Hybrid heat pumps

– saving energy and reducing carbon emissions

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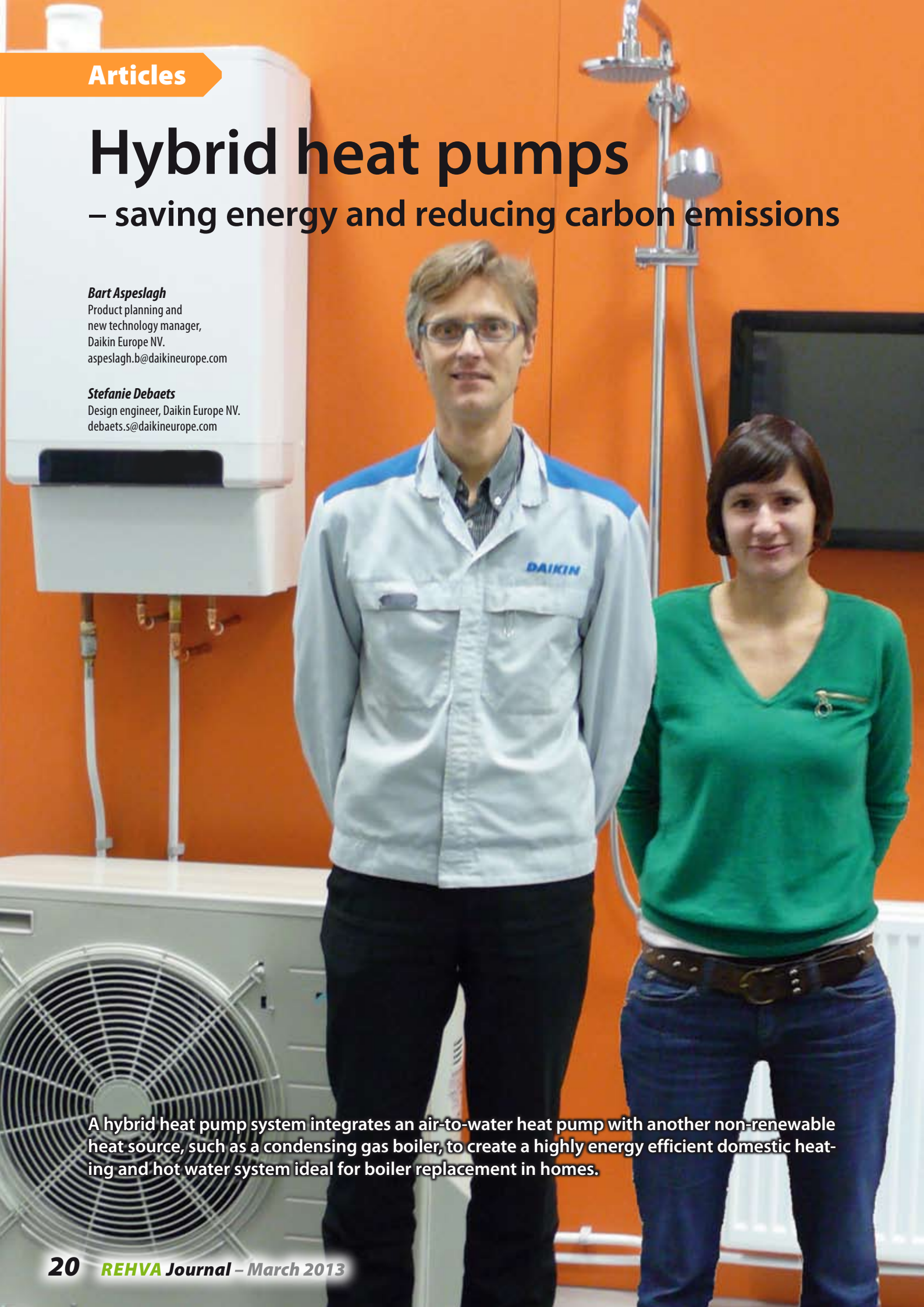


A hybrid heat pump system integrates an air-to-water heat pump with another non-renewable heat source, such as a condensing gas boiler, to create a highly energy efficient domestic heating and hot water system ideal for boiler replacement in homes.

