HPT-Annex 46
Domestic Hot Water Heat Pumps

Annex 46

Task 4 Research & Development

Country Report Netherlands

Edited by

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Technology Collabortation Programme on
Heat Pumping Technologies (HPT TCP)

iea Energy Technology Network

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The information and analysis contained within this document is developed to broadly inform on developments in the Netherlands. Whilst the information analysed was supplied by representatives from various companies and sources a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood. Therefore, information should only be used as guidance.

The market of domestic hot water heat pumps (DHWHP) is developing fast and at the moment of publication some information can already be overtaken by new developments. There are some websites listed at the reference pages of the report.

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Summary

The development of the heat pump market in Netherlands has shown a steady but slow growth in the past decade, where especially in the commercial building sector the technology has become state of the art in new as well as in the renovation market. The report Heat Pumps in Rotterdam shows large scale heat pumps in in commercial buildings, often Rotterdam landmarks. In the industrial sector new technologies have been developed and applied as is reported in the Dutch Heat Pumping Technologies Journal Vol 2.

In the domestic sector although a lot of innovations are reported here the deployment is much slower, but unavoidable as future energy system. The Dutch Heat Pumping Technologies Journal Vol 1 is reporting on a number of innovations and applications. The first development for this technology were for domestic hot water heat pumps in the eighties by Inventum as traditional manufacturer of electric storage water heaters dversifying its product range. After that first period the market became dominated by gas boiler technology and as late as 1997 the first developments of domestic heat pumping technologies were supported by a tender procedure. Which in the end was not very successful, but stll had triggered a first start. Slowly the first projects were realized with Swedish and German technologies, when companies like Techneco, Inventum and ITHO entered the market.

As these first main maufacturers are not Original Equipment Manufacturers there focus was strongly on applied development. Fundamental R&D was executed at institutes like ECN and TNO, where especially ECN concentrated on industrial technologies. Other institutes and Universities are Technical University of Delft and Eindhoven.

Funding for R&D came from Novem, the forerunner of RVO. From 2010 onwards funding comes from the TKI a special governmental program for innovation.

Contents

1. Introduction

In an international context, the Dutch government aims for a low-carbon energy supply that is safe, reliable and affordable and aims to reduce greenhouse gas emissions by 80-95% by 2050. According to European agreements, member states must ensure that by the end of 2020 all new buildings are almost energy-neutral. In addition, it has been agreed in the Energy Agreement that for existing buildings in 2030, at least average label A will be sought. In 2050, the built environment must be energy-neutral.

In Netherlands, heat pump research is conducted at the level of universities, research institutes and manufacturing companies. From the public sector, a total of EUR …. million was made available to finance research activities in the field of heat pumps and refrigeration systems in the period from 2009 to 2017. This corresponds to an average funding of about EUR … million per year.

In order to be able to make further statements with regard to the scientific / technical focus, areas of application and the type of research, selected research and development projects will be analyzed in more detail below. Starting point of a Dutch R&D Roadmap for heat pumps developed from this base material, will be the market needs in the development to an energy infra-structure with zero CO_2-emissions in 2050 and 'freed from natural gas' as soon as possible. The main Dutch heat pump manufacturers are not Original Equipment Manufacturers and get their components for manufacturing heat pumps from the world-wide market. Compressor technologies, valves and evaporators are not the core technologies of the Dutch manufacturers. Therewith, R&D in Netherlands will be mostly 'application development' focusing on the application boundaries of the existing and future markets and customer needs and preferences.

A huge market for innovations.

This was already proven in the past decade with the introduction of the hybrid and booster heat pump concepts and the development and mass scale of plug & play heat pump concepts fitting in the building structures.

The R&D program for the further development of heat pumping technologies is based upon the actual needs and fit to the. For the building sector, three main application or innovation areas can be identified, which have a different development and market deployment level:

- Heat pumps for residential and non-residential buildings
- Heat pumps in Smart Electric Grids
- Heat pumps in Thermal Networks

The roadmap is orientated in its thematic structure to these fields of application and is structured as follows. The HPT-Annex 46 Task 1 report for Netherlands gives details in its scenario's

2. Backgrounds

One of the most important insights in innovation sciences in recent decades is that innovation is a strong collective activity. Innovation takes place within the context of a complex innovation system. Specifically for technological innovation, research has shown that the innovation system is decisive for the success of the technology. Successful diffusion of heat pumps will only take place in an innovation system that stimulates the heat pump in both development and application. Parties that want to stimulate heat pumps as technology can achieve this by strengthening the heat pump innovation system.

The structure of an innovation system consists of five elements: Actors, Interactions, Institutions, Technology and Infrastructure.

Actors
Value chain: heat pump manufacturers, installers, wholesalers, construction companies, customers, etc. Indirectly: knowledge and training institutes, governments, branch organizations, financiers etc.
Interactions
Within the value chain (s), in research projects, at symposia, in joint pilot projects, during training courses or meetings of sector associations etc.
Institutions
Written rules: standards, minimum requirements in legislation and regulations, goals and strategies. Unwritten rules: culture in the sector or standards / values at customers.
Technology
Heat pumps exist in all shapes and sizes: stand alone or in combination with a high efficiency boiler, various external energy sources, large or small capacity etc.
Infrastructure
An infrastructure is needed that facilitates the release of financial resources and the training of sufficiently trained personnel. Knowledge must also be recorded somewhere (eg in databases), physical space in the home is needed and there must be sufficient production capacity.

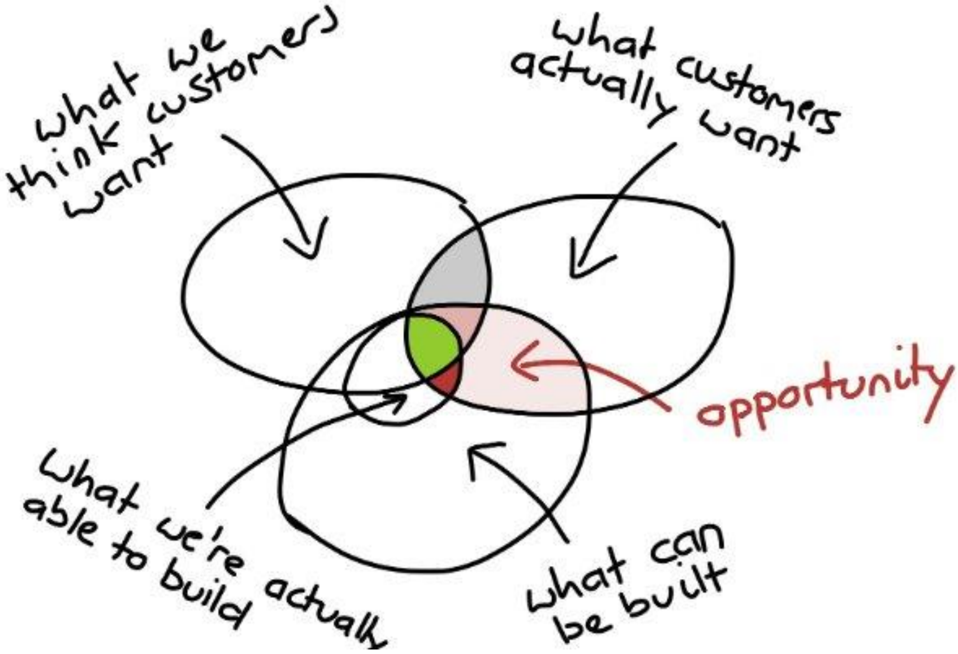
Netherlands, a land with the most extensively spread gas network second to none, is in combination with the lowest prices for gas boilers in Europe, a challenging environment for the out roll of renewables.

The gas network covers almost all areas in the Netherlands and 98% of all buildings is connected to it. Since the discovery of the natural gas reserves in the '60s, the gas network grew rapidly. Policy now focuses on a strategy of drastically decreasing the consumption of natural gas for heating and thus the dependency of the building sector on the gas grid. 'Away from Gas' has become an important almost main-theme of the latest energy policy.

New housing should be all-electric or connected to a heat network and existing houses must be renovated.

Heating networks are not common in the Netherlands. There are 13 large heating networks, which serve 230.000 customers. Excess heat from large electricity plants feeds most of these networks. The largest heating network is in Rotterdam and serves 44.000 customers. Besides, there are about 7.000 small-scale grids, which serve in total 336.000 customers. The costs for heating by a heating network are legally not allowed to exceed the costs for heating by gas.

