Trane Engineering News

Multi-pipe unit for heating and cooling buildings

Today, it is common to find buildings with traditional heating and cooling systems working simultaneously to satisfy the comfort of the occupants. These systems work well but neglect the energy saving potential. New multipurpose equipment, able to satisfy simultaneous heating and cooling needs in buildings while recovering energy, has recently been introduced to the HVAC market.

The goal of this white paper is to show the potential benefits of a multi-pipe unit for heating and cooling a building and the impact it can have on energy running costs.

Context

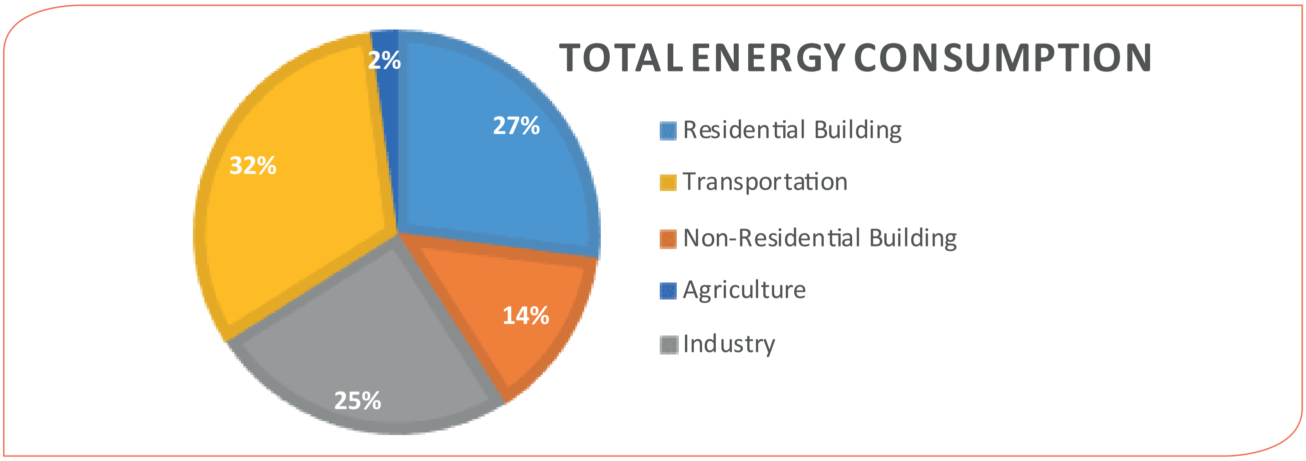
To reduce the European total energy consumption and lower CO_2 emissions, the EU has adopted measures to improve energy efficiency in Europe.

The 2012 Energy Efficiency Directive establishes a set of binding measures to help the EU to reach its **20% energy efficiency target by 2020**.

An update to the Energy Efficiency Directive, including a new **30% energy efficiency target for 2030**, was approved in April 2018 by the European Parliament. In the coming months, the member states will have to transpose the new elements of the Directive into national law.

In Europe, buildings are responsible for 41% of energy consumption and 36% of CO_2 emissions. Of all the end-use sectors, buildings represent the largest sector, followed by transport with 32% and industry 25%. (1)

Figure 1: Total energy consumption in Europe



In the non-residential (or tertiary) building sector (banks, offices, shops, hospital, etc.), lighting, heating, cooling, refrigeration, ventilation, appliances and IT-equipment are the typical end-users of energy and their proportions depend on the building type and location.

