GAS HEAT PUMPS
THE RENEWABLE HEATING SYSTEM FOR THE FUTURE?

Dr. Rolf Albus, Werner Weßing, Dr. Stephan Ramesohl
E.ON Ruhrgas AG, Research and Development
Gladbecker Straße 404, D-45326 Essen, Germany

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Background
Rising energy costs, increasing requirements in terms of home energy efficiency and greater environmental awareness have pushed the demand for heat pumps. Current market analyses confirm that customers no longer consider today's 'basic' heating technology as a viable option for the future. They at least demand equipment solutions which allow the integration of renewable energies in compliance with legal regulations (e.g. solar).

Gas heat pumps display a high energy efficiency and – properly configured – reduce natural gas consumption by up to 30% compared to a condensing boiler (lower operating costs). The increased efficiency comes hand-in-hand with CO₂ reductions and thus also meets climate protection demands. In addition to the technologies already available today, such as the combination of condensing boilers with solar water heating and space heating support, the gas heat pump technology can be expected to assume an important role in building heating in the near future.

The gas industry has teamed up with appliance manufacturers in a joint 'Gas Heat Pump Initiative' to further develop this technology to market maturity through practical laboratory tests and field trials.

Political and regulative framework
Following on from the Kyoto decisions and the requirements specified at European level, Germany has defined concrete targets to reduce carbon emissions in order to protect the climate. The German government has drawn up a catalogue of 29 measures, 14 of which apply to natural gas use (Meseberg resolutions).

The German carbon emission reduction initiative is based on a three-stage approach (base year 1990). The first stage is aimed at a 21% reduction by 2012; the second stage is a 40% reduction until 2020 and the third stage is an 80% reduction until 2050. These targets are to be achieved through improved thermal insulation, higher appliance efficiencies and a greater use of renewables. To this end a number of acts have been adopted.

The 2009 version of the Energy Conservation Ordinance (EnEV), which has just been adopted (March 2009), calls for a further reduction of primary energy use by 30%. This can be achieved by better thermal insulation of the buildings or the use of highly efficient technologies such as heat pumps. Further steps to reduce energy consumption are planned.

The Renewable Energies Heat Act (EEWärmeG) calls for the share of renewables in new buildings to be increased from 6% to 14% by 2020. Existing buildings are governed by local laws of the federal states (e.g. EWärmeG in Baden-Württemberg). Unlike the earlier policies, the present policy calls for heating system solutions that involve the use of renewables. In the case of a gas boiler installation in a new building, for example, the federal legislation specifies 0.04 m² aperture area (collector area certified under the European test mark ‘Solar Keymark’) per square metre floor space. For gas heat pumps, however, the target to be met is an annual coefficient of performance (ACOP) of 1.2. Minimum requirements have also been specified for electrical heat pumps: air source: 3.5 (heating only) and 3.3 (heating + hot water); ground source: 4.0 (heating only) and 3.8 (heating + hot water). The act calls for the installation of energy meters so that the end user can ultimately also monitor the efficiency of the system.

In 1995, the gas industry committed itself to reduce carbon emission by 45 million tonnes of CO₂ by 2012. According to the latest calculations, 43 million tonnes have been achieved so far, which corresponds to a target attainment of 96%. This was predominantly achieved through the use of highly efficient technologies and by getting end users to switch from fuel oil to natural gas.
Financial incentives are important for buyers’ decisions and the government support is needed to avoid discrimination against competing technologies. Incorporating renewable energy sources into the heating process will cut running costs and significantly reduce the burden on the environment in terms of CO₂ emissions. Further steps to cut investment costs (e.g. borehole heat exchanger) are needed. Figure 1 shows countries in which gas heat pump technology is being promoted nationally.

In Germany a market incentive program at federal level is under way and an additional direct support by local utilities. Switzerland, Austria and France also offer direct support by local utilities. The technical associations in Germany (DVGW), Switzerland (SVGW) and Austria (ÖVGW) are working together in setting up rules and standards.

In Germany, the release of commercial products onto the market will occur in 2011. Continued field and additional lab tests are under way, and there is further cooperation with Gas heat pump manufacturers to demonstrate / further increase system efficiencies.

Market development

Initiatives and innovations were the prerequisites for the market entry of natural gas. The spreading and consolidation of natural gas on the market was based, among other factors, on developments of low-pollution burners, energy-efficient low-temperature boilers, and later condensing boilers.

The role of natural gas as a modern and ecologically compatible energy source (“Blue skies over the Ruhr”) was further extended by the emergence of condensing boiler technologies in the 1990s (Fig. 2).

Natural gas was able to displace light fuel oil from its leading position on the heating market. The technical efforts were flanked by corresponding measures addressing the market partners (manufacturers, installation trade, etc.), as well as politics and public relations.