Electrification is the next step where a major role in the Dutch Energy Agreement is foreseen for wind power, off- and onshore, but also solar PV. Heat pumps are in this context strongly recognised to have a huge potential as an instrument to increase the amount of renewable energy in the building stock. The out roll of heat pumps and e-mobility alone are already justification enough to deploy firm smart grid initiatives. Heat pumps and e-mobility in combination with electricity from intermittent production like wind and solar-PV, makes smart grid technology/applications an unavoidable necessity. Governmental policy, and foremost consistency in policy keeping are considered to be stronger drivers for the increase of use of renewables, besides the financial context.


what we think customers want
what customers actually want
opportunity
what we're actually able to build
what can be built

3. R&D in Netherlands

R&D in Netherlands is done at several levels partly publicly funded and partly in-company funded by manufacturing companies.

Public funding in the past came from technology programs run by RVO (then Novem) and nowadays these programs are under the 'Topsector Energie'-program. For domestic applications the TKI-Urban Energy program is the leading program (see Addendum 1 and 3). For Industrial applications it is the TKI-ISPT program. Projects in this support program are often Fundamentals being researched by private companies with the support of technical institutes. In company developments are of application developments directly focusing on the application challenges in the market. It concerns less fundamental development as the largest part of heat pump suppliers/manufacturers in Netherlands are not OEM's. Compressor technologies, valves and evaporators are not the core technologies of the Dutch manufacturers.

Financing of R & D activities is thus largely based upon own funds or current revenues, with three companies using more than 6% of their turnover for R & D activities. Six companies each spend 4 to 6% or 2 to 4% of their turnover on financing their R & D spending. Of the public funding programs, the most commonly used is the FFG basic program, which provides comparatively low non-repayable grants; followed by European funding programs and state subsidies.

3.1 Support from Governmental programs

Since the start of TKI-EnerGo and later TKI-Urban Energy a large number of projects have been supported. Among those projects on Heat Pumps or directly related to Heat Pumps (see for an overview Addendum 2).

TKI Urban Energy was founded in 2015 as a merger of TKI's Solar Energy, EnerGO and Switch2SmartGrids. The three TKIs, from which TKI Urban Energy originated, have each implemented their own program from 2012 to 2014 inclusive. In 2015, the cooperation between these three TKIs led to joint programming and the establishment of TKI Urban Energy.

The TKI Urban Energy program consists of five program lines:

1. Solar power technology (PV);
2. Heat and cold installations;
3. Multifunctional components;
4. Flexible energy infrastructure;
5. Energy control systems and services.

Projects that contribute to the program lines are the result of the schemes of TKI Urban Energy and its predecessors, the TKI supplement scheme, IPIN (Innovation program Intelligent Nets), ERA-Net schemes, the DEI scheme (demonstration energy innovation), the HER (renewable energy regulation) and the MIT scheme (SME innovation stimulation Region and Top sectors).

The 2018 program has the same structure and main division in program lines as in 2017, but there are some accent shifts arising from the Transition paths. Non-technological aspects, storage and conversion and standardization (open standards) will get more attention in 2018. TKI Urban Energy also wants more space for long-term programs for a number of subjects that will have a major impact on the energy transition as a whole.

Within the program lines the shifts in emphasis are:

- More explicit attention for embodied energy and circularity;
- Explicit attention to domestic hot water;
- Explicit attention to digitization and industrialization in building processes;
- Strengthening geothermal energy, not just 'shallow' geothermal energy;
- System integration at the decentralized level;

The energy transition in the Netherlands requires a large acceleration compared to current developments. TKI Urban Energy sees three major risks challenges:

- too little effort on a number of issues that can only be solved with partly fundamentally new technology;
- timely scaling up innovations in time;
- the lack of open standards to physically connect the multitude of new technologies to 'communicate' with each other, i.e. smart solutions;

In order to overcome the first-mentioned risk, extensive multi-annual programs are required. For faster scaling up, a rewarding perspective is needed, for example by demonstrating that innovations work in large demonstration projects. Industrializing renovations in construction will also contribute to mitigating this risk.

Guidance is also required, for example through clear price mechanisms and preconditions (CO2 targets, subsidies for unprofitable top, energy label for buildings and appliances, etc.) and a framework for considering local energy infrastructure. The development of an ICT reference architecture is a means to limit the third mentioned risk.

The development of components and appliances that provide domestic hot water and a good indoor climate (air quality, temperature) and are attractive (convenience, use of space, aesthetics, sound, both inside and outside). These are ultimately suitable for energetic renovation concepts for low-temperature heating and associated heat demand limitation, for less than €45.000 for terraced houses. There are similar ambitions for other building types. The goal is that by 2050 all neighbourhoods in the Netherlands will be energy-neutral.

The energy modalities "heat" and "electricity" are better connected in the new system: Heat storage in combination with electrically driven heat systems (heat pumps) offers flexibility for variable sustainable energy supply in the electricity system (power2heat in heat battery) and thus enables further growth of renewable energy.

Three new types of heat pumps are under development from basic material research to component and system "looks like real", including roof system and business cases. For compact storage material research is needed for real breakthroughs. In parallel, reactors have been developed with, among other things, innovation in valves. In addition to heat storage in PCM and TCM, the program has resulted in a new storage route of (solar) electricity in heat via redox reactions, even more compact than TCM and cheaper than electrical batteries. Roadmaps have been drawn up for both storage and heat pumps.

Ventilation projects have developed knowledge and practical solutions for quality measurements of ventilation installations and for specific emissions in the cooking environment and shower. Air source heat pumps will make an important contribution to the energy transition. The development of these requires attention on two points to reduce risks for acceptance, being noise production of installations with these pumps. The second are the current standards for legionella prevention and some refrigerants that may be more stringent than necessary. More focused rules for safe application can pave the way for significant yield improvements.

Program 2a: Heat Pumps and Heat Distribution The development of small, quiet, highly efficient, affordable components and systems suitable for heat and cold supply in existing buildings (residential and non-residential building). These include innovations in materials, miniaturization, noise reduction, aesthetic fit, and other refrigerants for heat pumps; low temperature distribution systems for renovation; saving and sustainable production of hot water. Significant cost reduction is possible in the production of heat pumps, comparable to the costs of high efficiency boilers at comparable numbers. This requires a combined approach to demand development and change in production.

Program 2d: Heat and Cold Storage technologies. Development of compact thermal storage, significantly more compact than water (ultimately about factor 5 more compact), which can help to link and flexible fluctuating heat supply (collectors, heat network) and demand. In combination with electric heat pumps, thermal storage can also offer flexibility to the electricity system. In addition to the development of low-cycle solar thermal storage (80°C), this also concerns storage systems that can be charged on shorter time scales (a few weeks or even 24-hour basis) with lower-value heat, for example from heat pumps (around 45°C). Both specifications are particularly challenging and require research into their practical feasibility. These are compact storage installations.

Program 2e: Integration of components and system efficiency. Development of combined and integrated devices in which compact storage, heat emission, and compact heat pump and / or solar heating system and / or ventilation are combined. Components (especially if it concerns components from different suppliers) connect optimally. Points of attention are standardization of connections, modular, compact, performance guarantee and certification. This involves the development of combined and integrated devices. Smart grid compatibility for the provision of flexibility is particularly important for heat pumps and storage (heat battery). Control systems for this are part of program line 5.

3.2 Dutch heat pump manufacturers and suppliers

The Dutch heat pump manufacturers are among the most innovative in the European market and have many years of experience in developing the technology for various applications. Triggered by the stiff competition of cheap gas boilers and focusing on the mass market of middle priced privately owned houses as well as the enormous renovation market in the segment of rented houses and apartments. This competition and the weak electric infrastructure lead to the development of the Hybrid Heat Pump for renovation. The challenge of multifamily buildings triggered the development of Booster Heat Pumps for Domestic Hot Water. But also the lack of space in the average domestic house has led to smaller sized systems.

A particular strength of the Dutch heat pump industry lies in the production of heat pumps for the capacity range smaller than 10 kW's, even down to 3,5kW's. On the other side of the spectrum for commercial buildings and industries manufacturers build and supply systems up to 6MW's. Of particular relevance are air/water systems, which, in contrast to most other heat source systems, have been posting strong sales increases since 2014. Dutch heat pump manufacturers have recognized this trend in good time and invested accordingly in this technology.

The supply of heat pumps for domestic application is from a various number of suppliers of which a number consists of manufacturers and a number of importers. For this Annex the most relevant suppliers seem to be the Dutch manufacturers, however some interesting concepts appear from a number of suppliers, even challenging their home company to develop special products for the Dutch market.