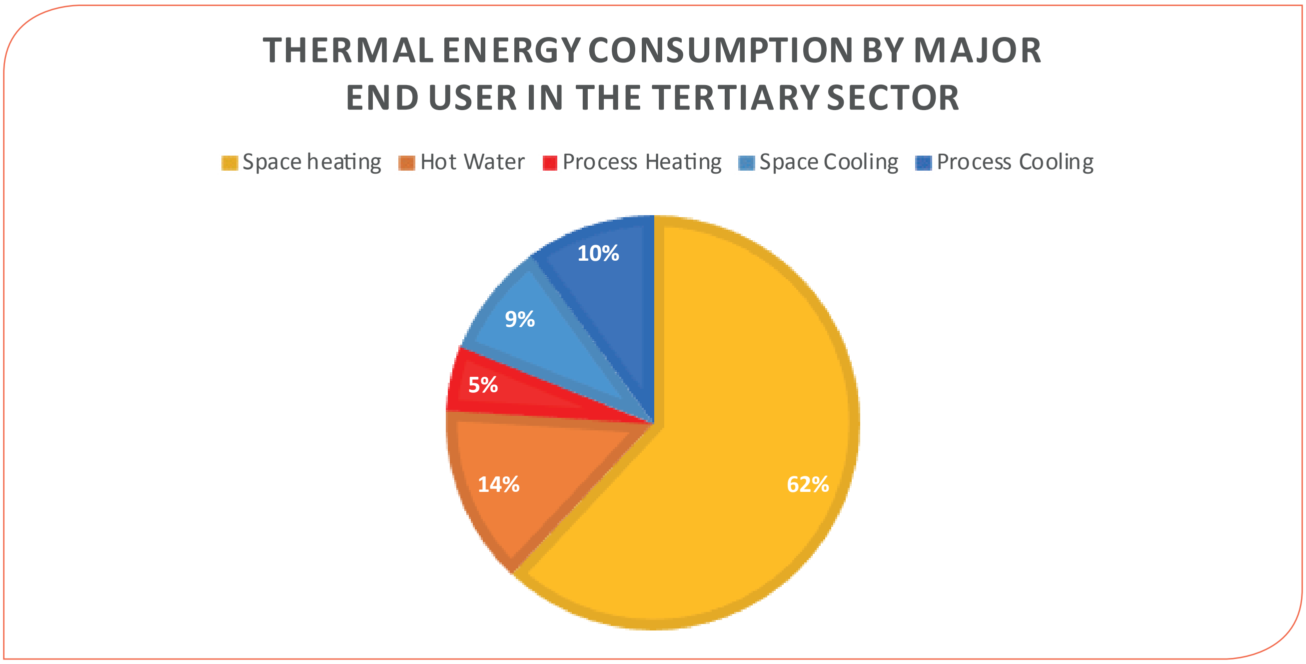
Heating and cooling

The thermal energy consumption (heating and cooling) in buildings and industry accounts for approximately, half of the EU's energy consumption.

For the building sectors, space heating is the largest thermal energy user.

For the tertiary sector in aggregate, space heating accounts for 62% of this energy consumed, cooling for 19%, hot water for 14% and process heating for 5% (2).

Figure 2: Thermal Energy Consumption per user in the tertiary sector



Given this context, higher energy efficiency and a lower use of fossil energy in existing and new buildings will be required to achieve the objectives set by the EU.

In many cases, space heating, cooling and sanitary hot water can be provided by heat pump units. When simultaneous demands for heating and cooling exist, energy can be saved and CO_2 emission reduced using multi-pipe units.

Achieving the energy savings in a building is a complex process and requires a meaningful understanding of several characteristics of the building.

With heat pumps or multi-pipe units, the demand profiles for heating and cooling are obviously important, but the heating and cooling system design temperatures greatly influence the choice of equipment and the efficiency of the solution.

What is the difference between a traditional heat pump and a multi-pipe unit?

A traditional heat pump can either cool or heat and is a two-pipe unit using one water heat exchanger to provide chilled water or hot water to the building.

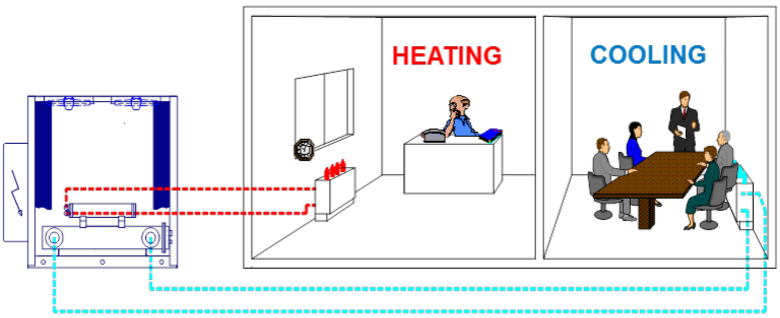
A multi-pipe unit can be defined as an electrical heat pump able to **simultaneously** satisfy cooling and heating demands on a 4-pipe system at the highest efficiency possible.

The 4-pipe unit has three main heat exchangers: a condenser that heats the water for space heating, an evaporator that cools the water for space cooling and a balancing air coil. The balancing coil works either as a condenser in a cooling mode or an evaporator in a heating mode to balance the difference between the heating and cooling demands.

Figure 3: Example of a 4-pipe unit

The operation of the unit is based on the principle to transfer heat from the ambient to cool, or to the ambient to heat.

