Cooling Without Warming:

Energy-Efficient ACs and Heat Pumps

Tuesday, 28 April 2026

SUSTAINABLE ENERGY WEEK

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Heat Pumps as High-Efficiency Heating and Cooling Systems

Björn Palm, KTH Royal Institute of technology

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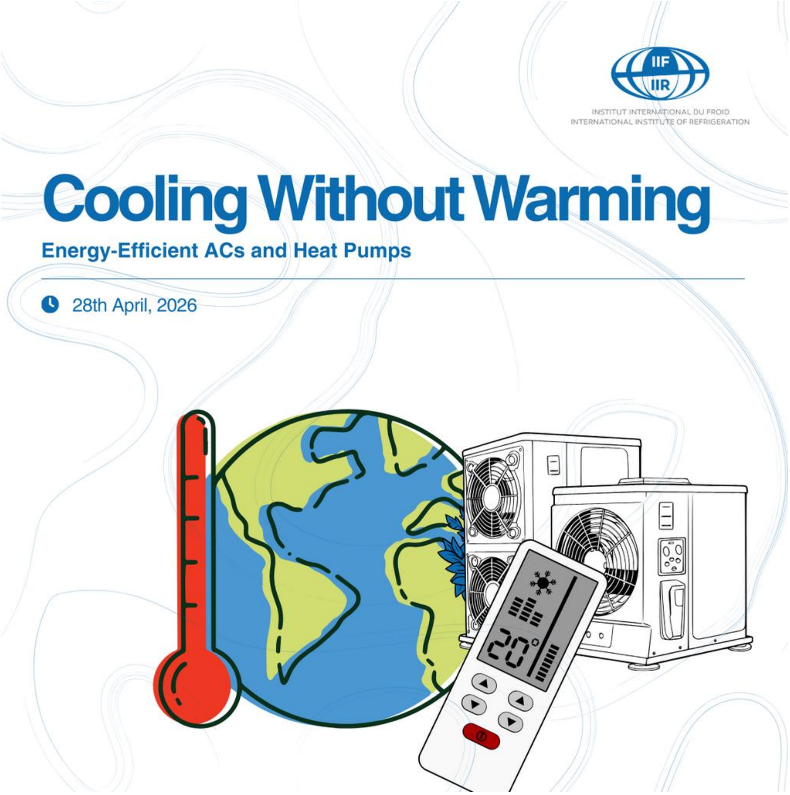
OUTLINE

- Introduction
- Use of energy for heating and cooling
- Effects on environment
- Development trends
- Implementing change to hp
- Conclusions



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Introduction

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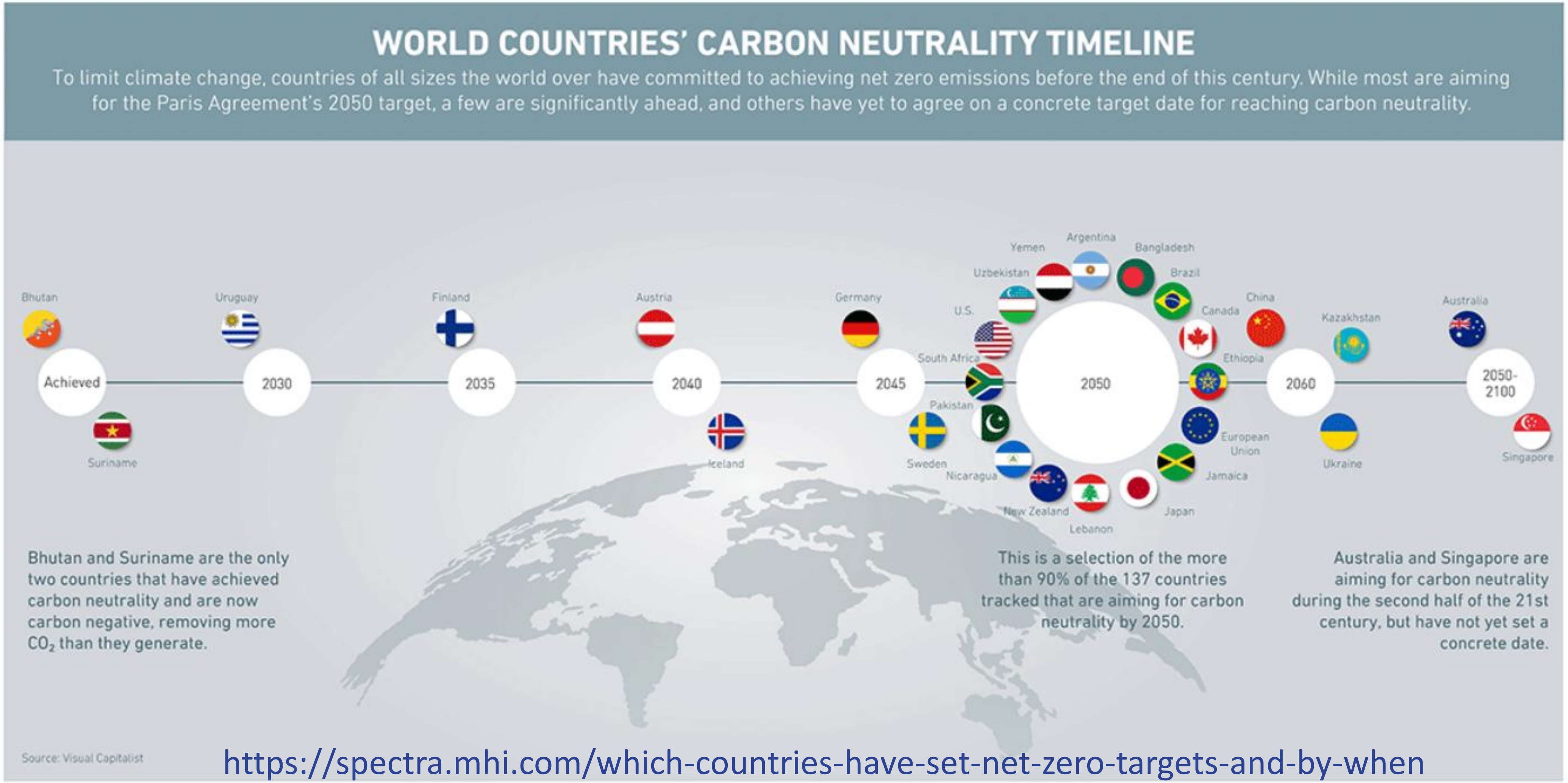
PARIS AGREEMENT – MOST COUNTRIES CARBON NEUTRAL BY ~ 2050



https://spectra.mhi.com/which-countries-have-set-net-zero-targets-and-by-when

First Conference on Transitioning Away from Fossil Fuels to be held in Santa Marta, Colombia in April 2026. View upcoming events in Santa Marta and globally.

About | Progress | Latest | Santa Marta | Get Involved | English | DONATE

THE FIRST CONFERENCE ON TRANSITIONING AWAY FROM FOSSIL FUELS

EVENTS

HOW TO GET INVOLVED

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Ongoing conference in Colombia

To date, we have the participation of over 53 nations:

Angola, Australia, Austria, Bangladesh, Belgium, Brazil, Cambodia, Cameroon, Canada, Chile, Costa Rica, Denmark, Dominican Republic, European Union, Fiji, Finland, France, Germany, Ghana, Guatemala, Iceland, Ireland, Italy, Jamaica, Kiribati, Luxembourg, Maldives, Marshall Islands, Mauritius, Mexico, Mongolia, Netherlands, Nigeria, Norway, Palau, Panama, Papua New Guinea, Philippines, Portugal, Senegal, Singapore, Slovenia, Spain, Sri Lanka, Sweden, Switzerland, Trinidad and Tobago, Türkiye, Tuvalu, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, Uruguay, Vanuatu, Vietnam.

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Use of energy for heating and cooling

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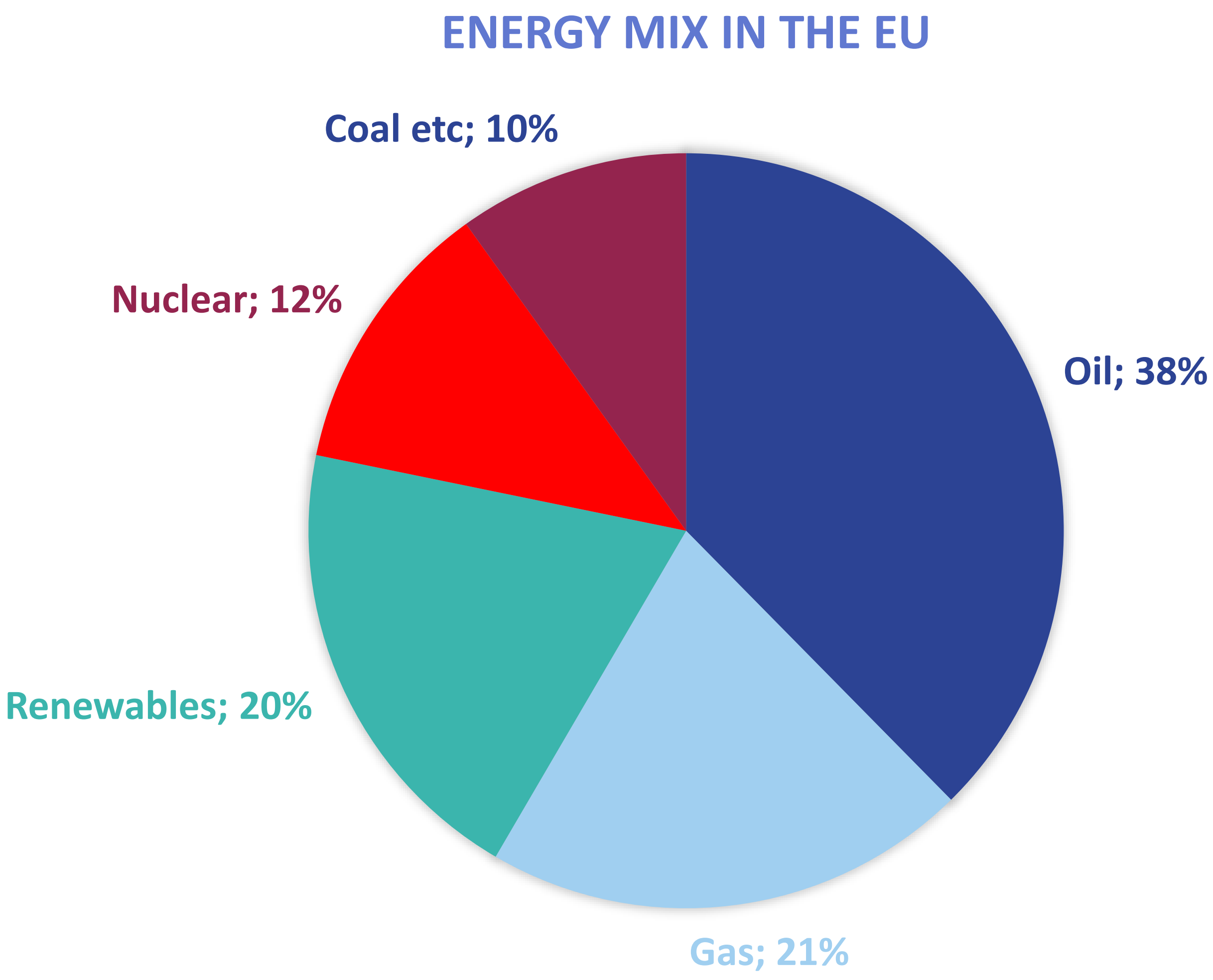
“Heating and cooling accounts for about half of the global final energy consumption and is responsible for more than 40% of global energy related CO2 emissions”
(IRENA)