The Dutch manufacturers focusing on smaller domestic applications are:

- ATAG, as part of the Ariston Thermo Group, is starting to distribute heat pumps by mid-2018. The main speciality is being a manufacturer of gas boilers and solar thermal installations
- Inventum, originally a manufacturer of storage water heaters, supplies a number of heat pump ranges for space heating and domestic hot water. The Ecolution ventilation heat pump is one of the innovations. Inventum supplies storage tanks and heat pumps also for other suppliers. Next to heat pumps Inventum supplies a large range of electric storage water heaters[1].

[1] The author of this report has been working for Inventum for eight years at the development of water heaters.

- ITHO-Daalderop, originally a manufacturer of storage water heaters, supplies a number of heat pump ranges for space heating and domestic hot water. The air to water heat pump can be installed as mono or hybrid with storage water heater, whereas ITHO-Daalderop has been one of the first to have fully integrated hybrid heat pump based upon ventilation air. Furthermore their concepts for Energy Zero are installed in a number of projects like Rijswijk Buiten. This latter project based upon their WPU4 double function heat pump, also supplying cooling in summertime. Developed by the company of ECOON the booster heat pump was introduced by ITHO-Daalderop. The company is one of the main suppliers of the 2nd Skin project focusing on plug & play concept for the renovation of existing domestic buildings.
- Nefit, as part of the Bosch group, manufactures gas boilers and combine these with heat pump technologies from the Bosh group. Both ventilation (VentiLine), air source and ground source heat pumps are sold, potentially in combination with solar thermal and/or pv.
- NRGTeq is Dutch manufacturer of a large range of heat pumps. A special High Temperature range has been developed for renovation projects in Multi Family Buildings. Their TNG series ranges from 4 – 250kWs and has DHW tanks added to the concept. The company has a licensee in USA.
- Remeha, as part of the De Dietrich group, manufactures mainly gas boilers to combine these with technological know-how from De Dietrich. The main heat pump products are the hybrid Tzerra combined with a gas boiler and storage tanks ranging from 50 – 350 litres.
- Techneco, manufactures a wide range of heat pumps for the domestic market, having ELGA as the first Hybrid Heat Pump on the market and TOROS as a plug & Play Concept. For the hybrid ELGA heat pump an air source unit from Toshiba is used. The larger systems are Aquatop with capacities up to 45kW. Techneco is also representing as a supplier ROBUR in the Dutch market. As manufacturer and supplier of heat pumps, in addition to supplying the heat pump, Techneco can also supply the integral system with a closed loop ground source and low temperature floor heating system in the house.

A number of Dutch suppliers for large heat pump manufacturers develop their own market approach with technologies based upon the heat pumps from their mother company. To enter these markets a competitive advantage is in developing a number of plug & play concepts.

- Alklima, as supplier of a broad range Mitsubishi technology developed a successful approach for the NZEB market developing plug and play concepts for new buildings and renovation of multifamily buildings. One of these is the WATTZ approach where Alklima offers renovation concepts. Together with Zehnder and ABB another plug&play concept is marketed. For renovation Alklima works together with large construction companies like Dura Vermeer in pilots.
- Daikin, together with the European Development Centre in Ostend in Belgium have developed the Daikin Altherma LT Integrated Solar Unit, to be installed in NZEB in Europe and first to be demonstrated as example project under Annex 46. This unit is based upon the smart domestic hot water storage unit. Together with Dutch Intergas gas boiler manufacturer Daikin is market the integrated hybrid heat pump unit, sold in Germany by Rotex.
- Dutch Heat Pump Solutions have based upon Panasonic technology developed the Hydrotop and the Hydrowall as a plug and play concepts for existing and new domestic buildings. A special integrated unit has been developed combining heat pump technologies with solar energy.
- Nathan as supplier of Alfa Innotec is primarily active as system integrator in the building sector, supplying a number of heat pumps, designing and drilling ground sources. A booster heat pump designed by Nathan appeared on the market and is monitored in a pilot project in Sophiastaete. Furthermore Nathan developed an Energiemodule as a plug & play concept and applied the concept of an NZEB building for a related company in the NATHAN Group.
- Valliant Group together with AWB, has developed for the Dutch market a small hybrid heat pump preferably combined with the UNISTOR storage tank for DHW. Special combinations are applied in NZEB projects and examples like in Amersfoort can be found on the website.

Next to manufacturers and suppliers for smaller domestic application there are manufacturers and suppliers for larger collective systems and commercial buildings:

- Carrier with their Dutch support unit and French development is one of the important players in the Dutch market mainly active in larger projects in commercial buildings and agriculture.
- Coolmark is supplying the high temperature Q-ton heat pump developed by Mitsubishi Heavy Industries
- ETP, is a company mainly active in the market for commercial buildings supplying heat pump project up to 10Mws as turn-key projects based upon standardized procedures. Their care is including ground sources, monitoring, reporting and maintenance. Together with a large energy company a new product for domestic hot water is tested in a pilot project.
- Grenco is part of the German GEA company, producing as OEM screw compressors. GEA-Grenco mainly supply their heat pumps for industrial applications.
- Linthorst Techniek, manufactures large capacity high temperature heat pump TT68 with an interesting application at a multifamily building in Leiden. The heat pump was developed under the R&D program TKI-Urban Energy.
- Reduses, manufactures as part of the Installect Group, gas engine driven heat pumps ranging from 100 – 500 kW. These heat pumps supply high temperatures and are fit for renovation in multifamily buildings and for medical applications.
- Triple Aqua is a manufacturer of a heat pump developed in Netherlands using propane as refrigerant. This development has already won numerous awards such as the Eneco Dutch Innovation Award at the 12th IEA Heat Pump Conference. Typically Triple Aqua heat pumps are applied in commercial buildings. The heat pumps are marketed by suppliers like Beijer and Coolmark
- OSH is a system integrator supplying and installing plug & play concepts for commercial as well as collective domestic buildings based upon heat pumps by Waterkotte. OSH claim to install these systems in one day and guarantee the performance on the longer term. An interesting example is the system installed at Clarissenhof in the city of Tilburg, which is one of the example projects under this Annex. For individual single family buildings the One@home plug & play concept is developed.

In the R&D program for TKI Urban Energy a number of new names appear.

3.3 Original Equipment Manufacturers

The majority of the Dutch manufacturers are no Original Equipment Manufacturer (OEM). Compressors, expansion valves, evaporators are almost all manufactured outside of the Netherlands. Thus the development within the manufacturing companies almost always focuses on the strengths of the company. Companies like Inventum and ITHO-Daalderop typically have always been manufacturers of storage water heaters, while Nefit, Remeha and Intergas are experienced in Gas-technologies and Grenco is a manufacturer of refrigeration equipment and screw compressors. The others are relatively 'new' as manufacturers, combining in a smart and innovative way technologies with expert knowledge of the market.

- Inventum, originally a manufacturer of storage water heaters, supplies a number of heat pump ranges for space heating and domestic hot water. The Ecolution ventilation heat pump is one of the innovations. Inventum supplies storage tanks and heat pumps also for other suppliers. Next to heat pumps Inventum supplies a large range of electric storage water heaters.

- ITHO-Daalderop, originally a manufacturer of storage water heaters, supplies a number of heat pump ranges for space heating and domestic hot water. The air to water heat pump can be installed as mono or hybrid with storage water heater, whereas ITHO-Daalderop has been one of the first to have fully integrated hybrid heat pump based upon ventilation air. Furthermore their concepts for Energy Zero are installed in a number of projects like Rijswijk Buiten. This latter project based upon their WPU4 double function heat pump, also supplying cooling in summertime. Developed by the company of ECOON the booster heat pump was introduced by ITHO-Daalderop. The company is one of the main suppliers of the 2nd Skin project focusing on plug & play concept for the renovation of existing domestic buildings.

- Grenco is part of the German GEA company, producing as OEM screw compressors. GEA-Grenco mainly supply their heat pumps for industrial applications.

Innovation is a major topic in the industry.

The survey of companies according to their strengths also shows that motivated employees who have been working in the company for years, as well as a high level of customer satisfaction, are the central strengths of the national industry. Another strength is the positive corporate development. Nearly half of the companies have seen steadily rising sales over the last three years; to a further 36%, this development is largely true. These figures are consistent with the steadily rising sales figures in the Dutch heat pump market.

