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Innovators above the standards

Smart city: heat pumps applied to data centers

Poletto Fabio, 24/05/2023

Increasing data creation leads to high demand for data centers, driving the need for infrastructure across the globe.

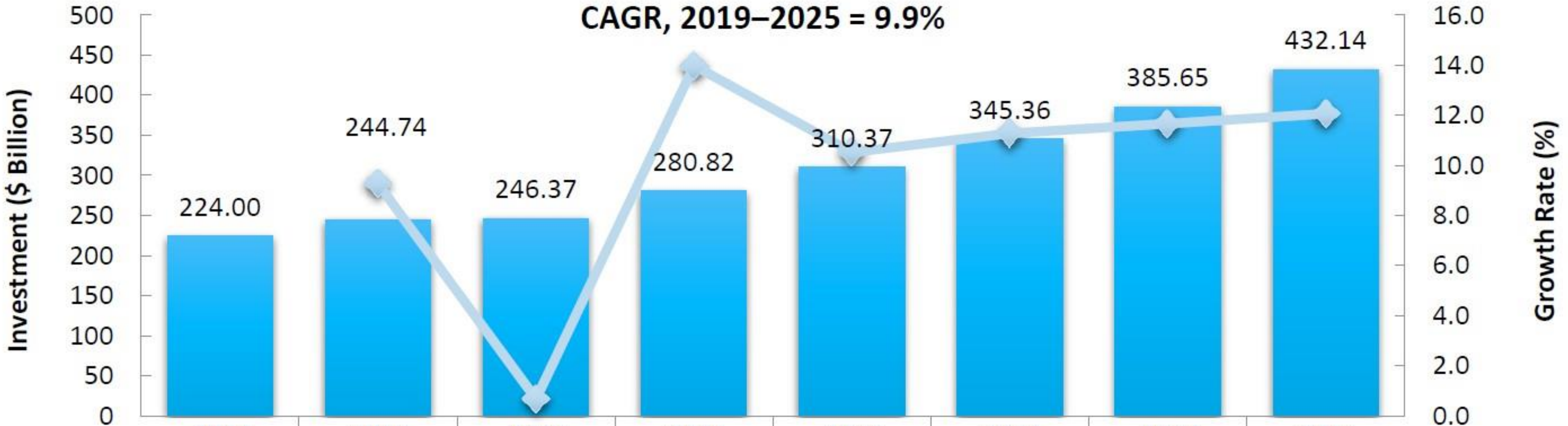
Emerging technologies such as 5G lead to newer types of Edge Data Centers to be developed

Growth in colocation and cloud services leads to increased medium and hyperscale data center development.

Hyperscale data centers are expected to increase from 509 data centers in 2019 to 890 in 2025 – CAGR 9,7%

Increasing HYPERSCALE AND COLOCATION investments drive the data center infrastructure market

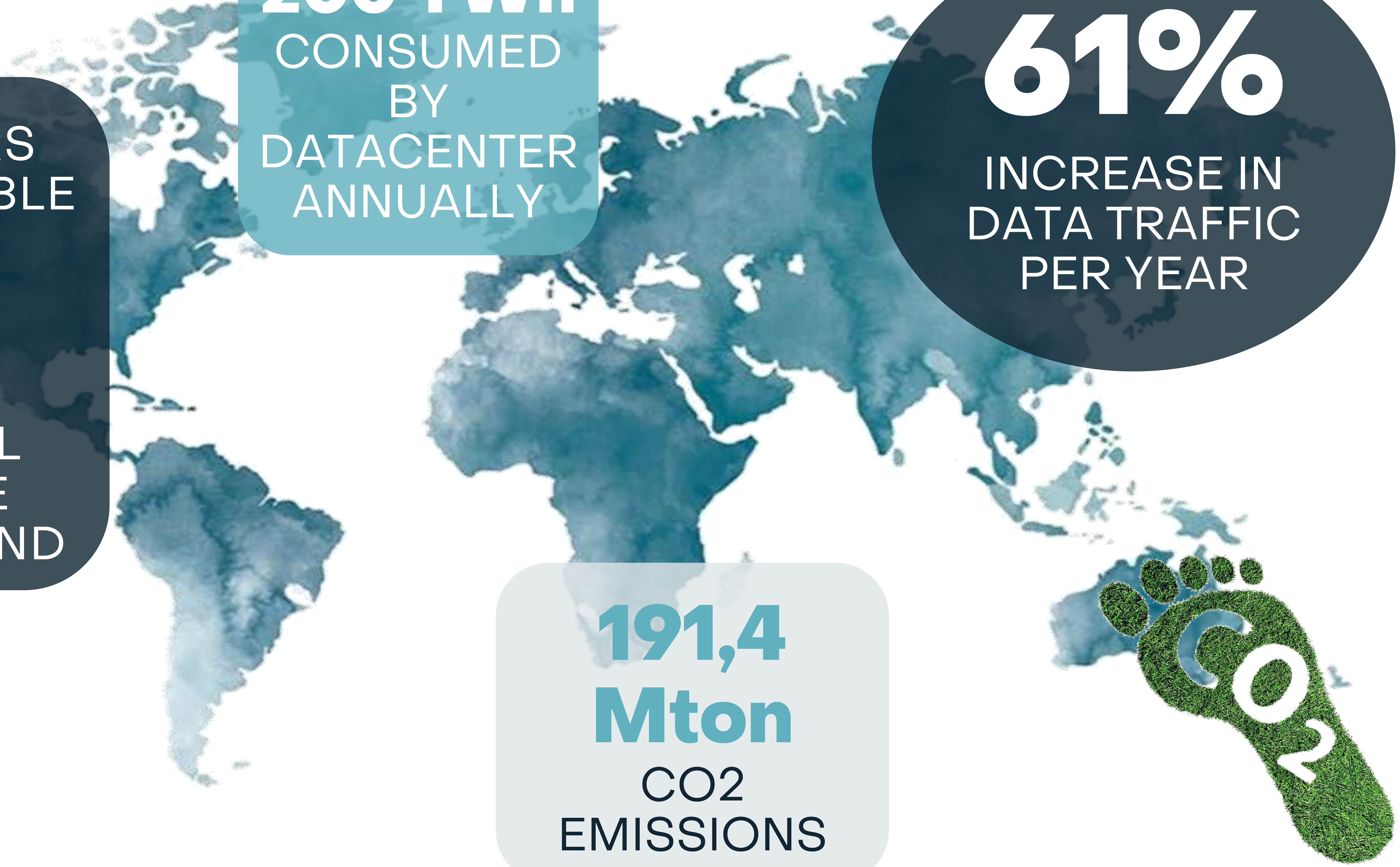
DC Investment Growth Forecast: Global, 2018–2025



	2018	2019	2020	2021	2022	2023	2024	2025
Investment	224.00	244.74	246.37	280.82	310.37	345.36	385.65	432.14
Growth Rate	-	9.26	0.67	13.98	10.52	11.28	11.66	12.06

