Task 1: Market Overview

IEA-HPT Annex 45: Hybrid Heat Pumps

Netherlands

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BDH
Paul Friedel
Martin Horstink

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Part I – General overview

1 The energy sector

1.1 Overview of main challenges

Main challenges in built environment are threefold, interacting with each other

1 Historically, the Netherlands have a heavy inclination towards low-caloric natural gas, found in Northern provinces. However, gas production needs to be strongly decreased due to earthquake hazards.
2 Most residents in densely populated areas: no room for large heating installations.
3 Big part of housing stock is poorly insulated and need high temperature heating in cold periods. Changing the insulation levels of the whole housing stock is time consuming.

These challenges actually provide an incentive for hybrid HP:

1 Hybrid systems allow for smaller HP installations to be placed.
2 Due to well-developed gas-network (around 95% penetration), back-up high temperature energy is always available.
3 Hybrid heat pumps don't require extreme modifications of existing energy infrastructures.
4 A hybrid heat pump is relative affordable and the installation of a hybrid heat pump is relative easy and fast.

Therefore, hybrid heatpumps have the potential to lower the natural gas use dramatically with relative low costs and in a relative short period. Also, it doesn't obstruct other energy savings measures the next coming decades.

Policy support for residential heat production has been modest, but starting in 2016, a subsidy scheme for heat pumps has been developed. This scheme is as yet especially favourable for hybrid systems, awarding up to €2300 for a single installation. Hybrid installation sales have sharply risen since 2016, driven by the subsidy.

1.2 Electricity generation

1.2.1 Production park

In the Netherlands about 90% of the electricity supply is produced on the domestic market itself. The remainder is imported from other neighbouring countries, mainly Germany and Norway.

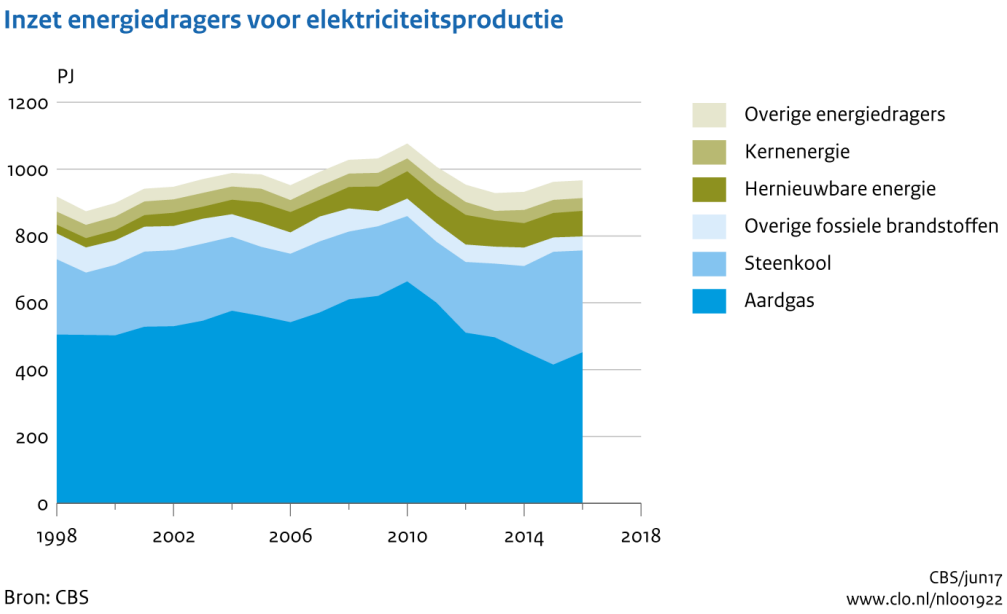
Natural gas is the most important source for the production of electricity, with about 60% of total kWh production. In central gas-fired power plants high-caloric natural gas of foreign origin is mainly used to produce electricity. In the Netherlands there is a high share of decentral gas-fired power plants as well. These systems use generally low-caloric domestic natural gas.

Many sectors use CHP plants to produce heat and electricity simultaneously, which is energy efficient. Furthermore, these systems are generally very flexible making the Dutch electricity park well-suited to different market circumstances and flexible power production of renewable energy sources.

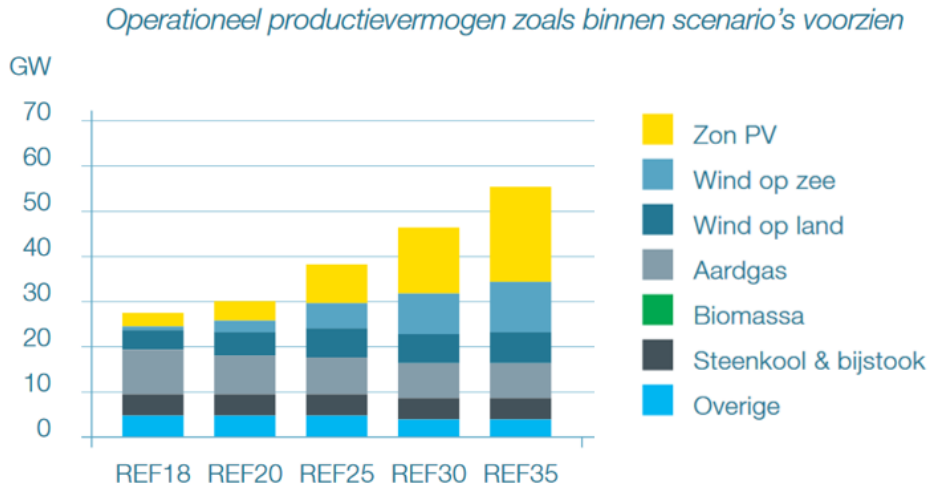
Coal is also an important energy source in the electricity mix. The last couple of years three new coal fired power plants have been built and almost at the same five old power plants have been shut down. Expectations are that soon another two coal power plants will shut down and the remainders will shut down or being transformed into biomass power plants before 2030, because of more pressure on the national CO_2-emissions. Due to the current low prices of coal, it is presently more favourable to operate a coal fired power plant than a gas fired power plant.

In the Netherlands there is one nuclear power plant. Furthermore, there are some power plants that work on industrial gasses and waste incineration plants.

In the coming decades the production capacity of fossil fuel sources will decrease, from about 20 GWe in 2018 to about 16 GWe in 2035. However, the production capacity of renewable sources will increase substantially, from about 7-8 GWe to about 40 GWe in 2035. In 2035 solarPV capacity will be 20 GWe, onshore wind 8 GWe and offshore wind 12 GWe.



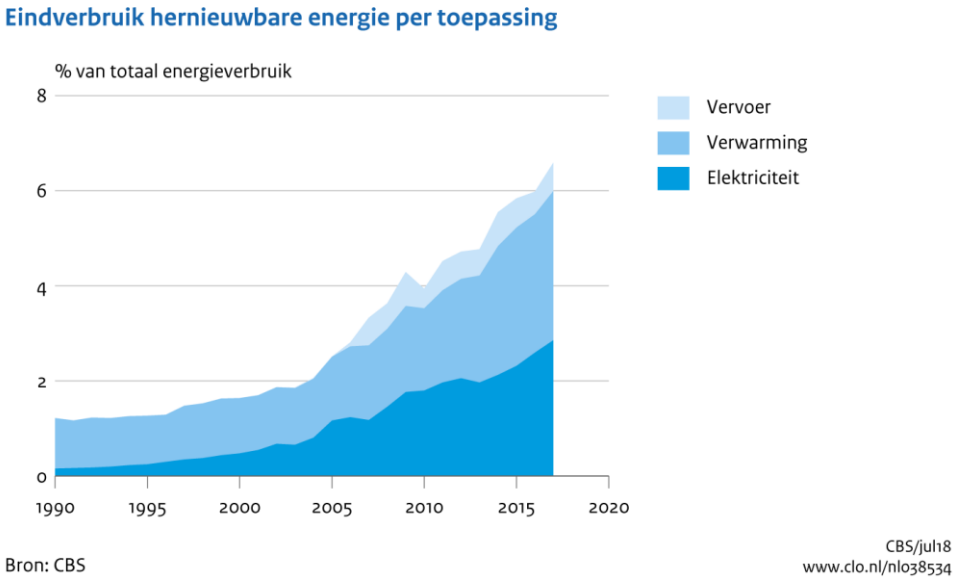
Fuel sources for electricity production 1998 – 2016 in the Netherlands. Legend from top to bottom: Miscellaneous (light brown), Nuclear, Renewables, Miscellaneous fossil, Coal, Natural gas.
Source: Central Bureau of Statistics.



