An affordable, efficient, and technically feasible decarbonization of residential heating

May 2025

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Introduction

The achievement of the climate targets and the objectives set out in the REPowerEU plan should be supported by Member States' national policies and measures, as referred to in the EPBD (Article 3, Article 13(7) and Annex II). The assumption that electrification will be achieved across all building stock and the heating sector via power-driven heat pumps has **limitations**. These limitations depend on factors such as electricity supply chain constraints, energy prices attractiveness, building stock characteristics, climate, local socioeconomic conditions, and the decarbonization policies and finance programs implemented by Member States. Broad deployment of power-driven heat pumps alone is a limitative option path, and it will have unintended effects on the overall energy system (affordability, security of supply, sustainability and efficiency of the full energy system).

It is essential to ensure that other complementary options, such as renewable and low carbon gaseous energy carriers and their related heating technologies are also recognised as valid options where they excel. This recognition is key to achieving an environmentally, industrially and socially sustainable energy transition within a timeframe consistent with the European Union ambitions. Only an adequate, diverse, fit-to-purpose energy and technology mix in the built environment will allow for reaching the objectives timely. This is particularly true for the existing building stock where only a case-by-case approach defines the fastest way towards decarbonization.

1) Affordability of heat pumps and alternative options for end users

Electric heat pumps are promoted by European and national regulations due to their appliance efficiency and environmental benefits. However, **these regulations may overlook or underestimate the financial impact on the end-users and systems**. The initial purchase and installation costs are often high, and maintenance expenses can be significant, making it challenging for many households to afford this technology. While long-term savings and environmental advantages are achieved when the system is correctly installed, **the upfront financial burden of switching to a heat pump remains a critical issue for many households**.

Apart from the investment for purchase and installation of a heat pump, the efficient use of a heat pump in an existing building often requires

- **prior insulation measures to further reduce the heat demand;**
- **equipment with a low-temperature delivery system like low-temperature radiators or, even better, floor heating.**

That obviously further increases the investment costs substantially. So, a professional case-by-case analysis seems the most appropriate way to define and fit the specifications of the building, the supply of energy vectors and the end-users' needs.

Beyond the high initial costs and uncertainties surrounding future energy sources, the **ability to invest, closely tied to the annual income and funding possibilities of each household**, poses significant challenges. This issue exists in many countries, e.g. Spain (Sedigas, 2023) (Figure 1) and Italy (BIP, 2024) (Figure 2) illustrating diverse social situations across Europe.

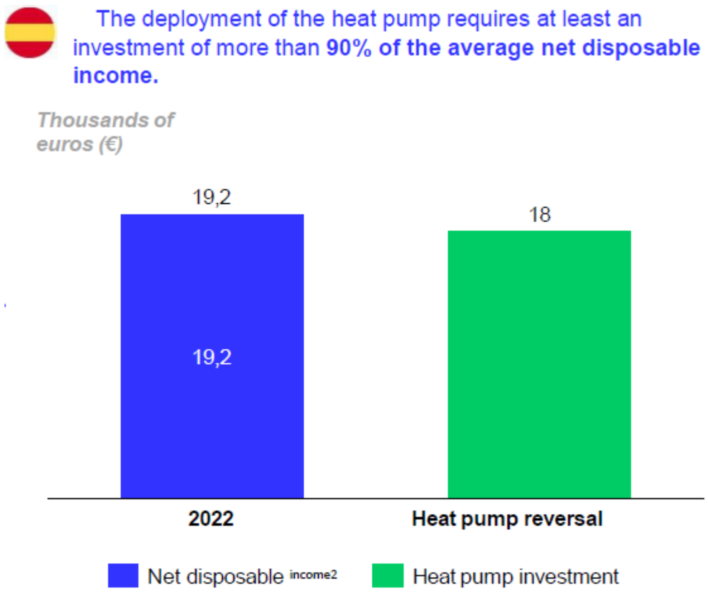


Figure 1: Comparison between the investment costs in an electric heat pump and the average net disposable income in Spain (Sedigas, 2023)