Background

About 40% of all energy consumed in the EU is in the home, of which space heating and hot water production account for 70% of the primary energy use in dwellings. With the majority of the 122 million homes in the EU being heated by combustion of fossil fuels, a heat generating system that could improve domestic energy efficiency significantly has the potential to deliver dramatic reductions in primary energy consumption and CO_2e emissions throughout the EU.

At the same time, a heat generator needs to be affordable for the vast majority of the EU's population, particularly in the face of the continued debt crisis, expected to last for another five years, and the reduction, or even complete cutting, of financial incentive schemes for renewable energy installations.

Additionally, any heat generation needs to be flexible enough to be installed easily in the wide range of house types across the EU, many of which use radiators with water flow temperatures of up to 80°C.

The Daikin Hybrid heat pump

Daikin's Hybrid heat pump meets all of these pre-conditions and has no major limitations because it combines two proven and well-established technologies: a heat pump that uses air as renewable energy source and a condensing gas boiler. A hybrid system can produce water flow temperatures from 25°C up to 80°C, making it suitable for any type of heat emitter, including underfloor heating and radiators.

Thanks to its excellent environmental performance, its suitability for a wide range of house types and its fairly low installation and equipment costs, the hybrid heat pump has the potential to help meet the EU's ambitious environmental 20-20-20 targets of achieving a 20% cut in greenhouse gas emissions compared with 1990 levels; a 20% increase in the share of renewables in the energy mix; and a 20% reduction in energy consumption by 2020 (*EU Directive for Renewable Energy, Directive 2009/28/EC*).

How the Daikin hybrid system operates

The intelligent hybrid heat pump from Daikin measures the outdoor temperature, automatically adjusting the flow temperature to the emitters and calculating the efficiency of the heat pump. The system continuously evaluates whether or not the efficiency of the heat-pump is higher than that of the condensing gas boiler. Based upon this evaluation, the energy source is selected, ensuring the most efficient heat source is being used at any one time. As shown in **Figure 1**, the height of the heating season in Western Europe corresponds to an outdoor temperature of approximately 4°C.

Daikin has developed a unique and patented algorithm which reduces energy consumed by the boiler because water is pre-heated by the more efficient heat pump. This intelligent interaction between the two systems is the difference between a true hybrid system and a bivalent system. This hybrid operation mode increases energy efficiency by approximately 10%, compared with a condensing gas boiler, at outdoor temperatures from –2°C to 3°C.

There are three operating conditions (see **Figure 1**):

- **Heat pump only:** For about 60% of the year, when outdoor temperatures are "mild", the heat pump will supply energy for space heating. The primary energy based efficiency in this mode is about 1.5.
- **Hybrid operation:** For about 20% of the year, when outdoor temperatures are between –2°C and 3°C, the heat pump and condensing gas boiler work together to provide energy for space heating. The system efficiency is about 1.0 in this mode.
- **Boiler only:** When outdoor temperatures are below –2°C (for about 20% of the year) the condensing gas boiler provides the energy for space heating.

Across the year, the overall weighted primary energy efficiency is between 1.2 and 1.5, which is 30 to 60% higher compared with the best gas condensing boiler on the market –currently considered as the best available technology for replacing traditional heating systems in refurbishment projects.

The above scenario is valid for a typical house in Western Europe equipped with radiators and water flow temperatures of 60–70°C. Obviously, efficiency will increase if water flow to the emitters is at lower temperatures. This means that, as insulation of building envelopes becomes ever-more effective, lower water flow temperatures will be sufficient to heat homes, making hybrid heat pumps even more suitable.

Domestic hot water production

Domestic hot water is produced by the condensing gas boiler. However, it is possible to pre-heat the hot water using the heat-pump (see **Figure 2**). In such cases,

a storage tank is required. The system can also be used in combination with solar thermal panels for hot water production.