The heating market is the largest sector for the consumption of natural gas. The inherent benefits of the product, in combination with modern, efficient and convenient technologies, have until today raised natural gas to the status of no. 1 energy choice among customers. Since 2005, however, the observed trend has been downward. Especially in association with new buildings, there has been a decline in service connection density from 80 % to less than 60 % (Fig. 3).
reducing heating technology. The gas industry must respond to the customers’ new environmental awareness and increasing demands for autonomous solutions with innovative and modern heating technologies and with renewable energies. Alongside the established condensing boilers with solar solutions, gas heat pumps, in particular, enable suppliers to meet the market’s political demands for highly efficient heating systems in conjunction with a renewable energy source.

**Technological development in the gas sector**

The challenge now facing the German gas industry, together with its appliance manufacturers, is to develop and offer the customer appropriate technical alternatives under the difficult conditions encountered in competition with other energy fuels (to a large extent renewable energies). In addition to the technologies already available today, such as the combination of condensing boilers with solar water heating and space heating support, the gas heat pump technology can be expected to assume an important role in building heating in the near future.

Arguments in favour of the gas heat pump are:

1. Gas heat pumps display a high energy efficiency and – properly configured – reduce natural gas consumption by up to 30 % compared to a condensing boiler (lower operating costs).
2. The increased efficiency comes hand-in-hand with CO₂ reductions and thus also meets climate protection demands.
3. The heat pump technology is able to raise the ambient heat energy to a temperature level suitable for the heating of buildings.
4. Combinations with further renewable energy sources, e.g. solar thermal energy or bio natural gas, promise additional efficiency improvements in conjunction with the gas heat pump technology.

Figure 4 places the development of appliances and the use of bio natural gas on a timeline. From the point of view of E.ON Ruhrgas, the broad market entry of the gas heat pump (from 2011) could be followed very closely by that of micro-cogeneration. The very promising fuel cell is still farthest away from series production. Bio natural gas, on the other hand, is already now being fed into the gas supply network and is thus already contributing to CO₂ reductions.

**Function principle of the heat pump**

Heat pumps can be differentiated according to the following technical principles:

- Compression heat pumps (electric-driven heat pump, gas-driven heat pump)
- Sorption heat pumps (absorption heat pump, adsorption heat pump)

Common to both principles is that an evaporator draws ambient heat energy from a heat source and, after an increase in pressure, subsequently makes a higher temperature level available at the condenser for input into a heating system (heating water and/or warm water). The aggregate state of the refrigerant (liquid/gaseous) is continually changed to effect the heat absorption and transfer.

The decisive difference is to be seen in the manner of compression: Whereas a technologically simple compression heat pump employs a mechanical compressor (driven by an electric motor or combustion engine), a sorption heat pump (gas heat pump) achieves its compression by thermal means. It is here only necessary to provide an electric-driven pump for the solution circuit, the current consumption of which, however, lies far below that of the compressor in an electric-driven heat pump.

Sorption heat pumps, whose applications lie above all in the output range up to 40 kW, are further differentiated into absorption and adsorption heat pumps. In an absorption heat pump, the evaporated refrigerant is absorbed in a liquid solution (e.g. ammonia/water). The function principle is shown in Fig. 5.
The refrigeration branch has already gathered many years of experience with the absorption heat pump technology. One special type of absorption heat pump is the diffusion-absorption heat pump, in which the solution pump is replaced by a bubble pump requiring no electrical drive energy whatsoever. This technology is implemented in the gas heat pump from Bosch Thermotechnik (Fig. 6).

The adsorption technology, by contrast, evaporates water as a refrigerant and in this way takes up ambient heat energy. The water vapour is adsorbed at the surface of a solid (e.g. granulated zeolite). This reaction releases heat at a higher temperature level. Once the zeolite is saturated, the water is expelled in a desorption phase using the heat of a gas burner (Fig. 7). This process runs in a vacuum. Energy is transferred to the heating circuit in the form of heat in both phases.

Whereas absorption functions continuously, the adsorption technology is a cyclic process (adsorption / desorption), though it is not perceived as such due to the response time of the heating circuit. The necessary drive energy for a gas heat pump is introduced via a modulating gas burner. Possible ambient heat sources are the air and the ground, with the integration of ambient heat energy via solar collectors representing a special form.

With a gas heat pump, the proportion of ambient heat is for technological reasons (thermal compressor) less than with an electric heat pump, but the primary energy input lies on a comparable level (Fig. 8).

Consequently, the natural gas solution brings significant system benefits, as the borehole heat exchanger can be made shorter. This translates directly into a reduced drilling depth.

The heat dissipated from the working medium can be used for space heating or for water heating. Against the background of the constantly decreasing heating energy demands of buildings, gas heat pumps, in particular, represent an interesting alternative to the heating systems available today for output ranges up to 10 kW.