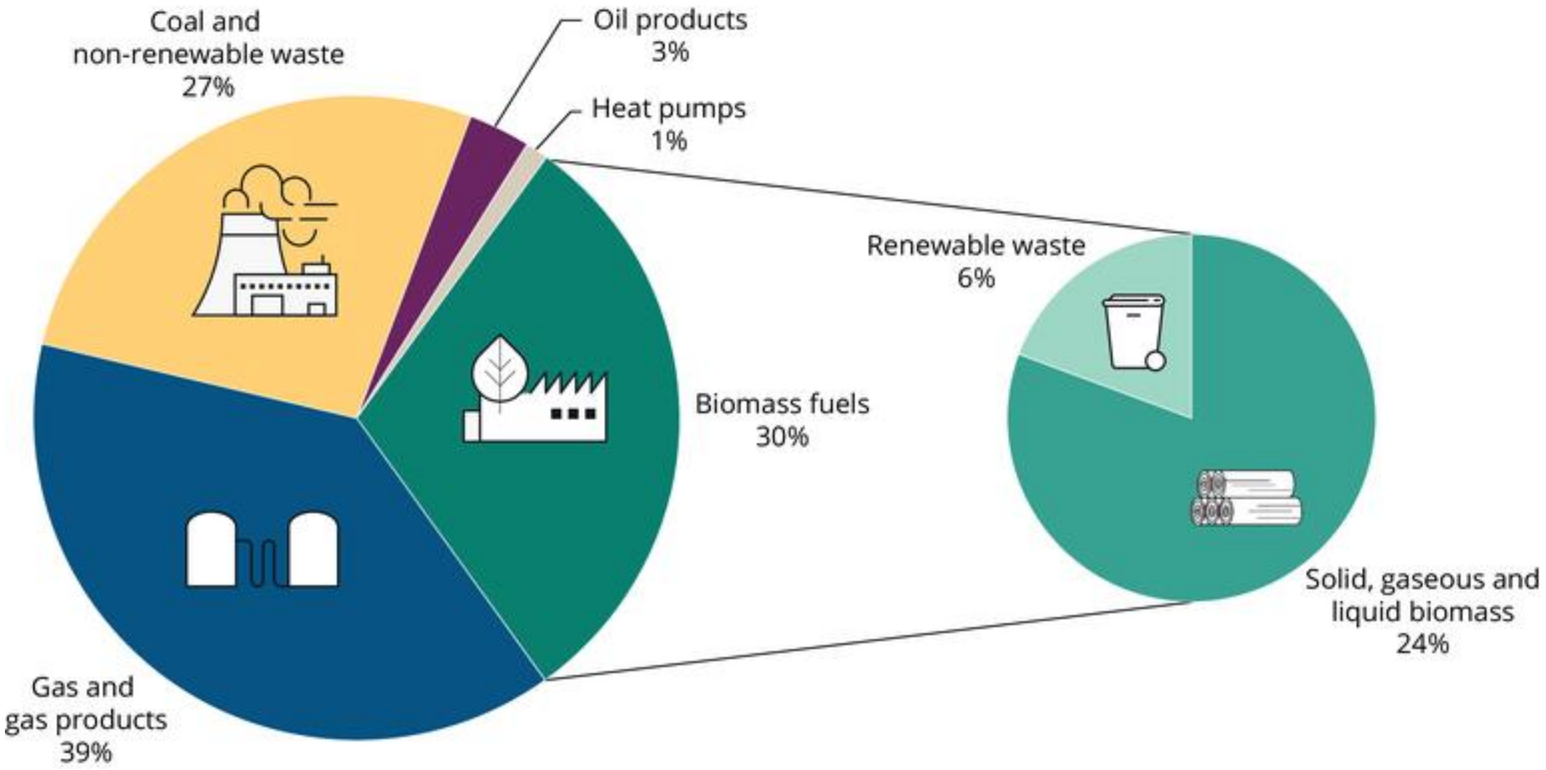
SOME STATISTICS

- About to 69% of all energy used in EU came from fossil fuels in 2024



SOME STATISTICS

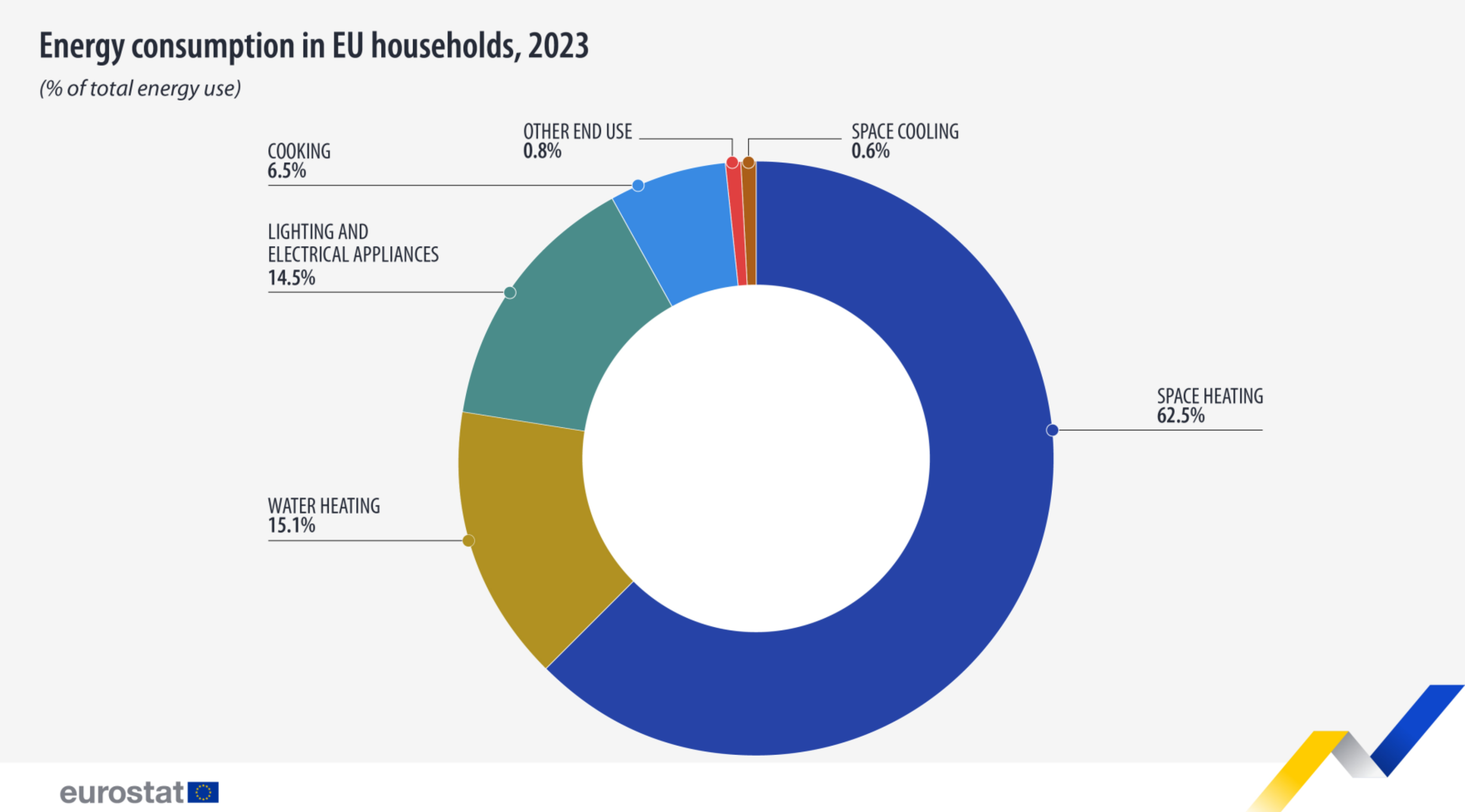
- About to 66% of all heating in EU was by fossil fuels in 2020



[Decarbonising heating and cooling — a climate imperative | Publications | European Environment Agency (EEA)]

SOME STATISTICS

- Heating stands for about 77% of the energy consumption in EU households
- Cooling stands for less than 1%



Energy use in EU households down second year in a row - News articles - Eurostat

WHERE DOES THE ELECTRICITY COME FROM?

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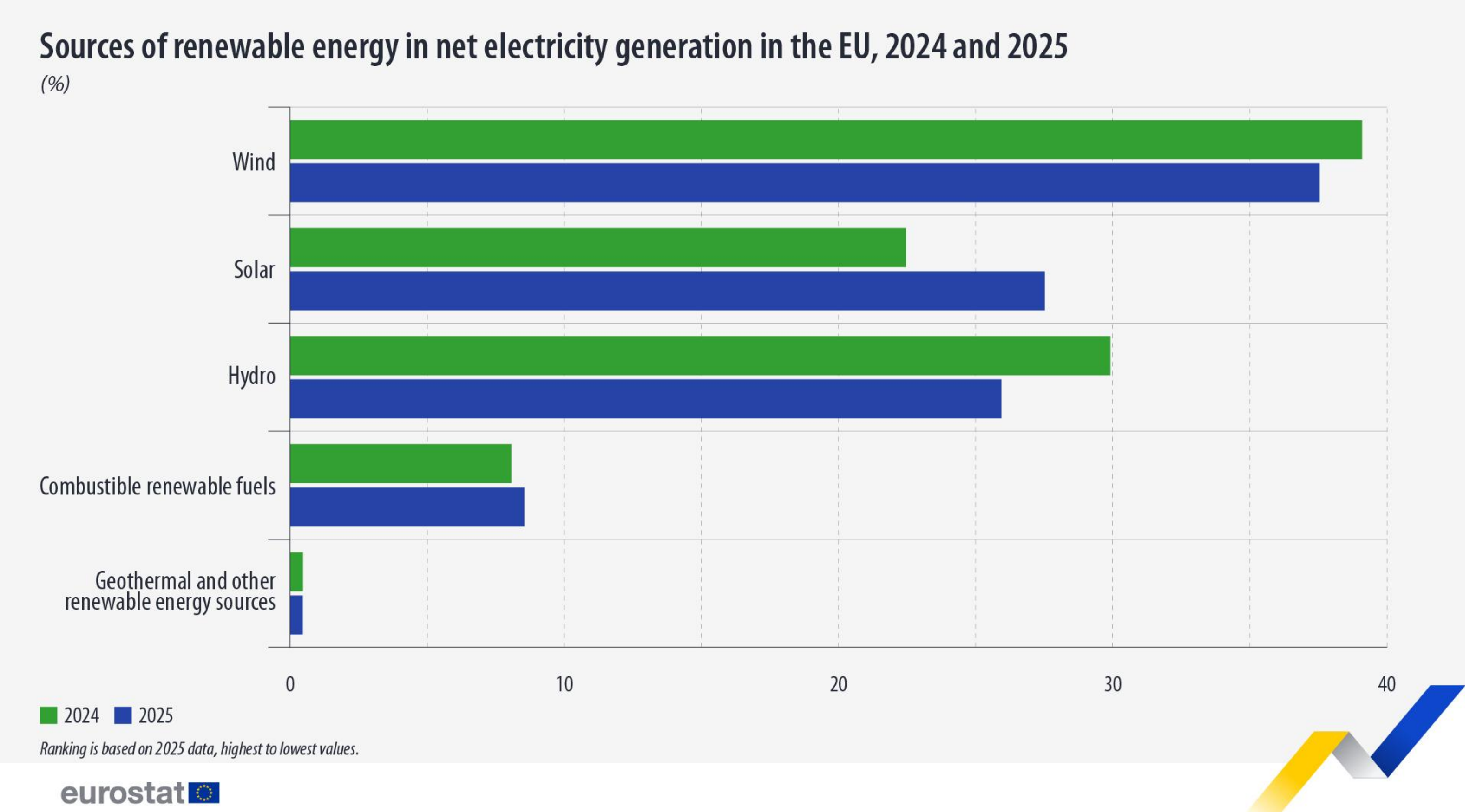
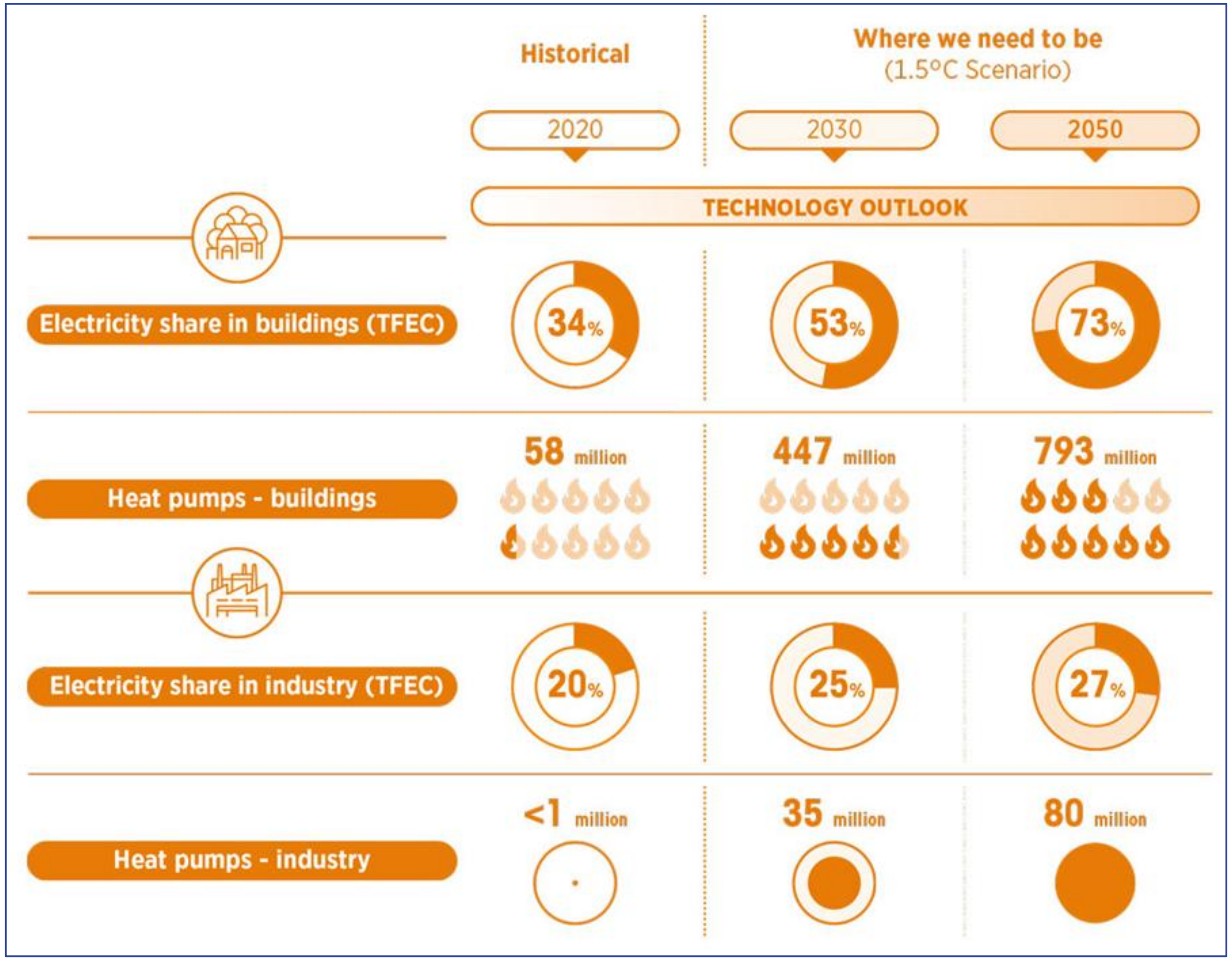
- In 2024 47.3% of the electricity generated in EU came from renewables
- and 23.3% from nuclear (EC)



Eurostat

WHERE WE ARE AND WHERE WE NEED TO BE

- IRENA´s 1.5C –scenario, worldwide
- “Electrification, primarily of heating, is the key strategy for decarbonising heating and cooling (and meeting the 1.5°C target by 2050)”



IRENA’s 1.5°C Scenario for the industry and buildings sectors

WHERE WE ARE AND WHERE WE NEED TO BE

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iea 50

Energy system · Topics · Countries · Data · Reports

Reports / Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030

Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030

Part of Technology and innovation pathways for zero-carbon-ready buildings by 2030

Overview

About this report

This analysis is part of a series from our new report, Technology and innovation pathways for zero-carbon-ready buildings by 2030, and