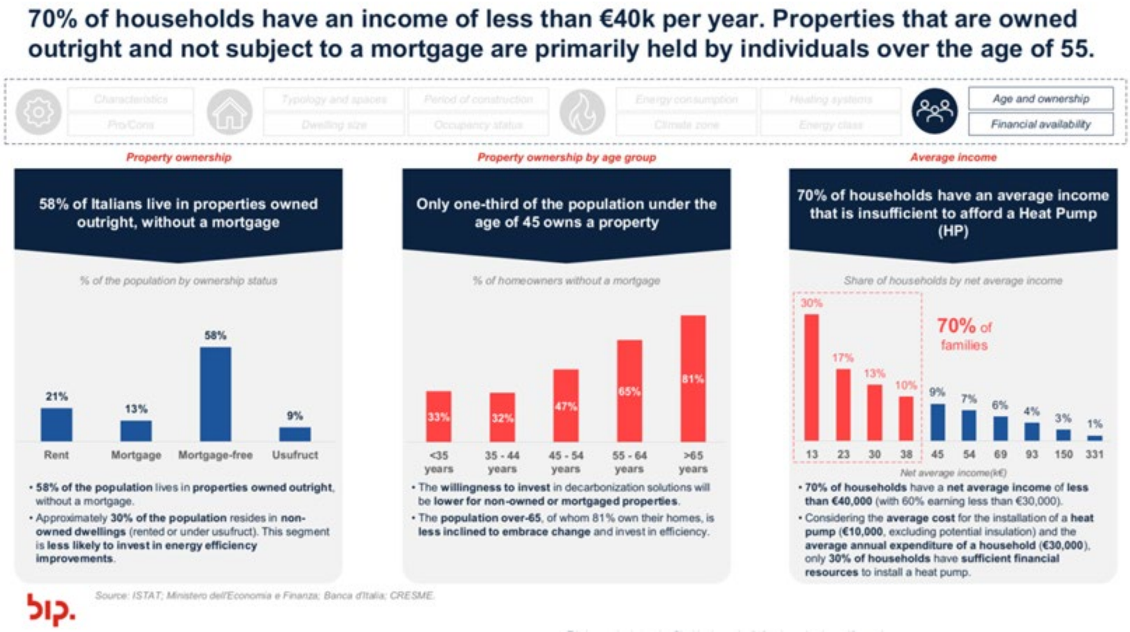


Figure 2: Social repartition of the Italian citizen and impact on their possibilities to invest (BIP, 2024)

2) Challenges on installing heat pumps in many existing buildings

Requiring the implementation of electric heat pumps throughout the entire building stock in Europe does not seem realistic, as it **does not fully consider the physical realities of existing housing typologies in the building stock**, particularly in urban areas, as noted in the European Building Stock Observatory statistics, or several National studies (Pouget Consultants for the French Government, 2022).

- **Heat pumps,** particularly hydronic (air/ water) systems, **require substantial indoor space** due to the necessity for heat storage (for both heating and domestic hot water) and the associated pipework and hydraulic unit connecting the outdoor unit and the electrical resistance add-on. Figure 3 (Sedigas, 2023) illustrates the practical challenges of replacing a boiler (in Spain typically installed in the kitchen, particularly in apartments) with a heat pump that offers equivalent heating and domestic hot water services.

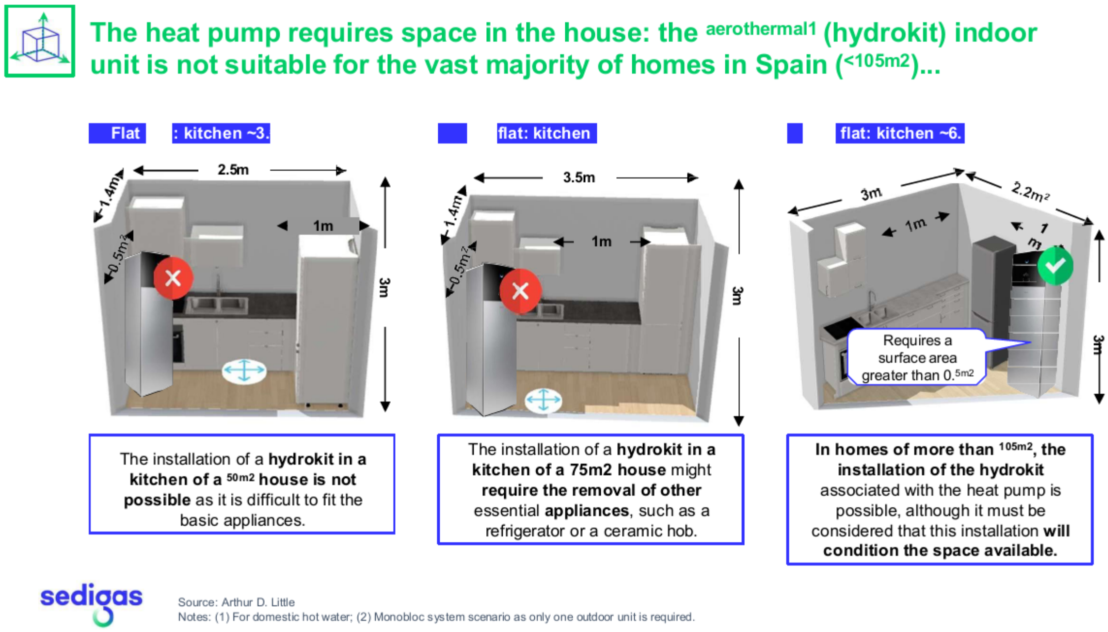


Figure 3: indoor installation constraints for houses and apartments in Spain (Sedigas, 2023)

- The installation of the outdoor unit of a heat pump can be challenging due to technical constraints on façades, inner courtyards and roofs. Heat pump solutions may not be suitable in all scenarios, particularly in vertically structured, small or low-income buildings, as illustrated in Figure 4. Specific legislation related to installation and noise, which can affect neighbours, may also play a role (Pouget Consultants for the French Government, 2022), (Sedigas, 2023). It is important to note that outdoor units must be installed and maintained safely, requiring easy access for one or two technicians.

