Cogeneration units and heat pumps for sustainable heat and power supply

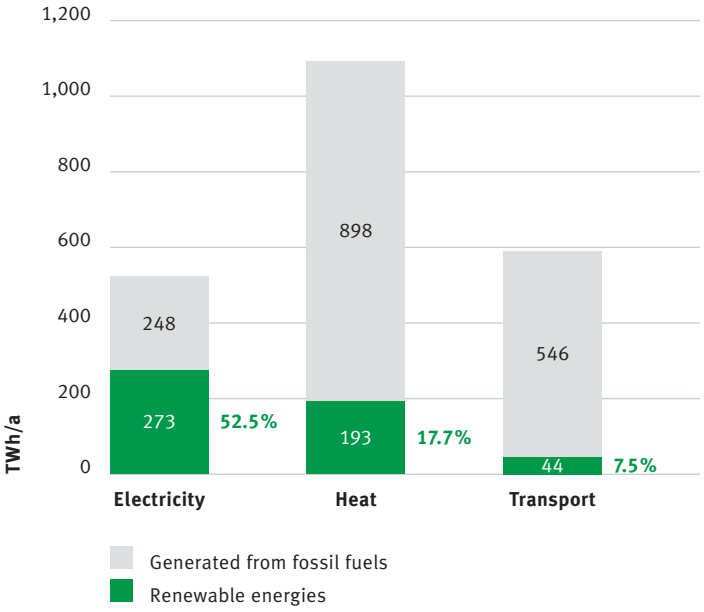
SOKRA® therm
Heat pumps

Potentials in the energy transition

Whether electrons or molecules will be generated renewably, stored and transported tomorrow is becoming the central question of the energy business. It will play a key role in the climate-neutral energy supply of the future. By now, the energy policy debate and the consideration of the necessary interventions have been focused very strongly on the electricity sector. However, the much greater consumption of resources takes place in the heating sector – with a currently very low proportion of renewable energy (RE). The demand for economically and technically feasible concepts regarding the heating market therefore is enormous.

