IRENA
International Renewable Energy Agency

URBAN TRANSITIONS MISSION

Harnessing Heat Pumps for Building Heating and Cooling in Sustainable Cities. Challenges and opportunities

Juan Pablo Jiménez Navarro

Urban Transitions Mission, May 2024

Heat pump – the concept

The “**magic of heat pumps**”:
Several units of heat and cold* are per each unit of electricity.

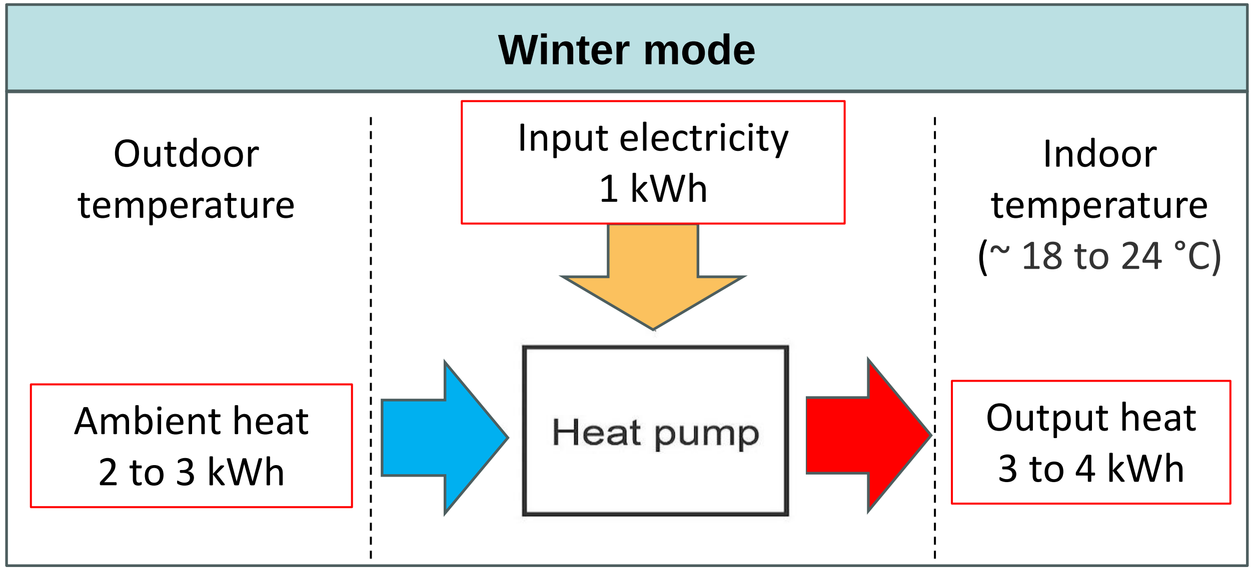
Heat pump efficiencies are 3 to 5 times higher than gas boilers

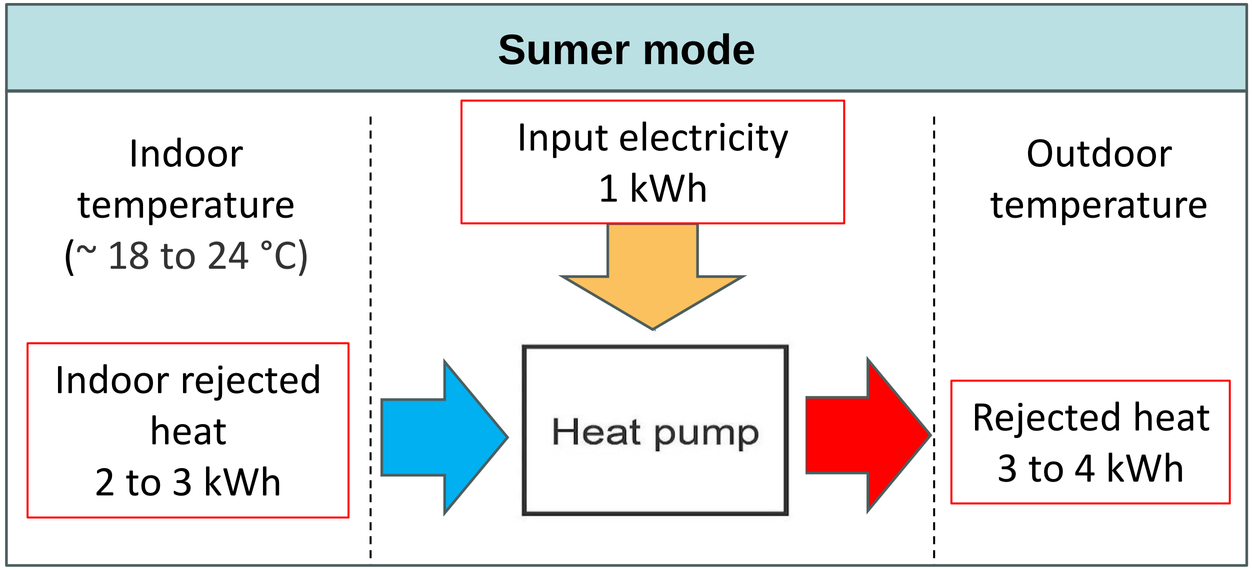
Heat pump efficiencies are subject to the difference between indoor and outdoor temperatures