4. Research Priorities

The TKI-Urban Energy has highlighted a number of topics in the definition of a Road Map for heat pumping technologies:

- EU regulations F-gases: heat pumps with other (natural) refrigerants; purpose: heat pumps that comply with these EU regulations;
- Decentralized use of heat pumps: noise reduction; goal: first 25 dB (A) and finally 22 dB (A) in the bedroom, and to first 30 dB (A) and finally 25 dB (A) in other rooms;
- Use in existing construction: miniaturization of components as heat exchanger and total system size; the aim is to achieve a halving of the volume for the devices to be used, compared to the current state-of-the-art;
- Better use of (residual) heat; purpose: sorption cooling with lower T hot water by desorption; increase efficiency at high outside temperatures and in price competitive with normal air conditioning.
- Low temperature heat emission systems without affecting comfort due to cold radiation.
- New principles / new applications existing techniques that are more efficient, quieter, cleaner, more compact and / or cheaper: thermoacoustic technology, sorption cooling; heat exchanger with nanofluids, magnetocaloric heat pump.
- Better price / performance ratio of the heat pumps (at installed level); target [€ 500-700] / kW.

The development of small, quiet, highly efficient, affordable components and systems suitable for heat and cold supply in existing buildings (residential and non-residential building). These include innovations in materials, miniaturization, noise reduction, aesthetic fit ability, and other refrigerants for heat pumps; low temperature distribution systems for renovation; saving and sustainable production of hot water.

Significant cost reduction is possible in the production of heat pumps, comparable to the costs of high efficiency boilers at comparable numbers. This requires a combined approach to demand development and change in production.

The current R & D priorities of the companies participating in the survey are in particular the following topics:

- Increasing the efficiency of the refrigeration cycle;
- Coupling of electricity and heat - Smart Grid Ready;
- Combination with photovoltaic self-consumption optimization;
- System integration in the living area;
- Increasing efficiency of partial load behavior;
- Reduction of production costs;
- Improvement of manufacturing processes.

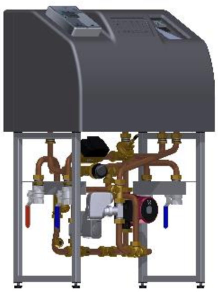
A comparison with the research topics of the publicly funded projects shows the high research relevance of the topic "Increasing the efficiency of the refrigeration cycle". Of a certain urgency is also a "more efficient system integration in the living area." Differences in R & D priorities are particularly evident in the research topics relating to optimization of heat pump components, such as heat pumps. Make out compressor, evaporator, etc.

4.1 Innovative products on the market

As already mentioned in the past decade a number of innovative products have been developed by the Dutch manufacturers, being:

- **Hybrid Heat Pump** Technology, which started with a first idea in 1999 and developed in a R&D project funded by RVO. The basis of the idea was that the Dutch domestic buildings are mainly heated by gas boilers and that the electricity grid is/was too weak to support a mass introduction of an all-electric solution with heat pumps. A hybrid heat pump is a bi-valent system where the an air source heat pump delivers space heating and the gas boiler takes over when the outside temperature is too low to efficiently heat with the heat pump. In almost all cases hot water is generated by the gas boiler, so this is a solution without a storage tank. The first hybrid heat pump was introduced by Techneco in 2007. A special Hybrid Heat Pump Association was founded to accelerate the market introduction, as a number of manufaturers soon followed. The Association focused on getting the concept and technology accepted at European level with calcualtion models and test procedures.

Fig.4.1 – Hybrid heat pump conversion box



- **Booster Heat Pump** Technology, started with ideas on how to reduce the transport losses in heat distribution systems. The development was taken up in a project in the Nijmegen area where manufacturers were invited to find a solution for domestic hot water in a low temperature, so called 4th generation, district heating system. The a very low capacity water/water-heat pump, which is able to use heat sources of 25 to 40 °C at the evaporator side for the DHW-production, which is stored in a storage tank with a capacity of 100 – 150 litres. The small capacity of the micro heat pump avoids the use of 'heavy duty' electrical networks. An interesting example project is in a multifamily building in Sophia Staete in Netherlands, showing that this solution is not only for district heating systems.

  Fig.4.2 – Booster Heat Pump

  Simultaneously these products have been developed in Denmark, because of the focus in the 4th Generation of District Heating and are in focus for HPT-Annex 47 on Heat Pumps in District Heating. A larger number of manufacturers is getting into the market after the first product was introduced by ECOON.
- **Double function** heat pump for space heating and domestic hot water, is becoming the standard solution for newly built houses and for renovation. This concept was introduced by the end of the nineties for new housing project. Front runners in Netherlands have been Techneco and ITHO-Daalderop.
- **Combination with Solar Thermal**, under the TKI program Techneco has developed a combination that is also suitable for a combination with solar thermal energy (solar collectors). The smart scheme determines whether the available energy for tap water, heating or regeneration of the source is used. This depends on availability of energy, temperatures and demand. In the summer, for example, it is more easy to make domestic hot water with solar than in winter. Then the heat pump is used. By also using solar collectors for the heating and regeneration of the source, the normally lost energy can be used in colder days. The Techneco project focused on compact solar thermal heat pump systems, comprising compact stores (around 200 liter) and moderate collector areas (5-15 m2), typically systems in which a solar system assists the heat pump system. This investigation is complementary to work done on an international level i.e. IEA SHC Task 44 HPP Annex 38 [3], where projects tend to focus on relatively large systems with >1 m3 storage tank and > 15 m2 solar collector area.

  A special calculation model has been developed with support of RVO, which was presented at the 12th IEA heat Pump Conference in Rotterdam by Jacob van Berkel: 'Solar Heat Pump Standard Assessment Model'.

This model is now taken up in the Dutch legislation for calculating the Energy Performance of buildings (EPC). Already a number of other systems, than that from Techneco have been tested accordingly

- **High temperature** heat pump, is especially of interest to renovation in collective distribution systems and on smaller scale for individual domestic applications. Under the TKI program Linthorst Techniek, has developed a fully electrical high temperature heat pump and control and control technology with high efficiency (cop 4.5 to 8) for the generation of domestic hot water (65ºC) in individual and collective systems and for the simultaneous generation of tap water (65ºC). An interesting application can be found in multifamily building in Leiden.

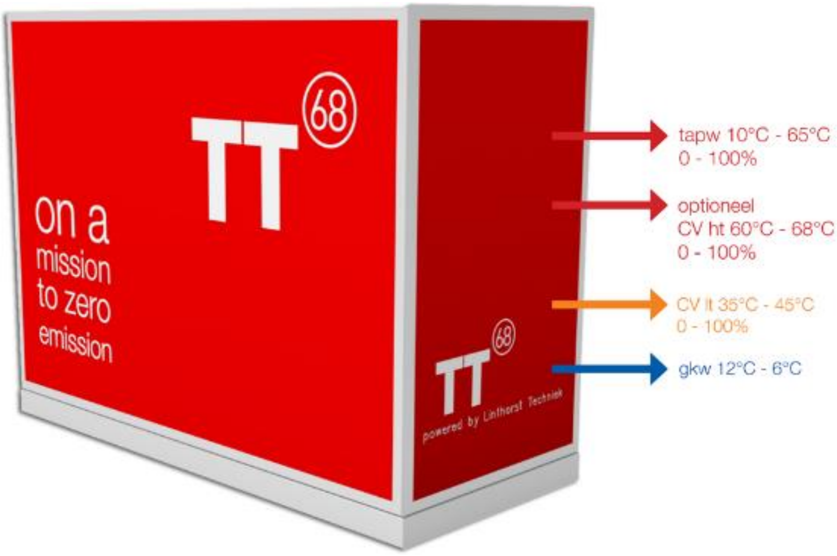


Fig.4.3 – Linthorst High Temperature Heat Pump

But there are other suppliers in this market active as this is an interesting market. A recent study by BEIS in the UK showed the market for this technology. In this study high temperature heat pumps are considered to be products capable of producing an output temperature of at least 65ºC. There are a number of heat pump designs capable of achieving high temperature outputs, including:

- Products with optimised design for specific refrigerants.
- Cascade systems with two separate refrigeration cycles.
- Enhanced Vapour Injection (EVI).
- Use of natural refrigerants and sorption products.

Whilst these products have been specifically designed for high temperature operation, the designs of “conventional” heat pumps are increasingly being improved to reach 60-65ºC at reasonable efficiency.

