Grant Agreement no. 285158 - HEAT4U Collaborative project

HEAT4U
"Gas Absorption Heat Pump solution for existing residential buildings"

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D1.1 "Report on Multi-local analysis for engineering parameters definition" and
D1.2 "*Report on survey about retrofitting value chain"*
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PP	Restricted to other program participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

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5	31.07.2013	all	Updated report D 1.1 and D1.2 with final review based on Amendment approval
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Executive summary

This deliverable represents the report of WP1 "Value Chain" in task 1.1 "Conceptual design and value analysis of a GAHP system architecture for space heating and DHW in residential applications" and in task 1.2 "Survey on building retrofitting value chain".

The activities and result of both tasks have been combined into this deliverable.

It does contain a systematic study of a multi-local parametric analysis in order to define the characteristics of the GAHP system which better fits the needs of the European Market.

Detailed information has been gathered from market research and is mirrored with local sales professionals to establish a realistic view.

Experiences and known effects of the introduction of electric heat pump systems have been included into the evaluation.

This analysis does not focus on heating systems with peak boilers as this would constitute a bivalent GAHP system (Gas Absorption Heat Pump). It primarily considers monovalent systems with one heat source which is the standard in the considered market.

This analysis defines all needed requirements and details information regarding the current situation in each market with respect e.g. to building stock, type and share of heat sources, standards and building regulations and incentive programs.

Key selling points will be based on the efficiency of a GAHP air/water system that exceeds that of an boiler with solar support and that of an electrical heat pump and is therefore much better suited for the use in a retrofit situation for renovation. In addition air as renewable source compared to a borehole system for ground source provides a cost advantage.

For the success of the GAHP appliances the ability to combine the existing heating system (in particular the distribution system) without changes is essential. Ideally a GAHP system can be treated like a known heating system fitted with a condensing boiler. Requested heat demand has to be provided as with condensing appliances. Installers of the European market expect the same installation time and handling as a condensing appliance, maintenance and serviceability like standard heating appliances.

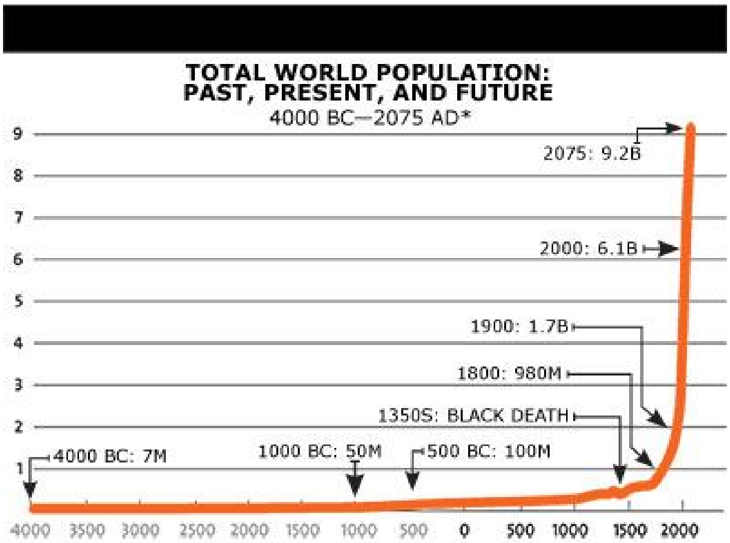
The result of the analysis indicates that to fulfill the majority of the residential dwelling (semidetached and detached) in terms of space heating and DHW (with limited buffer tank) a nominal power of 18kW would be needed. Ideally for a design load of 18 kW for a retrofitted house the market request is that the appliance should provide 18 kW at peak demand during the heating season.

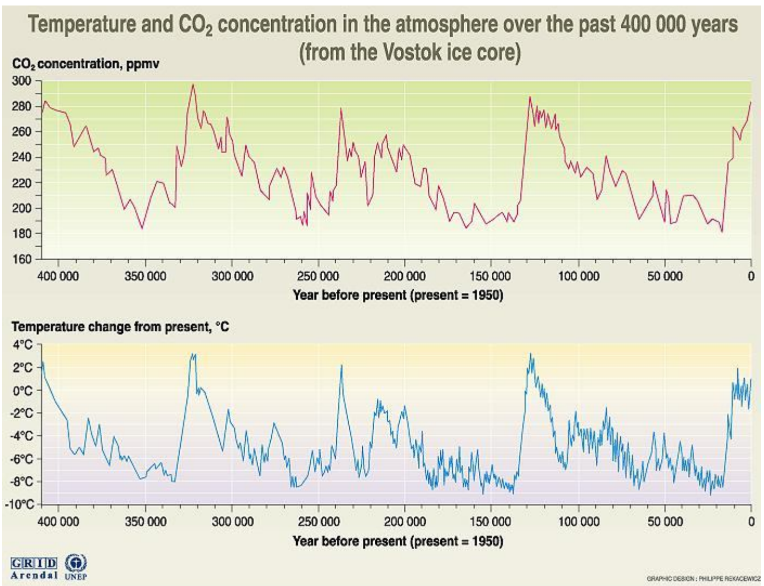
GAHP systems potentially provide significantly better power and efficiency stability than EHP (Electrical Heat Pump) Systems. Nevertheless providing lower capacity in winter times imposes either to select a bigger appliance or install an additional peak boiler. This drives extra costs and possible disadvantages in space and installation. Therefore further evolution in this direction will be need by technological research since the EU market asks for a standalone solution without support of additional heating systems (peak boiler).

1. Energy: heating is the opportunity for Europe

1.1. The European Challenge

The incumbent environmental pressure on energy policy makers is driven both from the demographic growth on a world wide basis and by the indirect consequence of the economic development in developing countries that is fuelling worlds’ CO2 emissions. The following graphs summarize these elements that are creating concerns over the sustainability of the current energy policies.



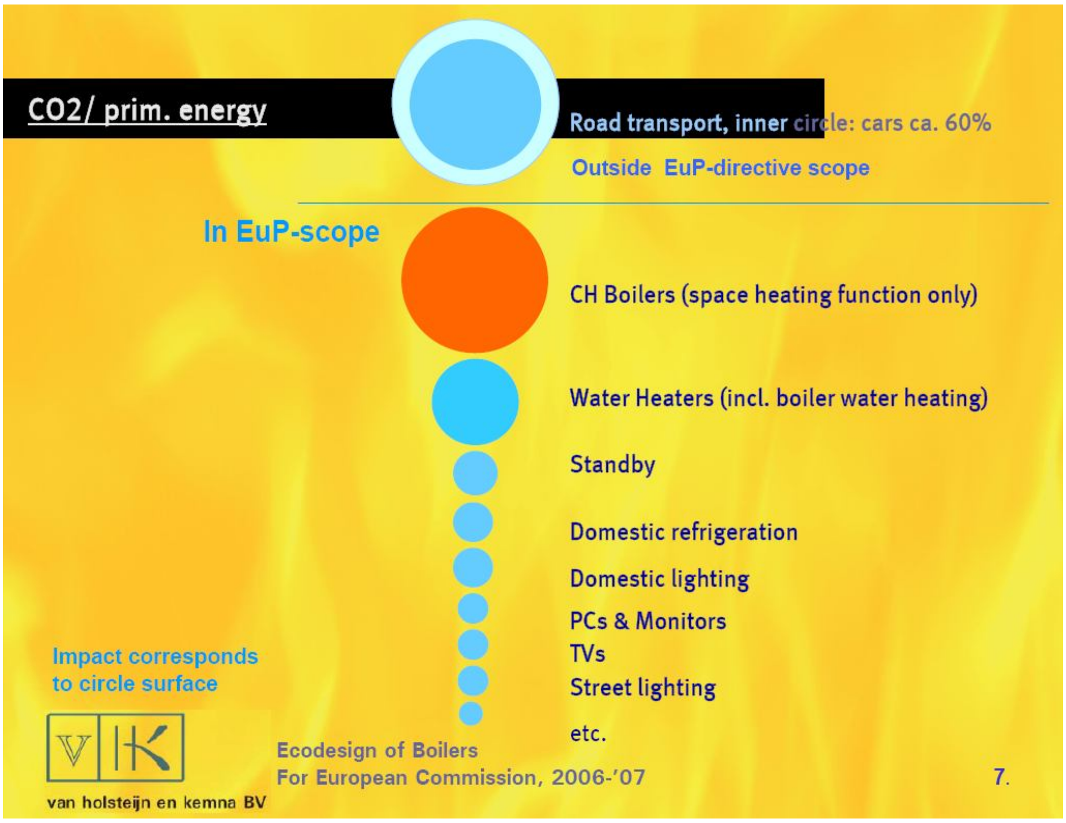


Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

The European Commission has shown a high level of active support for initiatives aimed at mitigating the impact of emission at European level. In order to address this challenge the EU has identified uses of energy, their specific emissions and the potentials for reduction.

With reference to the energy used directly by citizens (vs. energy used in the industry or energy used in conversion of energy) EU has released the Ecodesign Directive aimed at improving the energy efficiency/consumption of all appliances used by end users.

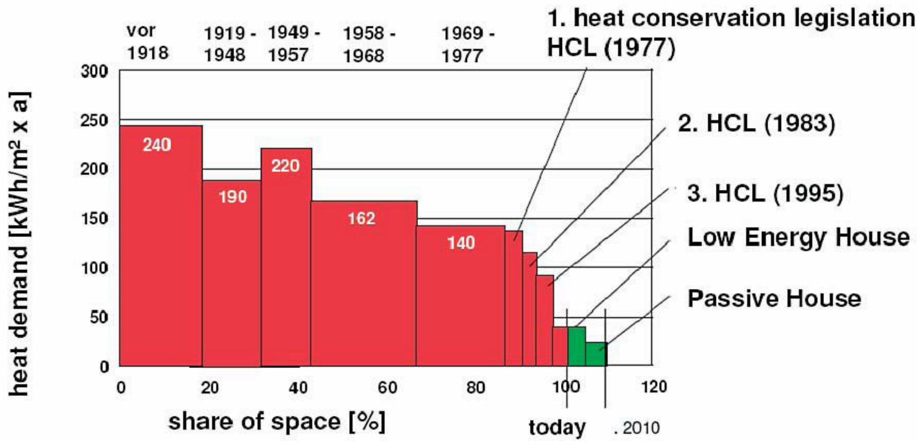
In the ranking of the energy use two categories of product consume approximately 80% of total energy used in Europe: transportation and heating (Central Heating and Domestic Hot Water).

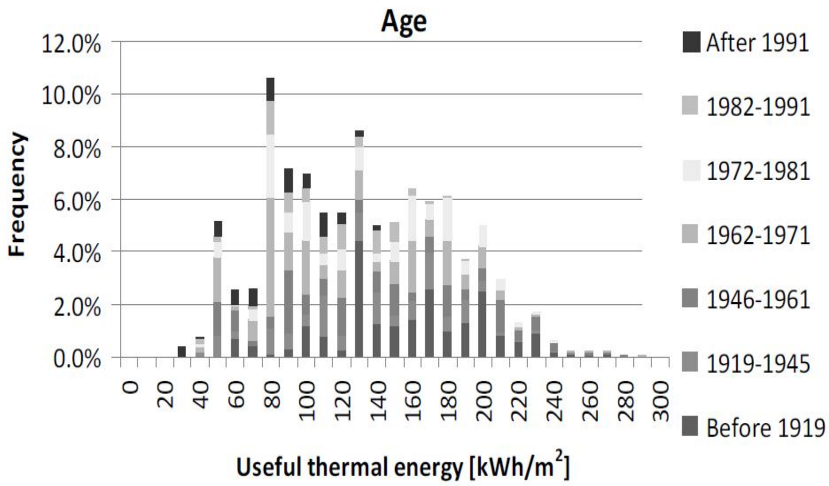


Indeed the EU building construction industry consumes the highest percentage of energy (40%) and is the largest contributor to produce greenhouse gas emissions (with a 36% of total CO2 emissions in the EU).

1.2. European buildings

The challenge of energy consumption of heating function is closely related to the building, particularly its insulation. The quality of the building (expressed in terms of kWh/m²/annum) is very poor across Europe. Only very recent building achieve values in the order of 25 kWh/m²/annum, while the majority of the building in Europe still feature specific consumption of 150 or more kWh/m²/annum. The graph here below exemplifies the quality of the building in Germany and in Italy.





The European Commission imposed drastic reduction in consumption of existing buildings (from 300 kWh/m²/annum to less than 50 kWh/m²/annum) and the result of such impressive targets can already be measured by the very high efficiency reached in the new buildings (“Class A”, “Gold Class” “Passive house”, ‘Energy Plus House’, etc.).

Consequently the challenge for Europe is not only the one of imposing severe standards for new buildings, but in particular managing the transition of the existing building stock toward higher level of energy efficiency.

Unfortunately the building stock evolves very slowly. Indeed the renovation rate in Europe is approx. 1% per annum (new building on existing building stock). Therefore approximately 80% of dwellings of 2030 already exist today. It is of paramount importance to identify solutions for these buildings. Indeed the Ecofys study (see graph below) indicate that even if all “new-building” and “renovation” will adopt the latest standard for the energy consumption, by 2020 only a marginal contribution will be delivered to the overall consumption of energy for heating.

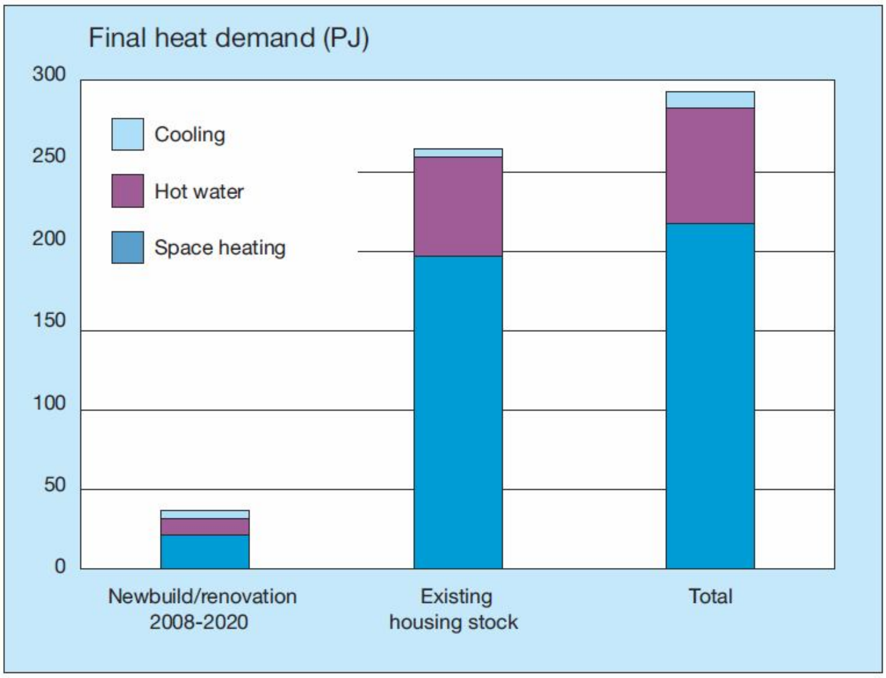


Figure 20 Demand for heating and cooling in newbuild and existing dwellings, 2020 (Global Economy). *Source: Ecofys (2007)*

Last but not least, European building stock features an additional level of complexity: 30% of buildings are historical buildings and their historical and cultural (and economic) value is associated with their envelopes (exterior walls and roofs). These buildings represent an additional challenge in terms of insulation with currently available technologies.

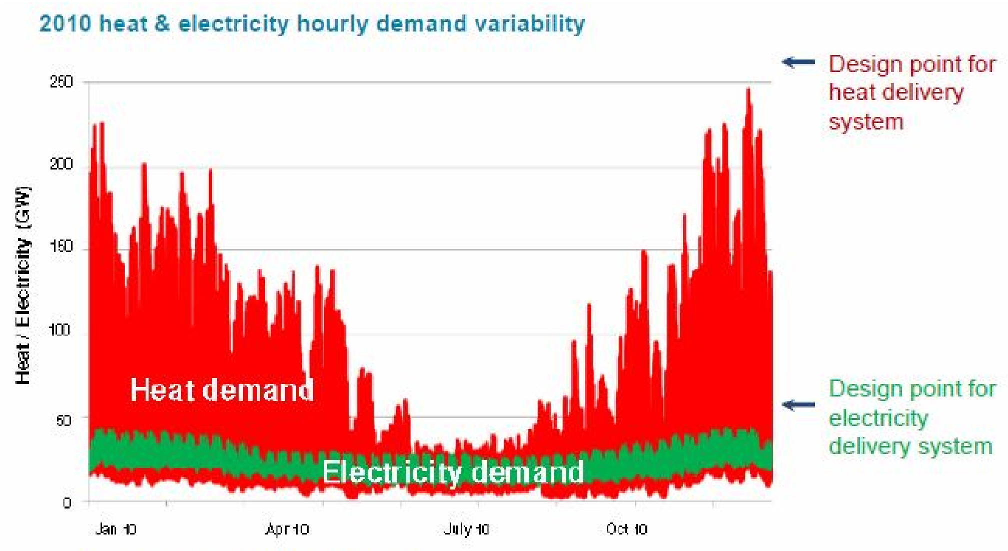
In conclusion technological solutions that can quickly allow for energy efficiency in existing building without imposing major retrofitting activities and not relying only on envelop insulation are highly welcomed to accelerate the reduction in energy consumption and CO_2 emissions.

1.3. Gas vs. electricity

When discussing heating in Europe, the fact that this function is currently largely dominated by fossil energy (gas and oil) need to be considered. Several considerations have recently appeared in the media about possible “electrification of heating” (transitioning the heat toward the electrical vector). Electrification of heating is very often a synonym for simultaneous development of the two necessary building blocks: Heat Pump and Smart Grid.

While in the next sections the concept of electrical heat pump will be discussed in detail in comparison with the GAHP technology at application level, here are a few considerations of implications at infrastructure level.

In the UK, the DECC (Department of Energy and Climate Change) has hypothesized the electrification of heating as a possible solution to decarbonizes the UK. The Energy Technology Institute modeled in a recent study the effect that such electrification of heating might drive on electrical systems.



Source: Energy Technologies Institute, 2012

As shown not only the overall electrical grid (generation, transmission and distribution) will need to be designed for peak of demand (that is several time the current demand), but in particular this load (heating) is highly seasonal and as such will create a significant issue in terms of return on investment for such huge investments.

Indeed the existing gas grid is capable of transporting and storing large amount of energy in a cost effective way as described in the following slides (source: GasNaturally).

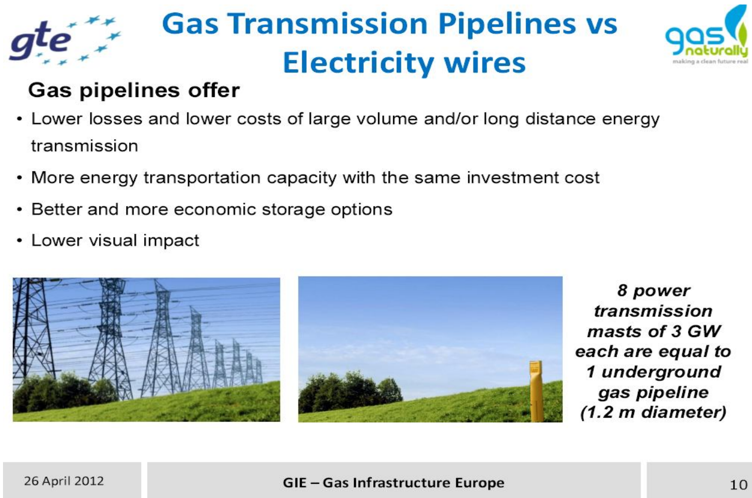
Gas Transmission Pipelines vs Electricity wires

	Britned (NL-UK)	BBL (NL – UK)
Length	235 km	260 km
Budget	500 M€	600 M€
Capacity	**1000 MW**	**≈ 17000 MW**

- Similar Length, similar capital , but

→ **Gas capacity = 17 times electricity capacity!**

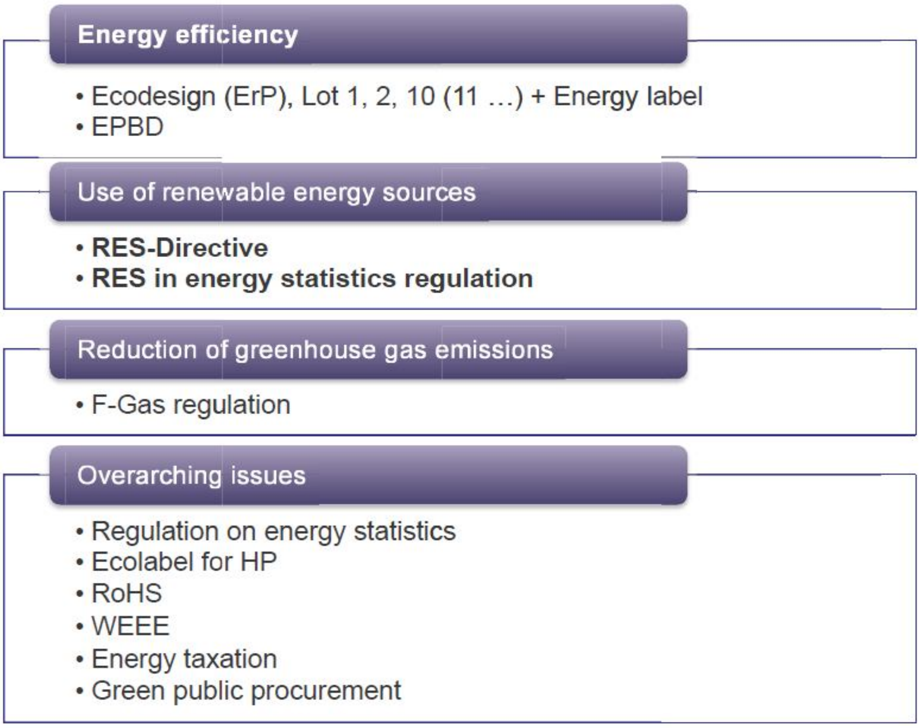
→Transport of energy in the form of gas is much cheaper than by electricity!



In conclusion technological solutions that can allow for energy efficiency improvement without affecting the existing grid are highly welcomed to avoid the time and the costs associated with the development of smart grids and the required electrical infrastructure.

1.4. European and national norms

The European Commission is working on an agenda where parallel initiatives and measures are planned simultaneously to mitigate the energy consumption and increasing the use of renewable energy. With reference to the heating and building construction the following measures are among the most prominent ones.



These measures are defining a background scenario which is very favorable to the growth of technological solutions that improves energy efficiency in the heating industry. The local national governments in implementing these measures by means of local norms create incentive programs and mandatory thresholds that are consistently driving the industry (utilities, manufacturers, developers/construction industry, planners, end users, public administration) upward in terms of energy efficiency and use of renewable sources.

1.5. National Incentive Programs

In order to obtain a complete and realistic market study we have taken into account one of the elements that can significantly contribute to promote the diffusion Gas Absorption Heat Pump Technology in the market: the financial and tax subsidy systems at European and national level, that promote energy efficiency in buildings and products that use renewable energy sources advantageously.

It should be emphasized that, recently, the policy measures in this direction are being intensified, fuelled by a growing awareness of the risks associated with the security of energy supply, the rising of the energy costs and the environmental impact of non-renewable energy. Here below is a summary of the incentive schemes on energy efficiency of buildings through the use of renewable energies in some representative European countries is presented.

1.5.1. Italy – Conto Energia Termico

Beneficiaries admitted to the incentives:

- Public Administration – 200 millions € (for calendar year 2013)
- Private individuals – 700 millions € (for calendar year 2013)

Eligible interventions to increase energy efficiency in existing buildings:

- Thermal insulation of building envelope
- Replacement of windows
- Replacement of existing heating systems with heating systems using condensing heat generators
- Installation of shielding and/or shading systems

The following interventions on small production of thermal energy from renewable sources and high efficiency systems are also admitted:

- Replacement of existing air conditioning systems with heating systems with **heat pumps, electric or gas**, using aerothermal, geothermal or hydrothermal energy
- Replacement of heating systems in greenhouses and existing rural buildings with heating systems based on biomass
- Installation of solar thermal collectors, also combined with solar cooling systems
- Replacement of electric water heaters with heat pump

Duration of the incentive as per following table:

Action	*Persons admitted*	*Duration (years)*
Thermal insulation of surfaces bounding the volume air-conditioned	Public Administration	5
Replacement of locks and fixtures	Public Administration	5
Replacement of existing air conditioning systems with heating systems using condensing heat generators	Public Administration	5
Installation of shielding and/or shading systems	Public Administration	5
Replacement of existing air conditioning systems with heating systems with **heat pumps, electric or gas based**, even geothermal with nominal power lower than 35 kW	Public Administration and private individuals	2
Replacement of existing air conditioning systems with heating systems with **heat pumps, electric or gas** based, even geothermal with nominal power greater than 35 kW e and lower than 500 kW	Public Administration and private individuals	5

Minimum criteria for GAHP eligibility see following table:

Tabella 2 - Coefficienti di prestazione minimi per pompe di calore a gas

Tipo di pompa di calore Ambiente esterno/interno	Ambiente esterno [°C]	Ambiente interno [°C]	GUE
aria/aria	Bulbo secco all'entrata : 7 Bulbo umido all'entrata : 6	Bulbo secco all'entrata: 20	1,46
	Bulbo secco all'entrata: -7(**)		1,1 (**)
aria/acqua	Bulbo secco all'entrata : 7 Bulbo umido all'entrata : 6	Temperatura entrata: 30(*)	1,38
	Bulbo secco all'entrata: -7(**)		1,1 (**)
salamoia/aria	Temperatura entrata: 0	Bulbo secco all'entrata: 20	1,59
salamoia/ acqua	Temperatura entrata: 0	Temperatura entrata: 30(*)	1,47
acqua/aria	Temperatura entrata: 10	Bulbo secco all'entrata: 20	1,60
acqua/acqua	Temperatura entrata: 10	Temperatura entrata: 30(*)	1,56

(*) Δt : pompe di calore ad assorbimento: temperatura di uscita di 40°C. Pompe di calore a motore endotermico: temperatura di uscita di 35°C

(**) Requisito valido esclusivamente per installazioni in zona climatica E o F.

Incentive is calculated on the bases of renewable energy generated as per following table:

Tabella 4 – Coefficienti di valorizzazione dell'energia termica prodotta da pompe di calore.

Tipologia di intervento	C_i per gli impianti con potenza termica utile nominale inferiore o uguale a 35 kWt	C_i per gli impianti con potenza termica utile nominale maggiore di 35 kWt e inferiore o uguale a 500 kWt	C_i per gli impianti con potenza termica utile nominale maggiore di 500 kWt
Pompe di calore elettriche	0,055 (€/kWht)	0,018 (€/kWht)	0,016 (€/kWht)
Pompe di calore a gas	0,055 (€/kWht)	0,018 (€/kWht)	0,016 (€/kWht)
Pompe di calore geotermiche elettriche	0,072 (€/kWht)	0,024 (€/kWht)	0,021 (€/kWht)
Pompe di calore geotermiche a gas	0,072(€/kWht)	0,024 (€/kWht)	0,021 (€/kWht)

Documents to be produced:

- Energy certificates before and after replacement
- Technical data on component/equipment used
  - Different performance thresholds are quested for different HP technologies (current appliances based on absorption technology exceed minimum threshold)
  - For air source equipment installed in coldest regions of Italy minimum performance threshold at -7 C is imposed)
- Asseveration by a certified technician
- Invoices and bank payments
- Declaration of conformity

1.5.2. Germany - BAFA

Aim:

- Promoting efficient heat pumps in existing buildings for:
  - Combined space heating and hot water production in residential buildings
  - Space heating of non-residential buildings
  - Provision of process heat or heat for heating networks

Application:

- A list of eligible heat pumps that exceed minimum threshold of (PER 1.3 according to VDI4650-2) has been created that includes also GAHP heat pumps.

Beneficiaries admitted to the incentives:

- Individuals, communities, municipalities, municipal utility companies and nonprofit organizations.
- The application must reach the BAFA within 6 months after commissioning of the plant.
- The following documents must be submitted for this purpose:
    - the output produced by the installer application for funding
    - the specialist contractor statement
    - the full statement, addressed to the applicant / applicants
- Small or medium sized enterprises (SMEs), contractors, SMEs where the majority of local authorities are involved, or the self-employed, agriculture, forestry, horticulture. Applications must be submitted before starting the project.

Eligibility criteria:

- Efficient heat pumps are eligible for combined water and space heating in buildings, and clean heating of non-residential buildings.
- The heat pump must be installed in an existing building.
- There must be electricity or gas meter, and at least a heat meter for measuring the largest heat quantity of the processing plant.
- Hydraulic balancing of the heating system is carried out.
- At least the heat pump in the heating system complies with the efficiency of Class A or with the energy efficiency index EEI. This is demonstrated by presentation of the invoice (copy). The manufacturer and the model number must be obtained from the bill.

Depending on the design, at least the following annual numbers were detected:

- COP 3.8 in water and with brine / water heat pumps residential buildings
- COP 4.0 with water and brine / water heat pumps in non-residential buildings
- COP 3.5 at air/water heat pumps
- PER 1.3 for gas-powered heat pumps

The time required for the calculation of the seasonal performance COP/PER is demonstrated by a test report from an independent testing institute. Even the EHPA heat pump quality seal is recognized.

Base funding:

- Electric air/water heat pumps: 1,300 Euro inclusive flat rate for systems up to 20 kW, 1,600 Euro for systems from 20 kW to 100 kW
- Electric water/water and brine/water heat pumps or gas heat pumps: 2,800 Euro flat in systems up to 10 kW. In addition, each additional kW with 120 Euro (for systems up to 20 kW) or 100 Euro promoted (for systems up to 100 kW).
- In systems with newly built buffer (at least 30l/kW), the base funding increased by 500 each Euro.

Bonus Promotion:

- Regenerative combination bonus: In addition to the base funding for the establishment of an eligible heat pump a bonus can be granted if at the same time an eligible solar energy for space and water heating or solar hot water is installed.
- Efficiency bonus: The efficiency bonus may be paid in addition to the base funding if the eligible heat pump serves a particularly efficient insulated dwellings.

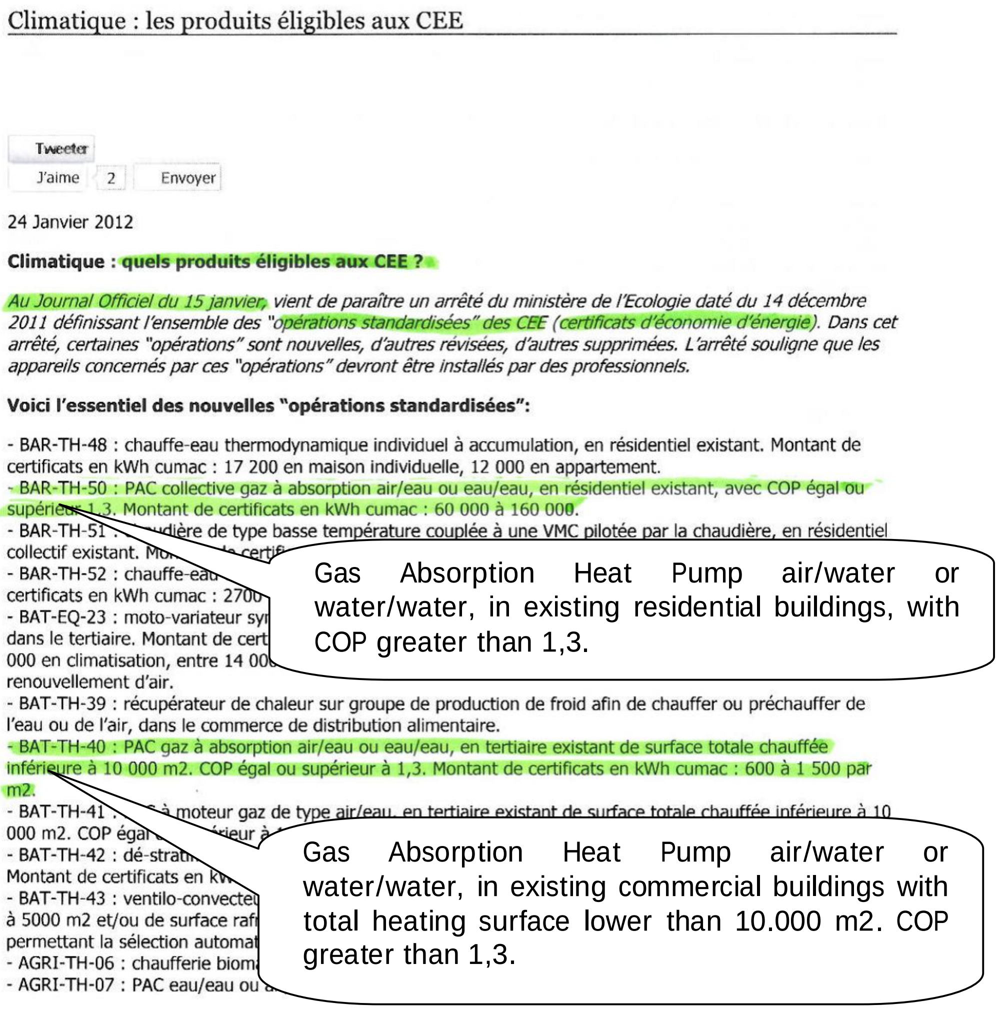
More info on http://www.bafa.de/bafa/de/energie/erneuerbare_energien/waermepumpen/index.html.

1.5.3. France – Certificats d'Economies d'Energie (CEE)

The certificates for energy savings (EEC) device, established by Articles 14 and 17 of Law No. 2005-781 of 13 July 2005 setting the direction of energy policy in France, is the one of the key instruments for the political control of energy demand.

This system is based on an obligation of achieving energy savings imposed by the government on energy sellers called "obligés" (electricity, gas, heat, cooling, heating oil and motor fuels newly). They are thus encouraged to actively promote energy efficiency among their customers: households, local and professional communities.

A three-year goal is defined and divided between operators according to their sales volumes. At the end of this period, the energy sellers must justify the fulfillment of their obligations by holding an equivalent amount of certificates to these obligations. The certificates are obtained by actions taken by the operators own or by purchasing from other actors leading energy saving operations. In case of non compliance with their obligations, they must pay a penalty of two cents per kWh missing. Certificates of energy savings are attributed, under certain conditions, by the services of the Ministry of Energy, to eligible participants implementing energy savings activities.



Climatique : les produits éligibles aux CEE

Tweeter
J'aime 2 Envoyer

24 Janvier 2012

Climatique : quels produits éligibles aux CEE ?

Au Journal Officiel du 15 janvier, vient de paraître un arrêté du ministère de l'Ecologie daté du 14 décembre 2011 définissant l'ensemble des "opérations standardisées" des CEE (certificats d'économie d'énergie). Dans cet arrêté, certaines "opérations" sont nouvelles, d'autres révisées, d'autres supprimées. L'arrêté souligne que les appareils concernés par ces "opérations" devront être installés par des professionnels.

Voici l'essentiel des nouvelles "opérations standardisées":

- BAR-TH-48 : chauffe-eau thermodynamique individuel à accumulation, en résidentiel existant. Montant de certificats en kWh cumac : 17 200 en maison individuelle, 12 000 en appartement.
- BAR-TH-50 : PAC collective gaz à absorption air/eau ou eau/eau, en résidentiel existant, avec COP égal ou supérieur 1,3. Montant de certificats en kWh cumac : 60 000 à 160 000.
- BAR-TH-51 : …udière de type basse température couplée à une VMC pilotée par la chaudière, en résidentiel collectif existant. Mo… certifi…
- BAR-TH-52 : chauffe-eau… certificats en kWh cumac : 2700…
- BAT-EQ-23 : moto-variateur sy… dans le tertiaire. Montant de cert… 000 en climatisation, entre 14 00… renouvellement d'air.
- BAT-TH-39 : récupérateur de chaleur sur groupe de production de froid afin de chauffer ou préchauffer de l'eau ou de l'air, dans le commerce de distribution alimentaire.
- BAT-TH-40 : PAC gaz à absorption air/eau ou eau/eau, en tertiaire existant de surface totale chauffée inférieure à 10 000 m2. COP égal ou supérieur à 1,3. Montant de certificats en kWh cumac : 600 à 1 500 par m2.
- BAT-TH-41 : …C à moteur gaz de type air/eau, en tertiaire existant de surface totale chauffée inférieure à 10 000 m2. COP égal… …érieur à…
- BAT-TH-42 : dé-strati… Montant de certificats en kW…
- BAT-TH-43 : ventilo-convecteu… à 5000 m2 et/ou de surface raf… permettant la sélection automat…
- AGRI-TH-06 : chaufferie bioma…
- AGRI-TH-07 : PAC eau/eau ou a…

Therefore the French system of CEE explicitly recognize GAHP technology as a mean to satisfy the national obligations and incentive the GAHP deployment.

More info on http://conseils.xpair.com/actualite_thermpresse/climatique-produits-eligibles-cee.html.

1.5.4. France – Réglementation Thermique 2012 (RT 2012)

This law enforce starting 01 January 2013 in all France Energy Efficiency minimum threshold for new buildings.

Objectives:

- Reduce energy consumption and greenhouse gas emissions
- Encourage the development of new technologies
- National energy independence

Aim:
The Réglementation Thermique 2012 (RT 2012) sets the new minimum standard of thermal insulation of dwellings and other types of construction in France. It will be applicable to all new planning applications submitted for non-residential buildings from Oct 2011 and for all new residential properties from January 2013.
Although a complex set of standards, the regulations require that all new dwellings must have an energy consummation level less than 50 kWh/m2 per year, although varied by locality and altitude within the range 40kWh/m2 to 65kWh/m2.

Application:

- Applicable to new residential and non-residential buildings
- Calculating consumption for heating, domestic hot water (DHW), lighting, air conditioning, ventilation and auxiliaries
- Set on the performance label BBC-Effinergie

Field of application:

- Buildings or parts of buildings with office and teaching uses, buildings or parts of buildings dedicated to the early childhood and buildings or parts of buildings for residential use.

The French institution CERTITA has published test reports of most of the HPs (EHP and GAHP) tested for compliance with RT2012 criteria. These reports confirm that according to the same independent laboratory that GAHP performance exceed EHP ones significantly when compared in terms of primary energy consumption.

More info on http://www.developpement-durable.gouv.fr/La-RT2012-un-saut-energetique-pour.html.

1.5.5. United Kingdom – RHI

Application and beneficiaries admitted to the incentives:
The program provides two phases:

- A long-term tariff support targeted at the big emitters in the non-domestic sector. This sector, which covers everything from large-scale industrial heating to small business and community heating projects, will provide the vast majority of the renewable heat needed to meet the targets and represents the most cost-effective way of increasing the level of renewable heat. As part of the first phase, the Government will also introduce *Renewable Heat Premium Payments* for the domestic sector, with funding of around £15 million, which will be used to make premium payments to households who install renewable heating. These direct payments will subsidize the cost of installing qualifying renewable heating systems. In return for the payments, participants will be asked to provide some feedback on how the equipment works in practice and suppliers will be asked to provide a follow up service on any issues that are raised. This will boost confidence in the technology and the information received will help enable Government, manufacturers, installers and consumers to better understand how to maximize performance of the various technologies. The Renewable Heat Premium Payments will support a spread of technologies across all regions of Great Britain and will cover households using gas and other fossil fuels. The support will be focused on *primary* heating systems, such as heat pumps and biomass boilers, on households off the gas grid, where fossil fuels like heating oil are both more expensive and have higher carbon content.
- A second phase of RHI support including long-term tariff support for the domestic sector coincides with the introduction of the Green Deal for Homes. People in receipt of the Renewable Heat Premium Payments will be able to receive long term RHI tariff support once these tariffs are introduced as will anybody who has installed an eligible installation. In the second phase, it will also be considered introducing support for a number of other technologies and fuels which are not supported from the outset. Given the current economic climate it is more important than ever that the RHI delivers value for money and ensures there is a fair spread of technologies across a range of properties types. The Renewable Heat Premium Payments will help ensure that, before committing to long term payments in a sector where it is difficult to predict levels of take-up and levels of performance of the different heat technologies, we manage their roll-out and learn more about them, as well as controlling budgets and ensuring the money goes where it is intended to.

Eligibility criteria:
The key aspects of the RHI tariffs from 2011 for the non-domestic sectors will be:

- Support for a range of technologies and fuel uses including solid and gaseous biomass, solar thermal, ground and water source heat-pumps, on-site biogas, deep geothermal, energy from waste and injection of biomethane into the grid
- Support for all non-domestic sectors including: industrial and the commercial sector; the public sector; not-for-profit organizations and communities in England, Scotland and Wales;
- RHI payments to be claimed by, and paid to, the owner of the heat installation or the producer of biomethane
- Payments will be made quarterly over a 20 year period;
- For small and medium-sized plants (up to and including 45kWth), both installers and equipment to be certified under the Microgeneration Certification Scheme (MCS) or equivalent standard, helping to ensure quality assurance and consumer protection

- Tariff levels have been calculated to bridge the financial gap between the cost of conventional and renewable heat systems, with additional compensation for certain technologies for an element of the non-financial cost
- Heat output to be metered and the support calculated from the amount of eligible heat, multiplied by the tariff level
- Biomass installations of 1 MWth capacity and above will be required to report quarterly on the sustainability of their biomass feedstock for combustion and where they are used to produce biogas
- Eligible non-domestic installations completed on or after 15th July 2009, but before the start of the RHI, will be eligible for support as if they had been installed on the date of its introduction
- The Gas and Electricity Market Authority (Ofgem) will administer the RHI including: dealing with applications; accrediting installations; making incentive payments to recipients; and monitoring compliance with the rules and conditions of the scheme

Base funding:

- The RHI will be funded from general Government spending, not through the previously proposed RHI levy.
- Non-domestic sector (as per August 2012), see following table

Tariff name	**Eligible technology**	**Eligible sizes**	**Tariff level (p/kWh)**
Small biomass	Solid biomass including solid biomass contained in municipal solid waste (incl. CHP)	Less than 200 kWth	8.3 (tier 1) 2.1 (tier 2)
Medium biomass		200 kWth and above; less than 1,000 kWth	5.1 (tier 1) 2.1 (tier 2)
Large biomass		1,000 kWth and above	1.0
Small heat pumps	Ground-source heat pumps; water source heat pumps; deep geothermal 100 kWth and above	Less than 100 kWth	4.7
Heat pumps		100 kWth and above	3.4
All solar thermal collectors	Solar thermal collectors	Less than 200 kWth	8.9
Biomethane and biogas combustion	Biomethane injection and biogas combustion, except from landfill gas	Biomethane all scales, biogas combustion, except from landfill gas	7.1

- Domestic sector (being approved), see following table.

Technology	**Air Source Heat Pumps**	**Biomass**	**Ground Source Heat Pumps**	**Solar Thermal**
Pence per kilowatt hour of heat	6.9-11.5	5.2-8.7	12.5-17.3	17.3

Currently GAHP are not yet formally recognized in UK. A group of interest including BGas and Robur is active to promote the inclusion of GAHP technology into the eligible technologies for RHI program.

More info on
http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/incentive/incentive.aspx.

2. Market analysis and geographical benchmark of Central Heating technologies

A short market analysis and geographical benchmark of Central Heating technologies available in the EU market is reported. The focus of the report was mainly devoted to developing up-to-date figures and scenarios for Gas Absorption Heat Pump deployment considering the following needs:

- to provide a building with both space heating and DHW
- residential sector
- single -family and two family dwellings mainly in suburban areas

In addition considerations have been made about the EPBD directive (substantially imposing use of renewable energy in buildings), the prospected ErP (Lot1 and Lot2) and the EcoLabel directive. In particular analysis have been detailed for further analysis and environmental comparison to the GAHP with two of most competing technologies in the frame of the project HEAT4U.

2.1. Central Heating Systems by EU27 Countries

Eurostat ProdCom data[1] concerning sales of Central Heating Systems by EU27 Countries from 2004 to 2010 have been elaborated and are reported here below. When available, figures belonging to the period 2000-2004 and referred to EU15 Countries are also reported. The data were compared to those reported in the "Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems"[2], the "2nd Technical Background Report"[3] and the "4th EHPA Market Report and Statistics 2011"[4]. Good overall consistency was found except for Heat Pumps statistics, whose data are derived from the EHPA Report. Sales figures are provided for three product categories, namely Gas/Oil Boilers, Solid Fuel Boilers and Heat Pumps. No comprehensive data were found for CHP units applied as Central Heating Systems for buildings. Data for Solar Thermal market in Europe were instead derived from European Solar Thermal Industry Federation[5]. This product category cannot be truly thought as Central Heating System as it provides DHW more than space heating if not coupled to one of the previous products.

According to chart below showing the sales of Central Heating Systems by EU27 Countries from year 2000 to year 2010, Gas-fired and Oil-fired Boilers represent the category with the highest share over Europe, worth of 75% market share both in 2006 (8 million units sold) and in 2010 (6.7 million units

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[1] European Commission – *Eurostat Prodcom Annual Data from 2000 to 2010* available at the web address http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/tables_excel

[2] Van Holsteijn, Kemna BV (VHK), *Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems, Draft Report,* Institute for Prospective Technological Studies (IPTS) of the Joint Research Centre (JRC), June 2011

[3] 2nd Technical Background Report, Working Document for 2nd AHWG-Meeting for the Development of Ecological Criteria for Hydronic Central Heating Generators, Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems, Institute for Prospective Technological Studies (IPTS) of the Joint Research Centre (JRC), November 2011

[4] European Heat Pump Association (EHPA), *4th EHPA Market Report and Statistics 2011*, http://www.ehpa.org

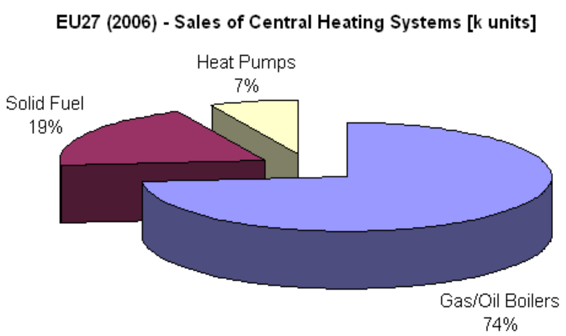
[5] *Solar Thermal Markets in Europe, Trends and Market Statistics 2010* – European Solar Thermal Industry Federation (ESTIF), June 2011, and *Solar Thermal Markets in Europe, Trends and Market Statistics 2011*, European Solar Thermal Industry Federation (ESTIF), June 2011, http://www.estif.org

sold). The sales of Solid Fuel Boilers has remained steady as well in terms of EU27 market share from 2006 to 2010, representing 18% market with 2.1 million units sold in 2006 and 1.7 million units sold in 2010. The sale of Heat Pumps accounts for 7% EU27 market share, with 0.8 million units sold in 2006 and 0.7 million units sold in 2010. These figures are in strict agreement with those concerning production of the same three product categories over EU27 Countries as reported in the previous paragraph.

From year 2006, the total number of heating products sold over EU27 Countries is decreasing. With 9 million units heating products sold in 2010, the market is reduced by almost 16% with respect to the 10.9 million units sold in 2006, most likely because of the global crisis. The Solar Thermal sector also experienced a dramatic decrease in newly installed capacity, reduced by almost 26% from 4.8 million m2 in 2008 to 3.5 million m2 in 2010.

The ongoing global economic and financial crisis continues to affect the availability of credit, and negatively influences consumer confidence and sentiment regarding any discretionary new investments. The slowdown and virtual collapse of the construction sector, particularly new build in many countries has halted activity in areas which had seen significant growth during previous years.

Product Group	2000 EU15	2002 EU15	2004 EU27	2006 EU27	2008 EU27	2010 EU27
Gas/Oil Boilers [k units]	5497	5472	7289	7976	7572	6720
Solid Fuel Boilers [k units]	722	1121	1458	2102	1756	1677
Heat Pumps [k units]	n.a.	n.a.	n.a.	785	688	675
TOTAL	-	-	-	*10863*	*10015*	*9072*
Solar Thermal [m^2]	n.a.	n.a.	n.a.	n.a.	4.786.038	3.554.940



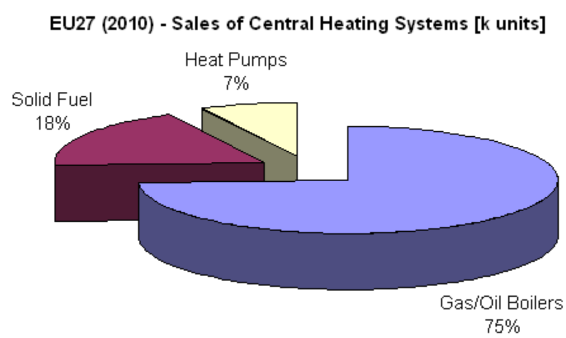
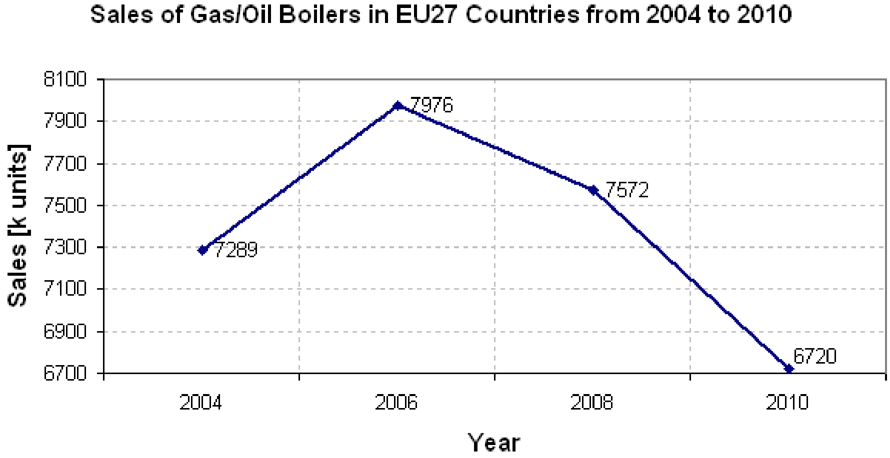


Table (top) and charts (bottom) reporting the sales of Central Heating Systems in EU27 Countries from year 2000 to 2010 (Sources: "*Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems", "Eurostat Prodcom Annual Data from 2000 to 2010"*).