The condensing gas boiler in Daikin's hybrid system has a unique 'dual pass heat exchanger' which allows direct heating of hot water through gas combustion. As a consequence, flue gas is condensed not only through space heating but also through hot water production. This increases efficiency in hot water production up to 20%, compared with a conventional condensing gas boiler.

Energy efficiency

The hybrid system delivers high levels of energy efficiency in space heating because it uses the most efficient air-to-water inverter driven heat pump on the market (COP of 5.04, at water temperature 35°C, delta-T of 5K and outdoor temperature of 7°C), combined with Daikin's patented Hybrid operation mode.

In domestic hot water production, high efficiency is achieved through the unique dual pass heat exchanger which enables condensation of the flue gases. Ultimately, this efficiency can be enhanced further by heat pump pre-heating and use of solar thermal panels.

Environmental performance

Daikin's Hybrid system achieves excellent environmental performance because of its highly efficient operation.

Primary energy efficiency is between 1.2 and 1.5, compared with real-life performance of approximately 0.9 for a gas condensing boiler. However, the CO_2e emission-savings are highly dependent on the country where the hybrid system is being used, relating directly to the country's energy mix used for electricity production. For example, a house in London consuming 18 000 kWh for space heating annually would produce CO_2e emissions savings of 1.5 tonnes/year.