Published
September 2022

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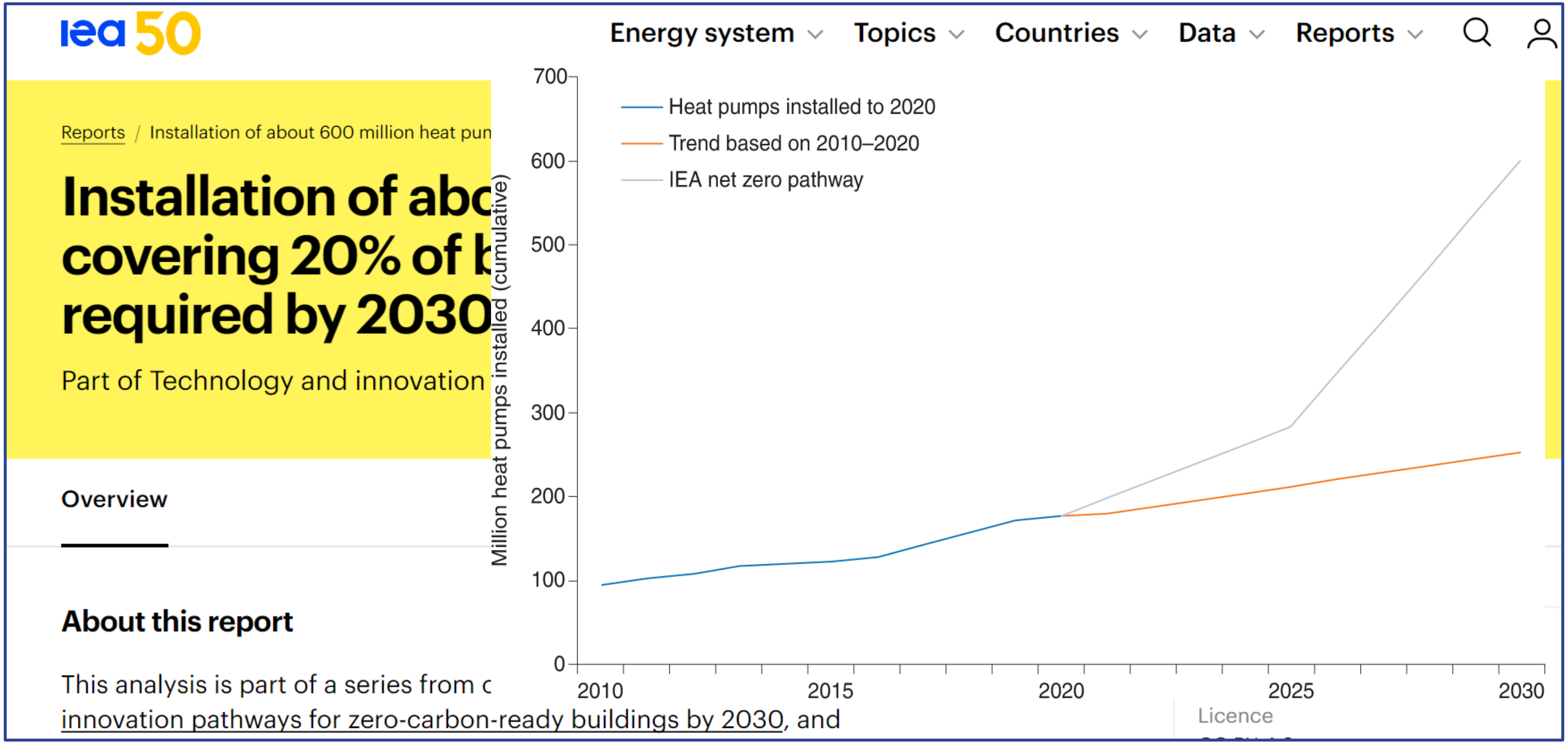
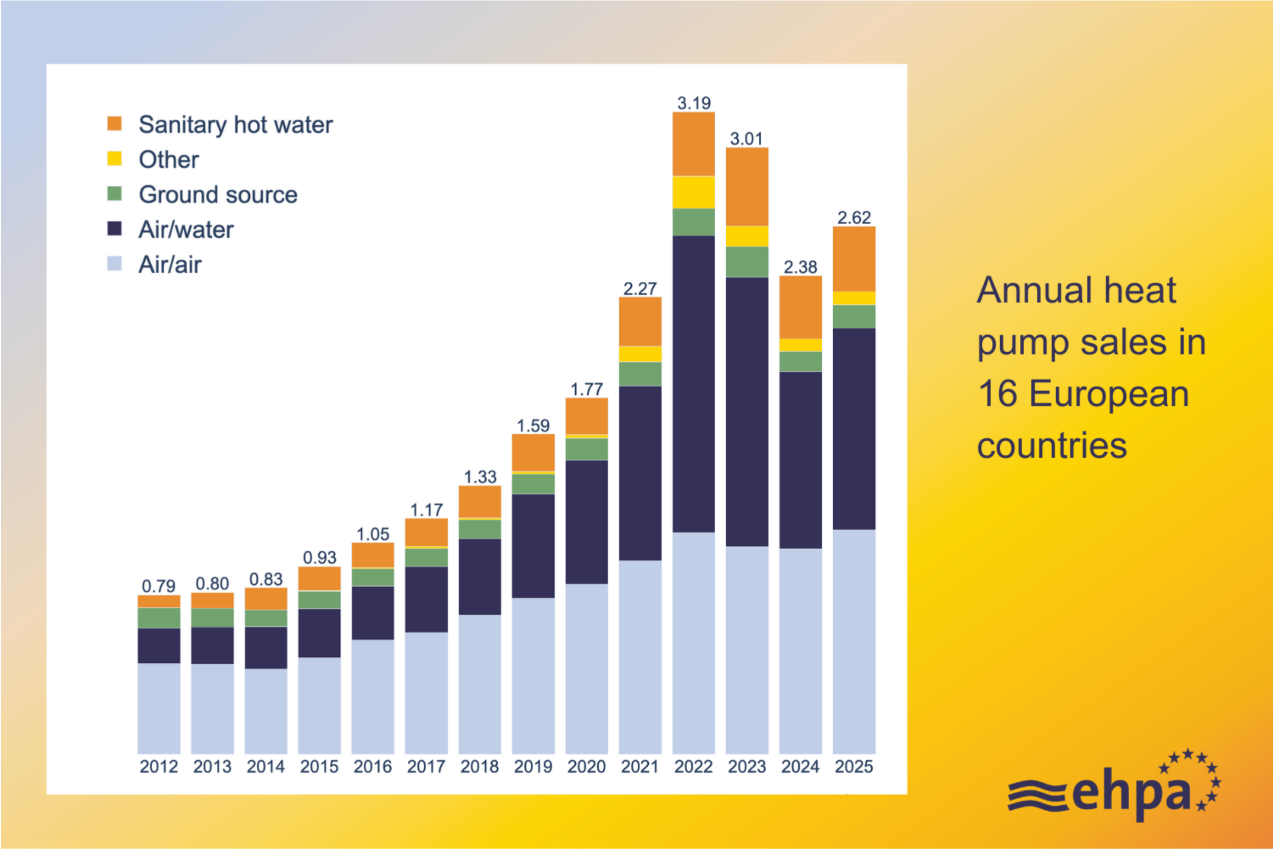
WHERE WE ARE AND WHERE WE NEED TO BE



HEAT PUMP SALES IN 16 EUROPEAN COUNTRIES

- Heat pump sales had a peak in 2022 due to expected gas shortage



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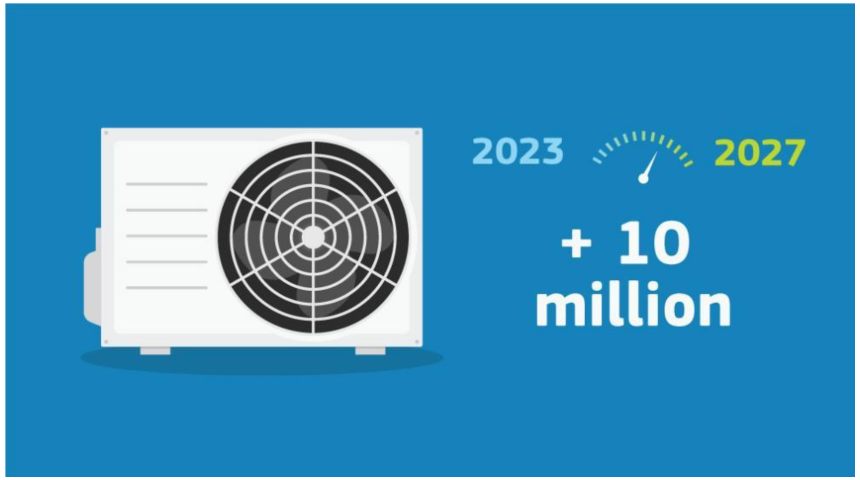
EU POLICIES

Programs/actions:

- Fit for 55 (reduce emissions by at least 55% by 2030)
- REPowerEU (reduce dependence on Russian gas)
- Net Zero Industry act
  - Support to net-zero technologies, e.g. heat pumps

- 60-65 million gas heaters need to be replaced in EU
- Goal to install at least 10 million heat pumps from 2023 to 2027



*https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202401735

Effects on the Environment

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ENVIRONMENTAL IMPACT

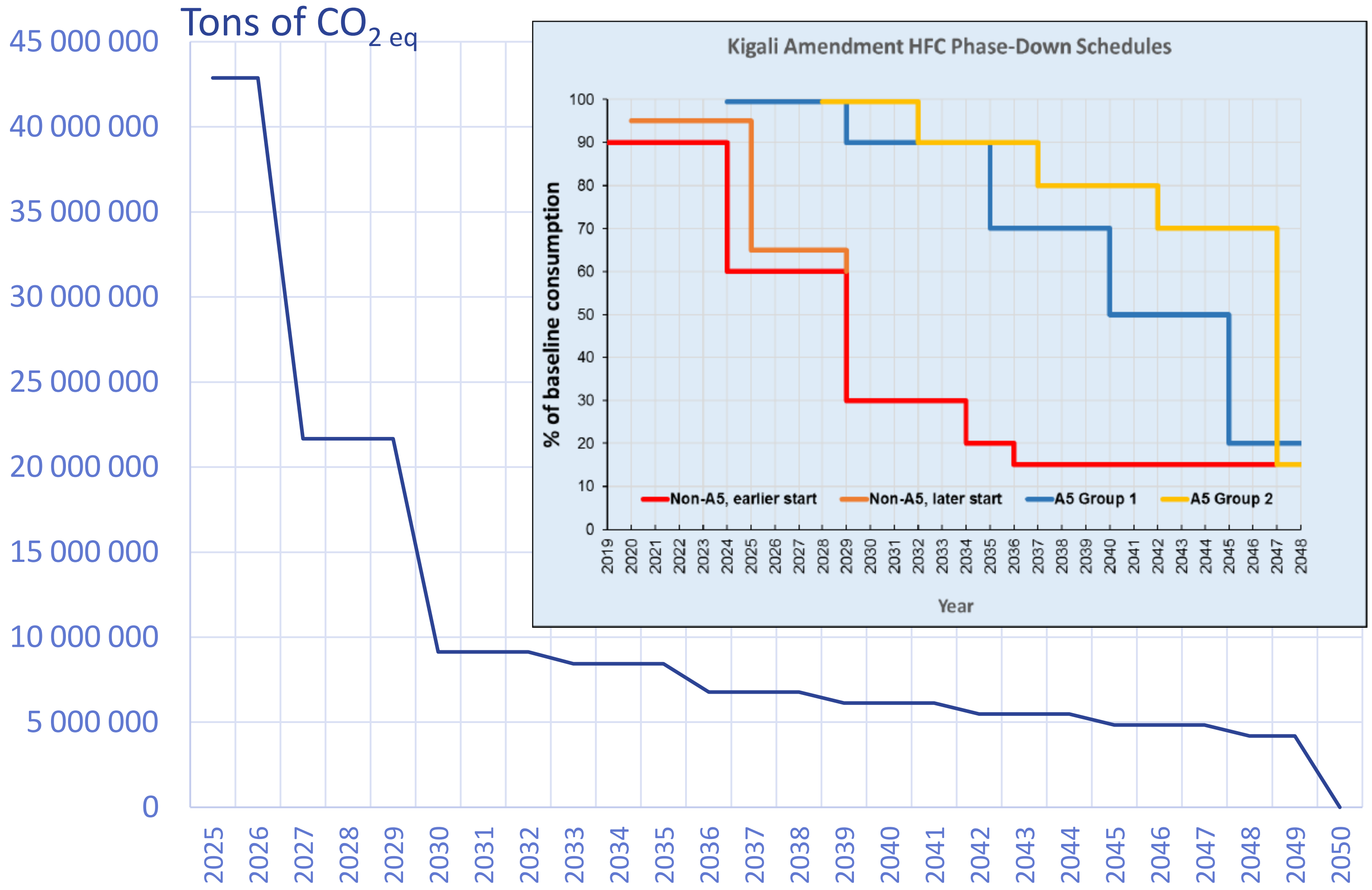
Environmental impact can be reduced by:

- Increased efficiency of AC and HP systems
- Substitution of gas/oil heaters for heat pumps
- Use of refrigerants which
  - give high efficiency and
  - are environmentally benign

F-GAS REGULATION: PHASE OUT OF HFCs (NOT INCLUDING HFO)

Maximum amount of HFCs allowed to put on the EU market year 2025 to 2050 expressed in tonnes of CO_2eq.

(European Union, 2024)



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F-GAS REGULATION:
BAN DATES OF SALES OF CERTAIN PRODUCTS

F-gas regulation, EU - 2024/573, Annex IV

Monoblock heat pumps and air conditioning equipment, Art 8			Split heat pumps and air conditioning equipment, Art 9		
a)	jan 1 2020	Plug-in, movable AC, GWP ≥ 150	a)	jan 1 2025	Single split, < 3kg, GWP ≥ 750
b)	2027	≤ 12 kW, GWP ≥ 150* (else GWP ≥ 750)	b)	2027	Air to water, ≤ 12 kW, GWP ≥ 150 *
d)	2027	12 kW - 50 kW, GWP ≥ 150* (else GWP ≥ 750)	c)	2029	≤ 12 kW, GWP ≥ 150*
e)	2030	Other, GWP ≥ 150* (else GWP ≥ 750)	e)	2029	> 12 kW, GWP ≥ 750*
c)	2032	≤ 12kW, F-gases* (else GWP ≥ 750)	f)	2033	>12 kW, GWP ≥ 150*
			d)	2035	≤ 12 kW, F-gases*

* except if required to meet safety requirements at the site of operation

No F-gases (incl HFO) in systems <12 kW from 2032 or 2035

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PROPOSAL TO BAN ANY PFAS SUBSTANCES IN EUROPE

- Almost all HFC and HFO refrigerants are PFAS (OECD definition)

- F-gases constitute about 38% of PFAS emissions worldwide

- Decomposition of many synthetic refrigerants result in Tri Fluoro Acetic acid (TFA)

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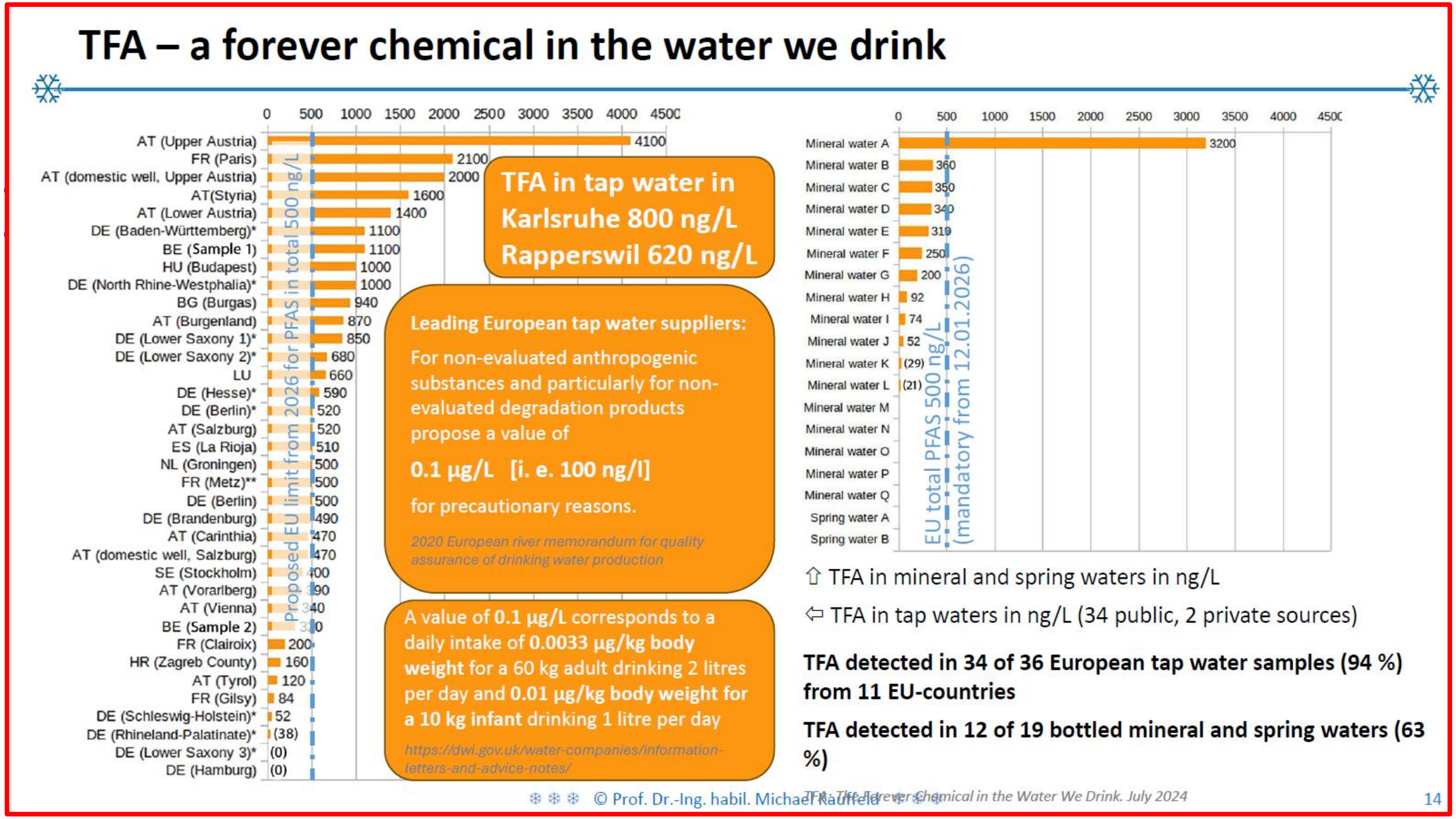
TFA IS ALREADY IN THE WATER WE DRINK, AND CONCENTRATIONS HAVE INCREASED SUBSTANTIALLY THE LAST TEN YEARS