Efficiencies are defined as follows:

$$COP = \frac{Output\_heat}{Input\ electricity}$$ Heating mode

$$EER = \frac{Indoor\ rejected\ heat}{Input\ electricity}$$ Cooling mode





Heat pump challenges within the urban context

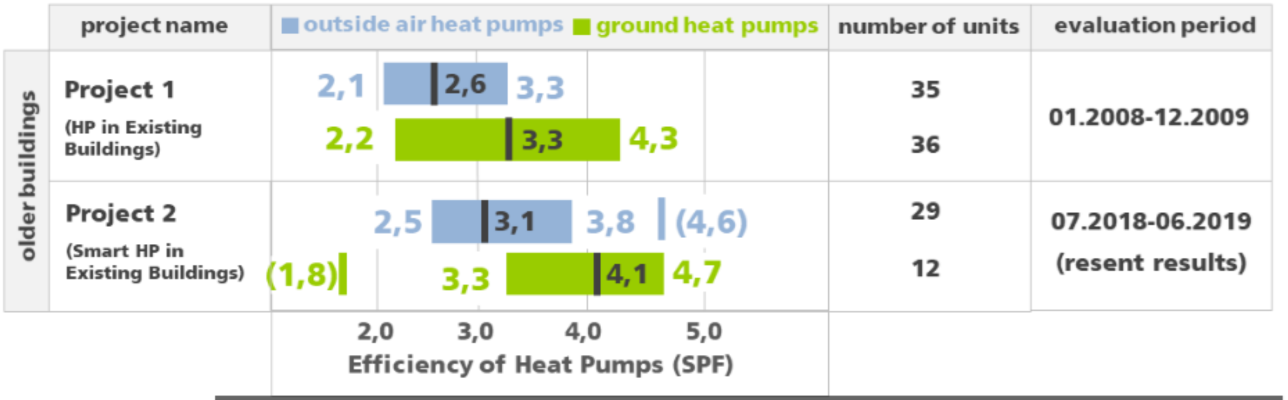
IRENA International Renewable Energy Agency

Heat pumps in existing buildings

– In many regions globally, future buildings exist today. For example, in **the EU**, **85%** of today's **buildings** are likely to still be **in use in 2050**.

– A common misconception assumes that heat pumps in old buildings would require **upgrade of (i) building envelope** and **(ii) terminal units (radiators**[1]**)** and then **CAPEX ↑ ↑**

– Heat pumps are **increasing their temperature ranges** reducing the needs for envelope upgrades at the cost of lower efficiencies.



Efficiency values of the heat pump systems from two field projects in existing buildings. © Fraunhofer ISE

Project 1, mainly non-renovated buildings – **90%** heated with radiators – were investigated.
Project 2, building age between **15 and 150 years** old, some partially or fully refurbished.

[1] *Radiators are frequently oversized in gas boiler installations.*

Heat pump challenges within the urban context

Heat pumps and climate

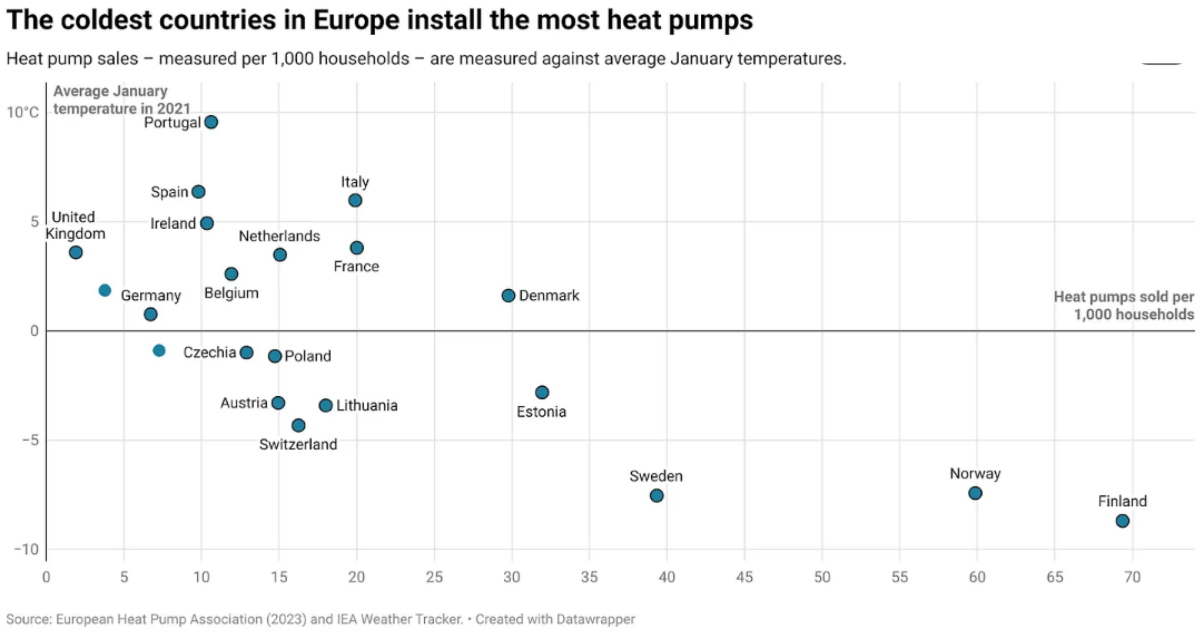
– Heat pumps have been proven to be effective in cold winter regions.

– In Europe, the Nordic countries have shown the highest adoption rate of heat pumps, while countries like Spain or Portugal, which have mild climates, have a lower level of usage.

– This result suggests that supporting policies and fuel availability (i.e. cheap/affordable electricity) are more important factors.

– Heat pumps designed for extreme cold show performances between 1.3 and 2 under temperatures of the order of -35°C.

– As for cooling, temperature ranges do not represent a major challenge for heat pumps operation.