2.2. Boilers

Analyzing in detail the trend of Gas/Oil Boilers, despite of a positive increase of sales from year 2004 to year 2006 – +9.5% from 7.3 million units to 8 million units, respectively – only 6.7 million units were sold in 2010. This represents a loss of 16% market. The negative trend of these last years gets even worse if the slope of the curve is considered, steeper from 2008 to 2010.

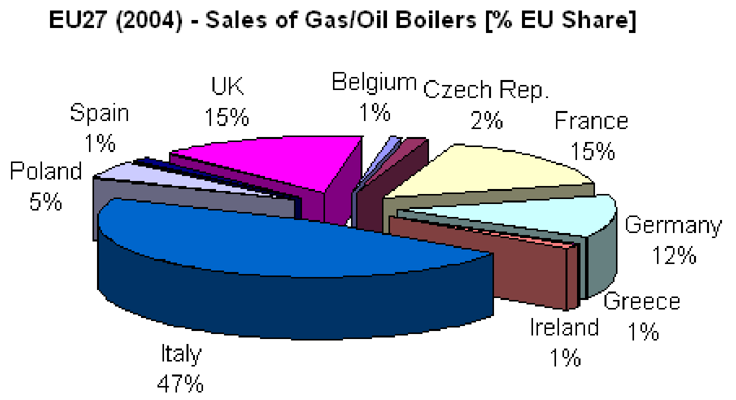


Sales of Gas/Oil Boilers in EU27 Countries from 2004 to 2010

Italy is still the dominant Country in EU27, though its market share is decreased from 47% in 2004 to only 31% in 2010. UK, Poland and Germany have a little increased their share (+2%, +2% and +4%, respectively), while France has reduced it (-6%). Portugal is the new entrant in the market (3% share). The trend is basically steady for the other EU27 countries.

Gas/Oil Boilers [k units]

	2004	2010
Austria	n.a.	42
Belgium	51	n.a.
Czech Rep.	114	152
France	993	581
Germany	801	1048
Greece	34	7
Ireland	87	82
Italy	2985	2101
Netherlands	n.a.	612
Poland	302	448
Portugal	1	165
Slovakia	n.a.	173
Spain	84	53
UK	986	1111



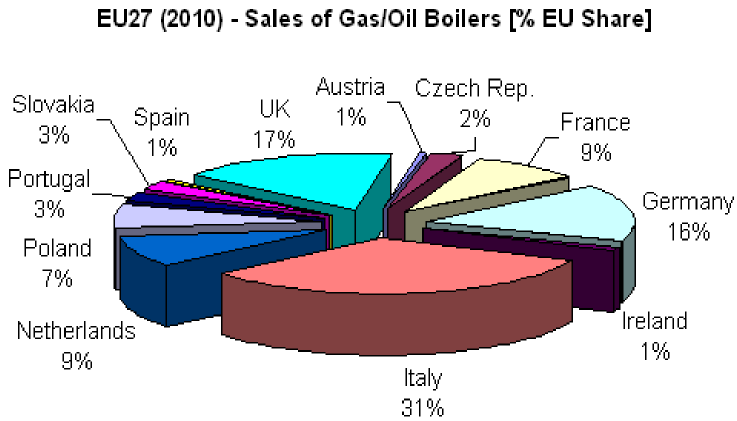
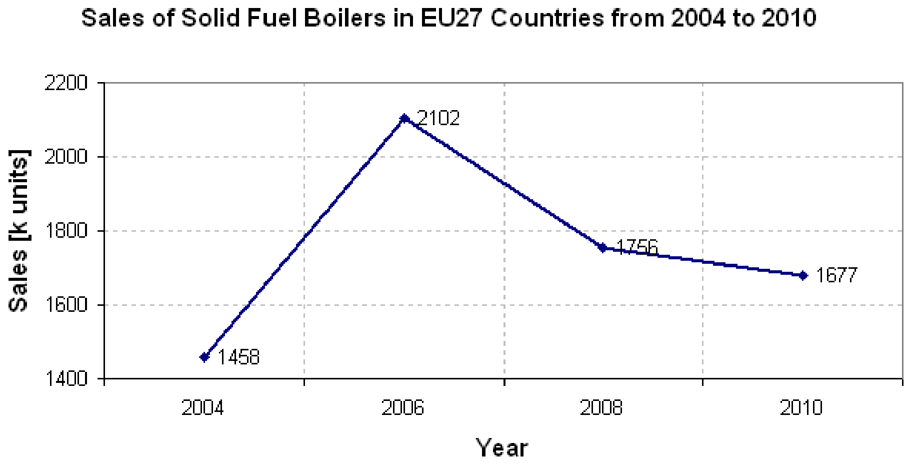


Table (left) and charts (right) reporting the sales of Gas/Oil Boilers in EU27 Countries from 2004 to 2010 (Sources: *“Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems”, “Eurostat Prodcom Annual Data from 2000 to 2010”*)

Concerning the trend of Solid Fuel Boilers, despite of a positive increase of sales from year 2004 to year 2006 – +44% from 1.5 million units to 2.1 million units, respectively – only 1.7 million units were sold in 2010. Though sales in 2010 are still higher than sales in 2004, a loss of 20% market is reached. The negative trend of these last years is less evident from 2008 to 2010 (see Figure 9).

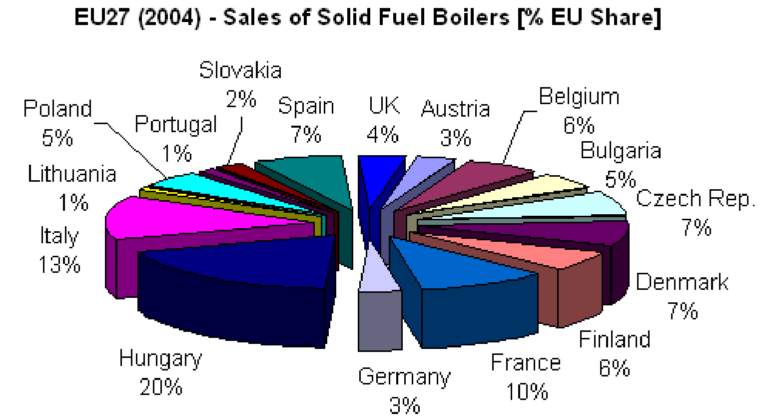
Hungary holds the highest share across Europe with 14% sales in 2010, suddenly followed by France (13% share) and Italy (12% share). Market figures were quite different in 2004, when Hungary held 20% share while France and Italy 10% and 13% share, respectively. Together with France (+3% share), Bulgaria (+3%), Czech Republic (+1%), Portugal (+1%) and UK (+6%) have also increased their share. On the other hand, together with Hungary and Italy, Belgium (-6%), Denmark (-1%), Finland (-1%), Lithuania (-1%) and Austria (-1%) have also reduced their share. The only new entrant in the market is Estonia (2%).



Sales of Solid Fuel Boilers in EU27 Countries from 2004 to 2010

Solid Fuel Boilers [k units]

	2004	2010
Austria	43	28
Belgium	81	n.a.
Bulgaria	68	138
Czech Rep.	101	114
Denmark	103	84
Estonia	0	29
Finland	84	78
France	140	202
Germany	45	38
Hungary	264	230
Italy	181	179
Lithuania	12	2
Poland	71	76
Portugal	12	27
Slovakia	34	30
Spain	96	98
UK	49	147



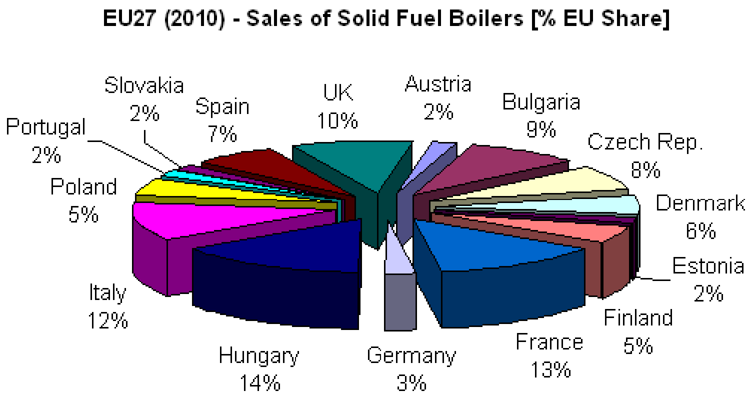
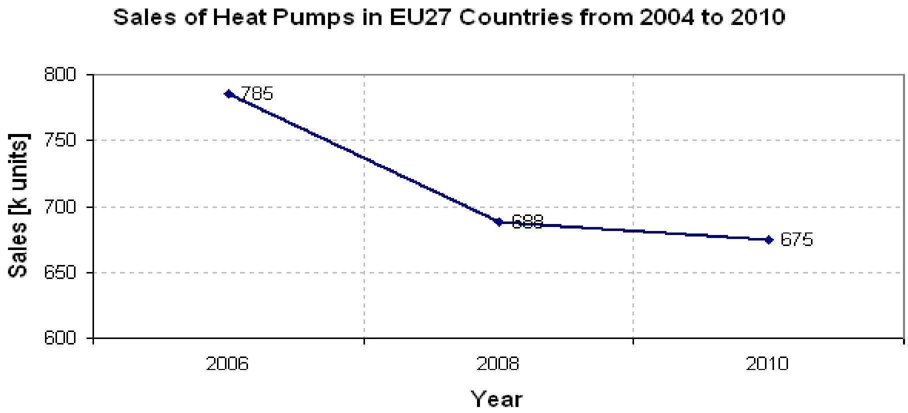


Table (left) and charts (right) reporting the sales of Solid Fuel Boilers in EU27 Countries from 2004 to 2010 (Sources: "*Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems*", "*Eurostat Prodcom Annual Data from 2000 to 2010*")

2.3. Electric Heat Pumps

According to European Heat Pump Association[6], the European Heat Pump sector witnessed a challenging market environment in 2010. With respect to year 2006, the market showed a negative trend with 14% reduction in number of sales.



Sales of Heat Pumps in EU27 Countries from 2006 to 2010

Because few data is available for sales of Heat Pumps in 2006, time-comparative considerations split by country are not reported. Looking at data of year 2010 from a geographic perspective, Sweden and Italy lead the market of sales both with 18% share. Noticeable share is also held by France (16%), Spain (11%), Finland and Germany (9%), as pictured in Figure 12. A significant proportion of the decline may be attributed to a small number of large markets led by France and followed by the Netherlands, Germany and Finland. In the past they accounted for a large proportion of the overall European market (approximately 80%). Their weak performance could not be overcompensated by the growth in markets such as Belgium, Czech Republic, Hungary, Italy and the UK which showed growing sales, albeit from a low base.

[6] European Heat Pump Association (EHPA), *4th EHPA Market Report and Statistics 2011*, http://www.ehpa.org

Heat Pumps [k units]

	2010
Austria	18
Belgium	8
Czech Republic	6
Denmark	27
Estonia	10
Finland	60
France	107
Germany	59
Italy	123
Netherlands	8
Poland	8
Portugal	19
Spain	72.
Sweden	128
UK	18

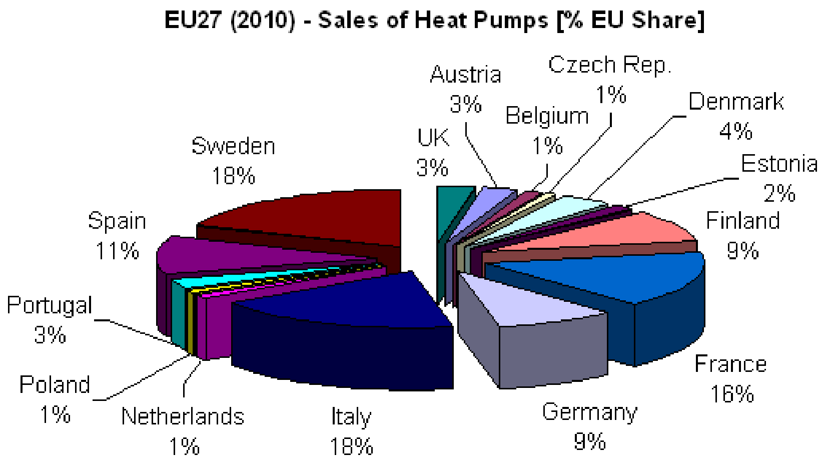
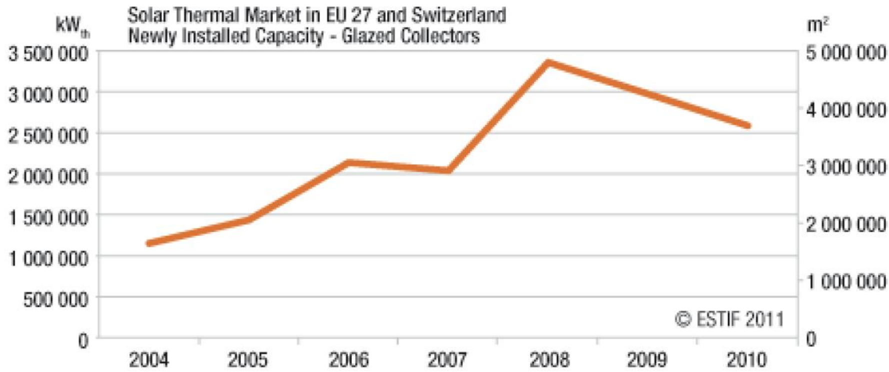


Table (left) and chart (right) reporting the sales of Heat Pumps in EU27 Countries from 2006 to 2010
(Sources: “*Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems*”, “*Eurostat Prodcom Annual Data from 2000 to 2010*”)

It need to be highlighted that in several countries (namely Italy, Spain) the figures about sales of Heat Pump include Air/Air units and Air/Water reversible units that are usually purchased for cooling needs and are almost never used

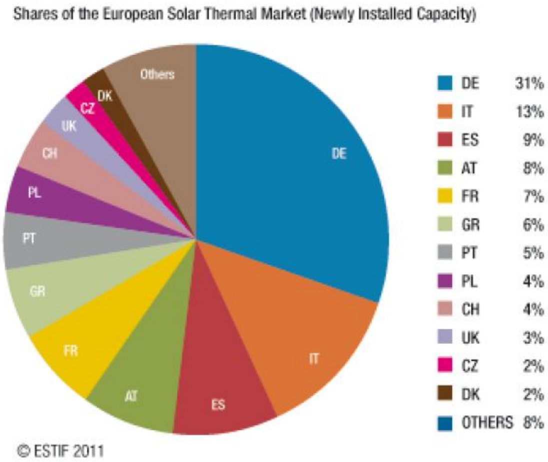
2.4. Solar Thermal

In 2010, the European Solar Thermal market (EU27 plus Switzerland) totaled 2586 MWth (3,694,940 m^2) of newly installed capacity, decreasing by an estimated 13% in comparison with 2009. It was the first time in over 10 years that the market declined in two successive years, though figures remain above the 2007 level.



Newly installed capacity of Solar Thermal systems in EU27 Countries plus Switzerland from 2004 to 2010 (Sources: *Solar Thermal Markets in Europe, Trends and Market Statistics 2010* – European Solar Thermal Industry Federation (ESTIF), June 2011)

Germany is still driving the Solar Thermal market with 31% share (805MWth corresponding to 1,150,000m^2 newly installed capacity in 2010) though the German market dropped by almost 29% in 2010 and by 23% in 2009. This sharp decrease has brought the market back to its 2007 level. Italy, Spain, Austria, France and Greece follow with 13%, 9%, 8%, 7% and 6%, respectively. The market of these countries is behaving very differently in these last years. While the Italian market confirmed its 2009 level (around 500,000 m^2 newly installed capacity), the Spanish market continued to decline, increasing the gap between the second and third European markets in terms of newly installed capacity. The Austrian market is following the trend of its northern neighbors, with a significant decrease of 21%. France also experienced a second year of decline, though more modest than in Spain (-3.4%). Finally, the Greek market recovered after a bad performance in 2009, in spite of the difficult situation faced by the country.



Pie chart reporting the shares of newly installed capacity of Solar Thermal systems in EU27 Countries plus Switzerland in 2010 (Sources: *Solar Thermal Markets in Europe, Trends and Market Statistics 2010* – European Solar Thermal Industry Federation (ESTIF), June 2011)

Recent studies[7] reveal that the newly installed capacity in 2011 remained close to the 2.6 GWth installed in 2010. Evolution in the different national markets has been very diverse during this last year. Few markets continue on the growth path, such as Poland, which has experienced a 70% growth of newly installed capacity in 2011 (177.5 MWth corresponding to 253,500 m^2) becoming the fourth European market behind Germany (889 MWth), Italy (290.5 MWth) and Spain (187 MWth), and on a par with France (176 MWth). Nevertheless, newly installed capacity in most of EU27 countries has been going through a very difficult time with respect to the previous year, especially in Southern Europe, such as Italy (-15%), Spain (-20%), Portugal (-30%) and Austria (-18%).

2.5. Trends and Forecasts for the Future

Map of climate zones in Europe

If EU27 Countries are clustered by climatic conditions, three most common climate zones can be found according to Figure 15[8], namely:

- warm or subtropical climate, characterized by hot dry summers and cool wet winters (Italy, Spain, Portugal, Bulgaria, Cyprus, Malta, Slovenia and Greece belong to this zone)
- average or humid oceanic climate, characterized by warm summers and cool winters with a narrow

[7] *Solar Thermal Markets in Europe, Trends and Market Statistics 2011*, European Solar Thermal Industry Federation (ESTIF), June 2011, http://www.estif.org

[8] http://printable-maps.blogspot.it/2008/09/map-of-climate-zones-in-europe.html

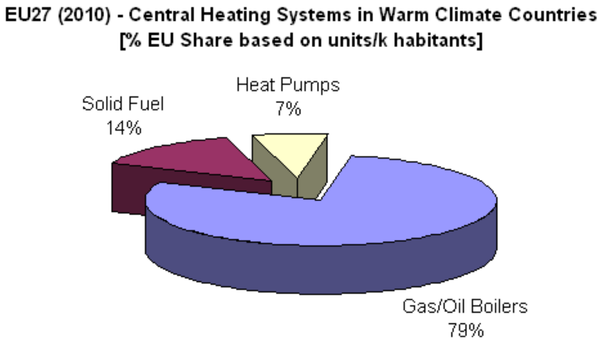
annual temperature range (France, Germany, Luxembourg, UK, Ireland, Austria, Denmark, the Netherlands and Belgium belong to this zone)

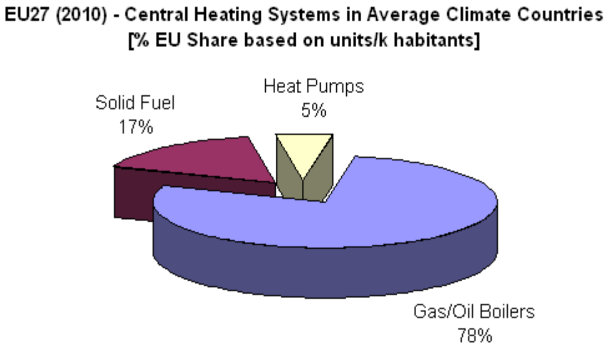
- cold or humid continental climate, characterized by large seasonal temperature differences, with warm humid summers and cold (sometimes severely cold) winters (Czech Republic, Poland, Hungary, Romania, Estonia, Lithuania, Latvia, Finland, Slovakia and Sweden belong to this zone).

Averaging the units of heating products sold in each climate zone with the population of the same zone, and neglecting sale figures for those countries which contribute less than 1% to the market, figures representing the number of heating products per person sold in 2010 can be drawn. This calculation allows highlighting that Gas/Oil Boilers represent the preferred technology across all EU27 Countries. Big margins over Solid Fuel Boilers and Heat Pumps are gained in the Mediterranean Countries with Warm climate (19.8 units/k inhabitants compared to 3.5 units/k inhabitants of Solid Fuel Boilers and only 1.8 units/k inhabitants of Heat Pumps) and in Central European Countries with Average climate (14.4 units/k inhabitants compared to 3.1 units/k inhabitants of Solid Fuel Boilers and only 1.0 units/k inhabitants of Heat Pumps). Such margins are widely reduced in Northern European Countries, where competing technologies challenge Gas/Oil Boilers (14.2 units/k inhabitants of Gas/Oil Boilers compared to 8.6 units/k inhabitants of summed data for Solid Fuel and Heat Pumps).

Though each central heating technology maintains a good share all over Europe, it is also worth to notice that the preferred market of Heat Pumps and Solid Fuel Boilers is represented by the Northern European Countries, while Gas/Oil Boilers dominate the Warm climate Countries.

	Gas/Oil Boilers		Solid Fuel Boilers		Heat Pumps	
Climate Zone	[k units]	[units/k inhb]	[k units]	[units/k inhb]	[k units]	[units/k inhb]
Warm	2,319	19.8	442	3.5	214	1.8
Average	3,476	14.4	729	3.1	245	1.0
Cold	773	14.2	326	5.3	213	3.3
TOTAL	6,568	-	1,497	-	672	-





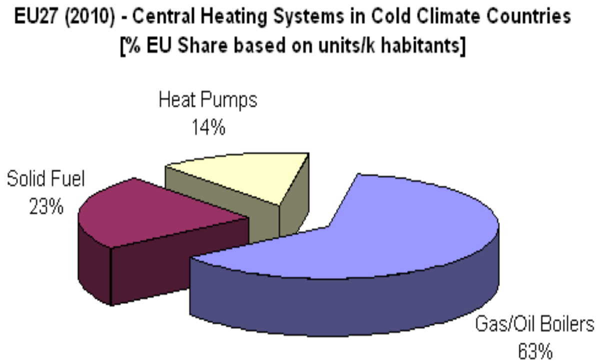


Table (top) and charts (bottom) reporting the share of Central Heating Systems in Warm (left), Average (right) and Cold (centre) Climate Countries during year 2010

Making the same calculations for Solar Thermal systems, what comes out is that new installations of this product category are widespread in Countries with Warm (9.2 m^2/k inhabitants) and Average (7.6 m^2/k inhabitants) climate regions more than in Northern Cold Countries. That is, the preferred market of Solar Thermal products is above all represented by South and Central Europe, with Austria and Greece being the countries in continental Europe with the highest newly installed capacity per capita, respectively 27 and 20 m^2 per 1000 inhabitants installed during 2011.

Solar Thermal

Climate zone	[m^2]	[m^2/k inhabitants]
Warm	1,267,184	9.2
Average	1,986,651	7.6
Cold	311,505	3.0
TOTAL	*3,565,340*	-

On the basis of what extensively described above and according to information available to date, the following scenario gathered high level of consensus discussed among Partners:

- The market of Gas/Oil Boilers and Solid Fuel Boilers is expected to growth in next years. Though the construction of new single-family and multi-family residential houses is stable and can be assumed to be stable at an average long term level – this means that the potential for first time installations is necessarily declining – and given that penetration of central heating systems is approaching saturation, the growth is expected to come mostly from an increasing demand for replacement. In addition, a considerable stock of old boilers in Eastern Europe will eventually need replacing. The entrance of novel technologically advanced boilers in the market will also support this growth in the near future. However, it is believed that traditional technologies will be replaced by more energy-efficient and low-carbon technologies in the long term.

- Among Boilers, the trend towards Wall Hung Boilers – relatively cheap and easy to install – is expected to continue in the next years together with a marked shift towards condensing boilers. The share of Gas and Oil Floor Standing Boilers is instead expected to fall. After a long period of declining sales, Biomass Boilers have experienced a growth over the last few years, it is therefore reasonable that this trend will continue to some extent. A limiting factor is that only a small portion of dwellings can handle solid fuel. Finally, Electric Boilers are expected to maintain their marginal position, though their future is strictly related to overall energy policy decisions.

- Given the high initial costs, sales of Heat Pumps are sensitive to subsidies and incentives. In countries where electricity is more expensive than gas and has high carbon factor, Heat Pumps are not the preferred technology. For these countries, they are most likely to be installed in the new build sector or when a house is undergoing major refurbishment. Due to the slowdown in new build activity, worth of only 1-2% of the existing building stock per year, a switch towards the renovation sector is noticeable. Few High temperature Heat Pumps are available to provide a cost effective alternative in retrofit environments for existing buildings and a viable option in areas where the gas grid is not available yet, such as in Eastern and Northern European Countries. However, they are also not suited for all houses. For instance, ground-coupled Heat Pumps need space for installing the ground process or to bore wells. Especially existing buildings in urban/suburban environments have severe space constraints.

Moreover, current electrical air-based Heat Pumps emit noise and show lower efficiencies in colder temperatures. Despite of this, it is likely that their share in the market of heating products will grow. The greater ecological benefit with respect to competing technologies especially regarding emissions is a key point on the expected trend. The potential energy and CO_2 savings from the wider use of heat pumps are substantial, given their high efficiency and relatively low market penetration for space and water heating. Most heat pumps and chillers providing the building sector with heating, are electrically driven. This implies that CO_2 emissions are moved from the building sector to the power generation sector. Therefore electrical Heat Pumps are the technology that benefits the most by the greening of the grid due to the more and more intensive use of renewable energy sources. Substitution of the electrically driven compressor by a thermally driven one could also lead to significant primary energy and emissions savings, especially if the thermal energy is provided from solar or waste heat.

- In addition, a substantial push for the application of Heat Pumps comes from recent European Directives, such as the revision of the Energy Performance of Buildings Directive (EPBD) and particularly Renewable Energy Sources Directive (RES Directive) which is becoming mandatory for ambient temperature control and environmental care. Also, the Ecodesign Requirements for Energy-Related Products (ErP) Directive and other labeling regulations play a favorable role for Heat Pumps. Concerning the emerging "smart grid" infrastructures and smart cities initiatives, Heat Pumps are seen as an enabling technology in the field. Pilot programs and extensive field tests abound in many European countries, with utilities becoming convinced of the role Heat Pumps can play in grid balancing, supply and demand side management, and smart grid energy storage.

- Solar Thermal technology works best for water heating and can be only supplementary to space heating in existing building or retrofit environment. Also, this technology requires space on roof level. Sloped or flat roofs are technically not a problem, but roof with wrong orientation pose additional challenges. Historical buildings are also prevented from exploiting this technology. It is thus likely that Solar Thermal systems remain primarily associated with DHW production in single-family houses of Southern European Countries where space heating is least needed. Another limiting factor is the initial cost that for a typical household Solar Thermal system can be paid back in 4 to 9 years depending on several factors such as climate, day-lighting, shading conditions, incident angle, etc. In spite of this, the total installed capacity in Europe is now 26.3 GWth, generating 18.8 TWth of solar thermal energy while contributing to savings of 13 MMt CO_2. With a turnover of around 2.6 billion € in 2011 and 32,000 people employed full time by the industry – a large share of which is concentrated in local small and medium businesses selling, planning, installing and servicing these products – the economic importance of Solar Thermal technology cannot be ignored. In addition, the analysis of the consolidated National Renewable Energy Action Plan (NREAP) submitted by the 27 Member States indicates that over the next 10 years Solar Thermal should on average grow at a rate of 15% per annum.

- Micro-CHP is an innovative and highly efficient energy solution for homes in Europe. This technology is characterized by relatively low electrical efficiency and high heat-to-power ratio. It is therefore most suited to applications in existing houses, which have a high heat demand compared to the need for electricity. In these places, Micro-CHP units can be installed as a direct replacement to a gas boiler, with the added benefit of generating some of the customers electricity needs as well as meeting the heat demand. Micro-CHP is a particularly good solution for tackling energy efficiency improvement in the mature building stock of many European member states particularly with a large installed base of gas boilers and difficult construction footprints. This technology is also seen as a flexible and controllable player in the new smart grid low carbon electricity market offering services to the grid and the opportunity to bring a whole new group of citizens into a new relationship with the energy market. To-date, Micro-CHP systems are in their early market stages and are still characterized by limited electric efficiency (ranging approximately from 18% to 25% according to technology and use conditions). The thermal plants on the electricity network are operating at an average efficiency from generation to end use of less than 40%. Also, barriers to Micro-CHP still exist: the traditional market based on large centralized supply is slow to change and the regulatory system must also adapt to encompass a much more decentralized supply approach. Grid connection and project authorization remain the most frequently quoted barriers by cogeneration project developers. Notwithstanding that, boiler companies as well as many European utilities see opportunities to generate value from Micro-CHP and represent the dominant route to market though electricity and gas suppliers represent a critical barrier. Cogeneration represents the most effective use of any given fuel. Cogeneration in the kW range is becoming commercially viable, offering the possibility to individual households of generating electricity locally, thereby relieving the large centralized plant of that role and taking pressure off the electricity grid, while covering all of the home's heating and hot water needs. Prices are still high, so Micro-CHP will rely on subsidies initially, but costs can be brought down if mass production is achieved. Installations are also evolving and adapting to the emerging challenges of the heat and electricity markets.

In relatively large buildings (light commercial and multifamily house) growth in demand for cooling is now being met through tri-generation units that can supply buildings with cooling as well as electricity and heat. Biomass and biogas geothermal and concentrating solar in combination with cogeneration is a more sustainable way to provide buildings with space heating and DHW. In other words, renewables and cogeneration have the potential to work side-by-side to achieve common low-carbon future. This view reflects the work carried out at the European level by the Renewable Heating and Cooling European Technology Platform. CHP technology is a growing category of distributed generation, especially in regions where natural gas is used for heating. In Northern Europe, for instance, and above all in Germany, CHP systems are already used in heating of large buildings, green houses and residential areas.

The use of Micro-CHP for domestic heating in single dwellings is expected to rise only in the next 10 to 20 years. Novel proton exchange membrane fuel cells (PEMFC) and solid oxide fuel cells (SOFC) for residential Micro-CHP characterized by power-to-heat ratio close to 1:1 are being developed too, which are believed to be well positioned to fully meet the heat and electricity needs of future buildings in the long term.

- The continuing expansion of <u>District Heating</u> could limit the possibility of builders and owners of single-family and multi-family dwellings to choose the best or favorite heating technology. As a consequence, the market for central heating products would be reduced. This aspect is softened by the big infrastructural work required by modern district heating technologies to be developed on a large scale and the fact that economics of District Heating impose large heat density that are common urban areas not common outside of such areas.

- The International Energy Agency (IEA) has developed the "Energy Efficiency in Buildings – Heating and Cooling" Technology Road Map as a collaborative effort between the IEA, its member countries, various consultants and experts worldwide. It looks for energy-efficient and low-carbon heating and cooling systems between now and 2050 to achieve a global reduction in total energy-related CO_2 emissions to 50% below today’s levels. Given the current trends in energy supply and use are unsustainable – economically, environmentally and socially – deployment of energy-efficient and low/zero-carbon energy technologies for heating and cooling in buildings is needed to allow the building sector to shift to a more sustainable energy and environmental future. The IEA Road Map focuses on four key technology options – Solar Thermal, CHP, Heat Pumps and Energy Storage – which are believed to have the greatest long-term potential for reducing or facilitating CO_2 emission reductions. According to the deployment of such technologies will deliver up to 2 Gt of CO_2 reductions, with 710 Mtoe of energy savings. Increased deployment of Heat Pumps for space and water heating, as well as deployment of more efficient Heat Pumps for cooling, is estimated to account for 63% of the heating and cooling technology savings. Within this scenario, called the BLUE Map scenario, the number of installed Heat Pumps will grow by about 4 times globally. As well, the use of CHP approximately triples in absolute terms between 2007 and 2050 and the share of CHP in power generation increases to 13% over this period.

- In low energy houses loads change significantly, in particular the space heating needs are notably reduced, and the share of DHW increases. The improved insulation standards in new buildings from 2020 onwards will drive a decline in overall space heating demand per square meter by 2050. This decline is opposed by increased overall floor space predicted for 2050. Hot water demand is instead predicted to remain significant in new buildings and the demand for cooling is expected to rise. In fact, in recent years market development shows an increasing integration of a comfort cooling option in the system layouts. In addition, mechanical ventilation may be required to guarantee the necessary air exchange due to the air-tight building construction. Integrated multifunctional solutions have favorable features for the use in low energy houses.

Among the technologies to-date available for Central Heating, namely Boilers, Heat Pumps, Solar Thermal systems and CHP units, the only technology actually negligible from a market point of view is represented by Micro-CHP systems – on the basis of the up-to-date figures available and the prospected scenarios discussed above. As a matter of facts, this technology is still in its early market stages.

Inside each technology group worth to be further analyzed from a technical/performance point of view, it is possible to identify the most used products (for example, Wall Hung Non-Condensing Boiler inside the group of Gas/Oil Boilers). Considering the need to provide a building with both space heating and DHW, the next part of analysis for the application of Gas Absorption Heat Pump solution to residential sector will focus on single-family dwellings mainly in suburban areas. The comparison will be performed primarily on the two most competing technologies:

- Wall Hung Condensing Gas Boiler coupled with a Solar Thermal system
- Air/Water Electrical Heat Pump

2.6. Gas Heat Pump (Absorption, Adsorption, Gas Engine Driven HP)

In this section we shall consider in greater depth the heat pump technology which uses gas as a primary energy source to supply the transport work that is necessary for heat pump operation. In order to assess the potential and evaluate the quality of the heat pump process we need to answer a number of questions:

- How efficient could GAHPs theoretically be?
- How do they rank in terms of primary energy?
- What is the comparison process?

These issues are considered below taking the example of an engine-driven heat pump. The entire process is divided into two separate parts, each of which corresponds to the model of a cyclic process. The process which provides the drive power is the clockwise cyclic process. This constitutes the operating principle of all heat engines and also defines their maximum efficiency. For a stationary operating mode, the ratio $\eta_{c,M}$ of work gained to energy invested can be attributed to two temperature levels T_1 and T_2.

$$\eta_{C,M} = \frac{T_1 - T_2}{T_1}$$

T_1 is the level of the heat input, and T_2 is the level of heat removal. The greater the temperature difference, the more work can be gained from the heat. In the particular instance of a gas engine, the temperature conditions are defined by the combustion temperature and the ambient temperature. The second cyclic process is a counter clockwise process. This process uses the work gained to transport energy from a lower level (ambient energy, e.g. air or ground heat) to a higher level. Similar to the clockwise process, we can write the theoretical maximum as a function of temperature levels. Because the result can – and should – be greater than 1, we refer not to 'efficiency' but to a coefficient of performance (COP) or, for an integral consideration of longer periods of time, energy efficiency ratios (EER).

$$AZ_{C,WP} = \frac{T_2}{T_3 - T_2} + 1 = \frac{T_3}{T_3 - T_2}$$

T_3 is the mean temperature level on which the heat is to be provided. As with all heat pumps, we can clearly see that a small rise in temperature favours the energy efficiency ratio.
If we combine both cyclic processes to form a unit, we obtain the following relationship for the energy efficiency ratio $AZ_{C,GHP,A}$ of the gas heat pump.

$$AZ_{C,GWP,A} = \eta_{C,M} \cdot AZ_{C,WP} = \frac{T_1 - T_2}{T_1} \cdot \frac{T_3}{T_3 - T_2}$$

In this case, temperature T_2 is the source level of the heat pump part as well as the heat sink level of the engine part. Other scenarios are also conceivable however. For example, the heat losses of the engine part can be made available on temperature level T_3. Theoretically this will increase the yield on the benefit side by ·$_{c,M.}$ Since the technical implementations of heat engines do not normally come below T_3 with their waste gas temperatures, this scenario is more realistic. The associated equation is as follows:

$$AZ_{C,GWP,B} = \eta_{C,M} \cdot AZ_{C,WP} + \left(1 - \eta_{C,M}\right) = \frac{T_1 - T_3}{T_1} \cdot \frac{T_3}{T_3 - T_2} + \left[1 - \frac{T_1 - T_3}{T_1}\right]$$

The result may look different at first sight but it can be mathematically transformed into the equation for $AZ_{C,GHP,A}$. Theoretically therefore it is irrelevant whether the level of the heat sink for the clockwise process is at T_2 or T_3.

Figure 2.1 plots EERs as a function of T1 for the standard points A2/W35 and A2/W55 (DIN EN 14511). It can be seen that values of significantly more than 1 are possible. It is also apparent how the magnitude of temperature level T3 – the level on which the heat is to be made available – affects the energy efficiency ratio. For use in existing buildings therefore, efforts must be made to reduce the feed temperature. This is particularly important when considered against the background that real appliances only achieve part of the theoretically possible efficiency.

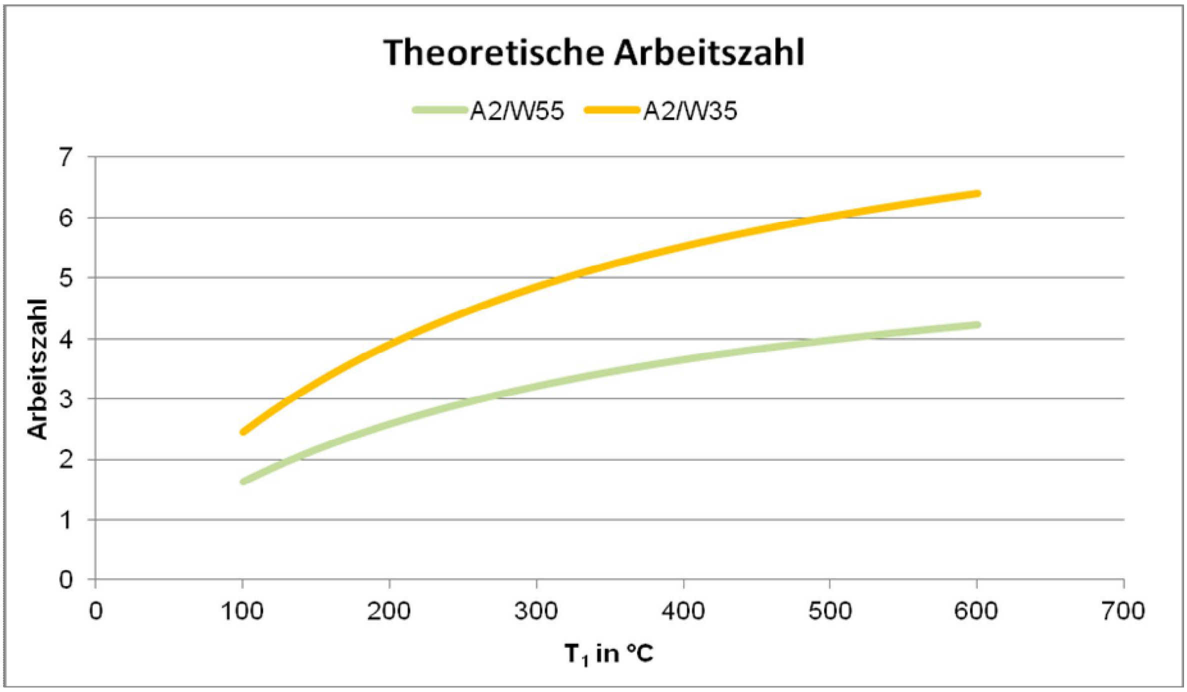


Figure 2-1: Theoretically possible EERs for gas heat pumps as a function of heat source temperature

Gas heat pumps can be divided into three groups depending on their physical operating principle:

- Absorption heat pumps - These appliances use the effect of the temperature dependence of the solubility of gases in liquids as a fundamental operating principle.
- Adsorption heat pumps - These pumps use the effect that the adsorption of fluids on surfaces is also temperature-dependent. Both sorption processes enable the refrigerant to change to another phase state so that – similarly to the conventional pumps that follow a cyclic process – a transformation enthalpy in the form of heat can be released or captured.
- Gas-engine-driven (GED) heat pumps - With engine-driven appliances, a classic compressor-operated heat pump is combined with a gas combustion engine which delivers the mechanical energy to drive the thermodynamic counter clockwise process.

2.6.1. Absorption Heat Pump

Absorption heat pumps belong to the continuously operating appliances in which the sorption and desorption processes can be arranged to take place spatially separately, but simultaneously. Because the operating principle is based on the dissolution of a refrigerant, a two-component mixture whose solubility field covers the desired temperature range is required. It is mainly water/lithium bromide and ammonia/water mixes which are used in practice. Water is the refrigerant in the former mixture and ammonia in the latter.

However, it needs to be pointed out that since most of the appliances that use absorption technology are not heat pumps (in particular the one using water/lithium bromide), but in fact "refrigerating" units (chillers). Following considerations will focus only on "heating" applications. To exemplify above considerations, the table below (based on figures taken from the manufacturers' data sheets) presents the Gas Utilisation Efficiency ratios for an air source absorption heat pump of approx 40kW manufactured by Robur. The table clearly shows the increase in efficiency achieved by reducing the temperature spread between heat input and heat output.

Table 0-1: Calculated Gas Utilisation Efficiency ratios for different temperature pairings

Appliance	A2/W35	A2W55	A7/W35	A7/W55
Robur "E3 A Luft"	1.50	1.31	1.59	1.35

The efficiency of the appliances depends on the required temperature difference. If we transpose this fact to the supply of domestic hot water (DHW), we can assume that the GAHP systems will achieve energy efficiency ratios still above the one achieved by regular condensing boilers (standard bench mark) even if the operate at a higher temperature.

Because the power that is needed for the HEAT4U target market is predetermined by an analysis of the housing stock, the following consideration will be based on a required heating output range of P_H = 10 kW to P_H = 20kW.

2.6.2. Adsorption Heat Pump

With this group of heat pumps, the refrigerant is adsorbed on the surface of a solid (adsorbent). In this sub-process, energy is released in the form of heat. During the adsorption process the partial pressure in the storage tank falls and triggers the evaporation of more refrigerant in the evaporator. The evaporation energy which this requires can be taken from the environment. When the adsorptive is completely evaporated or the adsorbent is saturated, the sub-process ends and the second phase of the transport process begins. Changing the adsorbate (the adsorbed fluid) back to gaseous adsorptive requires the input of heat at a high temperature level. The refrigerant is expelled and condenses back at a cooler place while giving off heat. The two-stage nature of the process makes clear that this is a periodically operating machine. It is only by adding a complete second cycle that a continuously working operating principle can be achieved. The less expensive option therefore requires a heat store.

Products using this principle are currently being introduced on the German market. The manufacturer claims a standard gas utilisation efficiency ratio of 131% for this unit, although this is very much dependent on the percentage of hot water production. The gas utilisation efficiency ratio is relatively low.

2.6.3. Gas Engine Driven Heat Pumps

Gas-engine-driven (GED) heat pumps are a combination of gas engine and compression heat pump. There are different ways in which the different units can be coupled together in practice:

- Engine + Generator + Compressor (electrical coupling)
  - Less efficient, can be hermetically sealed, standard components, electrically autonomous
- Engine + Shaft + Compressor (mechanical coupling)
  - More efficient, made to order, leaks
- Engine + Compressor in one unit
  - New development required.

If the different units are directly connected to each other, there is a problem of not being able to take advantage of the proven hermetic design of heat pumps, so this type may well suffer from leaks similar to those known in the automotive industry. Nevertheless their higher utilization ratio is an advantage over a coupled variant comprising engine, generator and compressor which fares worse because it involves an additional energy transformation process. It can be hermetically sealed however.

In the present case the anticipated seasonal energy efficiency ratios (SEER) are determined by applying established mechanical engine efficiencies of η_M = 22 - 25% in order to ascertain the amount of available mechanical power. This is a very conservative estimate because the efficiencies of reciprocating motors can also attain values of up to η_M = 40% (e.g. GE Jenbacher 2) depending on their size. There are no public available data about performance (measured on European Standards) of appliances available on the market in Europe yet, so we can only estimate the attainable performances of these systems.

The SEERs for brine-to-water heat pumps and air-to-water heat pumps are taken from an accompanying field study of heat pumps carried out by the ISE. For predictive purposes therefore, SEERs of 3.8 for the earth-based brine-to-water HP and 2.6 to 3.0 for the air-to-water HP were assumed. Because the field study contains too few appliances, a spread will represent the uncertainty.

$$JAZ = (1-\eta_M) + JAZ_{WP} \cdot \eta_M$$

If we use the above equation to combine these conservative indicators to create an annual efficiency for the GED heat pump, we obtain the following seasonal energy efficiency ratios for these pumps as a function of their heat source:

Table 0-1: Anticipated seasonal energy efficiency ratios of GED heat pumps

Energy source	η_M = 0.22	η_M = 0.25	η_M = 0.30	η_M = 0.40
Air $SEER_{HP}$(2.6 to 3.0)	1.35 - 1.44	1.4 - 1.50	1.48 - 1.60	1.64 - 1.8
Earth $SEER_{HP}$(3,8)	1.62	1.70	1.84	2.12

Unfortunately the summary of field measurements does not indicate the average temperature levels on which the heat pumps were operating. However the percentage of buildings with underfloor heating was 93%, and this affirms an assumption that the upper temperature level cannot be been much above t=35°C. The production of heat at a high temperature level for the reheating of heating water or for supplying domestic hot water is not a problem for GED heat pumps however since the waste heat from combustion accumulates at a high level.

It need to be pointed out that η_M above 0.25 will be extremely unlikely for residential application in particular for individual dwellings. In addition this technology is characterized by several other limitation factors in its application to individual dwellings:

- decay of performance on high thermal lift
- temperature level not ideal for retrofit application
- higher level of noise and vibration (because of presence of reciprocating combustion engine)
- high service and maintenance level

3. Gas Absorption Heat Pump Appliance

3.1. Technical Targets for GAHP Appliance and GAHP System

The requirements relating to the following points

- Dimensions and weights
- Noise emissions
- Installation/connection/operating conditions, and
- System temperatures

are defined by a comparison with heat generators currently obtainable on the market. The heat generators which have been examined include air-to-water heat pumps, brine-to-water heat pumps, gas heat pumps, condensing boilers – both floor-standing and wall-mounted – and chillers. Over one hundred heat generators are analyzed in terms of their technical data, and the results of this analysis are presented in chart form in the sections which follow.

3.1.1. Dimensions and Weights

The activities of HEAT4U are focuses on development of an outdoor unit. The fact that the units will be installed outdoor relax drastically most of the possible constrains in term of size and form factor.
In addition no relevant guidelines or standards have been pointed out to the Partners as far as overall size for an outdoor installation.

Should the future development of GAHP technology in residential building bring to consider an indoor appliances, then the following considerations might help understand possible limitations.

If we compare the minimum dimensions of different heat generators currently available on the market, we find that the width of many appliances is less than or at least in the region of W = 600 mm (see Table 4-1 and Figure 4-1). This can be explained by the door widths which are standardized according to DIN 18100 in Germany (and similar standard in the rest of Europe). In this standard, single-leaf doors are represented by 6 width sizes; it can be assumed that the probability of finding one of the 6 door types in an old building decreases with the width of the door. The width or depth of the appliance (the minimum dimension) should not exceed W = 610mm to ensure that the gas heat pump can be installed in almost any existing building.

Table 4.1: Dimensions for single-leaf doors to DIN 18100 in mm

Class	1	2	3	4	5	6
Standard DIN width	635	760	885	1010	1135	1260
Overall door leaf width	610	735	860	985	1110	1235

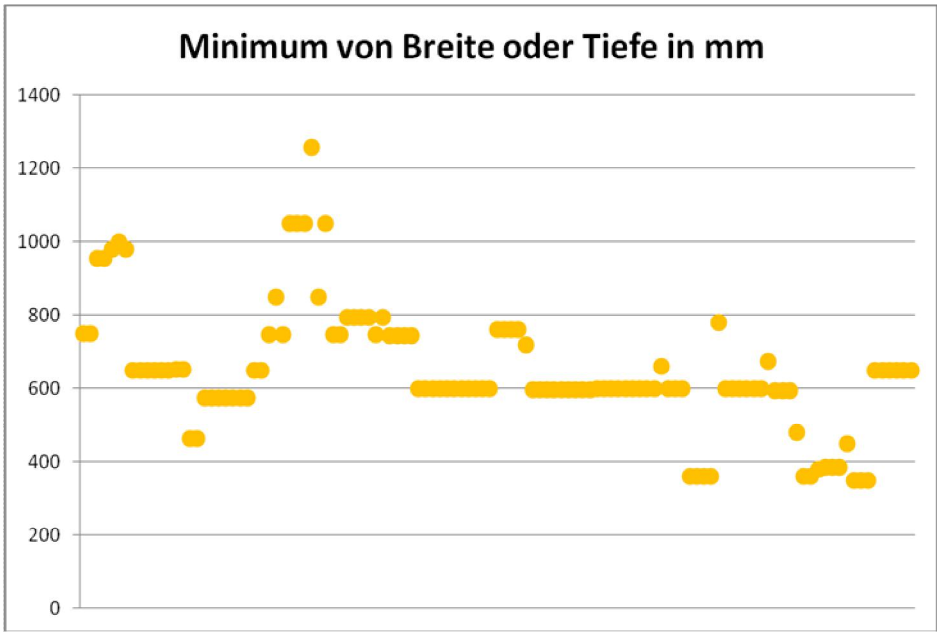


Figure 4.1: Plots the minimum width and depth of over one hundred heat generators

Similarly, should we also use DIN 18100 to determine the maximum height, then an appliance should be no higher than H = 1950 mm.

Similarly being the concept of HEAT4U not wall mounted, there are no specific standard or guideline for restriction on weight.

Nevertheless some considerations on the weight of heat generators currently sold can help understanding market expectations and range of acceptance.

While a wall-mounted appliance should not be overly heavy as it has to be installed by the technicians, and a mass of m = 50 kg represents a good guide value here, floor-standing appliances on the other hand are considerably heavier, as can be seen from Figure 4-2. Please note that largest majority of these heat generators are installed indoor (that implies usually some higher difficulty in access: stairs, doors, narrow corridors). Even so, it should be remembered that each additional kilogram makes handling more difficult, especially over stairs.