Figure 4: 4-pipe unit principle



Using the chilled water instead of ambient air as heat source when the outside air temperature becomes lower often allows higher evaporating temperatures in the unit and helps in efficiency. Moreover, as long as you use chilled water as heat source, there is no need to defrost.

This unique combination of heating, cooling and recovery operating modes generates a total efficiency which is far higher than the COP or the EER of the traditional heat pumps and makes these units an effective alternative to the traditional combination of a chiller associated with a boiler in 4-pipe plants, as they save installation and operation costs.

Case study

The following case study compares the energy costs of two different systems.

The base system is traditional, consisting of a condensing gas boiler and a high efficiency air-cooled chiller. The alternative system consists of a 4-pipe unit which can produce hot and chilled water either simultaneously or independently. Both systems operate to satisfy the same building's loads.

For the simulation, we have considered a "low energy" office building including individual offices, open spaces, meeting rooms, IT room, sanitary, small warehouse, and cafeteria.

The building is occupied from 07:00 to 19:00 during the week and unoccupied during the week-end.

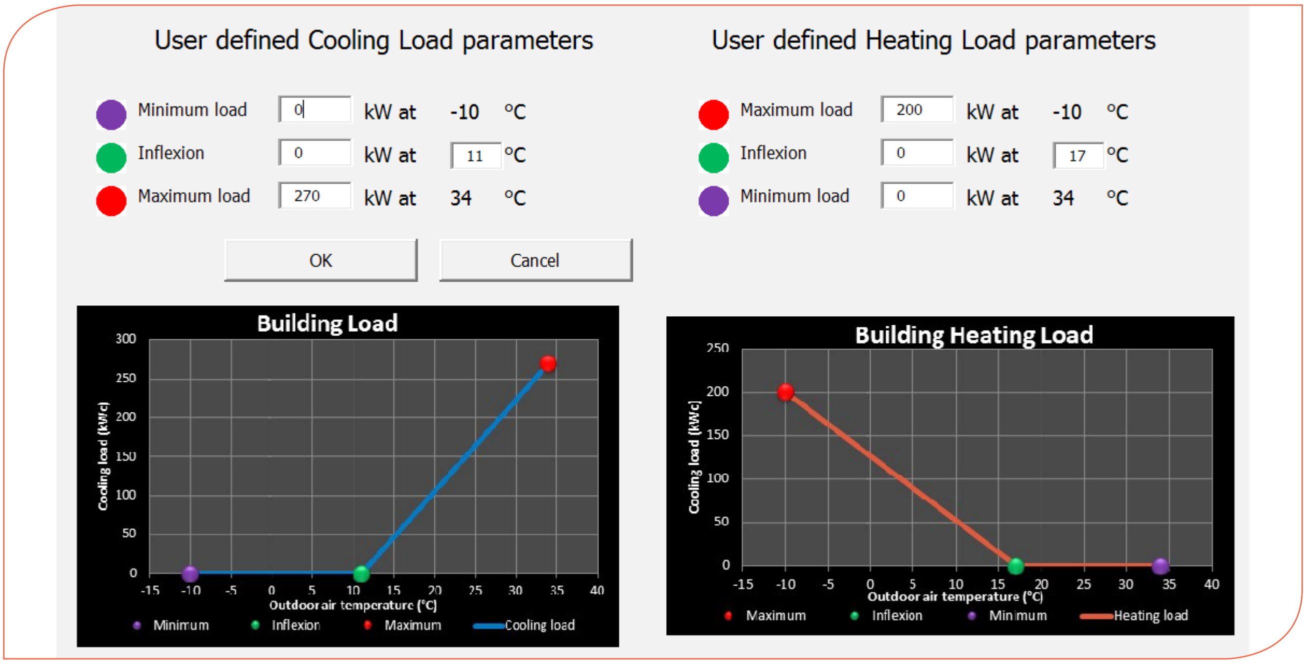
The HVAC system for heating and cooling the space is a traditional 4-pipe system and consists of a low temperature heating system and chilled ceilings. Fresh air requirements are managed by AHUs employing energy recovery.

The design conditions (for Brussels) are the following:

- Chilled water temperatures: 10°C - 17°C
- Hot water temperatures: 32°C - 40°C
- Peak cooling demand: 270 kW @ 34°C Outdoor Air Temperature
- Peak heating demand: 200 kW @ -10°C Outdoor Air Temperature

For achieving our comparison, we used the Trane Cooling and Heating Plant Analyzer tool (THPA) and the load profiles shown below.