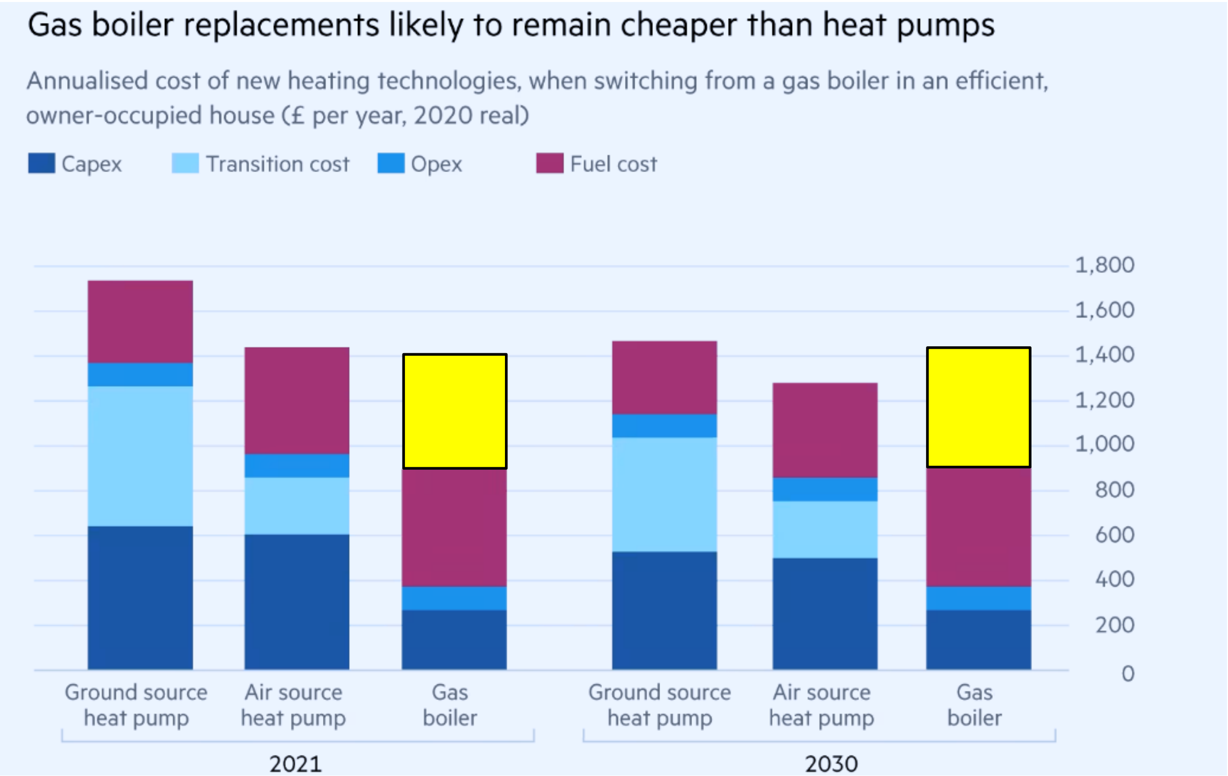


Source: Hannah Ritchie. Do heat pumps work in the cold?

Heat pump challenges within the urban context

CAPEX vs OPEX

$$\frac{\text{Cost of electricity (ct/kWh}_{el}\text{)}}{\text{Cost of gas (ct/kWh}_{thermal}\text{)}} \cong 2$$