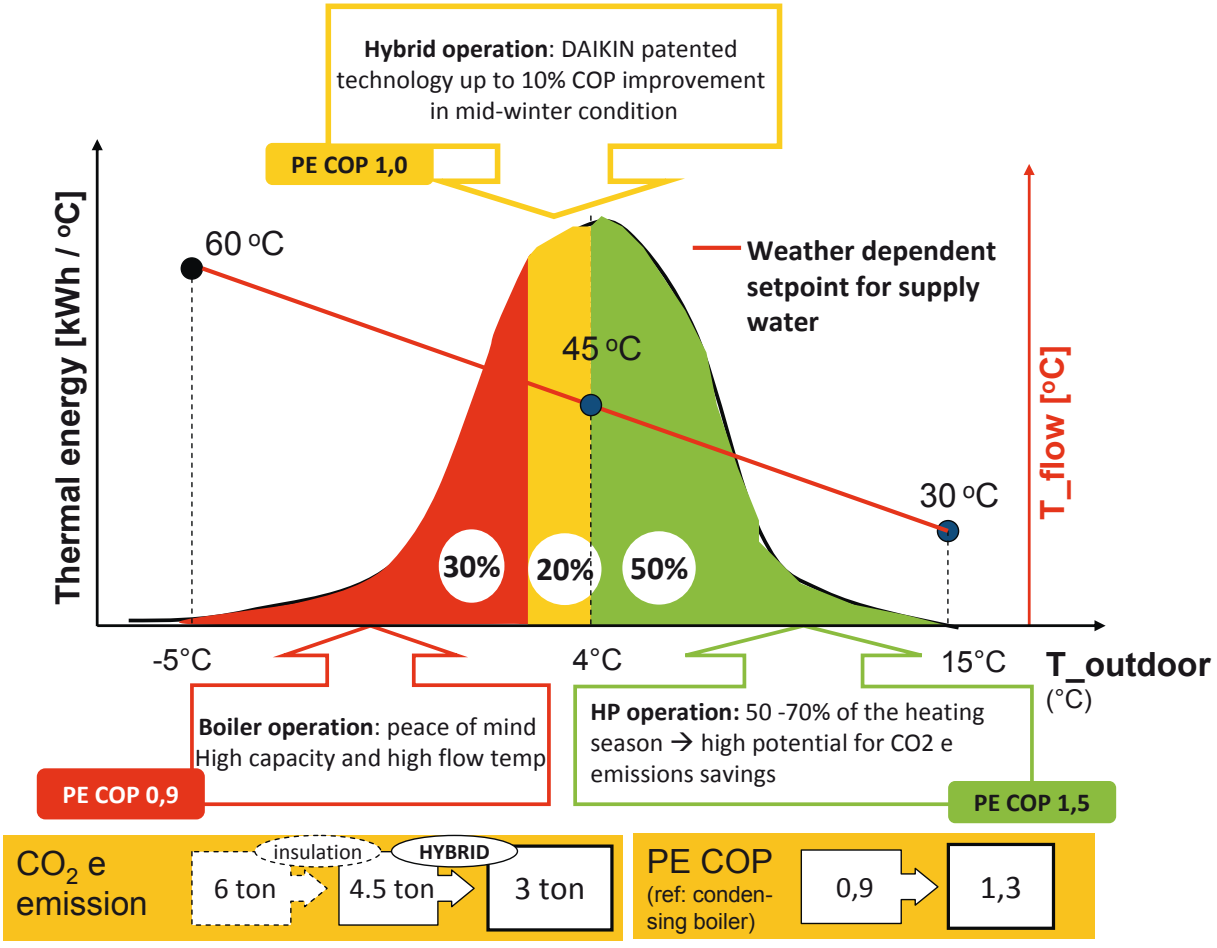


Figure 1. Distribution of space heating energy in London climate depending on outdoor temperature. Supply water temperature to heating system is controlled by outdoor temperature. PE-COP = Primary energy efficiency. Typical value for cold season is 0.9, for warm season 1.5 and for mild weather with hybrid operation 1.5.

The total CO_2e emissions in the EU from space heating are estimated at 750 Mtonnes/year, based upon an average space heating energy demand of 20 000 kWh/yr. If conventional heat generators were replaced with hybrid heat pump systems, the savings would be an estimated 200 Mtonnes of CO_2e annually. This technology has the potential to produce 25% of the CO_2e emission savings targets in the EU Energy Directive, being 250 times more effective when compared with implementing renewable energy sources in all new build homes.

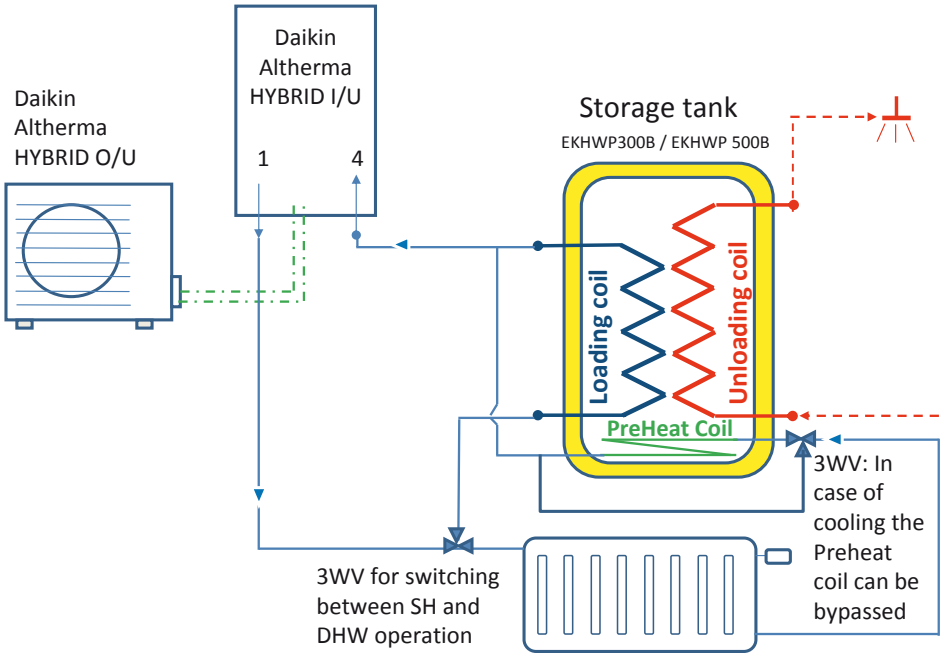


Figure 2. Domestic hot water can be preheated with heat pump in hybrid Altehrma system. **1**= SH supply water, **4** = SH return water, SH: Space Heating, DHW= Domestic Hot Water. Loading coil = coil for heating up the tank with an external heat source, Unloading coil = coil for tapping water, Preheat Coil= small coil for preheating.