Figure 5: Heating and cooling load profiles

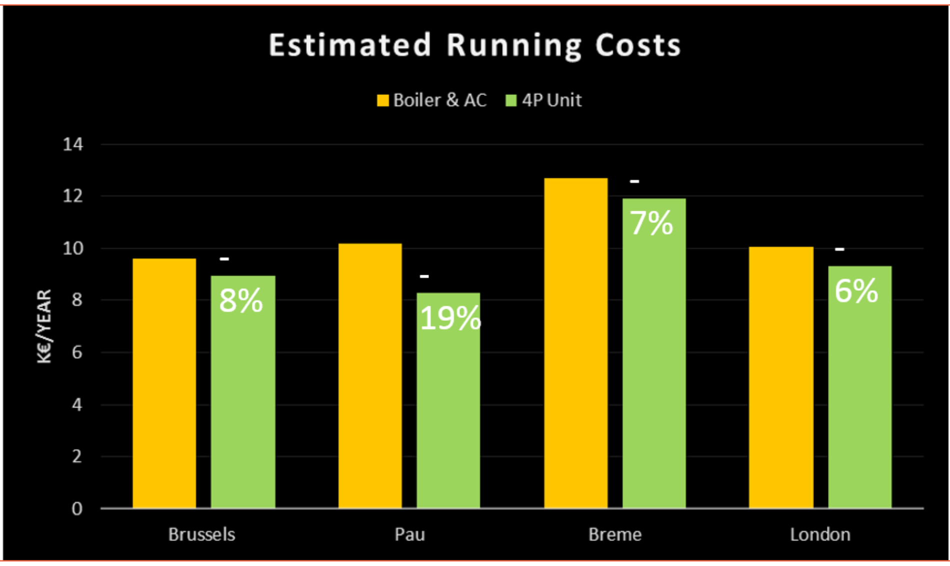


To show the impact of different climatic conditions, the simulation was run in 4 different locations (Brussels, Pau (South of France), Bremen (North of Germany) and London) and considered energy costs in the different countries.

The energy running costs and CO_2 emissions have been evaluated for the different locations and taking into account that the heating and cooling peak demands vary according to the outside air temperature.

THPA estimated running costs for different locations.

Figure 6: Estimated running cost for different locations



The simulation shows that, whatever the location, the 4-pipe unit satisfies the heating and cooling requirements throughout the year at lower operating cost. The efficiency of the 4-pipe unit, in cooling and heating modes, depends on the outside air temperature and water temperatures produced. The 4-pipe unit has significant advantage when there is a simultaneous heating and cooling demand in the building. During such times, the unit runs in heat recovery mode and has a greater efficiency. The efficiency in this mode is measured in terms of Total Efficiency Ratio (TER), is unitless and defined as follows:

Total Efficiency Ratio (TER) = (Cooling + Heating Capacities)/(Power Input)

Depending on the conditions the TER can reach values of 7 or 8.

This high efficiency provides better system performances compared to a traditional system with a boiler and air-cooled chiller for which heat recovery is not possible.

For the simulation, we have considered constant heating and cooling temperature set points. Additional savings could be achieved by optimizing the heating and cooling set points of the unit. Lowering the hot water temperature produced and/or increasing the chilled water produced, when possible, has a positive impact on the efficiency of the unit, but may increase pump energy.

Result for the CO_2 emissions

The 4-pipe unit solution also reduces CO_2 emissions. The CO_2 savings depend on the way electricity is produced in the different countries. For the above mentioned conditions, the savings have been estimated to 25 tons of CO_2 per year for Brussels and similar for other countries.

Installation

The installation costs of a 4-pipe unit are certainly not higher than those of a traditional system with a boiler and a cooler. At contrary, the installation is generally simpler and faster and does not require additional space for the boiler. The primary heating and cooling pumps can usually be integrated in the unit, which makes the installation even easier for the HVAC contractor.

It's nevertheless important to note that, like for any heat pump and chiller, the minimum loop volumes recommended by the manufacturer (4) must be respected to ensure the proper operation of this type of unit. These water volumes depend on the unit characteristics and the fluctuations of temperatures tolerated on the water sides. The required water volume on the heating side is usually more important and mainly due to the defrost cycles in heat pump mode.

