildings are heated by natural gas. Shifting the current infrastructure to renewable energy is a revolution in approach and practice. New systems and products need to be designed to match high customer expectations: easy to handle, capable of producing a comfortable and healthy indoor climate, low noise and minimal space. The Dutch are expert in very compact and highly efficient heaters and heat pumps that are key for domestic applications. These products can supply targeted heat in other types of buildings as well. Our deep experience and collaborative approach for developing integrated and compact solutions are the hallmarks of the R&D projects in our program. With the worldwide trend of growing urban populations, especially in locations at or below sea level, we all share in the climate challenges facing planet Earth and the urgent need to embrace new innovative solutions. TKI Urban Energy continues to contribute new innovations for sustainability and comfort in urban centers in low-lying areas. We look forward to working with innovators to meet future customer needs.

Would you like more information on the innovation program or being part of the innovation network of TKI Urban Energy? Please visit the website tki-urbanenergy.nl/en or contact us at info@tki-urbanenergy.nl
Abstract

In The Netherlands, more and more heat pumps are applied in residences. The implementation of heat pumps have an influence on the electricity grid because the heat demand of houses converse from the gas grid to the electricity grid. At local high penetration of heat pumps, the capacity of the grid in The Netherlands is expected to be local insufficient for peak demands from heat pumps. This means that the grid needs to be locally reinforced in those situations. For the new design of the electricity it is therefore important to have a good estimate on the simultaneous peak demand of the heat pumps.

In order to quantify the peak load of heat pumps on the grid, load measurements were made on the low voltage grid connected to 32 nearly zero energy residences. These measurements were compared with measurements on the low voltage grid connected to 35 conventional residences. This data analysis has shown that there are two challenges for the grid operator with nearly zero energy houses, namely: increasing peak demand due to the heat pumps and increasing feed-in due to the solar panels. The heat pump leads to a demand peak (2.7 kW) of 2.5 times the conventional peak load (1.1 kW) in a winter where the most extreme measured temperature was around -6.5 °C. Due to this higher peak demand the local electricity grid may have to be enforced.

The highest absolute peak, however, occurs in the summer/autumn where the maximum feed-in peak was 6.3 kW per residence. A conclusion can be drawn that the impact of solar panels on the grid are higher than the impact of heat pumps on the grid during the year that the measurement took place. In a different year with a colder winter the peak from heat pump is expected to be higher than measured during this winter. Currently the grid is reinforced for these energy trends. The demand peak can be reduced by demand response (e.g. controlling...
heat pumps) and storage systems (e.g. batteries). Next to storage systems, peak feed-in can also be reduced by (PV) curtailment. These are all new concepts that may lead to possibilities to stay within the limits of the current network, but the technical, economic and legislation feasibility still need to be determined (e.g. through pilot projects).

For heat pump installers it is important to know that they need to connect the heat pumps and solar panels symmetrical over the three phases even if the grid is reinforced. A simple action that can avoid unnecessary network problems. Next to demand response and energy storage as alternatives for grid reinforcing a collaboration of the concerned parties in the heat pump industry (e.g. heat pump producers and installers) and the grid operator would eventually lead to new heat pump designs that will be possibly more network friendly. The intention of collaboration is to cooperate in a sustainable society as grid operator and at the same time keeping the network affordable, reliable and attainable for the whole society.

Keywords: zero energy residences; heat pumps; low voltage grid

1. Introduction

The government of the Netherlands aims to have a CO2 reduction of 80-90% due to the signed Climate Accord of Paris. Phasing out natural gas is one of the ways to reach this goal. This means that more and more heat pumps are applied in residences for domestic heating and usage of hot water. The implementation of heat pumps have undoubtedly an influence on the electricity grid. At higher penetration rates of heat pumps, the capacity of the grid in The Netherlands is expected to be insufficient for peak demands from heat pumps. This means that the grid needs to be reinforced in those situations.

The implementation of heat pumps will play an important role in the future development of grids. Next to electrical transport, heat pumps are the most important component in the total energy demand of the households concerned. By 2020 it is estimated that approximately 0,5 million heat pumps will have been installed in the 7,7 million houses of the Netherlands [1]. As already mentioned heat pumps will have undoubtedly an influence on the grid. For Liander, largest utility company in the Netherlands, it is important to be prepared for the rapidly growing energy transition in order to keep the grid reliable, accessible and affordable at the same time. This is a quite challenging task for a grid operator. This is the reason why it is very important to know what the impact is of these challenging components on the low voltage grid. If the impact is known it enables the grid operator to take sophisticated decisions regarding the low voltage grid in order to be prepared for the rapidly growing energy transition.

Also in the Liander area residential areas with (nearly) net zero concepts are an upcoming trend. Liander has no choice than to reinforce the grid that is connected to these residences in order to manage the peak demands and feed-ins of the heat pumps and solar panels. By reinforcing the grid it is kept reliable for the residents of the nearly energy zero residences. Since these sustainable innovative projects are only growing it is important for a grid operator to be prepared for this transition. By knowing what the exact impact of these nearly zero energy residents is on the low voltage grid it gives the grid operator better insights how to be prepared for these revolutions and maybe search or develop concepts that are within the limits of the current network capacity. One way to figure out what the impact is of these nearly zero energy residents on the grid is to measure the electricity use of these households on low voltage grid.

Liander had an unique chance to measure in their own low voltage grid where these renovated nearly zero energy residences were connected and compare these measurements with low voltage grid measurements connected to conventional residences. The zero energy buildings were based on an all-electric concept due to the current law. The construction solutions of the residents imply high quality insulation of floors, roofs, windows and facades and a high-airtightness of the residences. The technical solutions imply the implementation of heat pumps, solar panels and heat recovery systems. Conventional residences are residences connected to the gas network for domestic heating, usage of hot water and cooking. The compared conventional residences in this article are the same type as the nearly zero energy residences.

2. Current electricity grid

Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. In order to understand the impact of the nearly zero energy residences on the grid it is important to know how the current electricity network is build up. In the Netherlands electricity is transmitted mainly through underground cables. Copper (Cu) and aluminium (Al) are the most commonly used metals in transmission wires. The cables have three phases and a zero wire. The standard 3-phase 4-wire distribution voltage level is 230V with a tolerance of 10% around this level [2]. The capacity is determined by individual load of the phases. This is why it is important to divide the load from the heat pumps and solar panels over...
the three phases between the residences.
The conventional electricity network in the Netherlands is designed around 1.2 – 2 kW as maximum load per residence. This value is based on the Strand-Axxelson method, a method intended for the calculation of the expected maximum load on components [2].

3. Impact of nearly zero energy buildings on the low voltage grid

The impact of nearly zero energy residences was determined through data analysis. Data analysis and interpretation were applied at the available data of the electricity usage originated from measurements at a low voltage grid cable connected to thirty two (32) nearly zero energy residences. These data were compared with the electricity usage originated from measurements at another low voltage grid connected to thirty five (35) comparable residences without heat pumps and solar panels. These conventional residences were still connected to the gas network for heating their house, usage of hot water and cooking activities. The residences are typical Dutch residences on a row with three floors and a total area of around 80m². They are social rented houses and inhabited by families with an order size of three to five family members. The implemented air source heat pumps have a nominal power of 1.6 kW and an electrical extra heating system of 2.0 kW. Solar panels (8.9 kWp) were installed on the roofs of each residence with an inverter of 7 kW. Since these houses are based on an all-electric concept they also make use of electricity for cooking activities and they also have an extra heat recovery system with an extra power of 1.4 kW to prevent for icing.

3.1 Comparison of the network load of a nearly zero energy residence and reference residence

Figure 1a shows the aggregated maximum demand and feed-in load profile per nearly zero energy residence occurred in the period October 2016 until February 2017 and the maximum load profile per conventional residence in the same period (winter profile).

It is clearly noticeable that the load of a nearly zero energy residence is higher than the load of a conventional residence. The old network capacity (1.2 – 2.0 kW per household) is not designed to capture the peak load of 2.7 kW. The peak load is probably caused by the heat pumps. The difference in electricity usage of a nearly zero energy residence and a conventional residence is around 1 – 1.6 kW for this measured winter period. The electricity usage is not equal to the maximum power (3.6 kW) of the individual heat pump. This implies that the 32 households did not have a 100% simultaneity for this measured winter. The corresponding temperature with the measured peak load of 2.7 kW was -6.5 °C [3]. This peak load was measured on the 6th of January 2017 at 18:13. The average temperature of the measured winter period was 3.8 °C. According to KNMI [4] this measured winter was mild, dry and sunny. If it gets colder than this measured winter period it is most likely that the peak load will be higher than 2.7 kW. The lowest measured temperature since 1901 in the Netherlands was -27.4 °C in January 1949 [5]. In February 2012, quite recently, a temperature of -22.8 °C was measured in the Netherlands which was the most extreme temperature of the past years 30 years.
[5]. These historic data of occurred Dutch temperatures implies that it is very likely that the peak load will be higher in other winters.

Furthermore, the graph shows that the highest feed-in peak was (-)3.5 kW. This peak is higher than the demand peak caused by the heat pumps for this measured winter. This feed-in peak is corresponding with a temperature of 7.0 °C [3]. This feed-in peak was measured on the 17th of February 2017 at 12:41.

Figure 1b shows the actual load profile of a nearly zero energy residence and a conventional residence on the 6th of January 2017. There was chosen for this day, because this was the day with the highest demand peak (2.7 kW) of this measured winter. Furthermore it can be seen that the feed-in peak of this day was 0.5 kW. The graph stops at 23:07 due to the missing dataset of this period (23:07-24:00).

Both graphs show that there is a little peak demand in the morning probably due to the usage of domestic hot water. The highest peak occurs in the evening probably due to the fact that most people are at home around that time and make use of the heat pumps.

Figure 2 shows the aggregated maximum demand and feed-in load profile per nearly zero energy residence occurred in the months August and September 2016 and the maximum load profile per conventional residence in the same period (autumn profile). Also in the autumn it is noticeable that the network load profile of nearly zero energy residences are higher than the network load profile of conventional residences. The highest demand peak of a nearly zero energy building was 1.2 kW in the months August and September. This demand peak corresponds with a temperature of 15.6 °C and it occurred on the 11th of September 2017 at 18:03. The difference in electricity usage of a nearly zero energy residence and a conventional residence is around 0.1 – 0.5 kW for this measured period. It is remarkable that the difference in electricity usage is by far not equal to the nominal power (1.6 kW) of the heat pump. This was predictable due to the fact that the average temperature of the months August and September were around 17.9 °C [6]. According to KNMI these two months were quite warm and sunny.

The heat pumps were probably only used for the usage of domestic heat water. Also in the autumn the demand peak occurs in the evening. The highest feed-in peak was (-) 6.3 kW. This feed-in peak was measured on the 5th of August 2016 at 12:33.

Figure 2b shows the actual load profile of a nearly zero energy residence and a conventional residence on the 5th of August 2016. There was chosen for this day, because this was the day with the highest feed-in peak (6.3 kW) of this measured period (August 2016/September 2016). It is also noticeable that the feed-in profile is very capricious. This capricious profile may causes voltage and current problems on the grid which is not conducive for the grid reliability. Also here the graph ends at 20:38 due to the missing data set of this period (20:38-24:00).

3.2 Comparison of the network load between the winter and autumn season

As predictable the demand peak (2.7 kW) of a nearly zero energy residence in the winter is higher than the demand peak (1.2 kW) of a nearly zero energy residence in the autumn. The demand peak of the winter is probably also
caused to the usage of heat pumps for domestic heating while the demand peak of the summer is probably only caused by the use of the electrical devices in the house and the usage of domestic heat water delivered by the heat pumps. The feed-in peaks are also as predictable. The feed-in peak (-6.3 kW) of the autumn is higher than the feed-in peak (-3.5 kW) of the winter. In both seasons the feed-in peak is higher than demand peak. Since this conclusion is only based on the measurements of this winter where the minimum temperature was -7 °C it is not a statement that the feed-in peak will always be higher than the demand peak. If other winters are colder than the measured winter it is possible that the demand peak will be higher than the feed-in peak in the winter. The simultaneity of solar panels in an area is around 80% (due to the difference in location and position) which means that if the sun shines all of the solar panels are feeding towards the network due to the fact that in that time frame most of the inhabitants are not at home. The simultaneity of heat pumps is not so predictable as the simultaneity of the solar panels, because the usage of heat pumps for domestic heating and usage of domestic heat water depend mostly on the behavior of the inhabitants next to the outside temperature.