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RESULT OF THE (EXPECTED) LEGISLATION

- Most major European HP/AC manufacturers are developing products for natural fluids, mainly propane

- Also many Asian producers offer propane products for the European market

- Only one (?) product from US with propane on the European market (40 - >500 kW)
- Components from US companies are used in propane HP

Development trends

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DEVELOPMENT TRENDS

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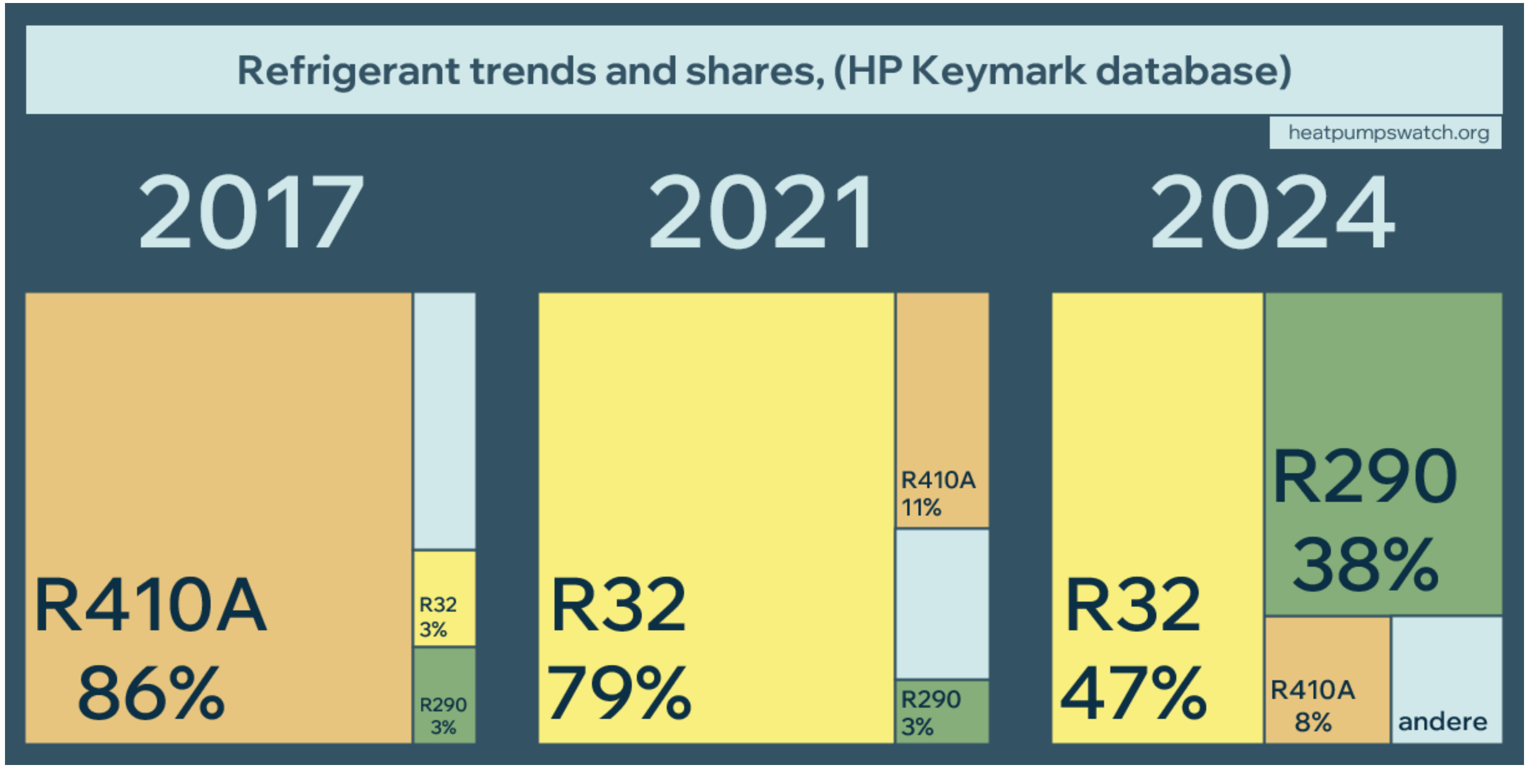
- Increased use of low GWP refrigerants
- Increased use of R290
- Lower refrigerant charge
- Air-water systems taking larger market share
- Increased COP

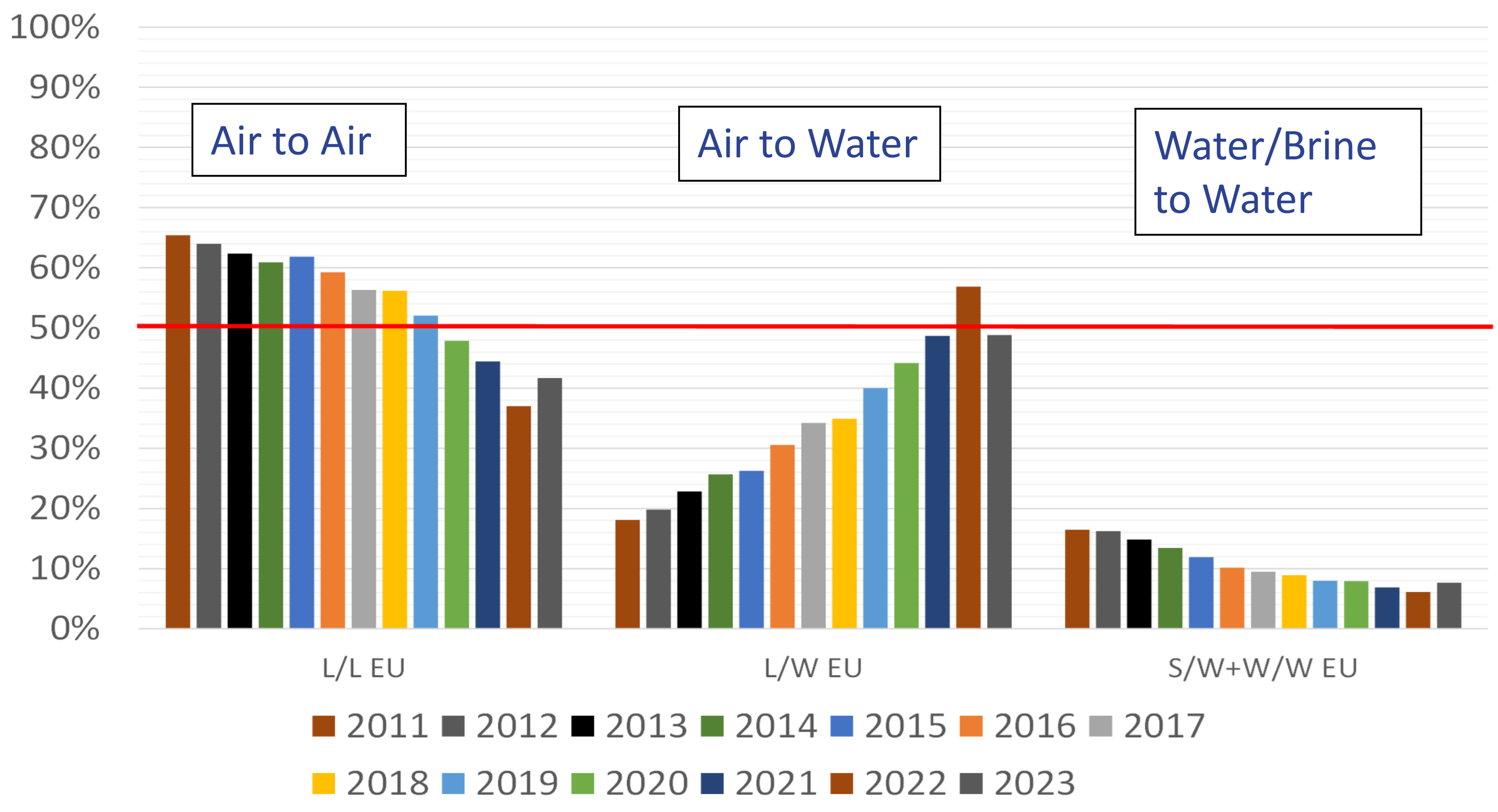
HP models with different refrigerants



Keymark: The voluntary European certification mark demonstrating conformity with European Standards

https://heatpumpswatch.org/heat-pump-refrigerants/

SALES OF HEAT PUMPS IN EU 2011 TO 2023



(Air to Air may be underestimated as they are not always in the statistics)

(Oltersdorf, 2024)

FROM PRODUCT INFORMATION

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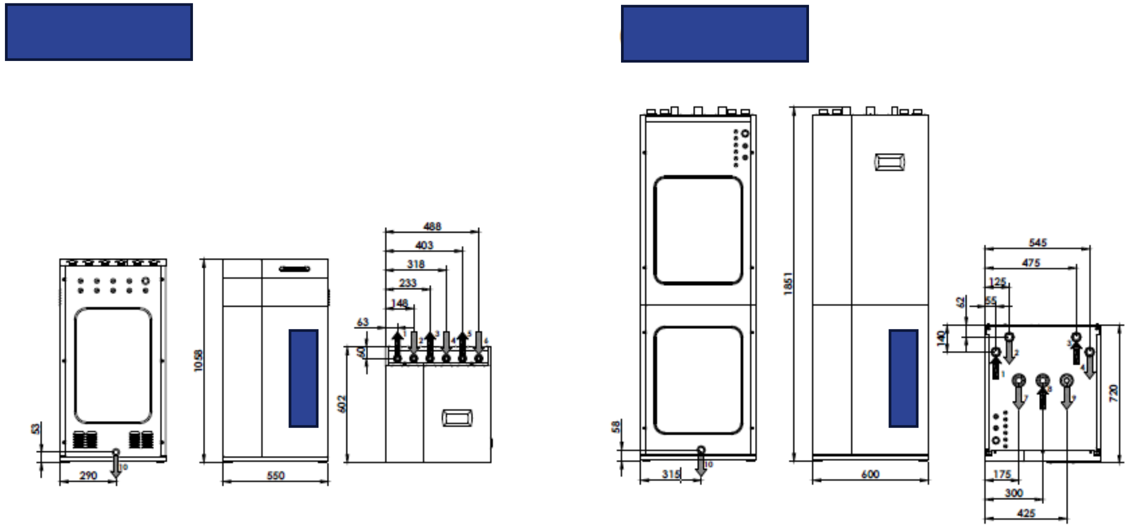
- Capacity: 1-6 kW heat
- Heating/Cooling
- Water/Water, 6 kW
- 150 g propane
- No ventilated enclosure
- No propane sensor
- Two plate hx
- No internal hx or desuperheater
- COP B0W35, 4.3

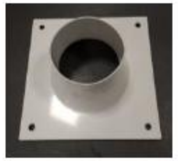
Dimensions and hydraulic connections



1. Heating/Cooling Outlet - 1 " M
2. Heating/Cooling Inlet - 1 " M
3. Brine Outlet - 1 " M
4. Brine Inlet - 1 " M
5. DHW system Outlet - 1 " M
6. DHW System Inlet - 1 " M
7. CW Inlet - 1 " F
8. DHW Outlet - 1 " F
9. DHW Recirculation Inlet - 3/4 " F
10. Drain - 16 mm

FROM PRODUCT INFORMATION

- Capacity 2-10 and 4-16 (kW):
- Tight ventilated enclosure
- 20 Pa under pressure
- Sensor stops compressor in case of leak
- Forced ventilation to the ambient



Picture from the outlet duct system fitting 80mm

Duct Inlet

Duct outlet

LIQUID TO WATER HP WITH 152 G OF PROPANE, 6 KW HEAT

- All refrigerant-containing parts within a tight box.
- Possible to have two boxes => 12 kW

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LARGE HEAT PUMPS FOR COMBINED DISTRICT HEATING AND COOLING

Example: 50 MW HC hp for district heating

Heat source: waste water treatment plant, 10ºC

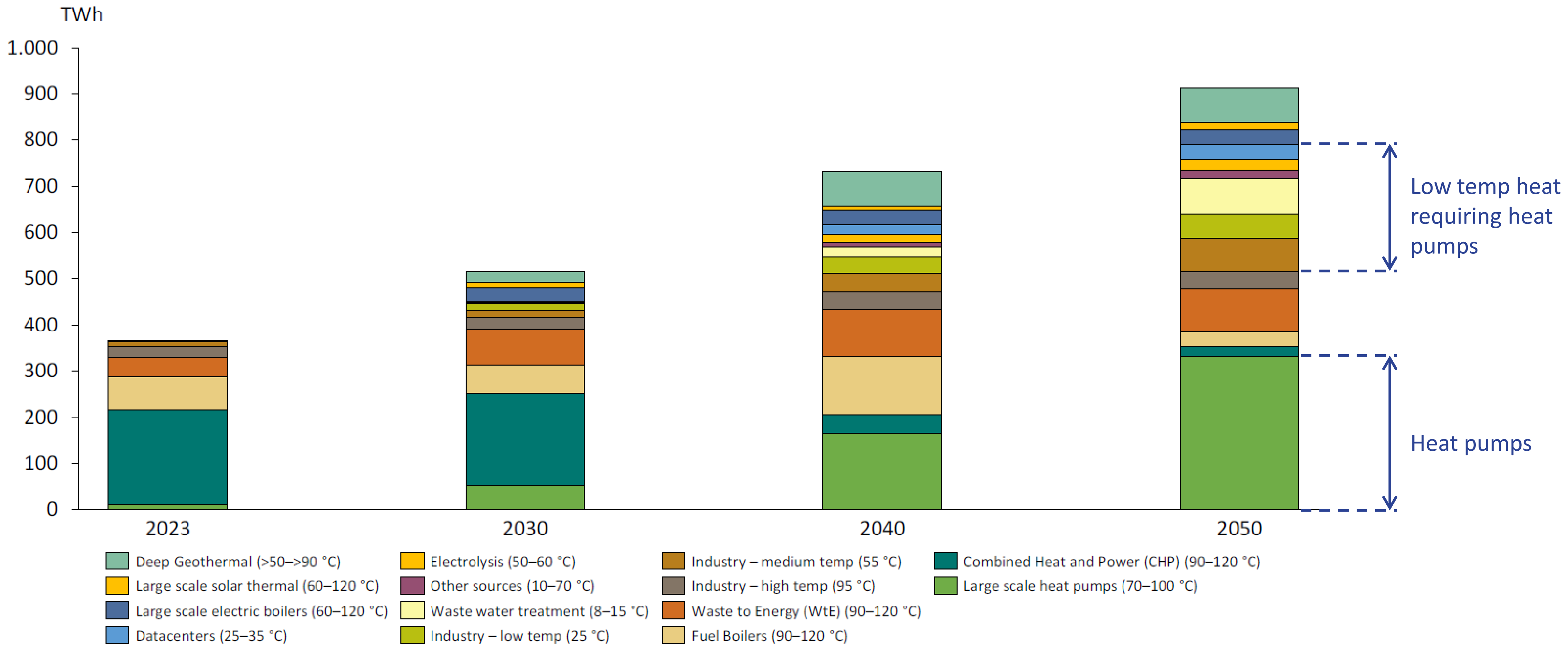
T_{out}: 90ºC

Refrigerant: Isobutane

Several plants with hydrocarbons or CO2 have been installed

STRABAG Umwelttechnik GmbH - STRABAG building 50 MW industrial heat pump in Gothenburg, Sweden