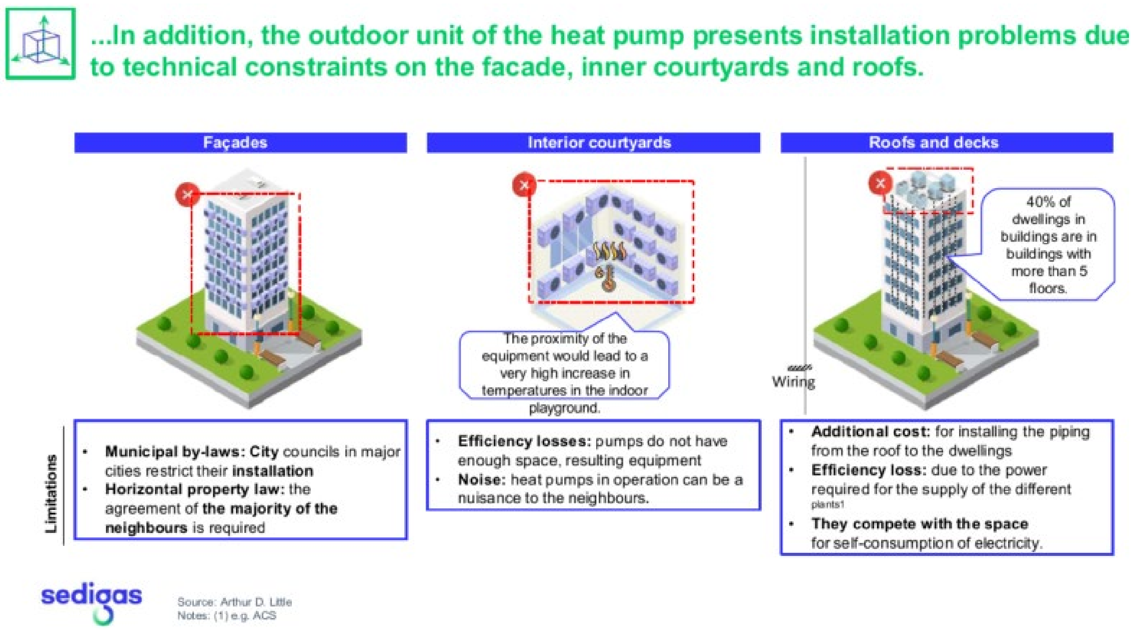


Figure 4: outdoor installation constraints for vertically structured dwellings in Spain (Source Sedigas)

- European regulations on refrigerants, including the F-gas Regulation (EU) 2024/573 and upcoming restrictions on Per- and polyfluoroalkyl substances (PFAS) (REACH and on-going discussion with ECHA1) will drive the market towards new natural refrigerants such as flammable hydrocarbons (e.g., propane, R290). These refrigerants require extended safety distances around the external unit, to prevent formation of hazardous zone in case of

[1] https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

refrigerant leakage, particularly for large installations with higher amounts of flammable refrigerant). Constraints on current refrigerant use aimed at reducing greenhouse gas emission introduce new risks related to end-user safety, which are not yet addressed in standards. As illustrated in Figure 5, an outdoor unit using R290 cannot be installed within at least 3 meters of any window or balcony, further restricting the feasible use cases, especially in urban area where buildings are close together, facades inevitably have windows. Manufacturers currently have distance recommendations for installing hydronic heat pumps' outdoor units on the ground or roof, but there are currently no such guidelines for building façades[2].

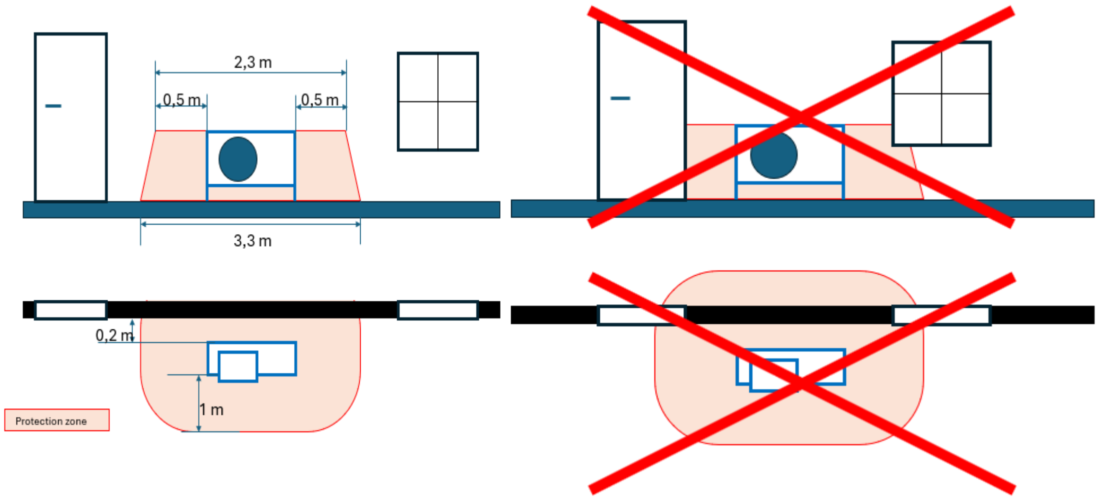


Figure 5: distances required around the outdoor unit with R290, to avoid inflammability, in case of leakage, example from (WOLF, 2020) but a reference between others

When deciding to replace an existing heating system by an electric heat pump, another limiting factor is the timeframe for offering, planning, decision and execution as it is not a simple matter of plug & play.