4. Possible concepts to stay within the limits of the current network with heat pumps
Currently the grid is traditionally reinforced wherever these new energy trends are implemented on neighborhood level in order to avoid network problems. A costly task for the grid operator and eventually the whole society pays for it. Alternative solutions, economic benefit still need to be determined, are demand response (e.g. controlling heat pumps) and energy storage (e.g. batteries).

4.1 Demand response and energy storage
Based on the data analysis of the measurements of the nearly zero energy residences and conventional residences it is clear that the peak demands (2.7 kW) occurred by the heat pumps are not within the limits of the current network (1.2 – 2 kW per residence). The peak load of heat pumps can only be reduced by 25% to maintain adequate comfort and the maximum peak reduction is only achievable in combination with smart/intelligent devices [7]. The peak load can be reduced by shifting loads in time. The potential peak reduction due to energy storage is dependent on system size. The buffer of the heat pump can also be used to store the energy from the PV panels. Hereby it is possible to reduce the feed-in peak by storing it as heat in the buffer of the heat pump. Enabling energetic flexibility (demand and feed-in) using smart devices is a promising development as an alternative for grid reinforcement. Next to storage systems peak feed-in can also be reduced by (PV) curtailment. Curtailment imposed by regulation is limited to 30% although higher curtailment is technically possible.

A combination of these alternative solutions is currently applied in a Liander service area (133 nearly zero energy residences) where virtual congestion is considered. Congestion is a point in the grid with too little capacity for the demand or generation behind this point. From this pilot project Liander wants to learn how much possible flexibility there might be on the grid by controlling heat pumps and having in-home batteries in the nearly zero

Figure 2a: Aggregated maximum demand and feed-in load profile per nearly zero energy residence occurred in the months August and September 2016 and the maximum load profile per conventional residence in the same period (autumn profile).
energy residences (these concepts are implemented and applied by a third external party). Furthermore, Liander also wants to learn how it works with the regulation side of these new concepts (e.g. giving fees for the supplied flexibility on the grid). Unfortunately no results were available yet at the moment of writing this article.

4.2 Connecting the heat pumps symmetrical over the three phases

As already mentioned in section 2 the capacity of the three different phases are determined by individual load of the phases. This is the reason why it is very important to divide the load of heat pumps and solar panels over the three phases. In one of the nearly zero energy areas of Liander the heat pumps were connected on one phase by accident. The network failed due to the overload of one of the phases. One of the phases had a current of above the 250 Ampere and the other two phases had a current of only 30 Ampere. This problem was solved by connecting the heat pumps symmetrical over the three phases. Connecting the heat pumps symmetrical over the Collaboration of heat pump industry and grid operator Next to demand response and energy storage as alternatives for grid reinforcing a collaboration of concerned parties in the heat pump industry and the grid operator would possibly lead to new heat pump designs that are more network friendly. The intention of collaboration is to cooperate in a sustainable society as grid operator and at the same time keeping the network affordable, reliable and attainable for the whole society.

It is remarkable that the demand peak of 2,7 kW does not equals the maximum power of the heat pump. The difference in electricity usage of a nearly zero energy residence demand peak and a conventional residence demand peak is 1,6 kW. The nominal power of the heat pump is 1,6 kW. This implies that the extra electrical heating system with a power of 2,0 kW does not turn at all or not simultaneously for this measured winter where the minimum temperature was -6,5 °C. It may also be a possibility to leave this extra electrical heating system out of the design and search for other alternatives to compensate if it gets colder than this measured winter. This may be an aspect which can be taken into account in the collaboration of the heat pump producers and the grid operator.

5. Conclusions & recommendations

This data analysis has shown that there are two challenges for the grid operator, namely: increasing peak demand due to the heat pumps and increasing feed-in due to the solar panels. During the winter overload is mainly caused by demand, while in summer overload is caused by solar panels feed-in. The heat pump leads to a demand peak (2,7 kW) of 2.5 times the conventional peak load (1,1 kW) per residence in a winter where the most extreme measured temperature was around -6,5 °C. The highest absolute peak, however, occurs in the summer/autumn. The maximum feed-in peak (6,3 kW) is more than 3 times higher than the conventional peak load (1,1 kW). A conclusion can be drawn that the impact of solar panels on the grid are higher than the impact of heat pumps on the grid in the measured period. It is very important to mention that these demand profiles are from residences with an energy label A which implies high quality insulation. During cold winters the peak load of the heat pump will
be higher but probably not higher than the feed-in peak in the summer/autumn. Currently the grid is reinforced for these energy trends. The demand peak caused by the heat pumps can be reduced by demand response (e.g. controlling heat pumps) and storage systems (e.g. batteries). Next to storage systems peak feed-in can be reduced by (PV) curtailment. Curtailment imposed by regulation is limited to 30% although higher curtailment is technically possible. These are all new concepts that may lead to possibilities to stay within the limits of the current network, but the technical, economic and legislation feasibility still need to be determined (e.g. through pilot projects). For heat pump installers it is important to know that they need to connect the heat pumps and solar panels symmetrical over the three phases even if the grid is reinforced, because the capacity of the three different phases are determined by individual load of the phases. A simple action that can avoid unnecessary network problems. Furthermore, it is a possibility to leave the extra heating system of a heat pump out of the design. A collaboration of the concerned parties in the heat pump industry (e.g. heat pump producers and installers) and the grid operator would eventually lead to new heat pump designs that will be possibly more network friendly. The intention of collaboration is to cooperate in a sustainable society as grid operator and at the same time keeping the network affordable, reliable and attainable for the whole society.
As a result of Dutch policy on energy conservation for domestic housing there is a decreasing demand for space heating. Newly built houses have to meet the Energy Performance Standard (EPC) where the bar has been raised every couple of years with the goal to get to Nearly Zero Energy Buildings by 2020. The peak capacity for space heating at \(-15^\circ C\) outside temperature, decreases in new domestic buildings to 4kW with a base capacity in mid-season of only 1kW.

The large market of renovation of existing buildings is supported from government by information and subsidy schemes. The energy performance of the building is rated according to a label scheme which is not yet mandatory. In practice upgrading focuses mainly on insulation and double glazing for private ownership reducing the peak demand in terraced houses to 8 – 10kW and base demand to 2 – 4kW. In large renovation projects in the collective sector the upgrading of building complexes undertaken, next to insulation, the renovation of heating distribution systems and heat generators [Ref 5].

At the same time, there is a trend with the end user towards a greater comfort of hot water (drench showers, luxurious baths, etc.). The basic tapping patterns (frequencies and volumes of DHW used throughout the day) are in the Dutch standard classified by class 1 – 6, where class 6 denominates the highest comfort and taping volumes. A large part of the market sales of high efficiency gas boilers is in class 4 – 6. The capacity of the heat generator is then chosen on the instantaneous demand being 32kW for a class 6 tapping pattern. However the combination of space heating and domestic hot water in one heat generator like a high efficiency gas boiler without a storage tank for DHW is no longer the obvious solution as this combination has a large impact on the overall efficiency of the system.
2 SYSTEM EFFICIENCY

The overall efficiency of domestic hot water (DHW) is influenced by several aspects inside and outside the dwellings. While the end user when buying a heating generator may only be interested in the efficiency of the apparatus. However, the benefits of a highly efficient generation device can be nullified by a poor system integration and large storage or distribution losses, ending up in a high energy bill. For energy policy, the broader perspective must be taken into account, i.e., the overall efficiencies for the complete chain from primary (fossil) energy to the end user will have to be compared on the longer term of the life cycle.

Main aspects are:

- ‘In house’ distribution losses caused by the distance from the heat generator to the main hot water taps in the kitchen and the bathroom in the building.
- Consumers behavior and demand patterns being many short and small amounts in the kitchen and large amounts for a longer time in the bathroom.
- Temperature level needed through legislation to prevent legionella growth in the system.
- ‘Outside distribution losses’ in district heating systems and in collective systems for multifamily buildings, as well as pump energy for the distribution.
- Efficiency of power generation and the development over the life cycle of the system towards an infrastructure more and more based upon renewables.

3 CONCEPTS FOR DOMESTIC HOT WATER

In the Netherlands many different system configurations have been applied or are under development as new alternatives, being individual and collective systems.

Individual systems: The standard heating system for space heating is based upon the condensing gas boiler providing instantaneous DHW. Due to the small space available storage tanks for DHW are not popular in the Dutch market. Other concepts in the market are:

- Combined systems that provide Domestic Hot Water and Space Heating
  - Ground source electric heat pump with DHW storage tank
  - Air source electric heat pump with DHW storage tank
  - Ground source absorption heat pump heat pump with DHW storage tank
  - Hybrid air source heat pump with condensing gas boiler for peak load in space heating and instantaneous DHW.

- Separate systems which only provide DHW:
  - Gas fired storage water heater
  - Storage heater on a high efficiency gas boiler
  - Electric storage water heaters, a small one in the kitchen and a large one for the bathroom.
  - Electric instant flow heaters, two separate devices for bathroom and kitchen

- Solar storage water heater with high efficiency gas boiler

- Heat pump storage water heater on ventilation exhaust air;

Collective systems:
Over 50% of the multifamily buildings and apartment blocks in Netherlands are heated by a block central heating system for space heating and DHW. Large District heating systems can be found in cities like Amsterdam, Rotterdam, The Hague and Utrecht. Also smaller systems are under consideration with a lot of political interest.
for so called waste heat. On the other hand large energy companies are withdrawing from this market as the decreasing heat demand makes the economic perspective rather meagre. Collective concepts are:

- Gas fired central heating boiler for space heating and DHW in a multifamily apartment building.
- Collective solar storage water heater in multifamily building with gas fired auxiliary back up heating
- Ground source absorption heat pump in a multifamily apartment buildings.
- Ground source (ATES) electric heat pump with heat distribution to the individual domestic (terraced) houses at 70°C supply and 40°C return (“mini” district heating).
- District heating with central heat generation by gas fired boilers.
- District heating on a gas fired power generation (STEG)
- District heating based on incineration rejected heat of electricity generating steam cycle; electrical efficiency decreases caused by heat extraction on steam cycle
- Hybrid system [Ref. 1] based upon a low temperature district heating (45°C supply and 30°C return) and a small heat pump with DHW storage tank in each dwelling (Figure 2).

In collective heat distribution systems the long distance of heat transport and distribution to the individual end user and the losses have to be taken into account. The average value of transport and distribution losses for these large district heating systems is based on 70°C supply and 40°C return, although practical temperatures are often much higher up to and over 100°C. In applying district heating often the argument of high heat demand density in areas with multifamily apartment buildings is used as a benefit for these systems. However the losses inside the building have to be taken into the calculation when compared to individual systems.

4 EFFICIENCIES OF DHW-SYSTEMS

The comparison of systems is based upon the chain efficiency where the overall efficiencies for the complete chain from primary (fossil) energy to the end user are compared and the weakest links in the chain are analyzed. All options have been modelled and calculated in order to be able to analyze the efficiency of the different DHW-options. The following aspects have been taken into account:

- Basic efficiency of the conversion from primary energy (natural gas or electricity) into heat
- Energy losses during starting and stopping of the heat production
- Energy losses of the water storage tank
- Transport and distribution losses (collective systems)
- Energy use of auxiliary/utility equipment (fans and pumps)
- Energy for prevention of legionnella

Auxiliary heating (solar system and collective systems)

In the modelling a central production efficiency of electricity of 47% (based on lower heating value) was used, this being the average value in 2017 in the Netherlands [Ref. 2]. As this figure is excluding combined heat and power and renewables the overall efficiency is in effect higher. Heat pump COP’s were based on test results at TNO. The tests were performed with a net demand of DHW of 14 GJ per year, where this study is based on a net demand of 9 GJ per year. Test values were adjusted and resulted in a lower COP for this study because the energy losses of the storage tanks become relatively higher compared to the
actual use. Efficiencies of gas fired equipment were based on discussions with KIWA/Gastec.