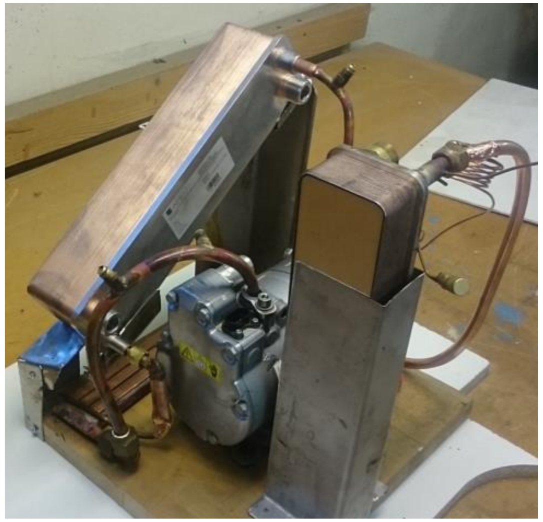
SOURCES OF HEAT FOR DH NOW AND IN THE FUTURE, EUROPE

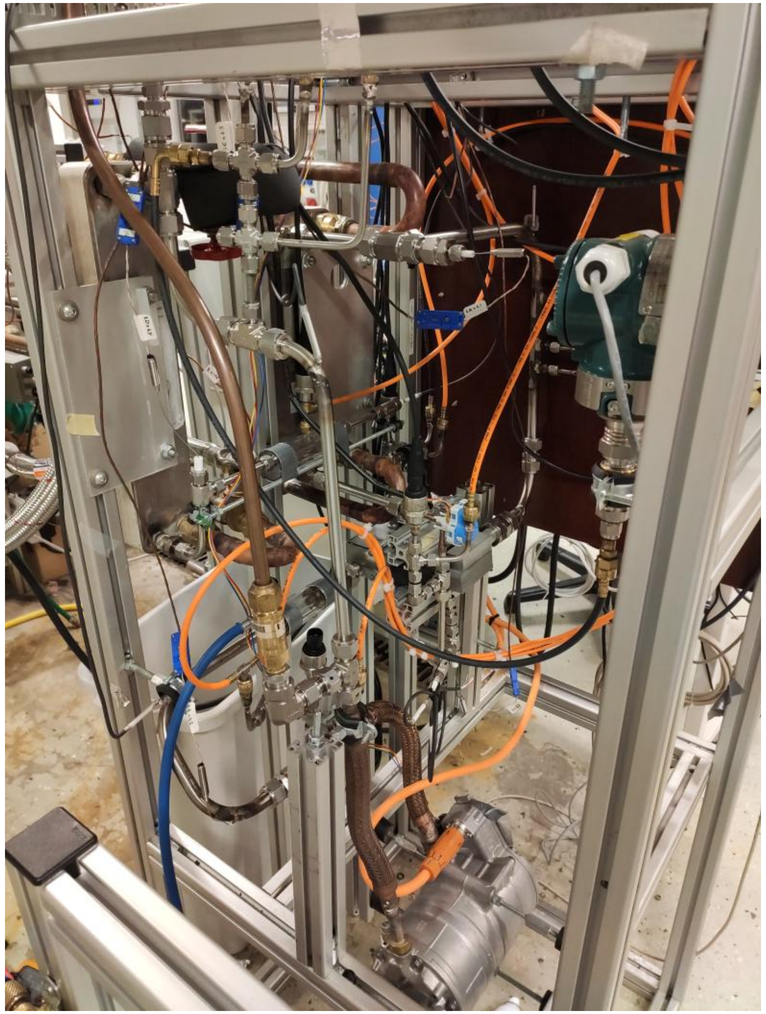


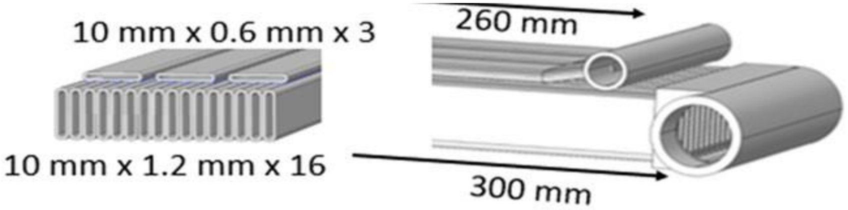
www.heatroadmap.eu

RESEARCH: ECOPACK, KTH, SWEDEN

- Up to 12 kW with 120g of Isobutane
- Mobile AC-type compressor
- Commercial plate hx
- Prototype internal heat exchanger







RESEARCH: LC 150 PROJECT, FRAUNHOFER ISE GERMANY

- Project to optimize heat pumps with less than 150 g of propane
- Demonstrated a 12.8 kW WtoW propane heat pump running on 124 g of propane,
- i.e. about 10 g/kW

(Fraunhofer ISE, n.d.).

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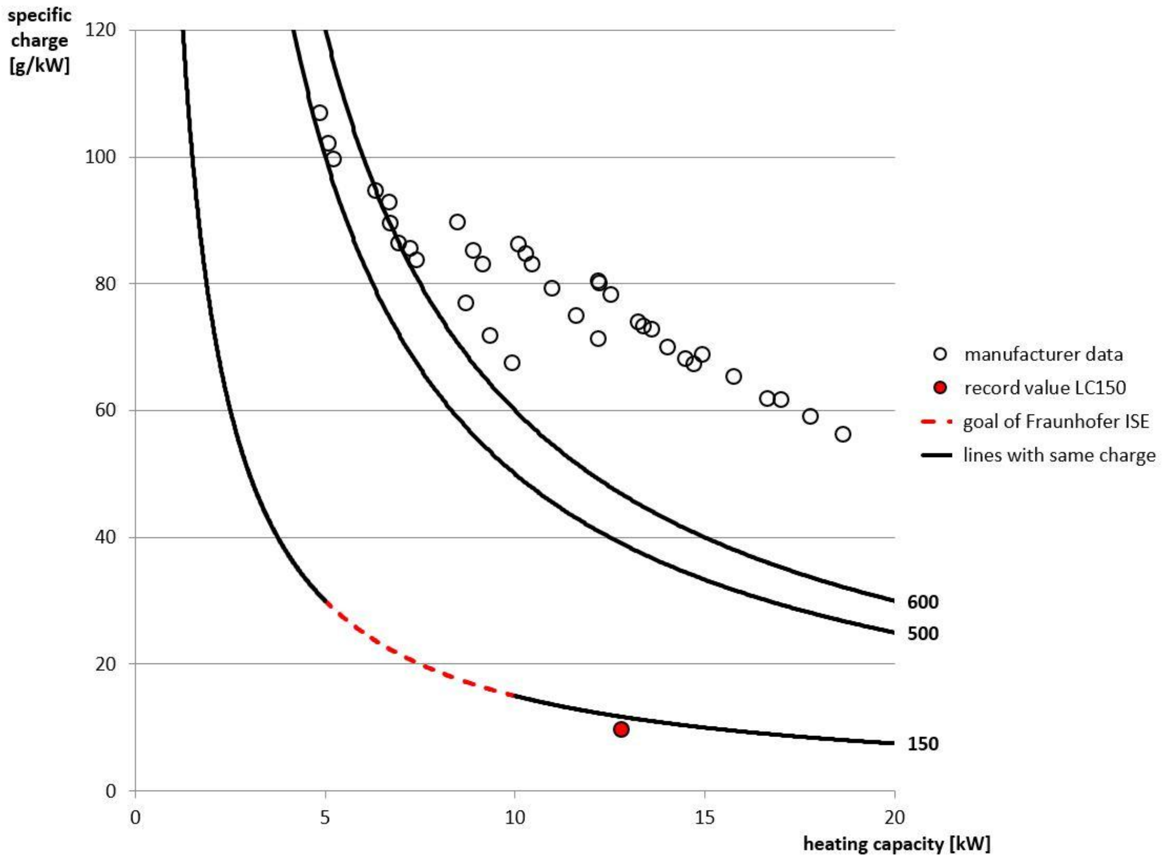

(Fraunhofer ISE, n.d.).

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Implementing the change

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REQUIREMENTS FOR FUTURE HEATING/COOLING SYSTEMS

- Affordable
- Efficient
- Safe
- Low environmental impact
- Invisible
- Low noise
- Combined space heating, hw production and cooling

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Conclusions

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CONCLUSIONS

- Cooling and heating requires about 50% of the world´s energy use
- Global warming will lead to increased use of AC
- Global warming will lead to phase out of fossil fuels and electrification of the energy system
- Electrification will lead to increased use of heat pumps substituting gas heaters, reducing energy demand considerably
- Heat pumps and ACs can (often) be combined in one unit by reversing the cycle
- Synthetic refrigerants will be substituted for natural fluids, mainly hydrocarbons
- There is a need for new products substituting gas heaters and ACs (low cost, small footprint…)
- The European heat pump/AC industry is strong, but face tough competition from Asia

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Thank you!

Björn Palm, KTH Royal Institute of Technology
bpalm@energy.kth.se

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Energy-Efficient Air Conditioning in Europe: District Cooling Systems

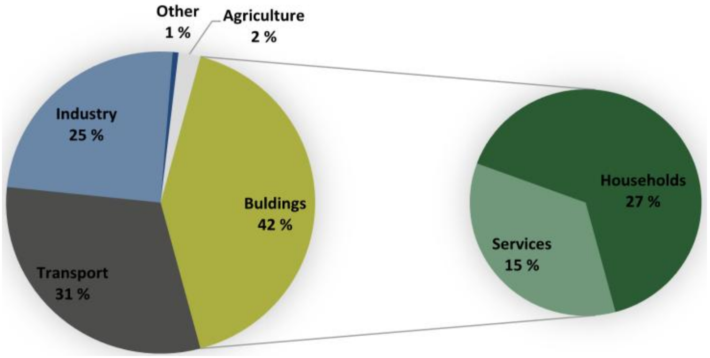
Yunting Ge, London South Bank University

SUMMARY

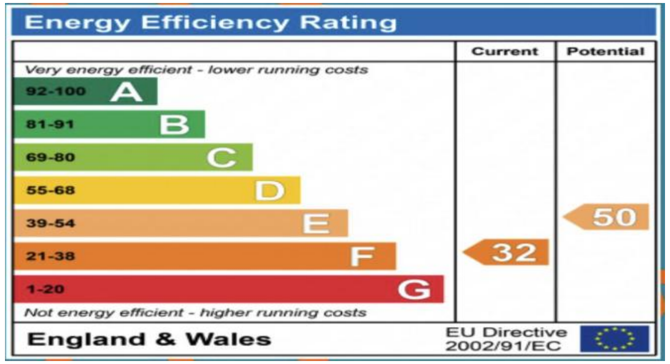
01. BACKGROUND

- Buildings account for around **40% of total energy use** in the European Union
- Buildings are also a major source of **CO_2 emissions**, contributing significantly to climate change
- Rising CO_2 levels are **increasing global temperatures** and intensifying global warming
- Hotter summers and more frequent heatwaves are expected to **increase cooling demand and air conditioning** in buildings
- Greater use of air conditioning will **increase electricity consumption** and pressure on energy systems

- A sustainable cooling pathway is therefore urgently required by: **improving building energy performance** , **reducing cooling demand**, **and developing more efficient cooling technologies**



Source: **ECA, based on Eurostat data on Final Energy consumption.**



02. EMERGING TRENDS IN COOLING DEMAND

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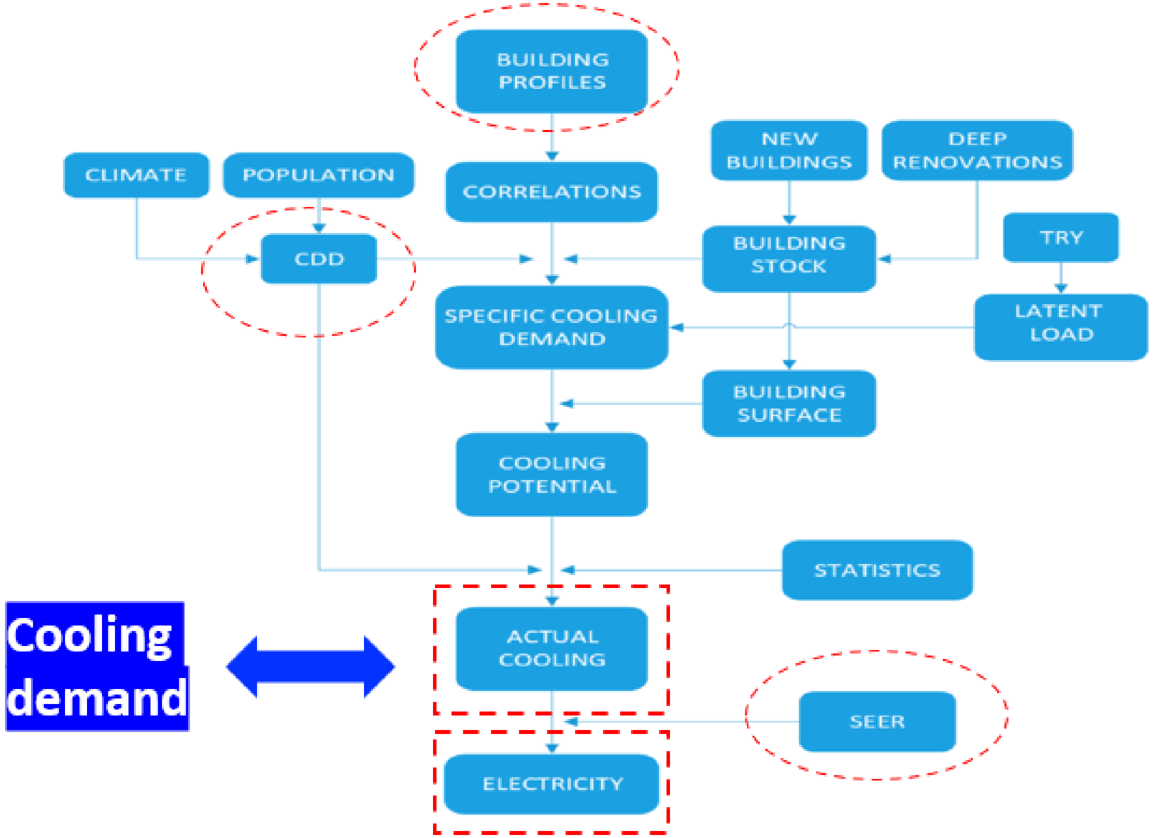
Cooling Demand, Degree days, SEER and Electricity<



Flow chart of the modelling process [1]

$$Cooling\ demand = M * CDD + B \quad [1]$$

where *M* and *B* are the coefficients and *CDD* are the Cooling Degree Days [2].

$$CDD = \frac{\sum_j CDD_j * P_j}{\sum_j P_j} \quad [2]$$

where CDD_j are the CDD of region *j* and P_j represents the population of the region *j*.