Irrespective of the chosen heat pump system, however, appreciable savings can only be achieved if the system is configured optimally, and if important general variables, such as building heating demand, heating
system and ambient heat energy supply, are observed. This requires corresponding coordination between the equipment manufacturers and the installation trade. Only then can the envisaged energy saving actually be attained for the customer in practice. This constitutes a great challenge for all market partners.

Field and laboratory test results with gas heat pumps

Apart from the established electric-driven heat pumps, it has been possible to identify significant progress in the development of gas heat pumps in recent years. Ongoing laboratory tests are investigating different operating principles for gas heat pumps and evaluating the energy-relevant parameters. Parallel field trials with larger numbers of pre-series systems confirm the fundamental reliability and operational stability of the gas heat pumps developed to date. Examples of such results are those obtained in field trials by Bosch Thermotechnik (Fig. 9).

Figure 9 – Results of field trials (without consideration of electrical auxiliary energy)

Taking all systems into account, an efficiency of 1.16 is achieved in heating operation only. If a solar thermal system is integrated, then even this pre-series configuration (absorption heat pump with bubble pump) complies with the threshold value specified in the EEWärmeG legislation (annual performance factor of 1.2).

Further process optimisation to increase utilisation, and at the same time to reduce manufacturing costs, are generally still necessary from the point of view of the end user, and are already being tackled by the manufacturers of gas heat pumps.

The “Gas Heat Pump Initiative” (IGWP)

Recognition of the necessity for concerted cooperation and a targeted application of resources gave birth to the idea of a “Gas Heat Pump Initiative”. After a period of preparation, the initiative was founded in February 2008. The members are utility companies EnBW, E.ON Ruhrgas, ESB, EWE, GASAG, MVV, RWE and VNG and the product interests are represented by the manufacturers Bosch Thermotechnik, Robur, Vaillant and Viessmann.

The bundled know-how of all these member companies is to be exploited to promote the market maturity of the future-oriented technology “gas heat pump” and to establish a new, innovative gas product which gives due consideration to all public demands. The development of corresponding appliances lies in the responsibility of the manufacturers. The comprehensive laboratory tests and field trials are to be organised jointly with the gas supply industry. The four manufacturers will be installing and testing up to 250 gas heat pumps at different locations around Germany by the end of 2010 / beginning of 2011. The first results from the test stands already indicate the enormous potential of the gas heat pump technology.

IGWP partner Robur launched a series gas absorption heat pump for the relatively high output range from 15 to 40 kW at the international fair ISH 2009 in Frankfurt. Test stand results obtained under near-practical conditions raise expectations of both high energy efficiency and reliability.
Generally speaking, it can be assumed that the energy efficiency of a heat pump system diminishes along the range of ambient heat energy sources from borehole heat exchanger / ground collector, via solar collector to air. To accompany the tests, extensive system analyses and optimisation options are to be considered within the framework of the IGWP, aimed above all at improving the heat input and thus the energy efficiency of borehole heat exchangers. On the basis of today’s development status, it is reasonable to reckon with up to a 20 % borehole heat exchanger length reduction.

Fig. 10 provides an overview of the appliances to be tested within the framework of the IGWP.

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<thead>
<tr>
<th>Bosch Thermotechnik</th>
<th>Vaillant</th>
<th>Viessmann</th>
<th>Robur</th>
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<tr>
<td>Output</td>
<td>&lt; 10 kW</td>
<td>&lt; 10 kW</td>
<td>15 – 40 kW</td>
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<td>Status</td>
<td>Lab. testing / field trials</td>
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<td>Market launch E³ at ISH 2009</td>
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Figure 10 – Gas heat pumps to be tested by the IGWP

There is still a good deal of development work, with comprehensive laboratory tests and field trials, awaiting the appliance manufacturers in respect of gas heat pumps for smaller outputs up to 10 kW. The products of two manufacturers, however, have already progressed to the point at which it has been possible to start IGWP field trials. Parallel to the technical advances, market analyses and an IGWP-sponsored marketing campaign are in preparation. Technical seminars and training programmes for the installation trade have also been planned for the short term.

Conclusion

The comprehensive laboratory tests are currently being performed at E.ON Ruhrgas in coordination with the project partners. Some 250 field trial systems will be ready for installation in the next two years and are expected to permit statements on the efficiency and practical suitability of the newly developed gas heat pumps. The first results appear to confirm the great potential of this technology. The marketing of gas absorption heat pumps with outputs up to 40 kW for larger buildings and multi-family housing (new and existing buildings) is already to begin this year. The wider market availability of gas heat pumps for (new) single-family homes should follow from 2011. Given successful future further development of the corresponding products, the gas heat pump technology will be able to complement present gas appliances, in particular condensing boilers, for the heating market in the medium term. In this context, the Gas Heat Pump Initiative is an outstanding platform.