Source: Frost & Sullivan

Global Data Center consumption



DATA CENTERS ARE RESPONSIBLE FOR

1%

OF THE TOTAL WORLDWIDE ENERGY DEMAND

200 TWh

CONSUMED BY DATACENTER ANNUALLY

61%

INCREASE IN DATA TRAFFIC PER YEAR

191,4 Mton

CO2 EMISSIONS

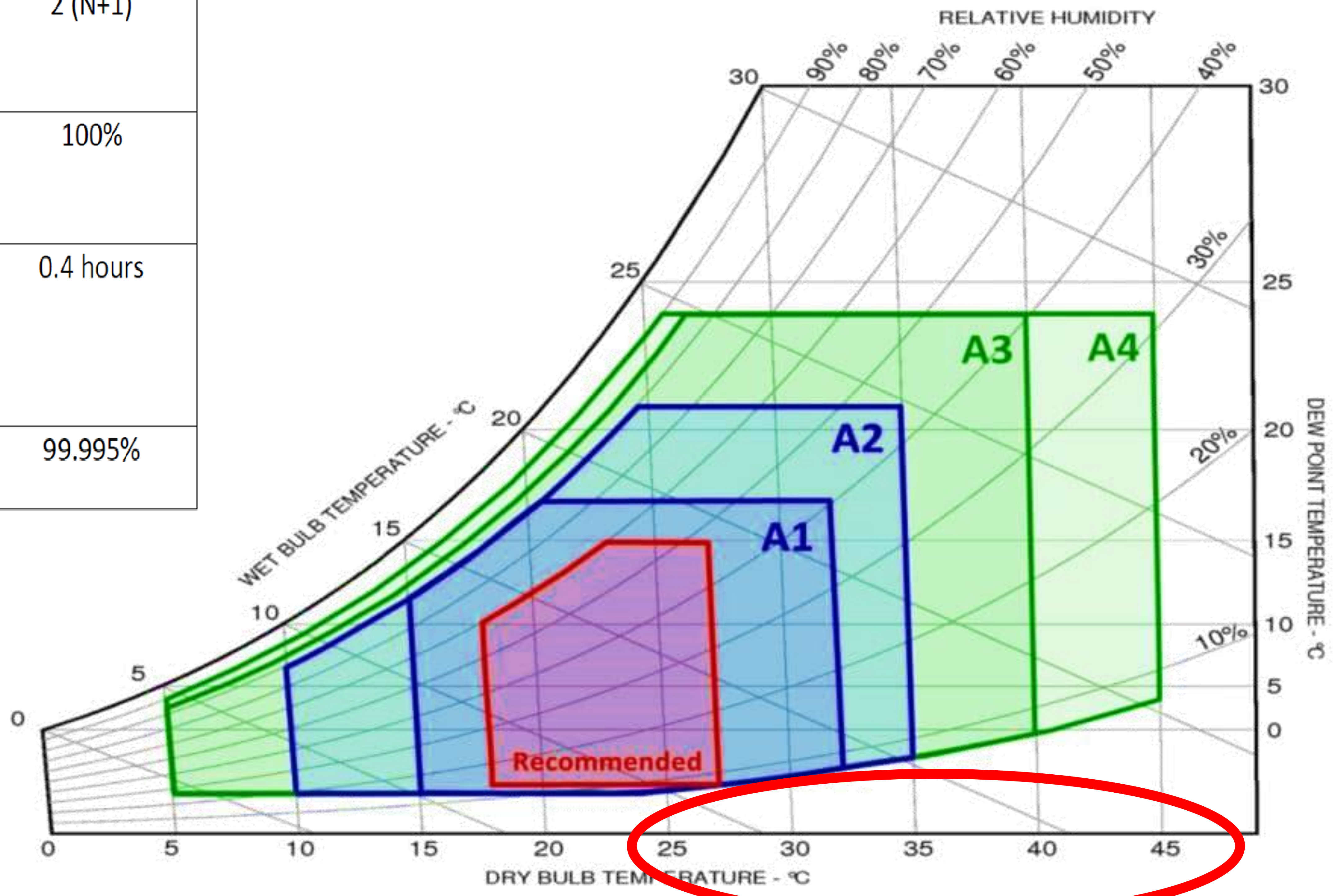
From: International Energy Agency

Cooling Trends impact in Data Center efficiency

Higher and higher temperature

Uptime Institute®

	Tier III	Tier IV
Number of delivery paths	One active One passive	Two active
Redundant components	N+1	2 (N+1)
Support space to raised floor ratio	80-90%	100%
Annual IT downtime due to site	1.6 hours	0.4 hours
Site availability	99.982%	99.995%



ASHRAE Thermal Guidelines for Datacom Equipment fourth edition psychrometric chart in SI units at sea level.

Growing of Liquid Cooling in the New Generation of Data Center

D2C

1-Phase

2-Phase

LESS AND LESS MECHANICAL COOLING

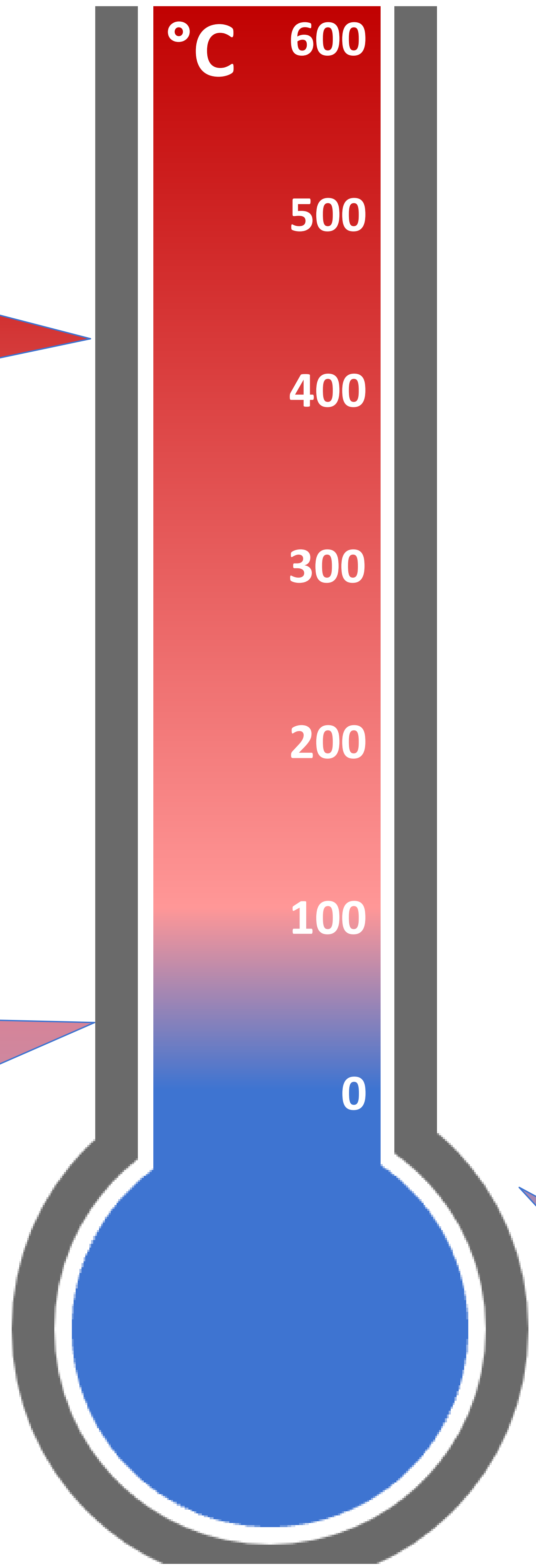
BUT

HEAT DISSIPATION IS ALWAYS REQUIRED:

THIS IS WASTE HEAT

Waste heat recovery

Which type of heat do we have?