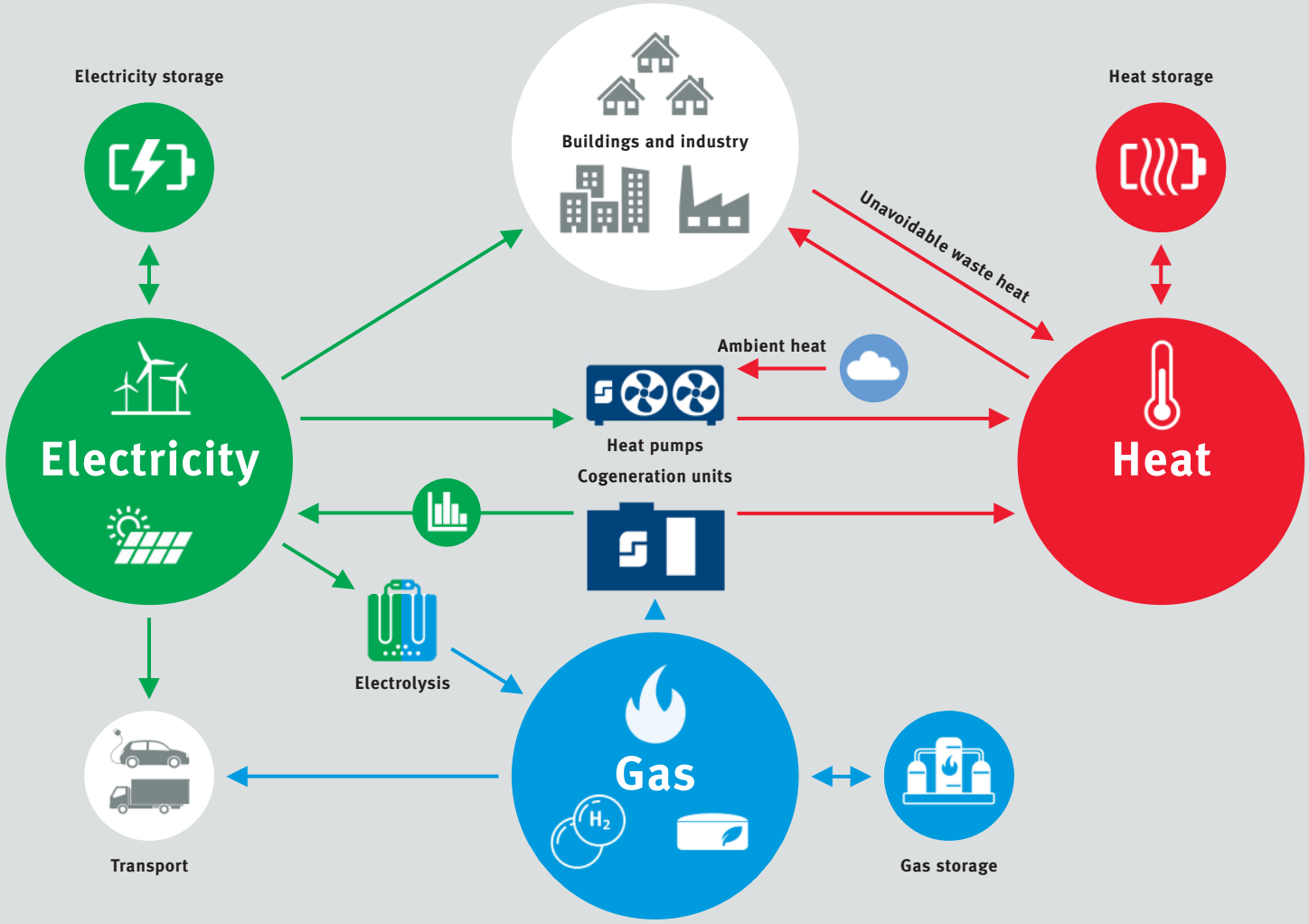
In the electricity sector, engine-based combined heat and power (CHP) with cogeneration units has for years been proven to be the ideal partner for balancing out volatile generation from wind and solar energy – with growing demand and increasing importance for the further expansion of wind and photovoltaic systems. In the heat sector, great potential can be realised through sector coupling with decentralised CHP heat generation and sensible heat pump concepts.