- As concluded by a study by (BIP, 2024) and a survey conducted on behalf of the EU Commission (BEUC, 2023)), this entire process can take **many weeks for a planned installation**, even up to four months. While a boiler replacement can generally be completed within 1 or 2 days, replacing an existing boiler with an air-water heat pump is simply unfeasible in a short timeframe.
- When replacing a failed energy system with a heat pump in an unplanned installation, significant logistical challenges arise, particularly in apartment buildings. Temporary measures are needed to maintain comfort during winter. Collective decision-making is required for modifications affecting common areas or the building's exterior, ensuring compliance with local building codes, noise regulations, and safety standards. Homeowners' associations (HOAs) often have specific rules, including obtaining permits and ensuring the installation does not disturb other residents. Proceeding without prior approval can lead to legal complexities, resulting in delays or practical impossibilities for the installation. Consequently, additional time delays or practical impossibilities for such change are expected.

[2] To the authors' knowledge

3) Caution to the generalization of some successful cases with particular features

As previously discussed, the deployment of heat pump faces several real-world challenges. Nevertheless, Europe has ambitious plans to accelerate heat pump deployment through measures that discourage other sustainable energies and solutions that are easier to fit in existing buildings and installations and that are more affordable.

This paper does not aim to undermine the benefit of heat pumps in the right cases. However, theoretical and lab test results often differ from real-world installation contexts, which require proper sizing of the appliance to match the building's characteristic (insulation, heat emission system, climate) and professional installation. In the largest field study of electric heat pumps to date (1,075 connected appliances analysed over 10 countries), (Brudermueller, 2025) found that "17% of air-source (…) do not meet existing efficiency standards"[3]. The study advocates for "standardized post-installation performance evaluation procedures and digital tools to provide actionable feedback for users and installers to enhance operational efficiency and guide future installations". Despite the expected performances benefits of heat pumps, customer surveys also bring mixed results regarding the economic gain for end-users. According to (UFC Que Choisir, 2024), 29% of owners have not seen a decrease in their heating bill, and 13% have noticed an increase since using their heat pump. According to (EEB, 2022), only 64% of users spend less after installing a heat pump.

These figures must be considered in the context of energy prices but also reflect incorrect installation or lack of experience of installers, indicating that the market is not ready for a large-scale conversion. The initial attempts to ban boilers and promote electric heat pumps generated a lot of debate and tension, while benefits were often unproven. Consequently, Germany and the UK have (temporarily) reallowed gas boilers after attempting to ban their installation in buildings. Initially planned until 2024 in Germany and 2025 in the UK, the allowed installation of new boilers of these appliances has been extended until 2045 and 2035, respectively. The UK government dropped this ban in January 2025 (The Guardian, 2025). A similar decision was taken in the Netherlands in May 2024 (EHPA, 2024), as the country faces electricity grid congestion problems at the transport and distribution levels (Oost, 2024), (NOS Nieuws, 2024), Figure 8.

The high penetration of heat pumps in the Scandinavian countries with their colder climates is often cited as an example to follow. However, it should be noted that their situation is not comparable with that of other European countries having higher population densities, less controllable renewable electricity production (hydro), different building types, more co-ownerships, etc. Heat pumps are indeed widely deployed in the Scandinavian countries, but they are most often

- used in buildings without access to a gas grid,
- air/air heat pumps that only heat one or two rooms,
- supplemented by individual room heaters such as stoves or fireplaces, electric convectors, etc., and equipped with a separate domestic hot water solution also working on electricity.

An extensive study by BIP on the Italian market, summarized in Figure 6, quantifies the main obstacles to the widespread adoption of heat pumps in relation to the different limits quoted in this document. **Out of 31.1 million Italian dwellings, only 1.76 million are considered suitable for installing an electric heat pump**.

[3] According to the study's authors, Seasonal Coefficient of Performance (SCOP) of 3.01