In combined and separate concepts the main energy loss is caused by the water storage tank. There is a number of standard available heat pump water heaters developed by Dutch manufacturers with special attention to minimizing the downtime losses of the storage tank by optimizing the insulation of the water storage tank, highly stratified tapping curves, pipe connections and a smart control. This results in average heat losses lower than 40W and COP’s as high as 4.0. In such cases the volume of the storage can be as small as 100 - 150 liters giving sufficient DHW during the day. Solar water heaters from the same manufacturers have a high efficiency because the high efficiency gas boiler is outside the storage tank giving instantaneous back up when tapping. The storage tank is thus only used for storing solar thermal energy which can be at a lower temperature than needed at the tap.

In collective concepts is the largest energy loss is in the transport and distribution of the heat (DHW is produced inside the dwelling with a plate heat exchanger). Only a part of the distribution system between the location of the heat production and the dwellings is allocated to DHW production. These are the losses outside the heating season to keep the network up to temperature and the additional losses during the heating season because the use of an outside temperature-dependent supply temperature is not possible.

The overall system efficiency of DHW production is given in Figure 6. These values include all aspects of the production from primary energy to the beginning of the DHW piping in the dwellings. The efficiency of electrical power generation is also included.

These results show that:
- Within the separate concepts, the heat pump water heater and solar water heater with gas fired backup result in significantly higher efficiencies than the other systems; within the combined concepts, heat pumps achieve the highest results;
- Within the district heating concepts the residual heat from a waste incineration (AVI) has the highest efficiency, but still significantly smaller than 90%.
- The hybrid concept gives the best efficiency of all systems, this is mainly due to the preheating of the water using waste heat.

The high efficiencies of heat pumps, solar water heaters and AVI waste heat are, of course, all due to the share of renewable and / or ambient energy that is used in these concepts.

In the chain efficiency an extra aspect is added: the energy losses of the hot water piping from the apparatus that produces DHW to the hot water taps. It is assumed that a hot water pipe contains no usable hot water anymore when the next tapping takes place. For the separate concepts, the piping length within the dwellings is determined based on two locations: placement of the heater for the bathroom in the attic and for the kitchen into the kitchen or above the sink.

The difference between worst case and best case is an energy loss of 2.5GJ/year and varies between 20% and 50% of the net demand of DHW. The extra energy loss of
Everyone’s sustainable energy

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2.5GJ can be avoided just by a well-engineered design of the hot water piping, 80 to 90% of these losses are related to short and frequent use of DHW in the kitchen.

4 CONCLUSIONS
A number of guidelines for designing and engineering an apparatus and an optimal DHW heating system can be drawn from this analyses. It is important to think in terms of complete system concepts. Even if the heat is produced with a high energy efficiency, high storage and/or distribution losses still remain unnecessary and eventually will cause a low overall system efficiency to the best generating apparatus. It is therefore important to consider the heat generators not only individually but to design a complete DHW concept with a critical view on performance, comfort and legionella prevention, taking into account the more long term perspective on increased generation of renewable electricity in the overall energy infrastructure. In general:

• Choose generating devices with a high efficiency.
• Install the generating apparatus or water storage tank as close to the tap with numerous small amounts of water use.
• Choose a (device with a) well insulated storage tank with high tapping efficiency

• Limit unnecessary consumption of auxiliary energy.
• Allocate space for the location of a water storage tank.
• Separate unit for the kitchen at large distances.
• Combine collective heat supply with individual generation of DHW.

The running HPT Annex 46 is focusing in the various Tasks within the Annex on these

References
[3] Eco-Design - Boilers and water heaters: Draft regulations for boilers (Lot 1) and water heaters (Lot 2)
Based on an energy masterplan1), the municipality of Rijswijk decided in 2010 to develop a new, all-electric district with 3,500 Zero Energy Dwellings. Since 2013, approx. 500 dwellings have been built and are now occupied; the district continues to develop quickly. The dwellings are well insulated: there is a heat recovery system in place for both shower and ventilation, a ground source heat pump and 3 kWp of solar panels. RijswijkBuiten, as this well-known project is called, is the first district in the Netherlands where sustainable energy ambitions on this scale have been realized.

The monitoring and research results of the dwellings that have been occupied for more than one year are, both in terms of energy consumption and customer satisfaction, excellent. For the next phase of construction, plans are currently in the works to further enhance energy efficiency. In addition, energy demand management, battery-powered energy storage and ready access to electrical vehicles will all be incorporated into future developments. A special characteristic of the RijswijkBuiten project is that heat pumps and the solar panels are rented by the house owner from an EsCo for € 100 per month. The EsCo provides a 25-year guarantee that the installation will work properly and that the energy required for space heating, domestic hot water and cooling is completely covered by the production from the solar panels.

Content of this paper:
1. The decisions behind this ambitious project.
2. Investment and exploitation costs.
3. Results of monitoring and energy consumption.
4. Results of the customer satisfaction research.
5. Plans for the future.

1. The decisions behind this ambitious project

Recently the Dutch government decided to rule out natu-
Natural gas as the main source of energy in the Netherlands for heating dwellings. The main reasons for this decision were: evidence that capturing natural gas in the province of Groningen had caused earthquakes and the fact that natural gas is a contributor to global warming. This is a huge change from past behavior. Since the 1970s, the Netherlands has developed and financed a dense natural gas infrastructure to heat all Dutch buildings. In doing so, the government had access to a major source of income as an owner of the energy source. It was thus quite groundbreaking when the municipality of Rijswijk suggested in 2010 not to implement a gas infrastructure in the new district, but only an electrical grid. Many calculations were made and partners had to be convinced. Ultimately, the municipality made the final decision. They required that all participating real estate developers construct buildings according to very high energy efficiency standards.

2. Investment and energy savings for homeowners

The average selling price of a typical terraced house with a gas-fired boiler, built in accordance with the minimum requirements of the Dutch Building Decree, is about €200,000. An net-zero energy building with better insulation, a heat recovery system for both shower and ventilation, a ground source heat pump and solar panels will cost approx. €215,000. This additional investment will result in a significantly lower energy bill (€0 instead of €110 per month). However, people who are looking for a new home primarily focus on the location and sale price rather than the energy savings. For this reason, the contractor Dura-Vermeer together with the EsCo KlimaatGarant searched for a solution to separate this investment from sale price of the home. Plans were made to lend the heat pump and solar panels to the consumers by means of the EsCo. The municipality was satisfied with EsCo’s proposal as long as it would meet the following requirements:

1. The way the monthly rent was calculated should be transparent; the yearly costs for the consumer should not exceed the yearly costs of a regular new home with a gas-fired boiler.
2. The consumer is not obliged to rent the system during the whole period but can buy the system at any time, for which the selling price is clear from the beginning.
3. Complete guarantee of proper performance and energy efficiency of the heat pump, ventilation unit and solar panels.
4. Yearly cleaning and replacement of the filters of the ventilation unit to secure a healthy indoor air quality.
5. Finally, EsCo met these requirements by offering a rental price of €100 a month. At this price, EsCo guarantees the home will be a net-zero energy building for 25 years. Energy production from the solar panels fully covers the energy use of the heat pump and ventilation unit, and provides an additional 2,500 kWh for the daily energy use by the residents. See Figure 2 for an explanation in graphic form.
3. Results of monitoring and energy consumption

After the first 26 homes were built in 2012, they were monitored for more than a year. Below are the measurements for heat pump usage. These are Itho heat pumps of approx. 4 -5 kWth with a 150 liter domestic hot water boiler. Each heat pump has an approx. 100 meter deep closed loop ground heat exchanger filled with pure water. The spaces are heated (and cooled in summer) by a floor heating system that operates at an average temperature of 30 °C.

The figure (3) shows relative high COP’s for both space heating and domestic hot water.

Table 4 shows the energy consumption of the 5 measured net-zero energy buildings. They almost all produced more energy (electricity) than they used. An important reason for this is that the winter was quite warm that year. But even when adjusted for temperature variations, the houses still produced more energy than expected. These results are in part a consequence of very conservative estimates with regard to energy consumption built in during the design phase of the project. A second reason is that the “other domestic energy use” appears to be lower than expected. The figures show a wide range. The energy-plus measurements of the third home reflect the residents’ lifestyle: they had, on average, long workdays and extensive travel abroad. The fifth home is an outlier due to the residents maintaining an average indoor temperature of 23.0 °C instead of 20.5 °C.

4. Results of the customer satisfaction survey

The monitoring offered us a lot of information about the performance of the system, but no information about the satisfaction of customers. Therefore, a study was com-
Figure 3 Coefficient of Performance (COP) of the heat pumps for space heating (COP_CV) and for domestic hot water (COP_Boiler)3)

completed in 20152). In this study, 130 occupants received a web-based multiple-choice survey of which 42 were completed. 10 occupants were selected for an in-depth interview.

From this research, it was concluded that the occupants were very satisfied, especially about the comfort in the summer and about their energy bill. One issue was the noise of the heat pump. The heat pumps themselves are actually not that noisy, however many people do not close the door of their bedrooms, and thus they hear the heat pump that is located in the attic. The main recommendation is to place the heat pump in its own self-contained cabinet. Another recommendation is to build homes, and specifically bedrooms, with a higher ventilation rate than is required by the Dutch Building Decree.

5. Plans for the future.

At this moment, almost all of the current homes are net-zero energy buildings. The solar panels produce surplus energy in the sunny summer months to compensate for the extra energy use in winter when the solar panels are unable to produce enough to cover energy consumption. Hence, the electricity grid is actually used as a battery. Currently there is no additional cost for this type of energy storage, but in the near future it is likely consumers will be charged. We thus performed a study 4) of whether we could use as much energy as possible by adjusting of the control of the heat pump (when we fill the boiler) and other energy users. In the same study, we investigated the possible role and business case of the house battery. The study concluded that a significant improvement can be made by means of more direct control of energy consumption but the imbalance between summer and winter will not be completely solved by batteries. So other solutions should be implemented as well.

At this moment, more net-zero energy and energy-plus dwellings are being built in RijswijkBuiten. The next step is to implement the usage of electrical vehicles and their batteries for balancing the grid. Another development will be the implementation and synching of the Internet of things to individual homes in order to better equalize the energy production of the solar panels with the energy demand of the buildings. The RijswijkBuiten district has developed at an amazing speed. People love to live RijswijkBuiten; more and more, residents stress that the district’s unparalleled commitment to sustainability is one of its main selling points.

References

[1] Projectplan energievoorziening Rijswijk-Zuid, 9 november 2010, Merosch;

[2] Bewonersonderzoek RijswijkBuiten, 14 oktober 2015, Merosch;

[3] Verantwoording eerste jaar Epc 0 woningen Rijswijk Buiten fase 1C, 26 oktober 2014, Klimaatgarant;

[4] Intended adjustments in net metering: threat or opportunity? Self-consumption solutions to tackle net metering adjustments for zero net energy residential buildings, 2 juli 2015, Merosch
Retrofitting existing Dutch housing stock to make it more sustainable is a real challenge. Apartments are difficult to insulate and have insufficient space available for PV panels and the installation of air to water heat pumps. In Groningen, contractor Dura Vermeer, installation company Klein Poelhuis and housing association Lefier worked together to develop a solution. As sparring partner for the parties involved, Alklima/Mitsubishi Electric provided input for using Ecodan air to water heat pumps. Heat pump for sustainable retrofitting of existing housing stock A first: existing apartment becomes zero energy installations. The complex also underwent a systems engineering metamorphosis. The gas boilers were replaced with air to water heat pumps in the 48 homes and high-quality solar panels were installed on the roof of the complex.

As these homes are transformed into zero energy homes, on average the tenant’s meter remains at ‘zero’. Two of the parties signing the Stroomversnelling, were Groningen housing association, Lefier and construction company, Dura Vermeer. Together with installation company Klein Poelhuis Installatietechniek, they completed the zero energy renovation of 48 apartments in Groningen’s Paddepoel district. This is a first, because these are the first Dutch apartments that have been retrofitted in this way. The front and rear façades were provided with insulated wall panels, the roof was fitted with additional insulation, triple glass was installed and the balconies were ‘shifted inwards’ to keep the winter weather outside. The front of the complex during the retrofitting process. What is clearly visible is that one of the porches has an additional insulated wall panel. The façade of the entire complex was covered with this.