The hybrid heat pump is not only a pragmatic solution because it combines the best of two proven technologies in an intelligent way, it is also the most affordable renewable energy source available.

About 70 to 80% of the energy supplied for space heating by the hybrid heat pump is produced through using air as a renewable energy source.

The price of renewable energy produced by the hybrid heat pump is about 1.7 €c/kWh RE. This based upon 15 000 kWh of space heating being produced by the heat pump per year. The power input of the heat pump is about 4 000 kWh/year and the renewable energy produced by the Hybrid is 11 000 kWh/year. This calculation also takes into account an operation span of the hybrid heat pump of 12 years (lifetime expectancy is 15 years) and a price premium of the hybrid heat-pump over a gas condensing boiler of 2 250 €.

In comparison, the cost of renewable energy produced by solar PV is nine times higher, at 16 €c/kWh, based upon 1 kWpeak PV costs of 3 500 € with a yield of 1 100 kWh. For solar thermal systems, the cost of renewable energy is 12.5 €c/kWh, or seven times higher than the hybrid system. This is based on four panels costing 2 500 €, with a yield of 1 000 kWh/year (in a typical German climate).

The hybrid heat pump is not only the best performing renewable energy source in terms of running costs, it also has the lowest capital cost. The cost of a hybrid heat pump is between 1 500 and 3 000 € more than a gas condensing boiler, while cost of a solar PV installation varies between 10 000 € and 20 000 € and the cost of a solar thermal system is between 2 000 € and 5 000 €.

The Hybrid heat pump system's major components

The Daikin hybrid heat pump system consists of three main components (**Figure 3**):

The outdoor unit transmits the renewable energy extracted from the air to the indoor unit (hydrobox). The compact and whisper-quiet outdoor unit contains the inverter driven compressor, which has a modulation ratio from approximately 20 to 100%. In partial load conditions, the outdoor heat exchanger is over-sized which increases the efficiency by up to 30%. The outdoor unit can be placed in a garden, mounted on a wall or on the roof, up to 20 m from the hydrobox.

The hydrobox is mounted on the wall behind the condensing boiler. As well as the controls for the system, it contains the water-side elements of the system, such as the expansion vessel and pump, and also the heat ex-