4.3 End-user focused technologies

End users in Netherlands are in general not so much interested in the ‘in-house’ technology, as they are used to a standard solution with a high efficiency gas boiler tucked away at the top of their house, or in case of collective systems are used to no installation at all in their apartment. A solution with a storage water heater and a heat pump water heater takes too much space in their house. A gas boiler does not have storage tank and with a capacity of approximately 30 Kw’s delivers instantaneous and comfortable hot water for their showers. A few decades ago it was quite normal having an electric storage water heater which was rented from the energy company and heated on the low tariff night electricity!

The larger systems seem to be no problem for newly built houses with the added value of a low energy bill (or no energy bill).

Small miniaturization of components and heating systems is the need to attract end users to invest in these systems for renovation. Most manufacturers in Netherlands have been working on this with some remarkable products, like wall hung heat pumps which can be installed at the same place as the gas boiler. This especially the case with the hybrid heat pump technology where there is no direct need for a storage water heater. In an all-electric solution this becomes more difficult. Solutions like in Switzerland are not yet on the market in Netherlands. For example, the company Swissframe AG[2] produces modular, fully equipped front-wall

[2] www.swissframe.ch

installations for bathrooms. The front-wall installations consist of a waste heat recovery system for air ventilation. (Büchel et al. 2016) extended the front-wall installation with a decentralized boiler with a high-tech isolation, a small heat pump and an intelligent control.

4.4 Installer focused technologies

An important question is how to capture the market opportunities. A large market potential depends on relationships of manufacturers with building developers. In Netherlands for newly built houses the focus is on realizing the Energy Zero goals at a cost effective way. The project supported by TKI Urban Energy is on the 'Building Integrated Energy for Prefab Production', but a large number of other initiatives are emerging in the market. These are listed already on page 11 of this report.

Fig. 4.4 Hydrotop roof top integrated solution

Companies like Dutch Heat Pump Solutions have based upon Panasonic technology developed the Hydrotop and the Hydrowall as a plug and play concepts for existing and new domestic buildings. A special integrated unit has been developed combining heat pump technologies with solar energy. The Hydrotop is a special plug & play solution as well for renovation as for newly built houses. The complete installation is built pre-fab at the factory, avoiding potential installation failures with 'new technologies'.

Alklima using technology manufactured by Mitsubishi-UK developed a number of plug & play concepts. At the first Annex 46 Working Meeting the Soesterberg project of Energy Costs zero houses has been visited.

The further developments focused on the WATTZ approach where Alklima offers renovation concepts. Together with Zehnder and ABB the plug&play concept is marketed.

Fig.4.5 Integrated outdoor solution by NATHAN

4.4 Refrigerants

As there are no real OEM's in Netherlands all manufacturers strictly follow the EU regulations for refrigerants to comply with these EU regulations.

The most common refrigerants used in heat pumps today are R410A, R134a and R407C. Until recently the maximum output temperature for domestic heat pumps using these refrigerants was about 55°C with R134a achieving slightly higher temperatures, however now temperatures above 60°C can be achieved. By using slightly different temperature and pressure characteristics the refrigerant can be flashed off at a higher temperature, increasing the output temperature, although this can reduce the overall thermal output. The maximum temperature is determined by the critical temperature of the refrigerant (the value above which it cannot form a liquid). As this temperature is approached in the condenser the performance of the vapour compression cycle deteriorates and the refrigerant can start to breakdown chemically.

Modifications to the refrigerant cycle such as EVI or cascading refrigerant cycles can be used to increase the output temperature further up to 80°C with these refrigerants. Carbon dioxide, propane and ammonia are natural refrigerants which have higher critical temperatures and can also be used to reach higher output temperatures up to 80°C. Alternatively, a sorption rather than a vapour compression cycle can be used.

Natural refrigerants are not currently in use in domestic heat pumps in the UK. Ammonia is toxic, however is used in sorption heat pumps within sealed systems, which are located outdoors. Propane is only suitable for small heat pumps which have to be sited outside because of the refrigerant's high flammability. Propane based products are available in Europe.

CO2 is in use in Netherlands in larger air to water heat pumps for sanitary water heating in commercial premises, and is being considered for domestic heat pumps by some manufacturers. Manufacturers like Mitsubishi have some of these projects in the Dutch market.

A cascade system consists of two single-stage cycles (a low temperature and a high temperature cycle using different refrigerants) which are thermally connected by an intermediate heat exchanger. The low temperature cycle uses the refrigerant R-410a which is able to evaporate at a very low air temperature and condenses in the intermediate heat exchanger at a relatively low pressure and a temperature of about 45°C. This process transfers heat to the evaporator of the high temperature cycle which induces the evaporation of the second refrigerant R-134a. This refrigerant is then able to condense at a pressure that is not too high to affect performance. Cascade systems are capable of reaching temperatures of up to 80°C. Some systems are able to fluctuate between using both cycles together, and using just a single-stage cycle to optimise performance. As developing such a cascade system demands a special development of compressor technology these systems are only on the Dutch market manufactured by companies like Samsung.

4.5 Water saving technologies

While efforts to reduce water consumption have gained momentum in recent years, there are a number of key barriers that have limited the effectiveness of such efforts. Chief among these is the fact that many consumers have limited awareness of their water consumption patterns due to poor data availability, and/or are unmotivated to reduce their consumption due to low costs and split incentives.

Two general categories for practices designed to increase water efficiency:

- Behavioural practices refer to changing users' habits irrespective of the technology being used.
- Technologies designed to passively reduce water irrespective of the user's behaviour, such as: water saving shower heads, low-flow toilets, etc.

This binary focus overlooks the conceptual area where technology and behaviour influence each other—an area that has seen much less attention, and is ripe for development.

Simple items informing the end user on their behaviour are available. Like a simple hour glass as Douche Coach or the more sophisticated Efergy.

Fig.4. 6 Efergy water usage coach

Studies show that real-time consumption feedback influences hot water use. For example, the Swiss start-up company Amphiro AG[3] developed a real-time feedback device amphiro a1/b1, an intelligent consumption indicator for the shower (Tiefenbeck et al. 2016). Amphiro measures the flow rate and water temperature and calculates the amount of water and energy used per showering. The water and energy consumption is directly displayed during showering and thus promotes a conscious handling of hot water. As the device automatically turns on whenever water flows, it does not require user action to start the measurement process. Test results show that real-time feedback on shower water use leads to very large saving effects. Participants saved on average between 19% and 21% of their energy consumption in the shower. The payback time of the device is less than 10 months. These special appliances for domestic hot water are available on the Dutch market, while software and monitoring systems for the overall energy use are becoming popular. A large number of manufacturers sell these as well as energy companies. As the data are available on the personal smart phone through a special app it creates a higher awareness for the end user and changes the behaviour more and more.

Technologies on the other hand are getting available starting with the popular water saving shower head.

The Shower heat recovery was introduced by the heat pump manufacturer ITHO-Daalderop. The principle is fairly simple: during the shower the used shower water is fed the incoming cold water pipe for the longest time, this preheats the cold water, so the heat pump has to supply and use less energy. The cold water pre-heated by the heat recovery can be sent to the storage tank for after-heating by the heat pump, but can also be offered directly on the cold water pipe of the thermostatic shower mixer. The thermostatic valve will then have to allow less water from the boiler to come to the correct mixing temperature of, for example, 38°C for showering.

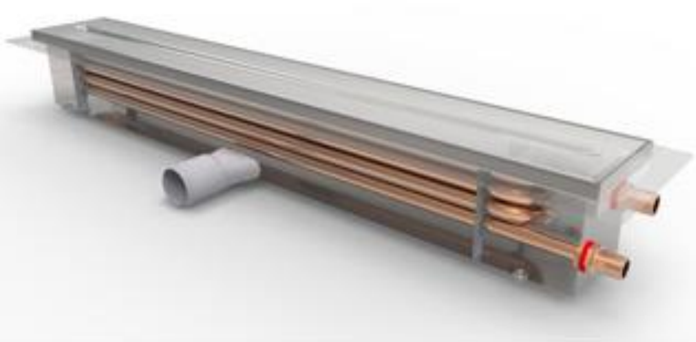
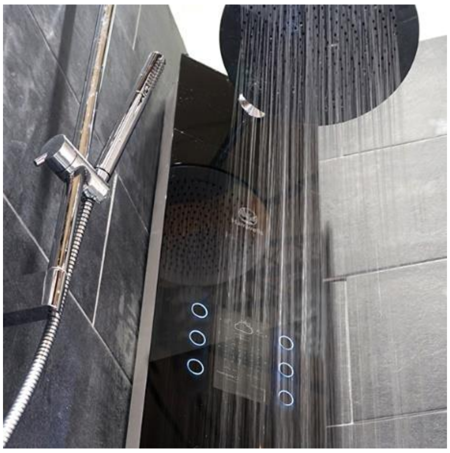


Fig. 9 – Shower Heat Recovery

Hamwells E-shower

[3] www.amphiro.com



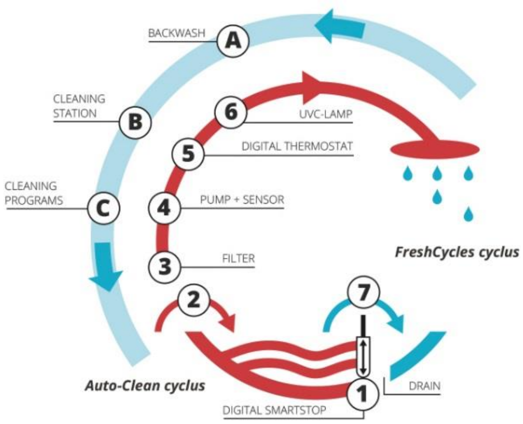
A more advanced system is introduced by Hamwells Europe B.V. with the 'E-shower' which is a shower that recirculated and cleans the used water during showering.