Klein Poelhuis Installatietechniek worked together with Alklima/Mitsubishi Electric, which supplied Ecodan heat pumps for the project. Rudy Grevers, Consultant for Alklima/Mitsubishi Electric: “The indoor unit of a heat pump system takes up more space than a traditional gas boiler, particularly as the buffer/storage tank for room heating

Heat pump for sustainable retrofit of existing housing stock
A first: existing apartment becomes zero energy
and a hot water boiler need to be added. In this project, no additional space could be freed up for the technical areas, which was a bit of a puzzle. However, this was resolved with a little adjustment here and there by using a particularly compact yet service-friendly system. The total heat pump system took up no more space in m² than the old boiler. Another challenge was that the existing high temperature radiators needed to be retained. For heat pump efficiency, however, a low temperature process is preferable (the CoP depends partly on the release temperature), but the high-quality wall insulation meant that this was no problem. However, there is a risk of contamination in one of the systems. “This challenge was resolved in consultation with our service department by setting up a ‘rinsing protocol’ and using specific filters”, said Grevers. Outdoor Units However, the biggest challenge was yet to come. In an apartment building, where do you put the individual outdoor units for 48 heat pumps?
Siting the units on the roof was not an option because the PV panels were already planned for the roof. In the end, after many calculations, and together with the installer, a sound, reliable and service-friendly solution was chosen, explained Grevers: “Each housing column of three floors of apartments has its own entrance to the garage units in the plinth of the complex. A casing was placed at the entrances to accommodate these apartments’ three outdoor units. This had multiple advantages: the casing provided sound proofing, the outdoor units were hidden from sight and the casing was vandal-proof, ensuring that vandals could not access the units. Together with the installer, this took significant calculation-work and we are very pleased with the result. In this instance, this good casing appeared to be the key to success. “Satisfaction. A resident survey has now shown that 44 households are ‘extremely satisfied’ and 3 households are ‘satisfied’ with the result, and that just one resident has a number of critical comments. As far as resident satisfaction is concerned, the transformation to zero energy was thus successful. The design and the provisional figures also indicate that the project is really zero energy from an energy point of view. “The provisional results show that the objectives have been achieved”, said Grevers. “A huge compliment to the construction team comprising the contractor, installer and housing association, because these types of apartments are difficult to retrofit into real zero energy homes. For Alklima/Mitsubishi Electric it was another confirmation that working together with the right parties enables all challenges to be solved in realising zero energy homes in a large proportion of the housing stock.” This transformation to zero energy was successful Duurzaam Bouwen Award (Sustainable Building Award) With the Groningen Paddepoel project, Dura Vermeer won the Duurzaam Bouwen Award 2016 earlier this year in the ‘Zero Energy retrofit approach to existing housing stock’ category. As well as this award, the project also received the audience prize. The rear. The casings in which the outdoor units of the Ecodan air to water heat pumps were placed are on the ground floor. This article was produced in cooperation with Alklima/Mitsubishi Electric. The total heat pump system took up no more space in m² than the old boiler.
Sustainable entrepreneurship does not only help protect the environment. It contributes to lower operating costs and enhances a company’s brand as eco-friendly. The heating and cooling of a business premises by means of a thermal storage system with heat pumps thus offers added value in various ways. At Park 20|20, a business park on the outskirts of the Dutch city of Hoofddorp, this added value is further enhanced by a particularly innovative way of reusing surplus heat and cold.

In order to maximize energy savings, a heat surplus should be reused as close as possible to the primary generator or recipient. At Business Park 20|20 in Hoofddorp, this process is optimized by using a thermal loop connected to a thermal energy storage system that readily exchanges excess heat and cold for immediate reuse. To make this possible, each office at Business Park 20|20 is equipped with a ONE (‘Own New Energy”) – installation on site. This plug & play heat pump unit has been developed and is distributed by OSH (One Solution Holland) in Zaltbommel.

**Park 20|20: the First of its Kind in the World**

The construction of Park 20|20, located between Hoofddorp and Schiphol Airport, started about six years ago. The park is still under development. After the completion of the NOW-building (opened in march), the next two buildings will be finished in 2018. The overall plan for the park, to be finished in 2020, counts 13 buildings and comprises over 90,000 m2 of office space, 2,100 parking spaces and 3,700 m2 of ‘other services,’ including restaurants, a gym, a hotel and a nursery (Figure 1). The park has been developed by the American architectural firm William McDonough + Partners. This agency is renowned for its vision of sustainable construction. They practice Cradle-to-Cradle (C2C), a construction process that ensures all materials will be optimally reused once the building has reached the end of its life cycle. C2C is the first of the four central tenets that have guided the building of the Park 20|20 complex:

- **Design for disassembly (C2C):**
  During construction, removable parts are used as much as possible so that all materials can be recycled at the end of the building’s lifecycle.

- **Productivity and Health:**
  A recent study, in collaboration with the Arizona State University [1], assessed what qualities make an office space a pleasant place to work. This study demonstrated that the current buildings in Park 20|20 have been thoughtfully designed in a way that increases employee productivity and reduces absenteeism.

- **BIM / Material Banking**
  By adhering to the methodology known as Building Information Modeling, there will be a clear record with
With a focus on leasing instead of purchasing, the customer will have access to the latest innovations plus a lower initial purchase price.

**Thermal Loop**

One of the most distinctive innovations of Park 20 has been the construction of a thermal loop that connects all of the complex’s buildings. This double loop, coming from a thermal energy storage-system with a heat exchanger, ensures that low temperature heat and cold (12 °C / 6 °C) is effectively distributed between the buildings. At present, the thermal storage can pump 200 m³/h groundwater, an amount which is sufficient for the six buildings that have been connected so far (figure 2). In May, this amount will be increased by another 200 m³/h in order to provide plenty of capacity (1.4 MW) for supplying heat and cold to buildings connected in the future. In the center of the business park a pond has been installed that, in addition to serving as a lovely landscape element, can regenerate the thermal source.

Each building connected to the thermal loop is provided with a similar ONE-system (Own New Energy), consisting of a source-connection module, one or more Waterkotte heat pumps, a buffer vessel and a monitoring and control unit (Figure 3 and 4). The ONE is a standard plug-and-play thermal storage unit, assembled in a factory owned by OSH and capable of being connected at location within a day. This method of prefabricated manufacturing and installing saves up to 20 percent on production costs and results in saved time (and money) in the transport of parts. Companies connected to the thermal loop will no longer have to worry about heating and cooling: Dubotechniek, a business unit of the Volker Wessels group (just like OSH), operates the entire system from end to end (the thermal source excluded). Maintenance, monitoring, billing, information for users and technical support are thus available in one interface and from one source.

<table>
<thead>
<tr>
<th>Building</th>
<th>Floor space (m²)</th>
<th>Completion date</th>
<th>BREEAM</th>
<th>Heat pump modules</th>
<th>Capacity (kW) per module</th>
<th>Total capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSH</td>
<td>8.600</td>
<td>July 2011</td>
<td>Very Good</td>
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<td>Excellent</td>
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<td>235</td>
<td>470</td>
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<tr>
<td>Plantronics</td>
<td>3.500</td>
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<td>Excellent</td>
<td>2</td>
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<td>224</td>
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<tr>
<td>NOW</td>
<td>6.500</td>
<td>March 2017</td>
<td>Excellent*</td>
<td>2</td>
<td>235</td>
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</tr>
</tbody>
</table>

*Figure 2. Characteristics of buildings connected to the thermal loop.*
Plug & Play

The fact that the ONE is a plug & play module is a perfect complement to the modular nature of the Park 20|20 thermal loop. Once the mechanical room of a new building has been completed, the ONE can be installed and be connected to the loop. The ONE-modules that so far have been installed range in power from 90 to 235 kW each. The capacity needed for an individual building is determined on the basis of a cooling load calculation, a transmission charge (husk), and a dynamic calculation (also referred to as ‘energy-design study’ or ‘comfort simulation’). The dynamic calculation is based upon a 3D simulation of the building, during which various scenarios involving different temperature, light and energy usage for a whole year are tested.

Plantronics: Thermal Energy Storage as a Sprinkler Source

One of the larger buildings at Park 20|20 that is currently in operation houses the Dutch office of the electronics company Plantronics (figure 5). In 2016, this was the fifth building connected to the thermal loop by means of a ONE-system. A highlight of the Plantronics office is that the thermal storage system not only provides heat and cold; it services the sprinkler system as well. The sprinklers draw water from the thermal energy source. This results in a significant cost reduction as no additional pumps need to be installed for the sprinklers. In case of fire, the thermal storage system pumps extinguishing water instead.

In conclusion

Internationally, Park 20|20 is considered a prime example of what is possible in the area of Cradle to Cradle building, sustainable enterprise and sustainable energy use. The responses from end users, i.e. the operators already settled in the business park, are overwhelmingly positive when it comes to the comfort levels experienced through the thermal loop/ONE-system. As part of Park 20|20’s commitment to excellence, the energy performance and comfort level of the connected buildings will be closely monitored over the months and years to come. Final results of measurements for the business park as a whole are not yet available; even more buildings will be connected in the future. Data will probably be available late 2020, once all the connected buildings and their ONE-systems have been in operation for a minimum of one full-season year. Based on current test results and responses from affiliates of connected buildings, expectations are high. Park 20|20 is already a wonderful showcase, and a clear example of what’s possible when innovation guides Cradle to Cradle building design and the reuse of surplus heat and cooling in a business park.

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All Dutch LIDL supermarkets have separated systems for HVAC and cabinets refrigeration: a R410A-3-pipe VRF, to heat / cool the store, warehouse and offices. The refrigeration and freezer racks (propane) are connected to a water loop and dry cooler. Both systems do never interrelate. In a pilot project, TripleAqua, a totally new 3-pipe heat pump system, using F-gas free natural refrigerant Propæne R433A, combines these with thermal storage, environmental advantages and creates large financial savings. The pilot is in operation since 2015 with success. LIDL asked Dutch wholesaler Coolmark B.V., a subsidiary of the largest HVAC&R group in Europe, Swedish Beijer RefAB, to develop a new system by means of which the store would operate exclusively with natural refrigerant to achieve energy saving and to fully reclaim waste heat from the refrigeration and freezer racks. A preference was given to hydrocarbons – with GWP near to zero. Also, individual and simultaneous heating and cooling in one circuit, cost-effectiveness and short installation times to refurbish the 1630 m² Zwijndrecht store.

Here, the TripleAqua system is connected to the glycol cabinet refrigeration loop by a plate heat exchanger. Waste heat is reclaimed by TripleAqua most of the year. In summer, a dry cooler rejects the shop heat. This system includes a 65 kW central heat pump type TripleAqua 3CA65, 15 TripleAqua indoor units of various sizes and the 3 pipe water loop for warm, cold and return water. In addition for this shop: BMS control, Energy Monitoring, AHU 3000 m³/h + HR, glycol loop and standard propane refrigeration/freezers were installed.

What makes TripleAqua so special?
The patented TripleAqua is a three-pipe natural heat pump and climate system, fully developed in the Netherlands. It can heat and cool and store thermal energy in one go. While sales rooms or offices are heated, refrigerators and freezers are also cooled and excess cold or warm energy is transferred or stored in PCM latent heat. The exchange and passive storage of thermal energy results in great cost savings for three reasons:

1 Exchange and Save energy
Heat is generated during any cooling process, cold is generated during heating. TripleAqua always exchanges this heat and cold for use in a different area or stores the energy for free future use - without additional costs. Heating and cooling at the same time, or in time delayed, is no longer a loss but a free fact.

2 Just three water pipes
Unlike 4 pipe water systems, three water lines connect the central heat pump to all room units. Each at an ideal, moderate temperature with lowest differences: Warm (at
28 to 36°C), Cold (at 12 to 18°C) and one common return line at building temperature. This has become possible as the room units are equipped with ultra-efficient mini-pipe heat exchangers, able to transfer all water energy into the room air. By deleting a full water return pipe, installation costs are reduced by 25%.