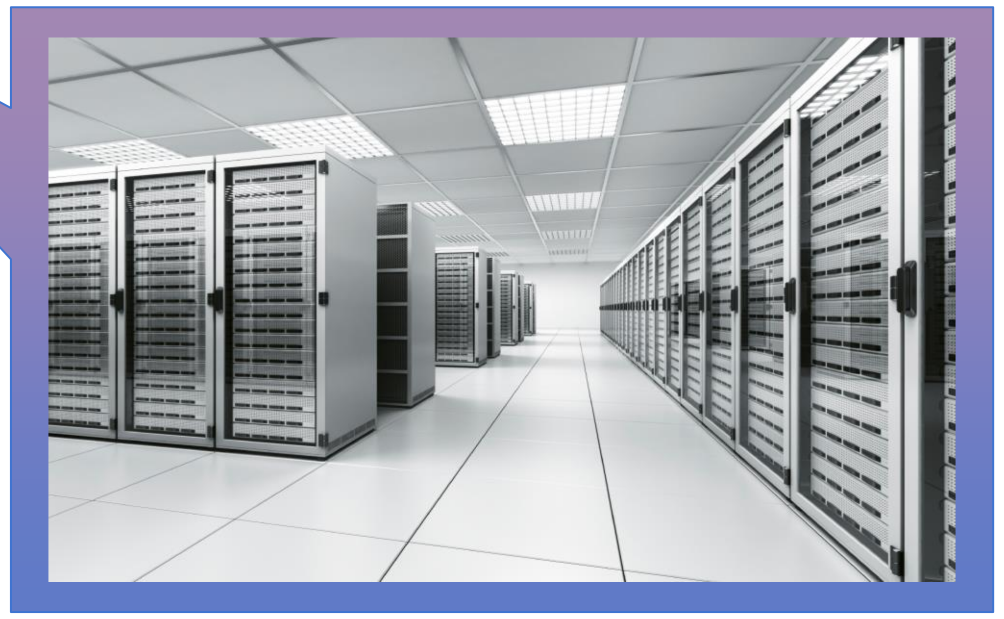


200 – 600°C
Exhaust from combustion process

50 – 100°C
Industrial Process

250 – 500°C
Waste heat from electricity production process

100 – 170°C
Steam generation plants



45-55°C
DC Liquid Cooling

20 – 40°C
Data Center Cooling

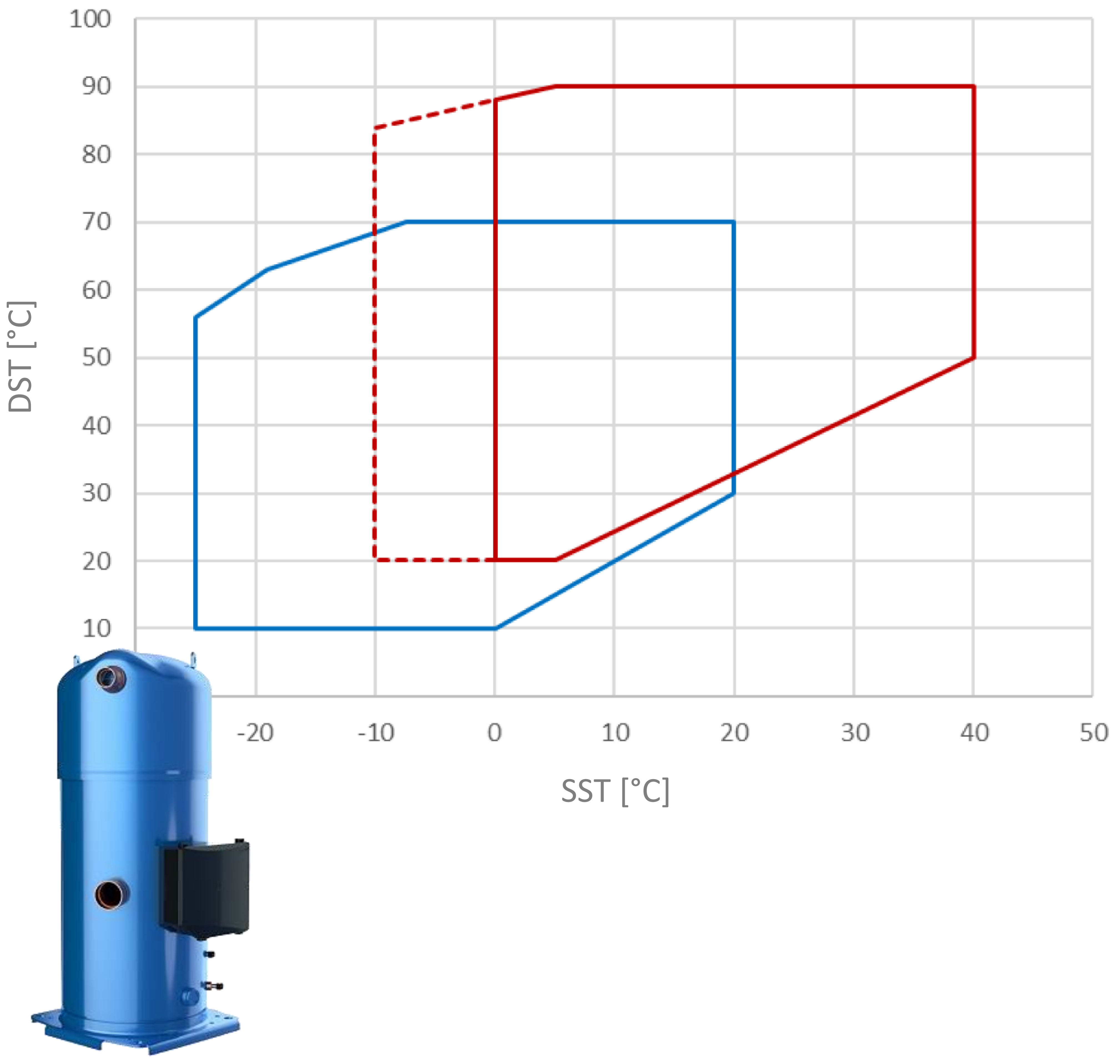
The heat pump is the way to increase the heat dissipation of a Data Center to the most useful temperature level