The formula for one **Cooling Degree Day (CDD_1)** is: [3]

$$CDD_1 = \max(0, T_{mean} - T_{base})$$

Where:

$T_{mean} = (\frac{T_{max} + T_{min}}{2}$, daily average temperature)

T_{base} =base temperature (typically **18°C** in Europe)

$$SEER = \frac{\text{Total cooling output over a season}}{\text{Total electricity input over the same period}} \quad [4]$$

$T_{mean} \downarrow \Rightarrow CDD \downarrow \Rightarrow$ Actual Cooling $\downarrow \Rightarrow$ Electricity $\downarrow$

SEER $\uparrow \Rightarrow$ Electricity $\downarrow$

02. EMERGING TRENDS IN COOLING DEMAND

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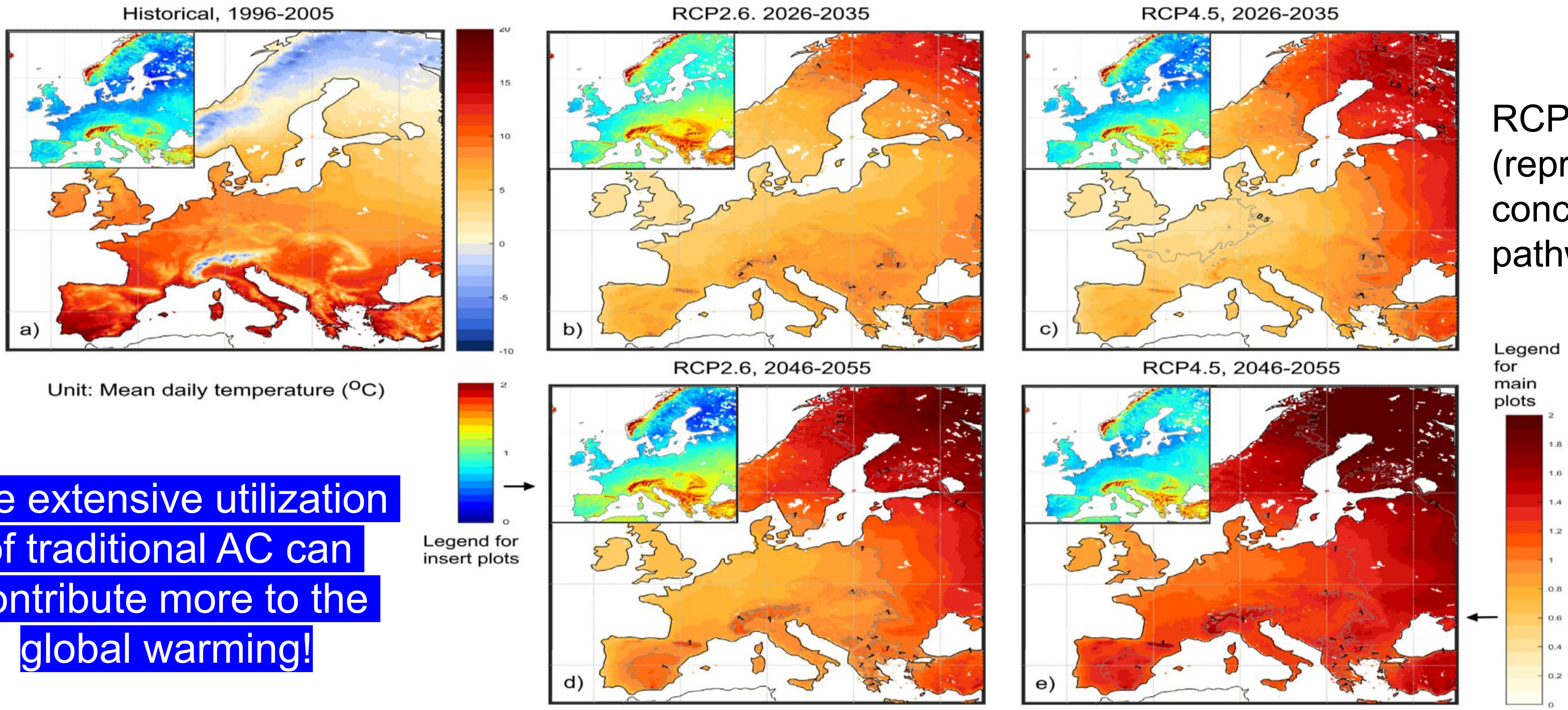


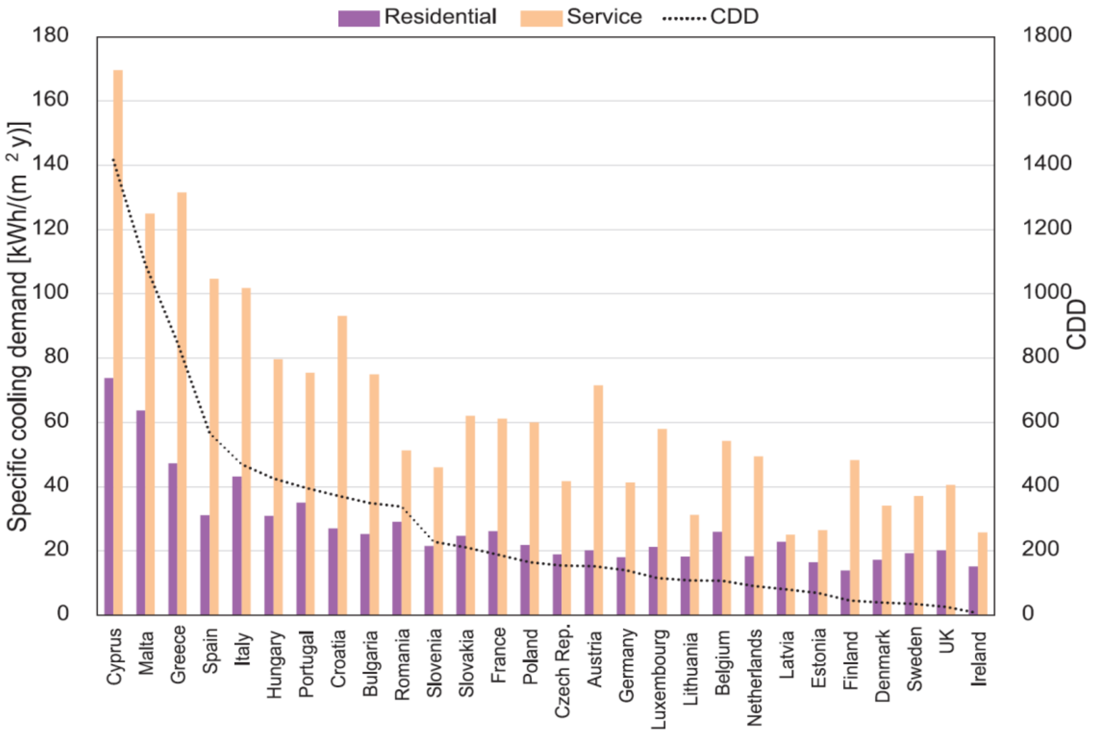
RCP (representative concentration pathways)

The extensive utilization of traditional AC can contribute more to the global warming!

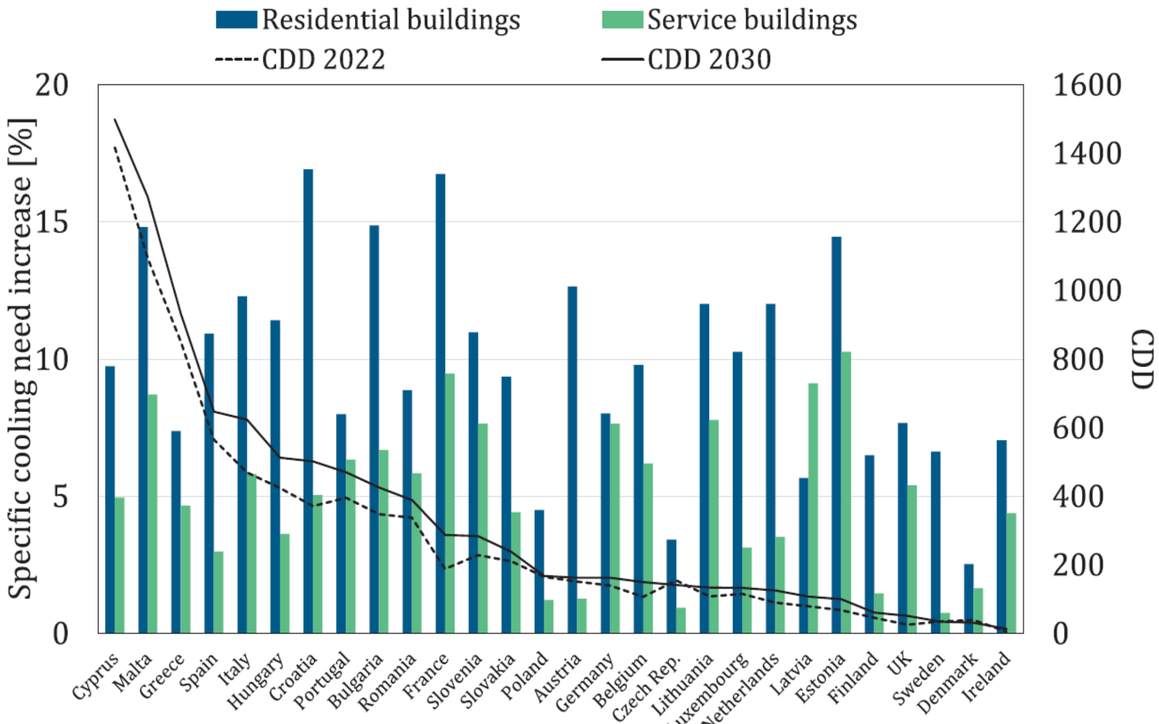
Plot a): 1996–2005 mean temperature (Tmean). Plots b)-e): Corresponding anomaly values (relative to historical period) for RCP2.6 (left) and RCP4.5 (right) for 2026–2035 (top) and 2046–2055 (bottom) including contour lines for the levels of 0.5, 1 and 1.5 C. Top-left insert plots b)-e): The corresponding inter-model Tmean standard deviation for each scenario and period [3].

02. EMERGING TRENDS IN COOLING DEMAND

Specific cooling demand and CDD



Specific cooling demand and CDD for each country in Europe [1]



Specific cooling demand for residential and service sectors increase between 2022 and 2030, and CDD for each of the EU27 + UK countries[1]

03. TECHNOLOGICAL INNOVATION

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Cooling Demand, Degree days, SEER and Electricity

As we know, the cooling demand can be calculated as:

$$\text{Cooling Demand} = M \cdot \text{CDD} + B$$

To reduce the cooling demand, the innovations can be developed or applied from **three angles**:

1. Reduce heat entering → ↓ CDD impact
- insulation, glazing, shading

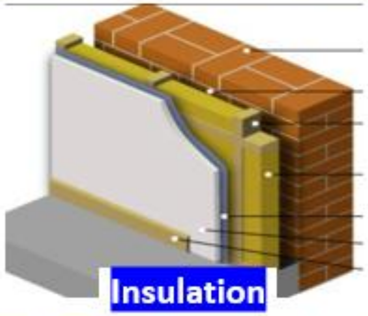
👉 **↓ M**

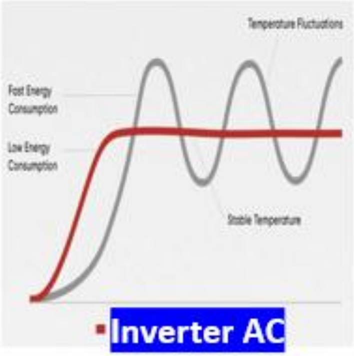
2. Reduce baseline/internal loads
- ventilation, green roofs, smart control

👉 **↓ B**

3. Improve efficiency of cooling
- inverter AC, **district cooling**

👉 **↑ SEER → ↓ electricity demand**





03. DISTRICT COOLING: PRINCIPLES, INFRASTRUCTURE, AND KEY EXAMPLES

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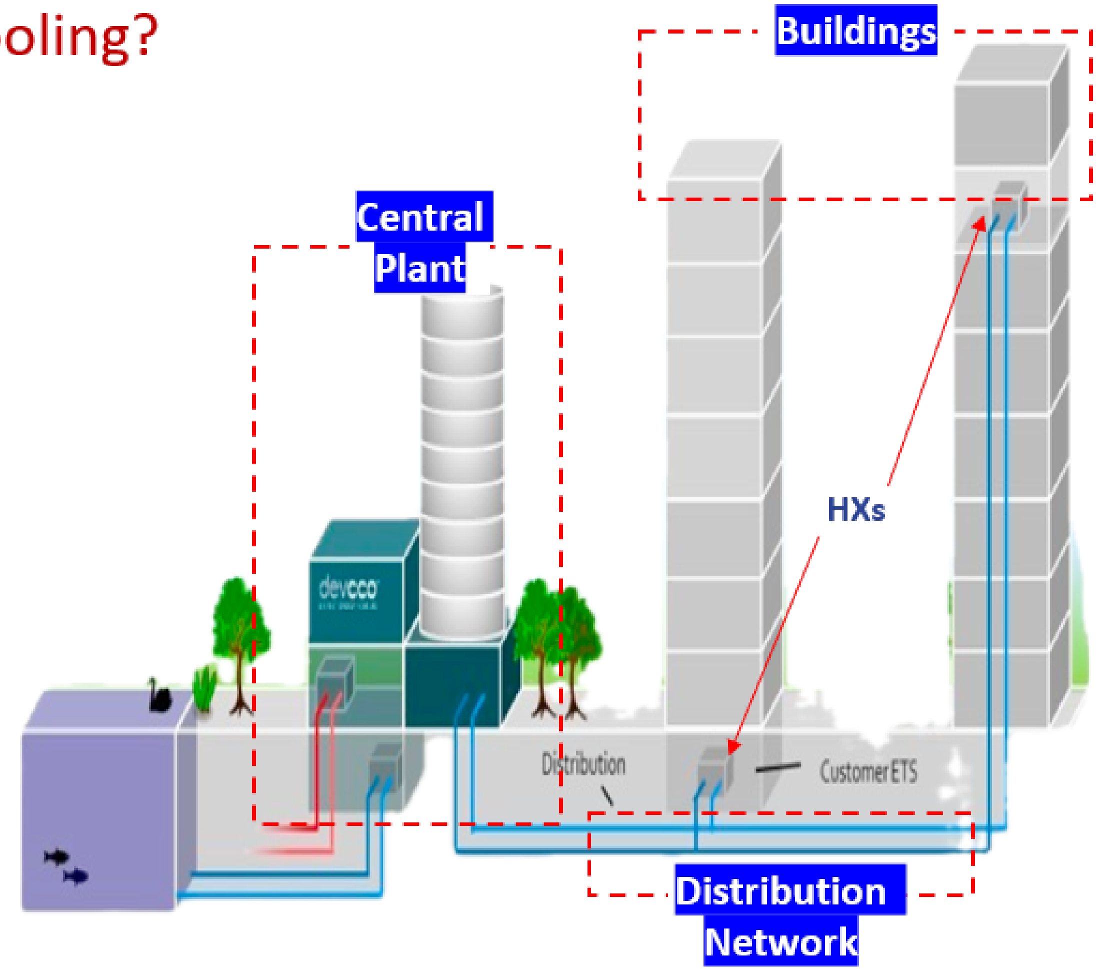
What is district cooling?