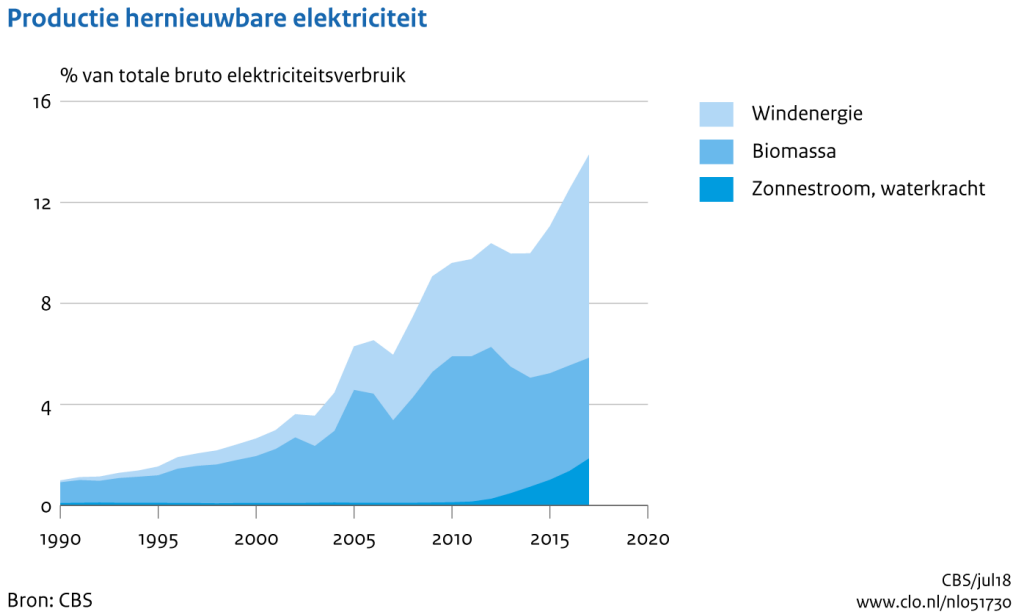
Expected production power 2018 – 2035 in the Netherlands. Legend from top to bottom: Solar PV (yellow), Wind @sea, Wind @land, Natural gas, Biomass, Coal, Miscellaneous (light blue).
Source: TenneT.

1.2.2 Renewable energy production

The share of renewable energy is fairly low with only about 6% of renewable energy in the total energy use and is increasing slowly the last couple of years. For electricity about 10-15% of the electricity is produced from renewable sources. The short-term goal for the share of renewable energy is 14% in 2020, with about 35% renewable electricity production. It is very doubtful if this goal will be met, though large wind power and solar project projects are being developed and will come online soon. Biomass is used for (among others) waste incineration plants, premixed biofuels in transportation, biomass boilers for heat in industries, biomass plant for electricity production.



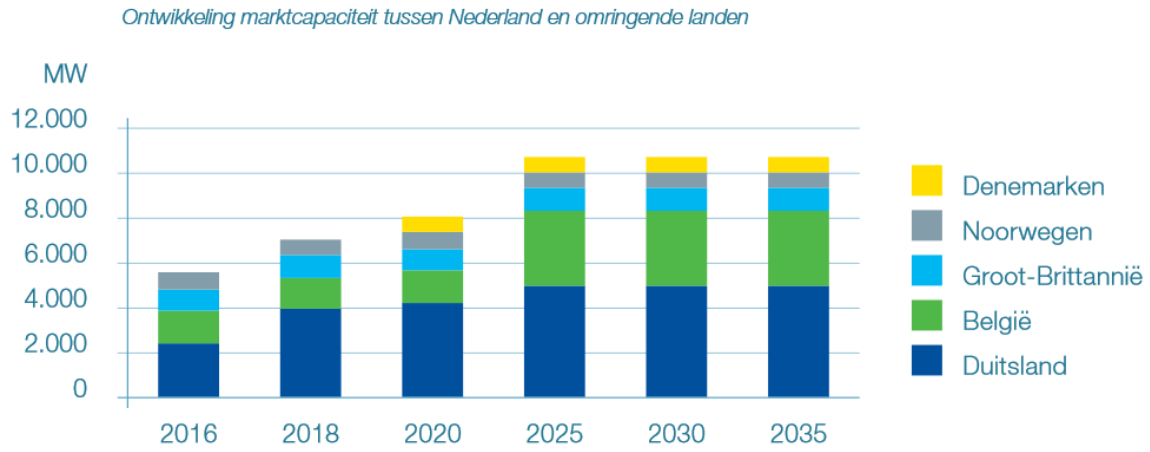
Renewable energy by application (% of total demand). Legend top to bottom: Transport, Heating, Electricity. Source: Central Bureau of Statistics.



Renewable electricity production (% of total demand). Legend top to bottom: Wind, Biomass, Solar/hydro. Source: Central Bureau of Statistics.

1.2.3 Capacity

The Dutch electricity network is already well interconnected with surrounding countries with almost 7 GWe interconnection capacity. With the current planned projects, interconnection capacity will increase to 11 GWe in 2025 with more capacity with mainly Belgium, Germany and Denmark.

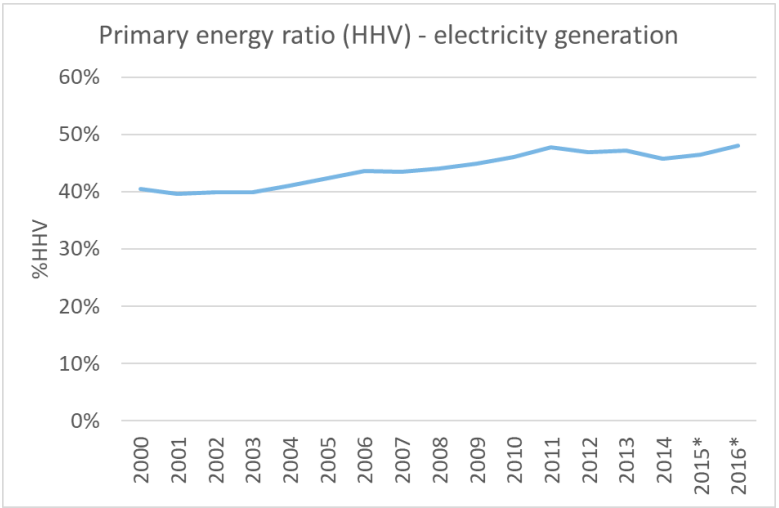


Expected development of interconnection capacity.
Source: TenneT.

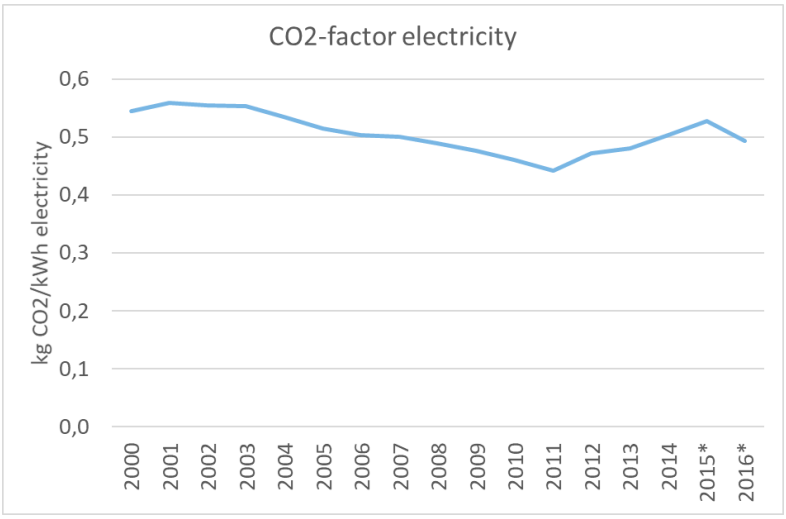
1.2.4 Performance

The Dutch electricity production park is getting more efficient leading to higher primary energy ratios. This is due to new power plants beings installed and old power plants being taken out of operation. The CO_2-factor has remained stable though, since new power plants haven been coal-fired and are usually cheaper to operate then gas-fired power plants. It is expected that due to the foreseen phase out of more coal fired power plants the primary energy ratio and CO_2-factor will improve the next couple of years.

Also, there are advanced plans to capture and store the CO_2 of among others power plants. However, the projects are being postponed because of low CO_2 prices, making CO_2 capture and storage economically unviable.



Primary energy ratio of electricity generation. A slow increase in PEF can be seen since 2000.



CO_2-performance of electricity generation. The increased PEF for electricity production does not yet lead to a better CO_2-factor, since several new power plants are coal-fired.

1.3 Energy Infrastructure

1.3.1 Gas and electricity network

In the Netherlands there is a dense and well-equipped gas and electricity network. Most households are connected to the national gas grid (90%, the remaining 10% mainly being district heating) and electricity grid (99%). In several larger cities district heating is in place and there are thousands of collective heating facilities that heat small heat grods, e.g. in buildings with a collective boiler room. In total 10% of the Dutch houses are heated through district heating or collective heating systems.

Although low-caloric gas from domestic sources, which is used in Dutch households, will be phased out in the coming decade or so, due to the earthquake hazards, high caloric gas will be used from other domestic and non-domestic sources. The Netherlands is directly connected to the international pipeline Nord-Stream, being able to import Russian gas, and there are several LNG-terminals in the Dutch harbours. Further, a nitrogen-production plant is being built to be able to transform the high caloric natural gas to low caloric natural gas, as is needed by Dutch heating installations in houses. It is expected that gas will play an important role in the Dutch energy transition for the next decades.