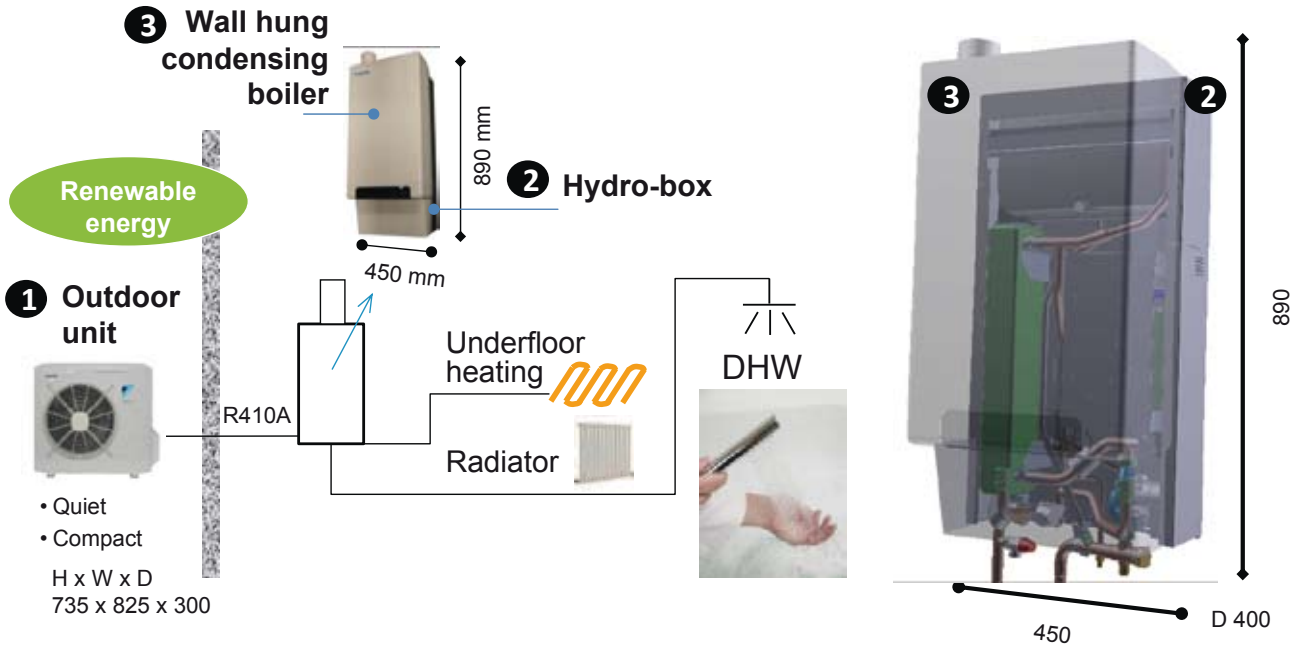


Figure 3. Major components and dimensions of hybrid heat pump system.

changer, which converts the renewable energy extracted from the air into hot water.

The condensing gas boiler is mounted in front of the hydrobox. The combined dimensions of the boiler and the hydrobox are about the same as a conventional wall-hung boiler, making the system ideal for the replacement boiler market.

Figure 4. The HYBRID heat-pump system was tested in this 110 year old, terraced UK house during winter 2011-12. A family of three lived in the building with heated floor area of 140 m^2. The house was heated with hot water radiator system with design supply temperature of water 70°C in design outdoor temperature of –6°C.

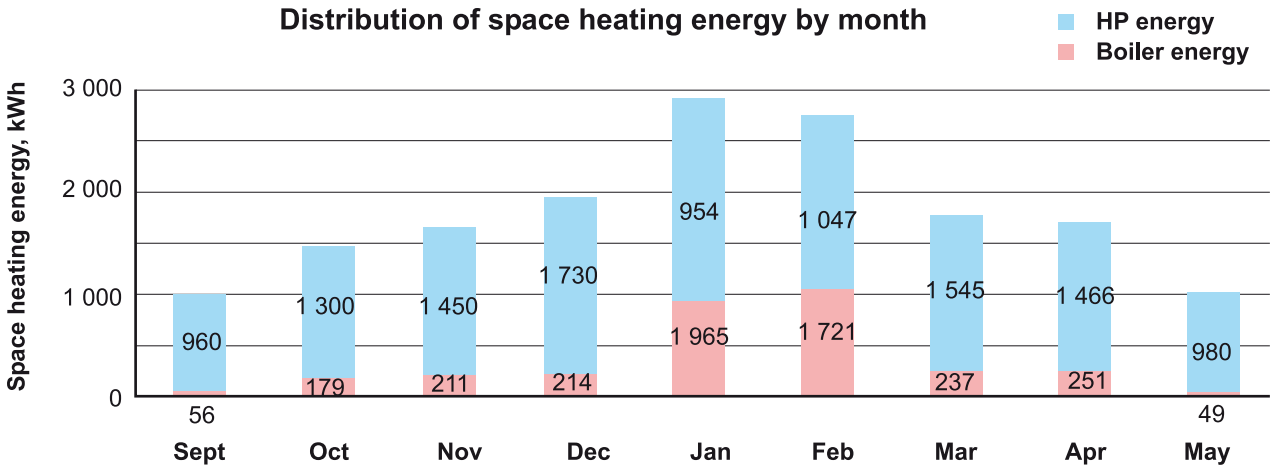
Field testing

The Daikin hybrid heat pump has been field tested in various climates and house types (size, age, and energy rating) with a range of different heat emitters. Seasonal efficiencies measured during the winter of 2011-12 varied between 1.25 and 1.6.