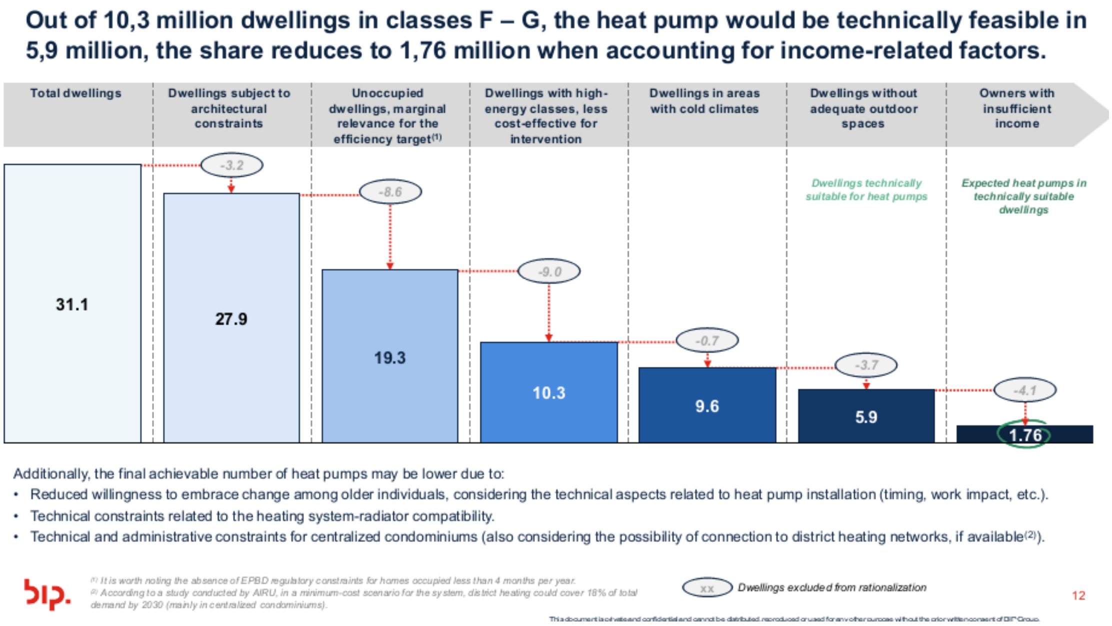
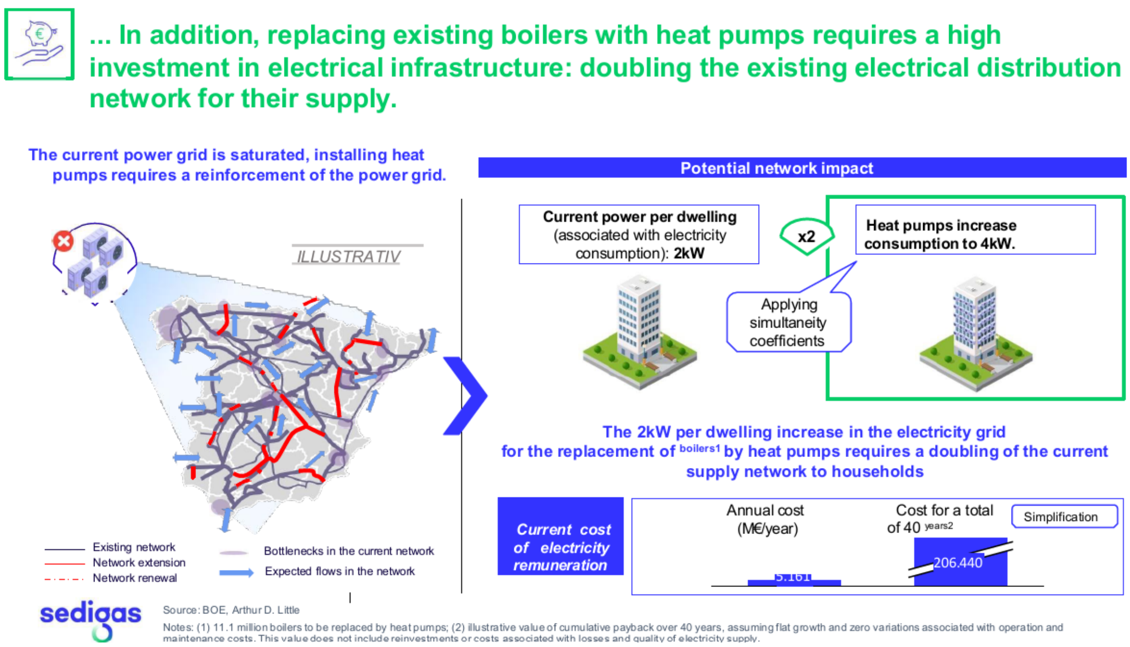


Figure 6: illustration of the different listed impacts of the initial stock of dwellings in Italia (Source: bip)

4) Electrification of heating and its impact on grid costs and competitiveness

A non-diversified electric heat pumps only heating strategy necessitates substantial investment in electricity supply and transfer infrastructure, specifically in the existing electricity transport and (mainly) distribution networks. These costs are often overlooked when considering the advantages of heat pumps. Official data (ACER, 2025) explains that the current annual grid investment is expected to double until 2050 (reaching up to 100 billion per year) and that this cost will undoubtedly be repercussed on the electricity final end-user through network tariffs. Conversely, these (often) same distribution companies already possess existing renewable-and-low-carbon-ready polyethylene pipes that could be utilized to supply appliances with decarbonised fuels at low conversion costs.