However, the future of gas use in the household sector is an ongoing and hot debate at this moment. There is a strong tendency and lobby for making the Dutch household sector gas-free in 2050 (“Gasloos”) and projects are being started to remove the gas infrastructure in residential areas. Two important options that are being consider replacing natural gas as a heat source are:

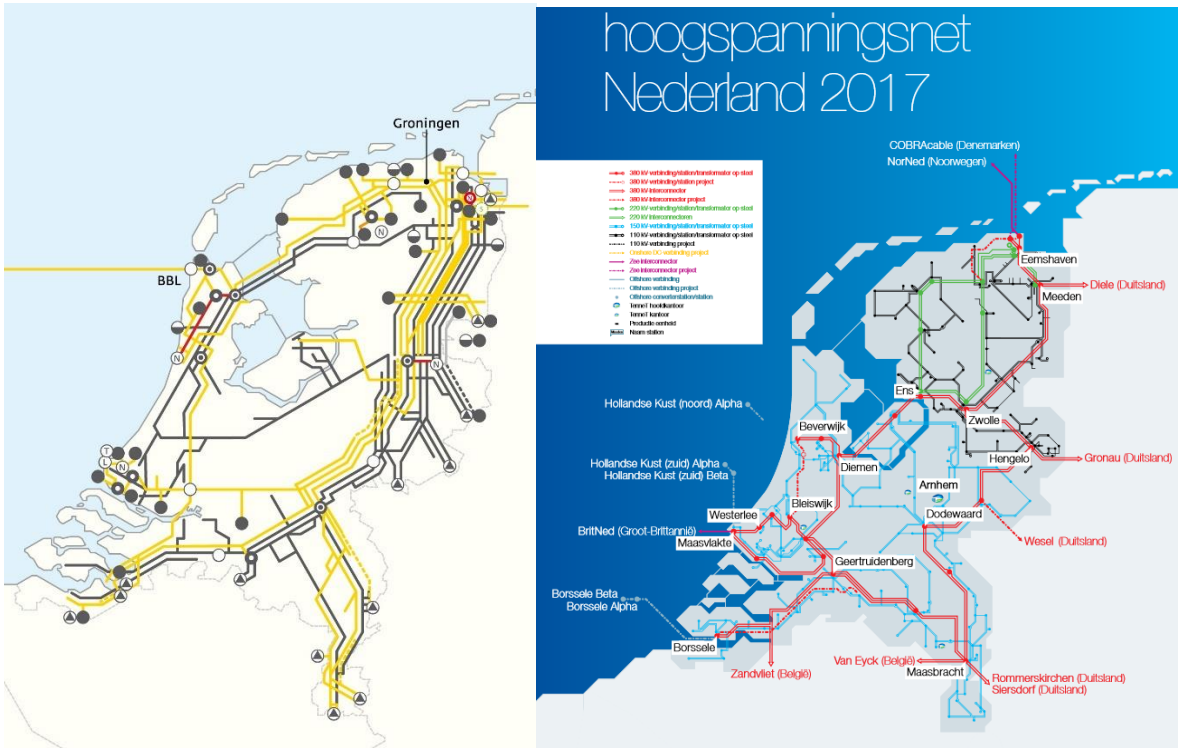
- All-electric houses. Houses that are being heated by heatpumps.
- Heat networks. In many potential studies heat networks are seen as an important way to make Dutch houses gas-free.

However, more and more parties also see the benefits of gas and are looking for the possibilities of sustainable gases, like biogas and sustainable hydrogen. Several hydrogen pilot projects are now being developed. Ranging from making hydrogen out of natural gas and putting CO_2 back into the natural gas source and using the hydrogen in a gas fired power plant to pilot projects in which homes are heated by special hydrogen boilers.

The Dutch distribution grid for electricity has to be strengthened in the near future. Due to the increase of solar PV on houses, the use of electric cars, electric cooking and heat pumps the limits of the current local grid will be reached soon. In some places already problems occur in neighbourhoods where a lot of solarPV and/or heat pumps are placed in a relative short period. The capacity of the local distribution grid is not designed for all-

electric houses and is technically and economically optimized for current use of electricity. Adaptations are expected to be costly and time consuming for the regional grid companies.

This latter problem leads to opportunities for hybrid heat pumps, especially for the short term (10 – 20 years). Since hybrid heat pumps can theoretically be operated flexibly, changing between electricity and gas use. Just for peaks in heating demand or if it's necessary for the electricity grid gas can be used. Therefore, on a short term it is possible to decrease the use of natural gas in houses, but costly and time consuming adaptations in infrastructure can be delayed, or at least spread out over a longer time period. Most distribution grid companies see the hybrid heat pump (at least) as a technology to gain time to make the local electricity grid ready for gas free houses or maybe as an end-technology if development of sustainable gases progress.



1.4 Energy Demand

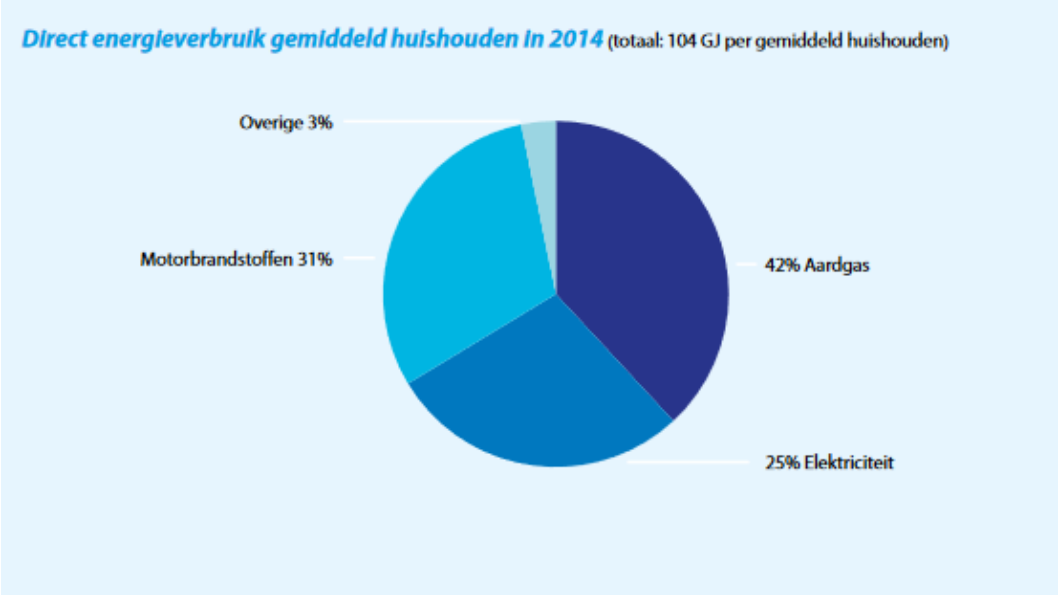
1.4.1 Domestic household demand

In Dutch households the main energy source is natural gas (on average 14.000 kWh/year) and it is used for space heating (75%), domestic hot water (20%) and cooking (5%). Electricity (on average 3.200 kWh/year) is mainly used for household appliances. Heat pumps or direct electrical heating are still only very limited. Even in new houses, condensing boilers have been the *de facto* standard up to 2018. Only for new buildings with a building permit after mid-2018, gas boilers are explicitly out-lawed.

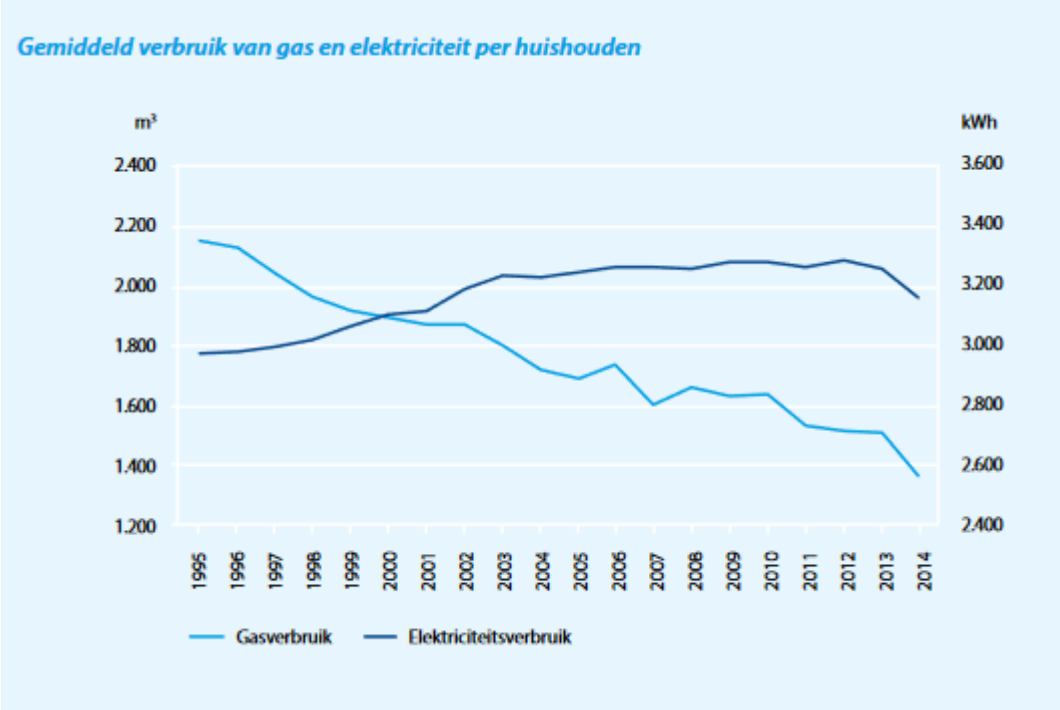
Due to stricter building regulations for newly built houses, energy savings programmes at social housing companies, energy savings measures by private home owners and more efficient gas boilers the use of natural gas per household has decreased substantial the last decades.

In the 1990s electricity demand increased in households due to new electric appliances. However, since mid 2000's electricity demand has remained equal, due to improved energy efficiency of appliances and lighting.

Apart from electricity and natural gas, transport fuel is the third large contributor to household energy demand.