Share of renewable energies from total consumption in Germany 2023



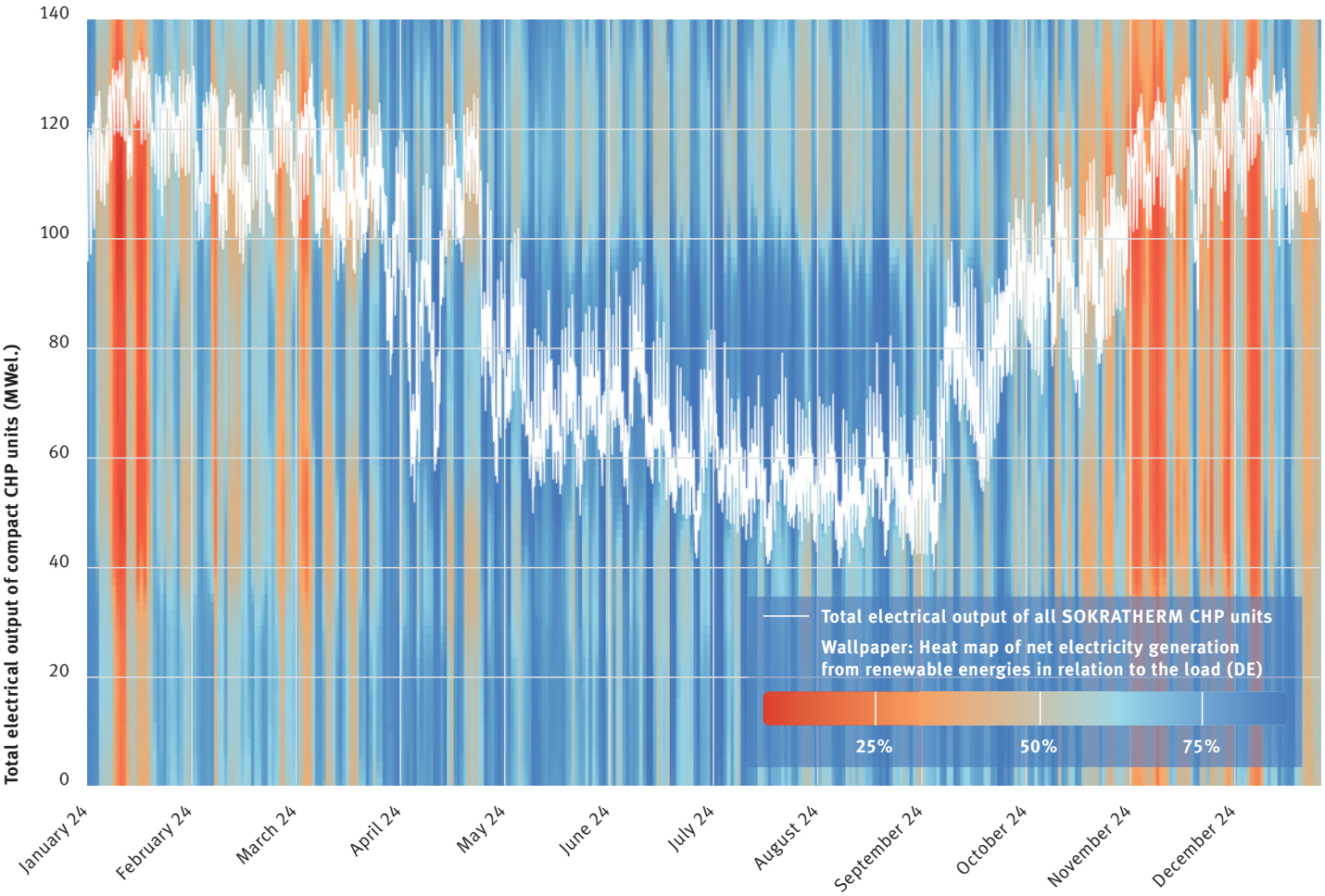
Sector integration in the future energy scenario

In order to synchronise the advantages of the various options for renewable supply in the electricity, heating and mobility sectors, complete integration is required. The central building blocks for this transformation are supply concepts with combined heat and power plants and heat pumps that are tailored to the current and future requirements of the energy markets.



Renewable energies and cogeneration units
A perfect team on the path to carbon neutrality