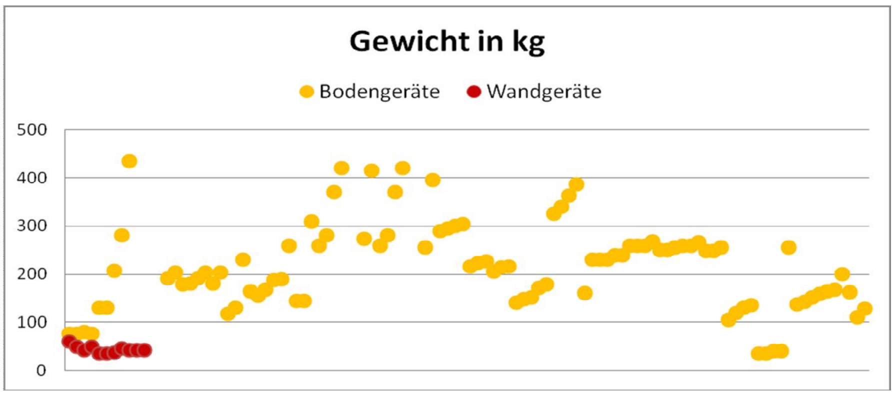


Figure 4.2: Weight distribution of heat generators

In conclusion weights in the range 100 to 300 kg are currently very common for heat generators installed as floor standing units. A comparison with Air Sourced EHP of residential range 10 to 20kW was carried out with similar outcome for the weight range.

3.1.2. Appliance Design

The heat generators that are currently available on the European market are highly dependent on the specific national tradition and can be classified as designed as freestanding, wall-mounted and split appliances (in the case of heat pumps with air as the heat source). The design of the appliance plays an important part depending on its particular application and duty (i.e. most of the condensing boilers for individual dwellings are wall mounted, while almost all air source HPs are free standing and split appliances). To ensure a broader market presence for gas heat pumps in the future, the outdoor freestanding design is likely to have the best market opportunities at the present time so should be developed as a matter of priority.

As far as using gas heat pumps in existing building stock is concerned, this often involves exchanging appliances, i.e. the gas heat pump replaces an existing older heat generator which frequently takes the form of a floor-standing boiler and is usually installed in the basement. The space available in an existing building for the hydronic part (GAHP system) and the space for an outdoor gas heat pump as a freestanding appliance are therefore available, and the continued of use existing connections also favours this design.

Were a gas heat pump to become successfully positioned as an appliance in competition with the condensing boiler in the new-build sector, then a wall-mounted version would no doubt enhance its market potential. This might represent a long term goal for GAHP technology.

Therefore a gas heat pump as a free standing split appliance (with an inside and an outside unit) might reamin the preferred option for heat pumps with air as their heat source, e.g. in existing large inner-city buildings in which air cannot be supplied through ducts.

3.1.3. Noise Emissions

Noise emissions depend to a great extent on the type of appliance. A comparison with other heat generators shows (see Figure 4-3) that there is a wide range of noise levels. Gas condensing appliances are some of the quietest, as their emissions are generally below p = 40 dB(A). These appliances contain a gas burner and a pump for the heating circuit, and are commonly installed indoor with high expectation on quietness (kitchen).

Since a HEAT4U gas heat pump is planned to be an outdoor freestanding unit, noise expectation are completely different. If we switch reference point and look at conventional heat pumps with compressors, we note that the air-to-water heat pumps are operated close to the limit of toleration, and installation in areas of buildings that are occupied or used by persons is not recommended. The following graph highlight the noise power level of several different technologies (and different power output)

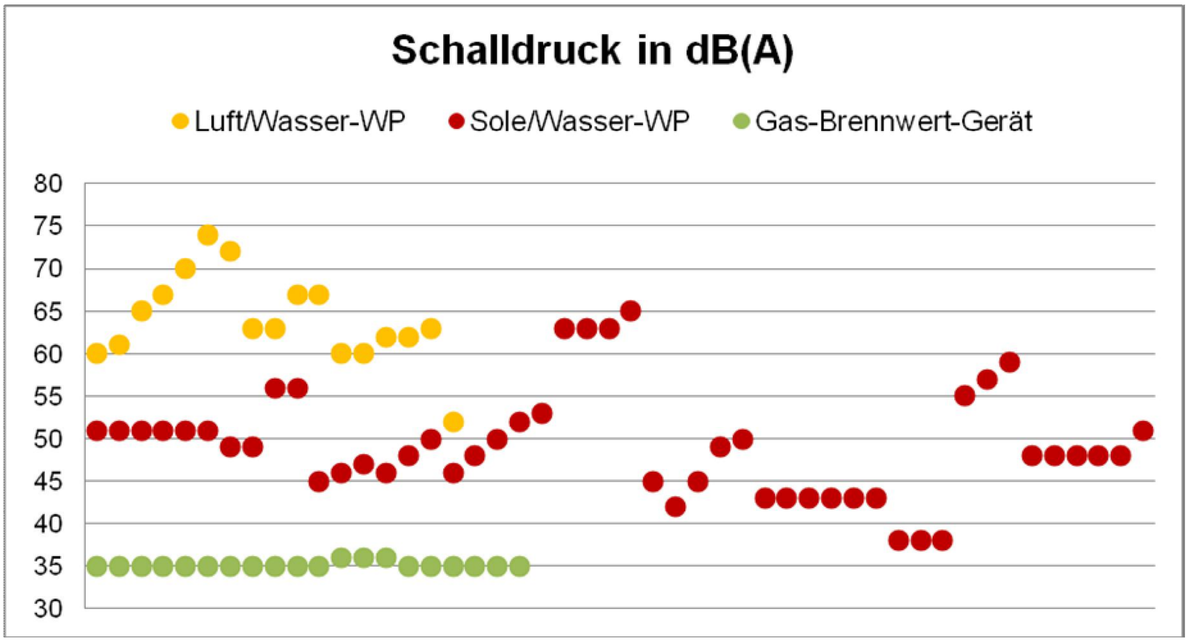


Figure 4.3: Comparative noise emissions of different heat generators

Of course the noise characteristics of an air sourced heat pump will be highly depended on the output power. After consideration of what is achieved by the current 16-20kW EHP a noise power level of p = 65 dB(A) or less should be aimed for as target for using quietness as a unique selling point.

3.1.4. Emissions from Combustion

The emissions of nitrogen dioxide (NO_x) and carbon monoxide (CO) from the combustion of natural gas should be limited. By contrast with gas condensing boilers, it is proposed that the pollutant emission limits for gas heat pumps should be based on the output energy.

The combustion-related emissions of recently developed gas heat pumps should not exceed the following limits in future according to [Heikrodt, 2011]:

- $NO_x \leq 60$ mg/kWh (based on net energy)
- CO ≤ 50 mg/kWh (based on net energy).

3.1.5. TEWI Limit

The TEWI value (Total Equivalent Warming Impact) describes the greenhouse effect caused by a chiller system/heat pump during its period of operation. A TEWI analysis takes into consideration:

- direct greenhouse effect from the release of refrigerants due to leaks and losses during disposal, and
- indirect greenhouse effect from producing the energy that is needed to drive the chiller system/heat pump

In RA2-U2118F, the TEWI limit for heat pumps is determined based on the generated net heat (TEWI/kWh in [gCO_2-eq./kWh]). With their combination of energy efficiency over utilisation ratio and the greenhouse gas potential of the refrigerant, efficient appliances have a chance of obtaining an ecolabel despite their high GHP value. A TEWI limit of < 202 is proposed for newly developed gas heat pumps.

3.1.6. Refrigerants

Different refrigerants can be used for sorption heat pumps. It is a point in favour of using ammonia as a refrigerant (designation R717) that ammonia belongs to the class of natural refrigerants and has no ozone depletion potential (ODP = 0) and no global warming potential (GWP = 0). Also the value of TEWI, index of indirect contribution to the greenhouse effect, is small compared to the one of synthetic refrigerants. The refrigerant mass can be kept relatively small because of its high specific enthalpy of vaporization.

The advantages of ammonia as refrigerant concern different aspects: from technical to economical, to environmental ones. Ammonia has excellent thermodynamic properties and high energy efficiency, in addition to being on average less expensive than synthetic refrigerants.

Refrigerant	ASHRAE Nomenclature	Chemical composition	Evaporation temperature (°C)	ODP	HGWP
Ammonia	R717	NH_3	-33,6	0	0

To all this is added the big advantage of not being subject to the legal requirements about its manipulation by qualified personnel (Regulation no. 842/2006) due to climate issues, as it is also happening with synthetic fluids of the latest generation, HFCs.

In sorption appliances, ammonia can be present within a steel sealed circuit in gaseous and liquid form, pure and to a large part dissolved in water, thereby further reducing the hazard. The international standard which regulate the equipment containing a refrigerant (either ammonia or an HFC), typical of heat pumps, is EN378. According to this standard, the maximum fill quantity of ammonia is restricted depending on where the appliance is installed:
in public places and living areas - up to 2.5 kg
in closed rooms which are not freely accessible – up to 10 kg
in machinery rooms – up to 25 kg and over.

It is important to highlight that this European standard specifies that, in case of outdoor installation of a heat pump containing ammonia, there are no special restrictions on quantities of refrigerant to be respected. Therefore for the current development with HEAT4U project (outdoor installation), no special restriction applies even in case of residential applications. Further developments will be needed for possible future development of indoor applications of GAHP technology in residential environment.

3.1.7. Gas Quality Detection

Gas heat pumps should be suitable for use throughout Europe. The increasing use of renewable energy sources (biogas, hydrogen, hydrogen methanisation), the growing use of liquefied natural gas (LNG) and more frequent changes in sources of supply mean that gas quality will vary more widely in future than it has in the past, in some areas of the grids at least.

New gas heater appliances will therefore benefit by featuring devices for the self-calibrating continuous regulation of the combustion process so that they can automatically adapt to changes in the composition of the gas delivered by their particular network. Gas appliances fitted with a lambda sensor could operate without having to be adjusted when there is a change in the type of gas, delivering consistent output and efficiency despite fluctuating gas qualities. This would also offer a benefit for the pump's owner/operator because the intervals between tests by the chimneysweep controls are longer for appliances with self-calibrating continuous combustion regulation than for those without (at least in Germany).

The use of a smart combustion system with gas quality detection might turn out to be cost effective also for gas heat pumps coming onto the market in future.

3.1.8. Power Modulation

The gas heat pumps that will be available on the market in the future should be fitted with modulating burners to reduce constant cyclic operation and associated drawbacks. Burner modulation makes particular sense with gas heat pumps operated in buildings in which the heat load fluctuates widely. The modulating mode of operation automatically matches the pumps output to actual demand, allowing the pump to achieve greater efficiency and so save energy in the process.

A look at the gas condensing boiler – a product in competition with the gas heat pump – shows that a modulation ratio of at least 1:3 between minimum and maximum output should be aimed at. The electrical demand of peripheral loads, in particular refrigerant pump, circulation pump, other electrical loads which are incorporated in the GAHP appliances, the standby heater element and control system should be reduced accordingly. The use of high-efficiency pumps (efficiency class A) could be a solution to this problem.

3.1.9. Heat Source

Ambient heat can be used with gas heat pumps essentially by developing the following heat sources:

- Air
- Geothermal/groundwater
- Solar radiation

Using air as a heat source often involves the least amount of technical effort and financial expense. There are many cases, e.g. existing large inner-city buildings with a high density of development, where air is the only meaningful and/or technically viable solution. Air as a heat source offers 3 options for GHP installation: indoors, outdoors and as a split appliance.

Geothermal as a heat source on the other hand is generally more expensive to exploit, involves greater technical complexity and has a bigger impact on the site selected for development. The essential advantage with electric heat pumps – their higher heat source temperature combined with low outside temperatures – is not so decisive for gas heat pumps owing to their operating principle (larger stability of performance with increasing thermal lift compared to EHP). This solution is therefore possible almost only in new building applications and beneficial in particular for EHPs.

Those wishing to harness solar power as a heat source have access to components that are technically mature and readily available on the market. The process of unlocking the heat source is only a problem if no suitable installation surfaces are available or if existing surfaces cannot be used because the building is listed, for example. The advantage with solar panels is that they allow the passive use of the sun's heat for domestic hot water heating and possibly for auxiliary heating as well. One drawback with standard solar panels is their insulation which complicates the use of ambient heat similarly to the air-heater solar panel in times when solar radiation is scarce.
These considerations where confirmed by all relevant Partners in their experience and during the survey performed in the HEAT4U Project. Therefore the initial assumption to focus the HEAT4U development on an Air Sourced GAHP solution as the most appropriate approach for exploiting the existing residential building was validated.

3.1.10. Installation, Connection and Operating Conditions

The heat generator market is essentially a replacement market. Indeed the installations in new building represent few point percentage of the total market. It needs to be highlighted that the replacement market include both the pure substitution of a faulty unit (usually unplanned and performed in a rush) and the planned replacement (retrofit).

The boundary conditions and requirements examined within the scope of this study for the deployment of gas heat pumps in existing buildings relate solely to the planned replacement of appliances, in other words, the gas heat pump replaces a conventional heating boiler or older heat pump. We can generally assume that this replacement of heat generators will very often (though not always) come about as part of building modernisation. This assumption implies a number of conditions for the installation, connection and operation of gas heat pumps in existing buildings:

- Use of existing gas connection and heating distribution pipework: depending on the extent of the modernisation that is being carried out on the existing building (one-off projects, partial or total modernisation), the distribution pipes of the building's heating system may also be replaced.

- Using the existing boiler room: even if the gas heat pump is to be installed outdoors, the existing boiler room can be used for the possible hydronic group (DHW tank). Factors that are relevant for installation and operation, such as size, weight and noise emissions, have already been dealt with.

- Incorporating the heat source
  Basically experience shows that it should normally be possible to integrate the heat source into the boiler room without difficulty and whatever the type of heat source. Nevertheless the outdoor installation address this need and is suitable for single family homes.

- Waste gas system and stack
  This does not entail any particular requirements for the heat pump however in particular for an outdoor installation.

4. Types of GAHP Systems

This chapter provides the characteristics of the optimal GAHP System for each homogenous market region as far as building types (retrofit degree), construction technologies, retrofitting methodologies, heating system’s typologies (generation, distribution, control), integration of renewable heating technologies, heat demand characteristics and tariff (and subsidies) schemes concern.

The homogeneous areas taken into account are representative of the highest market potentials for this technology (being a “heating solution”): north and continental Europe regions (France, UK, Germany, The Netherland, Belgium, Denmark, Poland, Switzerland, Austria, north and central Italy, north and central of Spain).

The definition of the characteristics will be given through the following parameters:

- Type of systems: “space heating and DHW” vs. “space heating only”
- Space Heating and DHW demand (based on climate and life style) temperatures and nominal power requirements for GAHP Appliance
- Installation habits, regulation and standards outdoor/indoor installation hydraulic schemes, auxiliaries requirements for system control requirements for hydronic system components
- Building construction/retrofitting regulations, standards and habits detailed requirements of the building envelope for pre-fabricated elements integration construction/retrofitting materials and schemes, accessories
- Pre-sales technical support, distribution, training, service distribution requirements service support requirements training and dissemination recommendations

To find the best market specification for the European market the theoretical information collected in the market research have been double checked with local professionals to get validated inputs.

4.1. Space Heating and DHW demand (based on climate and life style) temperatures and nominal power requirements for GAHP Appliance

The GAHP is targeted for the use in European markets for DHW and space heating. For retrofit market there are mainly heating systems with radiators, a minor portion with floor heating. Space heating only is a very marginal segment for individual dwellings.
Markets considered in this analysis are: France, UK, Germany, The Netherland, Belgium, Denmark, Poland, Switzerland, Austria, North and Central Italy, North and Central of Spain.
Different house constructions especially retrofitting have different demands on nominal power output and DHW temperatures. For replacement it is necessary to find a solution to combine existing hydraulics with GAHP appliances. Floor heating systems and in particular radiator systems have to be considered in the European market.

The results of these parameters in each country as followings:

- **France**
  The operating temperature (ambient) range is -15°C /+45°C. To secure the DHW comfort France market will use for DHW production additional tanks, the demand of DHW is approx.

200 liters per day. For safety Anti-legionella cycle should be implemented as for condensing appliances. Space heating will be done via radiators.

If we consider the retrofitting market, 65°C for heating & DHW temperature is enough. If the insulation of house is not being improved or radiators have not been oversized (as frequently happened), the GAHP appliance must be associated to a back-up boiler to achieve 80°C. Nevertheless market data show that: 47% of EHP is installed with high temperature radiators. Therefore large portion of market does not impose the back up boiler.
To be adapted to all existing buildings, even without retrofitting of insulation, and with high temperature radiators, the integration of GAHP appliance with new or existing boiler shall be possible. Concerning DHW demand in term of comfort:

- Tank volume = 200 liter max.
- Flow rate > 16 l/min (according to EN 13 203-1: 3rd position comfort label - specification of Effinergy label. The maximum is 4).

The nominal capacity of the GAHP for application in the French market can be 18 kW (A7/W50). Regarding the highest load in market of retrofit houses at -7°C, the GAHP has to provide 17 kW (A-7/W65) minimum if we consider GAHP in monovalent mode. This capacity could be achieved using a back-up burner if the GAHP maximum capacity is 12 kW (A-7/W 65). Without back-up boiler, the GAHP in monovalent use (with 12 kW instead of 17 kW) will be adapted to only 42% of exiting retrofit housing in France. The Seasonal Primary Energy Efficiency Ratio shall be higher or equal to 1.25 based on condensing technology. The modulation range shall be at least 1:3 to optimize SPER, Seasonal Primary Energy Efficiency Ratio (can be more or less, the important point is the SPER).

- **UK, Netherland, North and central of Spain**
  For domestic hot water production in these markets will be produced mainly via boiler for production domestic hot water and central heating(condensing). It is usual to use the max. heat power for DHW. Anti-legionella method is usual and expected same as condensing appliances. With a DHW (domestic hot water) production of demand are 50-100 Liter per day and person the coverage of the potential market reaches 80%. Maximum Domestic Hot Water temperatures is approx. 65°C. Space heating will be delivering via radiators, max temperature for heating demand is approx. 65 °C.

- **Germany, Austria, Switzerland**
  Germany, Austria and Swiss have usually a high DHW comfort. Preparation of DHW is performed via storage tank.
  The heat demand of existing flats is in a range of 100W/m² to 250 W/m², which means a maximum heat demand in dependence of the dwelling area of about 12 kW to nearly 30 kW. Operating temperatures may go up to 65°C in the coldest winter days (-15°C). In the largest majority of the cases the insulation of the house has already been upgraded and consequently the emission system (heating surface) is already sufficient to operate at 65C or lower temperatures.
  80% of the market have a DHW demand approx. 120 – 200 liters per day/person. Space heating in old houses is realized mainly via radiators with flow 70/50, floor heating systems for new building or deeply renovated with low flow temperature (floor heating).

- **Belgium**
  For DHW production Belgium use storage tanks with approximately 200-300 liters; flow rate at least 16l/min. 70% of the market have a request of DHW demand of 50 -100 lietrs per day and person. Domestic hot water temperatures is approx. 65°C. Space heating is performed mainly via radiators flow 70/50.

- **Denmark**
  80% of the market use DHW tanks. The typical tanks in DK are 50 to 150 liters. In DK, 65°C for DHW is used and accepted as sufficient for the protection against legionella. Annual demand for DHW is 2000 kWh/year. The national DHW standards are based on a tapping that requires about 35 kW to be fulfilled without a water tank. Typical tanks in DK are 50 to 150 l would be sufficient to fulfill the DK requirements with an 18 kW GAHP. For new renovated buildings the heating is performed mainly by floor heating systems with low flow temperatures.

- **Poland**
  70% of the market use Combi appliance (for DHW production due to less demand of DHW of 40-80 lt/person/day. For anti legionella once a week it is necessary to get 70°C inside DHW tank. Space heating is performed in renovated houses by means of radiators with central heating temperature of up to approx. 70 °C. (flow temperature).

- **North and central Italy**
  60% of the market have a DHW demand of 300 lt/day with peak consumption 15 lt/min. DHW production will be provided via Combi or system appliances. Heating is delivered for both and new building by means of radiators. Anti-legionella is performed by means of cycling temperature up to 60°C, one hour, once a week.

4.2. Installation habits, regulation and standards outdoor/ indoor installation hydraulic schemes, auxiliaries requirements for system control requirements for hydronic system components

The results of this parameter in each State are the following:

- **France**
  Buffer tank for heating is not necessary.

  Hydraulic kit (pump, 3-ways valve, expansion vessel and DHW tank) shall be installed at indoor side. 2 modules have to be considered:
  - 1 module outside (GAHP),
  - 1 hydraulic module inside (with option to separate DHW tank from the module). In the French market manufacturer usually provides the circulator/pump, the 3-ways valve and the all hydraulic components to simplify as much as possible the installation work and to minimize installation failures.

  Concerning anti freeze issue on water quality, recommendation is electricity tracing (inside the unit), but most of fitters prefer glycol for warranty reasons.
  In any case, as far as the antifreeze protection it is recommended:

- as sequence of operation when water temperature is approaching freezing point, to activate the circulating pump first, and then the unit;
- as installation guideline: to position the unit as close as possible to the house,
- as installation guideline: to bury the hydraulic connections as much as possible.

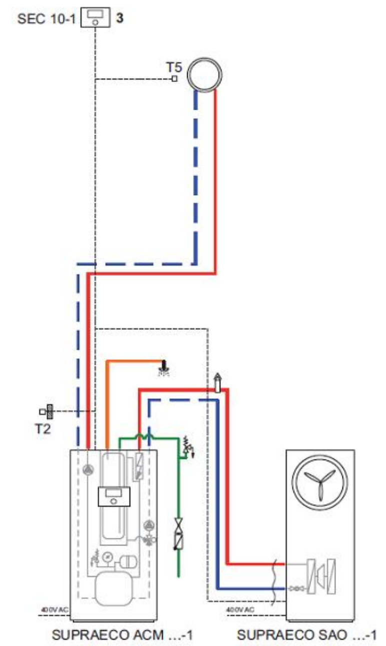
Cleaning of water hydraulic system at installation should be considered mandatory by the manufacturer, but it is also recommended to install a good filter (since in too often cleaning is not performed). Using filter to prevent corrosion has to be chosen in priority.

The France market has experiences with electrical heat pumps, but expects with new technologies an installation as simple as possible (like "condensing appliances"). Business for retrofit with GAHP is expected to be mainly with Air/Water type. This is indeed in the French market 80% of EHPs sold. GAHP shall be installed outside of the building (primarily because of lower perception of noise; ideally GAHP could be installed at inside side, but it's not a blocking point), on the ground and with free circulation of air.

System control requirements are the same as with condensing appliances. The GAHP Air/Water will be installed outside and for this reason will benefit from being as much as possible discrete or stylish. GAHP installation will need to fulfill the EU regulations and will need to be certified according to NF PAC to not be penalised in RT 2012. Minimal GUE 7°C/42,5°C = 1,30 Hi (42,5°C is the average between inlet and outlet water temperature of the GAHP). An acoustic emission level lower than Electrical Heat Pumps will be perceived as clear competitive advantage since today several EHP installations have created troubles with neighbors.

In the following picture a possible hydraulic schematic that is very well accepted in France.

Hydraulic system France



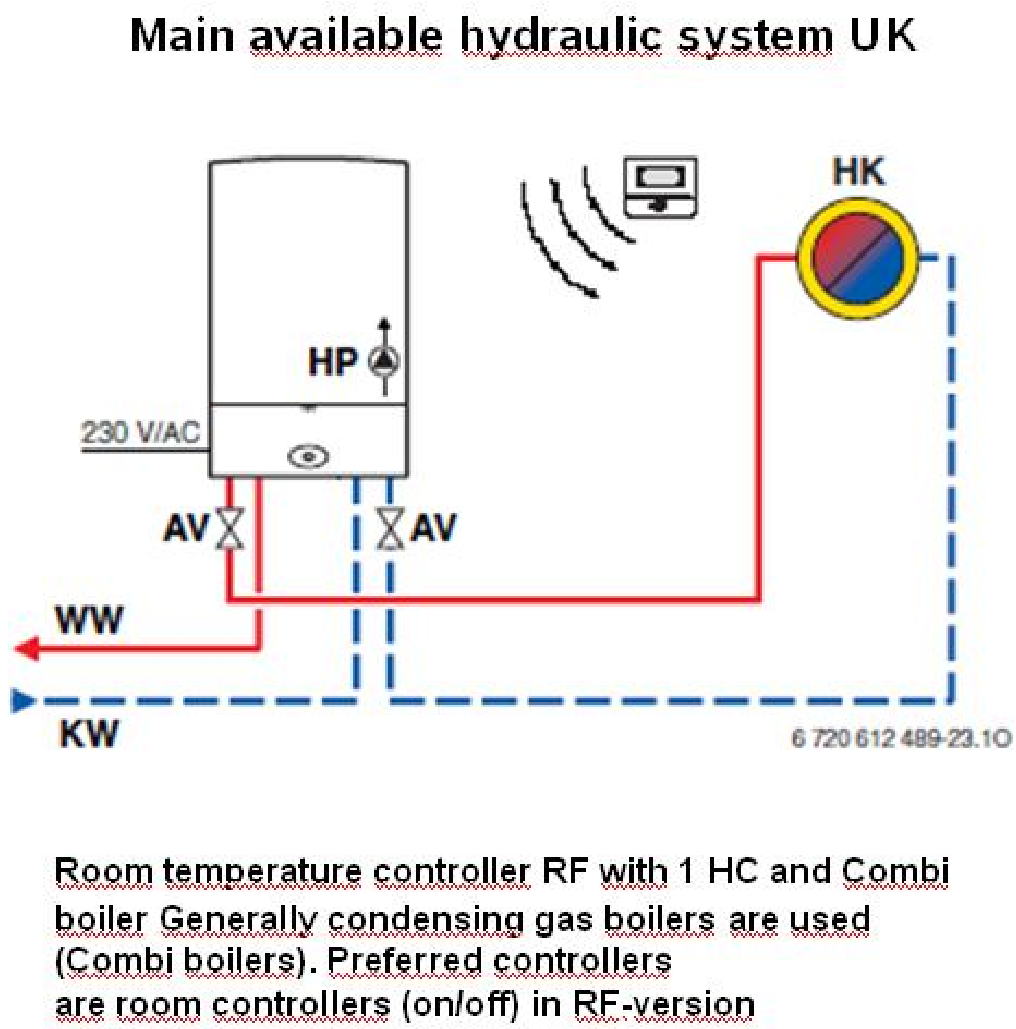
Room temperature controller with 1 HC and integrated tank

- **UK**

  For installation new heating system the installer will face dwelling constructions of 50% apartments and 50% house construction. It is anticipated that UK market will use GAHP air/water appliances mainly for retrofit. 80% of UK dwellings have available gas connection and therefore will be a good basis for the deployment of GAHP systems. Expectation of the market is that such system will ideally be installed like a condensing appliance. It is expected that the air/water appliance will be installed in the garden and have to be fit to the design of the house.

  To install the GAHP it's necessary to fulfill the EU regulations and building Act 1984, regulations 2011(Part L building Regulations).

  In the following picture the hydraulic schematic (for Wall Hang Boiler) that is most common in UK.



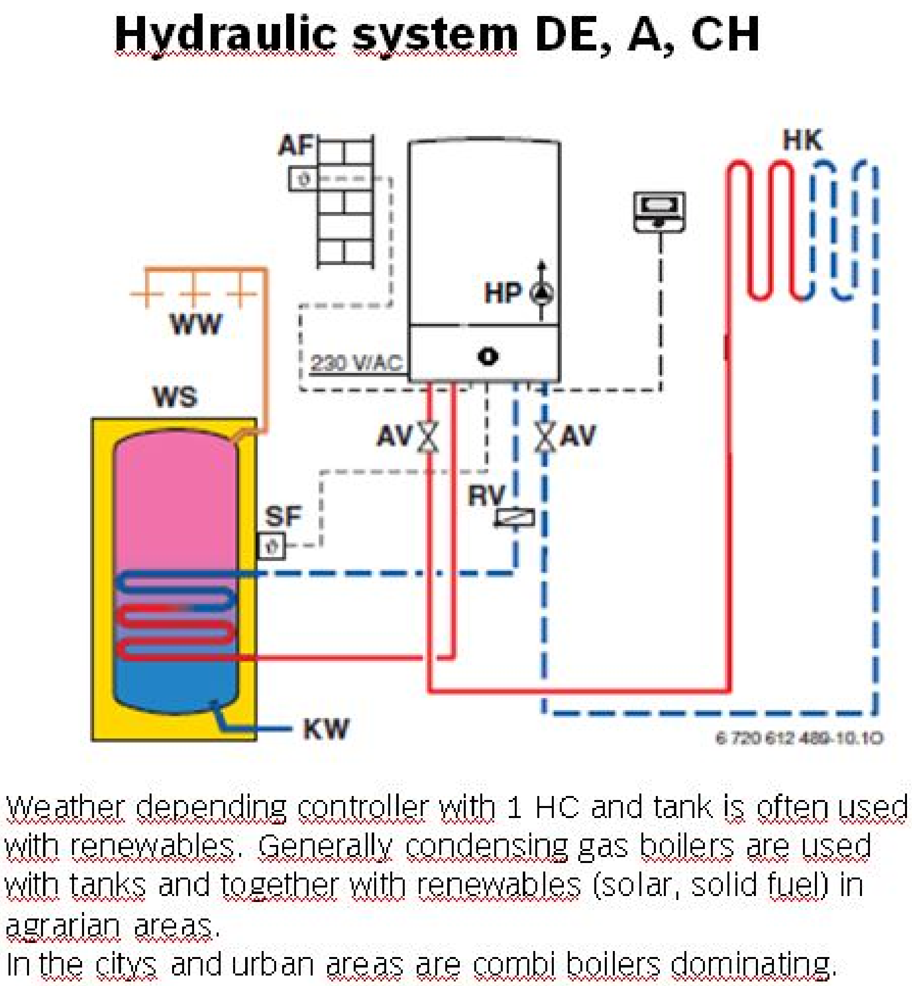
- **Germany, Austria, Swiss**

  Typical hydraulic schemes for German heating systems with a hot water storage tank.
    - One circuit heating system for radiators or floor heating devices
    - Two circuit heating systems for radiators and floor heating devices
    - On circuit heating system with solar panels for hot water production

  In single and double family houses in Germany domestic hot water is offered in a storage tank of 80l to 200l maximum. The heating system with radiators is directly connected to the appliance, for floor heating systems however often a three way mixing valve is integrated to control the temperatures. Water flow rates of 600 to 800 l/h for radiator heating systems and about 1200 l/h for floor heating systems are usual.

  Control systems in Germany usually ask for the outdoor temperature and regulate the outgoing temperature of the appliances.

  In the following picture the hydraulic schematic (for Wall Hang Boiler with DHW tank) that is most common in DE.

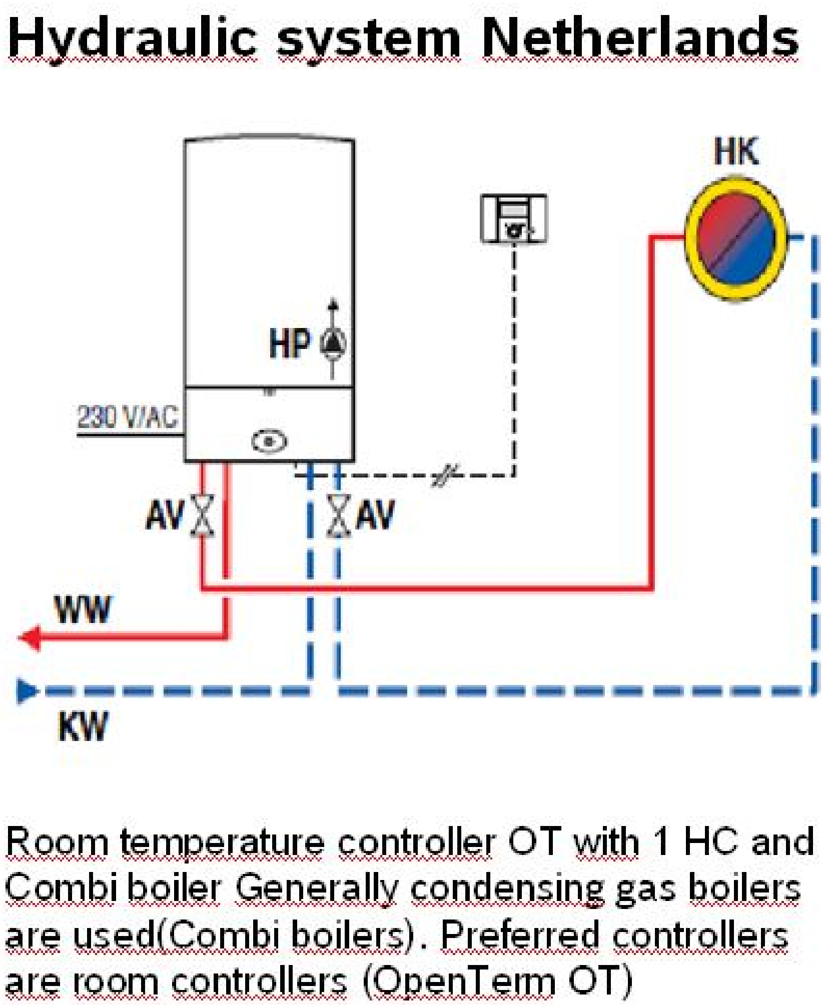


- **The Netherland**

  For installation new heating system the installation habits the installer has to consider dwelling constructions of 40% apartments and 60% house construction.

  It is expected that in the NL market GAHP air/water appliances will be used mainly for retrofit . Due to additional costs for ground source bore hole, GAHP air/water system gets more advantages for the future replacement market in the Netherlands.
  Expectations of the market are that GAHP will have the same installation like condensing appliances. It is anticipated that the GAHP air/water appliance will be install in the garden and have to be fit to the design of the house. To install the GAHP it’s necessary to fulfill the EU regulations.

  In the following picture the hydraulic schematic (for Wall Hang Boiler) that is most common in NL.



- **Belgium**

  The outdoor installation of GAHP air/water is perceived as compatible with the Belgium market since many condensing unit of Air conditioning appliances are already installed outdoor. No concerns have been raised because of expected the ground installation and need for free circulation of air.

  Concerning DHW production, the idea of using a storage tank fed by the GAHP in indirect mode is accepted and used in Belgium as well.

  The fact that buffer tank for heating is not necessary (additional losses, space problems) is perceived as an advantage compared to EHP solution that impose such additional tank.

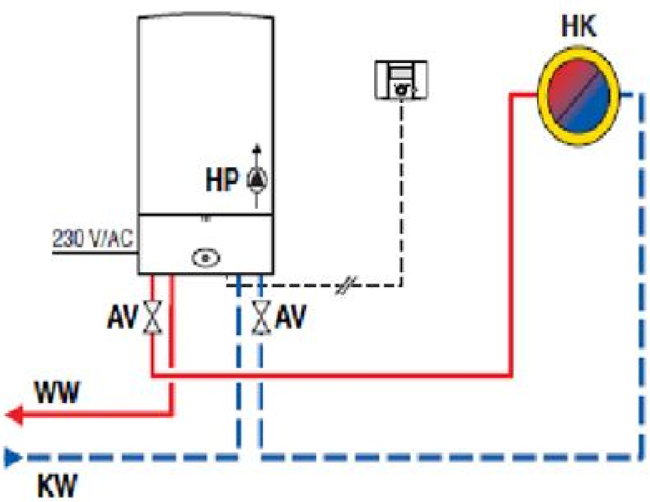
  A peak demand of about 20 kW should be covered by the system, ideally with the back-up burner, therefore a heat pump capacity of 12 kW (A-7/W65) is enough in a bivalent mode or for smaller premises in monovalent mode.

  Concerning anti freeze functionality the expectation is for using an anti freeze protection like electrical tracing and "Pumps ON" (water circulation).

  To install the GAHP in BE it has to be consider the Regional EPB (Energy Performance Building) implementation.

  In the following picture the hydraulic schematic (for Wall Hang Boiler) that is most common in BE.

Hydraulic system Belgium



Room temperature controller with 1 HC and Combi boiler. Generally condensing gas boilers are used (Combi boilers). Preferred controllers are room controllers (sales of tanks is growing)

- **Denmark**

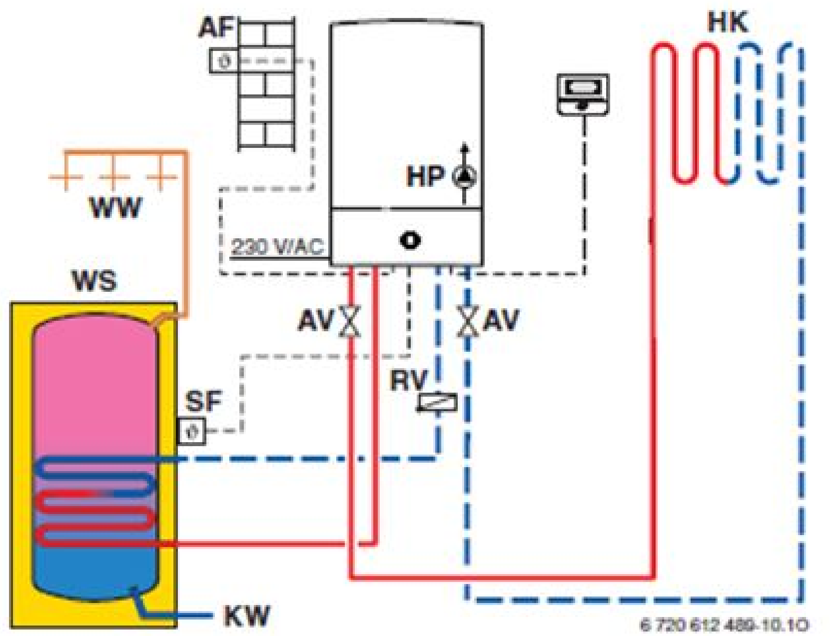
  In DK the most common HPs are heat pumps with ground source (60%); HPs with air/water system are approx. 20%, the rest of the market are HP DHW and HP for exhaust systems.

  Expectation of the market is the have same installation complexity like condensing appliances.
  In DK the DHW is the most common approach in the residential installation. Therefore the room for such appliance already exists.

  It is anticipated that the GAHP appliance will be installed in the garden and have to be fit to the design of the house.
  To install the GAHP it's necessary to fulfill the EU regulations and BR10 based on latest EPBD. Control display shall be placed in the house.

  In the following picture the hydraulic schematic (for Wall Hang Boiler with DHW tank) that is most common in DK.

Hydraulic system Denmark



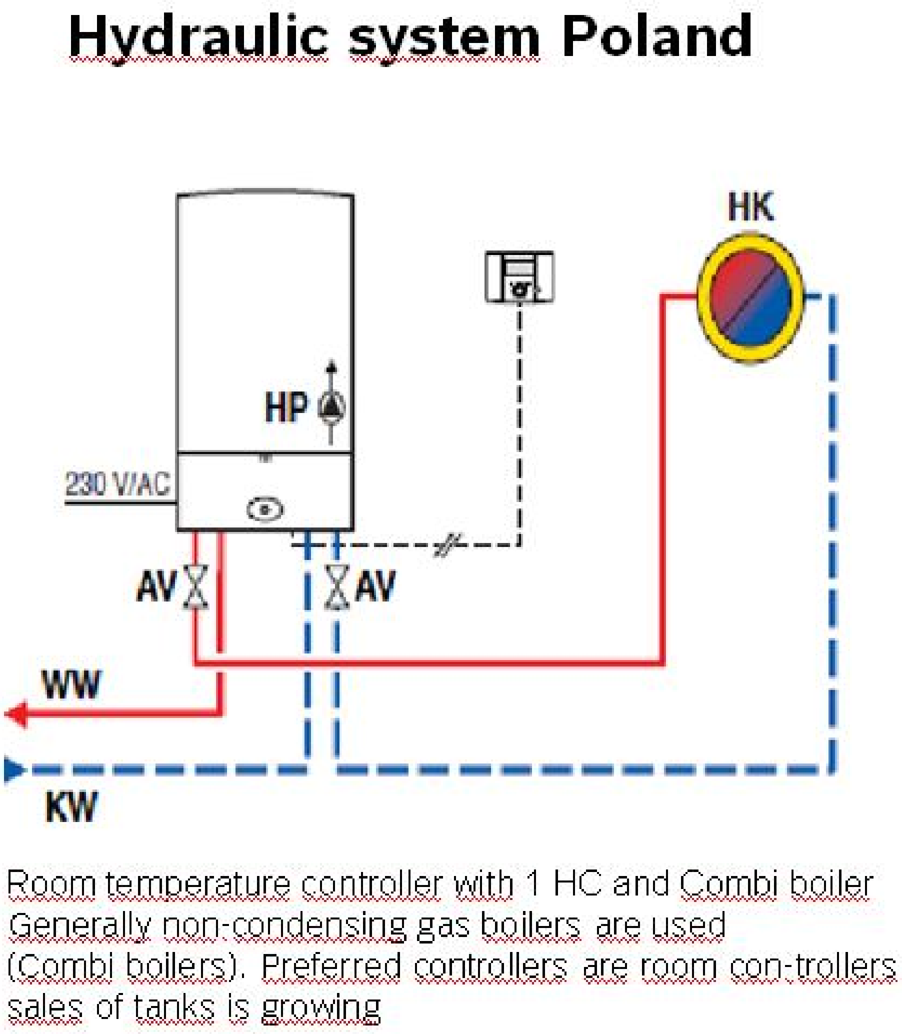
Weather depending controller with 1 HC and tank
Generally condensing gas boilers are used with tanks.
Preferred controllers are weather depending controllers

- **Poland**

  Operating temperatures (ambient) in Poland is approx -35 °C. to 45 °C. In Poland anti freezing for outdoor appliances is a major concern. In addition in some cases the electrical systems have prolonged blackouts. Therefore antifreeze solution should be compatible to lack of energy situation. Commonly anti freezing in Poland use glycol with separated heating circuit and additional heat exchangers.

  Regulations use din Poland do not differ from the ones used in rest of Europe: flue norms, gas norms, norms about heat pumps and refrigeration, noise, PED (Pressure Equipment Directive). Ideally GAHP user interface should feature a touch panel display with Polish language to be installed in technical room with possibility to add additional room units in reference places in the building.

  In the following picture the hydraulic schematic (for Wall Hang Boiler) that is most common in PL.



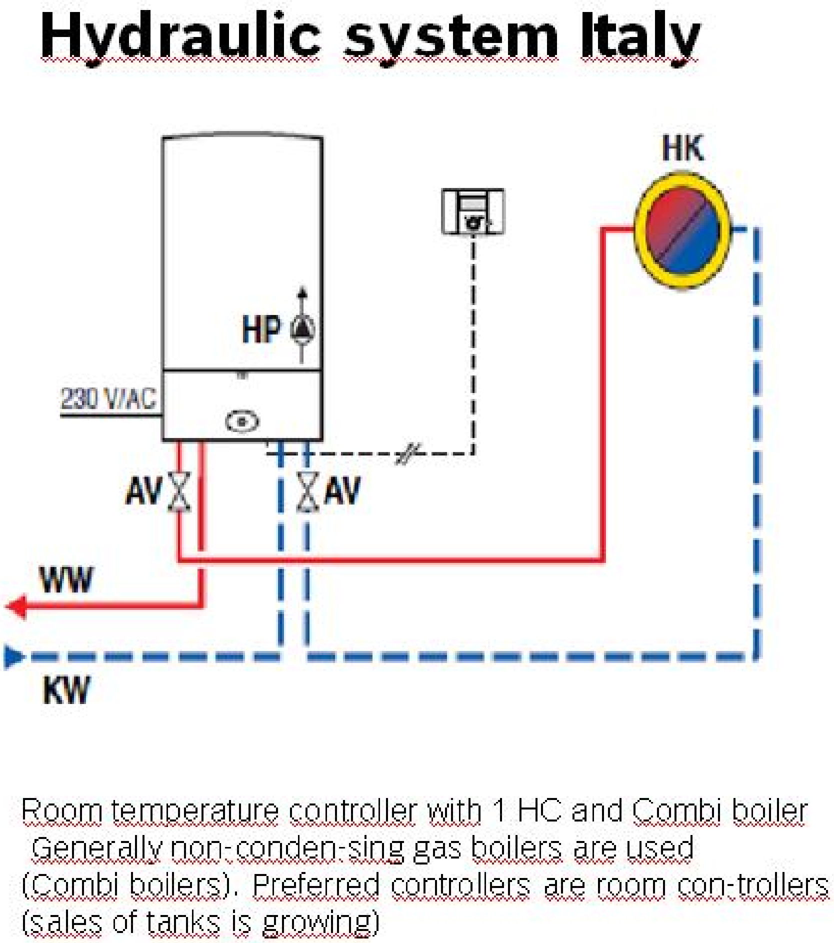
- **North and central Italy**

  In Italy sales of HP with air/water system are approx 80 %, the rest of the market are HP with ground source and DHW heating only.

  Expectation of the installer market is for installation complexity as simple as condensing appliances.

  It is anticipated that the GAHP air/water appliance will be install in the garden and have to be fit to the design of the house.
  To install the GAHP it's necessary to fulfill the EU regulations and Legge 10/91 - DPR412, relevant integrations and regional regulations. Control display shall be placed in the house.

  In the following picture the hydraulic schematic (for Wall Hang Boiler) that is most common in PL.



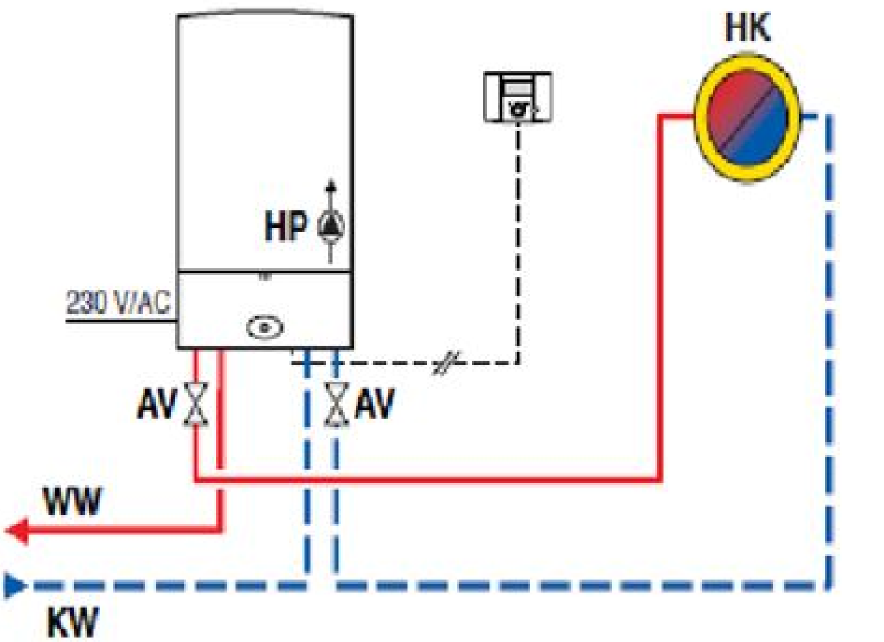
- **North and central of Spain**

  It is anticipated that Spanish market will use GAHP air/water systems for retrofit installations. Due to economic difficulties the heating market for Spain is currently suffering in general and in particular in the new buildings. In the retrofit market the market is currently based on very cheap solutions (e.g. non condensing appliances).

  Expectation of the installers is that GAHP installation will be like non condensing appliances. It is anticipated that GAHP air/water appliance will be install in the garden and have to be fit to the design of the house.
  Control display is expected to be placed inside the house.

  Ideally GAHP are expected to offer also cooling function, this in particular for new building market. There are no Spanish specific requirements to be fulfilled in addition to what necessary to fulfill the EU standards/regulations.
  In the following picture the hydraulic schematic (for Wall Hang Boiler) that is most common in SP.

Hydraulic system Spain



Room temperature controller with 1 HC and Combi boiler
Generally non-conden-sing gas boilers are used
(Combi boilers). Preferred controllers are room con-trollers
(sales of condensing is growing)

4.3. Building construction/retrofitting regulations, standards and habits detailed requirements of the building envelope for retrofitting materials and schemes, accessories

The new EPBD regulation and in particular its national implementations are paving the way for an increased use of renewable energy and upward trend toward higher energy efficiencies. From the analysis performed no constrains have been perceived to the deployment of GAHP technology while the local implementation (RT2012 in FR, DL63 in IT, ENEV and BAFA in DE, Part L building Regulations in UK, etc.) are always compatible and supportive of GAHP technology.

For the European market the installation of a heating system with heat pump technology today requires the installation of a hydraulic system with low flow temperatures. This is consequence of the limited attitude of available residential HPs to deliver efficiency when thermal lift increases. Therefore very often installation of HPs involves installation of floor heating, fan coils or at least larger radiators. While a reduced thermal lift will benefit also GAHP technology, the ability to maintain high efficiency even high flow temperatures allow minimal or no changes to the emission system of the dwellings. In general, however, the intervention for insulating the building envelope and the very frequent previous large over sizing of the emission system allow for operating the existing emission system at lower flow temperature.

The benefit of the GAHP technology is therefore appreciated in the construction industry for easy of application and deployment. Actual status of production for the DHW should be noted that the GAHP system will feature larger inertia compared to a regular boiler and therefore will require a separate DHW tank to guarantee comfort to the end user.

To fulfill all market requirements it is necessary to consider the complete GAHP system with all needed components e.g. controls, buffer tanks, DHW tanks, hydraulic pumps and flue accessories. All these components have specific norms and standards that can be used also for GAPH technology. With the exception of the EN12309 standard (dealing with performance measurement of sorption appliances) that need to be harmonized to the Ecodesign regulation, all other norms and standard are already available to create a GAHP system that is compatible with market accepted standards.

4.4. Pre-sales technical support, distribution, training, service distribution requirements service support requirements training and dissemination recommendations

In order to successfully introduce the technology of gas absorption heat pump technology in the European market of retrofitted buildings it is necessary to raise the awareness and address the need of pre-sales technical support, distribution, training, service and service support.

For each of the European countries it is necessary to define a sales story based upon the local structure and requirements identified. This should include the major advantages such as the benefit of using a renewable heating system which allows for significant CO_2 reduction.

The key message to the decision makes inside politics should be based upon the marketing argument that this technology contributes to the improvement of energy efficiency of housing moving residential dwellings towards nearly zero energy buildings and allowing European targets in CO2 reductions to be met.