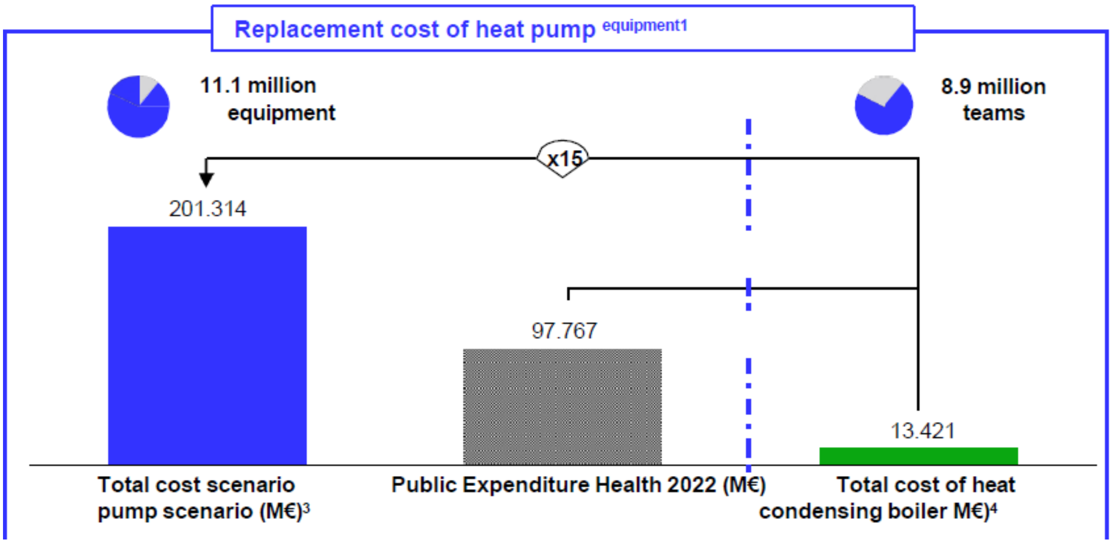


Figure 7: requests for installing electric heat pumps in buildings mean doubling electricity distribution infrastructure and multiplying costs by 15 (Sedigas, 2023)

Another aspect to be considered is that the efficiency of electric heat pumps is at least partly counterbalanced by the system impacts of variable renewables (that are supposed to feed these appliances): such as variability, security of supply issues, the lack of affordable and long-term mass storage, lack of flexibility, the need for more expensive grids, oversized generation infrastructure to compensate for lower running hours, grid ancillary services, and the need for new micro-storages at households and within the system (CRMs[4]...). Therefore, power demand and production must be considered when analyzing a system-scale deployment of electrification.

As illustrated in Figure 8, many regional grids in the Netherlands are already saturated. Other stable renewable and clean energy sources (non-electric) also exist with good potential for affordable, secure, and efficient heating (by molecules), providing an alternative that should neither be ignored, nor obstructed by policy measures.

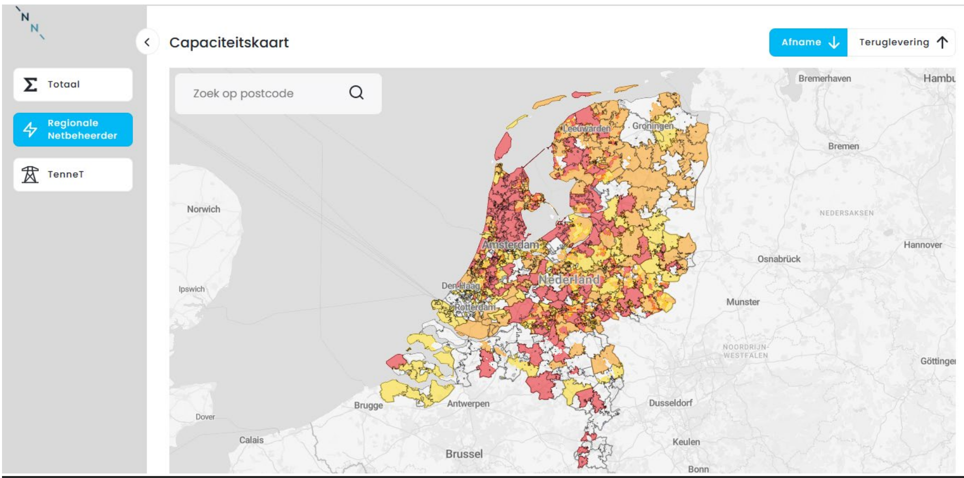
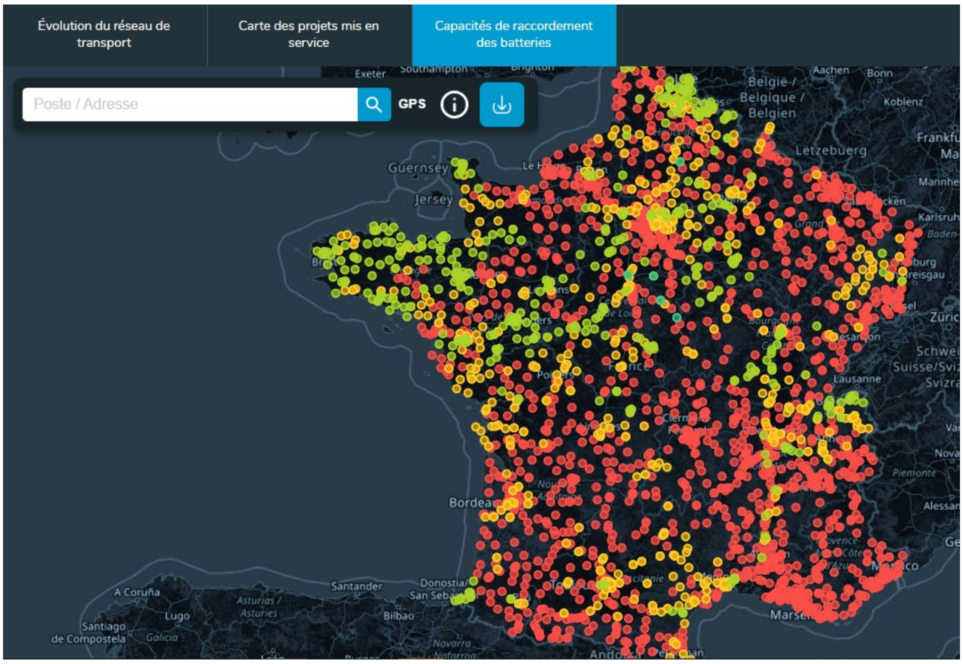