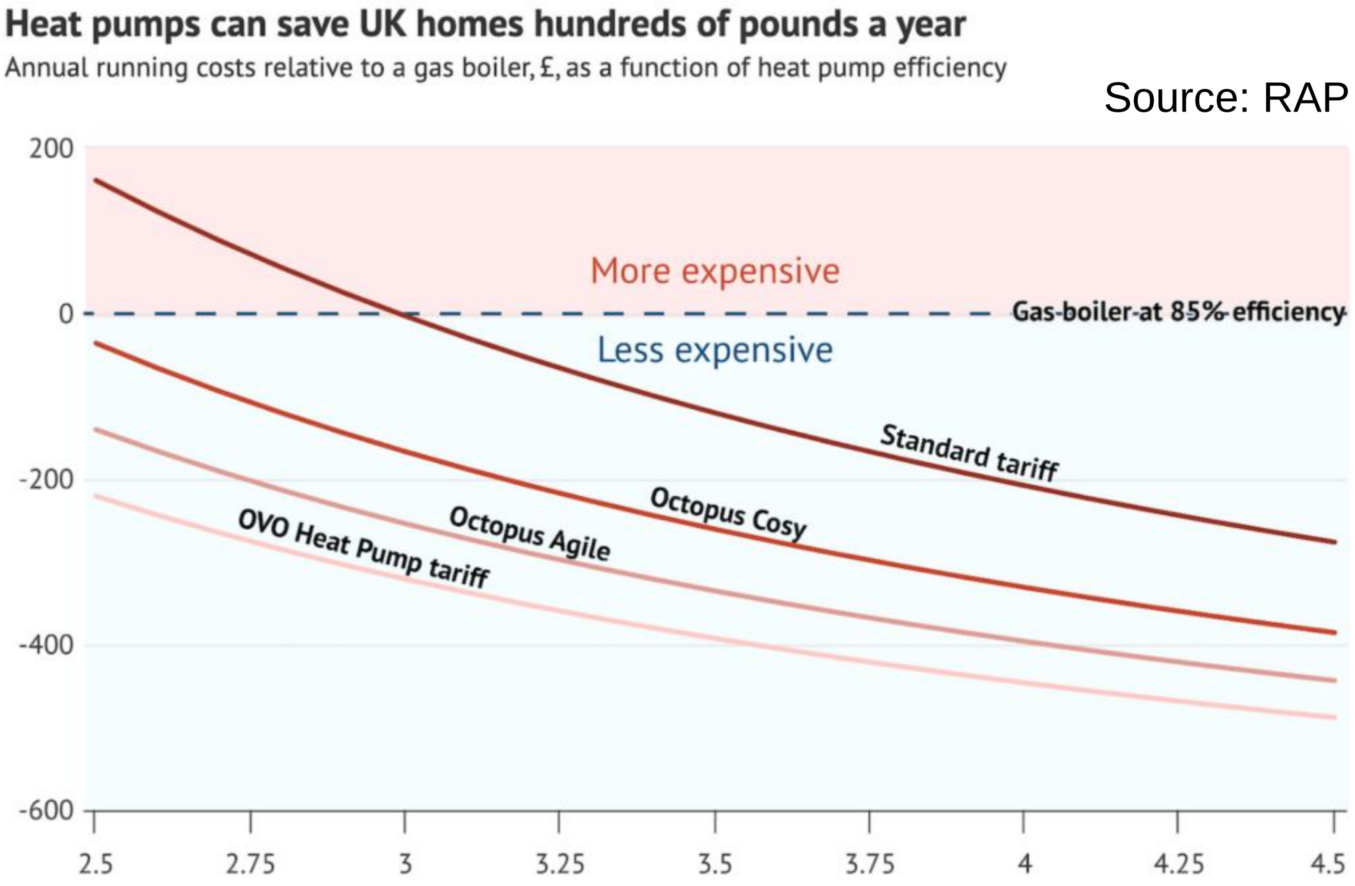


Source: FT (2023), Carbon counter: heat pumps are a greener, costlier option

Heat pump challenges within the urban context

CAPEX vs OPEX

– A cheaper electricity driven by a larger penetration of wind and solar can balance out CAPEX and OPEX



Source: RAP

Heat pump challenges within the urban context

What is the perception of users?

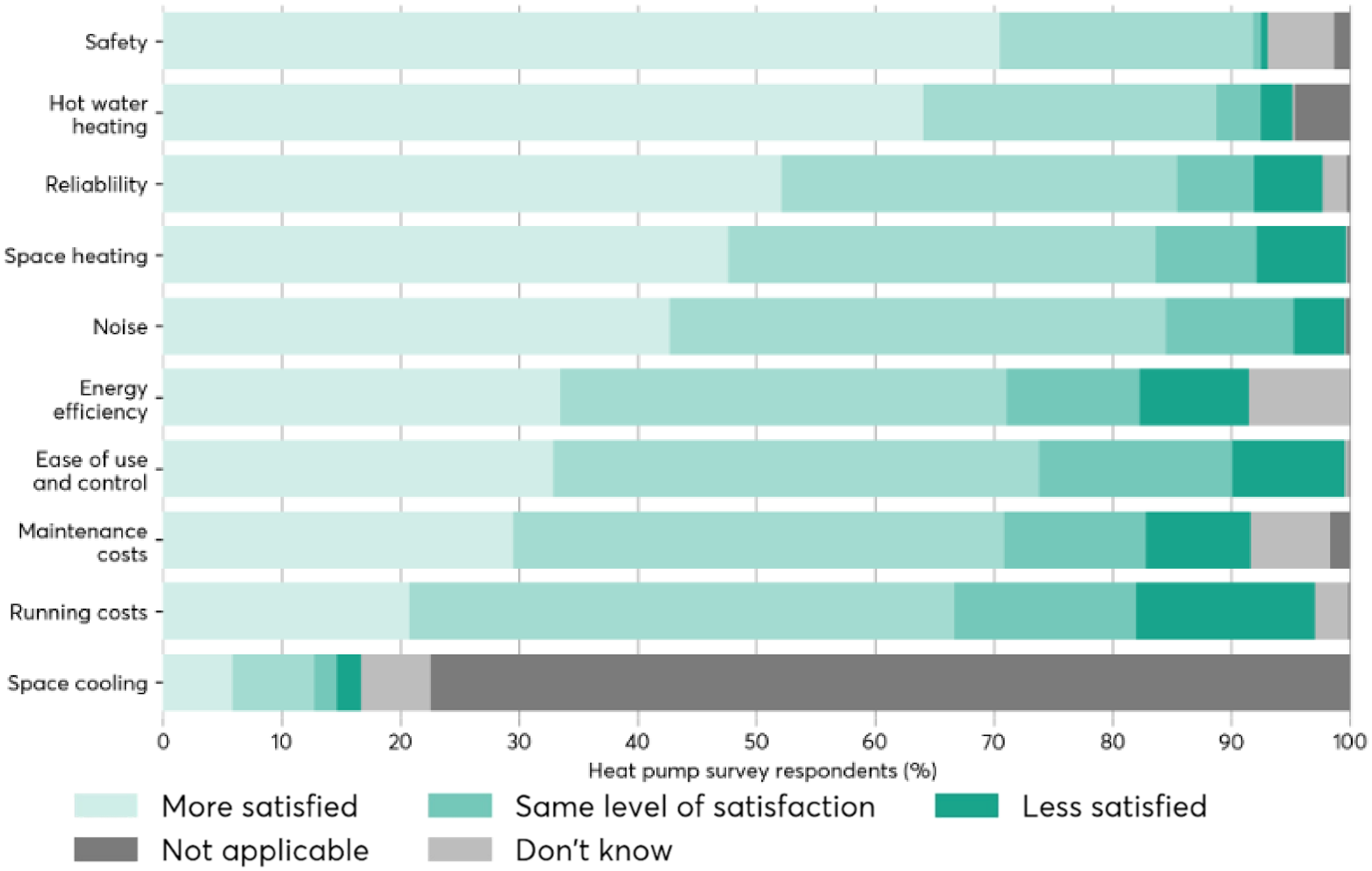
According to a survey study performed by NESTA in the UK (more than 2,500 users interwieved)