As this is a new technology to the market, the sales people, planners and installers involved have to be trained especially on heat pump technology and it is necessary to support this with promotion by official or local research institutes. Especially planners and architects are an interesting target group to generally raise the awareness for such technology. This group will influence the decisions of the subsequent supply chain. Suitable documents for planners and installers to describe the system and give support for professional interpretation would further advance the introduction of GAHP technology.

Support should be given to each market with the promotion of a service concept to keep the installation failure rates as low as possible. This activity should be supported by educating GAHP specialist for professional commissioning.

To raise the awareness of the general public, in addition to promote the product in traditional way (leaflets, training, exhibitions and dedicated webpage’s), concepts to create TV spots or internet campaigns, or offer the product via additional distribution channels such as internet. The support of gas suppliers and electricity utility companies would add another aspect to the promotion and marketing activities of GAHP technology.

5. Comparison of GAHP to alternative technology solutions

In order to understand the attractiveness of GAHP technology several considerations are gathered in the following section to illustrate the unique selling points of the technology. These elements will contribute to the analyses needed for market potential and price positioning.

The technology that is currently available on the market and that is the closest technical reference for the GAHP technology is the Electrical Heat Pump.

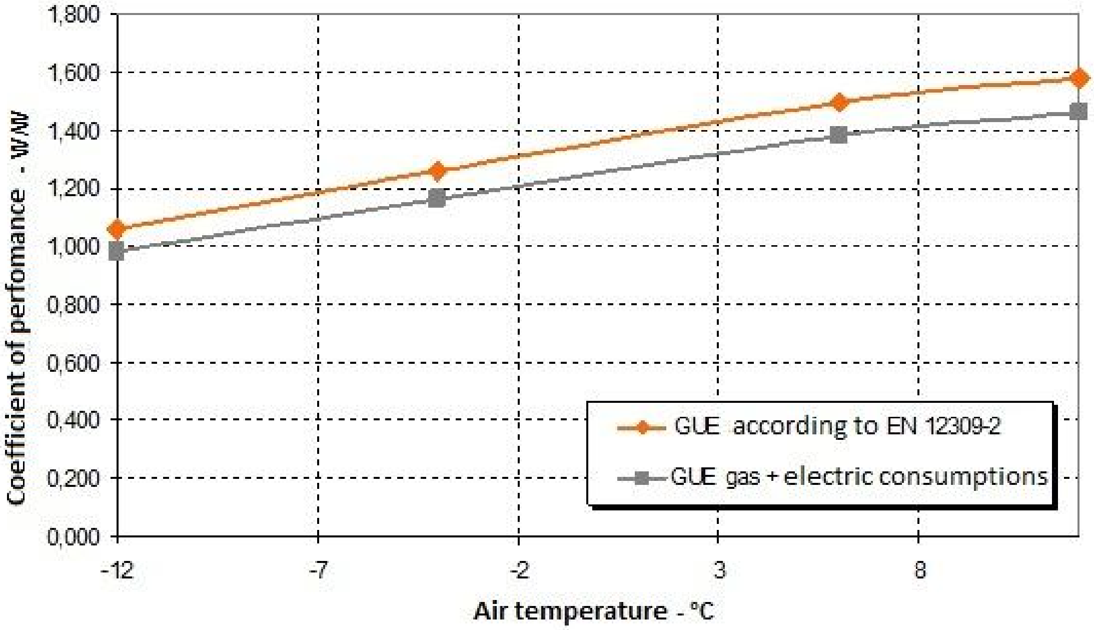
The following table shows the main technical characteristics (typical values) distinctive of gas absorption and electric heat pumps technologies.

	Gas absorption heat pumps	Electric heat pumps
Primary energy carrier needed	Natural gas or LPG	Electric energy
Type of refrigerant used	Ammonia and water	Safety refrigerant
Minimum operating temperature of air/water units	- 20°C	- 10/15°C
Maximum outlet temperature of the water	+ 65°C heating + 70°C for DHW	+ 50°C for heating and DHW
Types of suitable emission systems	Floor heating Fan coils Air Handling Units (AHU) High Temp Radiators	Floor heating Fan coils Air Handling Units (AHU)

Please note: the use of a heat pump, whether electrical or gas, allows an easy and economic exploitation of large amounts of renewable energy, which would not be otherwise usable.
To this must be necessarily added the advantage of the power density, which is far higher than that achieved by solar thermal panels or photovoltaic solar panels. The same power density reflects the "density of exploitation of renewable energy".

5.1. Energy comparison

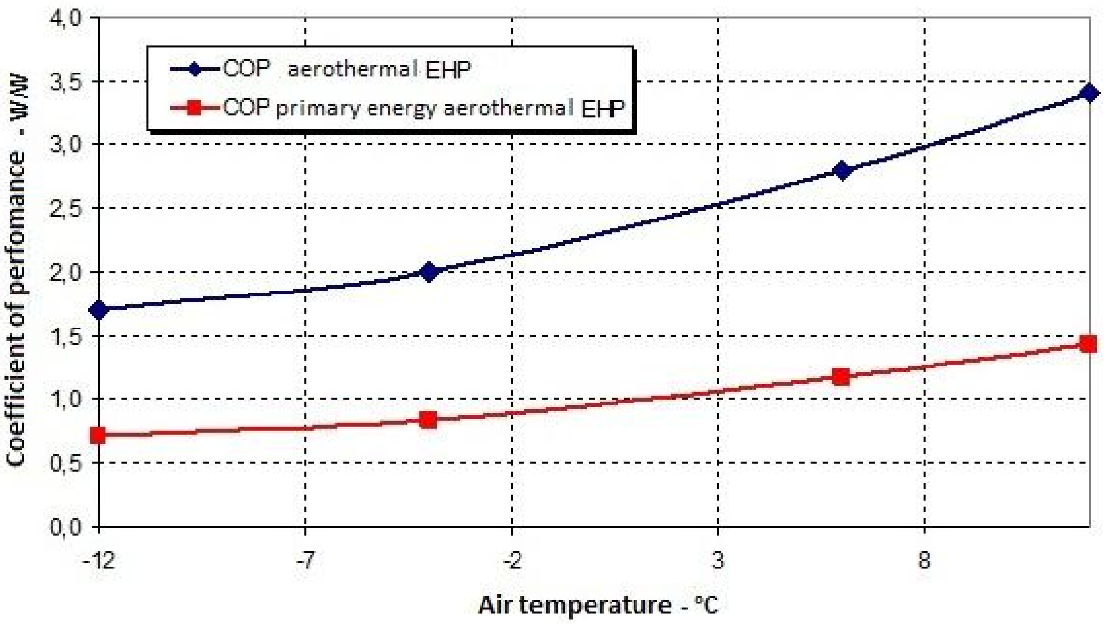
It is possible to develop a performance comparison among the different technologies in terms of efficiency on primary energy. In the Figure below it is shown the trend of the GUE for an aerothermal GAHP as a function of outdoor air temperature, considering a fixed outlet temperature of 50°C. The calculation is made according to the product standard EN 12309-2 (orange line) and for completeness the value of efficiency including auxiliary electric energy consumption is also shown (which is not included in the calculation of the GUE in accordance with the same EN 12309-2). The data is certified by a European certification body.



Thermal performance of an aerothermal GAHP (outlet 50° C)

In the next figure it is represented, under the same conditions, the COP of an electric heat pump at different external temperatures. Applying the primary energy conversion factor to the value of the COP turns the blue line in the below figure to the red line of the same figure.

It is to be noted that for the GAHP technology there is a limited dependency of the GUE on the temperature of the external source, while for the electric heat pumps (EHP) technology such dependence of the COP is more accentuated.



Thermal performance of an aero thermal EHP (outlet 50° C); conversion factor = 2.5 for primary energy calculation.

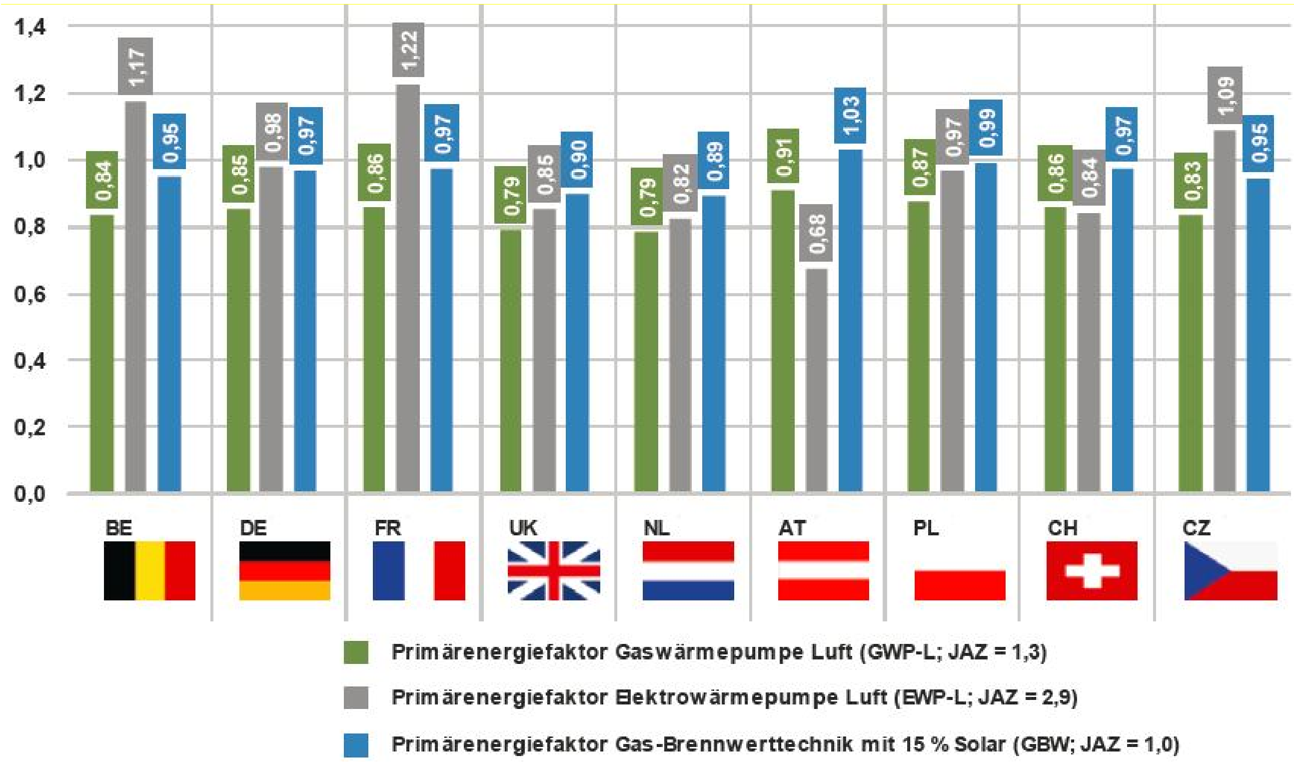
The trend of the GUE with changes in operating conditions of the absorption heat pumps allows a better understanding of what will be the seasonal average efficiency (SPF). In fact, the more critical weather conditions are the most costly in terms of energy and the most difficult in terms of maintaining comfort.

As expressed by the graphs above, the aerothermal gas absorption heat pumps are little influenced by the external climatic conditions and can boast efficiencies on primary energy substantially equal to a condensing boiler even when the outdoor air temperature is close to -15°C. These performances are reported in the following table, in which the values of GUE with changes in outdoor and outlet temperatures are provided for an already existing appliance that is comparable.

G.U.E. GAHP-A HT						
OUTDOOR AIR TEMPERATURE (T_a)	WATER SUPPLY TEMPERATURE (T_{hm})					
	40°C	45°C	50°C	55°C	60°C	65°C
	WATER RETURN TEMPERATURE (T_{hr})					
	30°C	35°C	40°C	45°C	50°C	55°C
-20°C	1,250	1,175	1,100	1,020	0,940	0,900
-19°C	1,260	1,185	1,110	1,030	0,950	0,910
-18°C	1,270	1,195	1,120	1,040	0,960	0,920
-17°C	1,280	1,205	1,130	1,050	0,970	0,930
-16°C	1,290	1,215	1,140	1,060	0,980	0,940
-15°C	1,300	1,225	1,150	1,070	0,990	0,950
-14°C	1,310	1,235	1,160	1,080	1,000	0,960
-13°C	1,320	1,245	1,170	1,090	1,010	0,970
-12°C	1,330	1,255	1,180	1,100	1,020	0,980
-11°C	1,340	1,265	1,190	1,110	1,030	0,990
-10°C	1,350	1,275	1,200	1,120	1,040	1,000
-9°C	1,390	1,307	1,223	1,140	1,057	1,007
-8°C	1,430	1,338	1,247	1,160	1,073	1,013
-7°C	1,470	1,370	1,270	1,180	1,090	1,020
-6°C	1,484	1,384	1,284	1,197	1,110	1,034
-5°C	1,498	1,398	1,298	1,214	1,130	1,048
-4°C	1,512	1,412	1,312	1,231	1,150	1,062
-3°C	1,526	1,426	1,326	1,248	1,170	1,076
-2°C	1,540	1,440	1,340	1,265	1,190	1,090
-1°C	1,547	1,457	1,366	1,281	1,195	1,105
0°C	1,555	1,474	1,393	1,297	1,201	1,120
+1°C	1,562	1,491	1,420	1,314	1,206	1,135
+2°C	1,570	1,509	1,448	1,330	1,212	1,150
+3°C	1,575	1,519	1,462	1,347	1,231	1,166
+4°C	1,581	1,528	1,476	1,363	1,251	1,183
+5°C	1,586	1,538	1,490	1,380	1,270	1,200
+6°C	1,591	1,548	1,504	1,397	1,291	1,218
+7°C	1,597	1,558	1,519	1,415	1,311	1,236
+8°C	1,602	1,565	1,527	1,428	1,329	1,254
+9°C	1,607	1,571	1,534	1,441	1,348	1,272
+10°C	1,613	1,578	1,542	1,454	1,367	1,290
+11°C	1,618	1,584	1,549	1,467	1,385	1,308
+12°C	1,624	1,590	1,557	1,480	1,404	1,326
+13°C	1,629	1,597	1,565	1,494	1,423	1,344
+14°C	1,634	1,603	1,572	1,507	1,441	1,362
+15°C	1,640	1,610	1,580	1,520	1,460	1,380

Trend of the GUE of a 41 kW aero thermal gas heat pump according to the working conditions.

Therefore in terms of primary energy performance GAHP can provide significant benefits not only when compared to a regular boiler, but also when compared to an electrical heat pump – see figure below. The new European regulation ErP Lot1 will introduce a direct comparison of seasonal performance for all heating appliances based on primary energy use. GAHP is therefore to deliver optimal performance when measured and ranked under such new criteria.



Comparison of primary energy factors of the competing technologies (Source: *Weltweite Gaswärmepumpenaktivitäten.* Leipziger Institut für Energie GmbH, 2011)

6.2 Economic comparison

The choice of a type of heat pump in respect to another can be done not only according to their energy performance, but also according to the various and different economic advantages.

The economic benefits associated with the technologies can be divided into:

- Initial investment costs (appliance purchase and installation)
- Operating costs
- Maintenance costs

The following sections are intended to summarize these decision factors in comparison with existing technologies.

5.1.1. Investment costs

When comparing GAHP to EHP, in addition to the direct cost of the equipment and its accessories, also the indirect costs must be included in the initial investment costs, i.e. the costs necessary to run the unit. In fact, usually for the commissioning of the unit it is necessary to provide for a series of additional work. The cost associated with these works can be very significant (for example for the realization of an electrical transformer substation).

The items which must then be taken into account for the evaluation of the investment cost are:

- upgrade of the electricity or gas meter and supply lines;
- realization of a possible flue (only for gas heat pumps);
- check and eventually change of the emission system if they are not suitable for systems with medium or low temperature (in particular for electric heat pumps);
- occupation of any spaces for the location of the equipment (in particular in the case of heat pump for indoor installation);
- building additional works (e.g.: construction and retrofit of the heating plant, masking works, soundproofing, etc.)

For an economic assessment of the investment, it is also worth remembering that *any comparison has to be made:*

- in the case of the aero thermal heat pump: taking into account the thermal power supplied at the design conditions and not at the nominal ones;
- in the case of geothermal or hydrothermal heat pumps: taking into account the cost of the geothermal field (geothermal probes) and / or of the heat exchanger for hydrothermal heat pumps. In this regard, we recall that the size of the geothermal probes for electric heat pumps is significantly higher than that required for gas heat pump and this represent a much greater cost than the heat pump itself.

In the investment cost we must also add the administrative costs, which in part depend on the type of technology used for the production of heat:

- Design (preliminary and executive)
- Supervision of works (where applicable)
- Attainment of the drilling/pumping authorization (for geothermal and hydrothermal heat pumps)
- Practices of fire prevention in the case of heating plants with heat output > 116 kW
- Obligations related to the European Directive 842/2006, for electric heat pumps, which use fluorinated refrigerants HFC.

5.1.2. Operating costs

The cost of energy carriers is different from country to country. In the table below, the values of the cost of natural gas and electricity (expressed in €/kWh) in the countries of the European Union are given, referring to the month of May 2012. For the latest information please visit www.energy.eu.

NATURAL GAS HOUSEHOLDS

Retail (end-user) energy prices for households.
Two consumption levels are identified. Research methodology.
Price data mentioned may not reflect the latest insights found in the commercial editions.

Reference month: **May 2012.**
Historical price data going back to the year 2000, visit EU Energy History.

Consumption: 15,000 kWh/year or 1,400 m3 of gas (± 25%)		Consumption: 30,000 kWh/year or 2,800 m3 of gas (± 30%)	
Country	**€ per kWh Natural Gas**	**Country**	**€ per kWh Natural Gas**
Austria	€ 0.0702	Austria	€ 0.0621
Belgium	€ 0.0574	Belgium	€ 0.0546
Bulgaria	€ 0.0428	Bulgaria	€ 0.0434
Czech Republic	€ 0.0541	Czech Republic	€ 0.0509
Denmark	€ 0.1146	Denmark	€ 0.1180
Estonia	€ 0.0414	Estonia	€ 0.0413
France	€ 0.0583	France	€ 0.0509
Germany	€ 0.0574	Germany	€ 0.0578
Hungary	€ 0.0568	Hungary	€ 0.0561
Ireland	€ 0.0506	Ireland	€ 0.0484
Italy	€ 0.0700	Italy	€ 0.0670
Latvia	€ 0.0394	Latvia	€ 0.0385
Lithuania	€ 0.0433	Lithuania	€ 0.0380
Luxembourg	€ 0.0516	Luxembourg	€ 0.0483
Netherlands	€ 0.0727	Netherlands	€ 0.0683
Poland	€ 0.0466	Poland	€ 0.0427
Portugal	€ 0.0609	Portugal	€ 0.0553
Romania	€ 0.0285	Romania	€ 0.0282
Slovakia	€ 0.0465	Slovakia	€ 0.0512
Slovenia	€ 0.0670	Slovenia	€ 0.0588
Spain	€ 0.0525	Spain	€ 0.0499
Sweden	€ 0.1226	Sweden	€ 0.1133
United Kingdom	€ 0.0419	United Kingdom	€ 0.0380

Notes:
- Amount is in euro (€) per kiloWatthour (kWh).
- EU Average Gross Calorific Value 38.48 (MJ/m3)
- Price data for non-eurozone countries are in euro. The average exchange rate valid for the referenced month is applied.
- Prices include: market price, transport through main and local networks, administrative charges and all taxes.

ELECTRICITY HOUSEHOLDS

Retail (end-user) energy prices for households.
Two consumption levels are identified. Research methodology.
Price data mentioned may not reflect the latest insights found in the commercial editions.

Reference month: **May 2012.**
Historical price data going back to the year 2000, visit EU Energy History.

Consumption: 3,500 kWh/year (± 25%)		Consumption: 7,500 kWh/year (± 30%)	
Country	**€ per kWh Electricity**	**Country**	**€ per kWh Electricity**
Austria	€ 0.1988	Austria	€ 0.1798
Belgium	€ 0.2134	Belgium	€ 0.1940
Bulgaria	€ 0.0829	Bulgaria	€ 0.0823
Cyprus	€ 0.2850	Cyprus	€ 0.2800
Czech Republic	€ 0.1480	Czech Republic	€ 0.1276
Denmark	€ 0.2982	Denmark	€ 0.2562
Estonia	€ 0.0989	Estonia	€ 0.0948
Finland	€ 0.1566	Finland	€ 0.1369
France	€ 0.1412	France	€ 0.1279
Germany	€ 0.2541	Germany	€ 0.2406
Greece	€ 0.1265	Greece	€ 0.1553
Hungary	€ 0.1708	Hungary	€ 0.1616
Ireland	€ 0.1920	Ireland	€ 0.1604
Italy	€ 0.2031	Italy	€ 0.2485
Latvia	€ 0.1187	Latvia	€ 0.1193
Lithuania	€ 0.1200	Lithuania	€ 0.1201
Luxembourg	€ 0.1707	Luxembourg	€ 0.1587
Malta	€ 0.1695	Malta	€ 0.1829
Netherlands	€ 0.2208	Netherlands	€ 0.2439
Poland	€ 0.1488	Poland	€ 0.1419
Portugal	€ 0.1689	Portugal	€ 0.1547
Romania	€ 0.1095	Romania	€ 0.1074
Slovakia	€ 0.1677	Slovakia	€ 0.1501
Slovenia	€ 0.1447	Slovenia	€ 0.1335
Spain	€ 0.1959	Spain	€ 0.1777
Sweden	€ 0.2098	Sweden	€ 0.1821
United Kingdom	€ 0.1419	United Kingdom	€ 0.1265

Notes:
- Amount is in euro (€) per kiloWatthour (kWh).
- Price data for non-eurozone countries are in euro. The average exchange rate valid for the referenced month is applied.
- Prices include: market price, transmission through main and local networks, administrative charges and all taxes.

(Europe’s Energy Portal)

In most contracts for electricity supply, the overall rate consists of a portion of fixed costs, one of variable cost and a portion dedicated to taxes and duties for various reasons. The cost of the supplied kWh depends very much on the type of user, on the annual consumption and on the contract with the electricity distributor.

With regard to gas tariffs, instead, they are divided primarily among those with full cost and those defiscalized, which, depending on the country, are applied to a series of productive and commercial activities and allow a 90% reduction of the incidence of the excise duty on the price of gas supplied.

As for electricity, the gas tariff is divided into a fixed part a variable part based on consumption and a part due to taxes and duties. Also in this case, the cost of a cubic meter of gas supplied depends greatly on the type of user, on the annual consumption and on the contract with the gas distributor.

Operating costs will therefore vary significantly in the different region also because of tariff differences. A multi-local analysis including operational costs aspect in some of the most relevant markets prospected for GAHP technology will be performed as part of Work Package 7.

6.2.3 Maintenance costs

In this category of costs we can identify the following categories: Complexity of construction and maintenance (moving parts), the need for specialized personnel, and environmental costs for the disposal of fluids.

- **Complexity of construction and maintenance (moving parts):**
  It is clear how complicated equipment with numerous moving parts are more susceptible to failure of purely static equipment (e.g. Solar panels) or with few moving parts, and consequently they need more frequent and expensive preventive and extraordinary maintenance. In general we can say that devices with a compressor are more delicate than equipment devoid of this component.

  In the case of gas absorption heat pumps, the only moving parts are the fan (in the case of aerothermal heat pumps) and the solution pump. For the rest the thermodynamic circuit is substantially static and moved by physical and chemical processes.

  Complex technologies usually require complex maintenance interventions, with a consequent increase in their duration (and therefore the unavailability of the service during maintenance intervention).

- **The need for specialized personnel**
  Complex and unfamiliar technologies require more specialized and more expensive staff and offer less choice regarding the possibility of consult different maintainers or training personnel for the same service.

  The Law identifies specific skills that the maintenance staff of the thermo-refrigerators must have, in order to ensure the appropriate quality standards. It is therefore appropriate to rely on specifically trained personnel, possibly with the support of the equipment manufacturer.

  With regard to the maintenance of gas absorption heat pumps, it can be compared to that required for traditional boilers. The sealed circuit (that contains the solution of water and ammonia) does not require any maintenance or any control, since the solution, in the normal operation of a heat pump, is never either refilled or replaced during the lifetime of the unit.

- **Environmental costs for the disposal of fluids**
  The technologies that require, under certain conditions, the complete emptying of the refrigerant circuit to recharge it, entail a series of costs associated with the disposal, the recovery of refrigerant, and the manpower required for intervention. This is the case of the electric heat pumps, which require periodic checks of the internal fluid and, in the case in which the loss

exceeds a given value (around 20%), they require integral emptying of the circuit and charging with a virgin fluid. This is due to the use of zeotropic mixtures refrigerants (composed of 2 or 3 different fluids) that in case of loss does not guarantee the preservation of the percentages of composition initially planned of the various fluids.

Technologies with hermetic circuit, such as the absorption heat pump, do not suffer from this problem, during normal operation.

Overall maintenance cost of a GAHP Appliance based on sealed circuit are expected to be lower compared to the maintenance costs of an Electrical heat pump (absence of the compressor and possible leakages) and in line with cost for regular boiler technology.

5.2. Environmental comparison

The environmental impact due to the use of gas absorption or electric heat pumps is undoubtedly and significantly lower than the one of the heating systems realized with traditional or condensing boilers. This thanks to the efficiency of heat pumps which, as mentioned several times, have the ability to use in their operation renewable energy taken from the environment and thus have, for a given heating power, lower consumption of energy.

The impact on the environment caused by the functioning of heat pumps depends particularly from the emission of pollutants into the atmosphere. These pollutants can be divided into:

- indirect emissions, caused and dependent by the use of energy for operating. These are proportional to the use of the equipment;
- direct emissions, caused by the presence within the thermodynamic circuit of a fluid harmful to the environment that, in the event of loss, impacts directly in a negative way on the environment.

5.2.1. Indirect emissions

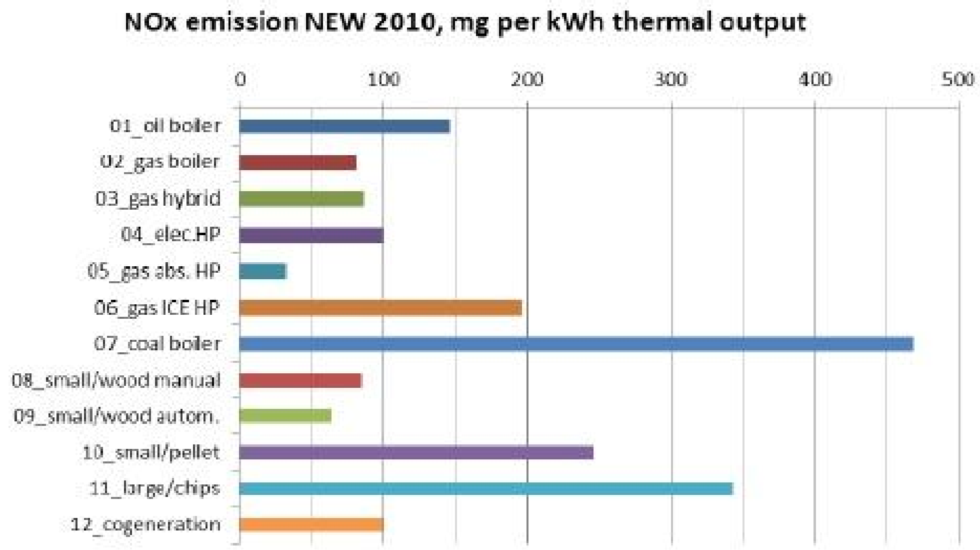
Atmospheric emissions are due to the energy used by the heat pumps for their operation. The impact on the environment, however, is different depending on the type of heat pump, electric or gas, because they use a different energy carrier, electricity and natural gas (or LPG). While gas heat pumps use for their operation only gaseous fuels (natural gas or LPG), electricity is produced using a mix of different types of fossil fuels: gas, oil, coal. This difference leads to a different environmental impact, since the emitted pollutants are different.

The environmental impact study carried out by the European Commission in Directive 2010/30/EU (Ecodesign Directive), has highlighted the direct and indirect emission achievable in particular for three types of pollutants resulting from the production of heat from different technologies available today.

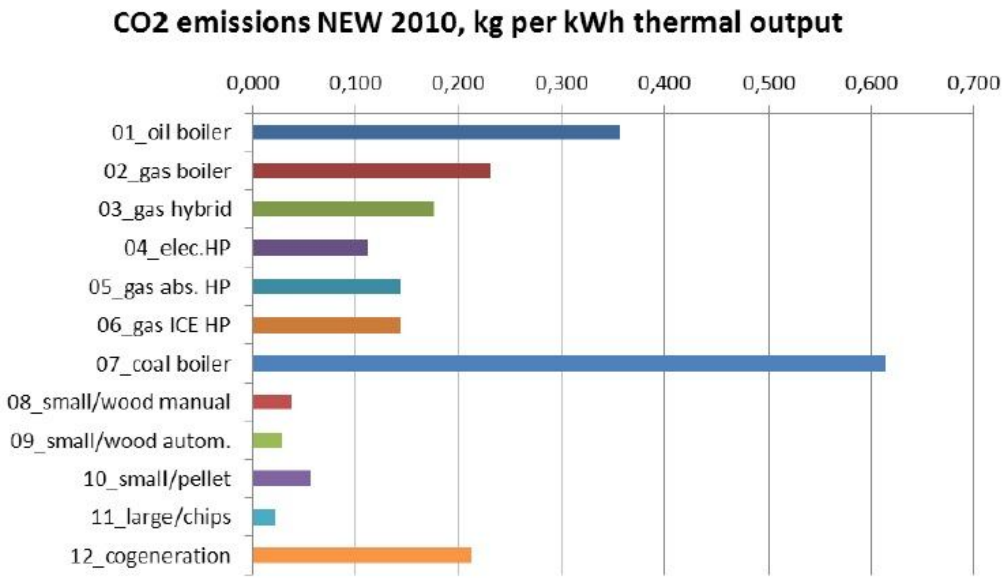
These three pollutants that are affecting the most the environment and the health are:

- NOx, i.e. Nitrogen oxides and dioxides;
- CO_2, carbon dioxide (which is not properly a pollutant, since it is not directly harmful to human health, but is a greenhouse gas);
- PM, i.e. particular matter

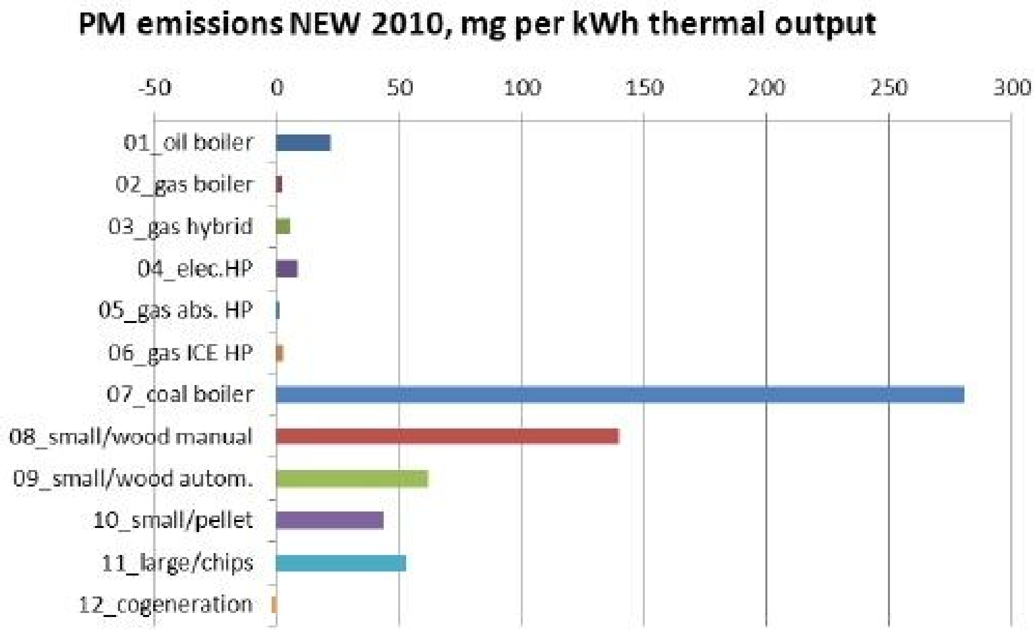
The study highlights the different values of pollutants emitted into the environment for each kWh of thermal energy produced by a series of technologies, including gas heat pumps, the electric ones and boilers (which we insert in this analysis only as a comparison value among different technologies), considering total emissions including emissions into the plant for the production of electricity.
In the Figure below it should be noted that NOx emissions (mg/kWh) are very low for the gas heat pumps (05) because they use a clean fuel used with a high combustion control. The electrical heat pumps (04) instead are penalized by the mix of the used fuels, which are often not as clean as natural gas.



In the following figure we note the difference in CO_2 emissions (kg/kWh) with an advantage of electrical heat pumps compared to the gas ones and both significantly lower than those emitted by boilers.

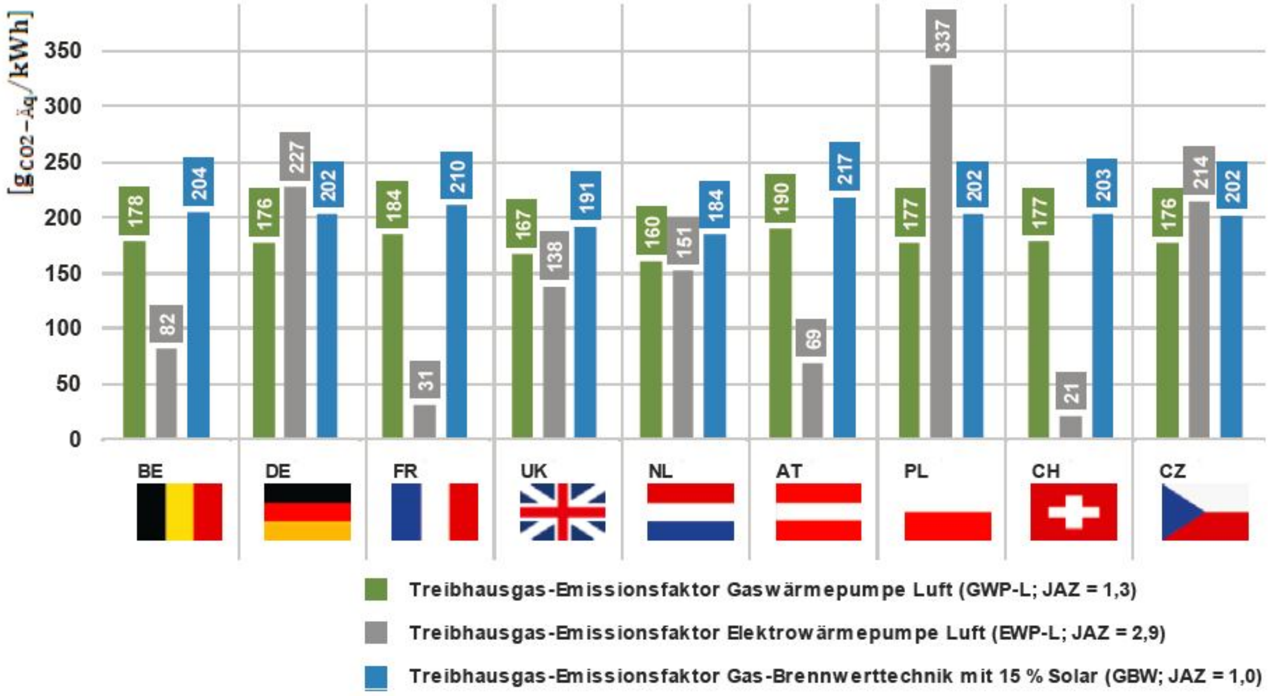


In the following figure, the difference in PM (in mg/kWh) is once again in favor of gas absorption heat pumps, thanks to the use of a less polluting fuel.



Looking at the overall environmental impact that the three technologies produce, it should be noted that at the present state gas absorption heat pumps is the less overall polluting technology available.
Of course, this assessment of the European commission was conducted by analyzing European data and reference values, therefore, sensible differences on this study can be found when local factors

(i.e. energy conversion factors) are included. Please see figure below for a comparison of CO_2 emission factors of different competing technologies.



Comparison of CO_2 emission factors of the competing technologies (Source: *Weltweite Gaswärmepumpenaktivitäten.* Leipziger Institut für Energie GmbH, 2011)

5.3. Cost – Benefit Analysis

The operating costs of heat pumps are generally substantially lower than those of traditional boilers and in any case lower than those of the new condensing boilers, thanks to their capability to use renewable energy.

However the benefit of a solution that has duration of life by an average of 15 years (it can be estimated an average lifetime of 15 years for a plant correctly maintained) should take into account this durability aspect, which is defined lifecycle of the product.

The investment cost of a heat pump plant is, on average, greater than a traditional boiler plant, but the operating costs are much less expensive. The choice of using a gas absorption heat pump in place of other heating technologies can not disregard from a careful economic analysis.

All cost items associated with a heating system should be included in order to perform the calculation for the analysis of the system costs and the comparison between different technologies. This can be easily obtained with the so called cost-benefit analysis.
It is possible, therefore, to identify two types of costs and benefits related to an activity:

- internal ones, i.e. those referring to the person making directly the investment
- external ones (also called externalities), i.e. those involving the community

Since the strictly financial aspects are not exhaustive to describe the possible impacts (positive and negative) of a project, the CBA based its assessment on social criteria as well, calculated from the results of the financial analysis through appropriate corrections to derive the overall costs and benefits of the work to evaluate. The variables considered for this analysis are therefore economics, i.e. of a financial type (monetary), and social (monetized).

Although very difficult, it is in fact still possible to give a monetary cost to externalities through mathematical models, which are usually very complex.

There are several ways to perform a cost benefit analysis, including:

- Simple payback
- Average rate of return
- Cash flow method
- Whole-life costing
- Net present value (NPV)

In assessments that will be made in the next units we will consider mainly internal costs and benefits, i.e. those that directly affect the person making the investment, because the time are not mature yet to leverage the benefits that the community would take in the environmental field from the use of heat pumps. The same considerations apply, however, if externalities are also used.

5.3.1. Costs of heat pump systems

The costs associated with all heating systems include capital costs, operating costs, and end-of-life costs.

capital costs	Design and project management fees
	Building regulations application
	Equipment cost (including delivery charges)
	Installation cost
	Commissioning cost
operating costs	Annual fuel cost
	Annual maintenance (labor + parts)
	Repair cost (if it breaks)
end-of-life costs	Disposal cost

- **Capital costs**

  Capital costs are one-time costs that must be paid to design, buy, install and commission the system. For small projects such as single houses, the items listed under capital cost may be provided by the installer for a lump sum. This lump sum may include the first year maintenance cost but probably excludes other costs associated with the project e.g.
    - Re-landscaping a garden after burying a ground coil
    - Upgrading the electricity supply and/or electricity meter
    - Installing a gas supply or oil tank for a conventional boiler
    - Removal and disposal of existing heating equipment
    - Re-decoration of rooms (e.g. if radiators are added or moved)

  The investment cost is variable depending on some purchase factors, but we can indicate the heat pump, generally, as a more expensive technology in terms of purchase compared to traditional systems, such as condensing boilers.

- **Operating costs**

  Operating costs are costs that must be paid to operate and maintain the system. The major operating cost is likely to be fuel. The annual fuel cost should be based on the unit cost of fuel.

  The fuel cost for heat pumps should be based on the most beneficial tariff for heat pump operation that is available to the customer. Special heat pump tariffs are available from electricity suppliers in some countries. These tariffs provide cheaper electricity when demand from other consumers is low i.e. early in the morning and for some short periods during the day. Off peak tariffs designed for electric storage heaters are not generally suitable for heat pumps unless they provide a heating period during the daytime.

  Electricity tariffs generally include a "standing charge". This is the fixed cost of connection to an electricity or gas supply. All homes need electricity, so it would not be reasonable to allocate the entire standing charge for electricity to the heat pump. However, where the installation of a heat pump increases the standing charge (due to the need for increased supply capacity or for use of a different tariff) then the additional cost should be allocated to the heat pump. This cost can be significant (e.g. in Sweden the difference in cost between a 16A and 20A supply (both 3-phase) is 200€/year).

  As already stated, one of the advantages of the gas absorption heat pumps is to utilize as a source of energy for its operation, almost exclusively natural gas (or LPG), a type of energy thoroughly diffused and available throughout the European territory.

  A precise analysis of fuel costs would take account of seasonal variation in energy consumption and link this to an estimate of monthly or quarterly billing but this level of detail is not necessary for simple comparisons of systems provided the unit cost of fuel is not seasonally dependent.

  Boilers and heat pumps are usually maintained under an annual contract that includes both scheduled maintenance and the labour element of repairs. The material cost of repairs may be charged separately or included within the maintenance contract or, in the early life of the system, covered by the warranty.

In terms of maintenance, for GAHP, it is similar to that performed in the boilers that work with gas, because the principle of operation is based on the presence of a premix burner gas, while there is no routine maintenance for the parts of the thermodynamic circuit (sealed circuit) for the whole lifetime of the absorption heat pump.

- **End-of-life costs**
  The cost of un-installing and disposing of used equipment is generally increasing as a result of environmental concerns and consequent legislation. Although it is likely that the cost of disposal of the major components of heating systems will eventually be covered by producer responsibility legislation (e.g. the Waste Electrical and Electronic Equipment Directive), reasonable provision for the cost of un-installing equipment should be included in the whole life cost calculation.

Operating costs: Gas absorption vs. Electric heat pumps

As regards the direct comparison among a system realized with electric heat pumps and one realized with gas heat pumps, it depends on several factors that affect, even in a significant way, the comparison, making one solution convenient respect to the other according to the considered cost variables, which, we can summarize in:

- the necessary thermal power at design conditions: the size of the heat pump should be selected according to the design conditions and not to the nominal conditions (e.g. if the heat pump is installed in Milan, the design temperature is -5°C);
- the operating temperature of the plant, which may be low (heating floor), average (fan-coils and AHU) or high temperature (radiators). This operating condition greatly influences the efficiency of the heat pump;
- the request for eventual production of sanitary hot water, which necessarily requires the production of hot water at high temperature (possible for gas heat pumps, instead often not possible for those plants that require the use of additional electric resistors);
- the purchase cost of energy carriers electricity and gas, which are highly variable in function of the consumption, of the type of fare and user, of the application or not of subsidies and tax exemptions;
- the fixed costs for the supply of energy carriers, often considerable for the supply of electricity;
- the period of activation and use of the system, which can be relatively modest (in buildings for occasional or periodical usage, such as for vacation homes), or continuous (such as in residential buildings).

Operating costs: Gas absorption vs. Condensing Boiler and Solar System
Comparing gas absorption with a system build up with a condensing boiler combined with solar heating system a number of topics should be considered if installed into a retrofit situation. Some are similar to the points above:

- the necessary thermal power at design conditions;
- the operating temperature of the plant and share of power required for central heating as well as for domestic hot water. Domestic hot water is produced at an elevated temperature this influencing the efficiency of the heat source;
- the purchase cost of energy carrier gas;
- the fixed costs for the supply of energy carriers, often considerable for the supply of electricity;
- the period of activation and use of the system.

- The availability and orientation of space on residential buildings to accommodate a solar system
- The number of hours a solar heating system can support with the generation of heat, varying depending on the geographical location inside the EU.

According to these data a first estimation of the economic benefits that can be obtained is possible, compared with an alternative solution.

It should be specified that the results will be affected, as stated, by several environmental, economic, cost and energy usage factors. Therefore, according to the different conditions stated above, it may result convenient a technology rather than another. It clear that there is not a technology that results winning in every condition, but a Decision Support tools will help assessing which technology best fits which application by which criteria (cost saving, energy saving, environmental impact). This Decision support tool represents the core of the WP6 deliverable.

In fact, a cost-benefit analysis should always be carried out with more or less sophisticated tools. As we shall see in the next units, in fact, the cost-benefit analysis can be done with different methods that consider or not certain variables (such as the life of the plant, the change over the years of the cost of money, etc.). Obviously, the more variables are considered, the more complex the method of calculation, but the greater the accuracy. Thus, it must be evaluated, case by case, which is the most appropriate calculation method (for example for a rough estimation it could be used a simple, but inaccurate calculation method, while for in-depth evaluations it would be more appropriate to use a more complex calculation method, but that gives results closer to reality).

For the overall evaluation investment and maintenance the costs have also to be taken into account.

5.3.2. Investment appraisal

Simple payback (SPB)

Simple Pay-Back (SPB) is a very simple method of evaluating the investment and it is useful for a first rough valuation that can provide a first meter of comparison between two investment options. It is the cost of the new system (installation included) divided by annual savings:

$$SPB = \frac{cost\ of\ the\ new\ plant}{annual\ savings}$$

When comparing two different investments (e.g. comparing a new heat pump with a new boiler), the simple payback is the difference in costs divided by the difference in savings. It is slightly more difficult to determine the simple payback period when the costs and benefits occur irregularly through the life of the investment. The usual method is to create a spreadsheet showing the cumulative costs and benefits on a monthly basis. The point at which the benefits exceed the costs can then be determined by inspection.

Investment appraisal: Whole life costing

The main problem with the simple payback is that it takes not into account the residual life of the investment after the payback has been achieved. In fact, for a more detailed analysis of the investment choice, it should be carefully considered the fact that the life-cycle of a heating system does not stop at the breakeven point (payback), but it continues to provide the benefits to the user until the end of its life.

The following example illustrates the principle of whole life costing (also known as life cycle costing) which is to add up and compare all the costs and benefits throughout the life of each system. This provides a more rational view of investments that continue beyond their simple payback period.
Assume now that we have to decide between two alternative plants

- investment cost for a heat pump installation: 16,000 €
- operating cost of the existing boiler: 4,000 €/year
- operating cost of a heat pump plant: 2,200 €/year
- annual savings: 4,000 – 2,200 = 1,800 €/year

Simple Pay-back = 16,000 / 1,800 = 8.9 years

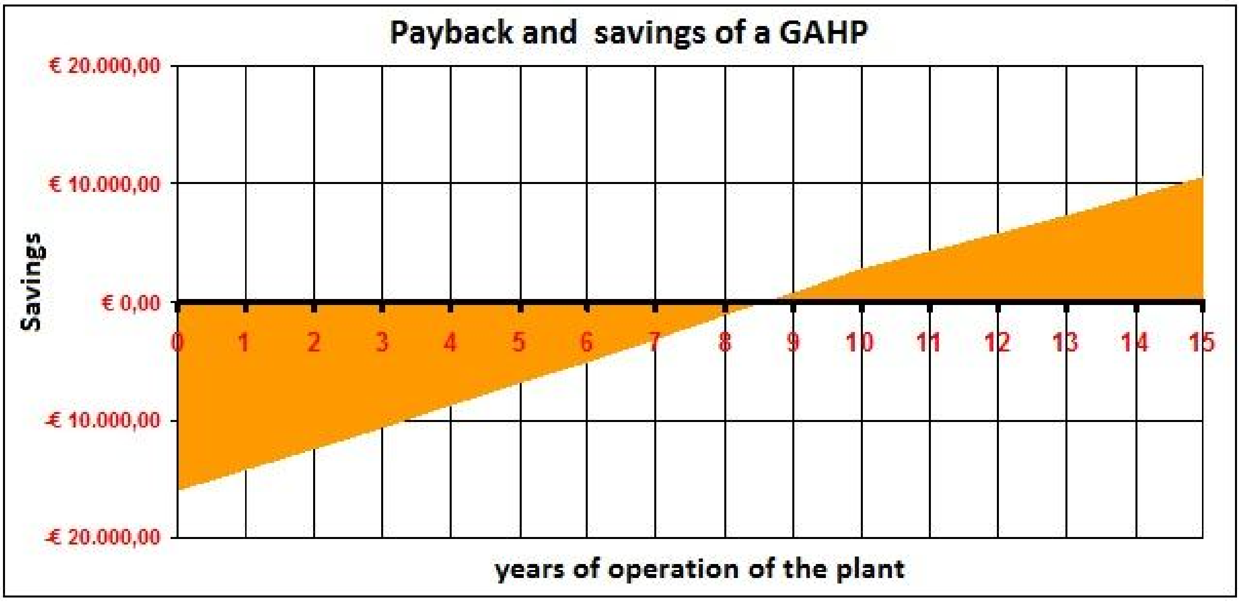
- investment cost for a condensing boiler installation: 5000 €
- operating cost of the existing boiler: 4,000 €/year
- operating cost of condensing boiler: 3,200 €/year
- annual savings: 4,000 – 3,200 = 800 €/year

Simple Pay-back = 5,000 / 800 = 6.3 years

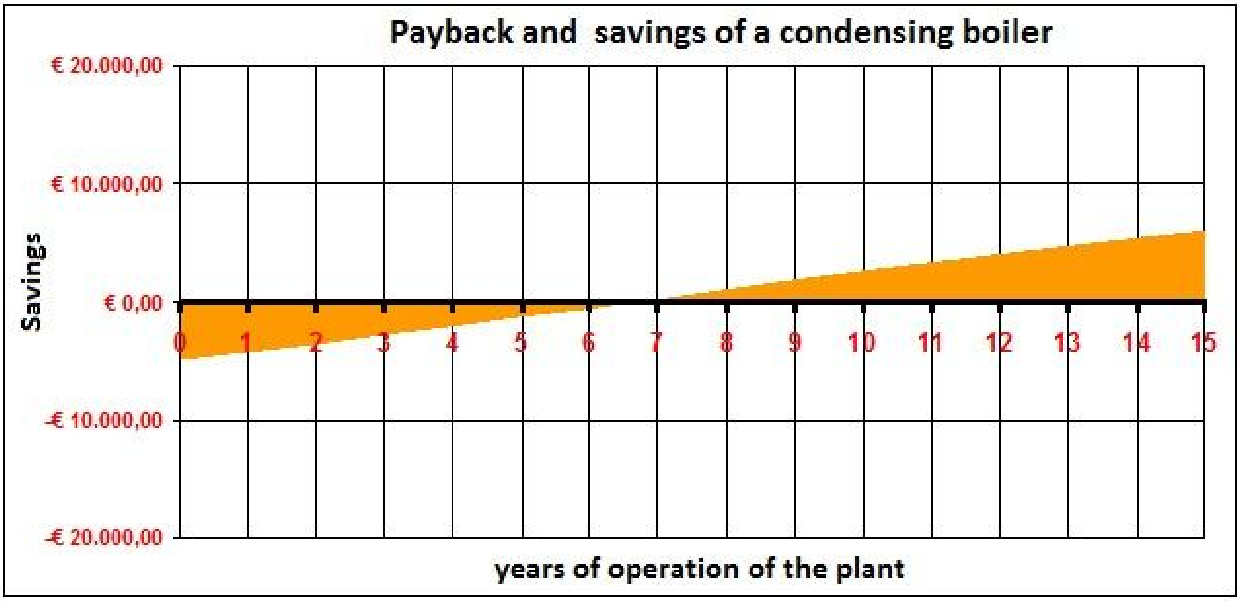
Now consider the cost savings achieved by the 2 systems for a life cycle of 15 years for both (we can estimate an average life of 15 years for a plant for which you do proper maintenance).

	heat pump	**Condensing boiler**
initial investment	16,000 €	5,000 €
annual savings compared to the existing plant	1,800 €	800 €
simple pay-back	8.9 years	6.3 years
average life of the plant	15 years	15 years
overall savings (15 years)	27,000 €	12,000 €
Difference between savings and investment	**11,000 €**	**7,000 €**

Apparently, after calculating the simple pay-back it would be better to install a condensing boiler than a heat pump. In reality, using a more detailed analysis, this is not true, because the function of the two technologies continues after the pay-back point. The savings related to the operating costs over the entire life of the two systems must be taken into account, as shown in the table above.
The trend of the savings obtained during the life cycle of the product is shown in the following figures (heat pump and condensing boilers), in relation to the existing system to replace.