With a classic shower, 10 minutes of showering takes about 70 to 90 litres of water. The water used during showering corresponds approximately to 30% of the total water use. The rain shower grows in popularity as comfort shower in modern bathrooms, but a rain shower uses 15 to 30 litres per minute! By recirculation more than 85% less water and thus 70% less energy is used. Each drop is recycled 9 times via a unique system that cleans water based on UV light.

https://www.youtube.com/watch?v=cOD-9iwbiG8

https://www.youtube.com/watch?v=F5FGbj5m-oU

By adding hot water, the reservoir is completely refreshed every minute. The membrane filter and the UV filter clean the water with each cycle. Thanks to the unidirectional system, stagnant water can never enter the pipes. In addition, the pipes are treated with an anti-adhesive agent.



FreshCycles Cyclus

- Safe start. The SmartStop drops automatically and separates the mini-reservoir from the drainage. This starts a safe, clean cycle.
- Warm water flows into the reservoir and keeps the temperature constant.
- The smart Micro-Filter blocks hair and dirt. Digital dirt detection automatically stops the cycle and activates an alert for cleaning.
- The pump with its in-flow sensor gives its own high water pressure. An in-flow temperature sensor gives feedback to the thermostat.
- The digital thermostat with its Hot Water injection maintains an exact temperature. LED coloured feedback (red/blue).
- The UVC-lamp continually purifies the water. The digital sensor activates a warning in the event of a malfunction.
- Continuous fresh water. Used water continually flows over the SmartStop to the drain. After 10 seconds of contact, the water is fresh.

Auto-Clean Cyclus

- Backwash. After this, the SmartStop lifts up and the system drains quickly. The filter is rinsed clean and conducts dirt to the drain.
- The cleaning station contains cleaning vinegar and activates an alert when this needs topping up every two or three months.
- Three smart digital clean programs keep the whole system continually fresh and clean from biofilm, shampoo and lime scale.

5 Innovative products under development

A number of development projects has been supported under the TKI-program since 2010. The heat pump related projects are described here.

5.1 Compact Thermo Acoustic Heat Pump for the Built Environment (CTWB)

The project on the Thermo Acoustic Heat Pump is a spin-off from the project run by ECN on industrial heat pumps.

Project goal is to develop a prototype compact TAWP for decentralized heating and cooling of buildings with a COP of 3.5 to 4.0 (air / water) and a thermal capacity of 1kW. This contributes to compact, inexpensive and efficient developments in the field of heat pump technology in the built environment.

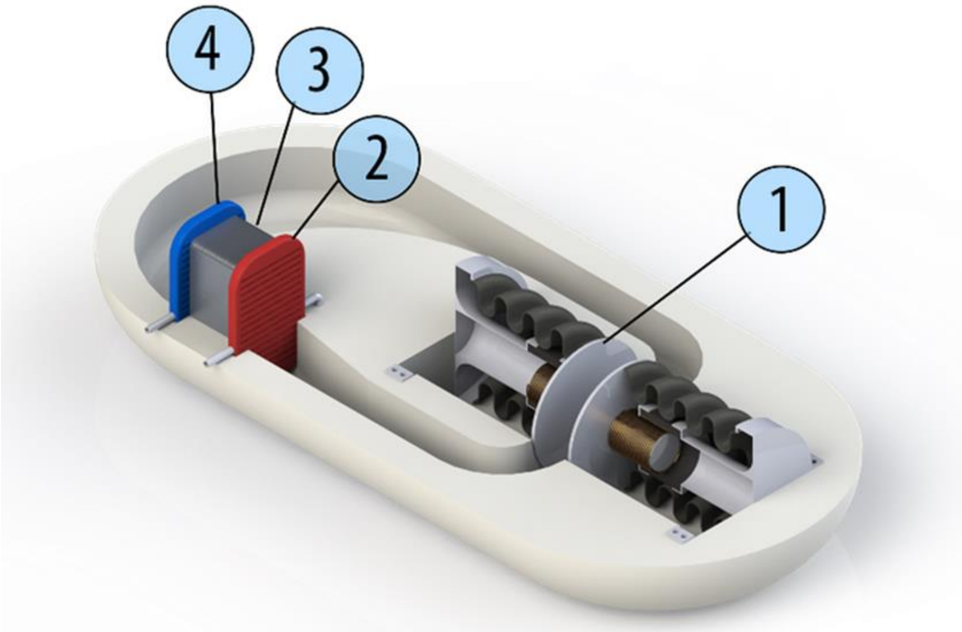
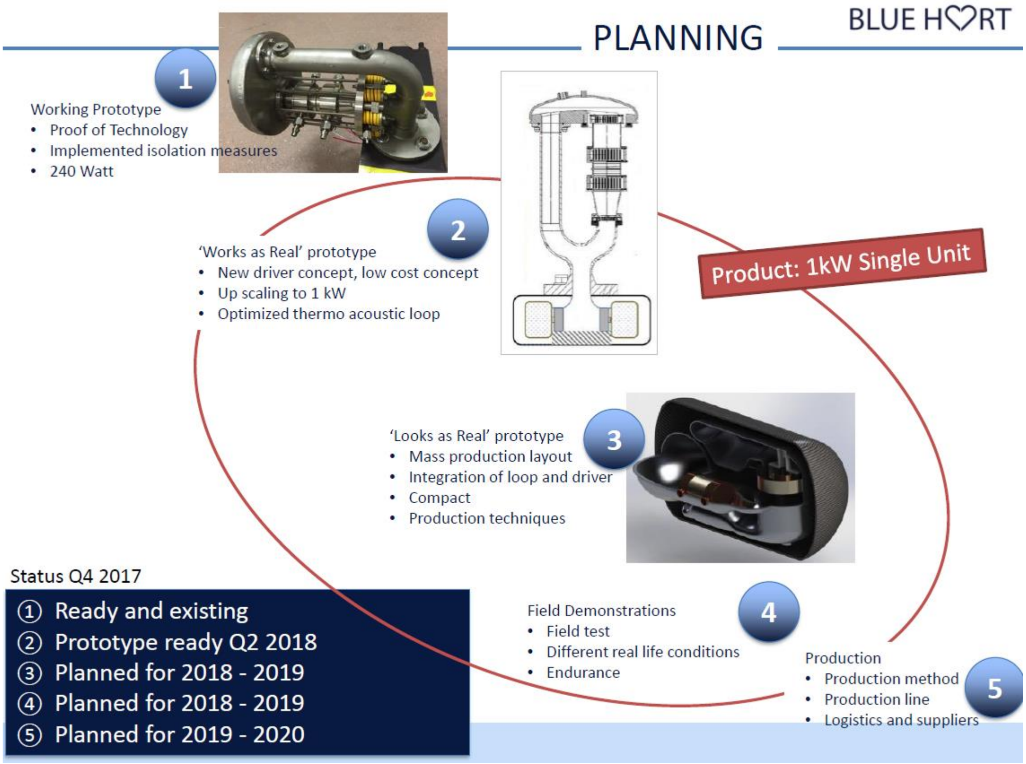


Fig.5.1 Blue Heart Compact Thermo Acoustic Heat Pump

Blue Heart heat pumps are closed systems that are filled with Helium under pressure.