3 No four-way valves
The new design of the heat pump makes the use of traditional four-way valves obsolete. TripleAqua works both in cooling and/or in heating mode, always in the efficient countercurrent operating mode. All year through. Thus, all known disadvantages of the 4 way valve are history. The unique system design of the three pipe water heat pump with its condensor-evaporator-combined heat exchanger lay-out is patented.

The development of this heat pump has also been made possible with thanks to many European innovative suppliers: Main components inside the TripleAqua heat pump: two separated Bitzer HC-compressors, Danfoss VLT, Emerson controls, Rosenberg EC Fans, LUVE mini-pipe heat exchangers, PCM storage and less than 5 kg of Propæne charge per system. The indoor units are controlled by the latest Siemens technology, self-adjusting Danfoss ABQM control valves, Camfil Micro M5 air filters and EC fans, not sensible for air pressure changes.

Field Experiences
The heat pump was put into operation on 19 November 2015 as planned, before the start of the Christmas sales. It is the only source of heat for the store. Installation and commissioning was simple and fast, as there are no water adjustments needed, neither any needs for wiring between indoor and outdoor units. In the first months, updates of the software were made to improve the performance of the plant. From the beginning, the system delivered comfortable temperatures. Over a whole year, the system faced a quite hard winter and tropical summer. The winter design condition for the Rotterdam area is -10°C / 90% R.H. At -7°C, wet snow and high humidity, the heat pump never hit the highest speed of the compressors. The summer brought some tropical days, heavy rain and exceptional humidity, up to 32°C. The air condenser was able to cool at a ΔT of just 8 K to the ambient temperature. The heat pump now reached the maximum capacity in the cooling mode.

From the other operating data of the heat pump, in the mid seasons and course of the year, it became clear that this kind of supermarket – depending on the sun’s intensity - already needs to be heated as soon as the ambient temperature drops below + 14 to 18°C. Because of delays in the programming of the external BMS, the most advantageous reclaim has not yet been fully available after commissioning.

With TripleAqua, all requirements were met, and even more: highest efficiency, cost-effective and easy-to-control operation, Global Warming Potential of near zero with standard components, competitive investment, very easy installation and a reliable operation. And the results so far are outstanding. The LIDL-NL department of construction stated: “We cannot give exact figures for the whole energy savings, since we do not have complete comparative data yet with conventional stores, but the data
we have so far is more than promising. Because of the extremely positive results from the pilot project, further projects are in the planning stage”. And Menno B.A. van der Hoff, the inventor of the “TripleAqua” adds: “39.915 kWh consumption of the heat pump compressor in 405 days for a store area of 1630 m² (that’s just 22 kWh / m² per year) - is an impressive low figure.

**Advantages of the heat pump system**

Simple and cost-effective installation: A complete “TripleAqua” system can be created with a small number of standard water- and central heating elements. There is no special knowledge or F-gas skills necessary. Very easy to connect hydraulically, no electrical wiring, no elaborate site-commissioning, no individual site settings, but simple Plug-and-Play. 100% Modular in construction and operation, the system outstands VRF and 4-pipe designs. With a minimum of thermal loss and no restrictions in size, distance or power, it helps each commercial building of any size to become CO2 neutral. The outdoor units are standard with all modern control devices and hydraulic components, including the use of EC and VLT technology. Capacity control is done over the water merits using intelligent EC pumps. The internal controls detect if thermal energy must be passively provided or stored. Adaptive weather sensors fit operating points permanently to the actual needs of the building. The indoor units are accessible with an intuitive control panel providing simple operation, also over a BMS (Building Management system).

**Green for the environment**

The built environment is the largest world user of energy and the largest global cause of CO2 emissions. Heating and cooling of buildings forms the majority of this consumption, around 50-70%! Heat pumps can avoid all CO2 emissions. Unlike all other heat pumps, TripleAqua has no more F-gases, which have a large contribution to the warming up of our planet. TripleAqua works with the natural refrigerant R433A, Propæne, an azeotropic mix of propane R290 and propylene R1270 with a temperature glide of less than 0.4 K. The p-T graph is similar to R22. This efficient refrigerant combines all advantages. Even, it has a strong smell for humans in case of a leak. Charge of units is just a few kg. All models have the highest possible cooling (SEER) Energy efficiency class A and the highest possible class A++ for heating (SCOP). Resulting in a substantial energy saving and superb emission reduction for new and existing buildings.

**Application**

TripleAqua can have significant effects on the reduction of energy and emissions in new and existing buildings like hospitals, retail, care centers, schools, hotels, shops, offices and supermarkets. Being a fully water based system, TripleAqua can directly be combined with all kinds of sustainable energy, such as solar, underground storage, and simply be connected to existing systems. In the first year, many projects have been sold and the export into the EU has started. First responses at trade fairs in NL, SE, D, F and B have been very positive. TripleAqua has recently won several awards, such as the KIC-InnoEnergy and Dutch NVKL Award. TripleAqua is exclusively distributed by the national BeijerRef AB distributors.

More information at: www.tripleaqua.com
Making houses sustainable requires much more than just innovative products. We believe you should never underestimate the fact that homes need to be comfortable and healthy in order for occupants to fully appreciate sustainability.

Another of our beliefs is that you should make sustainability pay off for all the parties in the supply chain. This requires a deep understanding of our customers in order to develop innovative business models. Furthermore, from our experience with supplying and monitoring heat pumps for almost two decades, we are the only manufacturer that guarantees not only the functioning of our systems, but also the fact that a house remains zero energy for 15 or even 25 years.

Interested in how sustainability pays off in your situation? Or would you like to start or develop your career with the Dutch market leader in sustainable indoor climate? Visit the website below, or contact us at heatpump@ithodaalderop.com.

www.ithodaalderop.com
Increased use of residual and renewable heat in urban areas can accelerate the transition from fossil fuels to renewable energy in cities worldwide. The lower the system temperature, the more this renewable energy source is available and the higher the power generation efficiency in the case of a collective heat pump. This article describes the solution to the problem that arises when temperature decreases, namely the challenge of making DHW (domestic hot water) in low temperature collective systems.

The changing energy market and the growing demand for sustainable energy production have greatly influenced the design of HVAC installations and how we think about them. From the perspective of the then applicable costs, the systems that were designed to a system flow temperature of 90°C - 70°C were considered reasonable at the time. Since then, however, the system flow temperature has gradually been reduced due to changing market conditions; as a result, increasingly more heating systems are now being designed below the 35°C flow temperature. An additional incentive to design very low system flow temperatures – as in the case of passive cooling - is the increased comfort for residents and the need for a larger heated area. From a cost standpoint, the investment in these very low system temperatures is debatable. However, given that floor-heating manufacturers are sometimes providing 50-year warranties, the systems are best prepared for the future by using the lowest possible system temperature as their starting point. It may therefore be very appealing to have the system temperature determined by the heating system and not by DHW.

Renewable heat
To encourage the increased use of residual and renewable heat, the value of this heat is now expressed in PER (primary energy ratio). An interesting discussion here is ‘what can be defined as residual and renewable heat?’ Government organizations only address whether or not fossil fuel has been used for the generation, and not its exergetic optimization. The heat from a waste incinerator, for example, is 53% renewable, because the proportion of biomass in the waste is 53%. It makes no difference whether it involves a heat of, 120°C or 45°C, or if the first temperature is at the expense of electricity generation. If the production process is fully optimized for power generation, a residual heat of about 45°C remains that is then discharged into the environment because the exergetic value is close to zero. The question is whether this heat should be valued as 100% residual heat, and thus renewable, and therefore be given the opportunity for reuse rather than dumping. 40°C, after all, is a good temperature for low temperature (LT) heating systems. In hor-
In cultural areas we are see a number of examples whereby the residual heat of a greenhouse is used as an input for heating homes. Residual heat is a relative concept. With the introduction of the fourth generation of district heating by Swedish Professor Svend Frederiksen and Sven Werner [i], based on a much lower temperature than we in the Netherlands are used to, it is clear that utilizing low temperature heat when building in urban areas is an international practice. The Danes are leading the way in taking advantage of these methodologies, and have made themselves truly energy independent in the process.

From existing construction and the NOM (zero-energy) initiative known as “Platform31,” there is a strong desire to reduce the system temperatures of current district heating for a variety of reasons. [ii]

Another opportunity for collective systems can be found in stacked housing. In stacked housing the units are smaller and the shell insulation is greater, resulting in lowered demand for heating both in relative and absolute terms. Future new housing development continues to focus on infill locations and, due to scarcity, will primarily be built in the form of stacked housing, i.e. apartments. Due to the low-energy requirements, individual systems are hardly an option. Collective systems with ultra low operating temperatures are the future, regardless of whether or not they include passive cooling.

To make it possible to use this low-temperature heat for heating, a good energetic solution will have to be found to generate DHW. Because the collective production of DHW still encounters too many technical and energy issues, and we plan to discard energy at a 70°C flow temperature, the collective production of DHW is not an option.

Generating DHW in low temperature district heating
There are several options available to us [iii):

**ELECTRIC BOILER**
- The disadvantages are well known. The high running costs, incurred due to the kWh price in combination with unavoidable downtime, are the main disadvantage for residents. In addition, the application of the electric boiler in the EPC (energy performance coefficient) has a negative effect. The E-boiler might be a better solution in the years to come when successfully combined with a smart meter and a temporary surplus of renewable energy. Its future utility will always be evaluated in combination with one of the following systems.

**VENTILATION AIR HEAT PUMP**
- This type of heat pump is one possible option, but the amount of DHW depends on the amount of ventilating air. If the amount of ventilation is determined by the required amount of DHW (which occurs regularly), the system will bypass its target. In my opinion, the 2 phrases highlighted in green contradict each other – which thing depends on the other? The combination of ventilation air heat pump and ventilation heat recovery is not possible. Demand-controlled ventilation is also not possible in combination with the ventilation air heat pump.

**BOOSTER HEAT PUMP**
- This small water-water heat pump is capable of making a great deal of DHW from low-temperature heat. The remainder of this article discusses the Booster heat pump in greater detail.
CHARACTERISTICS OF THE BOOSTER HEAT PUMP

- **Flow temperature evaporator**: 15 – 40°C
- **Maximum DHW temperature**: 70°C
- **Thermal power**: approx. 2 kW.
- **Electrical power consumption**: 400 – 700 Watt
- **Annual COP with flow 24/40°C**: 3.73/4.78
- **Annual COP with flow 40°C with heat exchanger**: approx. 8.5
- **Dimensions (wxhxd) cm**: 60x37x35
- **Weight**: 33 kG

**Booster heat pump**

When examining the feasibility of the first large-scale low-temperature heating network in homes, specifically in the Waalsprong housing development in the city of Nijmegen NL,[iv], it soon became clear that alternate techniques had to be employed to produce DHW with the highest possible efficiency. This high efficiency was critical for cost and energy savings, and important due to the fact that hot water was being generated by electricity priced at consumer rates. Although this first low-temperature heating network was ultimately converted into a conventional district heating project, these efforts served as a starting point for future product development. Currently, there are a few providers, such as Itho Daalderop, offering the Booster heat pump with a capacity of about 2 kW thermal.

Because of the Booster heat pump requirement, there are only a few choices for the construction of the refrigerating circuit. The desired 40°C flow temperature of the evaporator (the flow from the collective system), the high condensing temperature for legionella safe DHW and the small capacity of about 2 kW thermal together limit our choices to the refrigerant R-134a and a few compressor suppliers. Even with limited choice there are significant differences in performance, efficiency and structure, which is ultimately a good thing for the further expansion of this type of hot water production.