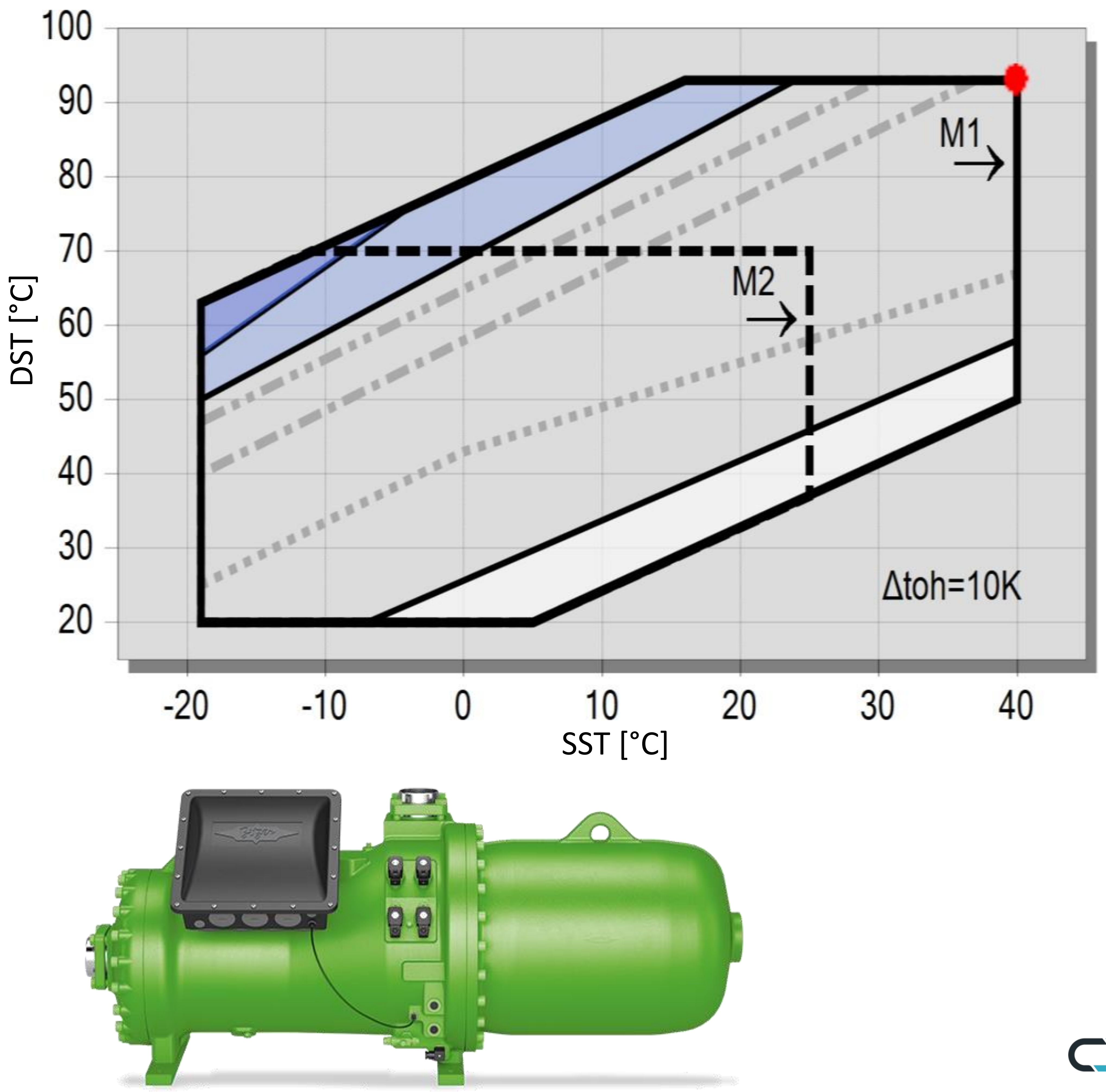
Suitable for high temperature sources up to 50°C

Suitable for high temperature production up to 90°C

High COP for better use of Electrical energy

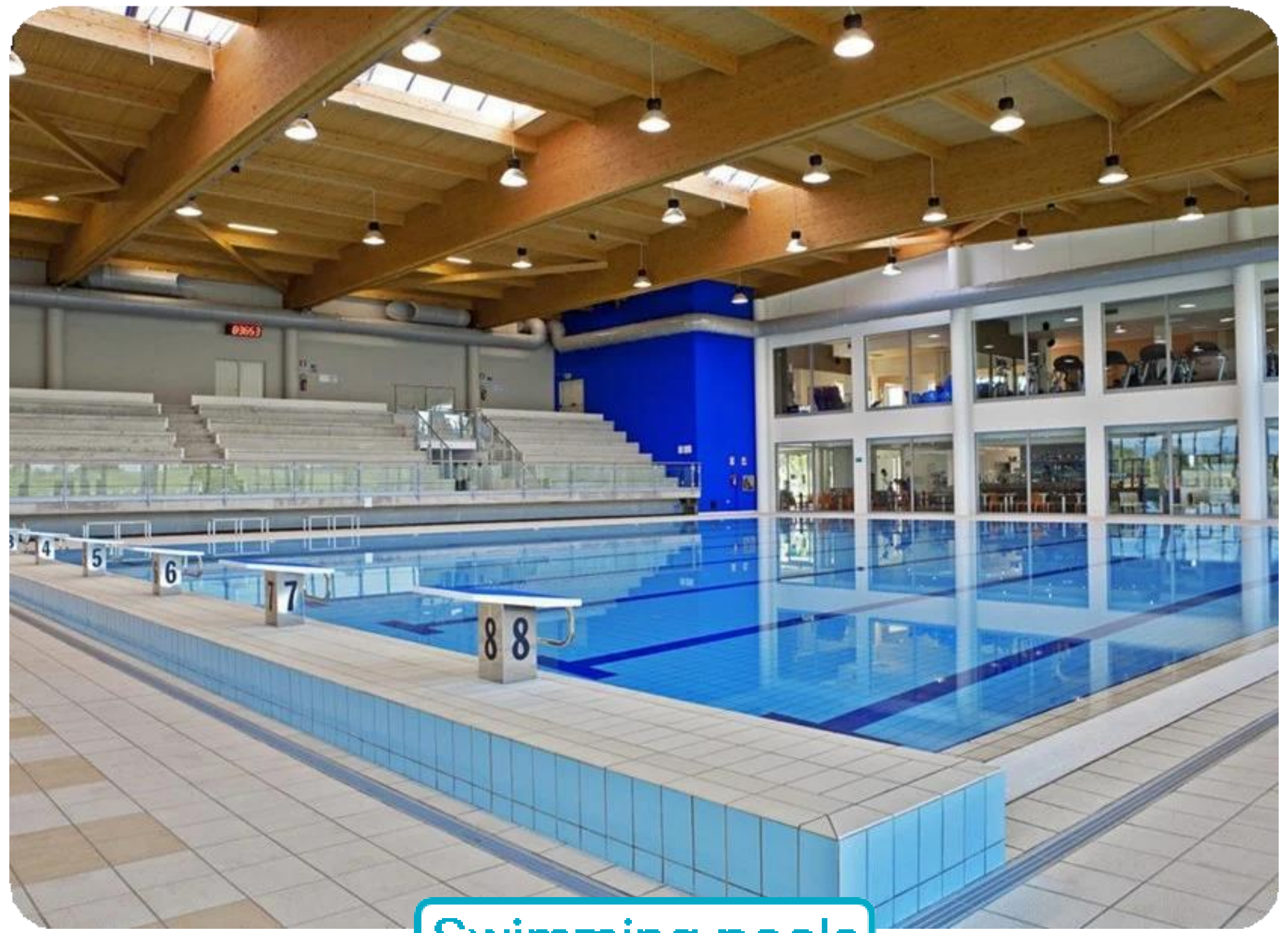
Optimized Operating Maps for High Temperature range