Household energy use. Legend counter-clockwise starting top left:Miscellaneous, Transport fuels, Electricity, Natural gas. Source Central Bureau of Statistics.



Evolution of electricity (dark blue) and natural gas (light blue). 1 m^3 of Dutch low-caloric natural gas equals approximately 10 kWh. A persistent downward trend for natural gas is clearly visible, while electricity demand has increased modestly.

It is uncommon for Dutch households to cool their houses. Though it is expected that cooling demand will increase, active cooling is not seen as a high priority for Dutch households. Rather, *passive cooling*, or simply feeding heat pump ground source water through the heat transfer system, is expected to increase as an 'additional service' for heat pumps.

For the future it is expected that household will use more electricity, mainly due to the use of more heat pumps and electric vehicles. On the other hand, households will generate more electricity due to more solar PV on roofs.

1.4.2 New technologies

Future expectations are that more electricity will be used due to the adaptation of heat pumps, electric vehicles and electric cooking.

Nowadays the penetration of electric vehicles is very low. However, the goal is set to have 2 million electric cars on the road in 2030, out of a total of about 8 million cars (as of 2018).

The amount of solar PV in households is expected to increase rapidly. The idea is to fill all available roofs that have direct solar irradiation. Additionally, more and more solar fields are being developed.

At this moment batteries are hardly deployed. The most important reason is that there is no favourable policy instrument yet for electricity storage on household levels. There is simply no business case for storing PV electricity to increase self-consumption of renewable production.

1.5 Energy Policy

Due to international energy and CO_2 policy and the earthquake hazard due to domestic natural gas production, national policy is getting more and more sustainable. For early 2019 a national climate agreement has been planned. This policy agreement will state that municipalities must develop transition vision for residential heating in which the timeline is established for sequentially making all neighbourhoods CO_2-neutral. These transition visions should be available in 2021. From 2022 onwards the neighbourhood-oriented approach will start. An

implementation agenda is drawn up at neighbourhood level. The municipality takes control, and will decide in consultation with residents, homeowners and other stakeholders in the neighbourhoods. Meanwhile, 75% of the planned newly built residential and non-residential building will be delivered without a gas connection.

It is also proposed that more than 100,000 existing homes under management of social housing companies will be natural gas-free or 'natural gas-free-ready' before 2022. Practically this means that 50,000 houses will be connected to local heat networks and into 50,000 houses a collective or individual (hybrid) heat pumps will be installed.

The above plans will already greatly increase the demand for heat pumps in the short term. In the years 2015-2017, a total of more than 41,000 heat pumps were installed. In the years 2019-2021 social housing companies will apply heat pumps in 52,500 homes, while a (substantial) part of the more than 160,000 planned new-build homes that have to be delivered will be installed with heat pumps before 2022.

1.5.1 Heating appliances regulations

For sustainable heating appliances a stimulation subsidy is active since the beginning of 2016. Yearly about 100 million euro is assigned to stimulate the investments of (hybrid) heat pumps, biomass boilers and solar boilers. Though officially the subsidy scheme will end in December 2020, it is expected this subsidy scheme will stay for another couple of years.

Also, in 2018 a manifest was presented, in which it was proposed to set minimal efficiency requirements for heating appliances in houses. Resulting in making it impossible to use solely gas fired boilers in houses. Though a lot of parties supported the manifest, the government didn't pick it up.

1.6 Energy Prices, Tariffs & Structures

In the Netherlands the consumer prices for electricity and gas are highly influenced by taxes. The tax level for both electricity and gas are about 50% of the total consumer price.

1.6.1 Energy providers

Consumers can freely choose their energy provider. Providers usually offers contracts between 1 to 3 years and dependent on the contract change the energy prices every 6 months to the latest market prices. The consumer energy market is open for all parties.

1.6.2 Commodity prices

Recent years the prices for fossil fuels were low, resulting in low prices for consumers for gas and electricity. In recent years the total energy costs of consumers has declined a bit. However, in 2018 the price of natural gas, coal and CO_2 increased resulting in about 50% higher commodity price of gas and electricity in one year.

1.6.3 Taxes

VAT

In the Netherlands 21% VAT is being taxed on energy related products and taxes.

Energy Tax

Energy use is taxed with an energy tax. The level is dependent on the amount of energy used. The energy tax is implemented to improve energy efficiency at energy users.

Recent years the energy tax policy is being adapted to make electricity for domestic use more interesting compared to natural gas. In 2016 the energy tax on electricity was decreased and the tax on gas was increased at the same time. In 2019 and 2020 more energy tax adaptions will be made to make electricity use more favourable.

Renewable energy levy

Since 2013 a new tax scheme came into place, called the renewable energy levy ("Opslag Duurzame Energie"). The tax scheme is introduced to make investment incentives possible in large renewable energy production projects (SDE+). Currently the renewable energy levy is relatively low compared to the energy tax and commodity

prices of energy. However, it is expected that in 2023 the levy will be more or less doubled compared to 2018 levels.

Tax remuneration
Every household in the Netherlands with an electricity connection will get a tax remuneration. In 2018 the tax remuneration was approximately €370,- including VAT in 2018. In 2019 this tax remuneration will probably be lowered to €310,- including VAT.

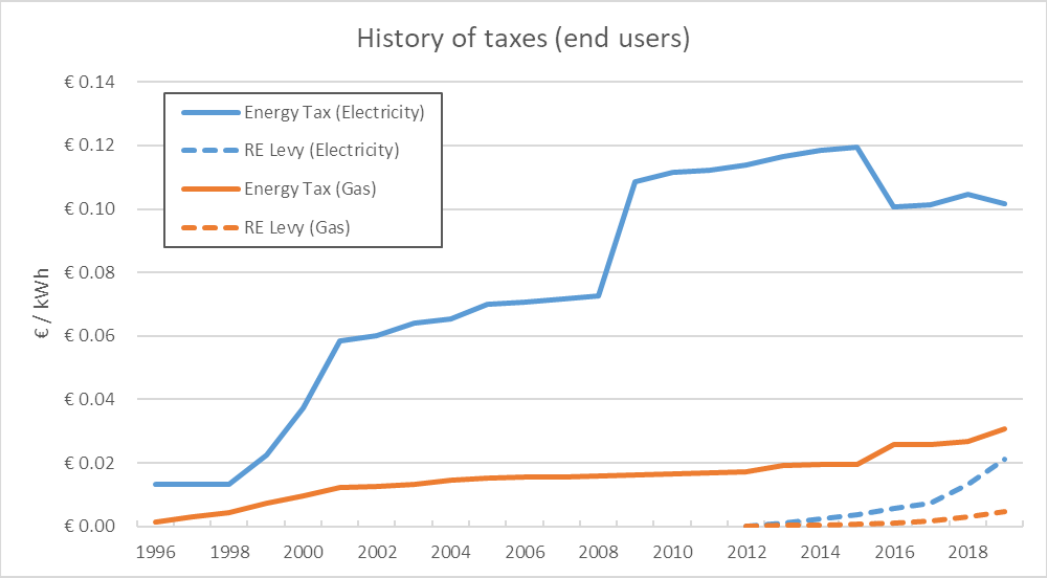
1.6.4 Network tariffs

The network tariffs for electricity and gas are strongly regulated and more or less 'socialized' in the Netherlands. The network distribution companies make calculations for their yearly cost, like maintenance, and prepare a proposal how to divide these costs over the several different connection capacities. These proposals are then assessed by the national authority for consumers and markets.

For most of the household the network tariffs for electricity and gas are around €210-270,- respectively €120-190,- per year dependent on the local network distribution company.

If a household can lower their gas use below 500 cubic meters per year a lower gas network tariff will be applicable. In such a case the gas network costs decrease to €90-140,- per year . This can be a stimulus for hybrid heat pumps in certain houses.

Yearly network costs of local network distribution companies							
	Liander	Enexis	Enduris	Rendo	Stedin	Westland	Cogas
Electricity							
3x25A(standaard)	€ 251,96	€ 224,27	€ 271,51	€ 226,65	€ 236,97	€ 210,56	€ 219,72
3x35A	€ 973,26	€ 816,08	€ 1 042,96	€ 816,44	€ 890,65	€ 803,74	€ 814,93
Gas							
G4/G6 SJV yearly use <500 m3	€ 138,02	€ 99,28	€ 125,30	134.26	€ 130,03	€ 92,96	€ 122,63
G4/G6 yearly use 500-4000 m3	€ 192,82	€ 168,53	€ 170,65	€ 187,43	€ 180,95	€ 122,58	€ 165,71



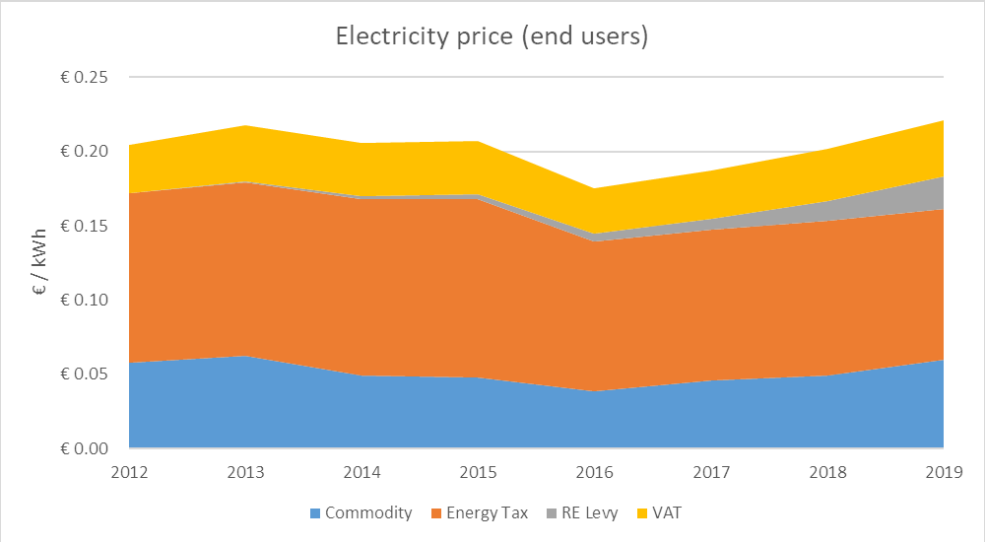
Energy taxes determine approximately 50% of the total consumer cost price for energy. Electricity is three times as expensive as natural gas. Starting in 2016, a deliberate effort is made to bring the energy taxes for electricity and natural gas closer together.