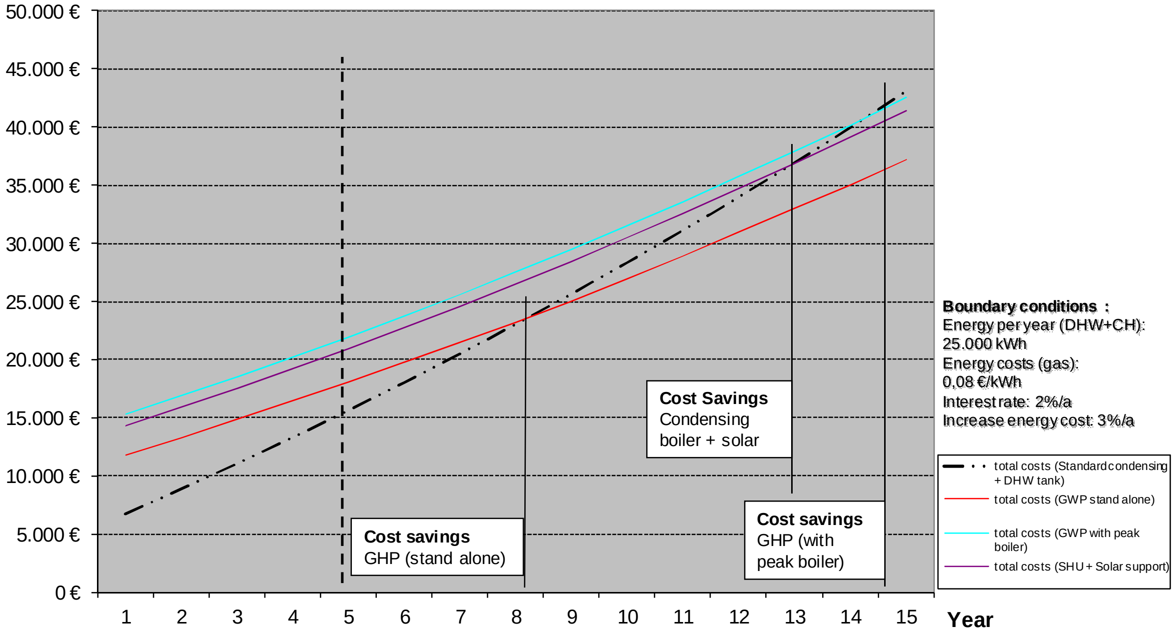


pay-back and trend of the savings obtainable from a heat pump compared to the existing plant



pay-back and trend of the savings obtainable from a condensing boiler compared to the existing plant

In a similar way the gas absorption heat pump can be compared to system combining an condensing boiler and a solar system, and also the possible effect if a gas absorption heat pump would require the use of a peak load boiler in case the design load of the building in question is exceeding the power supplied by the gas absorption heat pump.



pay-back and trend of the savings obtainable from a gas absorption heat pump, also in combination with a peak load appliance, a condensing boiler, a condensing boiler combined with solar thermal compared to the existing plant

As can be seen in the figure above the gas absorption heat pump has a payback-time of less than nine years compared to a condensing boiler. The breakeven point for a condensing boiler combined with solar thermal existing plant compared to a gas condensing boiler significantly later. The requirement to use of a peak load boiler in combination with a gas absorption heat pump makes this technology least commercially interesting.

The following procedure gives an example of how a whole life cost calculation could be carried out by a heat pump installer.

1. Calculate (or obtain a quote) for the capital costs of the installation taking account of any grants or financial incentives.
2. Assess the lifetime of the major system components. (Note 1)
3. Calculate (or obtain a quote) for the annual maintenance cost (Note 2)
4. Estimate the annual heat demand for the building. Divide the heat demand by the SPF of the heat pump (or seasonal efficiency for a boiler) to get the annual energy input.
5. Multiply the energy input by the unit cost of fuel to get the annual fuel cost (Note 2)
6. Estimate the likelihood cost and timing of any major repairs or replacements not covered by annual maintenance (Note 3)
7. Estimate the end of life disposal cost (Note 4)
8. Calculate the total costs

Notes:

(1) The lifetime of domestic boilers is quoted as 15 to 20 years. The lifetime of heat pumps depends on the type e.g. 10 to 15 years for air to air, 15 to 20 years for water to water. However, the lifetime of the ground coil of a ground source heat pump should be in excess of 30 years. Since the ground

coil is a major part of the cost of the system, it should be treated separately from the heat pump (see the example below).

(2) It is impossible to accurately predict price inflation over 20 years. The usual simplification is to assume that the costs of fuels and maintenance will not change over the life of the system. While this is certainly not true, it is reasonable to assume that price factors for alternative investments will increase at the same rate so the results of "constant price" costing should still be meaningful as a guide to the best investment.

(3) There are several significant components in a modern boiler that may need to be replaced during its life. These include the flue fan, domestic hot water heat exchanger (for combi-boilers), burner controls and circulation pump. In principle, the probable timing and cost of such replacements should be predicted and included in the cost calculation but this can be difficult. To simplify the life cycle cost comparison it can be assumed that the boiler and heat pump will be covered by an all inclusive maintenance agreement that covers replacement parts and labour.

(4) End of life issues are becoming increasingly important. It should be assumed that there will be some cost for removing and disposing of the heat pump and boiler at the end of its life.

The table below shows an example of the calculation for a heat pump system. This illustrates the problem of a system made up of components with different lifetimes. For example, the ground and underfloor heating have a much longer lifetime than the heat pump. It is probable that when the heat pump fails, a replacement heat pump will be fitted to the existing underfloor heating system and ground loop. Calculating an average annual cost of ownership gives a better indication of the relative costs of systems and components with different lifetimes.

	Investment €	**Annual Cost €/year**	**Lifetime years**	**Lifetime cost €**	**Annual cost of ownership €/year**
Installed cost of the heat pump	7000		15	7000	7000/15 = 466.67
Installed cost of ground loop	5000		30	5000	5000/30 = 166.67
Installed cost of underfloor heating	7000		25	7000	7000/25 = 280.00
Annual maintenance cost (including breakdown insurance)		120	15	120*15=1 800	120.00
Annual fuel cost		500	15	500*15=7 500	500.00
Disposal cost	200		15	200	200/15 = 13.33
Lifetime cost				**28500**	**1546.67**

Note: The costs shown in this table are used to illustrate the cost calculation. They are not the costs of a real system.

Investment appraisal: Net Present Value (NPV)

The valuation of the investment with simple pay-back and life-cycle costing tools are easy to use, but they are obviously characterized by approximate results. In fact they do not take into account other financial variables such as interest rates of the money and the relative fluctuations over the time. To do so we must consider that money has a purchasing power that varies over time. For example, if a certain amount of money is deposited in the bank, it may increase in value due to interest charged by the bank, or if this amount is not deposited in the bank but left in a safe, it will lose value because of inflation.

These evaluations can be made by calculating the change in the cost of money based on the discount rate and are called Net Present Value (NPV). The idea of net present value (NPV) is that money now is worth more than money in the future. This is because of the effect of interest rates. The NPV of a future cost or benefit ***V*** arising in ***n*** years is given by:

$$NPV = \frac{V}{(1+r)^n}$$

where:
V = value of the cost or benefit when it arises,
r = annual discount rate,
n = number of years.

The discount rate for private investment is usually made equal to the bank interest rate less inflation but different values may be used. Where businesses choose discount rates for internal investment appraisal, they may decide on a higher discount rate to reflect risk.
However, when comparing alternative investments the effect of NPV is to increase the relative attractiveness of projects with a lower initial cost or faster payback. As anticipated these cost/economic analyses will be further discussed in following sections and completed within WP7 for all major market and benchmark technologies ("boiler+solar" and "EHP").

6. Environmental and Economic Evaluations, Marketing positioning and Volume Forecast

6.1. Environmental and Economic Evaluation

The purpose of this study is to examine the requirements which gas absorption heat pumps (GAHP) must meet in order to gain a fundamentally market-relevant share of the future heat supply of buildings and so establish them as a meaningful alternative to conventional technologies on the heating market

Because the heating market will be dominated by existing housing stocks in the long term, this study examines the use of gas heat pumps in existing buildings. As part of the cost-efficiency analyses, gas heat pumps are presented in comparison with competing conventional options (gas condensing boiler -GCB- with and without solar domestic hot water supply (DHW) and/or solar DHW/backup heating and electrically operated brine-to-water and air-to-water heat pumps).

6.1.1. Environmental and Economic Evaluation of GAHP in DE[9]

In order to investigate the competitiveness of gas heat pumps, different scenarios have been identified in terms of the level of total annual cost of the GAHP in order to be able to determine the range of possible system costs (appliance costs, system installation and developing the heat source). The system costs are calculated for different thermal utilization ratios of the GAHP. From the thermal utilization ratio of a heat pump we can ascertain the energy costs which in turn essentially determine the total annual costs of the system solution.

The calculations take into account both the current energy price as well as potential price change scenarios over 20 years. From this we infer statements relating to the level of permissible investment costs of a GAHP. The total annual costs of the electrically operated brine-to-water heat pump were used as a basis for calculating the maximum investment costs of a GAHP. The minimum investment costs of a GAHP are based on the total annual cost of using a gas condensing boiler with solar heat. If the investment costs of a GAHP system fall within the stated price range, then the GAHPs are economically competitive on the heating market.

For environmental evaluation purposes the carbon dioxide emissions from gas heat pumps are compared with competing conventional plant options. In order to do this, we have considered scenarios for the changes in specific CO_2 emissions for natural gas, biomethane and electricity in the period 2010 to 2030, and have indexed the CO_2 emission factors over this 20 year period. We present the carbon dioxide emissions from GAHPs as a function of their thermal utilisation ratio and the energy source (natural gas and biomethane with different biomethane levels) and compare them with electrically operated heat pumps on the one hand and gas-operated systems (gas condensing technology, micro-CHP) on the other.

[9] Winiewska, B., Haupt, J**.,** *Requirements for Gas Heat Pumps for the Housing Stock, Final Report*, E.ON Ruhrgas,
AG, nov 2011

We investigate how gas heat pumps behave in terms of CO_2 emissions, and how efficient they would have to be to be environmentally comparable with competing systems. This is of particular interest when considering the anticipated decrease in CO_2 emission factors for electricity in the case of electric heat pumps.

Results of the Environmental Evaluation

CO_2 Emissions of the GAHP compared with EHP

In this section we present the carbon dioxide emissions of the gas heat pump as a function of the thermal system utilisation ratio, and compare them with the carbon dioxide emissions of B/W EHP and A/W EHP.

CO_2 Emissions in the existing Single Family House (SFH or in German EFH)

The carbon dioxide emissions of the systems under review in the single-family home can be seen from the following charts and table. A natural-gas-driven gas heat pump would currently generate annual emissions of some 6,500 to below 4,500 kg CO_2/a (depending on the utilisation ratio of the GAHP). The carbon dioxide emissions from the same system would be slightly less in the assumed later period under review (2020-2030). This can be disregarded however as the change is only due to the lower CO_2 emission factor for electricity and hence for the auxiliary energy. The CO_2 emission factor for natural gas remains constant in the period under review.

In the single-family home considered in this study, the use of an electrically operated brine-to-water heat pump would currently produce annual carbon dioxide emissions of around 5,600 kg CO_2/a. If the B/W heat pump were installed some 10 years later, then with the assumed increase in efficiency and reduced CO_2 emission factors we could expect less than 4,700 kg CO_2/a. If the B/W EHP is evaluated taking account of the improved efficiency indexes and the CO_2 emission factors forecast for the year 2030, then we obtain annual emissions of approx. 3,000 kg CO_2/a for the building under review. A detailed listing of all the data is given in Table 6-1. The chart in Figure 6-1 plots CO_2 emissions against the annual utilisation ratio of the gas heat pump.

If the figures are taken as a guide for the gas heat pump, then the GAHP should have a thermal utilisation ratio of approx. 1.42 now and around 1.70 in 2020 in order to achieve parity with brine-to-water EHPs in terms of CO_2 release.

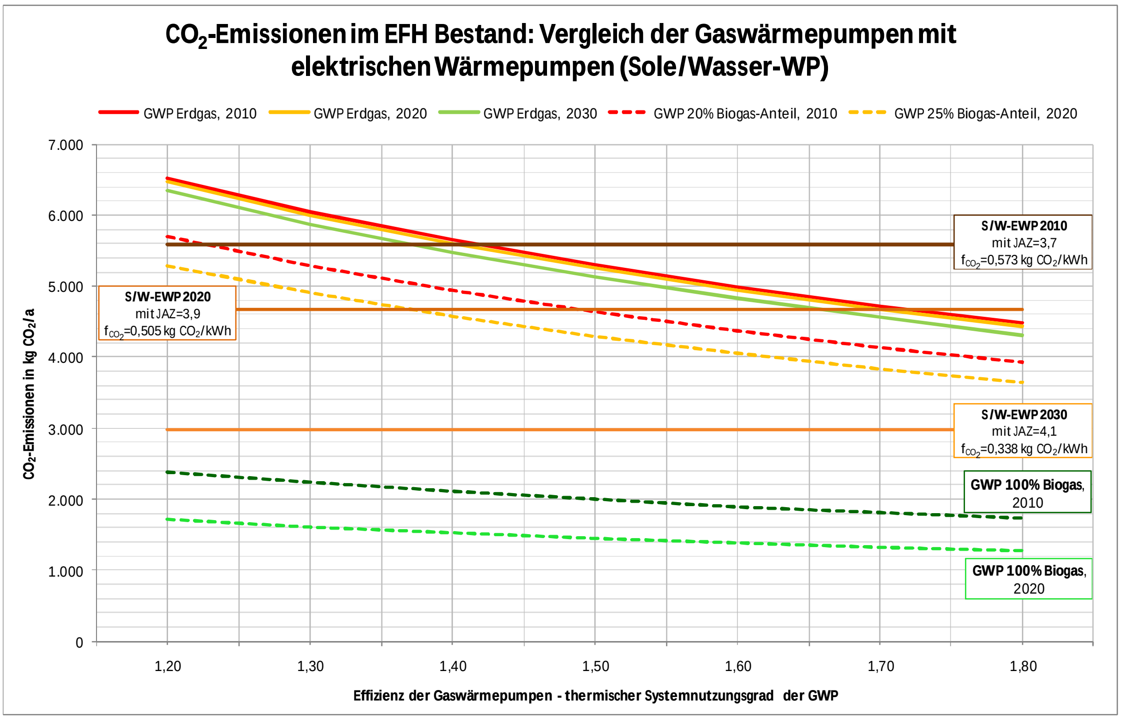


Figure 6-3: Carbon dioxide emissions in the existing SFH, gas heat pump with natural gas and biomethane in the period 2010 to 2030 compared with the brine-to-water EHP

With a biomethane share of at least 20% and a thermal system utilisation of at least 1.22, the GAHP currently produces lower annual CO_2 emissions than the brine-to-water HP. By 2020 the GAHP should achieve a thermal utilisation ratio of 1.37 for a biomethane share of 25% in order to achieve parity with brine-to-water EHPs on CO_2 release. If we assume that the gas heat pump is operated with biomethane (100% biomethane share), then the GAHP's carbon dioxide emission is well below the levels of the electrically operated heat pumps.

The carbon dioxide emissions from an electrically operated air-to-water heat pump would currently be around 7,400 kg CO_2/a in the single-family home, i.e. significantly higher than for the gas heat pumps. If we consider the presumed increase in efficiency of the A/W EHP and the lower CO_2 emission factor for 2020, we find that the CO_2 emissions of a natural-gas-operated GAHP with a system utilisation ratio of at least 1.26 are less than those of an electric air-to-water HP. The improved efficiency indexes and the CO_2 emission factor predicted for 2030 mean annual emissions of around 3,900 kg CO_2/a for the existing home under review, i.e. below the figures for the natural-gas-driven gas heat pumps (see Figure 6-2).

Table 6-2: Carbon dioxide emissions in the existing SFH, GAHP compared with EHP

Carbon dioxide emissions in the SFH in kg CO_2/a								
	System utilisation	1.20	1.30	1.40	1.50	1.60	1.70	1.80
GAHP	**Natural gas, 2010**	6,518	6,049	5,646	5,298	4,993	4,723	4,484
	Natural gas, 2020	6,469	6,000	5,597	5,248	4,943	4,674	4,435
	Natural gas, 2030	6,348	5,879	5,476	5,128	4,822	4,553	4,314
	20 % biomethane, 2010	5,692	5,286	4,938	4,637	4,373	4,140	3,933
	25 % biomethane, 2020	5,281	4,903	4,579	4,298	4,052	3,835	3,642
	100 % biomethane, 2010	2,386	2,235	2,105	1,992	1,893	1,807	1,729
	100 % biomethane, 2020	1,716	1,612	1,523	1,446	1,378	1,319	1,266
B/W EHP	**Electricity, 2010**	5,587						
	Electricity, 2020	4,671						
	Electricity, 2030	2,974						
A/W EHP	**Electricity, 2010**	7,401						
	Electricity, 2020	6,173						
	Electricity, 2030	3,856						

CO_2 Emissions of the GAHP compared with gas condensing systems

In this section we consider the CO_2 emissions of the gas heat pump as a function of its thermal system utilisation ratio and compare them with the carbon dioxide emissions from systems with gas condensing appliances.

The results of the calculations clearly show how high the CO_2 emissions of a GAHP with an assumed thermal utilisation ratio are compared with a competitor gas condensing system, and how the use of biomethane (20%, 25% and 100% biogas) affects the CO_2 emissions of another identical system.

CO_2 Emissions in the existing SFH

If we compare the gas heat pump with the gas condensing systems, we find that the carbon dioxide emissions of the GAHP in the single-family home are below the figures for the condensing systems, and – with a lower utilisation ratio of the GAHP (1.20) – are comparable with gas condensing with solar DHW and backup heating (assuming the same fuel is used). Figure 6-2 presents a comparison of the evaluated systems using natural gas and 100% biomethane. This covers both borderline cases.

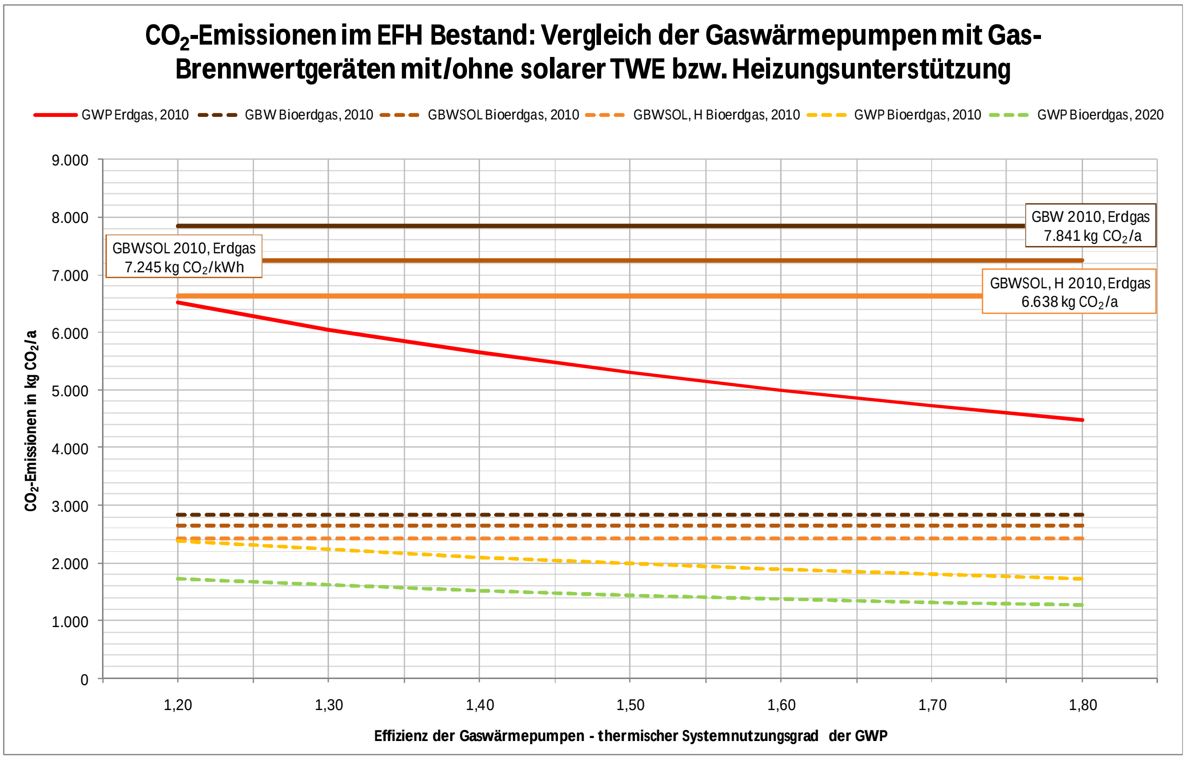


Figure 6-2: Carbon dioxide emissions in the existing SFH, gas heat pump with natural gas and biomethane (100% biogas) compared with gas condensing systems

Table 6-2: Carbon dioxide emissions in the existing SFH, GAHP compared with GCB systems; Comparison: natural gas and 100% biomethane share

Carbon dioxide emissions in the SFH in kg CO_2/a								
GAHP	System utilisation	1.20	1.30	1.40	1.50	1.60	1.70	1.80
	Natural gas, 2010	6,518	6,049	5,646	5,298	4,993	4,723	4,484
	100% biomethane, 2010	2,386	2,235	2,105	1,992	1,893	1,807	1,729
	100% biomethane, 2020	1,716	1,612	1,523	1,446	1,378	1,319	1,266
GCB	**Natural gas, 2010**	7,841						
	100% biomethane, 2010	2,829						
GCB SOL	**Natural gas, 2010**	7,245						
	100% biomethane, 2010	2,645						
GCB SOL,H	**Natural gas, 2010**	6,638						
	100% biomethane, 2010	2,432						

CO_2 Emissions of the GAHP compared with micro-CHP with Stirling engine

Figure 7-3 plots the carbon dioxide emissions of the gas heat pumps as a function of their thermal system utilisation ratio, fuel and biomethane share, and compares them with the CO_2 emissions of micro-CHP systems (taking the micro-CHP variant with Stirling engine 80/11 as its example).

If we assume the use of natural gas for both systems, then both now and in the future, the carbon dioxide emissions of the gas heat pump are considerably below the figures for the micro-CHP variant under review. Even assuming biomethane shares of 20% (2010) and 25% (2020), the GAHP returns lower CO_2 emissions than the micro-CHP system running on the same fuel.

If we assume biomethane with a 100% biomethane share for both systems on the other hand, we find that the micro-CHP variant generates far lower carbon dioxide emissions than the gas heat pumps.

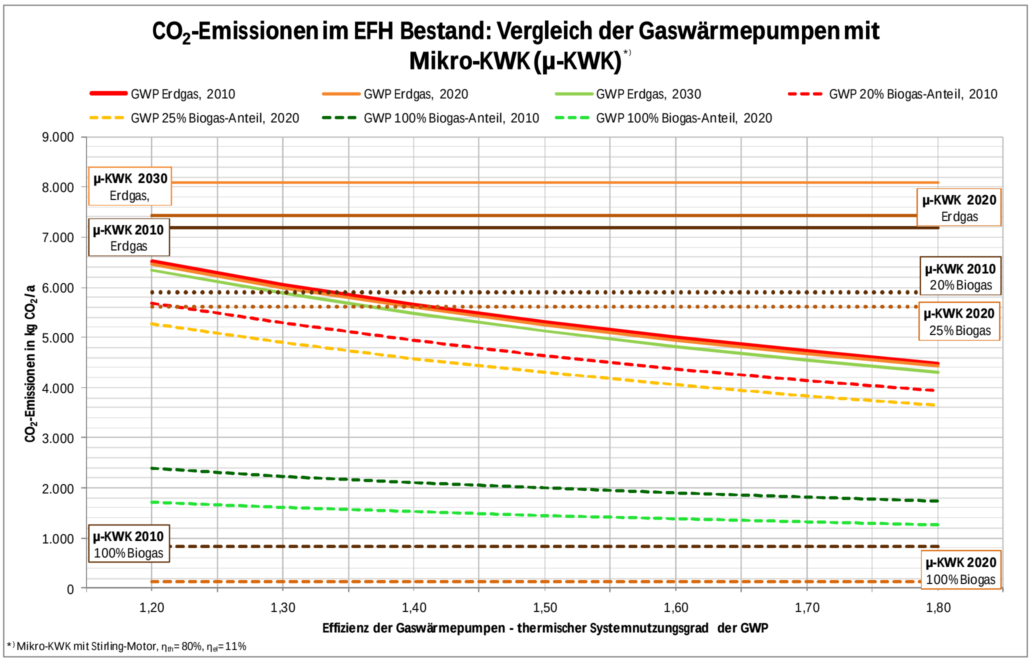


Figure 6-3 Carbon dioxide emissions in the existing SFH, gas heat pump running on natural gas and biomethane compared with micro-CHP

When comparing the systems under review it is clear that the calculated carbon dioxide emissions from the operation of a natural-gas-driven gas heat pump decline slightly over the given period under review, while for a micro-CHP system, higher CO_2 emissions than currently exist are calculated for the years 2020 and 2030. This is the result of the falling carbon dioxide emissions factors for electricity and hence for the electricity credit of a micro-CHP system.

Table 6-3 Carbon dioxide emissions in the existing SFH, GAHP compared with micro-CHP

Carbon dioxide emissions in the SFH in kg CO_2/a								
	GAHP							Micro-CHP, Stirling 80/11
	System utilisation							
	1.20	1.30	1.40	1.50	1.60	1.70	1.80	
Natural gas, 2010	6,518	6,049	5,646	5,298	4,993	4,723	4,484	7,174
Natural gas, 2020	6,469	6,000	5,597	5,248	4,943	4,674	4,435	7,437
Natural gas, 2030	6,348	5,879	5,476	5,128	4,822	4,553	4,314	8,082
20% biomethane, 2010	5,692	5,286	4,938	4,637	4,373	4,140	3,933	5,903
25% biomethane, 2020	5,281	4,903	4,579	4,298	4,052	3,835	3,642	5,609
100% biomethane, 2010	2,386	2,235	2,105	1,992	1,893	1,807	1,729	819
100% biomethane, 2020	1,716	1,612	1,523	1,446	1,378	1,319	1,266	126

CO_2 Emissions of the GAHP compared with Conventional Systems

In this section we consider the CO_2 emissions of the gas heat pump with different biomethane shares when compared with conventional systems:

- GCB: Gas condensing boiler, natural gas
- GCBSOL, H: Gas condensing boiler with solar domestic hot water supply and backup heating, natural gas
- µ-CHP: micro-CHP, natural gas
- A/W EHP: air-to-water heat pump with SEER=2.65
- B/W EHP: brine-to-water heat pump with SEER=3.7

In the single-family home under review, the carbon dioxide emissions of a natural-gas-driven GAHP are below those of the four compared variants: gas condensing system, micro-CHP system, electrically operated air-to-water HP and gas CB with solar domestic hot water supply and backup heating. Charts 7-4 presents detailed figures on the level of CO_2 emissions of the GAHP compared with conventional systems.

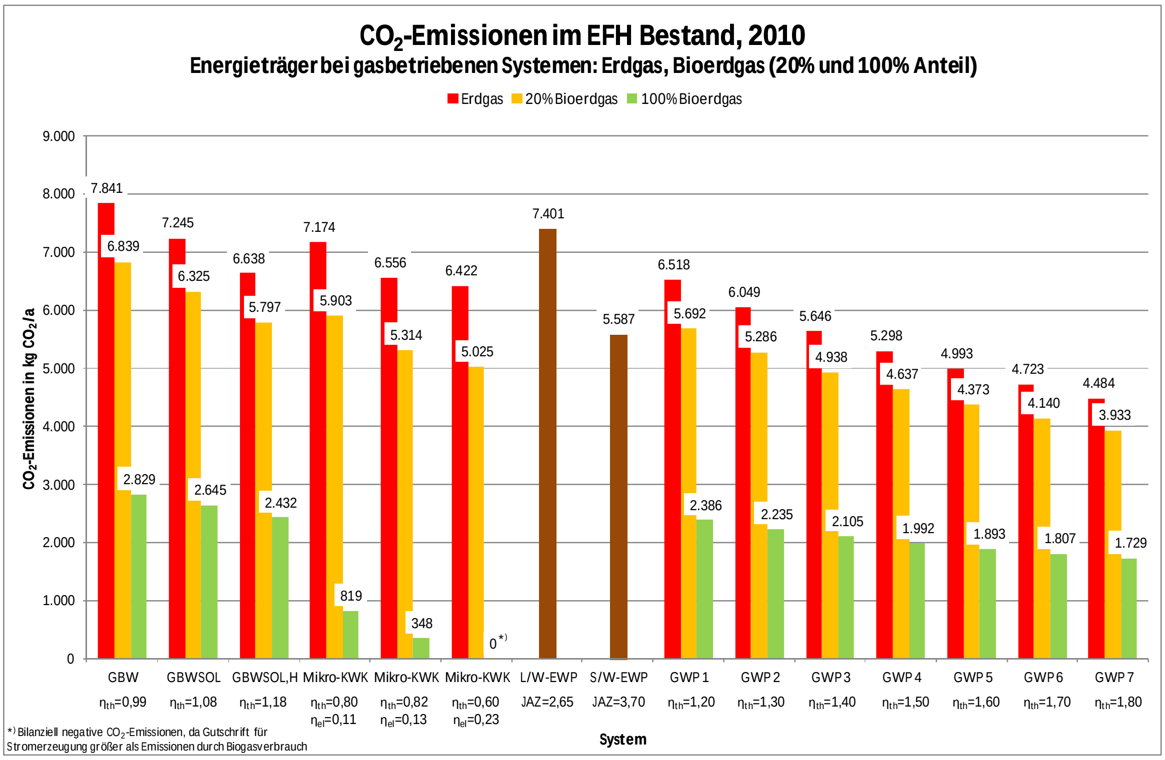


Figure 6-4: Carbon dioxide emissions in the existing SFH, gas heat pump compared with conventional systems, 2010

CO_2 Emissions of the GAHP: conclusions

In this section we have examined in detail the emission of CO2 of GAHP technology with different energy efficiency levels compared to alternative technologies. The analysis indicates that GAHP is always effective in reducing CO2 emission against condensing boiler and µCHP.

GAHP can exceed current EHP in reducing COP2 emissions when Gas Utilization Efficiency is approximately above 1.3.

Cost-Efficiency Evaluation of GAHPs
Total Annual Cost of the System Variants

The purpose of this section is to calculate the “market perceived value” (from the tangible costs point of view) of the GAHP system in comparison with existing technologies. Therefore a maximum price is calculated as a function of the system efficiency level.

The total annual costs of the evaluated system variants are presented in the following figures and tables. Assumptions used for analysis are listed as well in the following table. Assumption reflect typical situation of the German market. These values can be considered representative of most of the European countries and represent one of the major potential market. The determined total annual costs are made up of capital costs, consumption costs and running costs.

For the gas heat pump we have posited three benchmark scenarios in terms of the level of total annual costs.

- Scenario 1 - the investment costs of the gas heat pump are calculated in such a way that the annual costs of the GAHP are just as high as the total annual cost of the system variant 'gas condensing boiler with solar domestic hot water supply and backup heating'.
- Scenario 2 - we assume that the gas heat pump generates additional costs of 10% over the total annual cost of the above comparison variant.
- Scenario 3 - is based on cost parity between the gas heat pump and the electrically operated brine-to-water heat pump.

The investment costs of the gas heat pump calculated in the third scenario under previously defined boundary conditions represent the maximum permissible investment costs for a marketable product. Consequently the total annual costs calculated for the gas heat pump are oriented on the comparison variants and must be seen as target values. The level of capital, consumption and operating-related costs of the system variant with a gas heat pump as the heat generator is determined by the thermal system utilisation ratio, assumed energy prices and the considered scenario.

The costs of a gas heat pump with an assumed thermal system utilisation ratio, and of the heat source, can be determined using the target values for the total annual costs of the GAHP.

Total annual cost in the existing SFH

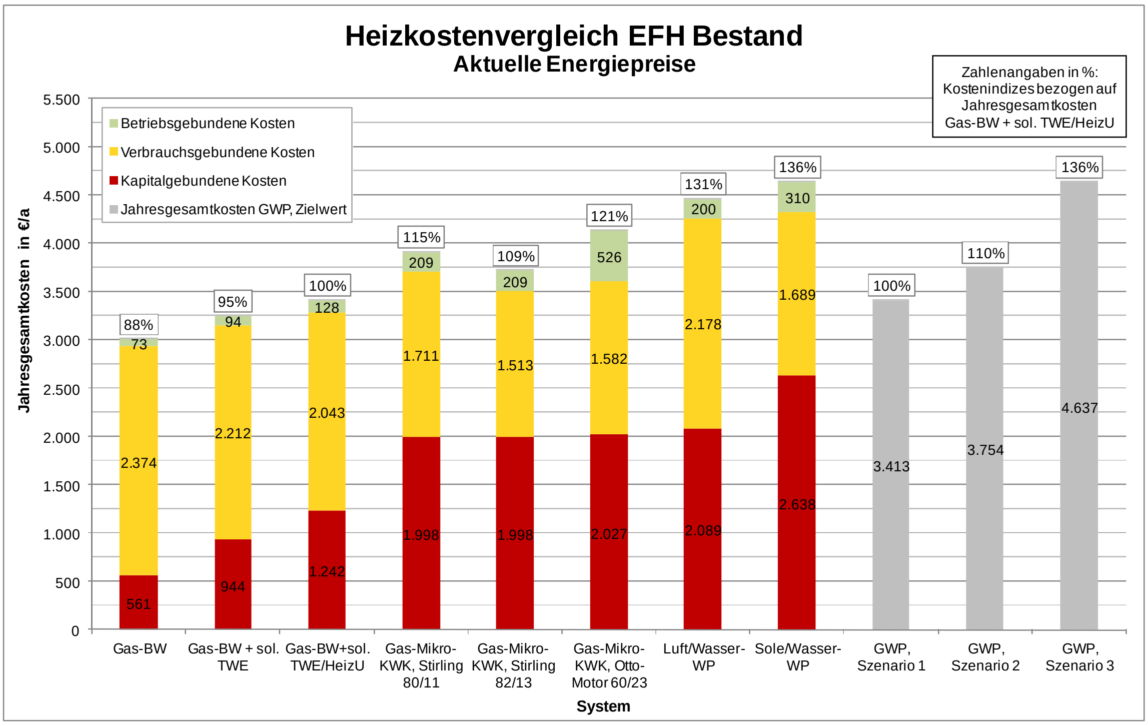


Figure 6-5: Heating cost comparison, existing SFH, allowing for current energy prices, total annual costs of the gas heat pump as guideline values

The tables provide an overview of the level of the total annual costs of the compared variants and of the level of maximum permissible total annual cost of a gas heat pump in each of the three scenarios. They take account of the possible movement in price assuming a constant price rise of 3% and 5% over 20 years.

Table 6-4: Total annual cost of the modernization variants allowing for a constant price rise of 3% over 20 years – existing SFH

	Heating cost comparison - System modernisation variants, existing SFH										
3 % price increase	Gas CB	Gas CB+ sol. DHW	Gas CB+sol DHW/backup	Micro-CHP, 80/11	Micro-CHP, 82/13	Micro-CHP, 60/23	Air/water EHP	Brine/water EHP	GAHP, Scenario 1	GAHP, Scenario 2	GAHP, Scenario 3
Capital costs	561	944	1,242	1,998	1,998	2,027	2,089	2,638			
Consumption costs	3,190	2,973	2,745	2,498	2,248	2,438	2,926	2,269	= Gas CB + sol DHW/backup	= Scenario 1 + 10%	= Brine/Water EHP
Operating costs	73	94	128	209	209	526	174	310			
Tot. Oper. costs	3,824	4,011	4,115	4,705	4,455	4,991	5,189	5,217	4,115	4,526	5,217
Cost indexes	93%	97%	100%	114%	108%	121%	126%	127%	100%	110%	127%

Table 6-5: Total annual cost of the modernisation variants allowing for a constant price rise of 5% over 20 years – existing SFH

	Heating cost comparison - System modernisation variants, existing SFH										
5 % price increase	Gas CB	Gas CB+ sol. DHW	Gas CB+solDHW/backup	Micro-CHP, 80/11	Micro-CHP, 82/13	Micro-CHP, 60/23	Air/water EHP	Brine/ water EHP	GAHP, Scenario 1	GAHP, Scenario 2	GAHP, Scenario 3
Capital costs	561	944	1,242	1,998	1,998	2,027	2,089	2,638	= Gas CB + sol DHW/backup	= Scenario 1 + 10%	= Brine/Water EHP
Consumption costs	3,926	3,658	3,378	3,209	2,912	3,211	3,600	2,792			
Operating costs	73	94	128	209	209	526	174	310			
Tot. Oper. costs	4560	4696	4748	5416	5119	5764	5863	5748	4748	5222	5748
Cost indexes	96%	99%	100%	114%	108%	121%	124%	121%	100%	110%	121%

System costs of a GAHP with air heat source

The following figures present the system costs of a gas heat pump with a heat source other than geothermal. The system costs of the GAHP include the investment costs of the GAHP, of the hot water storage tank and of all other components which are part of the system (incl. installation); the storage tank is identical for all GAHPs depending on the building type.

Maximum system costs of the GAHP in the existing SFH as a function of the system efficiency

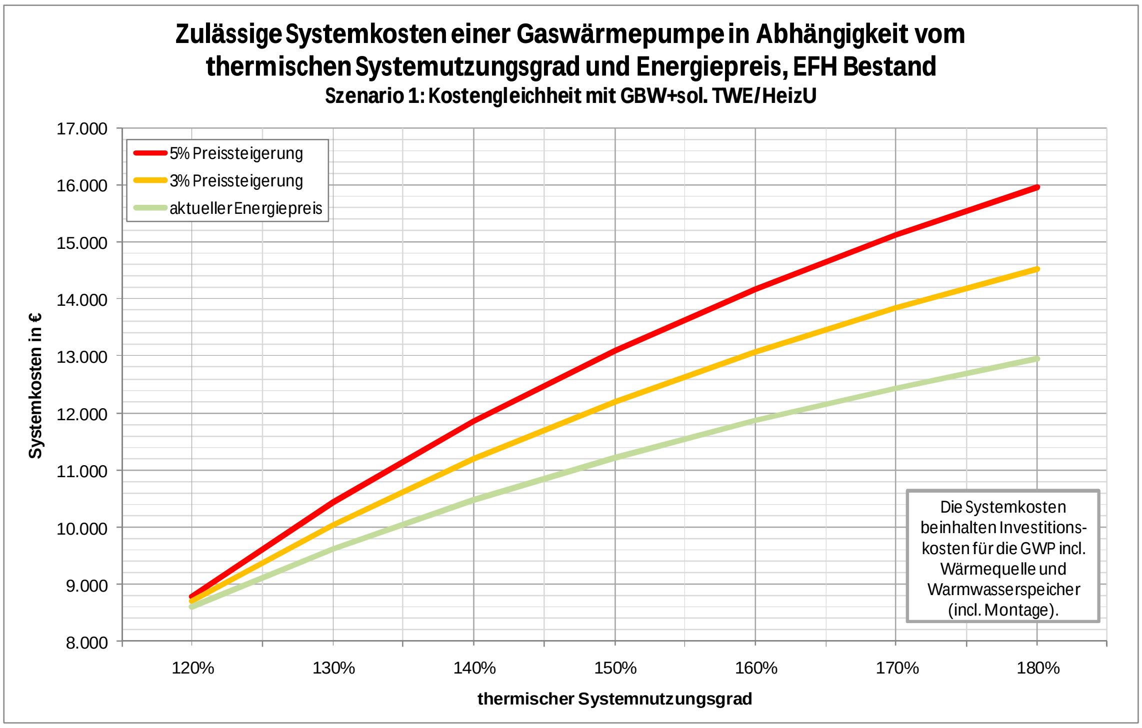


Figure 6-6: Permissible system costs of a gas heat pump (air or solar heat source) as a function of the system utilisation ratio and energy price, existing SFH, Scenario 1

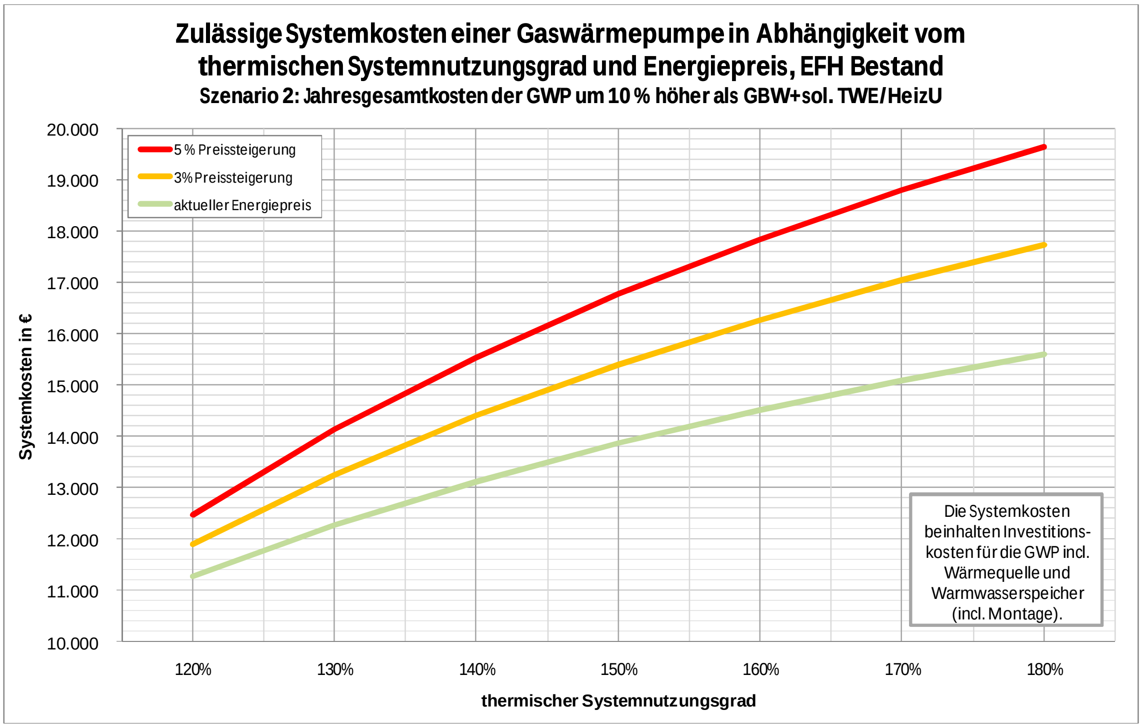


Figure 6-7: Permissible system costs of a gas heat pump (air or solar heat source) as a function of the system utilisation ratio and energy price, existing SFH, Scenario 2

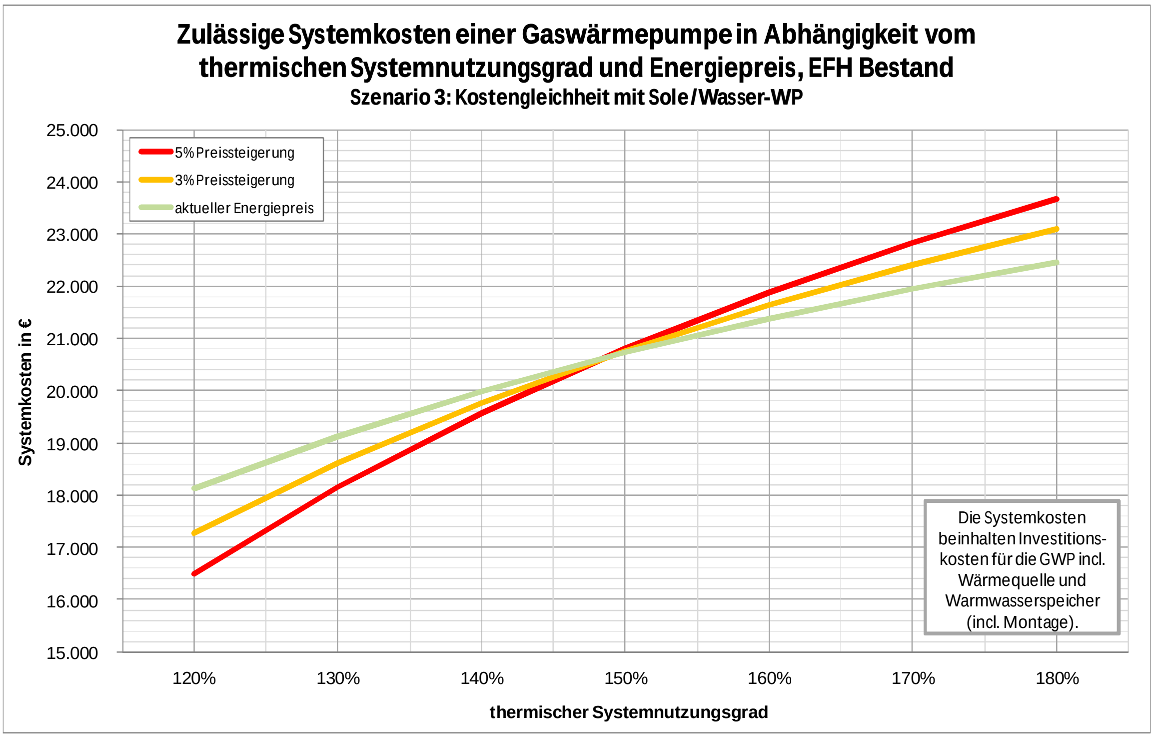


Figure 6-8: Permissible system costs of a gas heat pump (air or solar heat source) as a function of the system utilisation ratio and energy price, existing SFH, Scenario 3

Cost-Efficiency Evaluation of GAHPs: conclusions

In this section we have examined the cost effectiveness of the GAHP technology in comparison with several alternative heating technologies. The maximum system cost for cost effectiveness of a GAHP system depends on energy price, energy efficiency and best alternative technology considered. To exemplify some of the findings:

- with current energy price with annual system efficiency of 130% the GAHP system can be considered cost effective (in absence of incentive schemes) at cost of 10,000 Euro (when competing against a condensing boiler+solar).
- When compared to an Electrical Heat Pump, with current energy prices, a GAHP system with annual system efficiency of 130% becomes cost effective at 18,000 Euro.

System costs of a GAHP as a required value compared with conventional systems

The following figures present the system costs of the gas heat pump with three different system utilisation ratios as compared with the system costs of the conventional systems considered as part of this study. The system costs include the costs of the heat generator and hot water storage tank and the costs of developing the heat source (in case of ground sourcing).

Of the 3 scenarios considered, it is realistically the second scenario with its assumed energy price increase of 3% that is decisive for the level of system costs of a gas heat pump. While this scenario tolerates additional costs as compared with gas condensing technology, these additional costs are within a range that is acceptable to the end consumer. Additional costs are reckoned to be acceptable when they are around 10% above the total costs of a gas condensing system with solar domestic hot water supply and backup heating. The system costs presented for the gas heat pump with an assumed system utilisation ratio are therefore the maximum permissible investment costs and can be regarded as a required value for the level of investment costs of a GAHP.