Heat reuse destinations

Heating for surrounding users


Swimming pools


Laundries

Hospitals

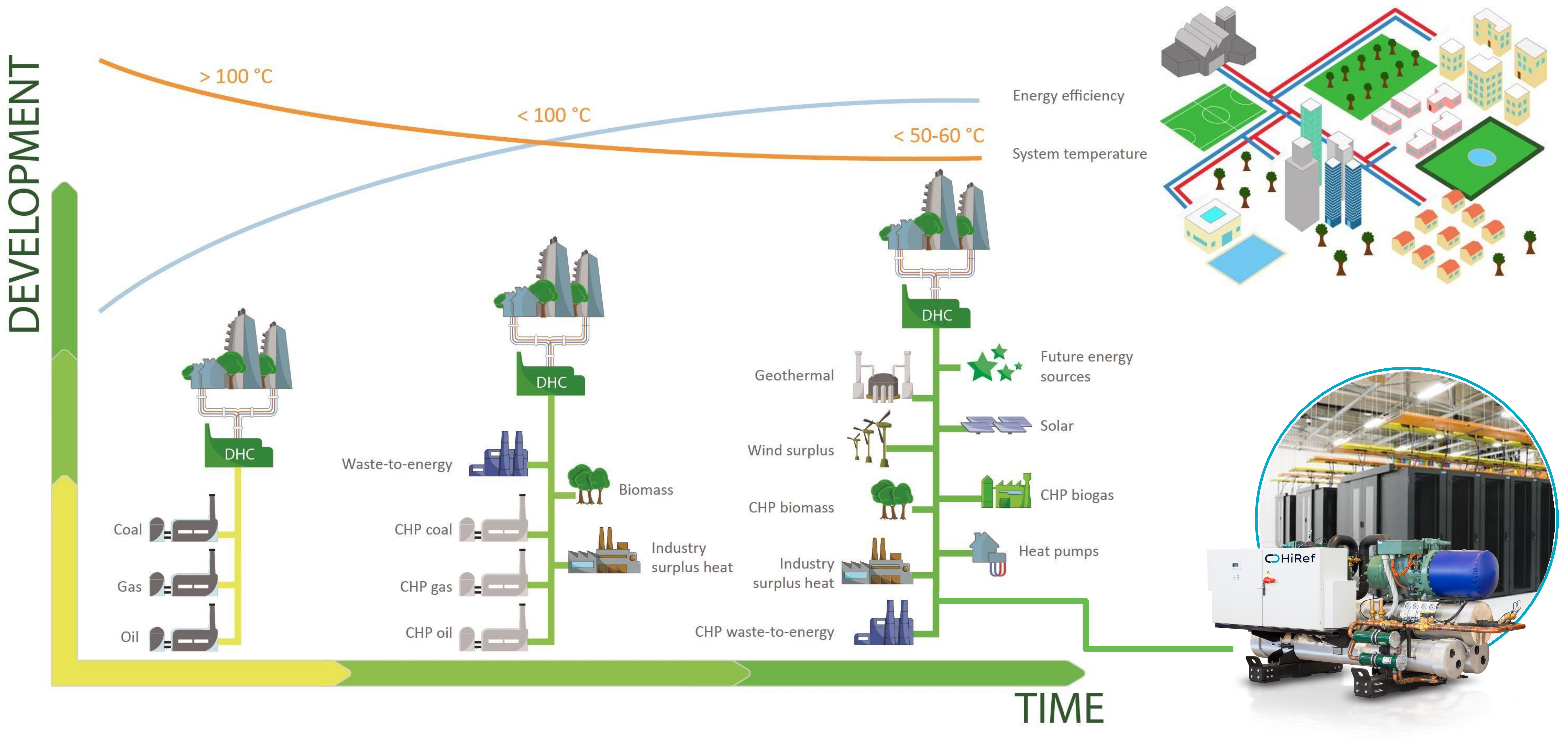

Food Drying Process

Heating for surrounding users

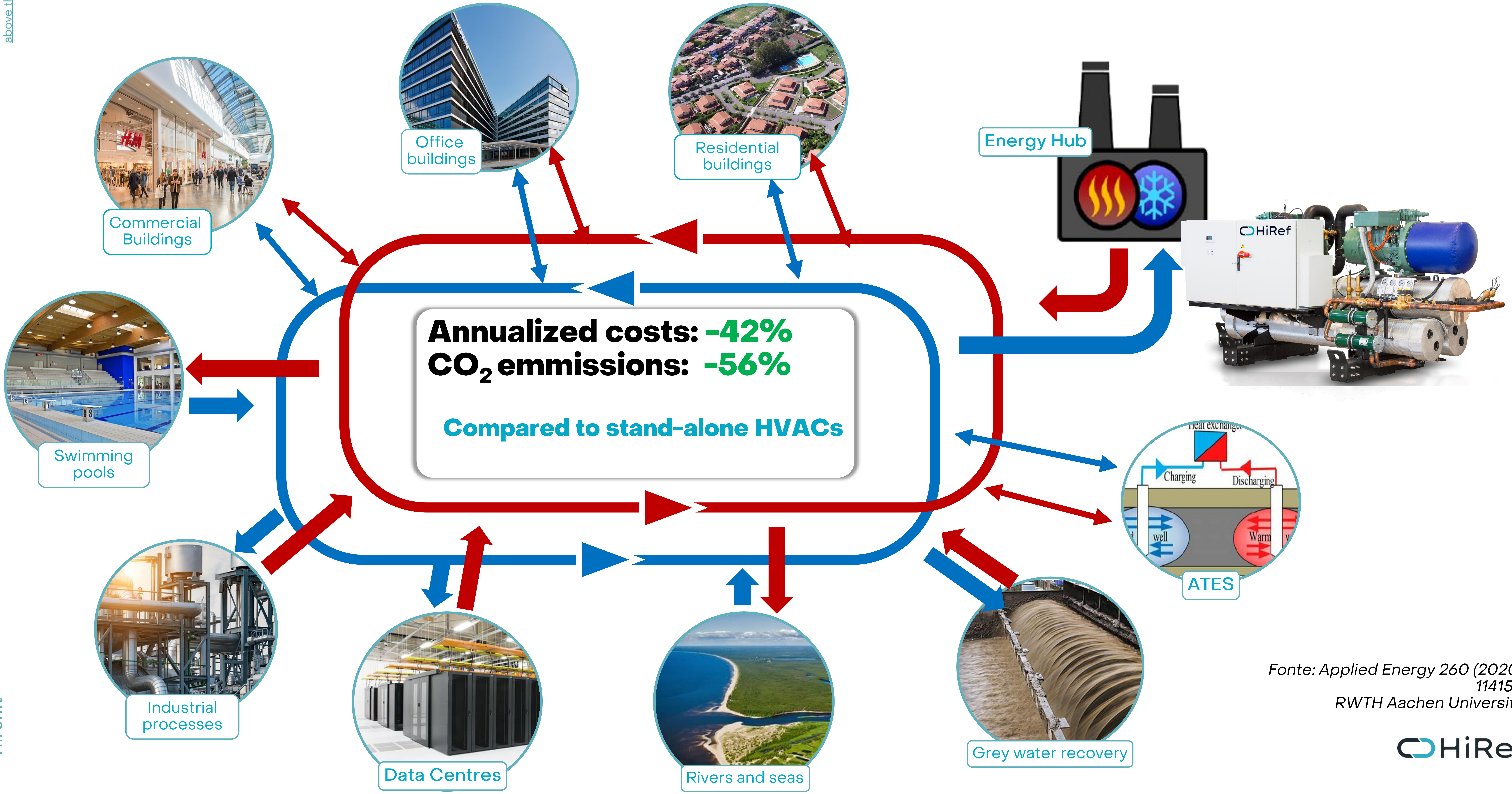
Farm Greenhouses

Vertical Farms

Integration in the District Heating Network



The Future is in the 5G District Heating Network



Fonte: Applied Energy 260 (2020) 114158
RWTH Aachen University

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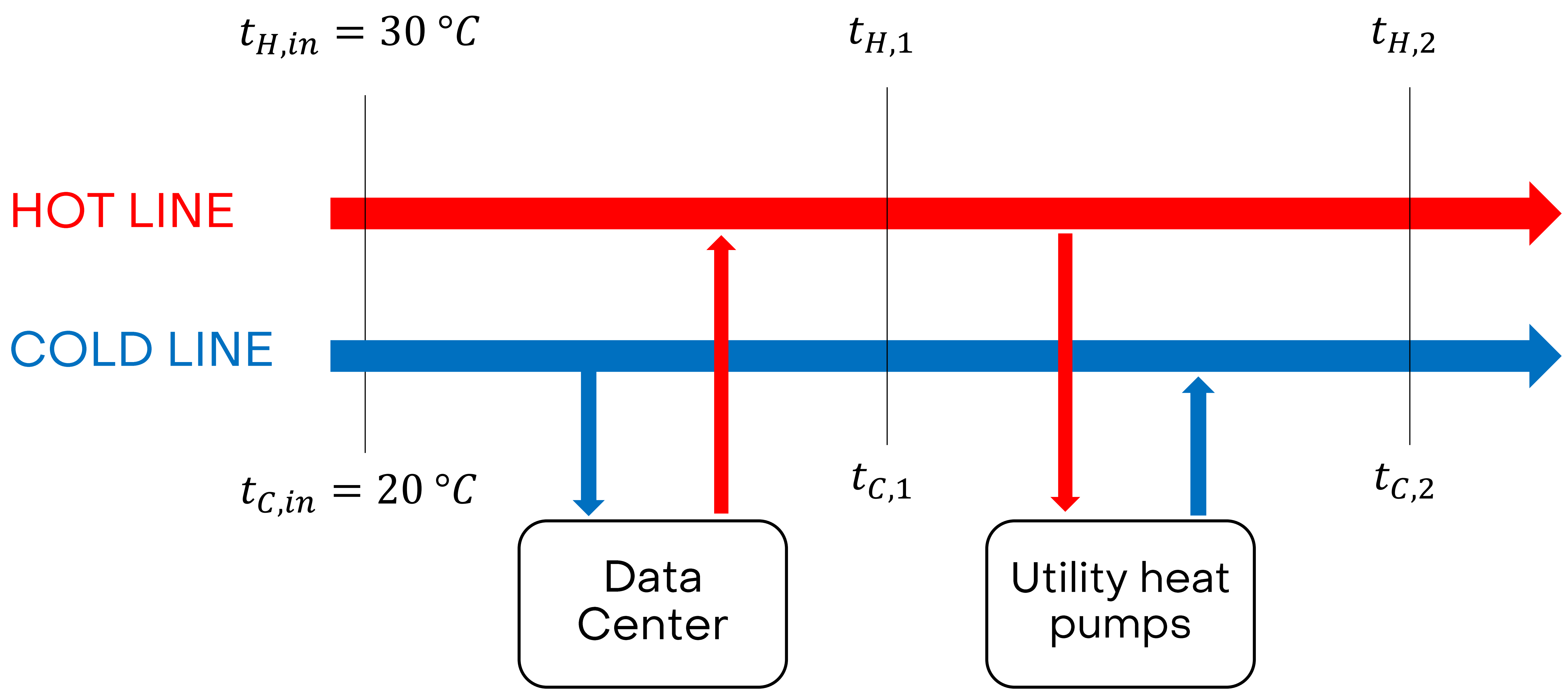
Network & Data Center Performances



The power balance is performed in each individual section where there is an external connection to the network, and the thermal evaluation of the heat transfer fluid is performed hour by hour.

The mathematical model can be used to evaluate:

- the operating temperatures of the network as the required heat/cooling load changes;
- the flow rates of the heat transfer fluid circulating in the network as the load changes;
- seasonal performance of heat pumps connected to the grid;