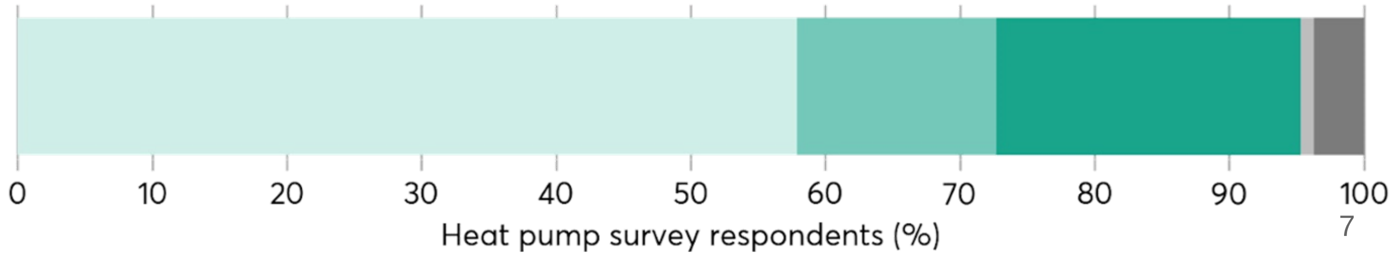
Main results

– **At least 70%** of people said they were 'fairly' or 'very' satisfied with all aspects of their heat source except running costs.

– No evidence that satisfaction varied significantly by property age.

– Upgrading building fabric alongside heat pump installations is common, but by no means universal (only 55% did both)





Heat pump challenges within the urban context

What is the perception of users?

According to a survey study performed by NESTA in the UK (more than 2,500 users interviewed)

Main results
– The building age does not seem to have a big influence in the satisfaction of respondents.

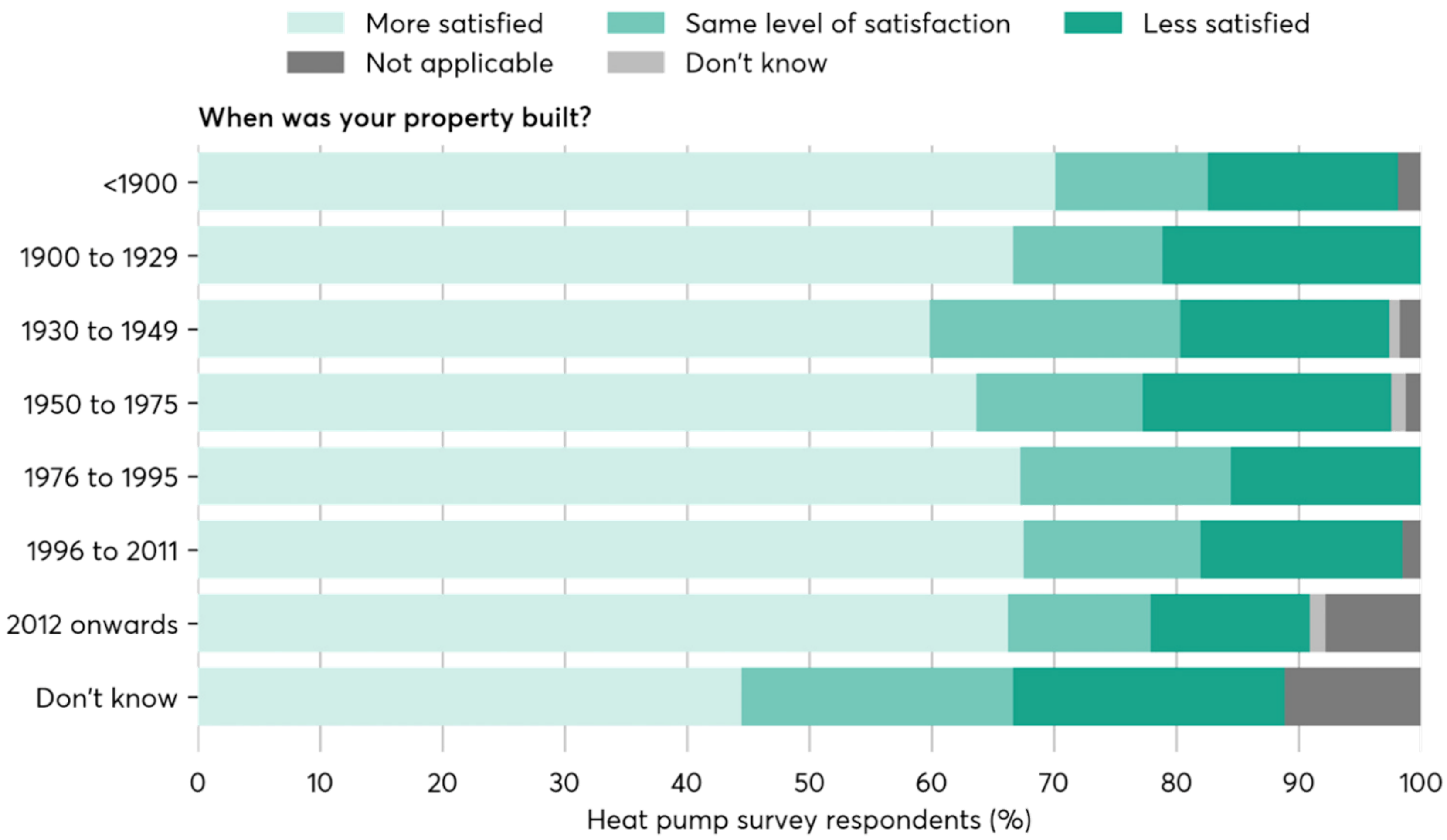


Figure 15: satisfaction compared to previous system, comparison with age of property.