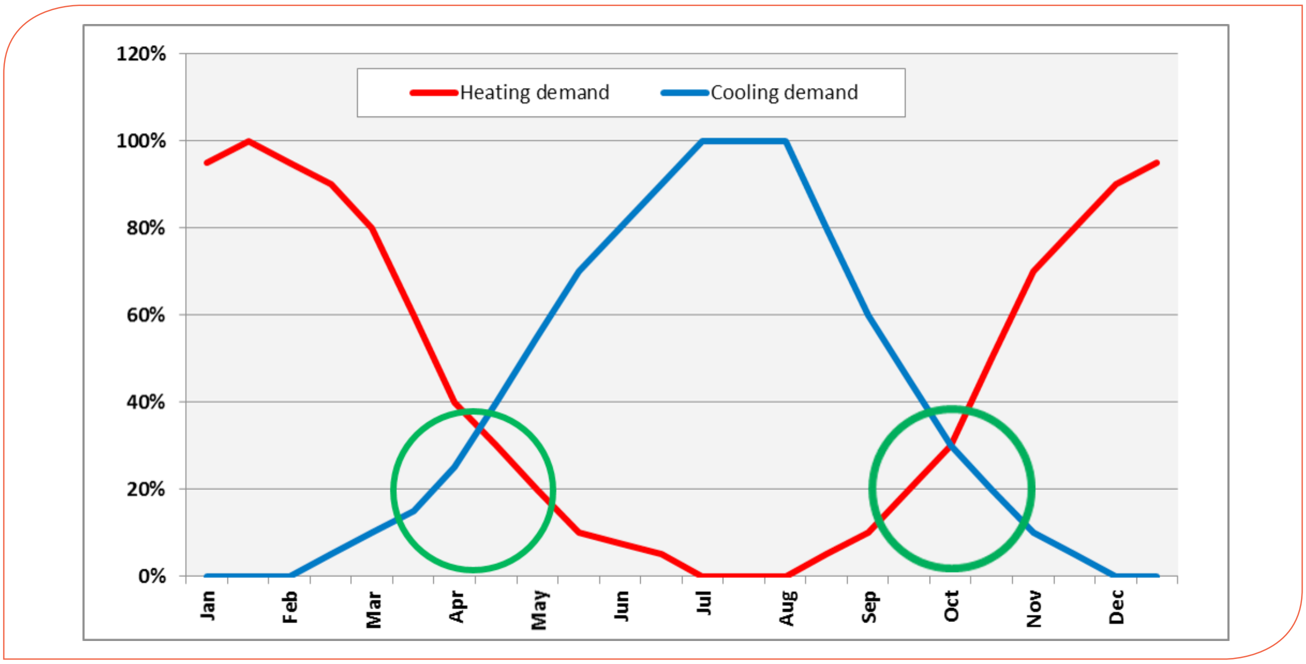
Summary

For buildings located in mild or temperate climates with the heating system designed for low water temperatures, simulations show that a system with a multi-purpose unit for 4-pipe systems can satisfy cooling and heating demands, at much higher efficiency levels than the traditional solution (chiller + boiler).

The simulations also demonstrate that it is not necessary to have a presence of a significant number of simultaneous heating and cooling loads to make this solution attractive.

The most temperate months (April, May, September and October) are usually characterized by the favorable balancing of loads (highest average simultaneousness factor). This is the situation in which a multi-purpose unit achieves the highest efficiencies and savings.

Figure 7: Example of typical heating and cooling load profiles



The results show that a 4-pipe unit running in heat recovery mode only 25% of its total running time remains more efficient than the solution with a condensing boiler and a high efficiency chiller.

The energy running cost savings depends on the price of energy in the different countries, but even in countries where the difference between the price of electricity and gas is less favorable, the multi-pipe unit remains advantageous.

Conclusions

Only a detailed study and analysis can quantify the potential savings but multi-pipe units are a valid and cost effective option to traditional systems.

Over a year, if the simultaneous heating and cooling demands occur, using a multi-pipe unit enables substantial energy savings.

If there are not simultaneous heating and cooling loads, a traditional reversible heat pump is a very viable techno-economical choice.

The case study is based on a real building and available equipment. We did not have all the data necessary to validate the model. Some assumptions were made and although we took the greatest care for the system simulations, the results remain theoretical. But data collected from other projects tend to correlate the findings.

References

(1) Source: Eurostat
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(2) Source: EU Strategy on Heating and Cooling document
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(3) Source: Energy prices (gas and electricity): Eurostat 2015
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(4) Installation, Operation and maintenance manual CG-SVX042A
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