1.6.5 Electricity prices

In the Netherlands the overall electricity price including taxes is fluctuating around 20€ct per kWh the last couple of years. It is expected that the electricity price will increase.

In the Netherlands consumers can generally choose between a fixed tariff or a day and night tariff. The price difference is relatively small though. Day and night tariffs were implemented to increase the use of electricity at night to prevent power plants to shut down completely. However, with increasing renewable energy production this tariff scheme is becoming outdated. Therefore, also new products are introduced in which the consumers can choose to follow the prices on the wholesale market. Since consumer prices are highly influenced by taxes also the products don't have big economic benefits for households yet.

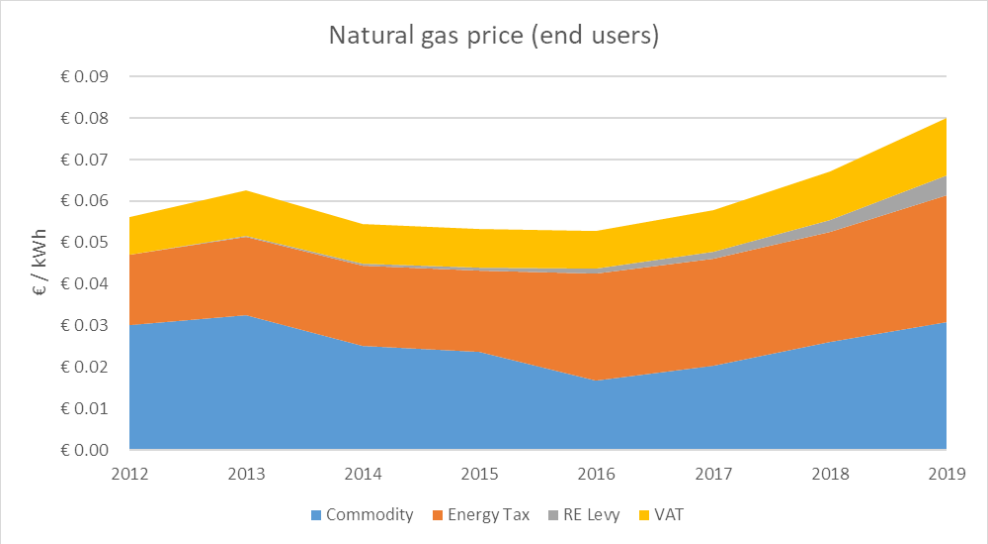
Currently for electricity produced by solar panels consumers get a remuneration that is equal to the overall electricity price. The means that the electricity price is essentially only paid for the net electricity use, *including solar PV production*. This method will be changed in 2020 into a feed-in tariff. In the first years this feed-in tariff is expected to have the same result as the current method for consumers. But it can be foreseen that the government will make the tariff structure in such a way that self-consumption of solar produced electricity will be promoted in the longer term. This brings in opportunities for local energy storage, like batteries, but also for heat pumps to produce heat for instance for domestic hot water on moments of a surplus of solar electricity.



1.6.6 Gas prices

Currently natural gas prices in the Netherlands are about €ct 65 per cubic meter, which result in a price of about 6,5€ct per kWh. Per kWh electricity will remain be more expensive than natural gas, which is also logical with the present CO_2-intensities of natural gas (0,2 kg CO2/kWh) and electricity (0,45 kg CO2/kWh). Therefore, electricity has to be used in an efficient way. The ratio electricity/natural gas price has improved the last couple of years is just below 3 at this moment. Making it necessary to have a heat pump COP of about 3 to be cost-neutral with a gas fired boiler. With the Dutch climate and housing characteristics this is certainly achievable.

Heating solely on electric heaters is economically not viable and in general not very sustainable with the current production mix of electricity.

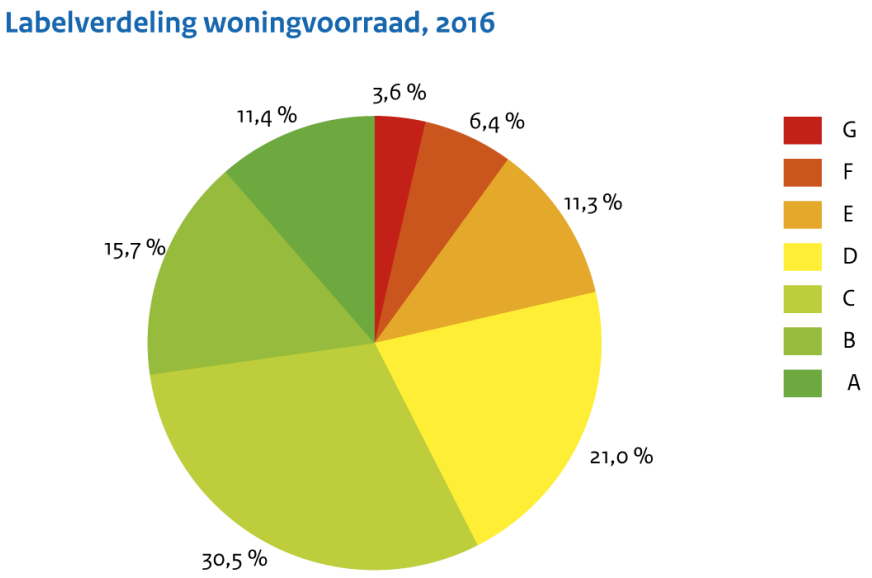


2 Buildings and heating systems

2.1 Housing stock characteristics

In the Netherlands there are about 7,6 million households. 56 percent of these houses are privately owned. About 65 percent of the houses are single family houses. About 50% is built after 1975 and about 20% is built before 1945.

Dutch housing stock. Left: breakdown of living area; Top: breakdown of built year; Right: breakdown of rent (huur) or ownership (koop); Bottom: breakdown of single-family (eengezins) or multi-family (meergezins) houses.



Energy labels of Dutch houses. Label C & D are considered suitable for hybrid HPs. Together, they form approximately half of the building stock.

2.2 Trends in the Heating Market

Approximately 85% of the Dutch households have central heating systems with gas fired condensing boilers. In these systems mainly radiators are used to release heat in the rooms. Floor heating systems are used mainly in relative new houses and in the more common rooms.
Local gas fired heating systems per room are decreasing and are used in less than 5% of the houses nowadays. In a small number of houses direct air heating is used.
Recent years in collective heating systems in buildings have been replaced by individual central heating systems, because of its efficiency and simpler regulations.

In 2018 new building regulation came into action in which it is forbidden to make new construction plans in which houses are connected to the gas grid, giving space for other heating technologies. Probably (collective) heat pumps will profit from this new building regulation.

District heating is being used in some cities and the heat networks are being extended. On average 16% of the new built houses are connected to a district heating system.
Electrical heat pumps increasingly often used, mainly in newly built houses. Nowadays on average 50% of the newly built houses are implemented with a heat pump and this percentage is expected to grow even more, because of the new building regulations. At this moment about 120.000 houses are being heated by heat pumps.

In 20% of the houses also a woodstove is present, mainly used for adding a cosy atmosphere to the living room.