**Storage**

The thermal capacity of 2 kW requires an additional buffer to provide sufficient DHW, one that is not solely based upon the power of the Booster heat pump, but upon the size of the storage tank that provides DHW comfort. For example: for tap capacity 4 [v], approximately 10.4 kWh of heat is required daily (180 liter, 60°C). With a 2 kW capacity of the heat pump, the operating time is thereby approximately 5 hours a day. This leaves excess capacity for any unanticipated situations or for a larger installation. In this example, a storage tank of 90 and 150 liter is sufficient; with a 200 liter storage tank, the charge may be limited to once a day. The larger storage tank might be an attractive solution; pricing if often determined by (residual) heat or electricity prices. For the moment, manufacturers have chosen to supply the Booster heat pump and the storage or buffer tank as individual components. This offers the advantage that each installation can be tailored to customer needs. Apart from the necessary boiler room space, stock units have the disadvantage of downtime losses. Although these are not immediately part of the energy performance certificate, they are nevertheless processed therein. [4]
Remarks
Since the downtime losses occur during the 24-hour measurement, they are not immediately included in the certificate even though they do affect the COP. These downtime losses for test validation are measured separately. In the case of Itho Daalderop, 14 Watt was registered electrically ‘on the plug’ with a 150 liter tank. With an assumed COP of approximately 3.8, that is 53 Watt thermal. One often-overlooked aspect of DHW storage is the drainability of the storage tank. While this is always measured by TNO, it is not considered relevant to the energy performance certificate and thus not mentioned therein. Yet measured drainability is still a valuable piece of information for buyers in the market; a well-constructed smaller tank can sometimes supply just as much hot water as a larger tank where less attention has been paid to stratification. Drainability should be included in the energy performance certificate.

Pre-heater
In homes that are connected to district heating with a permanent flow temperature of 40°C, there are benefits to pre-heating cold water to 10°C with the system water, and then further heating water to higher temperatures with the heat pump. As a result, very high COP’s with values above 8.5 can be achieved. This method of DHW heating requires 3 elements: a special setting of the Booster heat pump, a variable frequency pump and a suitable storage tank with high intake. In this scenario, the DHW is heated at once from 10°C to 60°C, thus creating a charge system. Proper stratification in the storage tank largely determines system efficiency: the colder the water to the heat exchanger, the greater its revenue.

Normative assessment and valuation of Booster heat pump
For these kinds of heat pumps, the offered heat on the evaporator may vary. This occurs in OTC- (outdoor temperature controlled) and installations with a collective change over. Booster heat pumps are designed for these instances and can handle a relatively high temperature with the evaporator of up to 40°C. The current method for measuring energy performance for DHW heat pumps [4] in the Netherlands is based on a fixed source temperature where there is a need for large distribution. In response, RVO TNO, KIWA and other market companies together developed a custom method for measuring energy performance for Booster pumps that make DHW. In two measurements with flow temperatures of 24°C and 40°C respectively and in which the flow over the evaporator remained constant, it was investigated whether the COP for the intermediate temperatures may be interpolated and extrapolated to 20°C. Further investigation took place by evaluating a third measurement at 32°C flow temperature. With interpolation from 24°C to 40°C, from 24°C to 32°C, and from 32°C to 40°C, the deviation in COP was found to be within a manageable range of 5% and is therefore considered justifiable. Manufacturers themselves have added an additional requirement, that the flow over the evaporator stop whenever the compressor is not running, as part of the solution to best address a common heating situation that frequently occurs.

Two systems were studied. In the first, the Booster heat pump is connected directly and permanently to the heating network; in the second, floor heating is used as a source for the evaporator in summer. In addition to the facts that the source is 100% renewable (minus the auxiliary energy for the floor circulation pump) and does not need to be assembled, the cooling penalty from the EPC can often be avoided because the house is cooled with the production of DHW.

Applications
The Booster heat pump is suitable for use in both large and small projects. In STES (seasonal thermal energy storage) installations, DHW invariably has a negatively impact on performance; practical measurements typically capture outcomes that are even worse than anticipated. With decentralized DHW preparation with the Booster heat pump, this negative effect can be eliminated and the number of pipelines in the collective network can be reduced. DHW can even be made with 2-pipe systems with a collective change over.

One option that is currently being explored is cascaded geothermal energy, whereby high temperature heat is first offered to existing (district heating) networks and then the remaining supply of 40°C is used to supply new building locations. The use of residual heat from a supermarket, for example, can also be offered to the apartments located above it.

Making DHW in BREEAM certified all-electric buildings is a challenge in itself. There, too, the Booster heat pump can provide significant benefits and energy savings.

After the Booster heat pump was introduced in 2012, the installation industry continued to expand its uses by developing new applications, especially in combination with solar thermal power systems and DHW circulation pipes, to generate the desired temperatures.
The search for low-quality heat with stable value and the highest possible temperature has led Inventum to ventilation return air. Since the late 1970s, Dutch homes have been heated with mechanical ventilation. This sucks contaminated, moist air from the residence and transports it outside. To ensure a healthy interior environment, the moisture and the contamination have to be sucked out continuously and thus a great amount of energy is lost. This energy, in the form of warmth, is the low-quality source for the Inventum Ecolution ventilation heat pump.

Advantages of ventilation return air
The ventilation return air represents a fairly consistent source temperature of around 20 °C. The high yield, the energy savings for a home no longer losing heat due to ventilation, and the possibility to combine ventilation return air with higher release systems are all advantages offered by the Inventum Ecolution ventilation heat pump. The Ecolution functions on a so-called natural ventilation system (type C). But even in balanced ventilation (type D), the Ecolution has something to offer. With the introduction of the Ecolution, Heat Recovery is no longer exclusively reserved for balanced ventilation units. Both products are virtually equivalent in the recovery of heat, but because of the heat pump function of the Ecolution, Ecolution’s final yield is almost twice as high as with HR-balanced ventilation. The Ecolution delivers recovered and upgraded heat where residents want it.

Complete climate system
Heat, hot water and ventilation
In heavily populated countries with extensive industry and traffic, air quality continues to decline. The population of Western Europe remains indoors on average more than 90% of the day. A high air quality and a healthy interior climate inside buildings and homes are thus very desirable outcomes. Contrary to popular belief, more ventilation is the right solution. With standard ventilation systems, much heat and thus energy is wasted and performance worsens over time. Do we ventilate for energy savings or for health reasons? The Ecolution turns the disadvantage of heat loss from ventilation into an advantage through Heat Recovery from ventilation return air. The Ecolution also makes use of Aerothermal energy. In addition to being an efficient generator of heat and hot tap water, the Ecolution is thus a complete ventilation system.

Multi-use ventilation heat pumps
The Inventum ventilation heat pumps can be used in many ways and in a variety of situations. The Optima uses ventilation return air exclusively to heat hot tap water for the supply of water heaters of 80 and 120 liters. The Ecolution Combi 50 heats and supplies much of the
hot water needed for daily use and can be integrated into an All Electric system in a well-insulated new building construction (with a primary thermal load < 15,000 Mj). The Ecolution Solo is designed exclusively for heating the home. Combined with the boiler, the Ecolution is also suitable for older, less well-insulated homes. This is our hybrid concept. Here, the Ecolution takes over the basic load and the boiler takes care of the peak load. This makes it possible to reduce the use of natural gas and in turn limit the emission of CO2. The multifunctional Ecolution can be used at virtually all times due to its small capacity. The Ecolution even scores low in energy usage and thus is relatively easy to power through sun and wind energy production.

Homes with glass wool and hemp
An All Electric system has been installed in the Brabant housing development in Sint-Oedenrode, the Netherlands. Built by the developer Wovesto, these homes are the most energy-efficient residences in the country. The homes have a simple but smart energy system and have been built and insulated with as many natural materials as possible. For example, there are PV cells for recovering electrical power and a solar thermal collector on the roof for heating water. The wall heating in the homes is fed by the Ecolution combined with a solar boiler. Together, both products provide the hot water needed by residents.

Innovation is in our DNA
We continue to look for new energy-saving solutions. This is our number one priority and why we are the leader in ventilation and hot water systems. Inventum offers a wide range of boilers, ventilation heat pumps and boiling water systems. Our energy solutions are applied in existing and new buildings, in homes and in non-residential buildings.

Let's make great things together!
We work closely with our customers to develop new ideas and products for private-label and other segments of the market. We design customized hot water solutions and manufacture them in our high-tech factory. For many years, we have been a reliable supplier & partner for several central heating, sanitary fitting and ventilation manufacturers, including Grohe and Bosch. We also produce ventilation heat pumps for the Dutch boiler manufacturer Nefit, the Dutch energy supplier Eneco and DUCO ventilation.

Every home can be sustainable
With our ventilation heat pumps, we and our partners serve a large part of the market. Since our acquisition of the Irish company Joule (www.jouleuk.co.uk), the services and products that we can offer has significantly increased. In addition to using heat pumps with ventilation return air, there are many more possibilities for using heat pumps with outside air. Inventum offers a complete package of heat pumps so that virtually every home can become sustainable.

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Abstract
This paper presents current performance of an adsorption chiller, driven by waste heat or solar heat. The paper focuses on an all in one adsorption unit which allows easy installation. Real life performance is compared with tests under laboratory conditions. It was found that the performance of the adsorption units in the field was equivalent to the performance obtained in the reference test under static conditions. Further an outlook on future developments is given. This will include energy storage and heating functionality to a system, which will allow to take advantage of deviations between supply and demand of energy (e.g. solar energy).

1. Introduction
The increasing prosperity of the world population is causing an increased demand for residential cooling and energy storage. Data obtained in studies [1,2] on the impact of cooling in the built environment, indicates its significant contribution to global warming. Sorption chillers driven by solar heat or waste heat can contribute to a more sustainable built environment. Sorption chillers have many possible applications and a large scale of heat sources is available in the built environment, e.g. district heating, solar heating, etc. However, introducing sorption chillers in dwellings, offices and small industry processes is complex and often requires the integration of multiple system, which leads to an increase in costs.

One way to increase the use of sustainable sorption cooling in the built environment is to offer an integrated all in one sorption chiller for in dwellings and offices. Currently the SolabChiller®, which is developed by de Beijer RTB B.V. for SolabCool B.V. is on the market. This machine uses silicagel as sorption material, and is suited for dwellings, small offices. Silicagel has been chosen due to its attractive properties, which allows to supply decent cooling power with driving temperatures as low as 55°C.
The SolabChiller® is equipped with an integrated dry cooler and a patented multiple-way valve to maximize the efficiency of the hydraulic circuit. The only installation steps required for a SolabChiller® are connecting the heat source and the cooling circuit of the dwelling to the respective circuits of the SolabChiller®.

Thermal driven sorption machines have a significantly higher COPe compared to compression heat pumps. A COPe of 15 till 20 is common for sorption machines. The Cooling factor for small commercially available sorption machines is in the range of 0.5-0.7.

The main mechanism of sorption heat pumps is the desorption and sorption of e.g. water or methanol into a sorption material. In the case of current the Solabcool machines the working pair silicagel-water is used. The silicagel is distributed over a heat exchanger; the silica bed. Each module consist of a silica bed and a combined Condensor/Evaporator (C/E), see Figure 1. Sorption and desorption cannot take place simultaneously in one module, so two separate modules are used to generate continuous cooling output. One of the two modules is in desorption phase, the silica gel is desorbed with using driving temperature. In this phase the C/E functions as a condenser. Condensation heat is released using the integrated drycooler.

The second module meanwhile producing chilled water, this is the sorption phase. The water at the bottom of the vessel evaporates and withdraws the needed energy from the fluid flowing in the C/E. The silicagel is sorbing water vapour which is generated by the C/E. The sorption heat is released using the integrated drycooler of the SolabChiller®.

### 3. Methodology

In Figure 2 a demonstration project is displayed with the SolabChiller® installed at a dwelling in Arnhem, The Netherlands. The driving heat source is in this demonstration project the district heating of the incineration plant AVR in Duiven, with constant supply temperature of 70°C. The cooling is distributed in the dwelling using floor cooling.

The SolabChiller® that is applied at the dwelling (see Figure 2) and the performance is monitored over the years 2014 and 2015. In the field test full load and partial load conditions are obtained. The behavior of occupants have an influence on the results. In the field tests the temperatures are measured using PT-100 Class A temperature sensors, with a measurement accuracy of approximately 0.02°C. The flow is determined by measuring the pressure difference over the water circuits, with a measurement accuracy of approximately 5%.

The performance of the adsorption unit applied in the demonstration project is compared with a lab measurements at 70°C supply temperature under full load conditions which are used to determine the seasonal performance of a SolabChiller using a TRNSYS model climate data from NEN 5060.