SOKRATHERM compact CHP units – Virtual entire machine 2024



The engine driving the energy transition

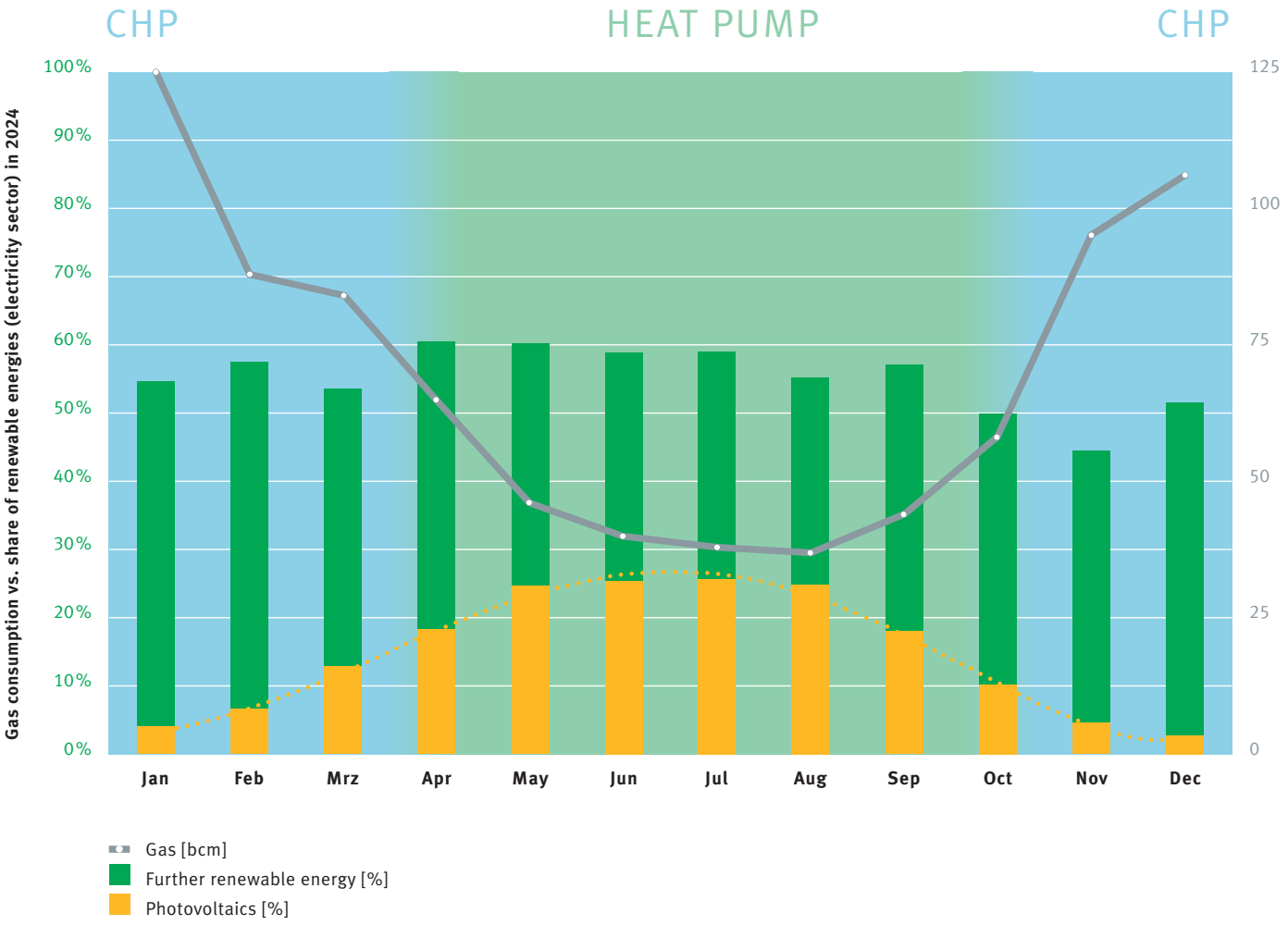
Well-designed cogeneration units perfectly support the expansion of renewable energies. Even now, simply controlled by seasonal conditions, they mostly supply energy when there is insufficient wind and solar power available, as the diagram impressively shows. They precisely meet the remaining demand that cannot be sourced from wind and solar, the so-called residual load. Cogeneration units therefore predominantly replace electricity from conventional condensing power plants. In contrast to these, however, cogeneration units utilise the waste heat produced during electricity generation for heat supply through the highly efficient CHP principle. By providing heat, cogeneration units therefore significantly contribute to the reduction of greenhouse gas emissions.

Residual load 2045

Achieving greenhouse gas neutrality by 2045 has been stipulated in the Climate Protection Act. To fulfil this commitment, wind and solar power in particular are to be further expanded. A lead study on the energy transition* comes to the conclusion that a high residual load will continue to exist even in a completely renewable energy world. From the target figures mentioned there, it can be assumed that in the future around three-quarters of the electricity demand can be covered by direct utilisation of renewable energies. The missing quarter can only be covered by electricity storage to a very small extent. The majority will have to be provided by gas-fired power plants, which will then use renewable fuels.

* Prognos, Öko-Institut, Wuppertal-Institut (2021): »Climate-neutral Germany 2045: How Germany can achieve its climate targets before 2050.« Summary published by Stiftung Klimaneutralität, Agora Energiewende and Agora Verkehrswende.

SOKRATHERM cogeneration units and heat pumps
Keys to a successful energy transition



Covering residual load? Only with CHP!