2.3 Customer Preferences

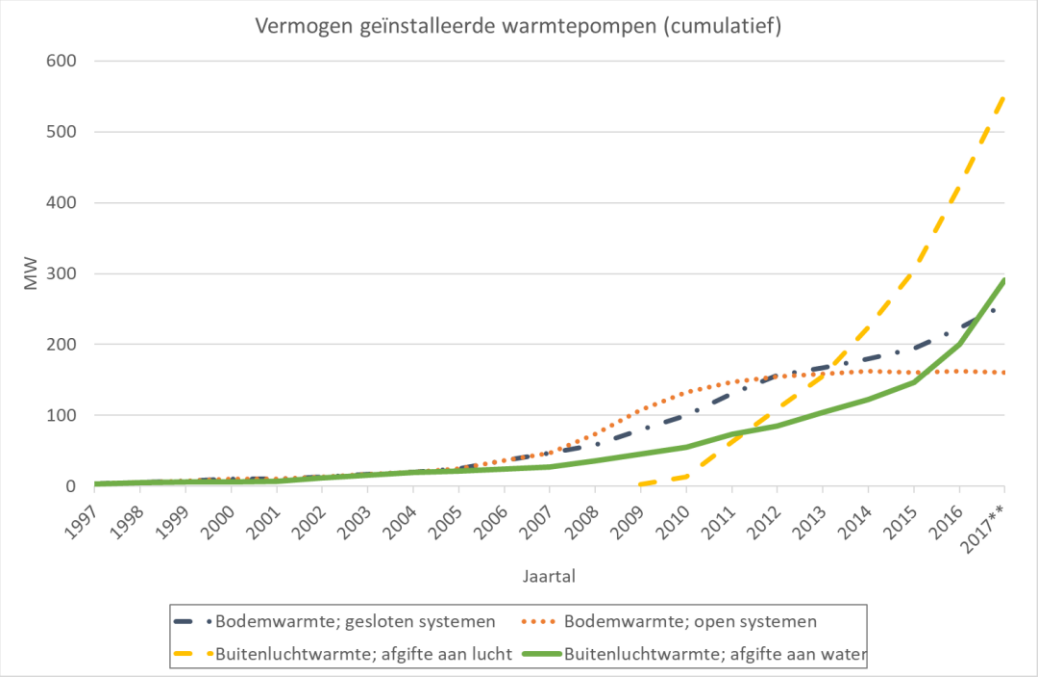
The way homeowners heat their houses is very dependent on the age of the house. In older, not well insulated houses, homeowners tend to heat the house when present at home and lower the heating when away from

home or during the night (10-15°C). In modern houses with low temperature heating systems, in which it takes a while to bring the temperature up in a house, homeowners keep the temperature relatively high.

Most of the houses have a combi-boilers, which means the gas condensing boiler produces heat for space heating and domestic hot water, without the use of a storage tank. The boilers are small and are usually placed in a small room, sometimes just a (kitchen) closet. In many cases available space is seen as a critical factor for new renewable heating installations which usually require more space. This is a chance for hybrid heat pumps, since no space consuming hot water boiler is necessary and is offering a solution that minimizes the required space in house.

3 Heat pump market

3.1 Presently installed capacity



Heat pump cumulative installed heating capacity. Legend: blue = ground source, closed system; red = ground source, open system; green = air to water; yellow = air-to-air. The air-to-air units are almost exclusively installed in small commercial buildings, mainly shops.

3.2 Trends in the Heat Pump Market

From 2005 onwards there was a relatively strong growth of ground sourced heat pumps using aquifers as a heat source in the residential market. These heat pumps were mainly used in apartment blocks as a collective heating and cooling system. The growth was due to governmental support and because these systems scored good in energy efficiency ratings for new building concepts. However, after 2012 the number of aquifer systems declined, due to stricter environmental legislation. Aquifer systems have to be in thermal balance. However, in the Netherlands heating demand is much bigger than the cooling demand, so thermal imbalance of such systems was very common. Expensive adaptations to existing systems had to be made and the concept was not applied anymore in newly built houses.

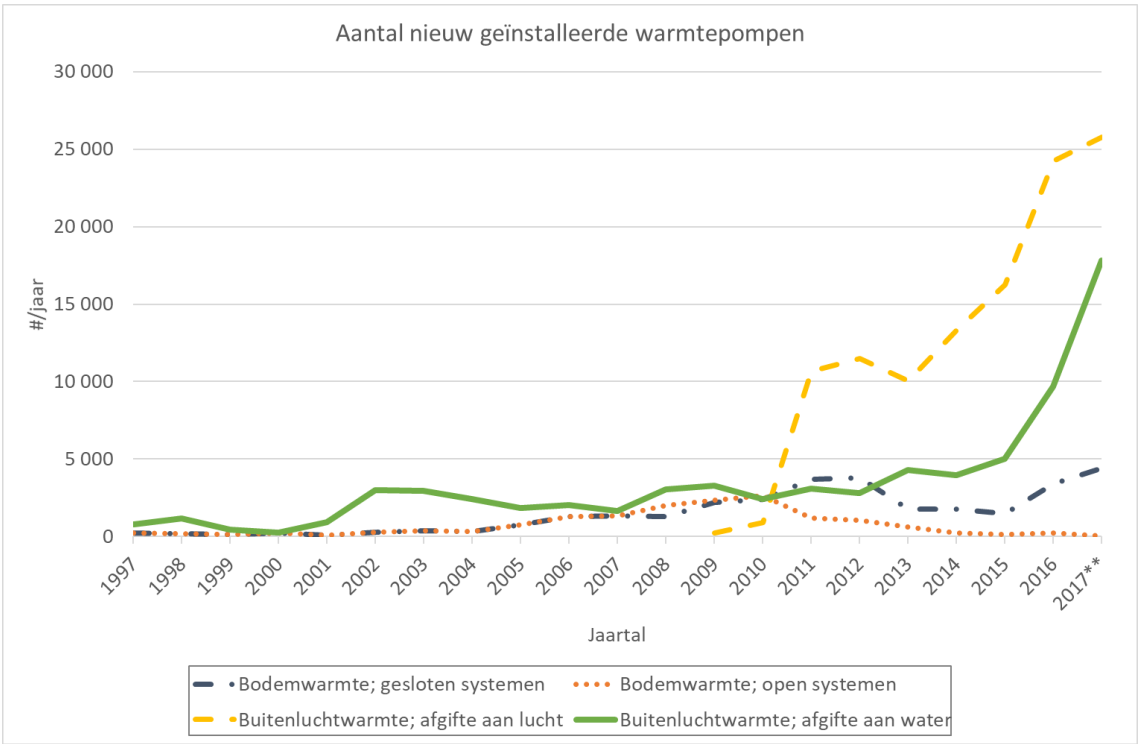
The recent growth of heat pumps is due to new national investment incentive (ISDE), legislation for newly built houses and public awareness of climate change and earthquake hazards of natural gas extraction. For newly built

houses heat pumps are being the standard nowadays. Also, in many existing houses heat pumps are being installed. The main growth is in air sourced heat pumps, mainly because they are cheaper and easier to install. A large share of the air sourced heat pumps are beings installed as hybrid systems.

Besides the economic crisis and the resulting decline of new building projects, the problems with aquifer systems also affected ground sourced heat pumps that used closed heat exchangers. In recent years, as new building projects have started up and the new subsidy scheme is in place, also these systems have seen growth.

Air-to-air heatpumps have shown a rapid growth over the last years. However, there is no consensus if these systems contribute to the heating of houses or that they are just being used as cooling systems.

The number of heat pumps being installed in houses yearly is about 20,000. Compared to 400,000 gas-fired boilers per year, this means a market penetration of about 5%.



Number of new heat pumps. Legend: blue = ground source, closed system; red = ground source, open system; green = air to water; yellow = air-to-air. The air-to-air units are almost exclusively installed in small commercial buildings, mainly shops.

It is expected that the application of heat pumps in the residential sector will increase the next coming years. In newly built houses a market share of at least 50% will mean about 30,000 heat pumps per year. Additionally, it is expected that (hybrid) heat pumps will be implemented in existing houses. With social housing companies it is agreed that yearly tens of thousands hybrid heat pumps will be installed in social houses. After 2021 it is expected that also a strong growth will be seen in the existing building to about 100,000 new heat pumps every year. The Dutch heat pump association expects 200,000 heat pumps per year by 2030.

3.3 Current hybrid products available

In the Netherlands the hybrid heat pump market is growing rapidly, with new products being introduced on a regular basis. Besides heat pump manufacturers also almost all the boiler companies offer hybrid heat pumps in their product portfolio. Nowadays about 20 different types of hybrid heat pumps exist on the Dutch market. The main heat sources for hybrid heat pumps are outside air and ventilation air. Most of the hybrid heat pumps

deliver heat for space heating, but some also offer domestic hot water. With the current product range of hybrid heat pumps, it is possible to find a proper hybrid heat pump for almost every house.

Most hybrid heat pumps can work together with any boiler manufacturer and can be added to an existing installation afterwards. Capacities range from 1 to 5 kWth. Of course, depending on the house size and heating characteristics it is generally possible to save about 50% on the natural gas use with an hybrid heat pump.

3.4 Drivers & barriers for hybrids

Since most of the installed hybrid heat pumps are air sourced heat pumps, the debate of noise is getting stronger. New legislation for sound limitation is expected soon. Most manufacturers see the risks of noise and make improvements in design to limit the noise and vibration of their systems. Aesthetical aspects also can become a barrier. Special casings exist to minimize noise and improve the aesthetics of the outside air unit of (hybrid) heat pump.

The installation of a hybrid heat pump is taking more time and capacity of an installer compared to the installation of a gas-fired boiler. Installers need to have special additional qualifications. The availability and quality of personnel is becoming a limiting factor in further growth. To tackle this barrier, seven new special teaching facilities for heat pumps were opened throughout the Netherlands in 2018. Thereby making it possible to train thousands of new heat pump installers every year.

With a hybrid heat pump there will still be gas use. In general, the public opinion is to become gas-free and therefore the hybrid heat pump is not regarded as a preferred new heating appliance. In contrast, by energy professionals the hybrid heat pump is seen as a relatively easy technology to reduce the natural gas use in households in a limited amount of time.

The investment in a hybrid heat pump is higher than a gas-fired condensing boiler. For many people this is a hurdle. It is expected that many private home-owners will still choose a gas-fired condensing boiler instead of a hybrid heat pump. Investment incentives for hybrid heat pumps are a driver for the implementation of hybrid heat pumps in existing houses.