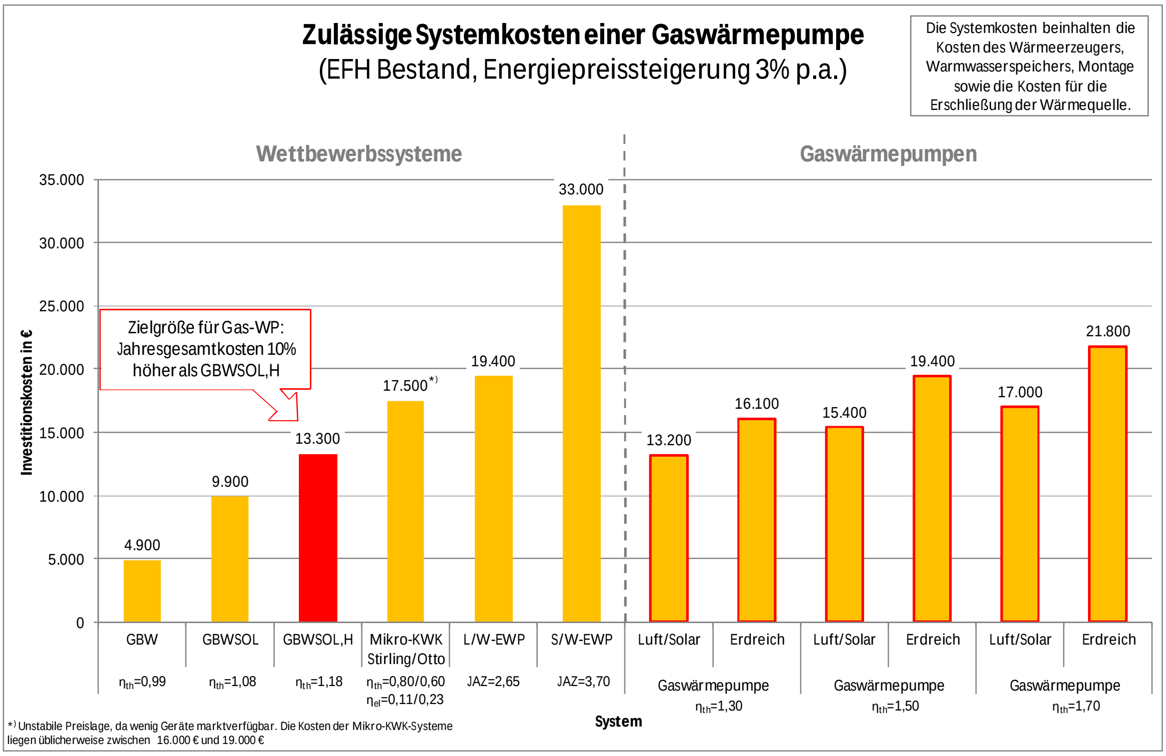


Figure 6-9: Permissible system costs of a gas heat pump as required value, existing SFH

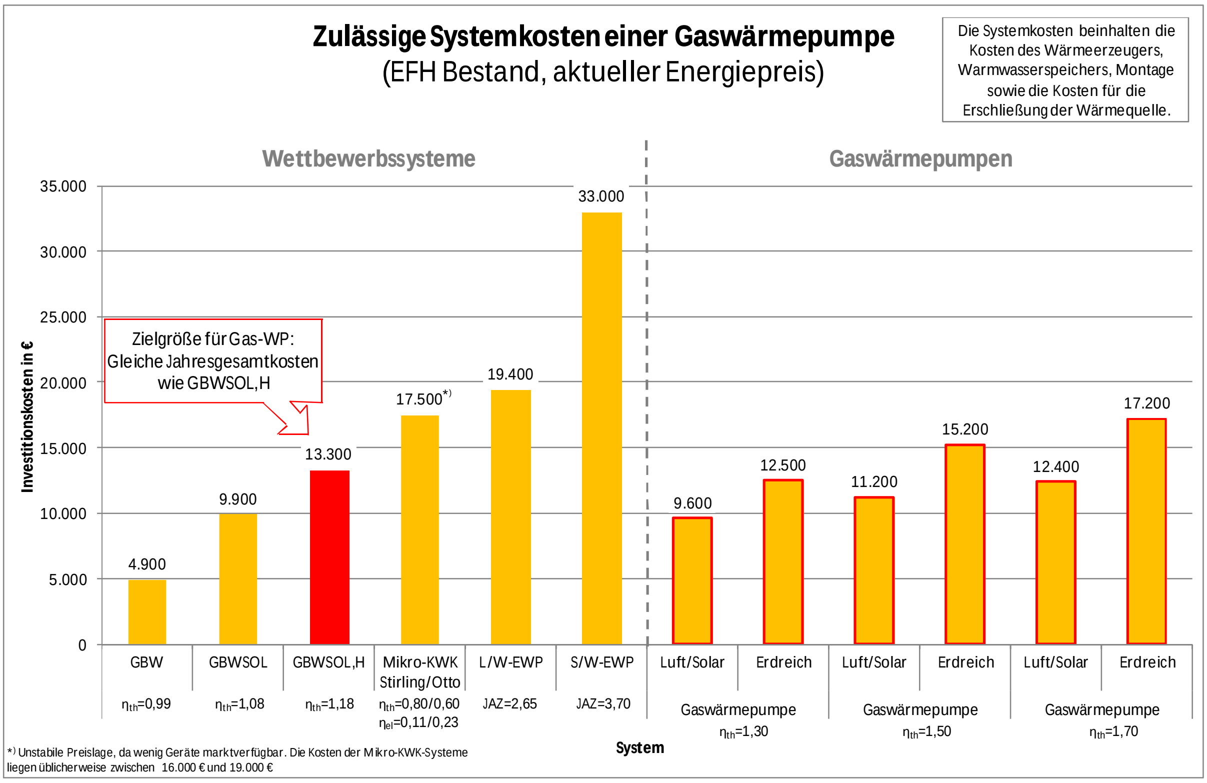


Figure 6-10: Permissible system costs of a gas heat pump as required value, existing SFH

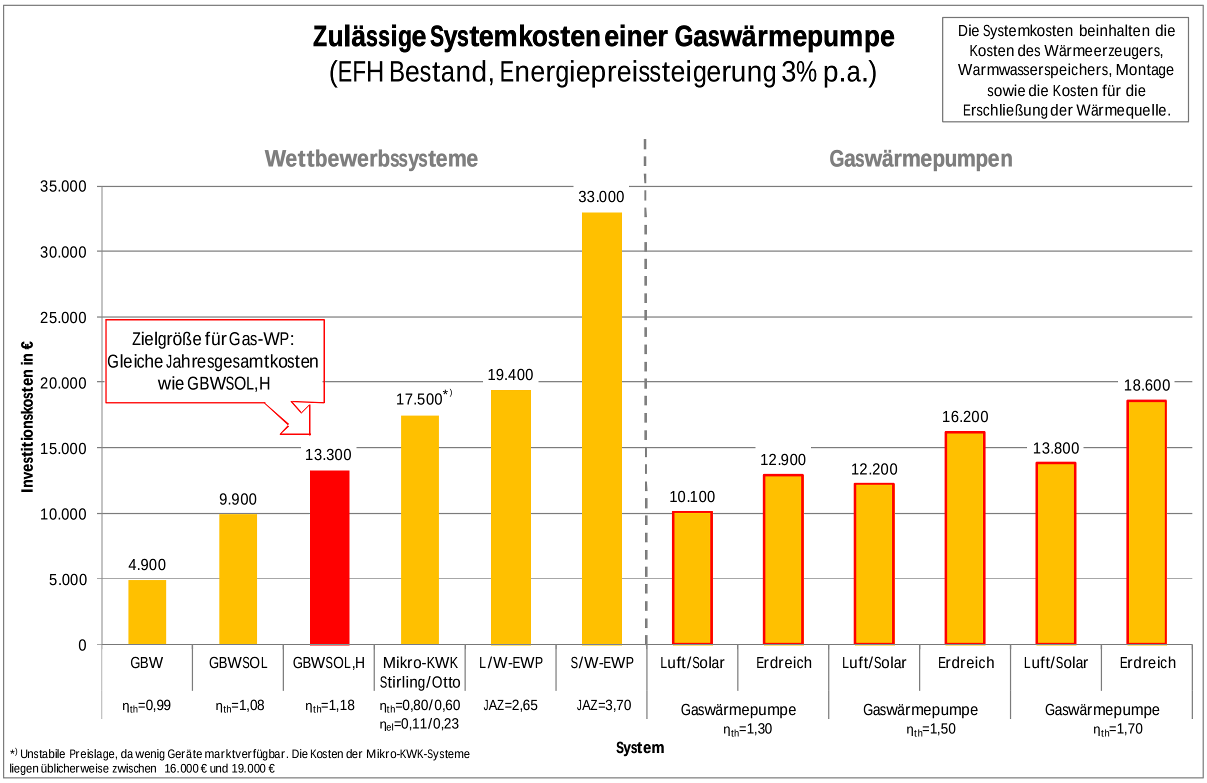


Figure 6-11: Permissible system costs of a gas heat pump as required value, existing SFH

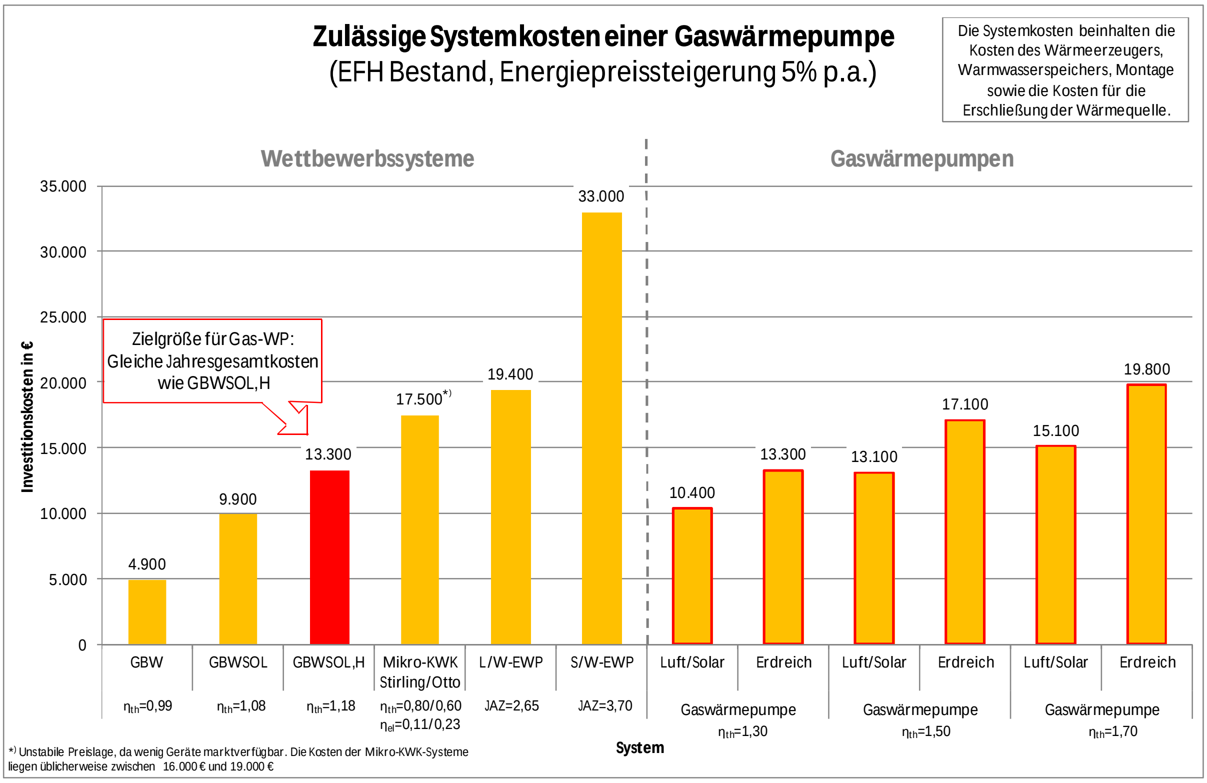


Figure 6-12: Permissible system costs of a gas heat pump as required value, existing SFH

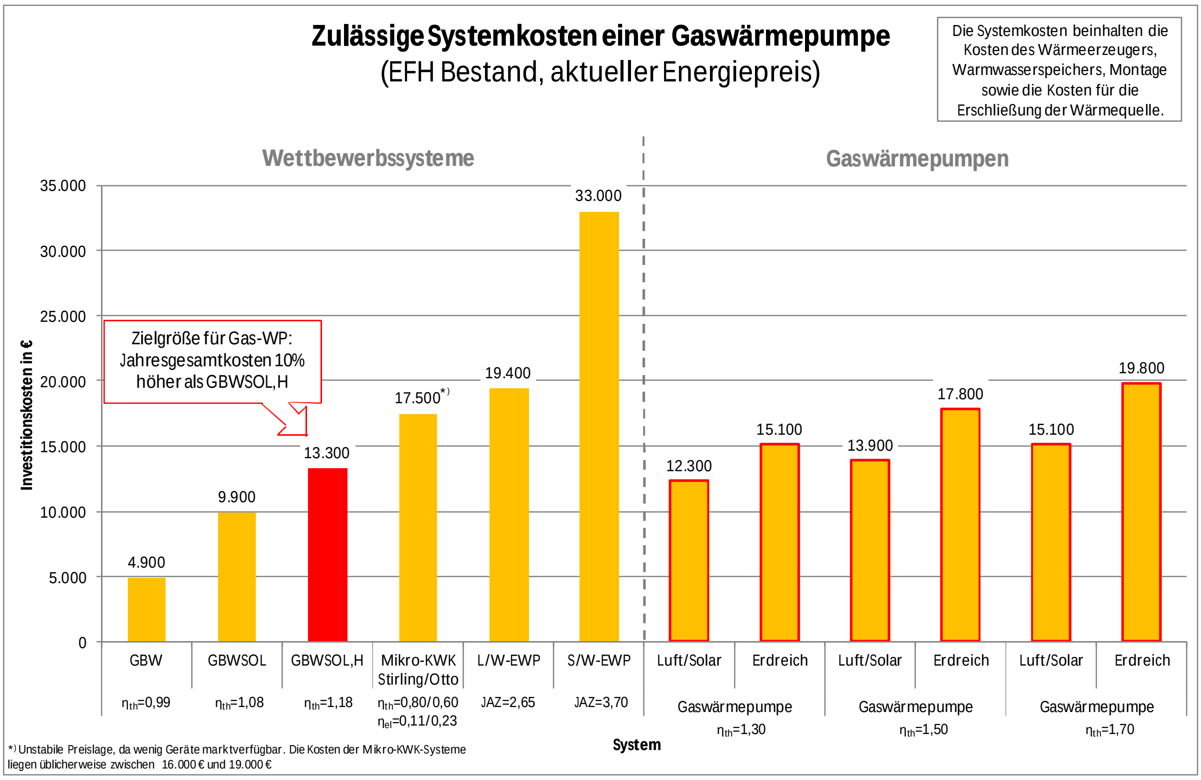


Figure 6-13: Permissible system costs of a gas heat pump as required value, existing SFH

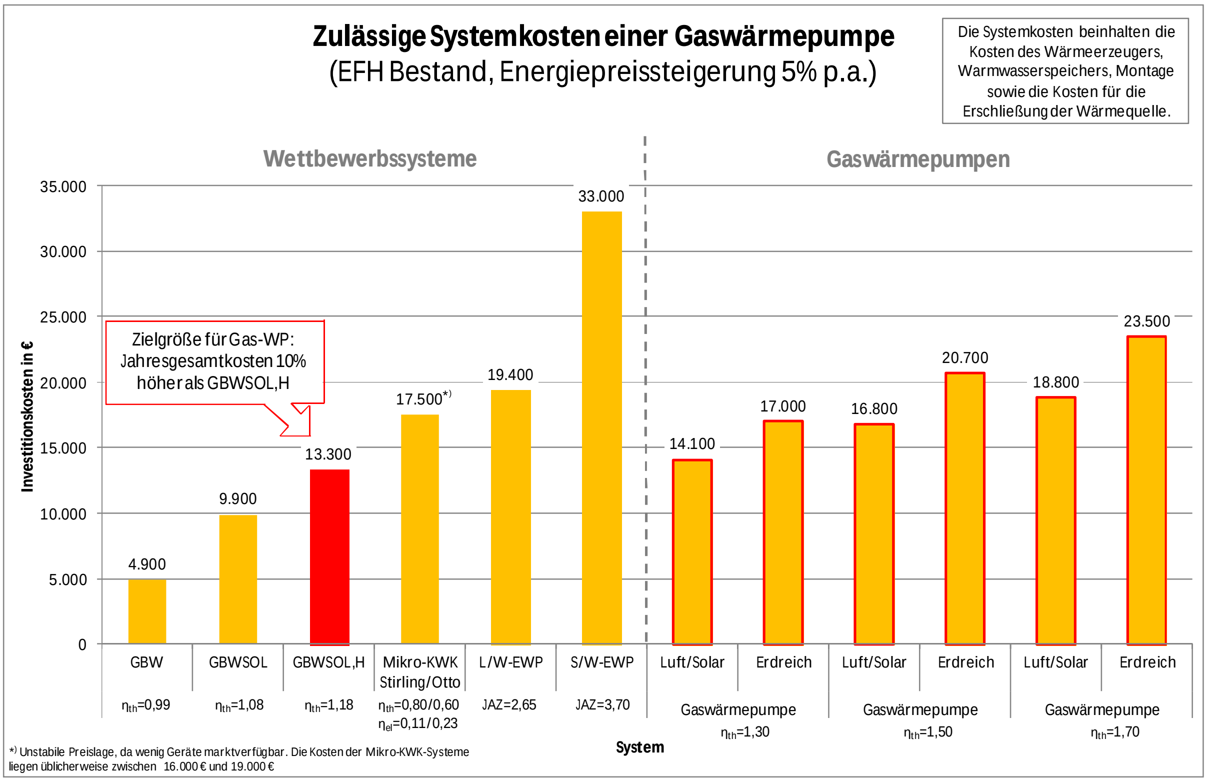


Figure 6-14: Permissible system costs of a gas heat pump as required value, existing SFH

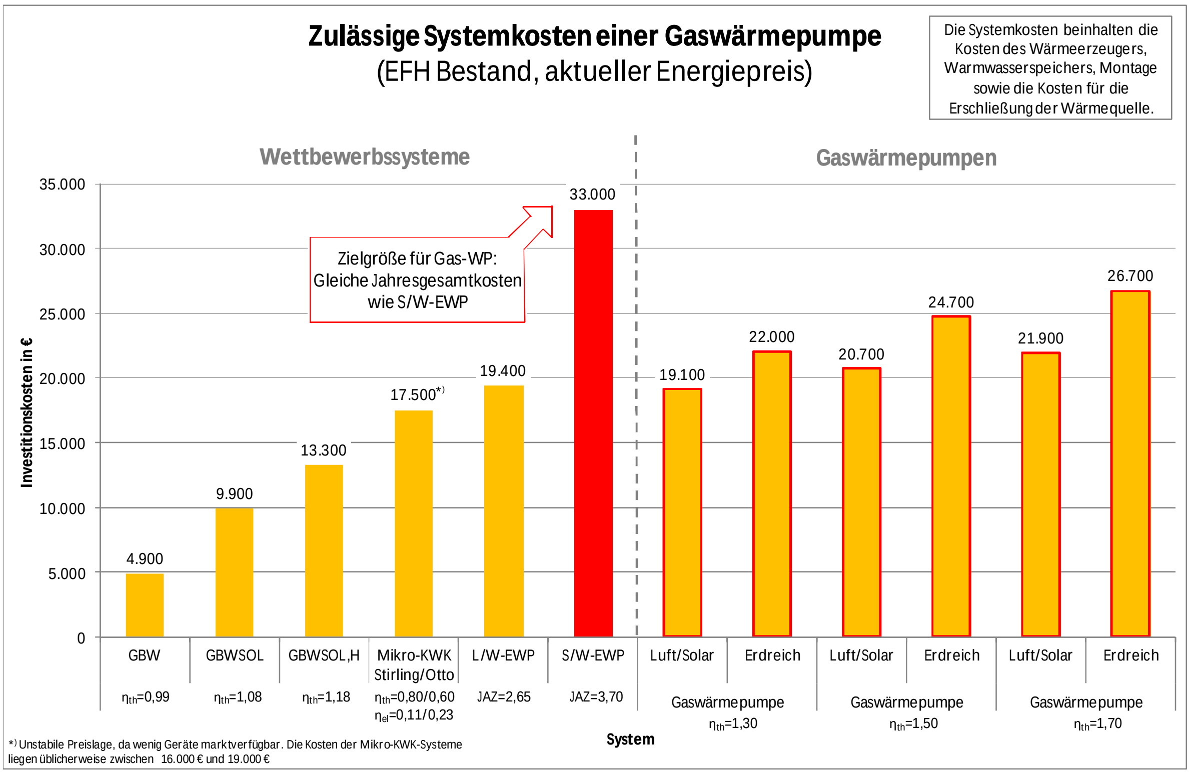


Figure 6-15: Permissible system costs of a gas heat pump as required value, existing SFH

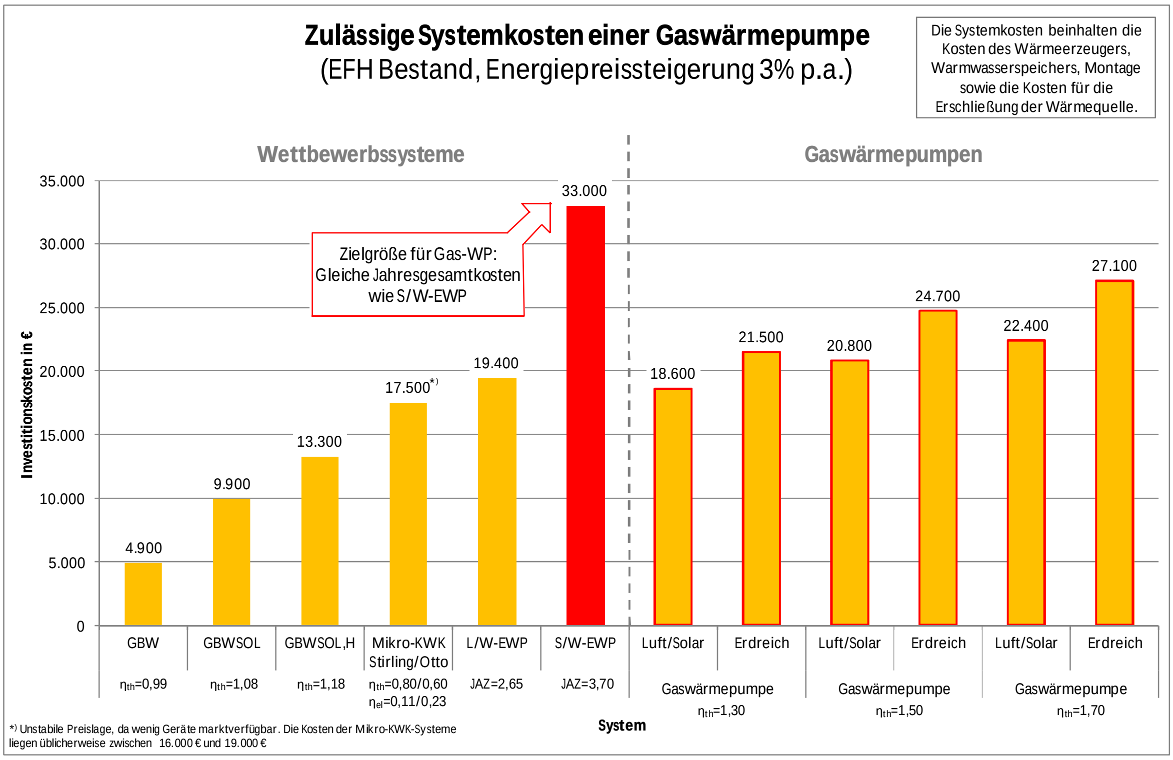


Figure 6-16: Permissible system costs of a gas heat pump as required value, existing SFH

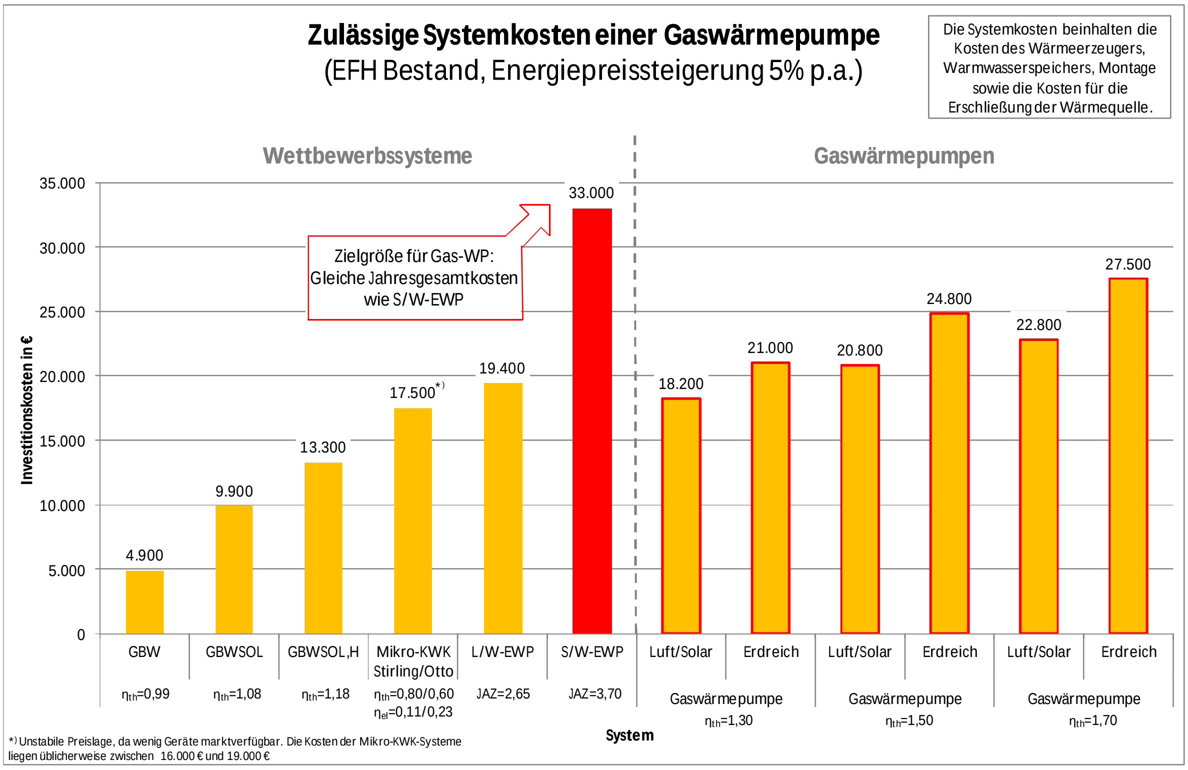


Figure 6-17: Permissible system costs of a gas heat pump as required value, existing SFH

Conclusions
From an economic standpoint, the gas heat pump technology can be competitive when the resulting total annual costs are within the range of the conventional appliances that are currently available on the market.

Cost parity with the 'gas condensing boiler with solar domestic hot water supply and backup heating' variant presented in Scenario 1 is seen as the optimum criterion for the competitiveness of the gas heat pump. However the resulting necessary investment costs, while relatively low, are difficult to achieve without a considerable amount of financial support. Realistically therefore it is rather the second scenario which is decisive for the level of the system costs of a GAHP. While this scenario tolerates additional costs as compared with gas condensing technology, these additional costs are within a range that is acceptable to the end consumer. Additional costs are reckoned to be acceptable when they are around 10% above the total costs of a gas condensing system with solar domestic hot water supply and backup heating. If the costs to the end consumer turn out to be much higher than this (higher than the figures given in Scenario 3), then broad market presence would be difficult to achieve. We can state as a basic principle that higher investment costs for gas heat pumps are acceptable as energy prices rise.

Regarding CO_2 emissions, when gas heat pumps are compared with gas condensing systems, it becomes apparent that in spite of solar backup, the gas condensing systems in the main produce higher CO_2 emissions than the gas heat pump (or comparable emissions for a low GAHP utilisation ratio). This gives gas heat pumps major advantages over gas condensing systems when it comes to the CO_2 balance.

Again in terms of CO_2 emissions, gas heat pumps also offer substantial advantages over micro-CHP systems whose operation produces significantly higher carbon dioxide emissions over their service lifetime despite the electricity credit.

If we compare the carbon dioxide emissions of a gas heat pump with those of an electric brine-to-water heat pump (B/W EHP), then the natural-gas operated GAHPs must have the following efficiency indexes in order to attain parity with brine-to-water EHPs in terms of CO_2:

- 2010: thermal utilisation ratio of at least 1.4
- 2020: thermal utilisation ratio of at least 1.7

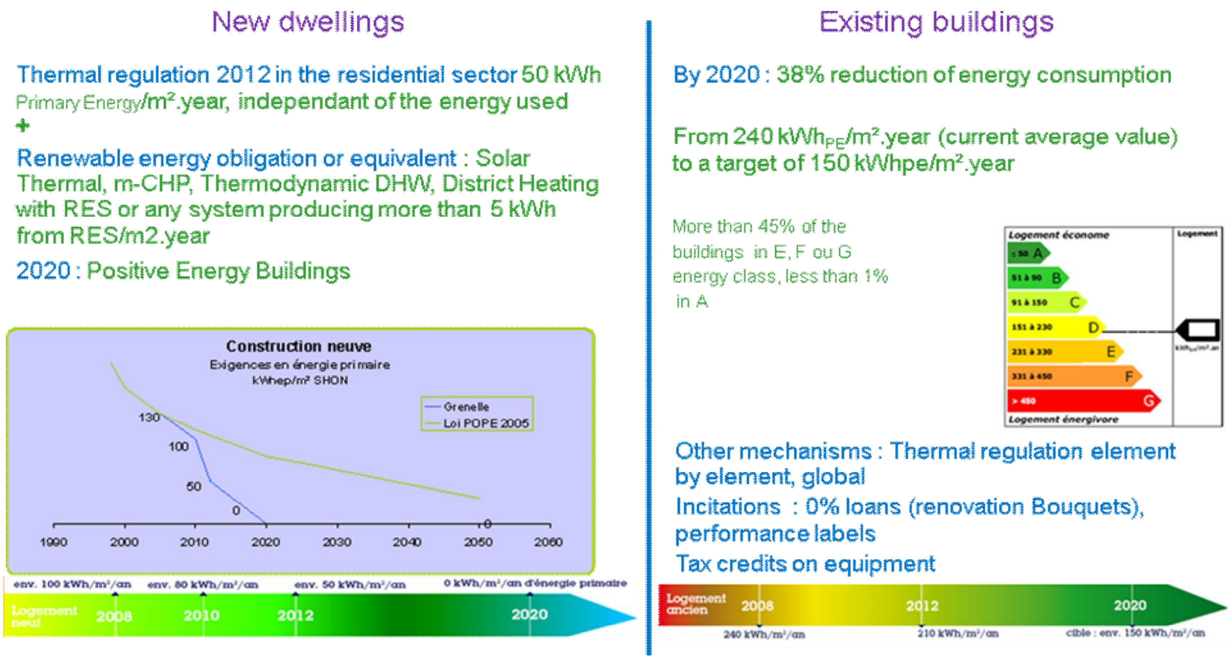
These figures can be defined as required values for the gas heat pumps in regard to CO_2 emissions. If we assume that gas heat pumps run on a mixture of natural gas and biogas, then they can achieve the same CO_2 emissions as brine-to-water EHPs with lower efficiency indexes than those given above, e.g. η_{th}=1.3.

6.1.2. Environmental and Economic Evaluation of GAHP in FR[10]

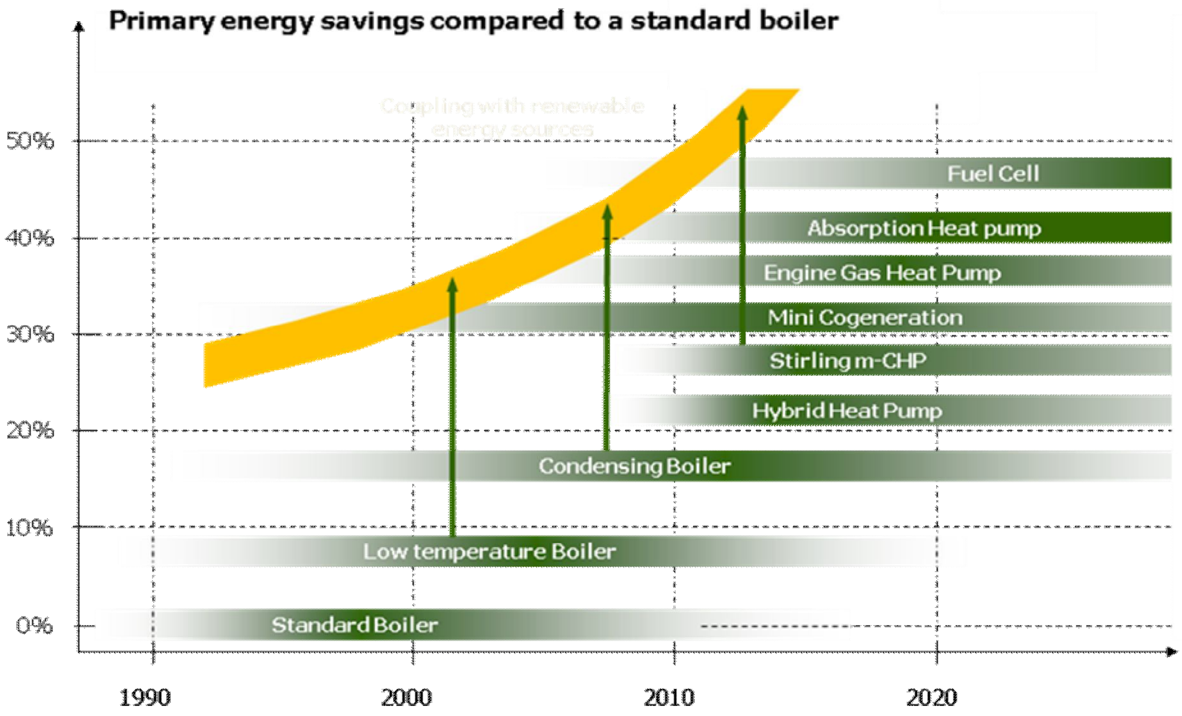
New regulatory context : French law orientations
The *Réglementation Thermique 2012* (RT 2012) sets the new minimum standard of thermal insulation of dwellings and other types of construction in France. It will be applicable to all new planning applications submitted for non-residential buildings from Oct 2011 and for all new residential properties from January 2013.

[10] GDF Suez, GrDF, *Data on the French Market,* HEAT4U WP1 meeting, Essen, feb, 22th 2012

Although a complex set of standards, broadly speaking, the regulations require that all new dwellings must have an energy consumption level less than 50 kWh/m2 per year, although varied by locality and altitude within the range 40kWh/m2 to 65kWh/m2.



This new regulation will significantly contribute to the improvement of the evolution of natural gas products, whose evolution is summarized in the following slide.



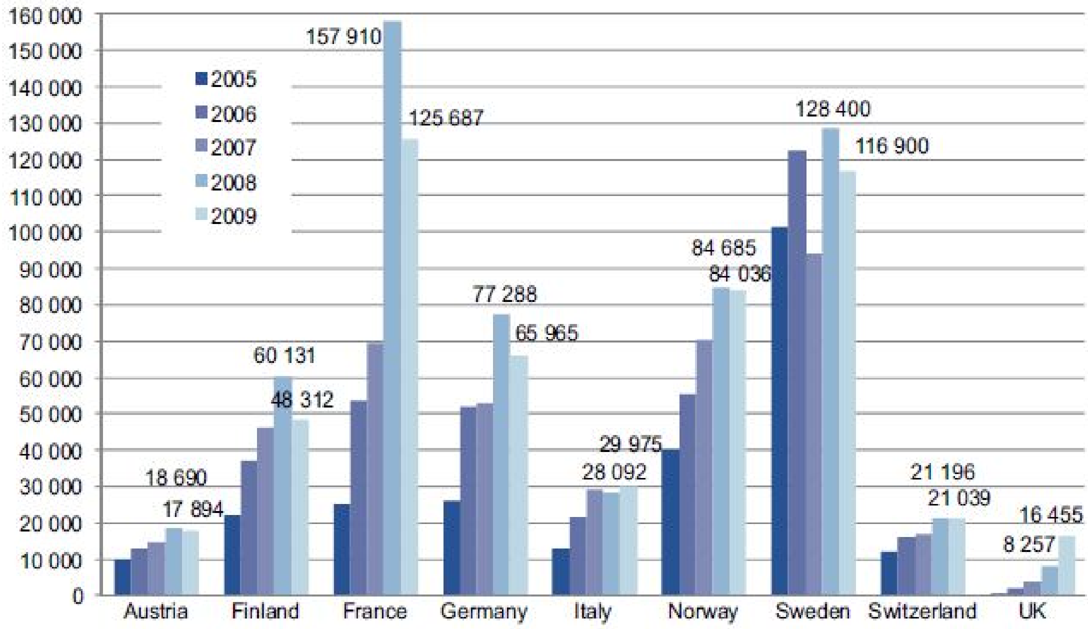
French market figures
The focus of the survey is the existing houses market for natural gas equipment:

Number of natural gas individual houses: 4,8 Million
- 4,5 private owners
- 0,3 social housing

Gas equipment sales in existing houses in France:
- Total of 270.000 gas boilers sales
  - 240.000 gas-> gas replacement /year
  - 30.000 other energy-> gas conversion
- ~ 90% private customers, 10% social housing
- ~ 35% sales share of condensing boilers, but fast increase expected
- ~ 70% wall hang boilers, ~half with DHW tank

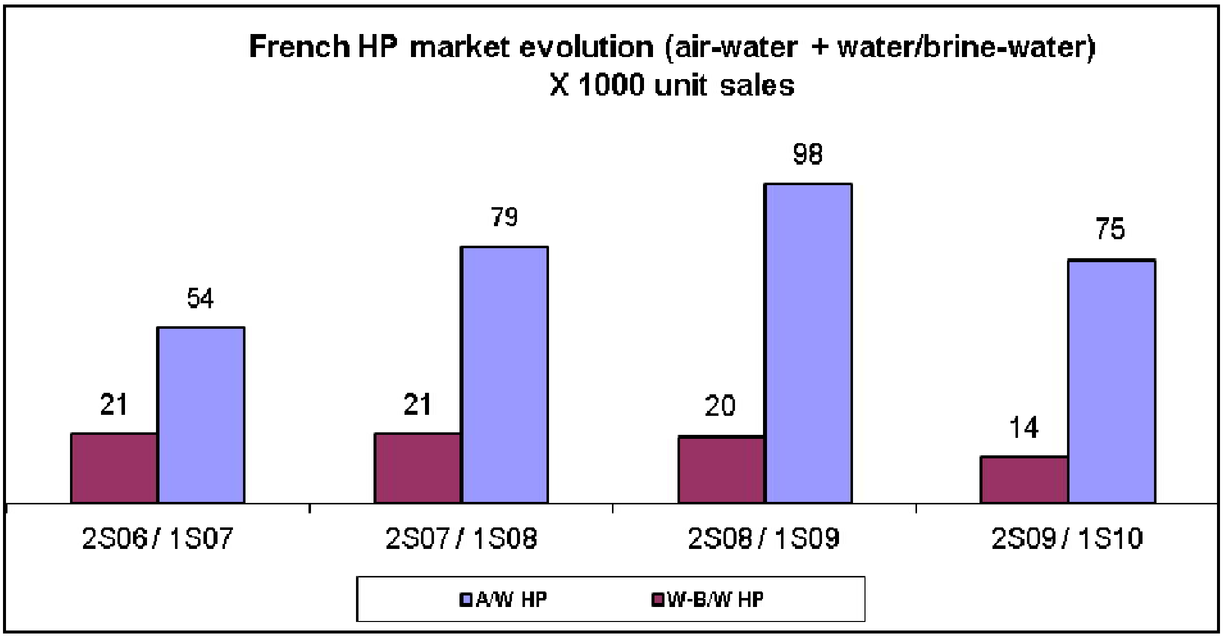
A rather stable market:
- amount of disconnections from the grid equal amount of new gas conversions,
- ...but this market is strongly linked to energy prices and incentives.

General HP sales in France
French heat pump market is the most important in Europe and the concept of heating by means of an (electrical) HP is fairly recognized by the professional of the heating industry and the end users.



Most of the electrical heat pumps (EHP) in the French market are Air/Water heat pump
<u>Estimation for 2011</u>:

- Quite same as 2010 (Air/Water)
- -19% as 2010 (Water-brine /Water)



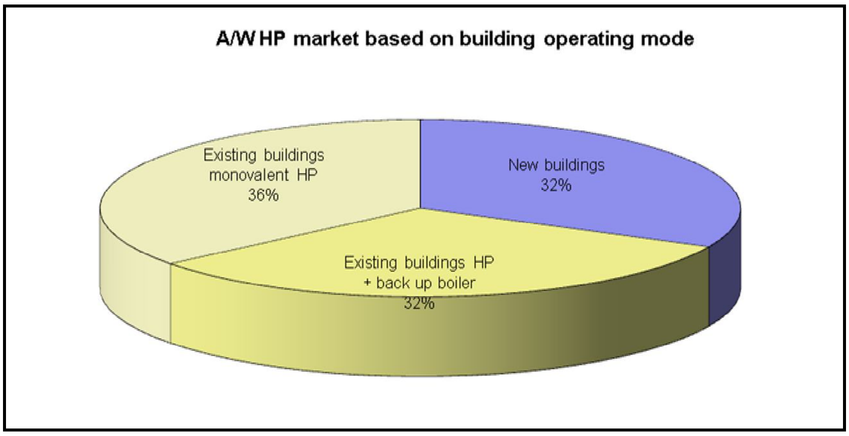
Focus on air / water HP sales
68% of the Air/Water EHP are installed in existing building

- 52% can provide DHW
- 51% provide heating at low temperature (under 60°C)
- 19% can provide cooling
- 47% are connected to High temperature radiators

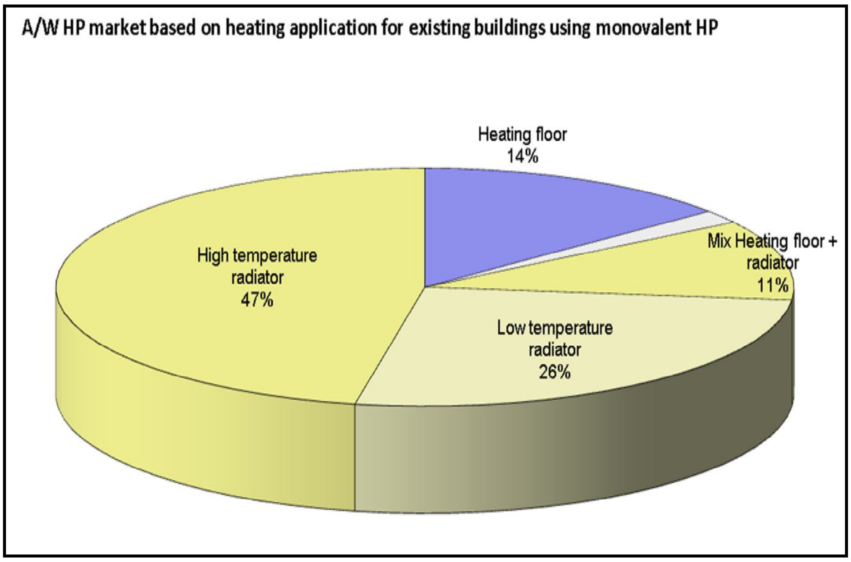
(source: installer survey)

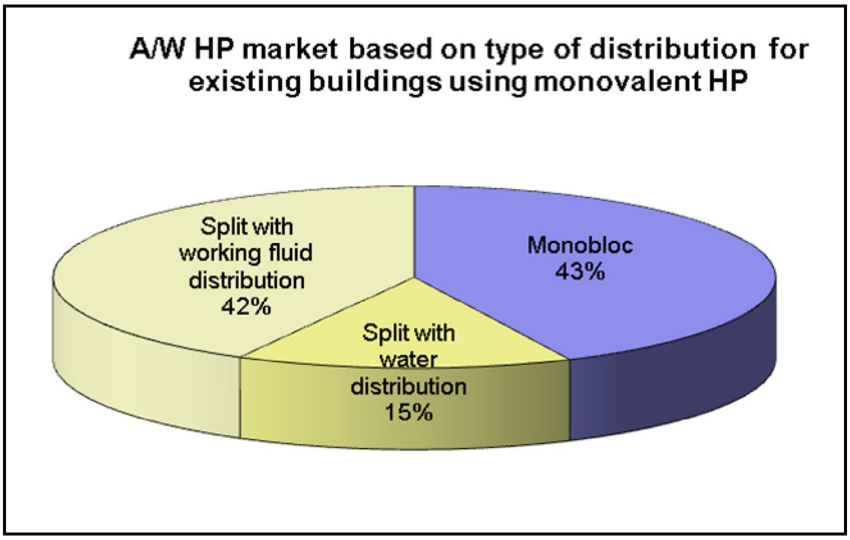
Figures for 2011 are substantially confirming growing role of Air/Water HPs:

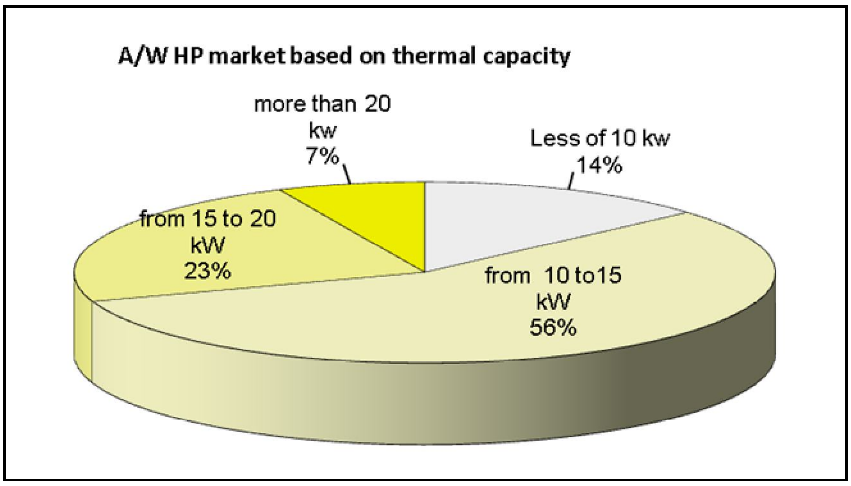
- Quite same as 2010 (Air/Water)
- -19% as 2010 (Water-brine /Water)



- Most of EHP can only produce heat at low temperature (=> maybe direct electrical heater to complete)
- High Temperature Heat Pumps are in the market as well



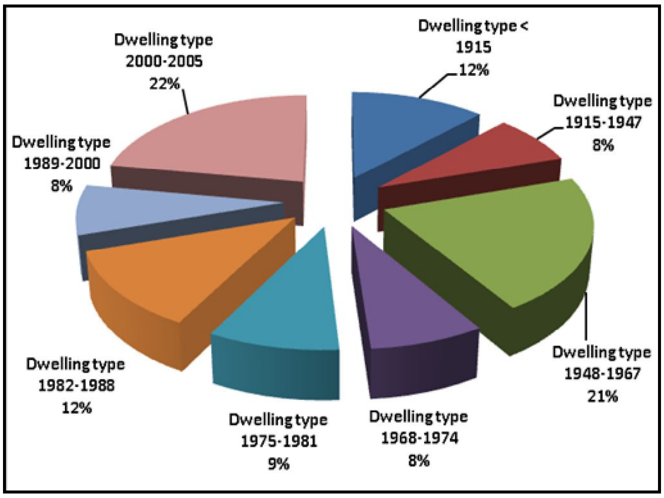


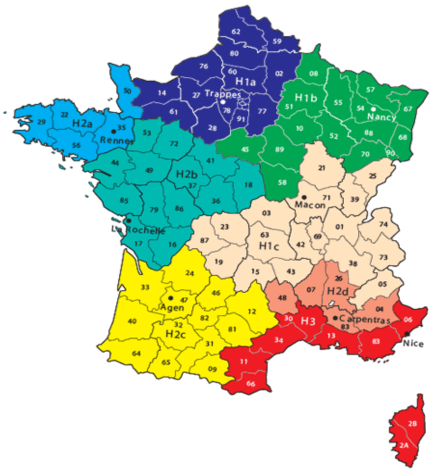


Focus on heating needs of exciting dwellings[11]

In order to assess the nominal power of the Heat Pump, the analysis if the existing dwelling has been performed by insulation level (date of construction as a predictor), surface and location (H1b, H2a, H3, etc.).

[11] Produced by simulation tool developed by GDF SUEZ-CRIGEN and dedicated to estimation of heating needs of referenced types of existing dwellings in order to positioning of several appliances (boiler, heat pumps, etc.)





In the following table the design power required for each dwelling type by location.