The residual load is particularly high when there is no wind, and the sun is not shining. This typically occurs between November and March, when the autumn storms have passed, and the sun is just low above the horizon. This demand is covered by gas-fired power plants, which are expected to take over the entire residual load following the phase-out of nuclear energy and coal-fired power generation. At the same time, a lot of heating is being produced from gas in winter. Accompanied by the planned expansion of renewable energies, this heat will be increasingly generated from electricity. Increasing the share of electricity generated from renewable sources in winter, on top of covering this additional demand, will be a challenge. CHP units supply heat at the right time as a waste product of gas-fired power generation and are therefore the key to a successful energy transition.

Green cogeneration

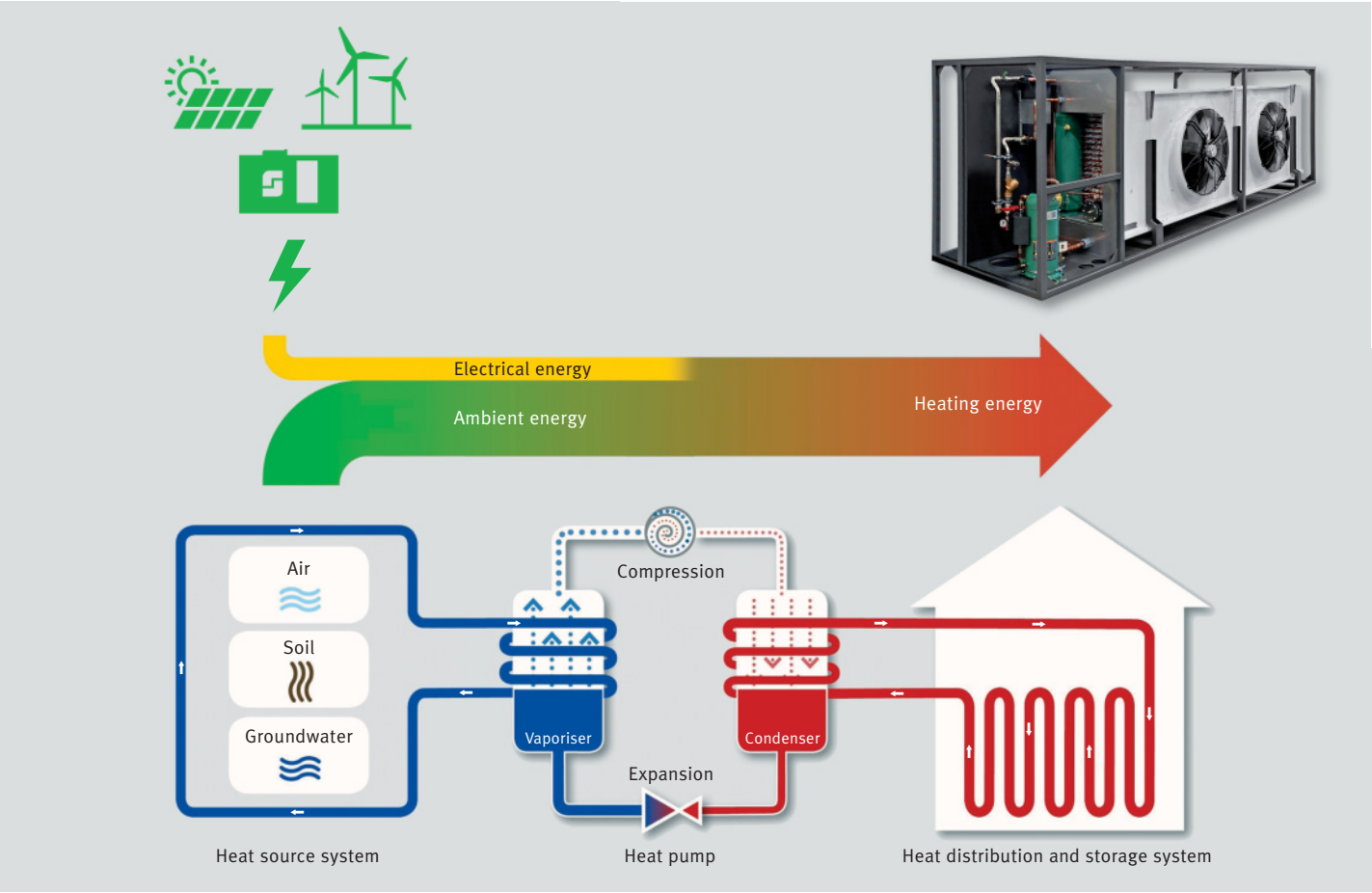
In the long term, the residual load is also to be covered without greenhouse gas emissions. The path to this target is firmly mapped out. Many cogeneration units are already being operated with renewable fuels, whether agricultural biogas, commercial biomethane, municipal sewage gas or landfill gas – there are many options for operating cogeneration units with renewable fuels. However, the amount of fuel available in this way is limited.