4 Hybrid heat pump field trial projects

Besides many private home owners that have installed hybrid heat pumps also social housing companies have implemented some interesting cases. An overview of the larger projects:

In 2017 on the island of Ameland, north of the Netherlands, the municipality and local social housing company introduced a special incentive to stimulate the amount of hybrid heat pumps on the island. In total more then 130 hybrid heat pumps were placed, which account to almost 10% of the total houses on the island. Mainly hybrid heat pumps with outside air as heat source were used. The houses were single family houses. The municipality has the vision a large part of the remaining natural gas use will be replaced by sustainable gases in the near future.

In 2016 and 2017 housing corporation Wierden en Borgen placed 100 hybrid heat pumps at single family houses in the North of the Netherlands. Hybrid heat pumps were chosen to lower the gas use of the households for the next 15 years. The inverters were surrounded with a casing to minimize noise and improve aesthetics. Renovation of the houses was not considered, since the liftetime of the houses is limited due to population decline in the region.

In Eindhoven, in the south of the Netherlands, the local social housing company Woonbedrijf placed four different types of heat pumps at 40 single family houses. The installation were closely monitored and achieved on average almost 70% natural gas savings on the space heating demand.

Part II – Reference cases

Reference case – Existing "average" house

Description

Terraced house, medium-sized, not too well insulated. Medium temperature heat distribution, may be improved with convectors or underfloor heating. Hybrid provides accessible and relatively cheap way to save CO_2. Immediate savings possible, no dependence on building measures.

Importance

Hybrid systems are expected to become a major alternative for standard boiler. These "average houses" correspond to 1/3 of all Dutch houses.

Potential natural gas savings

Group of average houses:	ca. 50%
Total over NL:	ca. 10 – 15%

Potential CO_2 savings

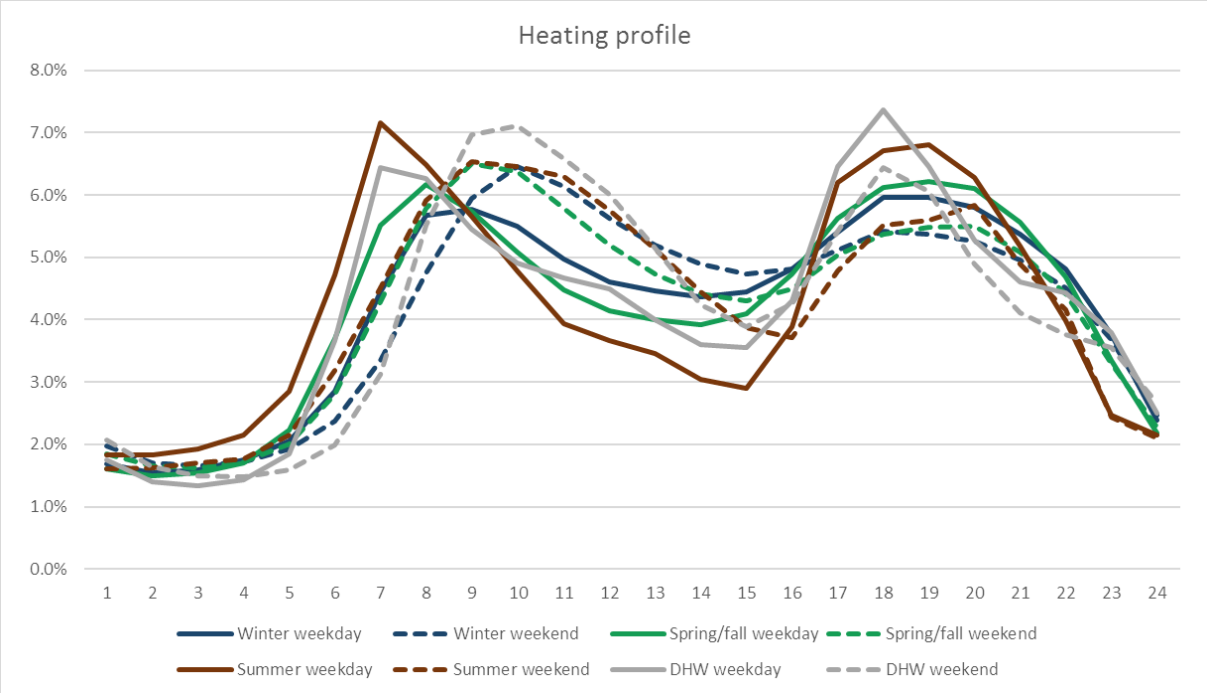
Group of average houses:	ca. 20%
Total over NL:	ca. 5 – 8%

House characteristics

Terraced house

Medium-sized:	120 m^2
Built year:	1960 – 1990
Insulation:	Medium
Heat demand:	30 – 50 GJ (70 – 115 kWh / m^2)
DHW demand:	7 GJ (1950 kWh)
Cooling demand:	0 GJ

Heating profile



System layout

Outside air source, HP capacity 3 – 5 kW.
With this setup, 50 – 70% of space heating volume is covered.

Switch to boiler @ ca. 0 °C -> Even before max capacity is reached, switch is effected. This is needed because of no low temperature heat transfer is possible. Thus, coverage never reaches above approximately 70%.

Obstacles

In some cases, space constraints will pose a real problem.

Number of knowledgeable installers still way too small.

The biggest hurdle, however, is the lack of customer knowledge / acceptance.

Economy is presently not optimal, but enough to justify investment, provided enough liquidity can be provided.

Potential

Up to 2 million houses out of 7.5 million total houses in NL
[only this reference case, total up to 4.5 million houses eligible for hybrids]

Market share of hybrids could reach over 50% of all new-sold installations.

Reference case – Existing small house / appartment

Description

Small house (apartment). Not too well insulated. Medium temperature heat distribution, may be improved with convectors. Hybrid provides one of few ways to access CO_2 savings. Other options (e.g. PV) not readily available.

Importance

Hybrid systems are expected to be major "add-on" to ventilation systems. Appartments correspond to 30% of all Dutch houses.

Potential natural gas savings

Group of appartments:	ca. 60%
Total over NL:	ca. 10 – 15%

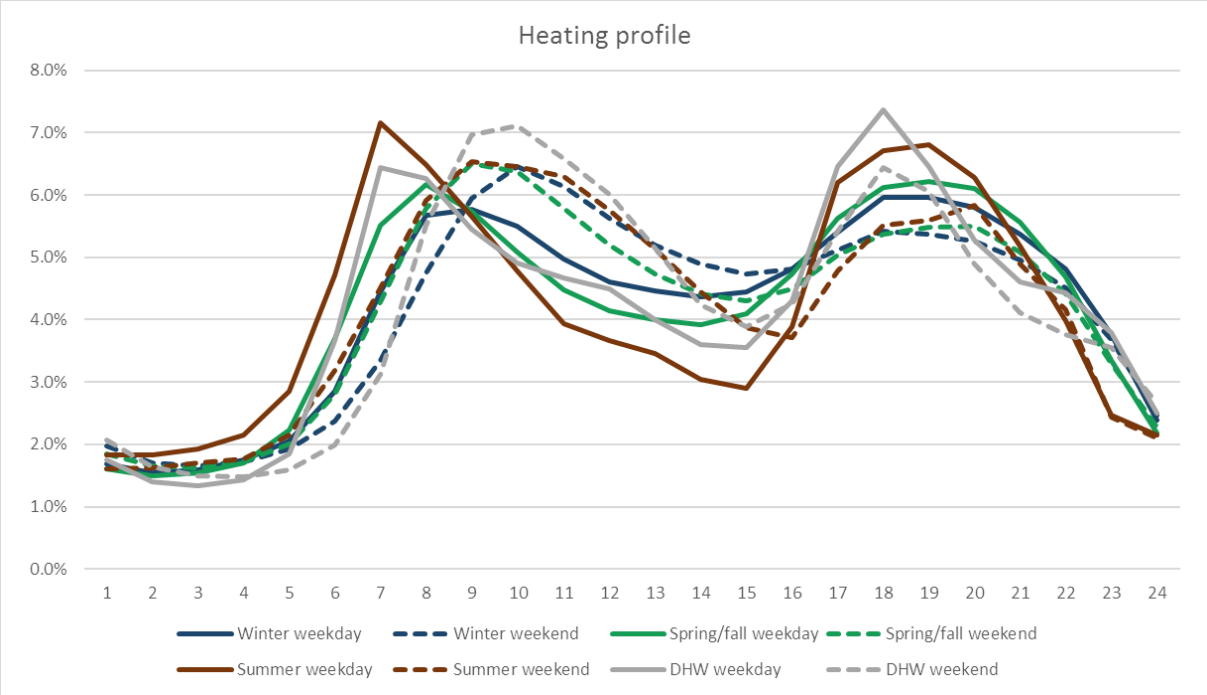
Potential CO_2 savings

Group of appartments:	ca. 30%
Total over NL:	ca. 6%

House characteristics

Appartment, Small:	50 – 90 m^2
Built year:	1960 – 1990
Insulation:	Medium
Heat demand:	20 – 25 GJ (80 – 100 kWh / m^2)
DHW demand:	5 GJ (1400 kWh)
Cooling demand:	0 GJ

Heating profile



SYSTEM LAYOUT

Exhaust air (ventilation) source, HP capacity max 1.5 kW.
With this setup, 70 – 80% of space heating volume is covered.

Switch to boiler not dependent on outside temperature, but max capacity of ventilation system limits heating contribution.

OBSTACLES

In some cases, space constraints will pose a real problem.

Number of knowledgeable installers still way too small.

The biggest hurdle, however, is the lack of customer knowledge / acceptance.

