

# A transformative system answer

Careful integration of heat pumps will pay off for decades to come

By Bashar Naser

Heat pumps today represent a paradigm shift for the district energy industry, their true potential emerging as a central component of sophisticated thermal management systems.

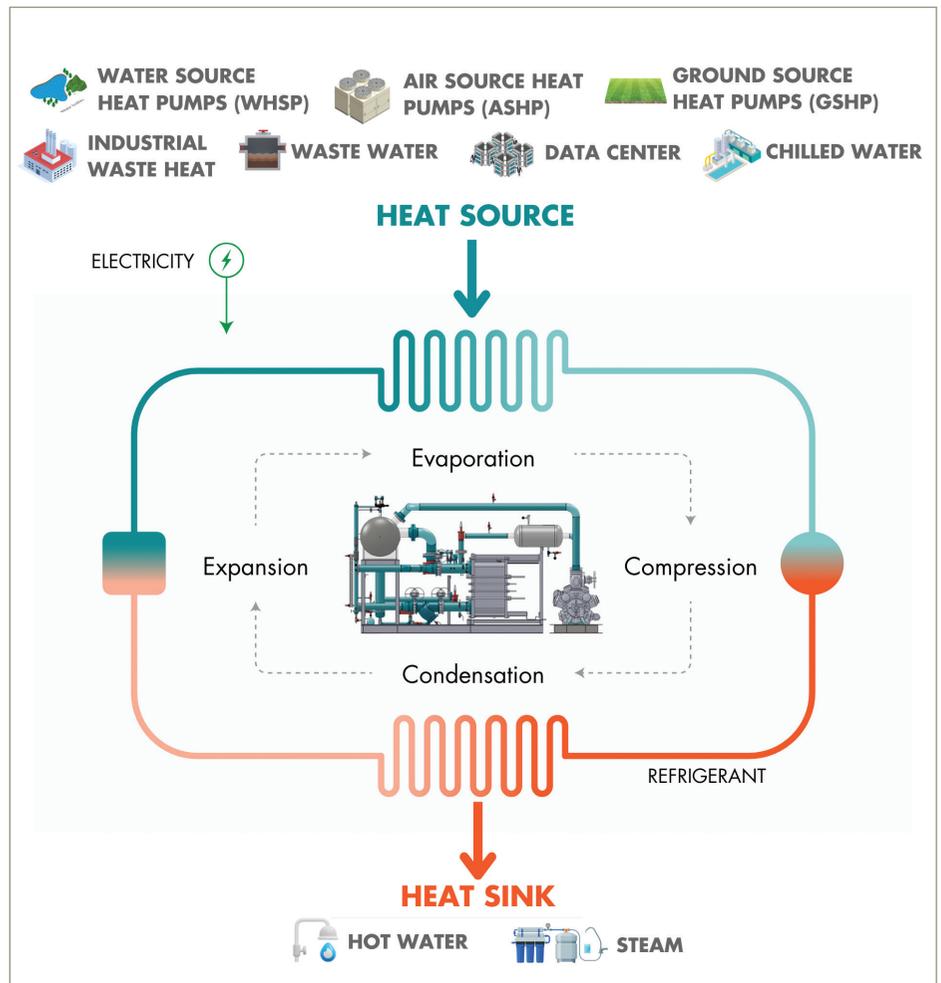
Over the past 15 years, global climate change mitigation initiatives have focused on reducing carbon emissions from buildings, which in turn has created market demand for efficient decarbonization technologies. This is where heat pumps are gaining ground – as part of holistic solutions that include thermal storage and backup boilers.

Manufacturers with refrigeration expertise have developed equipment suitable for heat pump systems capable of producing higher-temperature water and even steam in district systems. European countries have refined the technology in recent years, and adoption is well underway in North America.

Proper integration of heat pumps – taking into account source applications, sink temperatures, refrigerant selection and system configuration – can maximize efficiency, reduce emissions and create solutions that will remain viable through 2050 and beyond.

Heat pumps do require careful integration into district energy systems. But by optimizing source-sink pairings, selecting appropriate refrigerants and choosing the right system configuration, operators can solve the full system-decarbonization puzzle.

The most successful implementations will achieve high efficiency while remaining environmentally sustainable and economically viable, establishing heat pumps not as just an alternative to



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boilers but as a transformative technology toward district energy's low-carbon future.