In the future, renewable gases generated from surplus renewable power production and supplementary imports will therefore need to be used. The key advantage of gas fuels such as hydrogen or green methane is that they can be stored in large capacities.

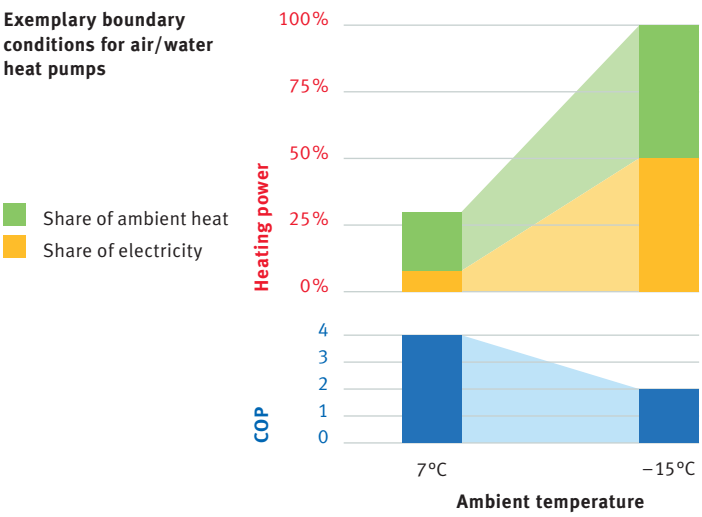
With gas engines, as used in CHP units, this transformation process can be gradually completed. In the coming years, CHP units will continue to run on the gases currently available. The engines in our CHP units are already capable of operating with a hydrogen content of up to 40% in the fuel gas and even engines for operation with 100% hydrogen are already available. Based on this, conversion kits are offered to upgrade the engines of CHP units already installed and previously operated with other gases for hydrogen operation, e.g. in the scope of scheduled engine overhauls.

How heat pumps work

Heat pumps are ideal for utilising renewable electricity in the heating market, as they allow ambient heat to be used for heating. Just as a small chiller in a refrigerator »pumps« heat energy from the inside out, heat pumps extract the thermal energy from the ambient air, for example, and make it available for heating. For this purpose, a refrigerant vaporises inside a heat exchanger at a low temperature in a closed cycle. The refrigerant heats up during the subsequent compaction with the help of a compressor. The ambient heat brought to a higher temperature level this way can be utilised for heating purposes by condensing the refrigerant in the condenser. Finally, the refrigerant is expanded, and the process starts again.



Exemplary boundary conditions for air/water heat pumps



Heat pumps and the matter of temperature

The coefficient of performance (COP) describes the efficiency of a heat pump. It indicates how many units of heat are gained from one unit of electricity. With increasing temperature difference between the heat source and the heating water, the COP decreases. Groundwater and soil can supply heat at around 5°C all year round, but extracting this is expensive. Down to this temperature, ambient air is the more favourable heat source. With high heat demand in winter, higher flow temperatures are also required, which reduces the COP further. As a result, the electricity requirement increases disproportionately in winter – particularly when the availability of renewable electricity is low. At this operating point, a CHP unit serves both to supply electricity and to raise the temperature.