Existing dwelling types **for same surface =100 m2**	**Pdesign (kW)** **H1b** (Tdesign=-15°C)	**Pdesign (kW)** **H2a** (Tdesign=-4°C)	**Pdesign (kW)** **H3** (Tdesign=-2°C)
Dwelling type < 1915	**21**	**14**	**15**
Dwelling type 1915-1947	**24**	**17**	**17**
Dwelling type 1948-1967	**24**	**17**	**18**
Dwelling type 1968-1974	**29**	**20**	**21**
Dwelling type 1975-1981	**24**	**16**	**17**
Dwelling type 1982-1988	**16**	**11**	**12**
Dwelling type 1989-2000	**9**	**6**	**6**
Dwelling type 2000-2005	**8**	**5**	**6**

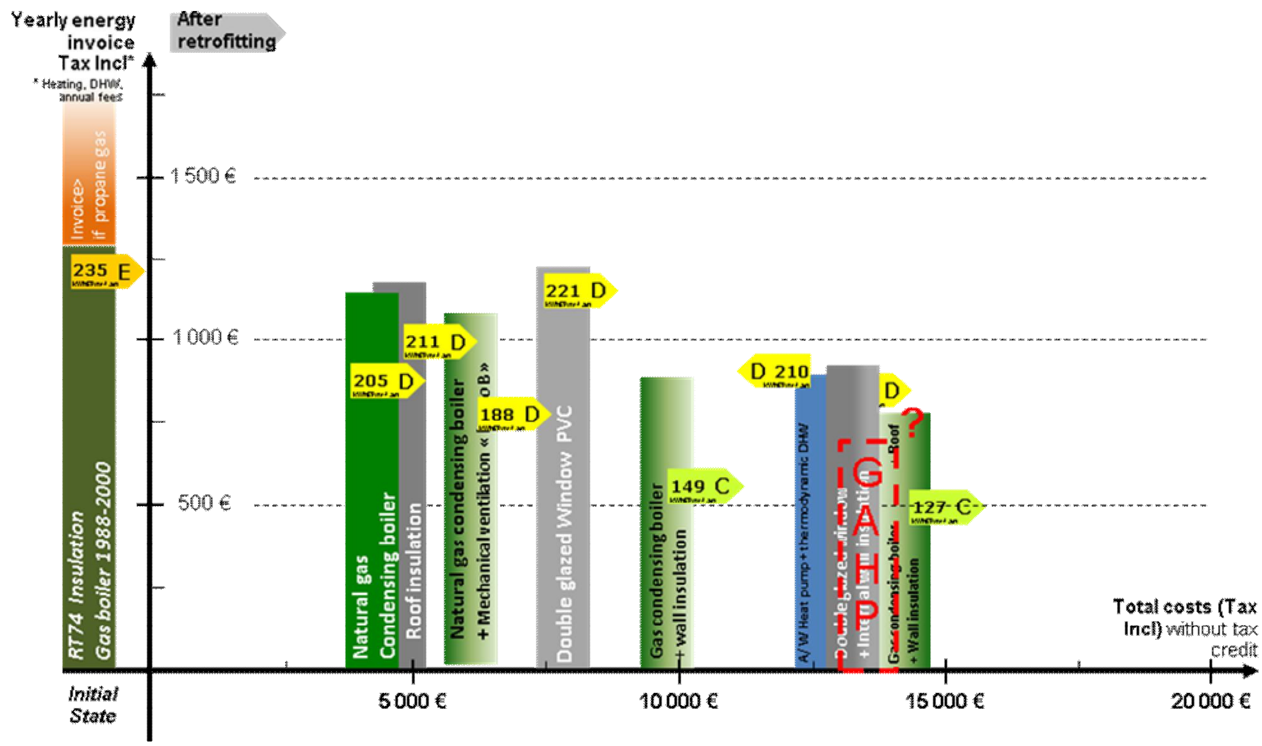
Targets for GAHP in existing houses

- Private Individual houses: 250,000 installation/year
  - Purchase motivation: Tax credit, 0% loans, payback
  - Key success factor for GAHP: Right pricing, efficiency, integration into incentive mechanisms
- «Social» individual houses: 20,000 installation/year
  - Purchase motivation: low total costs (invest + operation), easiness to use and service, but also often the obligation to reach “performance labels” and integrate a share of RES (regional specifications)
  - Key success factor for GAHP: Right pricing, efficiency, RES rate, low total costs (invest + operation), Service network

Other anticipated key success factor (common to all targets): Low noise level, esthetic integration (mostly for grouped houses), compactness (for outdoor and internal elements), adapted to installers habits (easy connections, integrated auxiliaries etc.)

In order to exemplify the options available for an owner of an individual dwelling in terms of energy efficiency improvements, a study that considers all technological alternatives (including envelope), their benefits in terms of annual savings and the possible different budgets available to exploit these options. The study has been conducted on an individual dwelling located in France dated 1975. The following picture summarizes the investments needed, the resulting operating expenses grouped by size of investment (5.000, 10.000 and 15.000 Euro bdgt)

1975 gas house retrofitting



6.1.3. Environmental and Economic Evaluation of GAHP in UK[12]

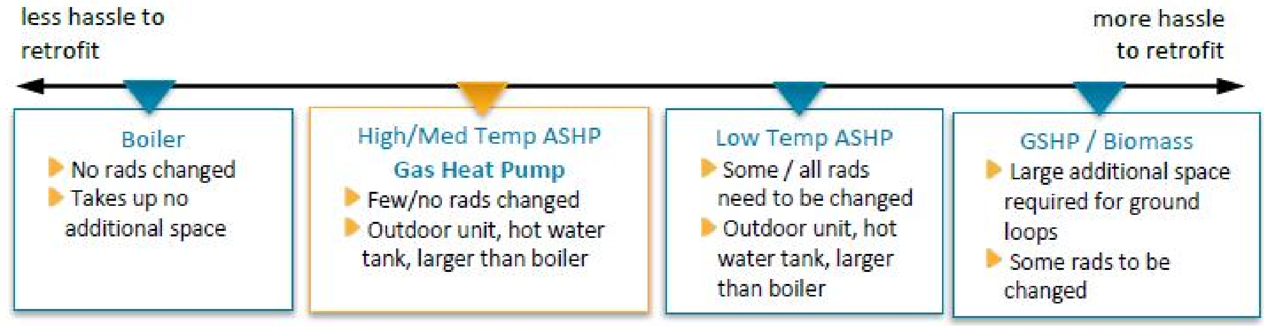
Gas heat pumps may open up new opportunities to reduce carbon in on-gas homes – a challenging sector for low carbon heating to penetrate
Decarbonising heat in the UK housing stock is challenging. 90% of homes - which are responsible for 80% of carbon emissions from UK housing - are connected to the gas grid, where alternative technologies struggle to compete. The step from gas condensing boilers to renewable heating is a large one: Gas prices are relatively low - electric heat pumps must perform very well to compete with gas on running costs Carbon emissions from gas are relatively low– when compared to carbon emissions from electricity. Electric heat pumps need to operate with high COPs to save carbon (although this challenge will reduce in the future if the electricity grid decarbonises as expected).

Gas heat pumps could be part of the solution to this challenge. They can use gas more efficiently than a boiler, typically with a GUE of 1.31 or above (compared to 0.95 for a high performing boiler), because they draw energy from a renewable heat source (air, ground loops or solar thermal). This increased efficiency leads to lower running costs, and lower carbon emissions without impacts on the power grid.
Gas heat pump products are starting to emerge for residential applications in UK as well.

Decarbonising the existing UK building stock through retrofitting alternative technologies is challenging. Many alternatives require a lot of space, and space is at a premium. Moreover, the UK market requires high flow temperatures for its traditional radiators – which is more difficult for some alternative technologies.

Emerging Gas heat pump products will be able to use air as a heat source and will be capable of producing relatively high flow temperatures (in some cases above 60C and possibly as high as 70C). These two elements combined will be a key instrumental asset for GAHP technology success in the market. The "retrofit-ability" is the key parameter for the success in UK.

Figure 1: retrofit-ability of selected alternative heating technologies compared to a boiler



Delta-ee, 2012

There are three main types of gas heat pumps presented in the UK market:

- **Gas engine driven heat pumps** – mature but only suitable for commercial buildings, not the residential sector

[12] *Gas-driven heat pumps: Opening opportunities in the UK retrofit sector?*, Delta-ee whitepaper, September 2012

- **Absorption heat pumps** – currently only developed for commercial-scale market, but being developed for residential applications.
- **Adsorption heat pumps** – currently available in Germany for the residential market.

Comparing the main types of Gas Heat Pumps today and in 5 years
In assessing the operational boundaries of the technology types, we consider two criteria as key for retrofit:

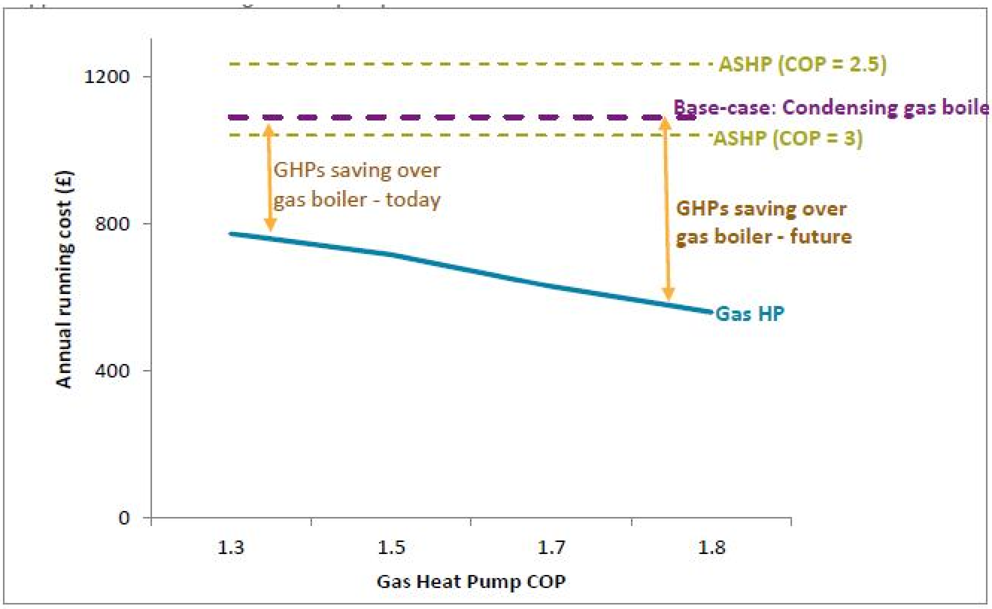
1. The ability to use a low temperature heat source (i.e. air, rather than solar thermal / ground loops)
2. The ability to produce a relatively high flow temperature

	2012			2017		
	Gas Engine	Absorption	Adsorption	Gas Engine	Absorption	Adsorption
Residential scale (individual solution for single family home)	✗	✗	✓	✗	✓	✓
Possible retrofit solution	✓	✓	✗	✓	✓	✓?

Delta-ee, 2012

Today, there is no gas heat pump product commercially available which is both residential-scale, *and* suitable for retrofit. However, we expect the next generation of ‘sorption’ technologies emerging between now and 2017 to have wider operational boundaries, opening up potential applications in residential retrofit.

Annual running costs for Gas HP replacing a gas boiler in a typical old suburban semi-detached home.
The following diagram shows the running costs for a typical UK home (thermal demand of 18,000 kWh) on the gas grid based on today’s electricity and gas retail prices. Gas heat pumps offer significant running cost savings over condensing gas boilers and ASHPs – more than £300 even with a conservative COP. The Renewable Heat Incentive could, of course, change this picture – depending on the support for electric and gas heat pumps.



Delta-ee, 2012

Gas Absorption HP technology has not yet reached the same level of maturity compared with boilers or even electric heat pumps. Therefore there is plenty of scope for:

- Efficiency gains through technology improvements (e.g. new refrigerants) – increasing the annual energy cost saving
- Substantially increased production volumes, and large opportunities for cost reduction from learning, experience, supply chain development & innovation.

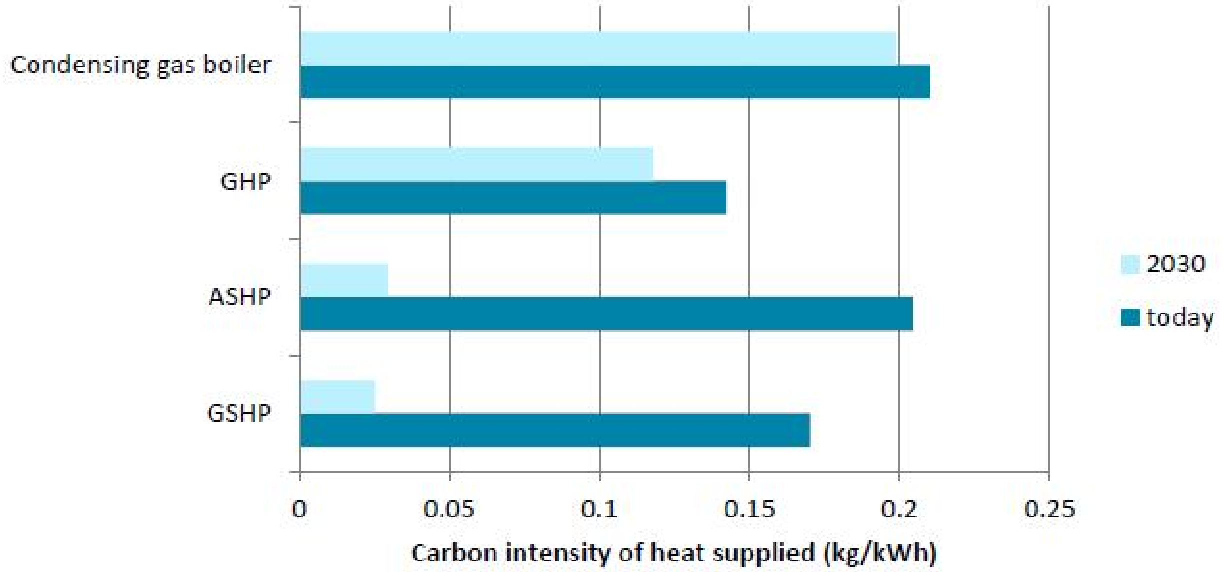
Upfront cost *could* come down substantially as the value chain is better developed, and sales volumes increase. At an increased gas heat pump COP of 1.7 or 1.8, running cost savings over a gas boiler could grow significantly. This combined with the drop in upfront cost, could bring paybacks down to an acceptable level (sub-5 years), although this is unlikely to happen in the next five years.

Significant carbon savings from gas heat pumps

Compared to both condensing gas boilers and electrically driven heat pumps, gas heat pumps today offer significant carbon advantages. Currently hypothesized decarbonisation of the electricity grid in UK might make electrically driven heat pumps much more competitive in the future, but gas heat pumps will remain a lower carbon option than condensing gas boilers.

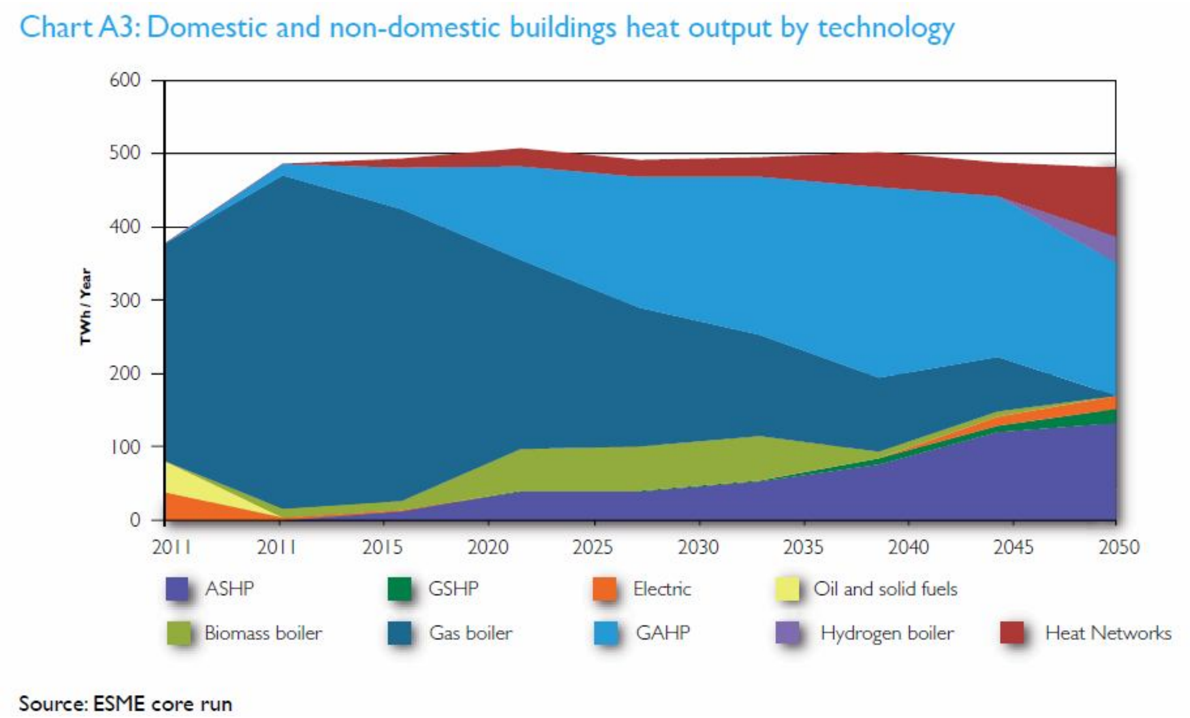
Figure 3: CO2 saving potential of GAHP relative to gas boiler

Gas heat pumps – although not yet available - are, today, a lower carbon option for homes than electrically driven heat pumps and condensing gas boilers. In 2030, if the electricity grid is highly decarbonised as initially forecasted by DECC (much work remains to achieve this), electrically driven heat pumps produce almost carbon-free heat.



Notes
Efficiencies today (and 2030): GSHP – 3.0 (3.5); ASHP – 2.5 (3.0); GHP – 1.3 (1.5); Gas boiler - 0.88 (0.89)
Current (and 2030) carbon emissions - gas 185 (177) g/kWh, electricity 511 (88) g/kWh
Delta-ee, 2012

Latest DECC study on Heating strategy highlight that the decarbonization plans initially hypothesized might be far too expensive for the country. The new heating strategy released in Mar2103 shows a more gradual role in decarbonizing the electricity and a much more relevant role for the GAHP technology as evolution of the standard/condensing boiler technology (see following graph).



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Conclusion

Gas heat pumps offer opportunities to reduce carbon emissions for the ‘hard to reach’ gas boiler market in the UK. Products are expected to be introduced into the UK in the next 3-5 years. The opportunity depends upon:

- The ability to turn product suitable for commercial buildings into a robust product suitable for the UK residential market.
- Government support and incentives for gas heat pumps.
- The ‘retrofitability’ of gas heat pumps for UK homes.
- The amount of heating industry engagement to bring the product to market.

If the above factors are met, gas heat pumps could have an excellent future in UK homes.

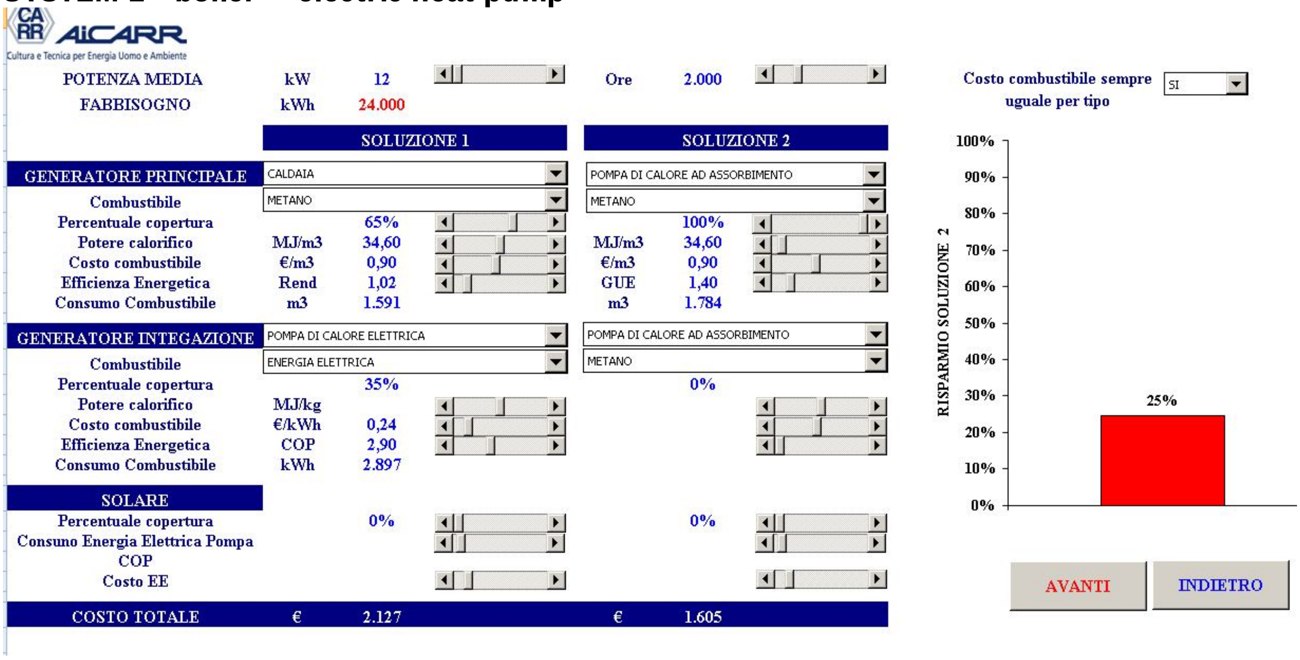
6.1.4. Environmental and Economic Evaluation of GAHP in IT

In this section, a recent study conducted by Aicarr (National Association of Thermotechnic Planners) which shows the main differences between the most common heating systems in comparison with the technology of GAHP is presented as an example. The systems considered by this survey are:

- The hybrid system boiler + electric heat pump
- - The system formed by condensing boiler + solar thermal

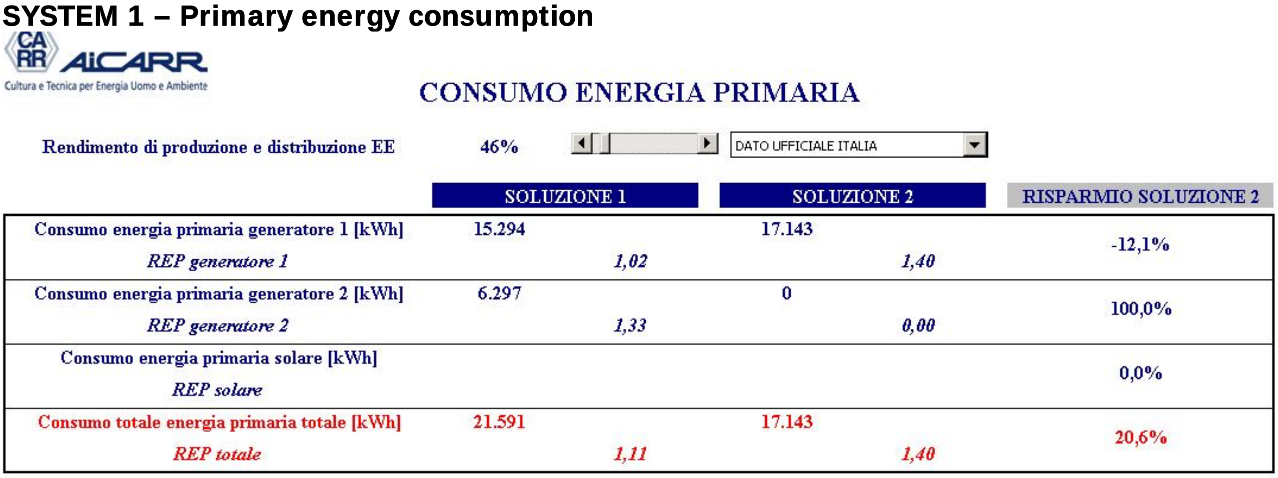
As can be deduced from the tables below the gas absorption heat pump proves to be better in both solutions investigated.

SYSTEM 1 - boiler + electric heat pump



In this case a Condensing Boiler integrated with an EHP are compared to an equivalent GAHP system in an hypothetical individual dwelling application. The economic saving are calculated for the two solutions.

SYSTEM 1 – Primary energy consumption



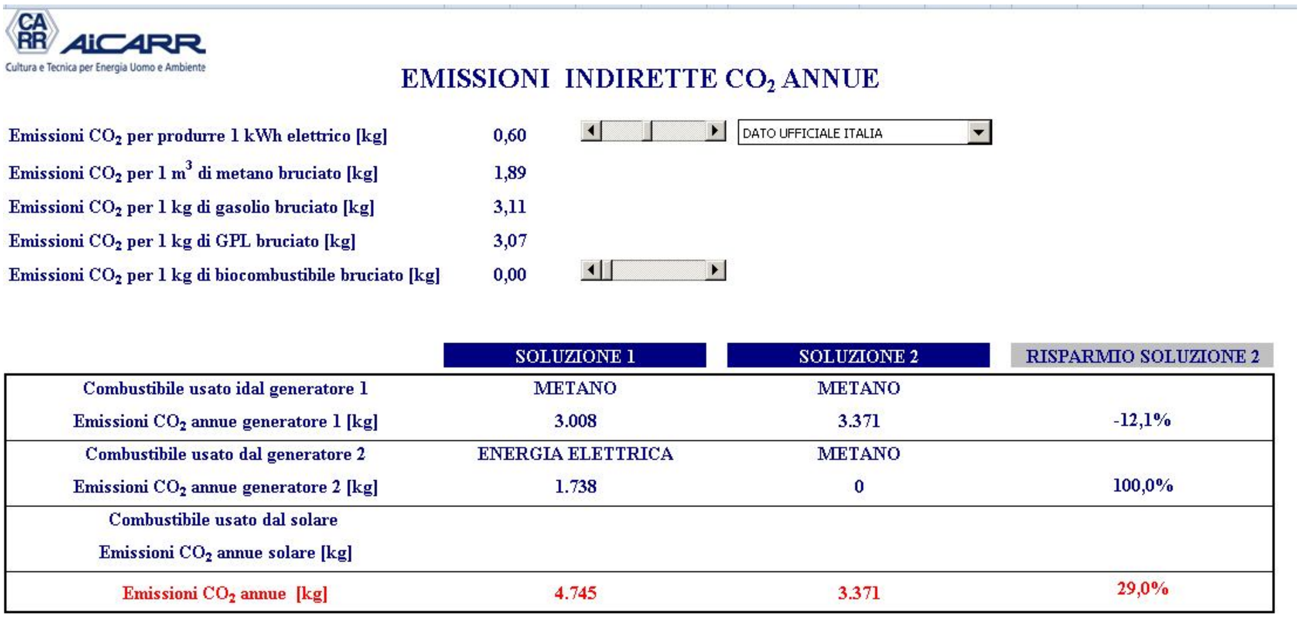
CONSUMO ENERGIA PRIMARIA

Rendimento di produzione e distribuzione EE 46% DATO UFFICIALE ITALIA

	SOLUZIONE 1		SOLUZIONE 2		RISPARMIO SOLUZIONE 2
Consumo energia primaria generatore 1 [kWh]	15.294		17.143		-12,1%
REP generatore 1		*1,02*		*1,40*	
Consumo energia primaria generatore 2 [kWh]	6.297		0		100,0%
REP generatore 2		*1,33*		*0,00*	
Consumo energia primaria solare [kWh]					0,0%
REP solare					
Consumo totale energia primaria totale [kWh]	21.591		17.143		20,6%
REP totale		*1,11*		*1,40*	

The primary energy consumption is calculated as well for the above mentioned case.

SYSTEM 1 – CO2 annual emissions



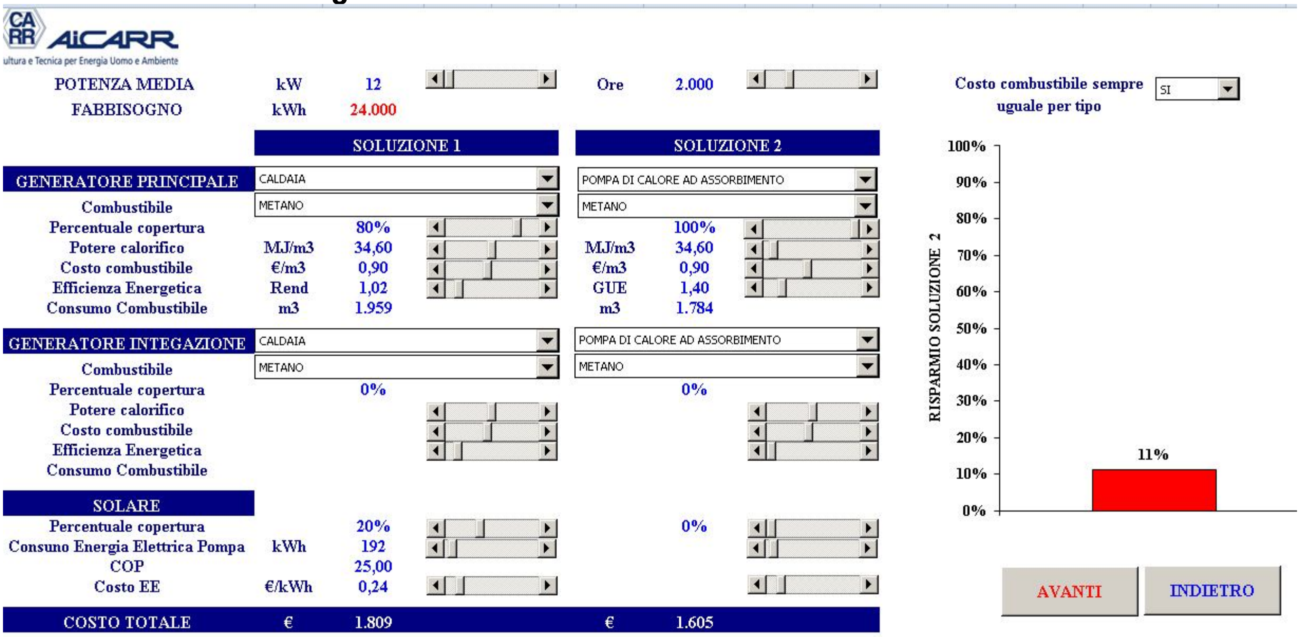
EMISSIONI INDIRETTE CO_2 ANNUE

Emissioni CO_2 per produrre 1 kWh elettrico [kg]	0,60	DATO UFFICIALE ITALIA
Emissioni CO_2 per 1 m^3 di metano bruciato [kg]	1,89	
Emissioni CO_2 per 1 kg di gasolio bruciato [kg]	3,11	
Emissioni CO_2 per 1 kg di GPL bruciato [kg]	3,07	
Emissioni CO_2 per 1 kg di biocombustibile bruciato [kg]	0,00	

	SOLUZIONE 1	SOLUZIONE 2	RISPARMIO SOLUZIONE 2
Combustibile usato idal generatore 1	METANO	METANO	
Emissioni CO_2 annue generatore 1 [kg]	3.008	3.371	-12,1%
Combustibile usato dal generatore 2	ENERGIA ELETTRICA	METANO	
Emissioni CO_2 annue generatore 2 [kg]	1.738	0	100,0%
Combustibile usato dal solare			
Emissioni CO_2 annue solare [kg]			
Emissioni CO_2 annue [kg]	4.745	3.371	29,0%

The CO2 emissions are calculated as well for the above mentioned case.
In conclusion GAHP technology delivers economic, energy and environmental savings when compared with an integrated system Boiler + EHP.

SYSTEM 2 – Condensing boiler + solar thermal



POTENZA MEDIA	kW	12	Ore	2.000
FABBISOGNO	kWh	24.000		
		SOLUZIONE 1		SOLUZIONE 2
GENERATORE PRINCIPALE		CALDAIA		POMPA DI CALORE AD ASSORBIMENTO
Combustibile		METANO		METANO
Percentuale copertura		80%		100%
Potere calorifico	MJ/m3	34,60	MJ/m3	34,60
Costo combustibile	€/m3	0,90	€/m3	0,90
Efficienza Energetica	Rend	1,02	GUE	1,40
Consumo Combustibile	m3	1.959	m3	1.784
GENERATORE INTEGRAZIONE		CALDAIA		POMPA DI CALORE AD ASSORBIMENTO
Combustibile		METANO		METANO
Percentuale copertura		0%		0%
Potere calorifico				
Costo combustibile				
Efficienza Energetica				
Consumo Combustibile				
SOLARE				
Percentuale copertura		20%		0%
Consumo Energia Elettrica Pompa	kWh	192		
COP		25,00		
Costo EE	€/kWh	0,24		
COSTO TOTALE	€	1.809	€	1.605

In this case a Condensing Boiler integrated with a Solar (thermal) collector are compared to an equivalent GAHP system in an hypothetical individual dwelling application. The economic saving is calculated for the two solutions.

SYSTEM 2 – Primary energy consumption

Cultura e Tecnica per Energia Uomo e Ambiente

CONSUMO ENERGIA PRIMARIA

Rendimento di produzione e distribuzione EE	46%	DATO UFFICIALE ITALIA

	SOLUZIONE 1		SOLUZIONE 2		RISPARMIO SOLUZIONE 2
Consumo energia primaria generatore 1 [kWh]	18.824		17.143		8,9%
REP generatore 1		*1,02*		*1,40*	
Consumo energia primaria generatore 2 [kWh]			0		0,0%
REP generatore 2				*0,00*	
Consumo energia primaria solare [kWh]	417				100,0%
REP solare		*11,50*			
Consumo totale energia primaria totale [kWh]	19.241		17.143		10,9%
REP totale		*1,25*		*1,40*	

The primary energy consumption is calculated as well for the above mentioned case.

SYSTEM 2 – CO2 annual emissions

Cultura e Tecnica per Energia Uomo e Ambiente

EMISSIONI INDIRETTE CO_2 ANNUE

Emissioni CO_2 per produrre 1 kWh elettrico [kg]	0,60	DATO UFFICIALE ITALIA
Emissioni CO_2 per 1 m^3 di metano bruciato [kg]	1,89	
Emissioni CO_2 per 1 kg di gasolio bruciato [kg]	3,11	
Emissioni CO_2 per 1 kg di GPL bruciato [kg]	3,07	
Emissioni CO_2 per 1 kg di biocombustibile bruciato [kg]	0,00	

	SOLUZIONE 1	SOLUZIONE 2	RISPARMIO SOLUZIONE 2
Combustibile usato idal generatore 1	METANO	METANO	
Emissioni CO_2 annue generatore 1 [kg]	3.702	3.371	8,9%
Combustibile usato dal generatore 2	METANO	METANO	
Emissioni CO_2 annue generatore 2 [kg]	0	0	
Combustibile usato dal solare	ENERGIA ELETTRICA		
Emissioni CO_2 annue solare [kg]	115		100,0%
Emissioni CO_2 annue [kg]	3.817	3.371	11,7%

The CO2 emissions are calculated as well for the above mentioned case.
In conclusion GAHP technology delivers on economic, energy and environmental savings when compared with an integrated system “Condensing Boiler + Solar”.

These elements are key factors in prospecting possible potential market volumes and positioning of the GAHP technology in the Italian market.

6.2. GAHP Market Potential

Premises

This analysis concerns a European multi-local parametric study in order to define the market potential of 18 kW Gas Absorption Heat Pump (GAHP) + air source renewable energy for heating only. This analysis defines all needed requirements with information regarding the current situation in selected European markets.

Methods

In order to define the market potential of 18 kW GAHP solution for selected market regions, the overall study has focused on the features of the single regions. The definition of the features will be given through the following parameters:

- Overall building stock
- Overall building stock supplied by gas service
- Annual new construction rate
- Annual replacement rate on overall building stock supplied by gas service
- Competing technologies sales
- Detached and semi-detached house stock supplied by gas net
- Annual replacement rate
- Annual replacement rate according to the target calculated on correction factor

Detailed information are coming from local market researches (data sources follow below) to come up with a realistic view.

Assumptions and market analysis

- *Background - Country-based analysis*
  The areas taken into account are representative of the highest market potentials for this technology, namely north and continental Europe regions, due to the fact that GAHP is suited primarily for the use in heating applications. Countries considered are: United Kingdom, Germany, France, Italy*[13], Netherlands, Belgium, Switzerland, Austria.

- *Background - Overall residential building sector*
  As first step, in order to well understand the potential of GAHP systems in the European market, the overall building stock data per each country is reported, taking into account the overall amount of the residential building stock supplied by gas service.
  The analysis also takes into account a new building construction rate (for which, according to the EPBD regulation, use of renewable energy at certain rates is imposed) of 1% and an annual gas heating system replacement rate of 5%.

- *Background - Competing heating technologies sales*
  The three most competing technologies, namely Gas Boiler, Heat Pump (heating type only, air/water version) and Solar Thermal System[14] are considered, due to the fact that they better

[13] **Correction factor:** For the Italian market, A1 Nielsen area (Liguria, Piedmont, Valle d'Aosta, Lombardy) and A2 Nielsen area (Trentino Alto Adige, Friuli Venezia Giulia, Veneto, Emilia Romagna) are considered as the greatest potential for the GAHP solution.

[14] Total Solar Collector area installed per country is divided by 4 in recognition of the typical/average size of the solar collector plant to calculate the total number of solar systems/plant installed.

fit the needs for residential heating operation in the European Market.

- *Market Analysis – 18 kW GAHP market potential*
  Keeping in mind the residential sector the 18kW GAHP is oriented to namely detached and semi-detached houses, this residential sector target has been investigated considering the rate of family buildings supplied by gas service. The analysis also considers an annual system replacement rate of 5% and an annual correction factor of 50% (boiler breakdown/failure as an emergency with no need for innovative and eco-friendly solutions in compliance with current regulations). Analyzing in detail the results and not considering the mere replacement, the report considers an annual rate of 10% of target with a positive attitude to apply innovative heating techniques (as known by several marketing studies about technology introduction).

Findings

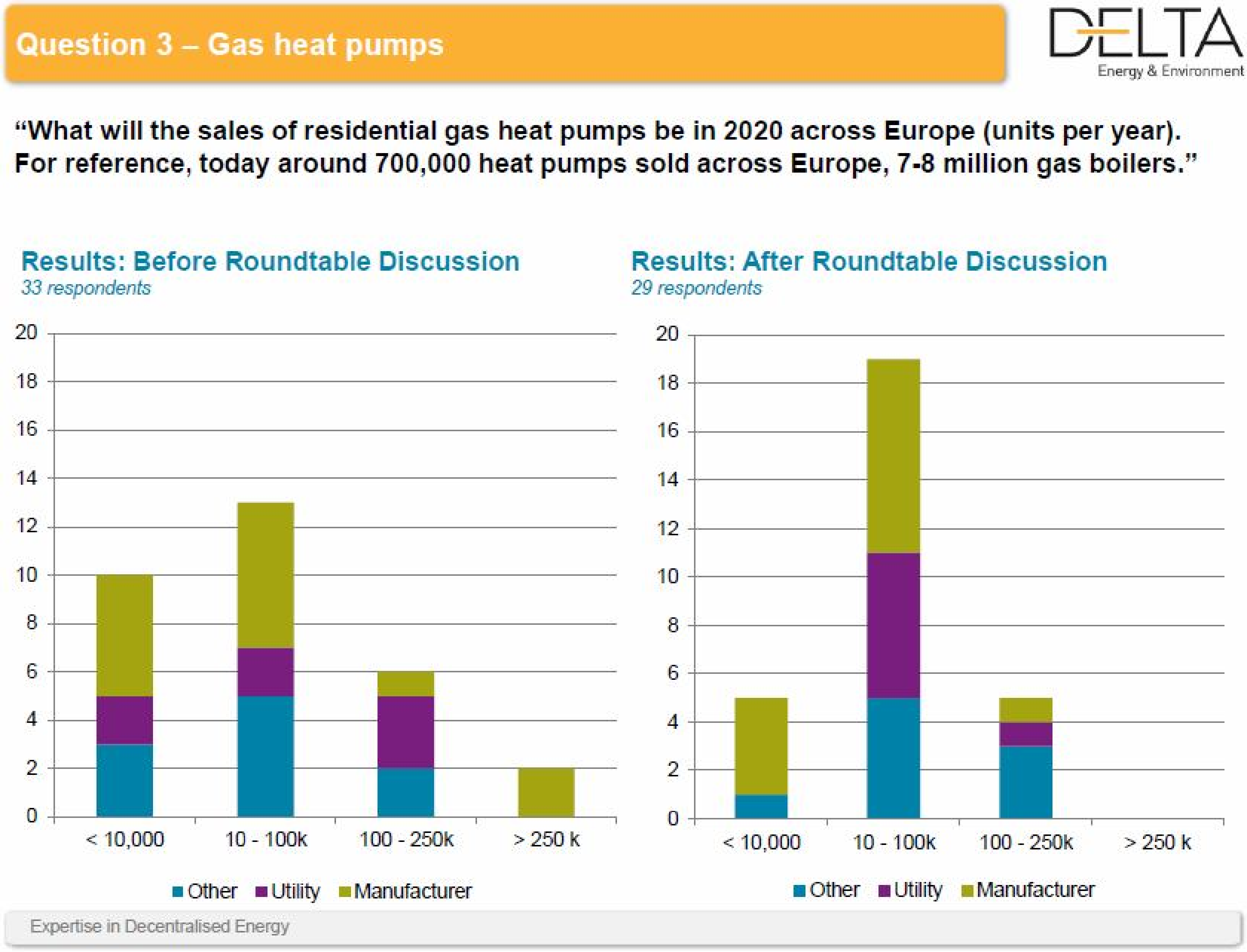
	RESIDENTIAL BUILDING STOCK				COMPETING TECHNOLOGY SALES			MARKET ANALYSIS				
COUNTRIES	OVERALL RESIDENTIAL BUILDING STOCK	OVERALL RESIDENTIAL BUILDING STOCK SUPPLIED BY GAS SERVICE	NEW RESIDENTIAL BUILDING CONSTRUCTION RATE (1% PER YEAR)	REPLACEMENT RATE ON RESIDENTIAL BUILDING STOCK SUPPLIED BY GAS SERVICE (5% PER YEAR)	SALES 2010 BOILER (gas only)	SALES 2011 HEAT PUMPS (heating type only air/water version)	SALES 2010 SOLAR THERMAL (flat plate - sqm/4)	DETACHED AND SEMI-DETACHED HOUSE STOCK SUPPLIED BY GAS SERVICE	REPLACEMENT RATE (5% PER YEAR)	CORRECTION FACTOR - FAILURE OR BREAKDOWN REPLACEMENT (50% PER YEAR)	TARGET WITH POSITIVE ATTITUDE TO INNOVATIVE HEATING TECHNIQUES (10% PER YEAR)	18 kW GAHP POTENTIAL MARKET
UK	25.800.000	21.900.000	258.000	1.095.000	1.600.000	14.930	27.000	11.700.000	585.000	292.500	29.250	29.250
GERMANY	38.600.000	18.700.000	386.000	935.000	478.000	32.616	262.500	9.315.000	465.750	232.875	23.288	23.288
FRANCE	32.600.000	14.344.000	326.000	717.200	481.500	55.299	71.250	6.864.000	343.200	171.600	17.160	17.160
ITALY	29.641.961	14.497.856	296.420	724.893	985.500	379	88.500	5.992.707	299.635	149.818	14.982	14.982
NETHERLANDS	7.168.000	5.734.400	71.680	286.720	448.000	3.016	11.250	4.082.400	204.120	102.060	10.206	10.206
BELGIUM	3.448.779	1.379.512	34.488	68.976	199.000	N.A.	10.375	689.756	34.488	17.244	1.724	1.724
SWITZERLAND	3.919.064	1.371.672	39.191	68.584	34.500	11.252	30.000	685.836	34.292	17.146	1.715	1.715
AUSTRIA	3.505.449	1.051.635	35.054	52.582	41.500	5.399	80.000	467.226	23.361	11.681	1.168	1.168
TOTAL	144.683.253	78.979.075	1.446.833	3.948.954	4.268.000	122.891	580.875	39.796.925	1.989.846	994.923	99.492	99.492

Alternative approach to definition of GAHP market potential: Delphi approach
In consideration that GAHP technology is a relatively new technology (in particular in its application in the residential environment) a different and complementary study was performed following the Deplhi approach for assessment of market forecasts and potentials in unstructured or brand new market/technologies

An additional study was performed in cooperation with Delta Energy involving several key influencers (R&D mgrs, members of the board, etc.) of several major European utilities and manufacturing companies. This study was conducted by:

- submitting to a panel of approximately 30 key players a survey about GAHP technology before a specific presentation of the GAHP technology,
- reviewing in detail the key and unique selling points of the GAHP technology and
- submitting again the same survey after such presentation and discussion.

The results highlight both the influence of the awareness (significant improvement of the expectation of the market potential) and the absolute market value that this technology might take in the next few years. A significant fraction of participant indicated that this technology would reach the many tens of hundreds of units by 2020. The following table summarize the analysis performed on the basis of the answer of these experts of the industry.



6.3. Competitors + Pricing

Competing technologies

The market of gas sorption heat pumps in European countries is still undeveloped or in the launching phases, so that a direct benchmarking for an 18 kW GAHP appliance against new sorption products just recently introduced into the market and still confined in low-volume niches may not be appropriate in a strategic perspective.

In order to provide some sensitivity for price positioning, the following alternative technologies have been taken into consideration as reasonable references:

- Hydronic Electrical Heat Pumps for combined space heating and DHW production (usually coupled to a hydronic kit);
- Condensing Boiler + Solar panels.

The rational behind the choice is that a comparison to a GAHP appliance should be based on the following key features:

- System delivering both space heating and DHW;
- System providing at least a fraction of renewable energy;
- Same target application (existing detached single-family house or new small multi-family).
- Although both technologies above (EHP and CB+solar) are matching the criteria for the comparison, it is worth pointing out that in fact CB+solar is a more homogeneous competitor, being a gas-based solution and being intrinsically more suitable than EHP for retrofit applications with high temperature distribution systems (radiators), whereas most EHP would rather be applicable almost exclusively in new buildings with low temperature emitters and often in off-the grid applications.

Market selection

The analysis was carried out on the four markets with the highest potential for a residential GAHP, as resulting from a multi-local parametric study on the buildings’ stock: UK, Germany, France, Italy.

Data gathered

This study aimed at providing a first-glance picture of each target market in terms of product prices of competing technologies, without entering into more tactical considerations about price placement and cost/benefit or pay-back analysis.

- EHP: prices are given as list prices of the equipment only; in most cases, the equipment is a set composed by the Heat Pump properly said and an accessory hydronic kit necessary to differentiate space heating from DHW production. The EHP may be either a monoblock or a split unit, but only hydronic Heat Pumps were taken into account. In most instances, the hydronic kit is integrated with the indoor part of the Heat Pump appliance (condenser). In any case, prices are given as a sort of “package” price, excluding any installation cost and any additional cost for auxiliary equipment or components regarded as standard for any heating / DHW system.

- Condensing Boiler + Solar: prices are given as list prices of the equipment as a complete package, including the Condensing Boiler, the standard size of solar panels for a single-family house (4-4.5 m2), the solar water tank and relevant components of the solar system. In this case, an extra-cost has been taken account to allow for the more expensive installation of the solar system (access to the roof, warranty on leakages, piping from roof to heating room, etc.); this extra-costs has been considered to be around 1000€ as an overall average across the four countries.

It is worth noting that all list prices presented are <u>VAT excluded</u> in order to make net prices comparable among different countries, but in fact for the residential market VAT should be taken into account in making a pay-back analysis.
Also, the benchmark is not taking into account operational costs, maintenance costs, expected life-time or any other element which could become relevant in a TCO (Total Cost of Ownership) analysis.

Results

Here is a summary table of the outcome:

COUNTRY	CONDENSING BOILER + SOLAR + DELTA INSTALLATION COST	EHP (around 18 kW) + HYDRONIC KIT
UK	**8.200 - 10.200**	10.400 - 12.500
GERMANY	**7.000 - 10.000**	15.000 - 21.000
FRANCE	**7.300 - 9.500**	10.000 - 14.000
ITALY	**8.000 - 10.300**	12.200 - 14.300

GAHP technology commercial deployment will need to consider these alternative technologies as options that installers and end users might consider at time of decision making. The above listed advantages (economic, energy and environmental savings) should guide the final product positioning according to the specific marketing strategy selected for the GAHP technology introduction.

7. Survey about retrofitting value chain

In an initial phase of the project the integration of the GAHP Appliance into an overall construction element (GAHP Module integrating the GAHP heat pump (GAHP Appliance), the associated hydronics and control (GAHP System) in an overall enclosure) was considered taking into account the local specific requirements (as detailed in the multi-local study), in order to investigate if such solution could enhance the adoption rate of the GAHP technology and could optimally interface to the building in case of deep renovation.

Market analyses performed so far indicate a high potential for GAHP technology in several different markets in the retrofit applications, but the initial idea of creating a "GAHP Module" for the "deep-retrofit" installations or for the "new buildings" appears to receive limited appreciation for several different reasons. In the following we summarize the key findings and outcome of such analysis:

- the intervention in the thermal envelope is rarely seen as complementary to the heating system upgrade;
- cost is a very limiting factor when considering an integral approach. The consequence is separation of heating system replacement and envelope retrofit, seriously hindering envelope integrated GAHP solutions;
- the ability to serve the "existing buildings" without imposing the replacement of the emission systems (radiators) is indeed perceived as a major attractiveness;
- the GAHP Module does not represent a cost effective solution, due to **the fact that it imposes the need for a** deep **renovation which would imply important constraints to the end customer (not least the need to leave the homes in order to allow the retrofitting activities**);
- aesthetic is a very important matter in residential application;
- the GAHP Module could imply problems of access for the maintenance of the GAHP Appliance
- the GAHP module could create some backward compatibility issue (what about after 15-20 year of use of a GAHP? At the end of life of a GHAP module is the owner expected to work again on the envelope to evolve toward a different technology?)

Some partners of the project (in particular ZAG, GDF Suez and GrDF) also focused a part of their market analysis more on the survey about retrofitting value chain and the involvement of the key actors opinions and practices by conducting surveys through focus groups especially planners and installers and service technician.

ZAG in particular has highlighted the technical problems relating to the possible adoption of the solution "GAHP Module" and the results is that, although GAHP wall modular solution (GAHP integrated into wall) seems a space saving and favorable solution there are several drawbacks that end to be considered in detail. These drawbacks may be grouped in two groups: building related issues and technical issues.

Building related issues are:

- Since heating systems in existing houses are predominantly high temperature systems with water temperature up to 65°C. Changing the regime of operation to low temperature system might involve heat storage. The later introduces problems in integration, such as load bearing capacity of the wall and risk of condensation or excess expansion due to temperature differences. This way unwanted loads might occur on the building, that need to be addressed individually which presents a big problem concerning costs.

- In contrary to the use of detached solution integrated solutions would require additional work in facade renovation. Typically the envelope is now renewed by application of thermal insulation to the wall. In modular integral solutions for the GAHP often installation would need to be reworked. Additionally currently gas-burners are installed in utility areas (often centrally in the building). There are operational noise complaints noted. Therefore in some cases by installing the GAHP on the external wall might introduce unwanted operational noise to become a problem (depending of course in what dwelling areas the GAHP would be installed).

Technical concerns for the GAHP/wall interface are the following:

- Often external walls are quite not load bearing and are quite thin but well insulated. In the cases where the new element would be thicker than existing wall lower insulation of the wall mounted element at particular spot means that energy loss will be higher or element would be seen on the facade, which is also not desired.
- Condensation of moisture and thermal bridges could appear if wall mounted elements would be installed. It is very difficult to prevent thermal bridges in such an element.
- Vibration and noise could occur in the walls if wall mounted element with fan would be installed. Noise could be irritating.
- Leakage possibility is much higher if several wall mounted elements is installed if they are compared with single unit.
- Potential of fire is also higher due to more electrical wiring to each wall mounted element. Fire test must be also done for standard element. The integrated GAHP solution might face serious difficulties because by assuming external wall function it becomes a construction product. Numerous tests would have to be adapted and criteria probably developed, especially in fire area. Due to rigidity of fire codes in most countries it might take substantial time to prove fire properties of such an element.