### 4. Results

The measurements and simulations done by TNO have resulted in a Seasonal cooling factor (SCF) of 0.51 using a so called AgentschapNL referentie tussenwoning, a single family house that is the standard reference building for the evaluation of energy performance of energy technologies. The performance of the SolabChiller® applied at a dwelling during two cooling seasons are presented in Table 1. The higher Seasonal average Cooling Factor in the field test can be declared to the occupants behaviour...
and operation under partial load conditions. In the field test the SolabChiller was only enabled by the occupants at periods with high ambient temperatures. In the field test the machines does not only operated at full load conditions, it is operated at partial load as well, causing an increasing efficiency. This results in a higher Seasonal average Cooling Factor in the measurements.

<table>
<thead>
<tr>
<th>Year</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cooling time [hours]</td>
<td>208</td>
<td>194</td>
</tr>
<tr>
<td>Total cooling capacity seasonal [GJ]</td>
<td>2.07</td>
<td>1.96</td>
</tr>
<tr>
<td>Seasonal average Cooling Factor (SCF) [-]</td>
<td>0.58</td>
<td>0.59</td>
</tr>
<tr>
<td>Electric consumption (including monitoring) [GJ]</td>
<td>0.28</td>
<td>0.26</td>
</tr>
</tbody>
</table>

5. outlook on current and future developments
De Beijer RTB is improving the SolabCool technology. It is expected to increase cooling output with 50% for the SolabChiller, while reducing production cost and further simplifying the integration in a width variety of applications in the build environment. Performance is improved by multiple optimizations, such as increase of the heat transfer in the silicagel bed. Improvements in the C/E, which is lowering the required excess temperature for evaporation by enhancing the heat transfer. Tests have shown improvements in heat transfer up to 270%.

Similar machines which make use of salt hydrates, such as sodium sulphide, are in development. The largest advantage of salt hydrates are the larger energy density (e.g. sodium sulphide 2.9 GJ/m3) and a relative high sorption temperature (approximately 65°C), which is required for domestic hot water production and it is more compact than sensible heat storage. A recent demonstration project [6] in which De Beijer RTB developed and built the storage modules had shown that a non-optimized system has an energy storage density of 100MJ/m3, which is not time dependent [7]. Additionally product development is heading towards integration of salt hydrates into a similar all in one solution, offering cooling, heating and production of domestic hot water using salt hydrates. This machine will also incorporate storage functionality. De Beijer RTB is participating in several national and European research projects, where application and improvement of properties of the salt hydrates, such as heat transfer, is investigated by encapsulation.

References
Abstract
This article describes the development and integration of a refrigerant expansion motor into the refrigerant circuits of heat pumps and chillers. The primary purpose of integrating a refrigerant expansion motor into the cooling circuit is to reduce the total electric energy required by the refrigeration cycle compressor in instances of consistent cooling and/or heating capacities.

Chillers and heat pumps have been further developed over the years and have become more and more efficient. This was due to pressure from a possible ban on effective but harmful refrigerants and to the European climate targets set for 2020.

1. Development of a Refrigerant Expansion Motor
Roodenburg Duurzaam b.v., a company based in Krimpen aan den IJssel in the Netherlands, has approximately 30 years of experience in the design and construction of Thermal Energy Storage (TES) installations and heat pumps. Roodenburg is among the leaders when it comes to cost-effective and large TES systems, including various installations with a capacity of over 2000 kW. An example of this kind of TES system is the thermal production plant at the Central Station in Amsterdam. The starting point for design is always to make these installations as energy-efficient as possible. In order to achieve this, the total installation as well as the refrigeration cycles must be continually optimized. The traditional compression refrigeration cycle (known as the Carnot cycle) adheres to the following principle: in order to be able to increase the pressure of the refrigerant, energy must be added by means of a compressor. The expansion valve then ensures a pressure reduction that releases kinetic energy. This same principle can be observed in electric cars.
Electric energy is required from a battery pack to drive electric cars. Braking then generates kinetic energy that is used to recharge the battery pack. Historically within...
the traditional refrigeration cycle, there was a throttling loss of energy that occurred during the expansion process. Nothing had been done to address this energy loss until now.

The goal of converting ‘lost’ kinetic energy into electrical energy can now be realized through integration of a highly efficient refrigerant expansion motor into a traditional cooling circuit. Using a refrigerant expansion motor, the throttling loss can be reduced during the expansion process and can thus be converted into usable energy. The traditional use of static expansion devices (expansion valves) must then be replaced by something more dynamic, the so-called “refrigerant expansion motor.”

2. The Basic Principle of the Refrigerant Expansion Motor
The possible means by which to recover energy during the expansion process has been investigated by several parties in the past few decades. These parties include Mr J. Brasz from the development department at Carrier Corporation [01] and Mr. Zhang from the Technical University of Tianjin, China [02]. They investigated the possibility of recovering energy (expended by the compressor to move the refrigerant at high speed) by using a refrigerant expansion motor next to the expansion process. The principle of successfully converting the throttling loss into useful energy is based on tests that entailed injecting a refrigerant under high pressure onto impeller blades using static injectors in accordance with the Pelton principle. See Figure 2.

During the development of the refrigerant expansion motor, Roodenburg joined the injectors and the impeller blade to form a kind of cyclone disc (see Figure 3). In an installation with a refrigerant expansion motor, the refrigerant flows through the cyclone disc (which has spiral-shaped ducts) at high velocity under the influence of the pressure differential between the inlet and outlet pressures. Once the refrigerant’s flow is re-directed, an opposite pressure is applied to the spiral of the cyclone that causes it to rotate. Once the refrigerant is flowing within the cyclone spiral, a pressure reduction will occur that lowers the vapor pressure. This in turn causes a partial evaporation of the refrigerant, thereby cooling the liquid. Due to the formation of vapor, the volume of the mass per kg increases. As a result the speed of the refrigerant in the channels also increases which then yields a further increase of the rotational speed of the disc. The high discharge velocity of the gas/liquid mixture will generate a second thrust force on the disc, which largely contributes to the total generated power.

3. Operating Principle of the Refrigerant Expansion Motor
The compressor compresses the gas out of the evaporator and into the condenser. The gas is converted into liquid in the condenser, and the liquid is guided to the expansion motor. De-pressurization takes place in the expansion motor, resulting in a high-velocity mixture of gas and liquid on the outside of the cyclone disc. The disc begins to rotate in response to the speed increase. The kinetic energy generated by the disc can be returned via a generator or directly via a fixed coupling with the compressor. The li-
quid and the gas are separated, and the gas is eventually fed directly back to the compressor. The 100% liquid refrigerant will be fed to the evaporator directly or via an expansion valve. The torque will be highest when the disc is stationary; it will decrease with the rotational speed of the disc. The workflow of a cooling circuit with an integrated refrigerant expansion motor is shown in Figure 4.

4. Energy Savings within the Refrigeration Cycle (Carnot Cycle)

The refrigeration cycle with an integrated refrigerant expansion motor is almost identical to the traditional refrigeration cycle with one exception: the expansion valve has been replaced by the refrigerant - cyclone expansion motor.

The energy savings consists of two components:

- The conversion of kinetic energy into mechanical energy
- The reduction of the quantity of flash gas that joins the evaporator (by extracting the flash gas). Since the flash gas is immediately fed back to the compressor, more liquid will enter the evaporator, which increases the total evaporator power (and decrease in entropy). This process is shown in Figure 5.


During the theoretical research on the prototype cyclone disc, researchers determined that the design (as shown in Figure 2) would not work as expected. Thus, consideration was given to further develop the disc through alternate methods such as enlarging and shortening the channels. The second design of the cyclone disc is shown in Figure 6. Roodenburg Duurzaam b.v. is looking for strategic partners to support further development of the refrigerant expansion motor principle.

References

[01] Performance characteristics of two-phase-flow turbo-expanders used in water-cooled chillers, J.J. Brasz (Carrier) 1999

[02] Experimental investigation on a turbo expander substituted for throttle valve in the subcritical refrigeration system, Zhenying Zhang, Minxia Li, Yitai Ma, Xufeng Gong | Published in December 2014
Within the housing corporation of Vestia the focus of new construction shifts towards increasing the quality and sustainability of existing housing stock. The development and operation of sustainable installation concepts is provided by Corporatie Energiebeheer formerly Vestia Energie B.V.. This organization addresses this part of the business thoroughly. Broad information to the tenants of the housing stock, clear (contract) agreements with suppliers and continuous monitoring are the backbone of the policy. Vestia gives attention to all residential themes. Focal point is provide housing for socially vulnerable and care for the needy. In recent years, the housing corporation also pays much attention to controlling the tenant’s living expenses and preventing energy poverty. Thus more and more attention is paid to CO2 reduction and energy saving. Vestia is definitely not a simple starter when it comes to the realization of sustainable projects. The corporation has now built up a beautiful portfolio of housing projects newly built as well as renovation, where heat pumps are the key technology. In 2006, Vestia received an award for her “oeuvre”.

It’s falling and getting up
Despite the appealing weaponry, Vestia has paid the necessary tuition fees. “In the past, we experimented a lot, falling and getting up,” says Mohammed Bachri, Technical Project Manager at Vestia Corporatie Energiebeheer. “But we have learned. This way we choose when it comes to applying heat pumps, basically only for closed ground source systems.

Closed ground source systems are less fault-sensitive, easier to maintain and also cheaper in maintenance than
open systems. We combine these ground sources with individual heat pumps even for multifamily buildings. Thus you can deliver more customized solutions. It may seem strange, one hundred small units instead of two or three, but we prefer it above the collective. We have learned from the experience in earlier projects like Duindorp.

Another strategic choice we have made is that we apply balanced ventilation with heat recovery, despite all negative publicity. In our view, this is the best choice when using heat pumps. And all the same when it comes to low-temperature systems. A good alternative is the DemandFlow CO2 demand-driven ventilation system from Itho Daalderop. As far as housing ventilation is concerned, we limit ourselves to these two concepts.

Unambiguously

Vestia Group offers housing service to residents of 89,000 homes in the Netherlands. The homes are divided between 15 local Vestia corporations, which operate in their own neighbourhoods. “These housing companies are the owners of the stones,” explains Bachri. “We develop the energy concepts that need to match with the bricks of our sister companies. The basics we use, the standard connection conditions, we have bundled into a booklet. This directive has been distributed to all Management Team members of our residential companies”.

The booklet describes the condition that the building must meet physically in order to be able to apply a heat pump in a good way. Then I’m talking about Rc values, airtightness, details, insulation frames and glass, and so on. We also set requirements for space needed for technical and energy installations.

We provide what needs to be done to ensure that installation noise remains within acceptable limits. The concept is unambiguous. We buy our installations with a limited number of suppliers. We know what a particular device produces on sound. And the characteristics of an installation space are known. This allows you to calculate exactly what the noise levels will be in the residential areas. “

Sustainability ambitions

“It’s important that you start a program that has clearly formulated your sustainability ambition,” Bachri continues. “During the design phase, it is a must to look for an integral approach for all themes. Then I talk about integration between the stones and installations, but also the integration between the components of the installation. Because we always talk about sources, generators and delivery systems. Additionally, you also have user profiles. Between all the essential elements you need to find optimal cohesion. What we do during the realization is to ensure increased supervision. The closer we are to the construction or renovation of a number of houses or apartments, the more we increase the supervision. In practice, increased monitoring means, inter alia, performing air tightness measurements and measuring installation noise.

We always do that and we will make it clear in advance with new partners which are the suppliers or builders. This way you keep your goal in mind and keep all those involved sharp. We’ve learned that you need to capture maintenance agreements with your partners in performance contracts, and that you need to name very clear performance indicators. Those performance indicators really need to be addressed when you want to do well.”

Monitoring

Does an installation generate according to what the supplier promised? In terms of energy use and comfort? Bachri: “We have developed a beautiful monitoring tool, keeping an eye on all the essential parameters, thus giving a good insight into the operation of the installations. We have promised our tenants, “You will receive an energy-efficient installation that provides comfort.” That promise is based upon our expectations. So it is important to keep close monitoring of these business as well.