SOKRATHERM cogeneration units and heat pumps
Management with proven iPC control

Cogeneration units and heat pumps: Optimal combination

But how can the individual advantages of the common heat supply options be utilised in the best possible way? How can the triangle of energy policy targets be sensibly fulfilled?

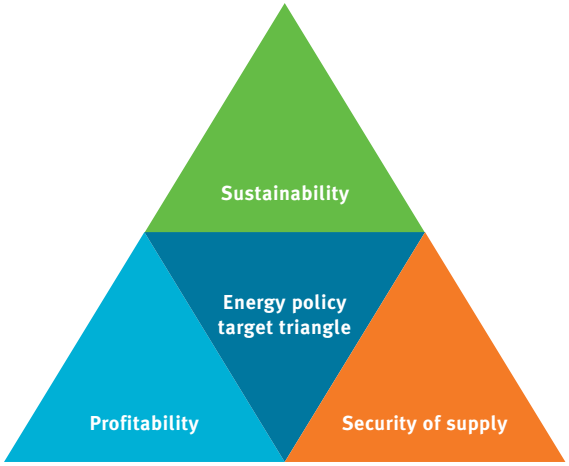
The solution is obvious:
Heat pumps cover the heat demand as long as
- operation with optimum COP is possible *and*
- the evaporator does not have to be defrosted *or*
- the CHP alone cannot cover the demand *and*
- sufficient electricity from RE or CHP is available.

Cogeneration units cover the heat demand as long as
- there is a need for high flow temperatures *and*
- residual load in the electricity sector has to be covered.

In combined operation, the CHP unit and heat pump can achieve an overall efficiency of around 120% even in winter, despite a low COP.

How to square the circle

With the combination of cogeneration unit, heat pump and peak load heat source, all aspects of the energy policy target triangle can be realised simultaneously with an aligned design and intelligent operation management:

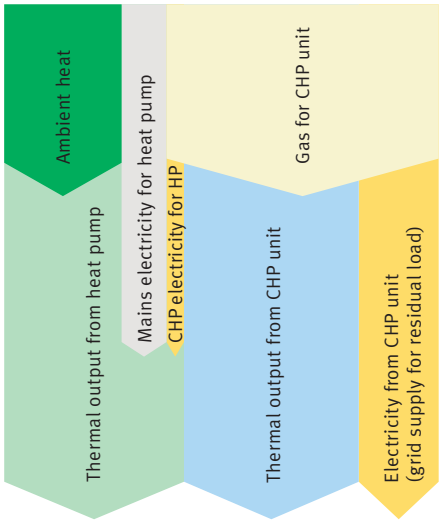


- Sustainability
  - the heat pump uses renewable electricity to recover a high proportion of ambient heat,
  - the cogeneration unit covers the residual load with maximum efficiency using increasing amounts of green gases.

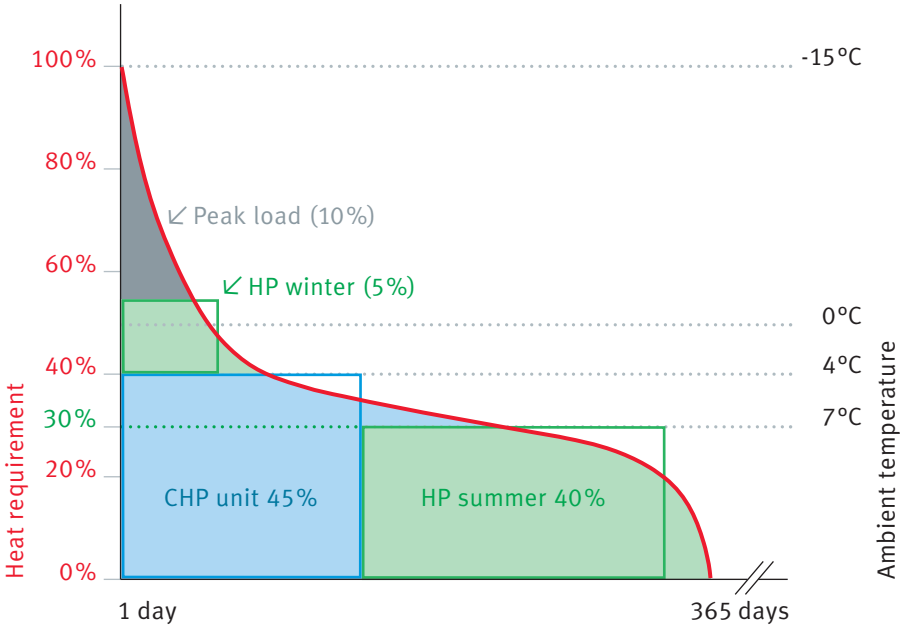
- Profitability
  - minimised electricity demand for the heat pump,
  - maximised electricity profits for the combined heat and power plant.