Figure 8: illustration of electricity grid congestion for connecting devices at transport level (Tennet N.V.)

For France, EDF has recently published a map in Figure 8B for the connection of batteries, and most substations have <5MW connection capability (red) or are within the range between 5 and 12 MW (yellow), so a similar situation is present. Lack of diversification unavoidably leads to saturation and bottlenecks.

[4] CRM: Capacity remuneration Mechanism (one type of System Adequacy mechanisms)



Source: https://analysesetdonnees.rte-france.com/reseaux/cartostock

Figure 9B: illustration of capacities for connecting batteries at substations (EDF)

5) All energy carriers have to be allowed to compete based on their intrinsic footprint characteristics

Under the European Union's strategy for Ecodesign (Directive 2009/125/EC), appliances must meet performance, noise and specific emission (NOx) thresholds before commercialization. The environmental impact of heat production is mainly based on its energy source used (the footprint of electricity, gas, biomass, fuel) and is considered to satisfy Ecodesign requirements. Both boilers and electric heat pumps must move from fossil to renewable energy sources. **It is not the type of equipment, whether boiler or heat pump, that determines its renewability, but the energy it uses**. A paper (EPB Center, 2024) affirms the same and makes a comparison between heat pumps using the actual electricity mix in Europe and a condensing boiler using biomethane, in terms of CO_2 emissions.

	Coal boiler	Oil boiler	Electric boiler	Natural gas boiler	Hybrid heat pump with oil boiler	Hybrid heat pump with gas boiler	Electric heat pump	Biomethane boiler
CO_2 emissions [g/kWh]	450	322	251	232	184	118	70	46

Figure 9: CO2 emissions from several heating systems (EPB Center, 2024)

According to EPBD (Article 13(8), Article 17(15)), the European Commission prepared [Notice](#) C/2024/7161 which defines what qualifies as a fossil fuel boiler (Article 4.2). It is crucial to consider not only the proportion of renewables (ratio of renewables to fossil fuels) used by the appliance but also the CO_2 emission factor and its overall footprint for each household and appliance (EPB Center, 2024).

- Currently, the notice proposes to evaluate renewable and low carbon gases appliances by the average percentage of theoretical decarbonization achieved in the grid system as a whole.
- This seems restrictive and limiting considering the technical, market, and juridical possibilities: all clean and renewable heating appliance solutions should be assessed based on their individual performance, decarbonization percentage of the fuels they actually use (by certification), general footprint, and full energy system impact taking into account the necessary flexibility. For instance, this approach is already applied for residential customers through the certification of green electricity, but not yet for renewable and low carbon gases (only the average percentage in the grid would be possible, no individual certificates), creating a disparity between energy types that could offer similar benefits for decarbonization.

There should be no additional barriers to using a diverse mix of clean energy carriers in buildings, nor any predetermined pathway for heating decarbonization with one technology over all other clean and renewable ones. In summary, regulations should be more comprehensive and precise for each type of appliance, ensuring a level playing field for all energy carriers based on actual footprints, rather than generic assumptions. Specifically, the certification of renewable and low carbon gases for use in households should be enabled and promoted in the same way that the certification of electricity is currently allowed for the same purpose.

6) Gas appliances are efficient system-wise

In addition to gas boilers, innovative technologies for the efficient use of renewable and low carbon gases such as gas heat pumps, hybrid systems and fuel cells **are readily available**.

Decarbonization through energy-efficient solutions using renewable and low carbon gases (e.g. gas boilers) can be applied immediately with effective and measurable results in reducing CO_2 emissions. This contrasts with other hypothesized solutions (full-electric heat pumps everywhere) where the reduction in emissions is based on theoretical calculations of appliance-only efficiency using average profiles often not supported by: adequate experimental real-life data, or by full-energy system based considerations (ignoring most of the value chain and its impacts: grids, generation over-capacity, storage and flexibility needs), and not calculating the full footprints, energy system affordability, security of supply, etc.