- the effectiveness of heat sources considered waste (such as Data Centers heat rejection)

Description of the mathematical model

A power balance will be used to study the thermal behavior of a district heating/cooling network (5GDHC).
It will take into account not only the powers entering and leaving the grid, but also the thermal storage present in the distribution network in every single section.

$$\rho c_p V * \left(\frac{t_{in_1} + t_{out_1}}{2} - \left(\frac{t_{in_1} + t_{out_1}}{2}\right)_{-\Delta\tau}\right) = \dot{m}_{in} c_p t_{in_1} - \dot{m}_{out} c_p t_{out_1} \pm Q_M + Q_T$$

- Thermal storage: $\rho c_p V * \left(\frac{t_{in_1} + t_{out_1}}{2} - \left(\frac{t_{in_1} + t_{out_1}}{2}\right)_{-\Delta\tau}\right)$
- Thermal power of the ring section: $\dot{m}_{in} c_p t_{in_1} - \dot{m}_{out} c_p t_{out_1}$
- Machine/Source power: Q_M
- Thermal losses to the ground: Q_T

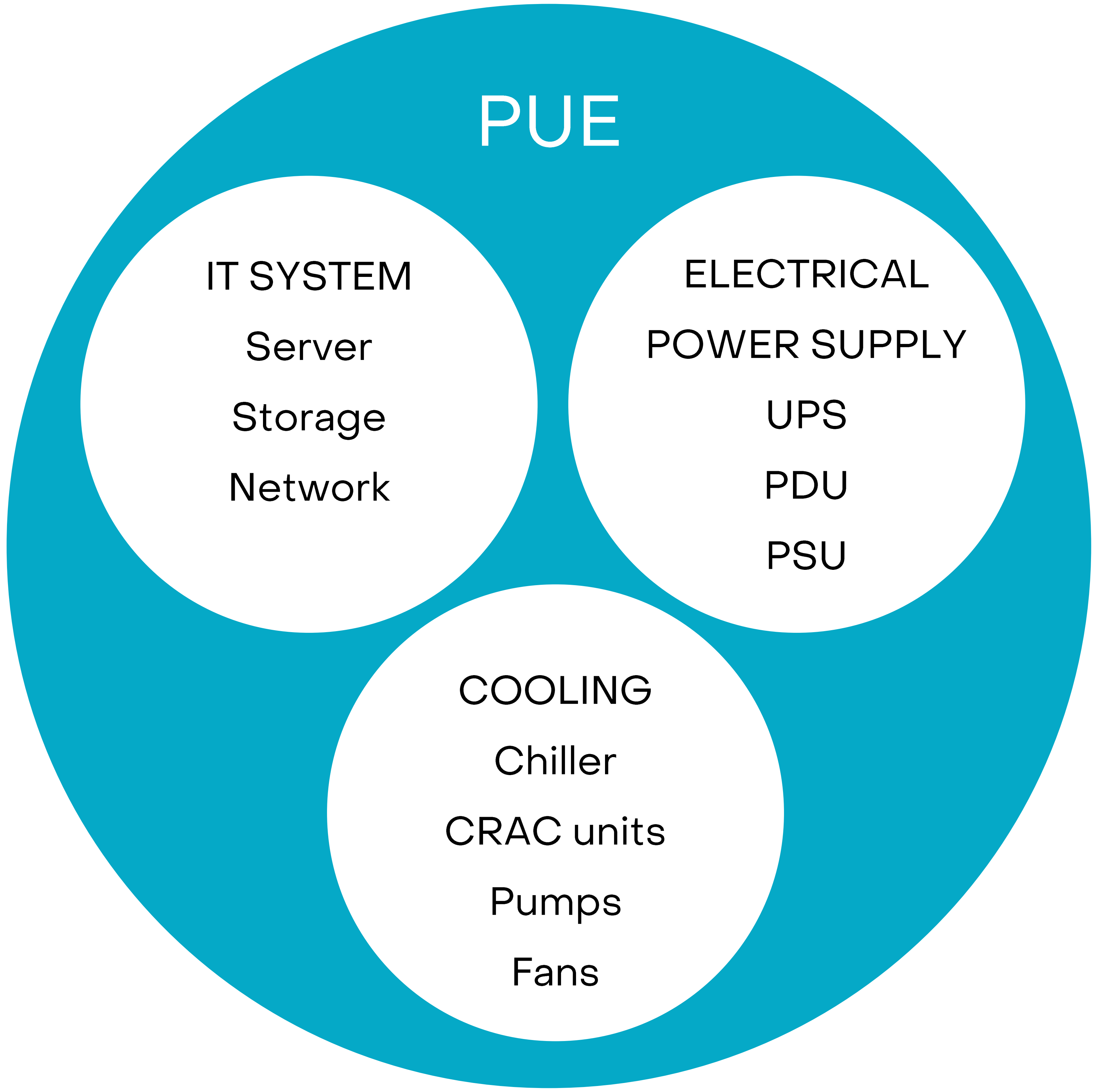
$$Q_T = \frac{L * \left(t_g - \frac{t_{in_1} + t_{out_1}}{2}\right)}{R_{TOT}}$$