1. Electrical driven drivers send an acoustic wave through the pump.
2. At the point where Helium is compressed heat is exchanged by a heat exchanger.
3. Between the two heat exchangers a regenerator is located. Within the regenerator a thermal cycle arises. In this way the regenerator creates a temperature difference or a so called thermal pump or heat pump.
4. At the point where the helium is expanded, heat from the source is added using a second heat exchanger.

The heat exchangers (2) and (4) are connected to either the source or heatsink, depending on the demand of the consumer. Either heating or cooling.



Application of thermo acoustic heat pump

With a thermal capacity of 1 – 100kW's the heat pumps of Blue Heart are developed for residents and offices. Special applications are as:

- Hybrid application with gas boilers.
- Domestic hot water generating. The thermo acoustic technology is especially suitable as an application for domestic hot water. Because there is no maximum temperature for thermoacoustics, it is extremely suitable for upgrading from low temperature (for example heating networks) to tap water temperature.
- Replacement of gas-boilers
- Small office buildings
- NzEB's
- Air Conditioning in buildings

Blue Hart Energy B.V will produce the thermos acoustic as OEM supplying the component to heat pump manufacturers.

5.2 Adsorption heat pump for sustainable heating and cooling in existing buildings -

Project leader: Cooll Sustainable Energy Solutions B.V.; Partners BDR Thermea Group B.V., Reith Laser B.V.

The technology from this project is an important possibility for making the heating and cooling of the (existing) built environment, in the Netherlands and abroad, more sustainable. The thermally driven adsorption heat pump can be used as a compact and highly efficient gas heat pump, but in the long run also as a (solar) thermally driven cooling unit.

Cooll develops an innovative energy and CO2-saving adsorption heat pump technology. It is a thermally driven technology that can be used, for example, in situations where electric heat pumps do not perform very well in terms of CO2-savings. It is a generic conversion technology that can reduce energy consumption and CO2 emissions for heating by 30 – 50%. The technology uses the combustion heat from fossil or renewable fuels in a smarter way than in traditional heating systems. Cooll is working with partners on a first application as gas-fired heat pump, which can become a successor of the condensing boiler in existing buildings.

The thermally driven adsorption heat pump can be used as a compact and efficient gas-fired heat pump, but in the long run also as the heart of an energy-efficient integrated system for heating and solar thermal cooling. The envisaged gas heat pump is a potential successor to the HR boiler in the existing building, because:

- The low weight makes the system suitable for indoor installation, the dimensions are comparable to those of a large boiler;
- The heat pump can use outside air as a heat source from solar thermal collectors. No ground source is needed;
- It can be connected to traditional HT radiators.

About 30% of gas can be saved per year in an average house with normal radiators, and about 40% in a house with low temperature (LT) heating.

The technology is also suitable for cooling applications. Refrigeration and air conditioning is globally responsible for at least 10% of the electricity consumption and thus contributes significantly to greenhouse gas emissions. The market for climatisation is growing continuously so this percentage will only increase. Cooling systems consume mostly scarce and therefore expensive electricity during peak hours. In this respect it is interesting that in many places on earth the cooling demand is approximately proportional to the local solar radiation. A sun-powered cooling system is, therefore, a logical concept. The heat pump of Cooll can be driven by heat from relatively simple and low-cost solar collectors, it is a thermally driven cooler. Alternatively, also waste heat can be used, for instance from (small) power plants. The system can be applied in mild climates such as the Netherlands. Of course, application is even more effective in hot climates with large solar radiation and cooling demands. Also for developing countries it is an ideal solution to climatize, for instance, remote hospitals.

A lot of focus in this project will be on the development of crucial system components. In addition to the demonstration of the gas heat pump technology, the project will work on the modelling, simulation and design of an autarkic energy system in which the adsorption heat pump is integrated with solar collectors and thermal buffering into one system for both cooling, heating and ventilation.

The team of Cooll also performs project-based R&D activities for the high-tech space industry, particularly in the field of thermally driven cryogenic refrigeration. Such coolers are used for the vibration-free cooling to very low temperatures of infrared detectors and other high-tech electronics.

Cooll is an innovative spin-off company of the University of Twente, based in Enschede, the Netherlands. Cooll was founded in 2009. Cooll works closely together with a large number of international high-tech companies and universities. Business partners are: BDR Thermea Group B.V., Reith Laser B.V. The business development is supported by a network of professionals around the team of Cooll. Cooll uses a number of patented technologies. The project is in the phase of prototypes which will be demonstrated in 2019.

5.3 Combination with Solar Energy concepts

Packaging DHW HPs with PV – significant market potential in some countries, & offers a new route to market via PV providers. – emphasising the economic benefits of the combination with PV is critical. A number of projects have been started in this area where the market for solar energy is discovering the potential of heat pumping technologies in support for their technologies. The so called solar roofs were developed and installed to regenerate the ground sources for heat pumps and solar PV is actually combined in a number of standard plug & play solutions.

Building Integrated Energy for Prefab Production (BIEPP) - This project concerns the development of a prefabricated system on the one hand and the functional and aesthetically integrated energetic elements BIPV (SCX Solar) and solar collector and heat pump (HRsolar) on the other. The construction components are tested at component level before being drawn up as a total system. Chematronics provides project management. The project results in prefabricated building parts that integrate into a significantly higher energy performance at reduced costs (integral design of fully prefabricated roof including PV, solar collector, heat pump). Project leader: SCX Solar B.V.; Partners HRsolar B.V.

PVT integrated Solar Heat Pump systems (PVT inSHaPe). The PVT inSHaPe project focuses on the unused market opportunities for PVT heat pump systems in the current renovation and new-build market for energy-efficient homes (zero-on-meter or BENG). Currently, there is a lack of sufficient knowledge about the integration of PVT systems and liquid-liquid heat pumps into energy-efficient and user-friendly systems that provide heating and hot water. For the realization of (almost) energy-neutral homes based on PVT heat pump systems, an integral system concept including better coordination of the various components and control systems is necessary, focusing on the Dutch climate, housing types and consumer profiles. The aim of the project is to design, realize and validate a number of PVT heat pump concepts without a soil source, which produce sufficient heat and power for a zero-on-meter or NZEB home. Different manufacturers of the various components work together on the PVT heat pump system. Knowledge institutes examine the concepts through simulations, field tests and emulation with a heat pump. Attention will also be paid to preconditions such as ease of installation, regulations, and techno-financial aspects. Finally, a number of functional set-ups in residential dwellings are realized and measured.

In WP2, the functional requirements for integrated PVT heat pump systems are drawn up after an inventory benchmark study. Based on this, a number of systems are designed and energy performance is simulated in a number of iterations. In WP3, the various system components are optimized for the best system performance and an arrangement is also designed. The various components are tested in the lab and in outdoor conditions before they are characterized as integrated systems for energy performance in WP4. WP5 provides the non-technical preconditions for the successful rollout of PVT heat pump systems: regulations (EPG, BENG), material environmental performance and a techno-financial analysis. Different demonstration systems are being built and monitored for energy performance in three different homes. WP1 is responsible for project management and knowledge dissemination.

The result of the project is the optimization of three PVT collectors, a modulating heat pump, three optimized and verified system designs for PVT heat pump systems and three pilot projects to demonstrate the energy performance, reliability, installation and ease of use and a healthy business case for PVT heat pump systems for space heating. and hot water supply for Dutch households.

6. Conclusion

Many innovations can be found on the Dutch market already.

The main Dutch heat pump manufacturers are not Original Equipment Manufacturers and get their components for manufacturing heat pumps from the world-wide market. Compressor technologies, valves and evaporators are not the core technologies of the Dutch manufacturers. Therewith, R&D in Netherlands will be mostly 'application development' focusing on the application boundaries of the existing and future markets and customer needs and preferences.

In the Task 1 report for Netherlands a scenario for future developments is written where there is a market division in individual terraced single family houses and collective multifamily buildings or apartment buildings. The other division is in all-electric and district heating systems.

The main technologies for domestic hot water are:

- Hybrid heat pumps, where the gas boiler is delivering instantaneous hot water
- Double function gas driven or all electric heat pumps, generating space heating/cooling ad domestic hot water.
- Collective high temperature heat pumps for space heating and domestic hot water distributed in multifamily buildings
- Collective low temperature heat pumps in multifamily buildings with individual booster heat pumps for domestic hot water
- Low temperature district heating with individual booster heat pumps for domestic hot water

In all but the hybrid solution an individual storage tank is used for the domestic hot water. Assuming that government regulation will not decree storage tanks in all houses, a technical option is required that are compact, appealing to consumers, economically viable and deliver DHW with much reduced energy consumption/carbon emissions.