- Techno-economic studies from reliable actors and energy regulators (CREG, 2024) indicate that heat pumps are not always the best solution for households and highlight the barrier caused by long paybacks. This depends on factors such as the year of construction, isolation level, socioeconomic level, ownership factors, etc.
- The European Heating Industry association (which includes heat pumps, but not exclusively) has completed a study (GuideHouse, 2022) proving that "*pathway B (diversity in heating solutions) achieves the objectives of Fit-for-55 and REPowerEU in an easier, cheaper, more socially acceptable as well as flexible way, with an aggregated cost benefit of over 520 bn EUR until 2050, compared to pathway A (only electric heat pumps)*"

There is significant potential for enhancing **energy efficiency in existing installations. Standard boilers can be replaced with condensing boilers**, a mature technology that is not yet widely adopted, offering a **quick reduction in energy consumption**. These boilers are highly economical in terms of both installation and maintenance, and they become decarbonised the moment their fuel is (the same applies to heat pumps).

Additionally, gas boilers can be integrated with heat pumps in a hybrid system. The heat pump provides part of the heating, while the boiler operates during peak demand or high marginal CO_2 emissions. This approach ensures efficiency, reduces the carbon footprint and decreases gas consumption, which can then more easily be supplied with biomethane. Extensive modelling on the European regions, (CERRE, 2024) demonstrated that hybrid heat pump deployment could play a role equivalent to massive electric storage development in addressing renewable energy intermittency in the electric network by 2050.

7) Gas appliances are ready for decarbonized fuels at affordable conditions and rely on existing and efficient transmission, storage and distribution systems

Technologies for producing renewable and low carbon gases (hydrogen, biomethane, blends) are competitive with other renewable and clean alternatives and are substantially safer from geopolitical constraints due to their diversification or local character (circular economy perspective). They are available and can be easily implemented with existing infrastructure repurposing or new installations at optimal cost. Biomethane is molecularly identical to currently distributed gas carriers, except for being close to net-zero emission. Polyethylene gas distribution grids are mostly hydrogen-ready.

Gas boilers already can operate with biomethane and can be easily designed to run on pure or blended renewable or low carbon hydrogen with minimal or no conversion costs. These boilers are an efficient and affordable tool for a faster decarbonization, supporting the energy transition by significantly reducing carbon emissions while optimally reutilizing existing infrastructure. While electric heat pumps are one solution for building decarbonization (Article 3 from EPBD), gas appliances running on renewable and low carbon gases offer an equally appropriate solution, ensuring reliability and efficiency in the journey towards a fully decarbonized building stock.

The transition to renewable and low carbon gas carrier allows extensive reuse of existing infrastructures with high resilience across all phases of the supply chain (transmission, storage, distribution and end-user appliances), resulting in lower costs and faster installation time. It also efficiently addresses energy storage needs and interacts synergistically with electrification, alleviating congestion burdens. Decarbonization solutions using renewable and low carbon gases or more efficient gas equipment produce effective and measurable reductions in CO2 emissions quite affordably and quickly.

8) A mixed-technology approach ensures security of supply, affordability and sustainability, and preserves customers' freedom of choice based on market and suitability

Households should have the autonomy to choose their preferred (best) heating decarbonization solution, as they pay for the costs of their own technical conversion. The available options should enable them to achieve their decarbonization targets conveniently and affordably with a solution that is fit to purpose. Diversification of decarbonizing solutions (mimicking diversity in the building stock and its needs) promotes competitiveness, increases users' choice options, and protects the security of supply by diversifying risks. It also activates cross-carrier synergies that enable efficiency gains, footprint reductions and better overall affordability. **No single solution fits all, a combination of clean solutions always performs better.**

The risk identified by Marcogaz is that effective and affordable decarbonizing technologies may be displaced by incomplete regulations and guidances that do not consider systems, infrastructure needs, mix diversity synergies (macro) or conversion costs (micro).

- The high efficiency of gas appliances is supported by the net-zero emissions of future clean gas systems (repurposed or new), with sufficient and affordable storage, flexibility, and efficient transmission and distribution costs.
- Condensing boilers allow for a cost per kg of CO_2 abated that is three times lower than electric heat pumps and have the same decarbonisation potential (Sedigas, 2023). Condensing boilers fuelled by renewable and low carbon gases are a viable solution for achieving building decarbonisation targets. **Boilers have and will continue to have a key system role for heating, which regulation and labelling standards should recognise by better enabling and facilitating their effective decarbonization**.

Coordinated plans for deploying electric heat pumps alongside renewable and low carbon networks and solutions would enhance the stability of the energy system, supporting the electrification of the heating sector (where suitable) and achieving ambitious CO_2 emissions reduction (M. Fesefeldt, 2023). **Prioritizing electrification alone will only delay the decarbonization of heating and limit its benefits to fewer people**.

The energy transition path for heating in the built environment through renewable and low carbon molecular carriers is socially sustainable, particularly for existing homes in urban contexts. It aligns with the average spending capacity of end users and the technical constraints of houses and apartments (micro). This approach is also efficient at the system level in terms of general affordability for infrastructure, security of supply and risk diversification (macro).

Technologies for the efficient use of renewable and low carbon gases, such as gas boilers, gas heat pumps, hybrid systems and fuel cells, are available. These technologies can be highly economical for both installation and subsequent maintenance on a case-by-case basis. Regulation should not restrict choices or prevent households from freely benchmarking convenience across energy carriers and applications based on accurately measured footprints. **The evaluation and comparison criteria for different technological options must be neutral**.

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