## RIGHT-SIZING SYSTEMS AND MAXIMIZING HOURS

Heat pumps have moved from niche-technology status to mainstream adoption by district systems. The

fundamental – a closed-circuit system circulating refrigerant, with an evaporator, compressor, condenser and expansion device – allows for a coefficient of performance, or COP, greater than 1. This means the thermal energy output exceeds the electrical energy input, making heat pumps a compelling solution for decarbonizing building heating.



## HOW TO TAKE STOCK OF VARIOUS ENERGY SOURCES

While air-source and ground-source heat pumps dominate single-building applications, district systems can leverage scale on ground-source, or geo-exchange applications, and can do the same with alternative sources that include lake water, river water, sea water, wastewater, data centers, industrial waste heat and building exhaust. Sources should be evaluated on capacity, temperature, availability and feasibility.

A 30-MW heat pump would require a source with an approximately 20-MW capacity. The availability profile must align with the desired heat pump operating profile. Source temperature directly affects system performance – heat pumps using colder sources require greater lift and therefore struggle with efficiency compared with systems with warmer source alternatives.

Feasibility concerns might include technical difficulty and capital investment required to connect a source to the heat pump system. Wastewater has become a popular energy source because of its relatively high temperature, consistent availability and proximity to populated areas where district heating centers are located. Data centers offer high-temperature waste heat year-round but are typically located outside densely populated areas, creating connection challenges.

The ideal source provides simultaneous useful cooling and heating, which significantly improves overall system economics. In such applications, the combined COP is calculated as the sum of the cooling and heating energy divided by the electrical input. For example, a heat pump providing simultaneous cooling to a chilled water district system and heating to a hot water system might achieve a combined COP of 5-7, far exceeding single-purpose applications.

Dual-purpose operations like this not only maximize efficiency and minimize operating expenses but also simplify connection feasibility because the source is directly integrated into the system design. For large systems that have a heating-dominant load, multiple

sources can be integrated to provide required capacity.

## PACKAGED SYSTEMS VERSUS BIGGER 'BUILT-UP'

Heat pump systems can be packaged or "built-up" in design. Packaged systems come with factory-installed refrigerant piping, electrical panels and controls, requiring only foundation preparation, hydronic piping connections and on-site electrical power installation. This provides quality assurance and reduces installation time and labor.

### Heat pumps for base load, thermal storage for peak usage, electric boilers as backups.

On the downside, freight-size limits typically restrict a single packaged unit to approximately 3 MW of capacity. Multiple units can be used in parallel, but this eventually inflates costs, increases footprints and compounds maintenance expenses.

Built-up systems use larger compressors and heat exchangers with field-installed interconnecting piping and control systems. This approach, successful in industrial refrigeration and European heat pump projects, benefits from economies of scale. A 9-MW system using packaged equipment would require at least three units, each with its own components. A built-up system can reduce initial cost by leveraging economies of scale with a single larger compressor, evaporator, condenser, starter panel and control panel, reducing footprint and maintenance costs. An experienced provider can pre-fabricate most field piping, minimizing installation costs and quality risks.

## AN ADDITIONAL CONSIDERATION: WHAT REFRIGERANT TO USE?

Refrigerant selection affects system COP, footprint, costs, safety and sustainability, and falls under applicable regulations. Different refrigerants perform better at different

temperature ranges due to their inherent thermodynamic properties. Fluorinated options (sometimes called "synthetic refrigerants" or "f-gases") like R515B or R1234ze work well for 130-140 F sink temperatures, while R1233zd performs better at 160-180 F.

Environmental concerns have led to phase-outs of refrigerants with ozone-depleting potential, or ODP, and global warming potential, or GWP. Newer HFO refrigerants have zero ODP and low GWP but can create acid rain or "forever chemicals." Regulatory phase-outs have begun in the EU and parts of the U.S.

ASHRAE 34 code classifies refrigerant safety by toxicity and flammability. While some fluorinated blends maintain A1 classification (lowest toxicity and flammability), newer HFOs have higher A2L flammability ratings, requiring more stringent ASHRAE 15 code requirements.

Environmentally friendly alternatives include natural refrigerants, or "non-fluorinated refrigerants," like ammonia, CO2 and hydrocarbons. Ammonia (0 ODP, 0 GWP) offers excellent COP across all temperature ranges, excelling at 180-212 F. Despite B2L classification for its higher toxicity, it has a century-long refrigeration track record with mature codes and expertise.

Hydrocarbons offer excellent performance but have the highest flammability rating (A3), requiring extensive safety measures. CO2 (A1 rated) performs well up to 180 F but requires a high temperature differential on the hot water loop to achieve good COP.

Natural refrigerants also cost significantly less than fluorinated options, reducing both initial and lifetime operating expenses. 



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