District cooling is basically centralised air conditioning for a whole area instead of every building running its own AC. It includes mainly three parts: **Central Plant**, **Distribution Network** and **Buildings [4].**

How it works

Central plant cools water
using chillers, seawater, lakes, or even ice storage;
cold water flows through a closed loop underground **distribution pipe network,**
typically, around **4–7°C** [5];
Buildings take the cooling,
via heat exchangers (HXs);
Warm water returns, and
comes back at ~**12–16°C** to be cooled again.



General scheme of a District Cooling system [6]

03. DISTRICT COOLING: PRINCIPLES, INFRASTRUCTURE, AND KEY EXAMPLES

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Traditional AC vs District Cooling

Aspect	Traditional AC	District Cooling
Setup	Individual systems	Central system
Efficiency	COP ~2.5–3.5	COP ~5–7 (large chillers)
Capital cost	Low upfront	High upfront (network + plant)
Operating cost	Higher	~20–40% lower
Emissions	Higher (baseline)	~30–50% lower CO_2
Urban heat island	+1–2°C local increase	Reduced / mitigated
Water temperature	Direct air cooling or small chilled water systems	Supply: ~4–7°C, Return: ~12–16°C
Free cooling & renewables	Rare (<10%)	Significant potential (can cover ~20–80% depending on source)

Reduce CDD, then Cooling Demand

Key Examples:ZUIDAS INTERNATIONAL BUSINESS HUB (IBH) DC PROJECT [7]

Parameter	Typical Range
Chilled water supply	4–6°C
Return temperature	12–16°C
ΔT	6–10 K
Pipe system	2-pipe closed loop
Cooling source	Chillers + free cooling + ATES
Building interface	Heat exchanger station
Pumping	Variable-speed pumps
Control	Smart BMS

View over the Zuidas area

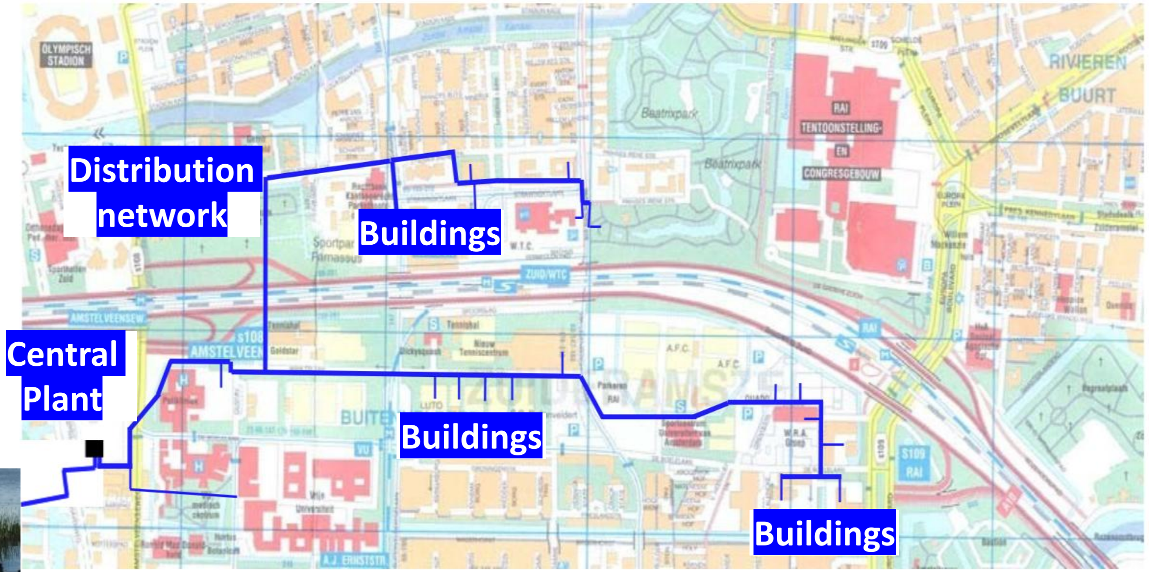
If lake water temperature is sufficiently low:

- **free cooling alone may cool the DC loop to ~6°C.**

Operation during warm lake conditions:

- **pre-cooling district return water by Lake Water**

This DC system reduces CO2 emissions by 75% compared to conventional chillers.



The DC system in Zuidas, Amsterdam

05 INTEGRATION POSSIBILITIES OF DIFFERENT TECHNOLOGIES

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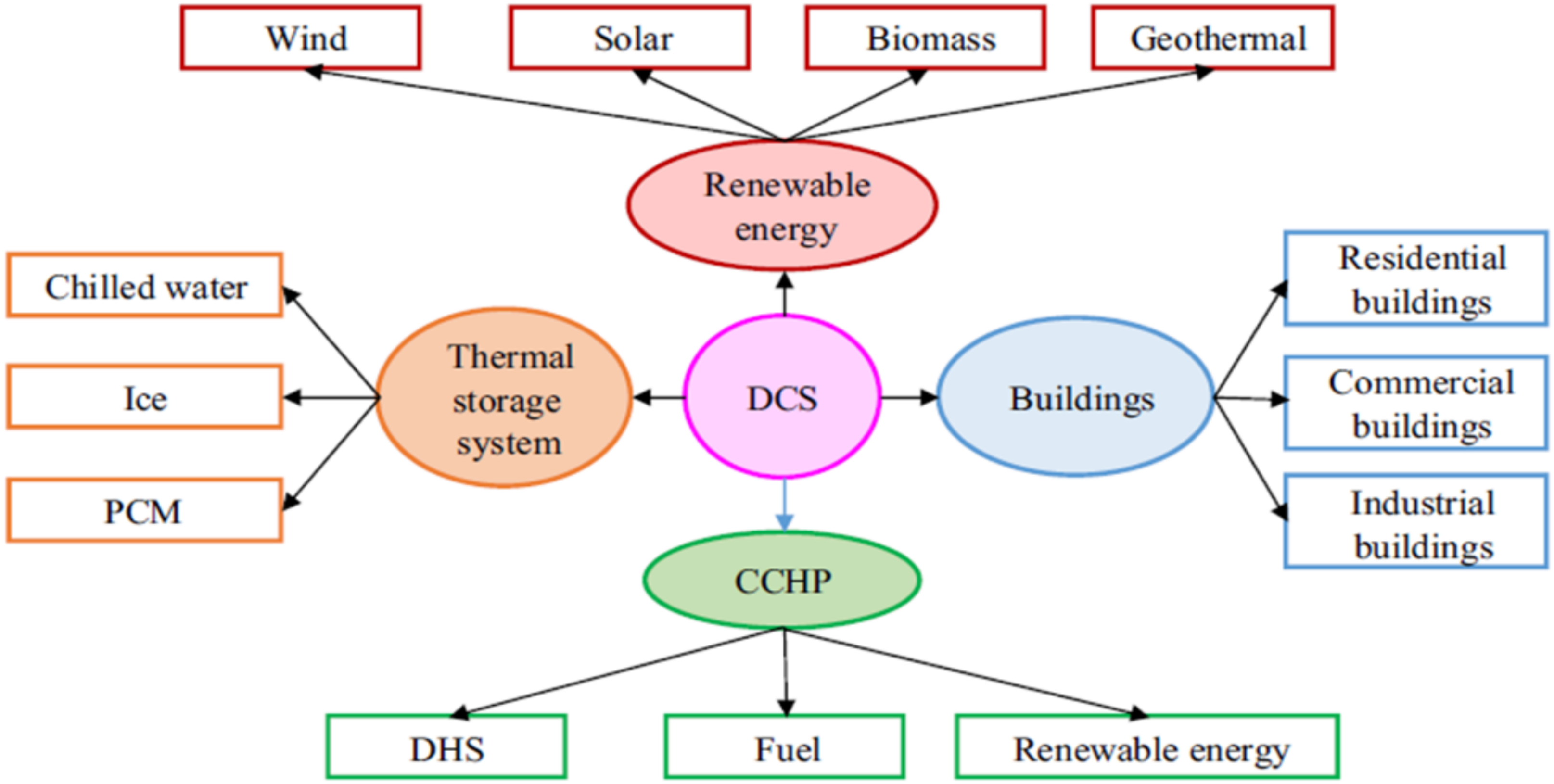
Integration



Integration possibilities of different technologies with DC system [8]

05 INTEGRATION POSSIBILITIES OF DIFFERENT TECHNOLOGIES

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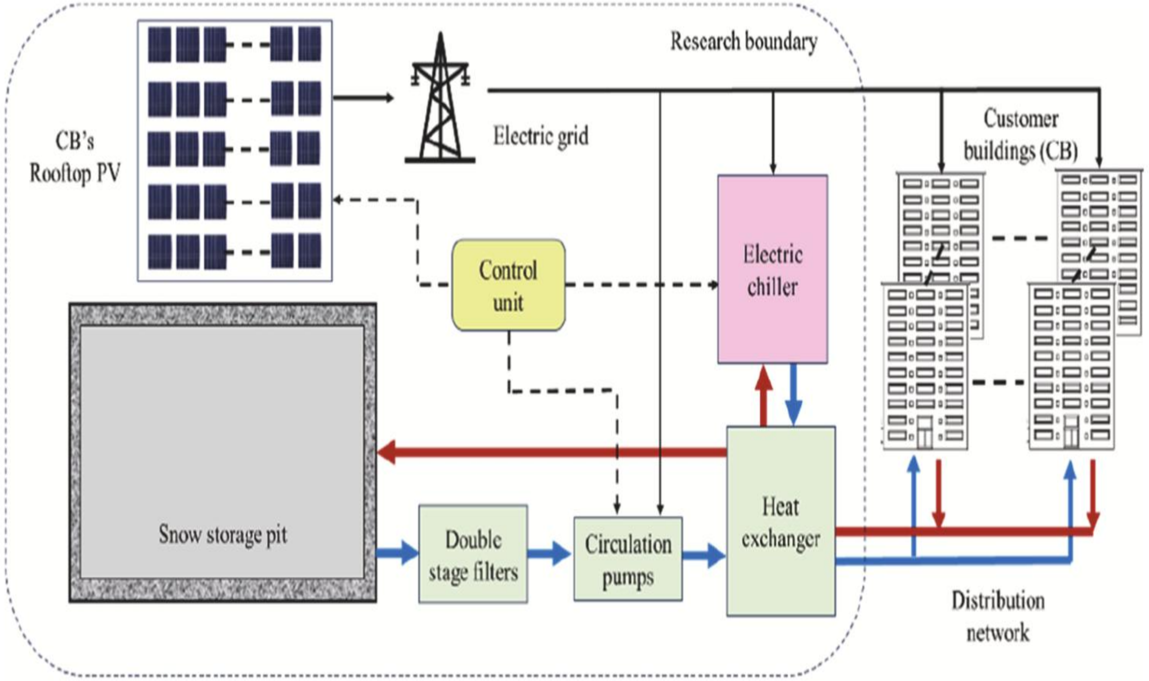
Renewable Energy Cooling [9]

- The most important characteristic of solar cooling is that the peak solar production and the peak cooling demand often match well.

  Solar cooling can be implemented with both solar collectors and solar photovoltaics (PV) when supplying cooling by sorption or compression-based cooling units, respectively.

- Regardless of the cooling technology, a solar cooling system can be adapted to produce heating as well.



Schematic of PV-integrated snow storage cooling system[10].

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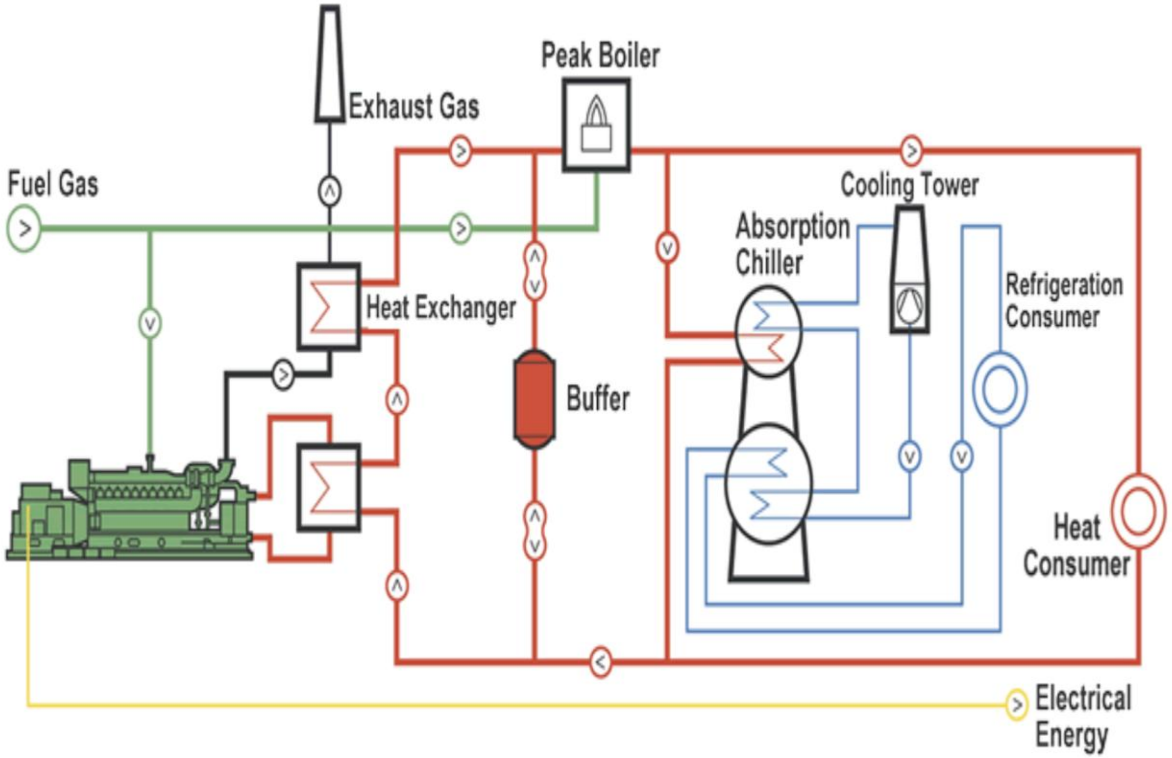
Trigeneration (CCHP)

- Trigeneration (CCHP) is a concept where all heating, cooling and electricity is produced in a single facility.