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Addendum 1 Overview of other projects under TKI-Urban Energy

67. TEID215041 - Compact energy storage with an Alternative Storage methodology – Development phase II (COMPAS-2) - The COMPAS project will develop a technology that stores excess renewable electricity as thermal energy in a highly compact and cost-effective system. The energy storage density of the system will be up to six times higher than that of thermochemical storage, while being an order of magnitude cheaper than batteries.

Project leader: TNO; Partner RTB de Beijer

68. TEID215048 - Energy-Pads ™: thermo chemical storage as a full-fledged product in the market - The objective of this project is to make thermochemical storage possible. For this purpose the Energy-Pads ™ and -Stacks are being developed to achieve a cost-effective, flexibly deployable, industrially manufactured heat battery.

Project leader: Artenergy; Partners: De Beijer RTB, TU / e

71. TEGB214010 - Multiannual Program for Compact Conversion and Thermal Energy Storage (MJP CCO): the Second Heat Revolution - In order to enable a better link between the demand and the supply of available (sustainable) heat and cold, the project has as primary goal: to accelerate the development of compact storage and conversion techniques for available heat and cold and to fit this into the existing building. This MJP aims to accelerate the integration of compact storage and conversion techniques for heat and cold in the existing built environment. Project Website https://www.projectcco.org/

Project leader: TNO; Partners Alliander nv, BJW Wonen, CCS BV, COMSOL, DOW, DWA, Itho Daalderop, Liveliness BV, Nedmag BV, Oxycom BV, Ares RTB BV, Wendelin BV, Delft University of Technology, TU / e, UT, Hanze University of Applied Sciences, HU

76. TKIGB01004 - Thermal Energy Seasonal Storage Energy-neutral Living (TESSEL) - Sustainable and cheap energy is sufficiently available on a global scale. The trick is to get this energy in the right form, at the right place and at the right time. At home level, more and more techniques are becoming available that produce the required energy sustainably. But this energy, for example solar energy, is often available at times when the energy cannot be used immediately.

Project leader: TNO; Partners De Beijer RTB, Hencon Holding BV, TexelEnergie, Koppen Vastgoed

77. TKITOE140701 – Search for Magento Caloric Materials - The project aims at further improving magnetocaloric materials and at the development of novel magnetocaloric materials that can efficiently operate in magnetic heat pumps.

Project leader: TU Delft; Contactpersoon Prof. Dr. E. Brück; Partners BASF Future Business GmbH, BASF Nederland BV

78. TKITOE130701 - Improved preparation of novel Magneto Caloric Materials - The project aims at further improving magnetocaloric materials and at the development of a reproducible and scalable production method of magnetocaloric materials that can efficiently operate in magnetic heat pumps.

Project leader: TU Delft; Partners BASF Future Business GmbH, BASF Nederland BV

86. TEHE116097 - Utilization of flow heat (BSRJ2016) - The realization of an environmentally friendly water-air-air heat pump through innovative heat exchange with a value of COP-6, using shallow heat flow in soil and water.

The heating power of the heat pump will be used to achieve zero-on-the-gas meters for private homes.

Project leader: TearaSolara Development Company; Partners DLV G & E, Koel-My, Freddomatic, RegenT, Renckens Agri services, Stainless Products, Daikin Netherlands, Mr . A. Ottenbros

87. MTHZH15039 - Heat sources for zero-on-the-meter renovation homes - The objective is to describe concepts with various heat sources where the investment costs are immediately transparent compared to the energy savings to be achieved.

Project leader: Techneco Energiesystemen BV

143. TEUE116150 - Variable / low-temperature heat (cold) network with automatic heat distribution .... (VarioNeTD) - The aim of the project is to demonstrate within three years (on the basis of extensive model studies and a functioning prototype of a small heat network) that our concept of the variable / low-temperature heat network, based on storage tanks equipped With a ThermoDifferential Bypass Valve (TDBV), a well-functioning concept is to realize a simple, flexible, efficient and legionella-safe fourth generation heating network.

Project leader: Conico Valves BV; Partners TU / e

139. MITEN14086 - Building Integrated Energy for Prefab Production (BIEPP) - This project concerns the development of a prefabricated system on the one hand and the functional and aesthetically integrated energetic elements BIPV (SCX Solar) and solar collector and heat pump (HRsolar) on the other. The construction components are tested at component level before being drawn up as a total system. Chematronics provides project management. The project results in prefabricated building parts that integrate into a significantly higher energy performance at reduced costs (integral design of fully prefabricated roof including PV, solar collector, heat pump). See: http://bpie.eu/wp-content/uploads/2016/02/Deep-dive-1-Prefab-systems.pdf

Project leader: SCX Solar B.V.; Partners HRsolar B.V.

144. TEUE116170 - Heat Infrastructure Netherlands with reduced System Temperature (PROFIT) - Making the technical / economic feasibility and consequences / limitations of an innovative heat infrastructure visible for the Netherlands, based on a low temperature heating network with a supply temperature between 30°C and 60°C and with which sustainable are provided for the heat demand of the Dutch built environment.

Project leader: DNV GL; Partners: TU / e, Thermaflex Insulation B.V., Visser and Smit Hanab BV, IF Technology B.V.

Addendum 2 Standard heat pump barriers

In this Annex we list the barriers identified for standard heat pumps, which are also relevant for high temperature products and domestic hot water heat pumps, with a similar level of relevance and magnitude.

Consumer Barriers

Consumer confidence / trust: The reputation of standard heat pumps has suffered because of previous poor installed performance in the market. For example, one housing developer interviewed has an 'absolute prohibition' on using ASHP due to negative experiences from previous schemes, and will only consider them in exceptional circumstances. This is a major barrier. Research suggested that poor performance was either due to poor installation or incorrect operation, both of which can be overcome.

This barrier is common to heat pumps more generally, and acceptable performance would need to be demonstrated for this technology.

Aesthetics: Aesthetics are a major barrier. Feedback from demand-side interviewees suggested that real-world buyers care more about aesthetics than marginal energy savings. This can be less of an issue in the countryside or for properties with more space, where units can potentially be concealed behind bushes or fences, or further away from buildings.

Technical Barriers

Space: Lack of space is a major barrier (and could also be considered a market barrier due to the nature of Dutch housing stock). External space is required for the heat pump unit, as well as internal space for a water tank. The effect of this barrier will vary by property type. Non-urban properties are less likely to have space restrictions than high-density urban dwellings. This is a major barrier in parts of the market with space constraints. While high temperature heat pumps are bigger than standard heat pumps, they usually require a smaller hot water tank.

Installation and Maintenance Challenges

Poor installation of standard heat pumps had a very negative impact on their reputation in the market. To avoid a similar situation with DHW heat pumps it is important that similar poor installation is avoided as the market grows.

Shortage of necessary skills: There has been a lack of capacity of trained installers for electric heat pumps. This is a minor barrier that could hold back supply once demand grows. Given the importance of installation quality on in-use performance, poor performance of early installations could be a barrier to further uptake of heat pumps (as has proved to be the case with standard heat pumps). Consumers may also be concerned about a skills shortage for maintenance.

The skills shortage has improved and many manufacturers run training courses or have special relationships with groups of installers. However, some stakeholders still raised this as an issue during interviews for this research.

The skillset required for installation of both standard and high temperature heat pumps is similar.

Speed of installation: When the boiler is a 'distress' purchase, speed of installation forms a significant part of the purchasing decision for a replacement. The gas boiler market is mature, with a number of experienced heating engineers in the market which would allow a boiler to be bought and installed in under a day. Installation of a high temperature heat pump will typically take a similar amount of time to a standard product, however there is less likely to be a need to alter the heat distribution system or radiators, which can shorten overall system installation time. This is a minor barrier.

Number of players in the supply chain: Feedback from interviews was that there are too many players in the supply chain, often resulting in poor specification or installation. A number of interviewees questioned why manufacturers are not involved in the design and installation of units. There was confusion as to why a manufacturer may not even perform a health check post-installation. This is a minor barrier.

Market Barriers

Readily accessible and low-cost gas network in Netherlands: The extensive gas network and relatively high cost of electricity per unit of energy compared to gas in the Netherlands is a major barrier as it means that that in-use cost savings from heat pumps are potentially lower compared to other countries. Volatility around energy prices adds to uncertainty around savings.

Low Replacement Opportunities: Gas boilers have long useful lives of 10 – 15 years, and consumers are reluctant to replace them unless they are coming to the end of their life. This is a minor barrier that is not limiting the market.