Heat pump challenges within the urban context

4. Integration of heat pumps in multi family houses

– Heat pumps are well established in the single-family house segment but not in the multi-family house segment.

– Reasons can be technical (capacity of available products or access to heat source for the non-air heat pumps) or economic. Yet, the major barriers is the **lack of knowledge**

Case study
Heat Pumps in Multi Family Buildings

Annex 50 MFB IEA HPT

"Energy-Island Petershagen", Germany

The new housing complex uses a ground-source heat pump in each of the six multi-family buildings for both room heating and domestic hot water.

Key facts

Building	
Location	*Petershagen, GER*
Construction	*2018 et seqq.*
Heat distribution	*underfloor heating*
Heated area	*unknown*
Level of insulation	*new building*
Heat pump and source	
Number of	7
Installed th. power	*7 * 36 kW (Prated)*
Operation mode	*monoenergetic*
Heat source	*geothermal*
Heating system	
Heating temperature	*unknown*
Domestic hot water	
Type of system	*fresh water station in each flat*
Max. temperature	*unknown*
Circulation system	*unknown*

Other information
- passive cooling with ground heat exchanger
- Photovoltaic system and battery storage device

Source: Bosch Thermotechnik GmbH

The new housing complex will comprise six multi-family buildings and one community building. The 80 flats are built to meet the requirements of older people.

In each building a ground source heat pump system is installed. The heat pump system provides the heat for both room heating and domestic hot water. In summer the ground heat exchangers (GHEX) are used for passive cooling of the buildings. Photovoltaic panels are installed on the roofs of each building. The energy production is primarily used on side by the households and the heat pump or stored in batteries.

Source: Annex 50. Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water

Heat pump challenges within the urban context

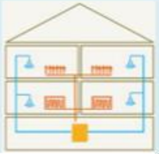
4. Integration of heat pumps in multi family houses

Case Studies

Heat Pumps in Multi Family Buildings

Annex 50+62 IEA HPT

Three Heat Pumps are enough to claim the BREEAM Certificate, Spain



F1.1

In San Sebastian de los Reyes in the heart of Spain, a building with 56 homes is heated and cooled by just three heat pumps.

Key facts

Buildings

Location	*Madrid, Spain*
Construction	*2019*
Project type	*newly built*
Heat and cooling distribution	*underfloor*
Heated space	*6,700m²*
No. of apartments	*56*
Level of insulation	*excellent*

Heat pump and source

Number of	*3*
Operation mode	*cascade*
Heat source	*Ground*
Services	*Heating & active cooling, DHW*
Type of system	*central*

Space Heating, DHW and Cooling

Installed power	*300 kW*
Heating temperature	-
DHW temperature	-

Pictures: AEDAS Homes, Ecoforest

Space Heating, DHW and Cooling

Installed power	300 *kW*
Heating temperature	-
DHW temperature	-

Other information

Coefficient of Performance	*4,6 - 5*
Refrigerant	*R410A*
Boreholes	*32 x 125m*

Lessons learned

- Savings compared to conventional gas boiler and aerothermal installation of 36%. This represents 32,600e per year.
- SPF July 2023 = 6,7

  SPF Annual = 5,3

Why is it a unique project? What innovation does it implement in terms of technology, design, services or other aspects?

This building is a sustainable construction both in its design, execution and final phase, obtaining the highest level of energy rating. Not only does it have a geothermal system with water-water heat pumps operating in cascade, but it also has an underfloor heating-cooling system, special attention to thermal insulation and a double-flow ventilation system with heat recovery.

What is the replicability potential of this project?

The replicability of the project is wide, it is applicable to any type of residential building. This technology not only makes it possible to comply with existing building regulations and satisfy European Directives, but also enables a seal of sustainability to be obtained that provides visibility, recognition and the capacity to become a guide for buildings to be constructed in the future.

Source: Annex 50. Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water

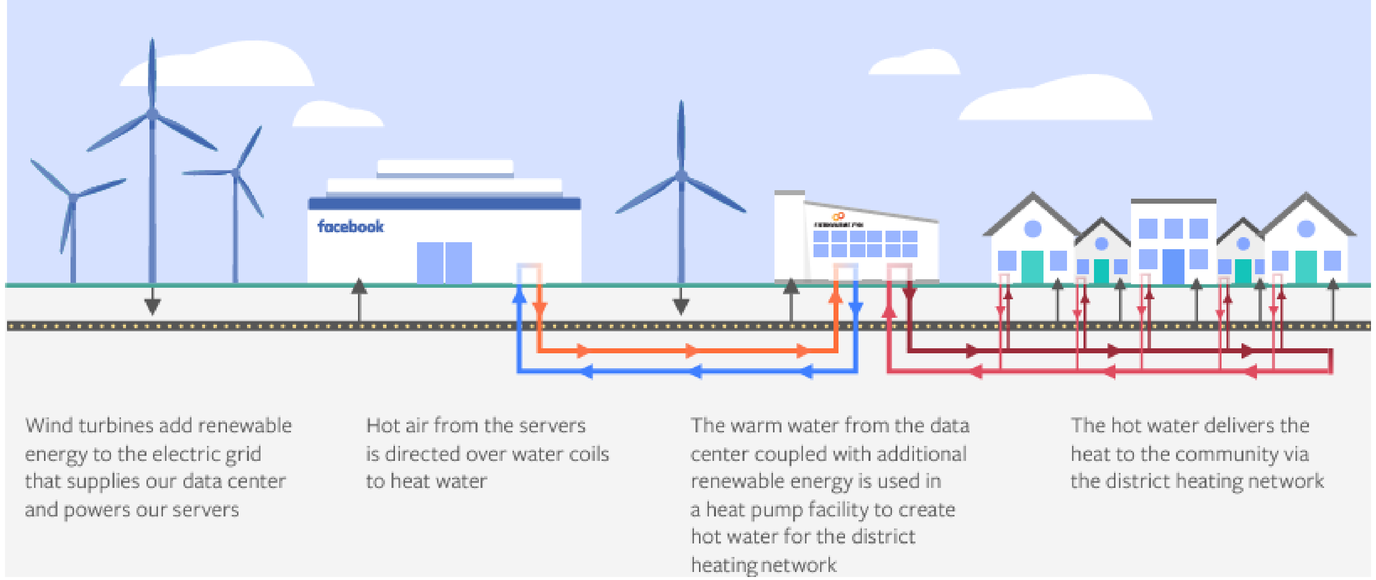
Heat pump opportunities within the urban context