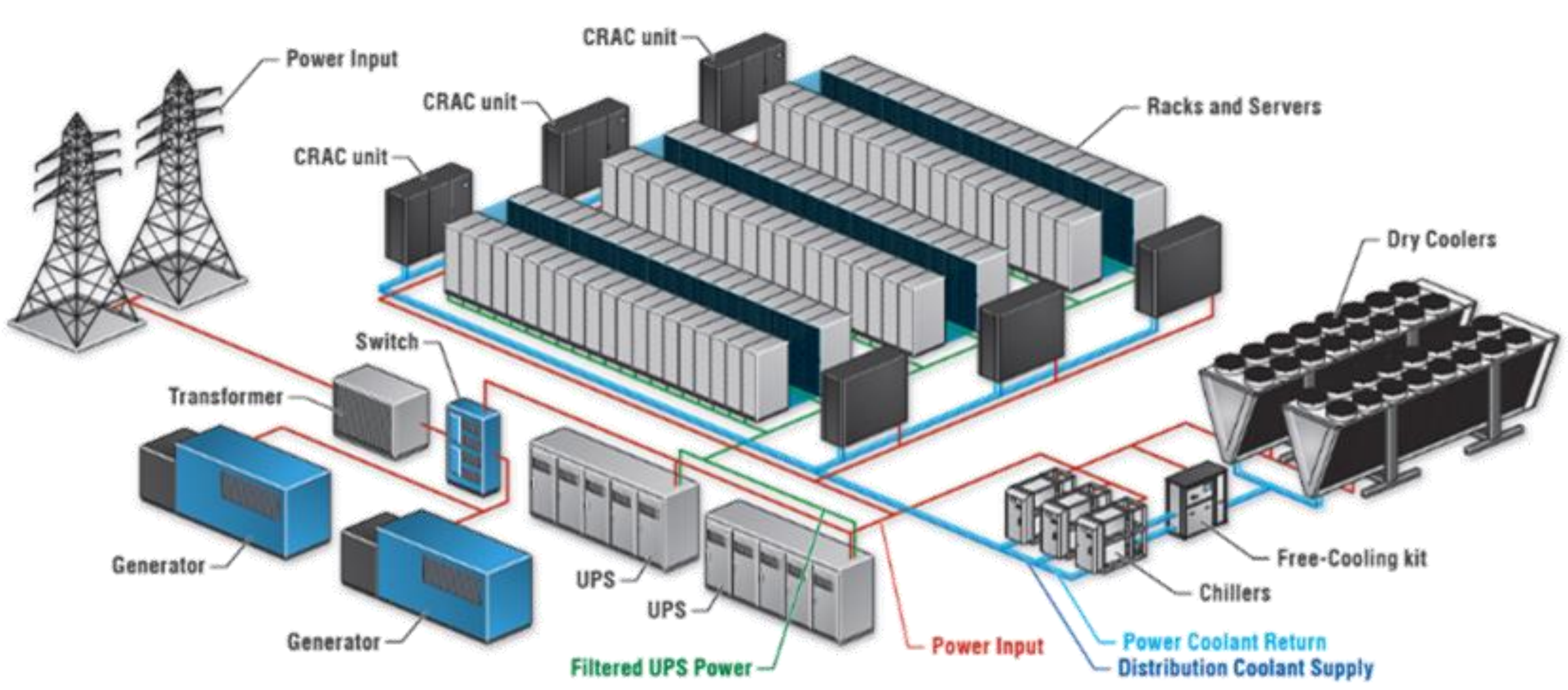
- **Thermal losses in the ground Q_T** take into account many aspects of the selected pipelines, such as: length, thermal resistance of materials and depth of installation.

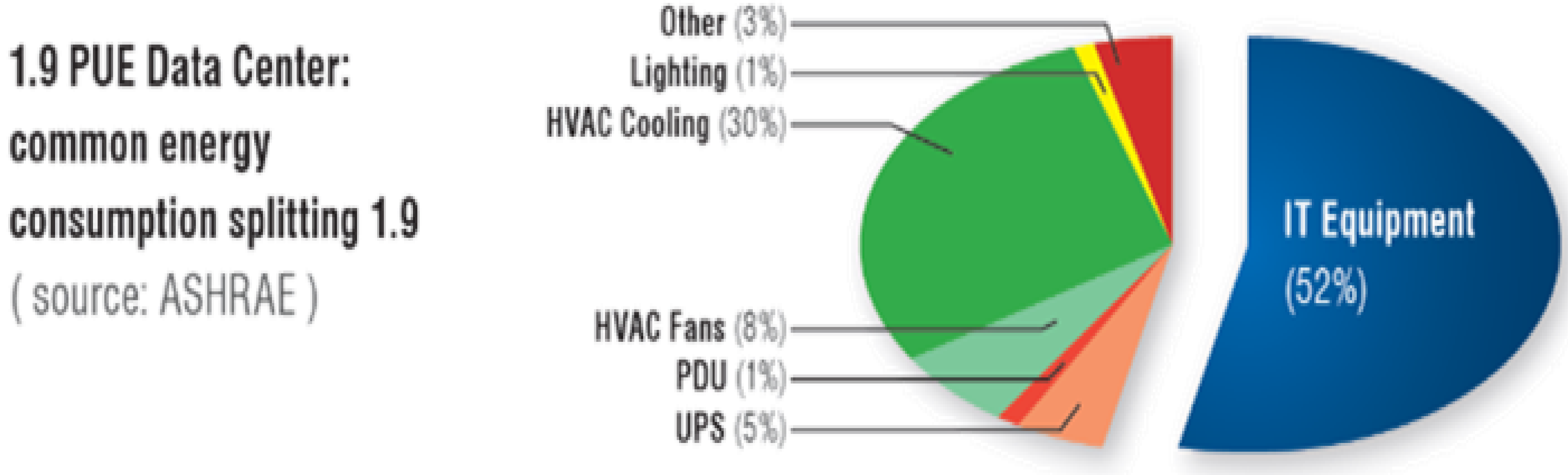
$$Q_M = \dot{m}_{PdC} c_p \left(t_{ring} \pm \Delta t_{machine}\right)$$