Economy is presently not optimal, but enough to justify investment, provided enough liquidity can be provided.

POTENTIAL

Up to 1.5 million houses out of 7.5 million total houses in NL
[only this reference case, total up to 4.5 million houses eligible for hybrids]

Market share of hybrids could reach over 50% of all new-sold installations.

Reference case – "Hard to treat" houses

Description

Large, old house. (Very) limited insulation. Often monumental status or severe building-related constraints for energy saving. Typically high temperature heat distribution. Hybrid systems provide one of few possible solutions for renewable heating.

Importance

Very few solutions available for these houses, so hybrid systems (perhaps combined with 'green gas'). May prove major installation type (next to district heating) as energy use requirements tighten.

These cases are only small part of the market (<5%), but hybrids are virtually only available solution for these houses.

Potential natural gas savings

Group of "hard to treat" houses:	ca. 40%
Total over NL:	hardly significant

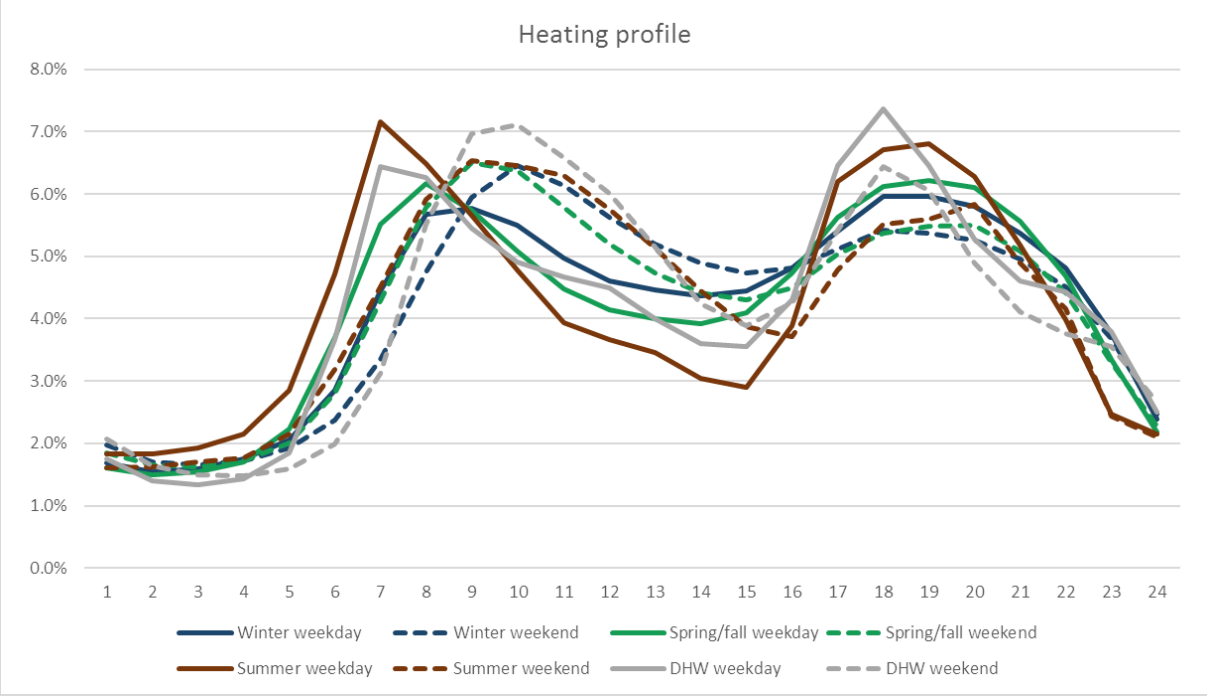
Potential CO_2 savings

Group of "hard to treat" houses:	ca. 10 – 20%
Total over NL:	hardly signigicant

House characteristics

Large:	150 – 200 m^2
Built year:	pre-1940
Insulation:	Bad
Heat demand:	60 – 90 GJ (95 – 140 kWh / m^2)
DHW demand:	9 GJ (2500 kWh)
Cooling demand:	0 GJ

Heating profile



SYSTEM LAYOUT

Outside air source, HP capacity up to 10 kW.

With this setup, 30 – 50% of space heating volume is covered.

Switch to boiler certainly above 0 ^{o}C, possibly earlier because of capacity demand & high temperature demand from heating distribution.

OBSTACLES

Building constraints may be problematic.

Monumental or 'heritage' standards may provide obstacle for outdoor unit.

Number of knowledgeable installers still way too small.

Economy is presently not optimal, but enough to justify investment. Liquidity not expected to be problematic in this group of house-owners.

POTENTIAL

Several 100k houses in NL.

Reference case – Multifamily house

DESCRIPTION

Collection of apartments with collective heating system. Typically, heat distribution is old and high temperature. Small improvements in heat distribution possible with convectors, but major renovation would be advisable in many cases. Other renewable options (PV, solar thermal) face lack of roof surface (relative to number of apartments in the building). All-electric HP not possible due to high distribution temperature in winter.
Hybrid system provide good balance between TOC & CO_2-savings in building's central heating room -> separate HP and boiler components allow perfect capacity sizing and balance between savings, running hours, maintenance etc.

IMPORTANCE

Hybrid systems are expected to play a modest role in multifamily buildings. Major renovation will be needed anyways in many cases; implementation of all-electric options seems more logical in those cases.
Still, about 1/4 - 1/3 of apartment buildings with central heating system are expected to be fit for hybrid solutions. This amounts to 500k – 800k apartments, equivalent to 12.5k – 20k buildings.

Potential natural gas savings

Per building:	ca. 50%
Total over NL:	ca. 5%

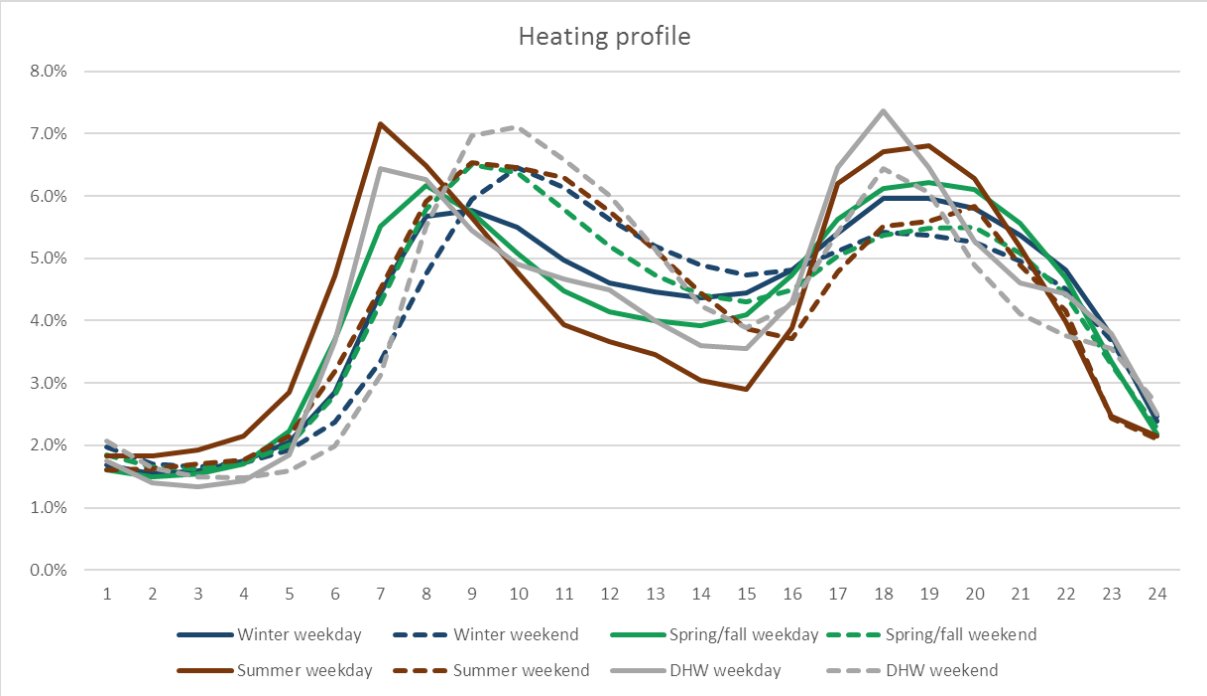
Potential CO_2 savings

Per building:	ca. 20%
Total over NL:	ca. 2%

HOUSE CHARACTERISTICS

Appartment, Small:	50 – 90 m^2
Built year:	1960 – 1990
Insulation:	Medium
Heat distribution:	mostly high temperature, in some cases hot water through same system (in that case, hybrid solution not possible)
Heat demand (p. apartment):	20 – 25 GJ (80 – 100 kWh / m^2)
DHW demand (p. apartment):	5 GJ (1400 kWh)
Cooling demand:	0 GJ

HEATING PROFILE



SYSTEM LAYOUT

Outsideair source. Separate HP and boiler components. Sizing optimized for specific building type, layout and technical constraints.

OBSTACLES

Major hurdle is heating temperature level. In a significant number of multifamily buildings, heating is provided through a circulation system. A permanent high-temperature flow is then needed, which makes hybrid systems impossible.

Number of knowledgeable installers still way too small.

Economy is presently not optimal, but enough to justify investment, provided enough liquidity can be provided.

POTENTIAL

500k – 800k apartments, equivalent to 12.5k – 20k buildings.