An example of this field testing in a UK home is shown in **Figure 4**. This house can be considered a 'worst case' scenario: it is 110 years old, with high flow temperatures to the radiators. The house has a floor area of 140 m^2 and a heating capacity of 9 kW at a design temperature of –6°C.

The annual energy demand is approximately 18 500 kWh, of which 16 300 kWh is used for space heating and 2 100 kWh for hot water production. Results from the trial of the hybrid system show that of the 16 300 kWh used for space heating, 13 060 kWh was produced by the heat pump (see details in **Figure 5**).

This example demonstrates clearly that, even in older properties with radiators, the heat pump in a hybrid system will supply most of the energy for space heating,



with the boiler acting as a 'supporting' heat source. In fact, the hybrid system is suitable for any house type: small or large, young or old, with underfloor heating or radiators.

The measured seasonal efficiency in the house, based on the primary energy source, is 1.26 for space heating and 1.2 for the total energy supply (space heating and hot water production combined). This is 37% higher than a state-of-the art gas condensing boiler, based on an efficiency of 0.9 for space heating operation (seasonally based) and 0.7 for domestic hot water.

The hybrid heat pump's efficiency is also 28% higher than a system comprising a condensing gas boiler with solar thermal panels for hot water production, which is generally considered 'best available technology'. Assuming 50% of the hot water is produced by the solar thermal panels (solar pump energy not being taken into account), the seasonal efficiency of such a system would be 0.94.

Smart grid ready

Besides the excellent comfort and top efficiency of a hybrid heat-pump system, we'd like to add that the system is the perfect tool for electricity grid management. Depending on the load of the grid, the system can switch between boiler and heat pump operation. At the moment, switching between the heat pump and boiler in the Daikin Hybrid heat pump is carried out via a voltage free contact, but in the future it is envisaged that a smarter solution can be embedded, for example based smart meters that are linked to the grid.

The hybrid heat pump – the heat source of the future

The hybrid heat pump can be considered as the heat source of the future: environmentally-friendly, able to cope with the complexities of energy mix and supply, while remaining easy to operate and ensuring comfort for end-users.

Regardless of energy prices, changing outdoor temperatures and the varying load of the heat pump, the hybrid system determines the most efficient and effective energy source to use, all while maintaining consistently high comfort levels.

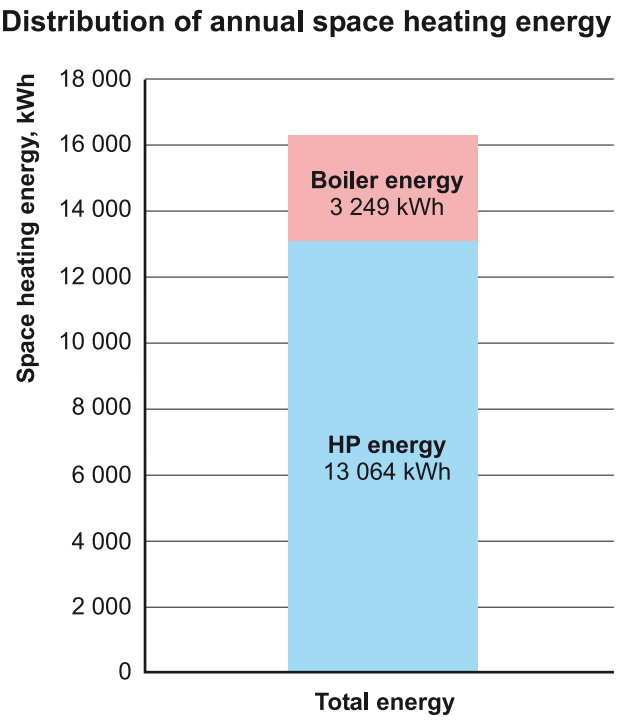


Figure 5. Monthly and annual distribution of the space heating energy between heat pump and boiler in the house of Figure C4 during winter 2011-12.