- Some of the heat produced by a cogeneration plant can be used to generate chilled water for air conditioning or refrigeration. An absorption chiller can be linked to the CHP to provide this functionality.

- Carbon dioxide from flue gases can be captured , stored and utilized .



Trigeneration (CCHP) scheme [11]

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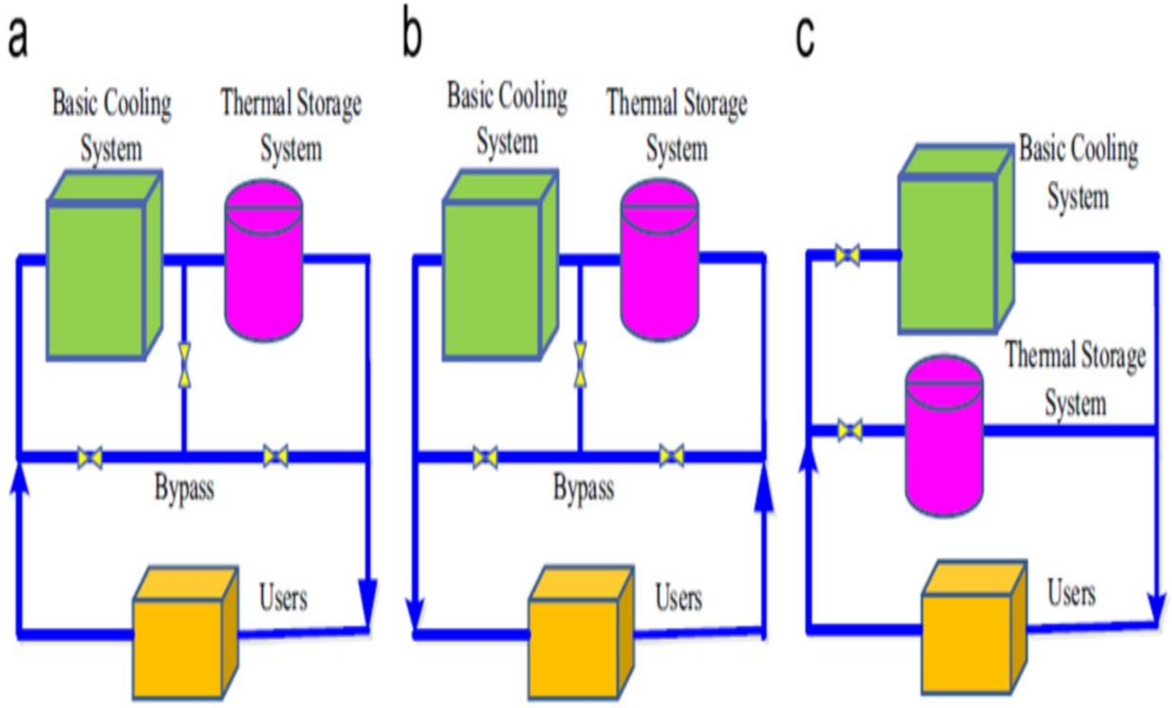
Thermal Energy Storage

- Thermal storage systems store cold energy during periods of low cooling demand and release the stored cold energy to meet the cooling load at a different time than it was produced.
- Therefore, cooling storage positively impacts electricity grids by reducing the peak electricity demand.
- Simultaneously, cooling costs may be lowered by shifting the electricity consumption to off-peak hours when the energy prices are lower.



Schemas of DC with different thermal storage systems : serial connection with chillers (a) upstream and (b) downstream; (c) parallel connection [11].

06 CLOSED LOOP UNDERGROUND DISTRIBUTION PIPE NETWORK

District Cooling Only

DC-Only Systems

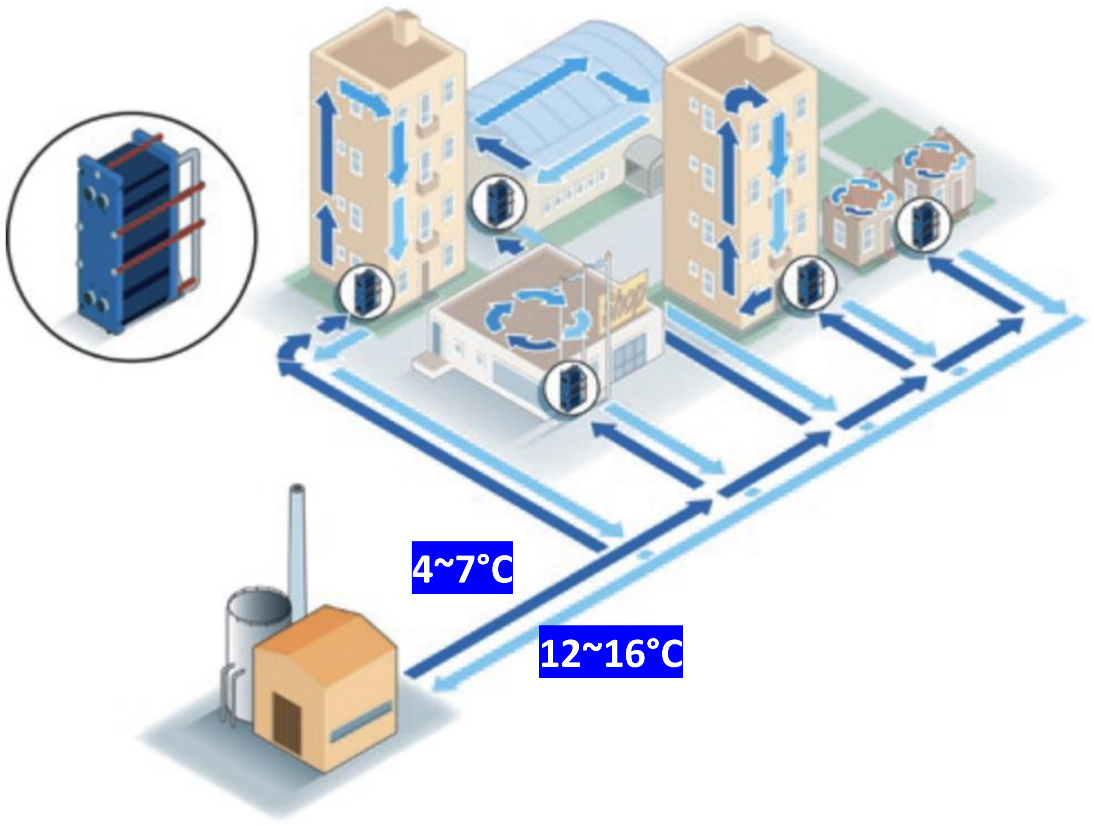
- The district cooling only network distributes chilled water purely for space cooling and process cooling.

DC-Only Systems Are Strong When:

- urban density is high,
- cooling demand is large,
- long-term sustainability is important,
- cities want low-carbon infrastructure.

Limitations

- limited annual operating hours,
- insufficient use of waste heat,
- and difficulty in balancing cost and low-carbon performance over the whole year



Schemas of DC with district cooling only

06 CLOSED LOOP UNDERGROUND DISTRIBUTION PIPE NETWORK

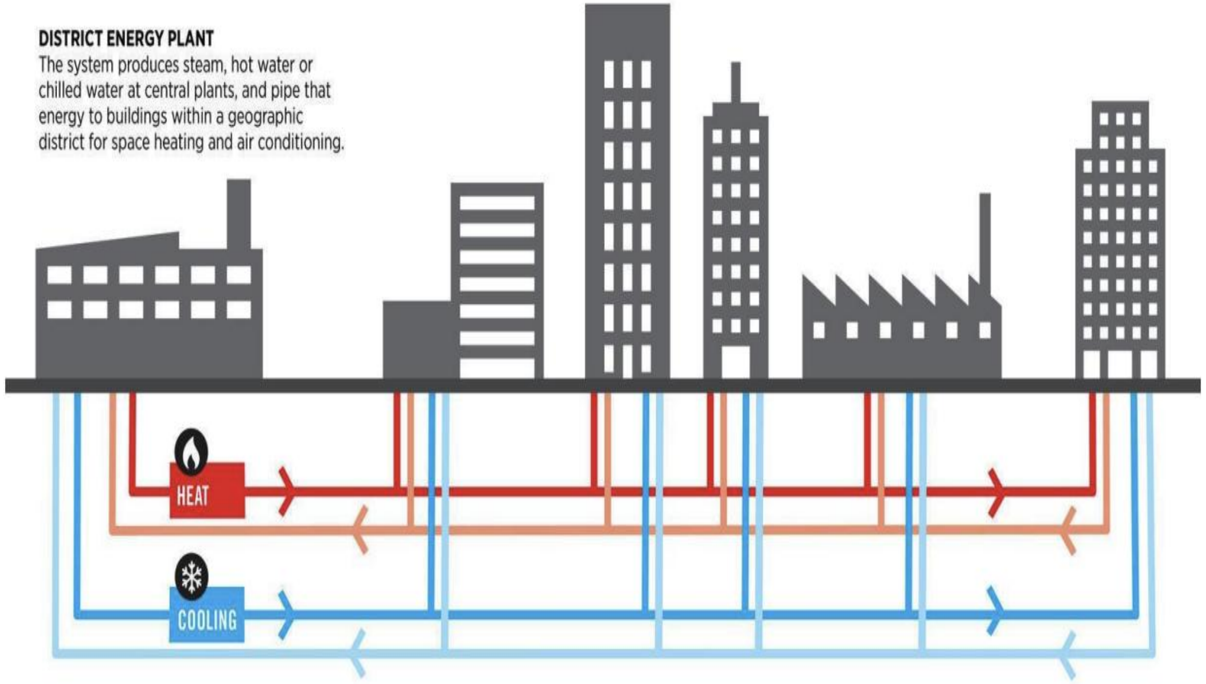
A Combined District Heating and Cooling (DHC) Network
(separate district cooling and heating networks)

Separate district cooling and heating systems

- It has **separate district cooling and heating network**, connected at central energy hubs through large heat pumps or heat exchangers.

Limitations:

- Although DHC technologies have gradually matured, separate district cooling and heating networks still require two distribution systems, which leads to **high investment and higher network complexity.**



Combined district heating and cooling with 4 pipe system [12]

06 CLOSED LOOP UNDERGROUND DISTRIBUTION PIPE NETWORK

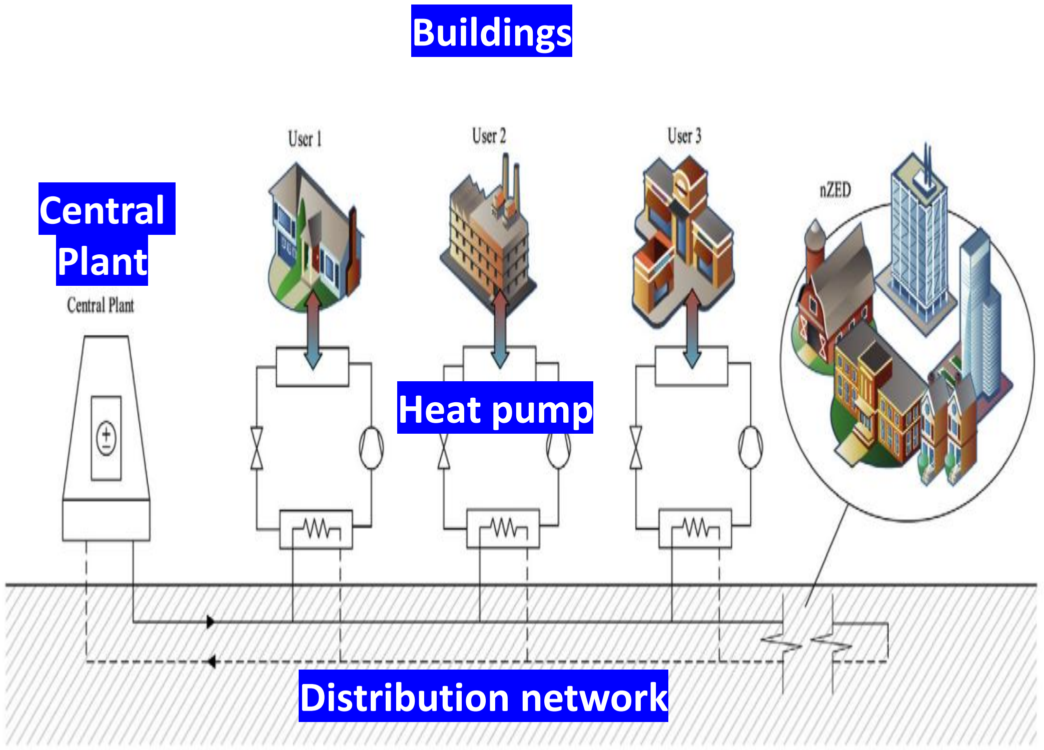
A Combined District Heating and Cooling (DHC) Network
(shared cooling and heating networks) -5GDHC

5GDHC

- the 5GDHC adopts a low-temperature cooling and heating network at **0°C~35°C** and supports year-round cooling and heating.
- **Heat pumps** are installed on the user side, so buildings can extract heat from the network or reject heat to the the network depending on demand.

Limitations:

- Although 5GDHC systems offer very high efficiency and excellent renewable integration potential, their widespread implementation is constrained by **high capital costs, dependence on electrification, thermal balancing challenges, building retrofit requirements, and operational complexity.**



5GDHC network functional scheme [13]

07 OPPORTUNITIES, BARRIERS, AND POLICY SUPPORT FOR DISTRICT COOLING

Aspect	Key Points
Opportunities	High efficiency, low emissions, renewable integration, lower peak demand
Barriers	High capital cost, infrastructure complexity, long payback
Policy Support	Incentives, climate policies, urban planning, public–private partnerships

08 CONCLUSIONS

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- Buildings account for significant energy use and CO_2 emissions in the European Union
- Rising CO_2 levels are increasing ambient temperatures and thus cooling demand
- District cooling is one of the prospective technologies to reduce cooling demand and improve efficiency
- District cooling systems can apply free cooling and integrations of renewables, energy storage and CCHP
- 5GDHC is a prospective district cooling system but limited by higher capital costs and operational complexity
- There are opportunities , barriers and necessary policy support for district cooling

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SUSTAINABLE ENERGY WEEK

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Thank you!

Yunting Ge, London South Bank University
yunting.ge@lsbu.ac.uk