Integration of heat pumps in urban areas. District heating and cooling

– Setting up common heat pump projects in multi-owned buildings can be difficult specially if heat pumps are not planned in the design phases. As an alternative, heat pumps can provide heat via district heating and cooling.

– In DHC, heat pumps can be the main energy generator or serve as asset to increase the temperatures of energy streams such as waste heat from data centers **(booster heat pumps)**

– Heat pumps in district heating and cooling benefits from economy of scale, can provide flexibility services to the grid and, ultimately, provide clean and affordable thermal energy to end users.



Source: META Sustainability.
CASE STUDY Denmark data center to warm local community

Heat pump opportunities within the urban context

Hibridisation with PV.

– Heat pumps can be combined with PV and consume the electricity on-site

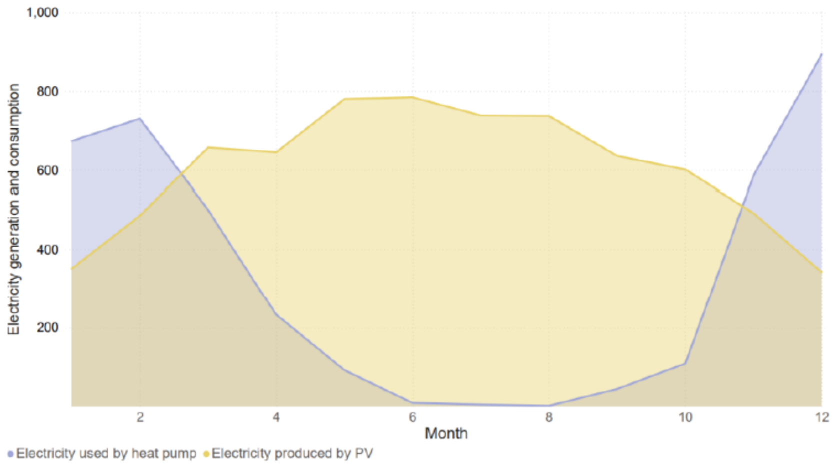
– In regions with significant cooling demand benefits increase since supply and demand coincide during the central hours of the day

– Home batteries can match supply and demand especially in winter periods

Figures shows the monthly electricity generation by PV and electricity consumption for space heating by heat pump, with the reference building located in the Netherlands and France, built between 1980 and 1999 if 20% of the roof is covered by pv.
Source: The Heat Pump Wave: Opportunities and Challenges, JRC (2023)