- Security of supply
  - various forms of energy for heat supply and redundant design for high security of supply.

Energy flow diagram CHP unit and heat pump



Annual load curve and heat sources



Classification of legal requirements

The RePowerEU plan, published in May 2022 as a cornerstone of the European Green Deal, targets the installation of ten million heat pumps in the European Union within the next five years. Our system solution, which consists of a hybrid heating system with a heat pump and a cogeneration unit, is aligned with this perspective. Country-specific heating roadmaps can be considered with combinations of heat pumps and cogeneration units that we design individually for each project. With customised design and smart operation management, the heat pump generates heat from surplus electricity at moderate outside temperatures with a very good coefficient of performance, and the cogeneration unit supplies heat at low outside temperatures and, at the same time, the electricity that is then needed in the grid – tailored to the demand, sustainable and economical.

Smart management

Our heat pumps are operated and monitored using the well-proven iPC control system which is also used in our combined heat and power plants. This ensures a simple connection to our internet-based remote monitoring system **RemoteManager**. In order to achieve the lowest possible heat generation costs with the combination of cogeneration unit and heat pump, the most cost-effective operation of the heat supply system is of central importance. Our **MiniManager Plus**, as a functional component of the iPC control system, determines the order of priority of the heat sources for a cost-optimised heat supply. In addition to the heat requirement and the filling level of the buffer storage, the criteria for selection are the COP of the heat pump, gas and electricity prices and the feed-in tariff to be expected for the CHP electricity.

Heat pump portfolio

For buildings or heating networks with heating water flow temperatures of up to 55 °C, our cost-effective, single-circuit air/water heat pumps with the modern low-GWP refrigerant R454B are used as compact devices for outdoor installation. Depending on the ambient and flow temperature, these frequency-controlled units achieve an outstanding efficiency with a COP of more than 4.

Our second heat pump series for comparable applications covers flow temperatures of up to 70 °C using the natural refrigerant R290 (propane). Thanks to the cascaded design, the capacity can also be adjusted in a wide range at maximum efficiency. An additional advantage of this series is the approximately 12 % higher COP at medium heating water temperatures.

In combination with a cogeneration unit, the flow temperature of both heat pump variants can be seasonally raised to a higher level during the transition period and in winter.

Additionally, we offer customised heat pumps for special applications and higher flow temperatures. They are designed with a single circuit or with a combination of a low-pressure and high-pressure unit to suit the specific requirements of the project. Depending on the available temperature of the heat source, we pay particular attention to optimising the COP during the design process.

System solution for real estate supply (example)

Max. heat demand approx. (Q_{max})	Air/water heat pump Type	Thermal output*	Cogeneration unit Type	Thermal output	Electrical output
250 kW	WP 130 M	83 kW	GG 50	107 kW	50 kW
350 kW	WP 160 M	109 kW	GG 70	139 kW	70 kW
450 kW	WP 200 M	132 kW	GG 140 r100	171 kW	100 kW
550 kW	WP 260 M	175 kW	GG 140	216 kW	140 kW
800 kW	2 x WP 200 M	264 kW	GG 202	323 kW	200 kW
1.000 kW	2 x WP 230 M	320 kW	GG 260	394 kW	260 kW
more than 1,000 kW					Customised configuration

* at 55 °C flow temperature
Partial load point A according to EN 14825 at -7 °C ambient temperature

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