When you monitor, you also know when to intervene. We prefer situational, state-dependent maintenance over preventive maintenance. If the efficiency of a heat pump decreases, you intervene. By calculating energy usage in advance, and communicating well with residents, you will avoid much discussion. In addition, the forecast of energy use increases the awareness of the end user. It is also clear that the demand for comfort and availability depends on the space temperature and the temperature and amount of domestic hot water. Of course, everything is privacy-sensitive. The user should always be aware that data is being collected. “

At a housing corporation, the customer, the resident, must always be at the centre of attention. Also in the communication. Vestia holds residents’ meetings and has a lot of written material in support. “You do not want to know how many bookmarks, climate leaflets and manuals we write on an annual basis. Readably manuals in many different languages, says Mohammed Bachri with a slight sigh. “The manuals of installers are, with all due respect, not readable. Those fat pills immediately disappear in the trash can. I would like to urge the manuals to be published in a simplified version, say ‘Jip and Janneketaal’. In addition to the written information material, we have also developed an internet site where residents can find everything. “
Heat Pump Installation at the
World Trade Centre in Rotterdam (and Timmerhuis)

What is the project about?
Rotterdam has a new characteristic building, the Timmerhuis, called by the Rotterdam citizen the ‘Glasbak’. The Timmerhuis built after the Second World War at the Meent, has been the epicentre of urban planning of Rotterdam’s city centre for many years. Until 2009, then the officials were flared over the city and the Timmerhuis was renovated and transformed into a centre of work and life. The new renovate building, designed by Rem Koolhaas architectural firm, consists of a stack of square blocks with an open connection to the street. Thanks to the heating and cooling system of ENECO the Timmerhuis has been awarded a BREEAM ‘Excellent’ rating.

The climate plant of the adjacent World Trade Centre is being renovated in the next couple of years and Eneco is responsible for the adaptations to the current installation and the connection with the adjacent ATES. The building was constructed between 1936 and 1941 and has its monumental status. The renovation therefore calls for a special approach. Jolande Huijers, Managing Director of Rotterdam Rotterdam N.V/Beurs-WTC: “This is a well-considered business economic decision for us. This investment reduces costs and ensures long-term comfort. In addition, I am pleased with the hybrid solution, which includes unprocessed parts of the building with appropriate heat and cold. This will ultimately reach the end result. “From 1 January 2015, the Beurs-World Trade Center will benefit from renewable heat and cold, thus contributing to the reduction of CO2 emissions for a period of at least 15 years.

“The Timmerhuis together with the World Trade Centre is the most energy-efficient building that the city of Rotterdam currently has,” says Michiel Bakker, System Engineer at ENECO. In the new Timmerhuis Rotterdam complex, there is an underground garage of approximately 120 parking spaces. The ground floor accommodates 3,500 m² shops and space for general use. Above the ground floor, 4 floors are offices for commercial purposes. The remaining floors is composed of a mix of 84 large and small apartments. On one side, the builders had to deal with installations in a monument. Which is why strict rules apply on construction. The other side was that the
new build construction is being done within a set steel prefab-cage. The plumbing had to go in between those steel pipes. It is a paradox to integrate the new and the old, yet mission was accomplished. No other building like this ever got the BREEAM Excellent**** certificate.

**Overcapacity is used**

“A few years ago together with the municipality of Rotterdam, ENECO had conceived the plan to the Timmerhuis to connect it to a large cold distribution network in the inner city, from the Maas to the Rotterdam train station,” says Bakker. “When those plans were delayed, we continued to be involved in the project, from our knowledge and experience, implement a sustainable heat and cold storage system through ATES- Ground Source system and Heat Pumps.”

“The ATES-installation in the Timmerhuis is equipped with two ETP heat pumps and two source pairs. In addition, the district heating as a backup and peak supply for the heat demand in the rest of the building. In accordance with the BREEAM requirements is the complete installation with various detection systems to detect any leaks, and quick to catch.”

The WKO-installation is in the basement of the monumental part of the Timmerhuis. Here was little space available, so several adjacent areas were used. Main contractor Heijmans had a number of walls broken out. Subsequently, Hager the piping to all delivery points. Energie Totaal Projecten (ETP), the WKO-installation turnkey to Eneco. Central in the basement of the building is an ETP HWS4400 WKO central which supplies 4100kW cooling and 1950kW heating to the entire building. The corresponding sources are performed underground. Detail is that the closing covers of the sources, at the special request of the municipality of Rotterdam, have been incorporated in the street work.

“The overcapacity is used in adjacent World Trade Center. The heat-and cold distribution network can also be extended and linked to other networks in the area.

The Heat Pump itself as well as the ground source system is manufactured by ETP and delivered as a flexible pre-fabricated skid. The controls are an integral part of the WKO skid, the control box is therefore pre-assembled on the frame and wired to the field equipment. The WKO skids are completely manufactured and built in the workshop. The installation is wired, tapped and tested for transport.

**Efficient installation**

The advantage of the joint installation with Timmerhuis and WTC is that there is only one installation is required. All the heat and cold from the installation is used in an optimal way. In addition, in the basement of the WTC there is much space saved.

The dry coolers that were first placed on top of the Timmerhuis’s homes have now been replaced by a dry cooler in the WTC basement. This serves to overcome any imbalance and / or as emergency provision. The dry cooler is also connected to the air conditioning units in the basement, which can be more efficiently conditioned. “In the WTC part the existing climate system has been retained to cover peak demand. “All climate systems are linked together,” says Bakker. “In order to properly tailor all the power, temperatures and arrangements, it was a decent - but also ‘fun’ challenge.”

**Sustainability ambitions**

“This unique solution integrates seamlessly into our sustainability ambition and has as far as we are concerned, definitely the future. We are still trying to develop the cold distribution network for the neighbourhood. Various parties have already shown interest. The next time cold distribution network will grow organically. Rotterdam is therefore soon an additional cold infrastructure richer, so we can meet the sustainability ambitions of the municipality of Rotterdam towards 2030. “

Article based upon interviews and articles on Eneco Website (www.eneco.nl) and other websites.

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**Heat Pump features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat pumps</td>
<td>double-run, each with screw compressor with economizer and optional additional subcooler</td>
</tr>
<tr>
<td>Capacity</td>
<td>compressors: frequency control (20-100%)</td>
</tr>
<tr>
<td></td>
<td>source pumps: frequency control (10-100%)</td>
</tr>
<tr>
<td></td>
<td>circulation pumps: fixed speed / frequency control</td>
</tr>
<tr>
<td>Control</td>
<td>direct, combined cascade control of the compressors and source pumps</td>
</tr>
<tr>
<td>Temperature ranges</td>
<td>Heating nominal: 40 - 55 (max. 70C)</td>
</tr>
<tr>
<td></td>
<td>Cooling nominal: 10 - 18 (minimum 7C)</td>
</tr>
<tr>
<td></td>
<td>COP nominal: cool approx. 40 / heat approx. 4.5</td>
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</table>
During the development of office building ‘The Edge’, which has been completed in 2014, the limits of sustainable building have been pushed. These efforts have been awarded with the highest BREEAM-NL certificate, Outstanding - while the original design was meant to be rewarded with BREEAM Excellent. One of the components that made a ‘greener’ reward possible, is the highly innovative heat pump system the building has been equipped with.

From the start of the development and construction process of the Edge, in 2006, property developer OVG established a solid ambition: this property should meet the requirements for a BREAAM Excellent certificate. The municipality of Amsterdam followed this ambition, for all other office buildings at business park ‘Zuidas’. The initial design certificate gave a taste for more, so the project team investigated whether Outstanding - the highest possible Bream qualification – could be met. This seemed to be the case. At completion, the Edge got a BREEAM score of 91% - well above the 85 limit used for the Outstanding certificate.

Aquifer Thermal Energy Storage
One of the system components contributing to the highest possible sustainability certificate, is the aquifer thermal energy storage (ATES) combined with a highly innovative heat pump concept. In Amsterdam, connection to the district heating system is mandatory, but OVG preferred to install an ATES. As a compromise, OVG was
allowed to connect the Edge to an ATES, provided the building would be connected to district heating as well, for thermal peak shaving.

The thermal source for the building is an ATES with 1 doublet (1 heat / 1 cold storage), 150 meters deep and with a capacity of 160 m³/hr. For the next 15 years, the ATES will be operated at own risk by energy company Eneco. It is connected to two highly innovative heat pumps designed and build by the Dutch company Energy Total Projects (ETP). The district heat network provides 600 kW of power, the two heat pumps account for 1,460 kW. The total heat output is thus 2,060 kW, about 200 kW more than the maximum required output. The ATES is able to supply approximately 2,500 kW of cold, which has been calculated to be the maximum demand of the building.

Heat pump innovation

The two HWS-4000 heat pumps are standard modules, but have been adjusted for this particular application. Each heat pump is equipped with a screw compressor with an economiser, an auxiliary control at the compressor and the evaporator and condenser pumps. This results in a temperature range of 40-55 (max. 70) °C on heating, and 10-18 (minimum 7) °C on cooling. Risk reduction isn’t the only reason for using two identical heat pumps: this dual installation offers the opportunity to use both a ‘conventional’ and an ‘innovative’ operation mode. One heat pump is operating in a conventional mode, the other one in a innovative mode. Both systems are closely monitored, to detect differences in efficiency.

So what is this ‘innovative’ mode? In a heat pump operating in ‘conventional’ modus, its refrigerant is fully evaporated and subsequently overheated by a (at least 5) degrees Celsius in order to prevent liquid refrigerant running into the compressor. Overheating of gas in the evaporator is a difficult process: on the one hand due to the poor heat transfer to gaseous refrigerant, on the other hand due to the deposition of an insulating film of compressor oil on the evaporator - which takes place as soon as the refrigerant evaporates. In the innovative mode in which one of the EPT heat pumps operate, ‘just’98 percent of the refrigerant initially evaporates, and there is no overheating of the gaseous refrigerant. In this way the less efficient transfer of heat to gaseous refrigerant is avoided. The 2 percent of liquid refrigerant continuously rinses oil from the evaporator, so there is no insulating oil film. Subsequently, the 98 percent gaseous and 2 percent liquid refrigerant mix is transported to an additional heat exchanger in order to evaporated and overheated by 20 degrees Celsius. For this process, the hot liquid from the condenser is used as a heat source. By this innovative way of operating, the evaporation temperature in the evaporator increases with 3-4.5 degrees, while the condensation temperature decreases from 46 to 45 degrees. Because of the reduction in temperature dif-
ference between the evaporator and the condenser, the heat pump operates with a better efficiency, with an improved COP as a result:

- Calculated COP
- COP full load: 6.55
- COP part load: 4.96
- Total COP heat pump and pumping equipment: 4.86

Solar energy
The two heat pumps of the Edge are fully powered with renewable energy. At the roof of the building, almost 1200 m² of solar panels have been installed, supplying 250 kWp per panel. All panels together generate enough energy for year-round operation of the heat pumps and ATES. In addition, there is a cooperation with the University of Amsterdam (UvA) and the ‘Hogeschool’ of Amsterdam (HvA). The buildings of both institutes have been equipped with 4100 m² of solar panels. The cooperation with the UvA and HvA is governed by regulations that state that sustainable energy generation within a 10 kilometer radius can add up for the EPC (Energy Performance Coefficient), a legally binding calculation method. According to property developer OVG, the combination of ATES + heat pumps + solar panels + district heating result in “a more or less self-sufficient system”. The innovative energy system saves approximately 50,000 kWh of electricity per year, compared to a traditional (fossil) energy system.

Still, a long list of other technical measures have been taken which contribute to an office building that is state of the art regarding sustainability. A technical innovation that has been used to reduce energy consumption is, for instance, the Philips Ethernet-powered LED-connected lighting system. In 2014, The Edge was the first building worldwide to be equipped with this system that offers employees the option to control the climate and light at their individual workplace by a smartphone app. This energy-saving innovation provides information about the way the office is used, so the efficiency of space and energy usage can be improved. Less extensive measures at the Edge have been the installation of a “gray water” circuit to flush toilets with rainwater, and the addition of an ecological area around the property, increasing the habitat of breeding birds and bats. The total sum of measures resulted in an EPC score that is 45 percent higher than required by building regulations, and an unprecedented Breeam score of over 98 percent. At completion in 2014, this was more than sufficient for the Edge to overthron the One Embankment Place in London – the worlds most sustainable office building until then.
Working together for added-value

Alkima is the exclusive importer of the heat pump concepts of Mitsubishi Electric for The Netherlands. Alkima is known for sharing knowledge and working together. In several construction projects this cooperation has lead to added value for all parties involved.