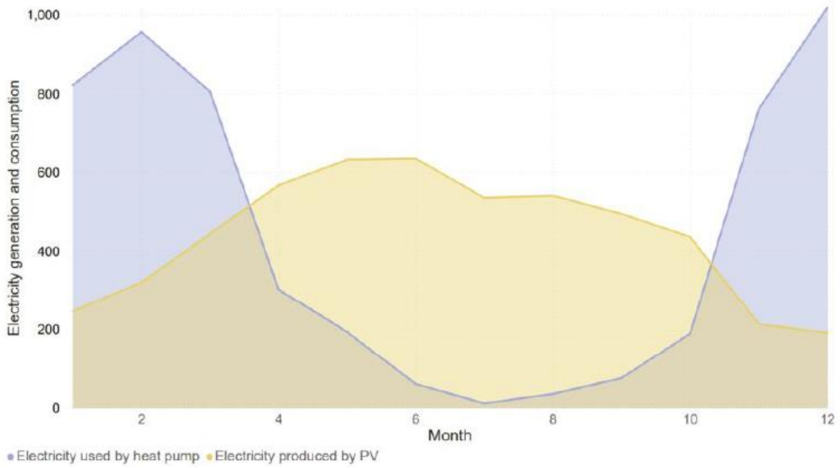
France

Monthly energy generation and consumption for a typical single-family house, kWh



The Netherlands

Monthly energy generation and consumption for a typical single-family house, kWh

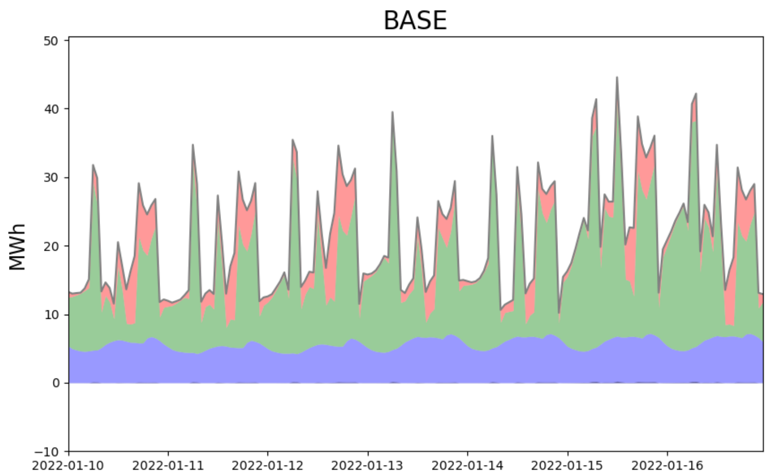


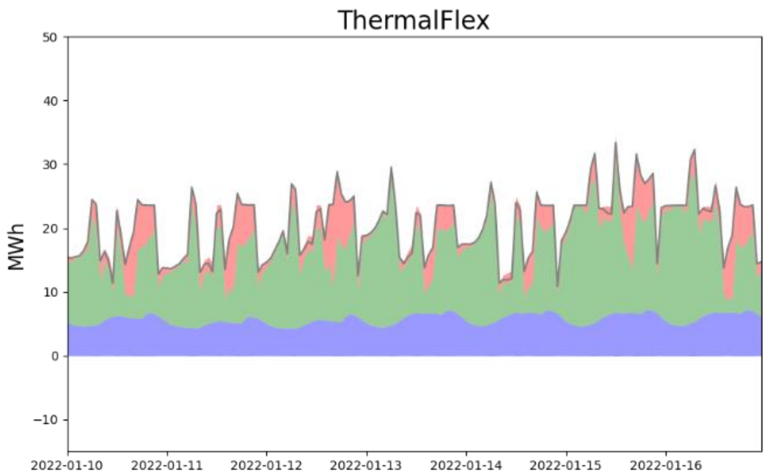
Heat pump opportunities within the urban context

4. Heat pumps in urban areas can contribute to the operation of distribution grids.

– Centrally managed heat pumps via either large scale heat pumps in MFH or via district heating systems can help manage distribution grids, reducing losses and, paradoxically, avoiding potential grid reinforcements.

– Individual heat pumps can also contribute to the grid operation, but the right mechanisms must be in place, such price signals.





The introduction of thermal storage equipped HPs in the grid (**50% penetration**) helps decrease **total network losses by 27%** and **reduce peak losses by 67%**, when compared with BASE scenario.

IRENA study on DSM (to be released in 2024)

Heat pump opportunities within the urban context

IRENA
International Renewable Energy Agency

4. Innovation in the power to heat interface

TECHNOLOGY AND INFRASTRUCTURE | MARKET DESIGN AND REGULATION | SYSTEM PLANNING AND OPERATION | BUSINESS MODELS

POWER TO HEAT AND COOLING

Technology and infrastructure

- **1** Low-temperature heat pumps
- **2** Hybrid heat pumps
- **3** High-temperature heat pumps
- **4** Waste heat-to-power technologies
- **5** High-temperature electricity-based applications for industry
- **6** Low-temperature thermal energy storage
- **7** Medium- and high-temperature thermal energy storage
- **8** Fourth-generation DHC
- **9** Fifth-generation DHC
- **10** IoT for smart electrification
- **11** AI for forecasting heating and cooling demand
- **12** Blockchain-enabled transactions
- **13** Digitalisation as flexibility enabler

Market design and regulation

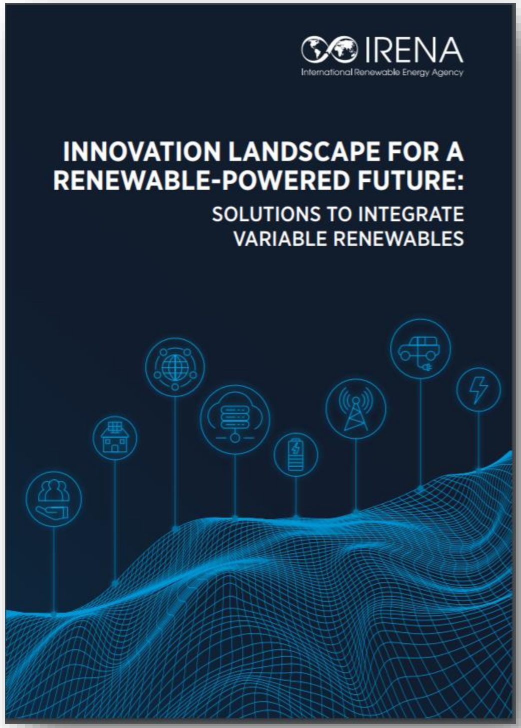
- **14** Dynamic tariffs
- **15** Thermal load flexibility
- **16** Flexible power purchase agreements
- **17** Standards and certifications for improved predictability of heat pump operation
- **18** Energy efficiency programmes for buildings and industries
- **19** Building codes for power-to-heat solutions
- **20** Streamline permitting procedures and regulations for thermal infrastructure

System planning and operation

- **21** Holistic planning for cities
- **22** Heat and cold mapping
- **23** Coupling cooling loads with solar generation
- **24** Smart operation with thermal inertia
- **25** Smart operation with seasonal thermal storage
- **26** Smart operation of industrial heating
- **27** Combining heating and cooling demands in district systems

Business models

- **28** Aggregators
- **29** DERs for heating and cooling demands
- **30** Heating and cooling as a service
- **31** Waste heat recovery from data centres
- **32** Eco-industrial parks and waste heat recovery from industrial processes
- **33** Circular energy flows in cities – Booster heat pumps
- **34** Community-owned district heating and cooling
- **35** Community-owned power-to-heat assets



Thank you!

Contact:

Juan Pablo Jiménez Navarro

jnavarro@irena.org