- **The power of the machines/source Q_M** allows the evaluation of the flow rates that are extracted from the network (or fed into the network), during their use in the heating / cooling period

Cooling impact in Data Center efficiency





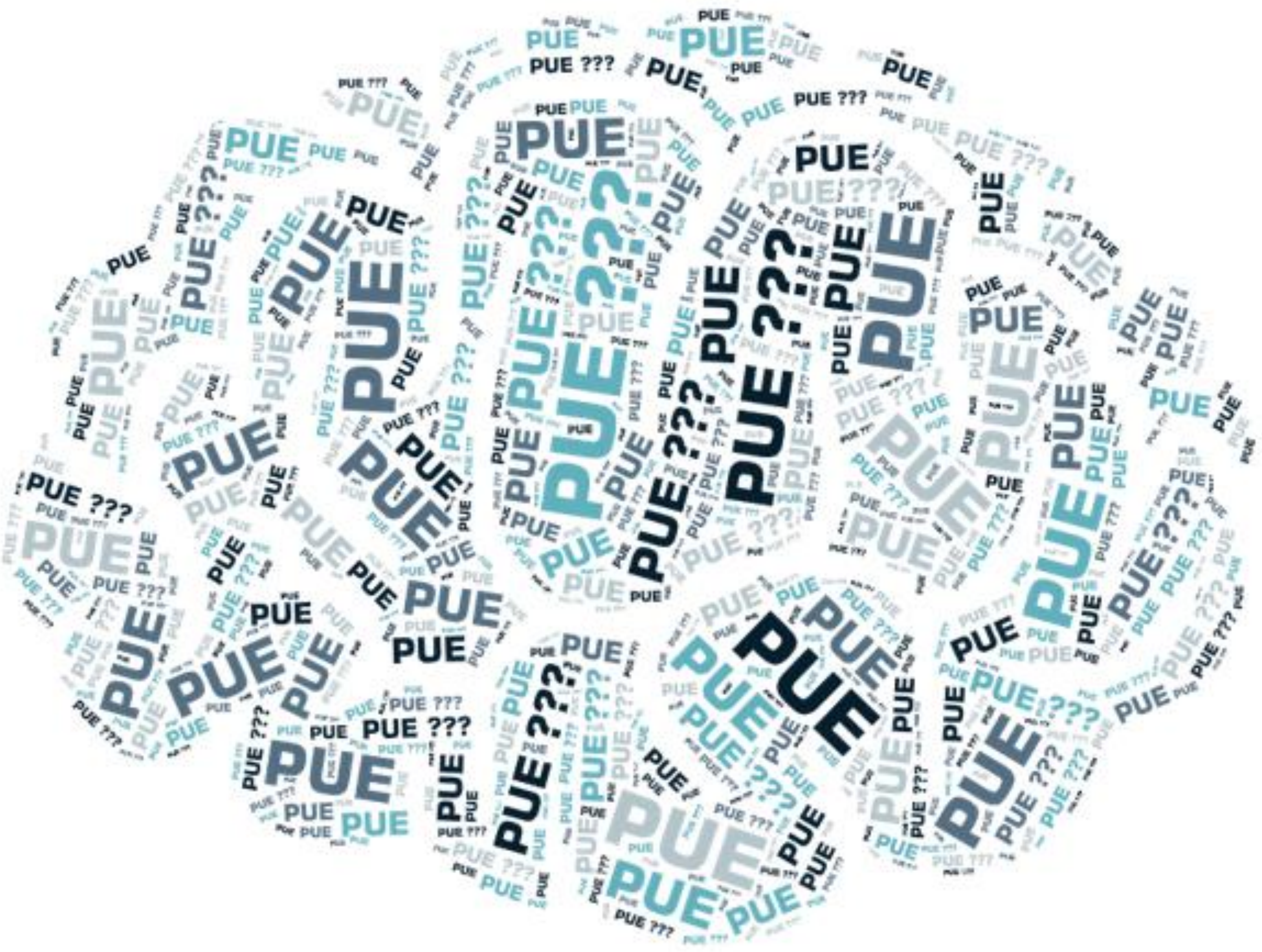


$$PUE = \frac{\text{TOTAL FACILITY ENERGY}}{\text{IT EQUIPMENT ENERGY}}$$

IS IT STILL THE PUE THE CORRECT PARAMETER TO BE CONSIDERED?

MAYBE NOT

$$PUE = \frac{Total\ energy}{IT\ energy}$$



With energy reuse, PUE value could go below 1.0;
however this is not allowed, since it is contrary to PUE definition.

New generic efficiency metrics shall be considered in order to provide more info about data center energy use and reuse.

$$\text{PUE} = \frac{\textit{Total energy}}{\textit{IT energy}}$$

$$= \frac{\textit{Cooling+Power Distribution+Misc+IT}}{\textit{IT Energy}};\ 1.0 \leq \text{PUE} \leq \infty$$

$$\text{ERE} = \frac{\textit{Total energy} - \boldsymbol{\textit{Reuse Energy}}}{\textit{IT energy}}$$

$$= \frac{\textit{Cooling+Power Distribution+Misc+IT} - \boldsymbol{\textit{Reuse}}}{\textit{IT Energy}};\ 0 \leq \text{ERE} \leq \infty$$

$$\text{ERF} = \frac{\textit{Reuse energy}}{\textit{Total energy}};\ 0 \leq \text{ERF} \leq 1.0$$

Source: Department of Mechanical Engineering, Aalto University
https://doi.org/10.1016/j.rser.2017.10.058

TIGHTER REGULATION

What may help drive data center exhaust heat re-use is a combination of the broader corporate push towards CARBON NEUTRALITY and SUSTAINABILITY

Finnish and Norwegian regulations require the reuse of residual heat:

data centers are considered complete heat suppliers

Some examples

Waste heat covers about

20.000

Helsinki residents heating demand

Reducing the electricity tax of heat pumps and data centers to a lower tax class promotes future carbon-neutrality projects.

Telia Finland's Pitäjänmäki

- It is one of the largest open data centers in the Nordic countries;
- The data center uses carbon-neutral electricity: hydropower and wind power;
- Clean recycled heat will be obtained from the data center to the district heating network as planned from June 2022;
- Helen's district heat will be fully carbon neutral by 2035.

From: https://www.teliacompany.com/

55 MW
surplus energy at
30 C
is planned to be used in Viborg district heating

Electrical heat pumps to boost temperature at apple to
50 °C

Apple, Viborg, Denmark

- The facility is also designed to capture excess heat from equipment inside the facility and conduct it into the district heating system to help warm homes in the neighboring community.

From: https://www.apple.com/, https://www.iea-ebc.org/

Helping to heat the High-Tech Campus

Businesses on the High-Tech Campus can lower their own carbon footprint.

Northc, Eindhoven, Netherlands

- Residual heat from this data center is brought via an underground ring system to other businesses on the High Tech Campus.
  In return, we receive cold water, which we then use to cool our customers' IT systems.

From: https://northdatacenters.com/en/northc-datacenters/eindhoven

The sustainability for the Data Center Market passes through the heat recovery and the integration in the smart city grid

The role of the heat-pumps for medium, high and ultra-high temperature will be fundamental in the transition

New metrics are required for evalutating the performances on the Data Center, not only PUE

Incentives and new regulations are needed to activate the improvement process for future sustainability

Thank you

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the standards

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