GDF Suez and GrDF carried out a survey on installers and planners on their installation habits, preferred technical choice and interest for the GAHP Appliance. Two groups of fitters were interviewed, one involved mainly on individual houses installations (new buildings & renovation) and the second involved both in residential (individual house and multi-family houses) and commercial works.

From the survey several points that must be considered in facing the question of the Module emerged:

- in the complex word of today, people are coming back to simple, reliable solutions;
- preference for "plug & heat" systems, all integrated, with all auxiliaries;
- the importance of having a single point of contact for the purchase, installation and maintenance of the heating system is perceived as very important (the installation of a Module would imply an increase of the actors involved in the process)
- The size of the Module could be a problem in residential installation
- Not a clear preference for outdoor, indoor installation or split: they all have advantages and drawbacks and the main criteria are noise, space and installation constraints

At the same time the Consortium has received more pressure/emphasis on other parts of the GAHP technology development:

- to achieve the best performance from the acoustic insulation/noise emissions (it is clearly perceived as a critical success factor)
- to achieve very high level of thermal insulation for the GAHP appliance (it is critically important to achieve energy efficiency for an "outdoor heat generator")
- to acquire evidence of technology readiness for mass market (in particular with reference to the limited availability of experimental data about possible impact of ammonia release in the environment or a fire event).

Using a GAHP should not impose a deep retrofitting activity which can be too heavy to support for final customers. In this sense the market analysis carried out where it is highlighted that the Module receive limited appreciation by the key actors of the building retrofitting value chain, gives us all the elements to decide to opt for the elimination of the module in favor of a simpler and more suited to the needs of the market solution.

8. Overall conclusions

The GAHP has the potential to significantly contribute to the reduction of energy consumption and CO_2 emissions in the EU building construction industry:

- The EU building construction industry consumes the highest percentage of energy (40%) and is the largest contributor to produce greenhouse gas emissions (with a 36% of total CO_2 emissions in the EU). The majority of the buildings in Europe still feature specific consumption of 150 or more kWh/m²/annum. The building stock evolves very slowly. Indeed the renovation rate in Europe is approx. 1% per annum (new building on existing building stock). Therefore approximately 80% of dwellings of 2030 already exist today. GAHP technology could quickly allow for increase of energy efficiency in existing building without imposing major retrofitting activities and not relying only on envelop insulation.

- The existing gas grid is capable of transporting and storing large amount of energy in a cost effective way. GAHP technology can allow for energy efficiency improvement without affecting the existing grid to avoid the time and the costs associated with the development of smart grids and the required electrical infrastructure.

- Compared to gas condensing boilers with 15% of solar support gas absorption heat pumps offer advantages on primary energy use as well as from an ecological point of view, since this technology always replaces 12-13% of the fossil fuel used by renewable energy.

- The maximum system cost for cost effectiveness of a GAHP system depends on energy price, energy efficiency and best alternative technology considered. From an economic standpoint, the gas heat pump technology can be competitive when the resulting total annual costs are within the range of the conventional appliances that are currently available on the market:

    - with current energy price with annual system efficiency of 130% the GAHP system can be considered cost effective (in absence of incentive schemes) at cost of 10,000 Euro (when competing against a condensing boiler+solar).
    - When compared to an Electrical Heat Pump, with current energy prices, a GAHP system with annual system efficiency of 130% becomes cost effective at 18,000 Euro.

- Cost parity with the 'gas condensing boiler with solar domestic hot water supply and backup heating' variant is seen as the optimum criterion for the competitiveness of the gas heat pump.

- Comparing gas heat pumps with gas condensing systems, it becomes apparent that in spite of solar backup, the gas condensing systems in the main produce higher CO_2 emissions than gas heat pumps (or comparable emissions for a low GAHP utilization ratio). This gives gas heat pumps major advantages over gas condensing systems when it comes to the CO_2 balance.

- Comparing the CO_2 emissions of a gas heat pumps with those of electric brine-to-water heat pump, the natural-gas operated GAHPs must have the following efficiency indexes in order to attain parity with brine-to-water EHPs in terms of CO_2:

    - 2010: thermal utilisation ratio of at least 1.4
    - 2020: thermal utilisation ratio of at least 1.7

- GAHP technology commercial deployment will need to consider the alternative technologies electrical heat pumps as well as condensing boilers in combination with solar systems as options that installers and end users might consider at time of decision making. The economic and energy benefits and environmental savings should guide the final product positioning according to the specific marketing strategy selected for the GAHP technology introduction.

Market specific product features are detailed in Appendix. A common subset of these features was used to generate technical target for GAHP Appliance and GAHP system development.

Appendix

A. Multi local analysis France and UK

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	France		UK	
				Market info GDF suez	Comments from the market	source BRG consult	Comments from the market
Section 1	**General key topics**						
Section 1.1.02	Type of heat pump		Air/Water	Air/Water	80% of EHP french market	X	main market
Section 1.1.03	Type of heat supply		Central Heating and DHW	Central Heating and DHW		X	
Section 1.1.05	Possible integration with new or existing boiler		no	yes	Yes. To be adapted to all existing buildings, even without retrofitting of insulation, and with high temperature radiators.	yes	due to UK is a replacement
Section 1.1.07	Domestic hot water production		indirect	no specific request		indirect	
Section 1.1.08	Typical installation position		on the floor/ground	on the floor/ground		on the floor/ground	
Section 1.1.09	Combination with buffer tank for space heating		not needed	no buffer tank		not needed	
Section 1.1.11							
Section 2	**Installation**						
Section 2.1.01	Installation time (heat pump appliance only)	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	no specific request		same as a condensing boiler	
Section 2.1.02	Replacement time (heat pump appliance only)	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	no specific request		same as a condensing boiler	
Section 3	**Dimensions (without packaging)**						
Section 3.1.01	max height		1200 mm	1200*1000*500 Should not be bigger than other heat pumps but not a blocking point	DAIKIN (main EHP competitor): 1350*900*320	1200 mm	
Section 3.1.02	max length		1000 mm			1000 mm	
Section 3.1.03	max depth		500 mm			500 mm	
Section 4	**Design / colour (details of design requirements)**						
Section 4.1.01	Appliance style outside (feature/blended in)		not defined jet	as discrete or stylish as possible (subject to client survey..)	CRIGEN POV only (no factual data)		fits to the garden,house
Section 5	**Technical Features**						
Section 5.1.01	Seasional Efficiency SPER (including electricity)		30 % better than a condensing boiler	if possible > 125% (not a blocking point)	DErP (Ecodesign): SPER higher than 125% = A++ Class	Needed efficiency to reach ErP standard to get subsidies	
Section 5.1.02	(Gas Utilization Efficiency Net Calorific Value)		162 % A 7/W50	162 % A 7/W50		162 % A 7/W50	
Section 5.1.03	max. heating output:		18 kW (A7/W 50	18 kW (A7/W 50)		10 kW	main market request e.g. 10 kW heat demand at -15°C.
Section 5.1.04	max. heating output:		12 kW (A-7/W 65)	Minimum 17 kW (A-7/W 65)		10 kW	main market request e.g. 10 kW heat demand at -15°C.
Section 5.1.05	modulation range		1 : 3	as much as possible to optimize SPER		1 : 3	
Section 5.1.06	Max. heating water temp.:		65 °C:	65°C		65 °C:	
Section 5.1.07	Max. Temperature for DHW production:		65 °C:	65°C		65 °C:	
Section 5.1.08	average electrical power consumption:		approx 1% of total output	As low as possible	Target : achieve SPER of 125%	approx 1% of total output	
Section 5.1.09	Operating pressure central heating		3 bar	no specific request		3 bar	
Section 5.1.10	Special demands for hot water comfort	e.g. size of the tank, flow rate DHW	to be defined; please specify	200l max, flow rate=15l/min	According to EN 13 203-1 : 3rd position comfort label. The maximum is 4.	max load capacity of the appliance necessary	
Section 5.1.11	Hydronic kit (pump, 3-way valve, expansion vessel and DHW tank)		indoor	indoor	If possible, all hydronics in a kit, to simplify the installation.	indoor	
Section 5.1.12	Location of connection		Gas, water and electricity on one side	Gas, water and electricity on one side		Gas, water and electricity on one side	
Section 5.1.13	Type of gas connection		15 mm Female 1/2"			15 mm Female 1/2"	
Section 5.1.14	Type electrical connection		wiring terminal			wiring terminal	
Section 5.1.15	Type of water connection		22 mm Femal 3/4"			22 mm Femal 3/4"	
Section 5.1.16	Weight:		220 kg	as lower as possible		160	same as competitor (Vaillant)

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	France		UK	
				Market info GDF suez	Comments from the market	source BRG consult	Comments from the market
Section 6	**water quality request**						
Section 6.1.01	Anti-legionella method implemented	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	to be defined; please specify	no specific request	not required if tank volume < 400 l	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	same as condensing appliance
Section 6.1.02	Anti freeze		active protection, anti freeze protection in the heat pump	Let open 2 possibilities: 1 - Electricity tracing : May be inside the unit 2- Glycol : fitters preference (even if it's not recommended) Others : Same protections as on E3 (put ON the pump and then the unit in case of too low water temperature), Put the unit as close as possible to the house, Bury the hydraulic connections if possible	According to fitters : in case of water pipes connection, electricity tracing (safety electrical resistance on the hydraulic pipe)	active protection, anti freeze protection in the heat pump	
Section 6.1.03	Robustness of appliances against installed system		cleaning of water hydraulic system at installation	cleaning is acceptable, but recommanded also to install a good filter in case it is not realised.		cleaning of water hydraulic system at installation	
Section 6.1.04	Corrosion prevention: planty corrosion inhibitors can be accepted		yes	the easiest procedure to apply	Using filter	yes	
Section 6.1.05	Definition of water quality	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	to be defined; please specify	no specific request (depend on water grid)		same requirements like condensing appliances	
Section 7	**Electric (Grid properties)**						
Section 7.1.01	ELECTRICAL POWER SUPPLY	220/240 V	220/240 V	220/240 V		220/240 V	
Section 7.1.02	TYPE OF ELECTRICAL POWER SUPPLY		1 phase	1 phase		1 phase	
Section 7.1.03	Electrical grid connection - applicable standards	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)			Directive 2006/95/CE (low tension)	2009/142/EG; 2006/95/EG; 2004/108/EG; 92/42/EWG; 2009/125/EG; 2010/30/EU; 97/23/EG	
Section 7.1.04	Nominal grid frequency	e.g. 50 Hz	e.g. 50 Hz	50 Hz		e.g. 50 Hz	
Section 7.1.05	ELECTRICAL PROTECTION RATING	e.g. IP xx	IP X4D			IP X4D	
Section 8	**Gas**						
Section 8.1.01	Natural gas (G25G20)	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	yes	yes		Natural gas (G25G20)	
Section 8.1.02	liquid gas G30/31		yes	no specific request			
Section 8.1.03	sardina gas		to be defined; please specify	no specific request			
Section 8.1.04	others		to be defined; please specify	no specific request			
Section 8.1.05	Conversion set necessary		to be defined; please specify	no specific request			
Section 9	**Flue systems**						
Section 9.1.01	flue categories	B22, flue less system	B23p, B 53b, flue less system	no specific request		B23p, B 53b, flue less system	
Section 9.1.02	measurement points		yes	yes		yes	
Section 10	**Environment (Design for Environment)**						
Section 10.1.02	Emmission output (e.g. CO2, Nox,...)		compliance with ERP directives	NOx max: 70 mg/kWh fuel input in terms of GCV	DErP requirement	compliance with ERP directives	
Section 10.1.03	Acoustics (dB)		45 dB (A) 5 m	Less than EHP (competitive advantage)	DErP requirement : Sound Power level (LwA) ≤75 dB, DAIKIN Altherma : LwA=71 dBA	45 dB (A) 5 m	
Section 10.1.04	Operating temperatures (ambiente)		-15 to 40 °C	-15 to 45°C	In France, 45°C can be achieved in average climate	-15 to 40 °C	
Section 10.1.05	...						
Section 11	**General Service**						
Section 11.1.01	No special tools required for Servicing		as per regular condensing boiler	as per regular condensing boiler		as per regular condensing boiler	
Section 11.1.02	Front access	**e.g.** should be serviceable from front only	only front access	only front access		only front access	
Section 11.1.03	Service Inspection Interval	**e.g.** 12 months	as per regular condensing boiler	as per regular condensing boiler		as per regular condensing boiler	
Section 11.1.04	Special local requirements	e.g. Engine replaceable in field		change of safety valve and thermostat generator (5 years), visual inspection of hermetic circuit (1 year), hydrolic test (15 years)	GAHP is concerned by Pressure Equipement Directive PED (french derogation CTP N°2)		
Section 12	**Certifications, Initiatives, Voluntary & Good Practice**						
Section 12.1.01	Special requirements regarding incentives skeems, etc.			Product must be certified according to NF PAC to not be penalised in RT 2012. Minimal GUE 7°C/42,5°C = 1,30 Hi (42,5°C is the average between inlet and outlet water temperature of the GAHP)	tax credit (15% for air/water EHP if COP > 3,4 (7/35))Eligible to White certificate without specific request	see section 7.1.03	

B. Multi local analysis Germany and Netherlands

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source EON Germany Market info EON	Source EON Germany Comments from the market	Source Bosch Netherlands source BRG consult	Source Bosch Netherlands Comments from the market
Section 1	**General key topics**						
Section 1.1.02	Type of heat pump		Air/Water	air/water; next step should be brine/water		Air/Water	Ground source same size as Air/water
Section 1.1.03	Type of heat supply		Central Heating and DHW	Central heating and DHW		Central Heating and DHW	
Section 1.1.05	Possible integration with new or existing boiler		no	yes		yes	
Section 1.1.07	Domestic hot water production		indirect	indirect with storage tank		indirect	
Section 1.1.08	Typical installation position		on the floor/ground			on the floor/ground	
Section 1.1.09	Combination with buffer tank for space heating		not needed	no		not needed	
Section 1.1.11							
Section 2	**Installation**						
Section 2.1.01	Installation time (heat pump appliance only)	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	same as a condensing boiler	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	
Section 2.1.02	Replacement time (heat pump appliance only)	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	same as a condensing boiler	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	
Section 3	**Dimensions (without packaging)**						
Section 3.1.01	max height		1200 mm	1950 mm		1200 mm	due to outside installation the planned size can be accepted
Section 3.1.02	max length		1000 mm	610 mm		1000 mm	
Section 3.1.03	max depth		500 mm			500 mm	
Section 4	**Design / colour (details of design requirements)**						
Section 4.1.01	Appliance style outside (feature/blended in)		not defined jet				has to be fit with the local house style
Section 5	**Technical Features**						
Section 5.1.01	Seasional Efficiency SPER (including electricity)		30 % better than a condensing boiler	130%		Needed efficiency to reach ErP standard to get subsidies	
Section 5.1.02	(Gas Utilization Efficiency Net Calorific Value)		162 % A 7/W50	162 % A 7/W50		162 % A 7/W50	
Section 5.1.03	max. heating output:		18 kW (A7/W 50	18 kW		6 kW	main market request e.g. 6 kW heat demand at -15°C.
Section 5.1.04	max. heating output:		12 kW (A-7/W 65)	12 kW (A-7/W 65)		6 kW	main market request e.g. 6 kW heat demand at -15°C.
Section 5.1.05	modulation range		1 : 3	1:3 to 1:4		1 : 3	
Section 5.1.06	Max. heating water temp.:		65 °C:	65 °C:		65 °C:	
Section 5.1.07	Max. Temperature for DHW production:		65 °C:	65 °C: (storage temp. 50°C)		65 °C:	
Section 5.1.08	average electrical power consumption:		approx 1% of total output	1% of total output, solution pump should modulate for saving electric consumption		approx 1% of total output	
Section 5.1.09	Operating pressure central heating		3 bar	<=3 bar		3 bar	
Section 5.1.10	Special demands for hot water comfort	e.g. size of the tank, flow rate DHW	to be defined; please specify	120 to 200 l storage tank	e.g. size ot the tank, flow rate DHW	max load capacity of the appliance necessary	
Section 5.1.11	Hydronic kit (pump, 3-way valve, expansion vessel and DHW tank)		indoor	in door		indoor	
Section 5.1.12	Location of connection		Gas, water and electricity on one side	Gas, water and electricity on one side		Gas, water and electricity on one side	
Section 5.1.13	Type of gas connection		15 mm Female 1/2"	1/2"		15 mm Female 1/2"	
Section 5.1.14	Type electrical connection		wiring terminal	wiring terminal, provided for an external control, provided for two heating systems"		wiring terminal	
Section 5.1.15	Type of water connection		22 mm Femal 3/4"	3/4"		22 mm Femal 3/4"	
Section 5.1.16	Weight:		220 kg	195 kg		160 kg	based on EHP with 6 kW output

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source EON Germany Market info EON	Source EON Germany Comments from the market	Source Bosch Netherlands source BRG consult	Source Bosch Netherlands Comments from the market
Section 6	**water quality request**						
Section 6.1.01	Anti-legionella method implemented	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	to be defined; please specify	no	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	same as condensing appliance
Section 6.1.02	Anti freeze		active protection, anti freeze protection in the heat pump	active protection, anti freeze protection in the heat pump		active protection, anti freeze protection in the heat pump	
Section 6.1.03	Robustness of appliances against installed system		cleaning of water hydraulic system at installation	yes		cleaning of water hydraulic system at installation	
Section 6.1.04	Corrosion prevention: planty corrosion inhibitors can be accepted		yes	cleaning of water hydraulic system at installation			
Section 6.1.05	Definition of water quality	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	to be defined; please specify	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	same as condensing appliances	
Section 7	**Electric (Grid properties)**						
Section 7.1.01	ELECTRICAL POWER SUPPLY	220/240 V	220/240 V	220/240 V	220/240 V	220/240 V	
Section 7.1.02	TYPE OF ELECTRICAL POWER SUPPLY		1 phase	1 phase		1 phase	
Section 7.1.03	Electrical grid connection - applicable standards	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)		e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)	2009/142/EG; 2006/95/EG; 2004/108/EG; 92/42/EWG; 2009/125/EG; 2010/30/EU; 97/23/EG	
Section 7.1.04	Nominal grid frequency	e.g. 50 Hz	e.g. 50 Hz	e.g. 50 Hz	e.g. 50 Hz	e.g. 50 Hz	
Section 7.1.05	ELECTRICAL PROTECTION RATING	e.g. IP xx	IP X4D	IPX 4D	e.g. IP xx	IP X4D	
Section 8	**Gas**						
Section 8.1.01	Natural gas (G25G20)	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	yes	Second Family-Natural Gas (NG) A natural gas will be used according to DVGW G260(A) Januar 2012 & G280. Combustion control system recommended	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	Natural gas (G25G20)	
Section 8.1.02	liquid gas G30/31		yes			liquid gas G30/31	
Section 8.1.03	sardina gas		to be defined; please specify				
Section 8.1.04	others		to be defined; please specify				
Section 8.1.05	Conversion set necessary		to be defined; please specify	not necessary in case of combustion control		Conversion set necessary	
Section 9	**Flue systems**						
Section 9.1.01	flue categories	B22, flue less system	B23p, B 53b, flue less system		B22, flue less system	B23p, B 53b, flue less system	due to outside installation planned definition can be accepted
Section 9.1.02	measurement points		yes	yes			
Section 10	**Environment (Design for Environment)**						
Section 10.1.02	Emmission output (e.g. CO2, Nox,...)		compliance with ERP directives	NO_x < 60 mg/kWh, CO < 50 mg/kWh (rev. to usefull energy)		compliance with ERP directives	
Section 10.1.03	Acoustics (dB)		45 dB (A) 5 m	55 dB (A)		45 dB (A) 5 m	
Section 10.1.04	Operating temperatures (ambiente)		-15 to 40 °C			-15 to 40 °C	
Section 10.1.05	...						
Section 11	**General Service**						
Section 11.1.01	No special tools required for Servicing		as per regular condensing boiler	as per regular condensing boiler		as per regular condensing boiler	
Section 11.1.02	Front access	**e.g.** should be serviceable from front only	only front access	only front access	**e.g.** should be serviceable from front only	only front access	
Section 11.1.03	Service Inspection Interval	**e.g.** 12 months	as per regular condensing boiler	like condensing boiler	**e.g.** 12 months	as per regular condensing boiler	
Section 11.1.04	Special local requirements	e.g. Engine replaceable in field			e.g. Engine replaceable in field		
Section 12	**Certifications, Initiatives, Voluntary & Good Practice**						
Section 12.1.01	Special requirements regarding incentives skeems, etc.					HR107, HRWW and electricity usage declaration	

C. Multi local analysis Belgium and Denmark

				Source GDF suez		Source Robur	
Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Belgium		Denmark	
				Market info GDF suez	Comments from the market	Market info Robur	Comments from the market
Section 1	**General key topics**						
Section 1.1.02	Type of heat pump		Air/Water	Air/water		Air/Water is fine	
Section 1.1.03	Type of heat supply		Central Heating and DHW	Central heating and DHW	DHW as option	Central Heating and DHW	
Section 1.1.05	Possible integration with new or existing boiler		no	yes	preference for condensation installation with back up burner included in the GHP	This would be a clear advantage	
Section 1.1.07	Domestic hot water production		indirect	indirect	storage tank fed by the GHP	DHW is mandatory / with water tank	
Section 1.1.08	Typical installation position		on the floor/ground		on the ground (because of th weight)	Floor standing (given the weight…)	
Section 1.1.09	Combination with buffer tank for space heating		not needed		no buffer tank for heating (additional losses, space problems)	not needed	
Section 1.1.11							
Section 2	**Installation**						
Section 2.1.01	Installation time (heat pump appliance only)	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	no specific request		no answer	
Section 2.1.02	Replacement time (heat pump appliance only)	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	no specific request		no answer	
Section 3	**Dimensions (without packaging)**						
Section 3.1.01	max height		1200 mm	the dimensions should allow to pass through a door of standard dimension		best, would be similar to CH boilers	
Section 3.1.02	max length		1000 mm			or can be a bit larger as it	
Section 3.1.03	max depth		500 mm			is installed outdoor	
Section 4	**Design / colour (details of design requirements)**						
Section 4.1.01	Appliance style outside (feature/blended in)		not defined jet	as less visible as possible		Not a must, but why not	
Section 5	**Technical Features**						
Section 5.1.01	Seasional Efficiency SPER (including electricity)		30 % better than a condensing boiler	if possible > 125%		No requirement, but payback time should be < 3 to 5 years	
Section 5.1.02	(Gas Utilization Efficiency Net Calorific Value)		162 % A 7/W50			no answer	
Section 5.1.03	max. heating output:		18 kW (A7/W 50	k. A.		To respect the DK standard you need at least ca 35 kW for DHW, 18kW is OK with a storage tank	
Section 5.1.04	max. heating output:		12 kW (A-7/W 65)		a peak demand of about 20 kW should be covered by the system, ideally with the back up burner, and a heat pump power of 12 kW (A-7/W65) is enough in a bivalent mode	see above	
Section 5.1.05	modulation range		1 : 3	1:4 to 1:3 (Heat pump)	Pay attention for the control system in intermittent mode	1:3 is OK to us	
Section 5.1.06	Max. heating water temp.:		65 °C:	65°C		65 C is OK	
Section 5.1.07	Max. Temperature for DHW production:		65 °C:	60°C		65 C is OK	
Section 5.1.08	average electrical power consumption:		approx 1% of total output	as low as possible		This shall be taken into account in the pay back time calculation. Boilers on the market have typically 200-500 kWh year el. consumption.	
Section 5.1.09	Operating pressure central heating		3 bar	min 2 bar		3 bars in DK	
Section 5.1.10	Special demands for hot water comfort	e.g. size of the tank, flow rate DHW	to be defined; please specify	storage tank of 200 … 300 l; flow rate at least 16l/min		Typical tanks in DK are 50 to 150 l	
Section 5.1.11	Hydronic kit (pump, 3-way valve, expansion vessel and DHW tank)		indoor	indoor		The kit shall be included for the DK situation. Hydraulic kit shall be assembled (labour cost is high in DK, so the less to assemble at installation, the better)	
Section 5.1.12	Location of connection		Gas, water and electricity on one side			WP1 proposed values OK to us	
Section 5.1.13	Type of gas connection		15 mm Female 1/2"			WP1 proposed values OK to us	
Section 5.1.14	Type electrical connection		wiring terminal			WP1 proposed values OK to us	
Section 5.1.15	Type of water connection		22 mm Femal 3/4"			WP1 proposed values OK to us	
Section 5.1.16	Weight:		220 kg	as low as possible		WP1 proposed values OK to us	

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source GDF suez Belgium Market info GDF suez	Source GDF suez Belgium Comments from the market	Source Robur Denmark Market info Robur	Source Robur Denmark Comments from the market
Section 6	**water quality request**						
Section 6.1.01	Anti-legionella method implemented	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	to be defined; please specify	no specific request		In DK, 65 C is used and accepted as suffissant for legionella. Temperature higher than 65 C will generate lime deposit issues in the some areas in our country where the lime concentrate is high.	
Section 6.1.02	Anti freeze		active protection, anti freeze protection in the heat pump	anti freeze protection solutions like tracing, pumps on; look for short outside hydraulic connections.		Needed	
Section 6.1.03	Robustness of appliances against installed system		cleaning of water hydraulic system at installation			no answer	
Section 6.1.04	Corrosion prevention: planty corrosion inhibitors can be accepted		yes			No requirements	
Section 6.1.05	Definition of water quality	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	to be defined; please specify	compatible with existing hot water installations		no answer	
Section 7	**Electric (Grid properties)**						
Section 7.1.01	ELECTRICAL POWER SUPPLY	220/240 V	220/240 V	240V		WP1 proposed values OK to us	
Section 7.1.02	TYPE OF ELECTRICAL POWER SUPPLY		1 phase	1 phase		WP1 proposed values OK to us	
Section 7.1.03	Electrical grid connection - applicable standards	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)				Low voltage directive requirements are to be respected (those are implemented in our national legislation)	
Section 7.1.04	Nominal grid frequency	e.g. 50 Hz	e.g. 50 Hz	50 Hz		WP1 proposed values OK to us	
Section 7.1.05	ELECTRICAL PROTECTION RATING	e.g. IP xx	IP X4D			IP 65 (outdoor)	
Section 8	**Gas**						
Section 8.1.01	Natural gas (G25G20)	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	yes	yes		EN 437 shall apply for all countries independantly of the gas distributed	
Section 8.1.02	liquid gas G30/31		yes	no specific request		EN 437 shall apply for all countries independantly of the gas distributed	
Section 8.1.03	sardina gas		to be defined; please specify	no specific request			
Section 8.1.04	others		to be defined; please specify	no specific request			
Section 8.1.05	Conversion set necessary		to be defined; please specify	no specific request		Injector + regulator	
Section 9	**Flue systems**						
Section 9.1.01	flue categories	B22, flue less system	B23p, B 53b, flue less system			No flue requirement if the appliance is installed outdoor (but installtion shall be done according the requirements (distance to windows etc...)	
Section 9.1.02	measurement points		yes			Needed for flue gas analysis & temp	
Section 10	**Environment (Design for Environment)**						
Section 10.1.02	Emmission output (e.g. CO2, Nox,...)		compliance with ERP directives	*compliance with directives implementation*		We have no specific requirements in DK but GAD for CO & ECO desugn for Nox has to be respected	
Section 10.1.03	Acoustics (dB)		45 dB (A) 5 m	compliance with directives implementation		35 dbA measured at the limit with the next house/building/ property	
Section 10.1.04	Operating temperatures (ambiente)		-15 to 40 °C	-15 to 40°C		-15 to 40 is OK, but T is few times a year < -15	
Section 10.1.05	...						
Section 11	**General Service**						
Section 11.1.01	No special tools required for Servicing		as per regular condensing boiler	as per regular condensing boiler		OK with similar to condensing boiler	
Section 11.1.02	Front access	**e.g.** should be serviceable from front only	only front access	easy access		only front access OK as long the access is easy	
Section 11.1.03	Service Inspection Interval	**e.g.** 12 months	as per regular condensing boiler	as per regular condensing boiler (24 months)		In DK the inspection frequency for cond boilers is defined by the manufacturer. Too frequent inspections should should be avoided for	
Section 11.1.04	Special local requirements	e.g. Engine replaceable in field					
Section 12	**Certifications, Initiatives, Voluntary & Good Practice**						
Section 12.1.01	Special requirements regarding incentives skeems, etc.				Uncertainty: incentives schemes can be federal and regional (3 regions), and they change at least once a year	Has to do you payback time. Incentives were used for condensing boilers. This is not likely to happen before the technology has more visibility and adavantages demonstrated	

D. Multi local analysis Poland and Swiss

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source Robur		Source Bosch	
				Poland		Switzerland	
				Market info Robur	Comments from the market	source BRG consult	Comments from the market
Section 1	**General key topics**						
Section 1.1.02	Type of heat pump		Air/Water	Air/Water; Boreholes/water		X	Air/Water and Ground source same level
Section 1.1.03	Type of heat supply		Central Heating and DHW	Central heating and DHW		X	
Section 1.1.05	Possible integration with new or existing boiler		no	yes (small boiler to support heat pump)		yes	due to replacement market
Section 1.1.07	Domestic hot water production		indirect	yes, by the heat exchanger and coil in DHW tank		indirect	
Section 1.1.08	Typical installation position		on the floor/ground	floor/ground, roof, balcony		on the floor/ground	
Section 1.1.09	Combination with buffer tank for space heating		not needed	needed (space heating with small volume and low accumulation are more and more popular) - combination I		not needed	
Section 1.1.11							
Section 2	**Installation**						
Section 2.1.01	Installation time (heat pump appliance only)	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	similar like outdoor boiler (we need to dig, install pipes in the ground etc.). Similar to standard boiler wont be possible.		same as a condensing boiler	
Section 2.1.02	Replacement time (heat pump appliance only)	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	similar like outdoor boiler		same as a condensing boiler	
Section 3	**Dimensions (without packaging)**						
Section 3.1.01	max height		1200 mm	no answer		1200 mm	due to outside installation the planned size can be accepted
Section 3.1.02	max length		1000 mm	no answer		1000 mm	
Section 3.1.03	max depth		500 mm	no answer		500 mm	
Section 4	**Design / colour (details of design requirements)**						
Section 4.1.01	Appliance style outside (feature/blended in)		not defined jet	visible to make people notice the unit and ask about it			has to be fit with the local house style
Section 5	**Technical Features**						
Section 5.1.01	Seasional Efficiency SPER (including electricity)		30 % better than a condensing boiler	more than 30%		Needed efficiency to reach ErP standard to get subsidies	
Section 5.1.02	(Gas Utilization Efficiency Net Calorific Value)		162 % A 7/W50	162 % A 7/W50		162 % A 7/W50	
Section 5.1.03	max. heating output:		18 kW (A7/W 50	18 kW (A7/W 50		15 kW	main market request e.g. 15 kW heat demand at -15°C.
Section 5.1.04	max. heating output:		12 kW (A-7/W 65)	12 kW (A-7/W 65)		15 kW	main market request e.g. 15 kW heat demand at -15°C.
Section 5.1.05	modulation range		1 : 3	min power 25 % of max (4 kW in minimum) (in this case we can consider to avoid buffer tank duty)		1 : 3	
Section 5.1.06	Max. heating water temp.:		65 °C:	65 °C:		65 °C:	
Section 5.1.07	Max. Temperature for DHW production:		65 °C:	55 °C (check below for legionella)		65 °C:	
Section 5.1.08	average electrical power consumption:		approx 1% of total output	no answer		approx 1% of total output	
Section 5.1.09	Operating pressure central heating		3 bar	3 bar (4,5 bar to test installation during start up)		3 bar	
Section 5.1.10	Special demands for hot water comfort	e.g. size of the tank, flow rate DHW	to be defined; please specify	40-80 lt/person/day		max load capacity of the appliance necessary	
Section 5.1.11	Hydronic kit (pump, 3-way valve, expansion vessel and DHW tank)		indoor	important is that control system will control all elements of installation		indoor	
Section 5.1.12	Location of connection		Gas, water and electricity on one side	no answer		Gas, water and electricity on one side	
Section 5.1.13	Type of gas connection		15 mm Female 1/2"	no answer		15 mm Female 1/2"	
Section 5.1.14	Type electrical connection		wiring terminal	no answer		wiring terminal	
Section 5.1.15	Type of water connection		22 mm Femal 3/4"	no answer		22 mm Femal 3/4"	
Section 5.1.16	Weight:		220 kg	no answer		200 kg	

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source Robur Poland		Source Bosch Switzerland	
				Market info Robur	Comments from the market	source BRG consult	Comments from the market
Section 6	**water quality request**						
Section 6.1.01	Anti-legionella method implemented	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	to be defined; please specify	once a week we need to get 70°C inside DHW tank. Considering vector fluid temperature we will have temperature losses on heat exchaner (glycol/water) and on the coil in the tank. Max 80°C of vector fluid will be enough.		same as condensing appliance	
Section 6.1.02	Anti freeze		active protection, anti freeze protection in the heat pump	#######################		active protection, anti freeze protection in the heat pump	
Section 6.1.03	Robustness of appliances against installed system		cleaning of water hydraulic system at installation	Flushing recommended		cleaning of water hydraulic system at installation	
Section 6.1.04	Corrosion prevention: planty corrosion inhibitors can be accepted		yes	yes		yes	
Section 6.1.05	Definition of water quality	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	to be defined; please specify	PN-93_C-04607		same as condensing appliances	
Section 7	**Electric (Grid properties)**						
Section 7.1.01	ELECTRICAL POWER SUPPLY	220/240 V	220/240 V	230 V - 50 hz		220/240 V	
Section 7.1.02	TYPE OF ELECTRICAL POWER SUPPLY		1 phase	1 phase		1 phase	
Section 7.1.03	Electrical grid connection - applicable standards	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)				2009/142/EG; 2006/95/EG; 2004/108/EG; 92/42/EWG; 2009/125/EG; 2010/30/EU; 97/23/EG	
Section 7.1.04	Nominal grid frequency	e.g. 50 Hz	e.g. 50 Hz	50 Hz		e.g. 50 Hz	
Section 7.1.05	ELECTRICAL PROTECTION RATING	e.g. IP xx	IP X4D	IP 66 (external use)		IP X4D	
Section 8	**Gas**						
Section 8.1.01	Natural gas (G25G20)	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	yes	G20 (E) - GZ50 - most common; Rare: Lw-G27 (GZ-41,5), Ls-G2.350 (GZ-35)		Natural gas (G25G20)	
Section 8.1.02	liquid gas G30/31		yes	yes		liquid gas G30/31	
Section 8.1.03	sardina gas		to be defined; please specify				
Section 8.1.04	others		to be defined; please specify	consider bio-gas			
Section 8.1.05	Conversion set necessary		to be defined; please specify				
Section 9	**Flue systems**						
Section 9.1.01	flue categories	B22, flue less system	B23p, B 53b, flue less system	no answer		B23p, B 53b, flue less system	due to outside installation planned definition can be accepted
Section 9.1.02	measurement points		yes	yes		yes	
Section 10	**Environment (Design for Environment)**						
Section 10.1.02	Emmission output (e.g. CO2, Nox,...)		compliance with ERP directives	*no answer*		compliance with ERP directives	
Section 10.1.03	Acoustics (dB)		45 dB (A) 5 m	as low as possible - we can consider possibility to add additional elements reducing noice - for example possibility to conect silencer to the fan.		45 dB (A) 5 m	
Section 10.1.04	Operating temperatures (ambiente)		-15 to 40 °C	-30 C (-35 C) to + 45 C		-25 to 40°C	
Section 10.1.05	...						
Section 11	**General Service**						
Section 11.1.01	No special tools required for Servicing		as per regular condensing boiler	as per regular condensing boiler		as per regular condensing boiler	
Section 11.1.02	Front access	**e.g.** should be serviceable from front only	only front access	Front acess the best - using front access there should be possible to change most of "consumable" parts like control box, blower, electrodes etc.		only front access	
Section 11.1.03	Service Inspection Interval	**e.g.** 12 months	as per regular condensing boiler	every year		as per regular condensing boiler	
Section 11.1.04	Special local requirements	e.g. Engine replaceable in field					
Section 12	**Certifications, Initiatives, Voluntary & Good Practice**						
Section 12.1.01	Special requirements regarding incentives skeems, etc.					see section 7.1.03	

E. Multi local analysis Austria and Italy

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source Bosch		Source Robur	
				Austria		Italy	
				source BRG consult	Comments from the market	Market info Robur	Comments from the market
Section 1	**General key topics**						
Section 1.1.02	Type of heat pump		Air/Water	X	main market ground source, figures based on air/water	Air/Water	
Section 1.1.03	Type of heat supply		Central Heating and DHW	X		Central Heating and DHW	
Section 1.1.05	Possible integration with new or existing boiler		no	yes	due to replacement market	yes	
Section 1.1.07	Domestic hot water production		indirect	indirect		indirect	
Section 1.1.08	Typical installation position		on the floor/ground	on the floor/ground		on the floor/ground	
Section 1.1.09	Combination with buffer tank for space heating		not needed	not needed		not needed	
Section 1.1.11							
Section 2	**Installation**						
Section 2.1.01	Installation time (heat pump appliance only)	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	same as a condensing boiler		1 day	
Section 2.1.02	Replacement time (heat pump appliance only)	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	same as a condensing boiler		1 day	
Section 3	**Dimensions (without packaging)**						
Section 3.1.01	max height		1200 mm	1200 mm	due to outside installation the planned size can be accepted	1200 mm	
Section 3.1.02	max length		1000 mm	1000 mm		1000 mm	
Section 3.1.03	max depth		500 mm	500 mm		500 mm	
Section 4	**Design / colour (details of design requirements)**						
Section 4.1.01	Appliance style outside (feature/blended in)		not defined jet		has to be fit with the local house style	blended	
Section 5	**Technical Features**						
Section 5.1.01	Seasional Efficiency SPER (including electricity)		30 % better than a condensing boiler	Needed efficiency to reach ErP standard to get subsidies		30 % better than a condensing boiler	
Section 5.1.02	(Gas Utilization Efficiency Net Calorific Value)		162 % A 7/W50	162 % A 7/W50		162 % (A7/W50)	
Section 5.1.03	max. heating output:		18 kW (A7/W 50	15 kW	main market request e.g. 15 kW heat demand at -15°C.	18 kW (A7/W 50)	
Section 5.1.04	max. heating output:		12 kW (A-7/W 65)	15 kW	main market request e.g. 15 kW heat demand at -15°C.	12 kW (A-7/W 65)	
Section 5.1.05	modulation range		1 : 3	1 : 3		1 : 3	
Section 5.1.06	Max. heating water temp.:		65 °C:	65 °C:		65 °C:	
Section 5.1.07	Max. Temperature for DHW production:		65 °C:	65 °C:		65 °C:	
Section 5.1.08	average electrical power consumption:		approx 1% of total output	approx 1% of total output		approx 1% of total output	
Section 5.1.09	Operating pressure central heating		3 bar	3 bar		3 bar	
Section 5.1.10	Special demands for hot water comfort	e.g. size of the tank, flow rate DHW	to be defined; please specify	max load capacity of the appliance necessary		- 300 lt/day - peak consumption 15 lt/min * 10 min	
Section 5.1.11	Hydronic kit (pump, 3-way valve, expansion vessel and DHW tank)		indoor	indoor		indoor	
Section 5.1.12	Location of connection		Gas, water and electricity on one side	Gas, water and electricity on one side		gas, water and electricity on one side	
Section 5.1.13	Type of gas connection		15 mm Female 1/2"	15 mm Female 1/2"		15 mm Female 1/2"	
Section 5.1.14	Type electrical connection		wiring terminal	wiring terminal		wiring terminal	
Section 5.1.15	Type of water connection		22 mm Femal 3/4"	22 mm Femal 3/4"		22 mm Female 3/4"	
Section 5.1.16	Weight:		220 kg	200 kg		220 kg	

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source Bosch Austria source BRG consult	Source Bosch Austria Comments from the market	Source Robur Italy Market info Robur	Source Robur Italy Comments from the market
Section 6	**water quality request**						
Section 6.1.01	Anti-legionella method implemented	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	to be defined; please specify	same as condensing appliance		>60 °C in the buffer for min 1 hour, once a week	
Section 6.1.02	Anti freeze		active protection, anti freeze protection in the heat pump	active protection, anti freeze protection in the heat pump		- sealed circuit designed to resist to freezing - active anti freeze protection - electric tracing of condensation discharge	
Section 6.1.03	Robustness of appliances against installed system		cleaning of water hydraulic system at installation	cleaning of water hydraulic system at installation		- cleaning of existing plants reccomended at commissioning - filter inside the Hydrayulic kit	
Section 6.1.04	Corrosion prevention: planty corrosion inhibitors can be accepted		yes	yes		yes	
Section 6.1.05	Definition of water quality	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	to be defined; please specify	same as condensing appliances		UNI CTI 8065 and UNI 9182	
Section 7	**Electric (Grid properties)**						
Section 7.1.01	ELECTRICAL POWER SUPPLY	220/240 V	220/240 V	220/240 V		220/240 V	
Section 7.1.02	TYPE OF ELECTRICAL POWER SUPPLY		1 phase	1 phase		1 phase	
Section 7.1.03	Electrical grid connection - applicable standards	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)		2009/142/EG; 2006/95/EG; 2004/108/EG; 92/42/EWG; 2009/125/EG; 2010/30/EU; 97/23/EG			
Section 7.1.04	Nominal grid frequency	e.g. 50 Hz	e.g. 50 Hz	e.g. 50 Hz		50 Hz	
Section 7.1.05	ELECTRICAL PROTECTION RATING	e.g. IP xx	IP X4D	IP X4D		IP X5D	
Section 8	**Gas**						
Section 8.1.01	Natural gas (G25G20)	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	yes	Natural gas (G25G20)		G20	
Section 8.1.02	liquid gas G30/31		yes	liquid gas G30/31		G30, G31	
Section 8.1.03	sardina gas		to be defined; please specify			yes (with gas change kit)	
Section 8.1.04	others		to be defined; please specify			biogas (only a percentage)	
Section 8.1.05	Conversion set necessary		to be defined; please specify			yes	
Section 9	**Flue systems**						
Section 9.1.01	flue categories	B22, flue less system	B23p, B 53b, flue less system	B23p, B 53b, flue less system	due to outside installation planned definition can be accepted	Sealed comb. chamber; air non-ductable	
Section 9.1.02	measurement points		yes			yes	
Section 10	**Environment (Design for Environment)**						
Section 10.1.02	Emmission output (e.g. CO2, Nox,...)		compliance with ERP directives	compliance with ERP directives		CE (as per Boiler)	
Section 10.1.03	Acoustics (dB)		45 dB (A) 5 m	45 dB (A) 5 m		45 dB (A) 5 m	
Section 10.1.04	Operating temperatures (ambiente)		-15 to 40 °C	-25 to 40°C		-15 to 40 °C	
Section 10.1.05	...						
Section 11	**General Service**						
Section 11.1.01	No special tools required for Servicing		as per regular condensing boiler	as per regular condensing boiler		as per regular condensing boiler	
Section 11.1.02	Front access	**e.g.** should be serviceable from front only	only front access	only front access		only front access	
Section 11.1.03	Service Inspection Interval	**e.g.** 12 months	as per regular condensing boiler	as per regular condensing boiler		as per regular condensing boiler	
Section 11.1.04	Special local requirements	e.g. Engine replaceable in field					
Section 12	**Certifications, Initiatives, Voluntary & Good Practice**						
Section 12.1.01	Special requirements regarding incentives skeems, etc.			see section 7.1.03			

F. Multi local analysis Spain

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source Bosch Spain source BRG consult	Comments from the market
Section 1	**General key topics**				
Section 1.1.02	Type of heat pump		Air/Water	X	main market air/water
Section 1.1.03	Type of heat supply		Central Heating and DHW	X	
Section 1.1.05	Possible integration with new or existing boiler		no	yes	due to replacement market
Section 1.1.07	Domestic hot water production		indirect	indirect	
Section 1.1.08	Typical installation position		on the floor/ground	on the floor/ground	
Section 1.1.09	Combination with buffer tank for space heating		not needed	not needed	
Section 1.1.11					
Section 2	**Installation**				
Section 2.1.01	Installation time (heat pump appliance only)	e.g. new houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	same as a condensing boiler	
Section 2.1.02	Replacement time (heat pump appliance only)	e.g. existing houses - max. 1 hours for 2 installers (appliance) - system installation	same as a condensing boiler	same as a condensing boiler	
Section 3	**Dimensions (without packaging)**				
Section 3.1.01	max height		1200 mm	1200 mm	due to outside installation the planned size can be accepted
Section 3.1.02	max length		1000 mm	1000 mm	
Section 3.1.03	max depth		500 mm	500 mm	
Section 4	**Design / colour (details of design requirements)**				
Section 4.1.01	Appliance style outside (feature/blended in)		not defined jet		has to be fit with the local house style
Section 5	**Technical Features**				
Section 5.1.01	Seasional Efficiency SPER (including electricity)		30 % better than a condensing boiler	Needed efficiency to reach ErP standard to get subsidies	
Section 5.1.02	(Gas Utilization Efficiency Net Calorific Value)		162 % A 7/W50	162 % A 7/W50	
Section 5.1.03	max. heating output:		18 kW (A7/W 50	15 kW	main market request e.g. 15 kW heat demand at -15°C.
Section 5.1.04	max. heating output:		12 kW (A-7/W 65)	15 kW	main market request e.g. 15 kW heat demand at -15°C.
Section 5.1.05	modulation range		1 : 3	1 : 3	
Section 5.1.06	Max. heating water temp.:		65 °C:	65 °C:	
Section 5.1.07	Max. Temperature for DHW production:		65 °C:	65 °C:	
Section 5.1.08	average electrical power consumption:		approx 1% of total output	approx 1% of total output	
Section 5.1.09	Operating pressure central heating		3 bar	3 bar	
Section 5.1.10	Special demands for hot water comfort	e.g. size of the tank, flow rate DHW	to be defined; please specify	max load capacity of the appliance necessary	
Section 5.1.11	Hydronic kit (pump, 3-way valve, expansion vessel and DHW tank)		indoor	indoor	
Section 5.1.12	Location of connection		Gas, water and electricity on one side	Gas, water and electricity on one side	
Section 5.1.13	Type of gas connection		15 mm Female 1/2"	15 mm Female 1/2"	
Section 5.1.14	Type electrical connection		wiring terminal	wiring terminal	
Section 5.1.15	Type of water connection		22 mm Femal 3/4"	22 mm Femal 3/4"	

Specification ID	Market specification	Remarks	Proposed value Partners WP 1	Source Bosch Spain source BRG consult	Spain Comments from the market
Section 6	**water quality request**				
Section 6.1.01	Anti-legionella method implemented	e.g. once a week (day adjustable) or daily (temperature adjustabele up to 80°C)	to be defined; please specify	same as condensing appliance	
Section 6.1.02	Anti freeze		active protection, anti freeze protection in the heat pump	active protection, anti freeze protection in the heat pump	
Section 6.1.03	Robustness of appliances against installed system		cleaning of water hydraulic system at installation	cleaning of water hydraulic system at installation	
Section 6.1.04	Corrosion prevention: planty corrosion inhibitors can be accepted		yes	yes	
Section 6.1.05	Definition of water quality	e. g. requirements of VDI2035 - possibility to operate with full de-ionised water and full de-salted water (<=10 µS/cm); Scale protection device - see Accessories section	to be defined; please specify	same as condensing appliances	
Section 7	**Electric (Grid properties)**				
Section 7.1.01	ELECTRICAL POWER SUPPLY	220/240 V	220/240 V	220/240 V	
Section 7.1.02	TYPE OF ELECTRICAL POWER SUPPLY		1 phase	1 phase	
Section 7.1.03	Electrical grid connection - applicable standards	e.g. VDE 0100 VDE 0100-551 VDE 0140-1 TAB VDE AR N 4105 EN 60335 (=VDE 0700)		2009/142/EG; 2006/95/EG; 2004/108/EG; 92/42/EWG; 2009/125/EG; 2010/30/EU; 97/23/EG	
Section 7.1.04	Nominal grid frequency	e.g. 50 Hz	e.g. 50 Hz	e.g. 50 Hz	
Section 7.1.05	ELECTRICAL PROTECTION RATING	e.g. IP xx	IP X4D	IP X4D	
Section 8	**Gas**				
Section 8.1.01	Natural gas (G25G20)	Second Family - Natural Gas (NG) A natural gas will be used according to DVGW G260-1 & G280.	yes	Natural gas (G25G20)	
Section 8.1.02	liquid gas G30/31		yes	liquid gas G30/31	
Section 8.1.03	sardina gas		to be defined; please specify		
Section 8.1.04	others		to be defined; please specify		
Section 8.1.05	Conversion set necessary		to be defined; please specify		
Section 9	**Flue systems**				
Section 9.1.01	flue categories	B22, flue less system	B23p, B 53b, flue less system	B23p, B 53b, flue less system	due to outside installation planned definition can be accepted
Section 9.1.02	measurement points		yes	yes	
Section 10	**Environment (Design for Environment)**				
Section 10.1.02	Emmission output (e.g. CO2, Nox,...)		compliance with ERP directives	compliance with ERP directives	
Section 10.1.03	Acoustics (dB)		45 dB (A) 5 m	45 dB (A) 5 m	
Section 10.1.04	Operating temperatures (ambiente)		-15 to 40 °C	-15 to 40 °C	
Section 10.1.05	...				
Section 11	**General Service**				
Section 11.1.01	No special tools required for Servicing		as per regular condensing boiler	as per regular condensing boiler	
Section 11.1.02	Front access	**e.g.** should be serviceable from front only	only front access	only front access	
Section 11.1.03	Service Inspection Interval	**e.g.** 12 months	as per regular condensing boiler	as per regular condensing boiler	
Section 11.1.04	Special local requirements	e.g. Engine replaceable in field			
Section 12	**Certifications, Initiatives, Voluntary & Good Practice**				
Section 12.1.01	Special requirements regarding incentives skeems, etc.			see section 7.1.03	

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